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Da ormai quasi quaranta anni la Rivista "Informatica e diritto", fondata nel 1975, testimonia e promuove lo sviluppo delle discipline dell'Informatica giuridica e del Diritto dell'informatica ospitando saggi e commenti dei più importanti studiosi di queste discipline e pubblicando speciali numeri monografici che si propongono di offrire una panoramica il più possibile completa e aggiornata su specifici temi di interesse nel campo del rapporto fra diritto e nuove tecnologie.

Questo Numero speciale della Rivista è dedicato alle possibili relazioni fra diritto e scienze sociali computazionali, emergente ambito di ricerca interdisciplinare che si colloca all'intersezione tra le scienze sociali, le scienze computazionali e le scienze della complessità, raccogliendo contributi di studiosi italiani e stranieri appartenenti a varie aree disciplinari che offrono letture diverse di un fenomeno che sembra destinato a incidere sensibilmente sui metodi e gli strumenti delle scienze umane e sociali.

Confidiamo che questo quattordicesimo volume monografico della Rivista susciti l'interesse dei nostri lettori e contribuisca a sviluppare un dibattito che può aprire nuove interessanti prospettive applicative e di ricerca per l'Informatica giuridica e per la scienza giuridica nel suo complesso.

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For almost forty years the Journal "Informatica e diritto", founded in 1975, has demonstrated and promoted the development of legal informatics and computer law hosting articles and comments by the most important scholars from these disciplines and publishing special Issues aimed at providing as complete and updated overview as possible of specific topics of interest in the domain of the relationship between law and new technologies.

This special Issue of the Journal is devoted to the possible relations between law and computational social science, an emerging interdisciplinary research field that lies at the intersection of the social sciences, computational sciences and the sciences of complexity, bringing together contributions by Italian and foreign scholars belonging to various subject areas who offer different interpretations of a phenomenon that seems destined to significantly affect the methods and tools used in the humanities and social sciences.

We trust that this fourteenth special Issue of the Journal will arouse the interest of our readers and contribute to developing a debate that can open the way to exciting new perspectives for research and applications of legal informatics and for legal science as a whole.

Law and Computational Social Science

edited by

SEBASTIANO FARO
NICOLA LETTIERI

Introduction

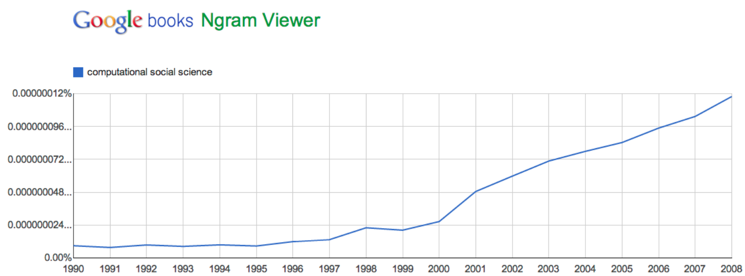
Contributions

Appendix

Introduction

Walking Finelines between Law and Computational Social Science

SEBASTIANO FARO, NICOLA LETTIERI*



"Computational social science" entries in Google N-gram Viewer from 1985 to 2008

1. Four years ago, "Science" published a position paper on the emergence of a new research paradigm – computational social science – destined to have a profound impact on social sciences[1].

The authors, 15 leading scientists coming from strongly diversified disciplinary spheres, from physics to economics, begin with the observation of a phenomenon that is a fundamental characteristic of the information society: "we live life in the network", each transaction that occurs in the network

> "leaves digital traces that can be compiled into comprehensive pictures of both individual and group behaviour, with the potential to transform our understanding of our lives, organizations, and societies"[2].

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[1] D. LAZER, A. PENTLAND, L. ADAMIC, S. ARAL, A.-L. BARABÁSI, D. BREWER, N. CHRISTAKIS, N. CONTRACTOR, J. FOWLER, M. GUTMANN, T. JEBARA, G. KING, M. MACY, D. ROY, M. VAN ALSTYNE, *Computational Social Science*, in "Science," Vol. 323, 2009, n. 5915, pp. 721-723.

[2] *Ivi*, p. 721.

In their view, the capacity of new technologies to collect and analyse massive amounts of data is bound to play a fundamental role in the future of science.

The position of the authors demonstrates that social sciences are going through a phase of profound change due to two main factors. Firstly, there is resort to computational tools and approaches: understanding social phenomena means increasingly using statistical and analytical tools, exploiting data mining techniques, running simulation models or, in other words, exploiting the power of computation[3]. Secondly, there is integration, enabled by computational tools, among different disciplines and sciences, a process that is involving different areas of social sciences from economics to political science, from sociology to anthropology.

The scenario in which the article in "Science" is inserted is that of the ever increasing availablity of information in electronic format regarding the most varied aspects of reality[4]. The so-called "Data Deluge"[5] is at the basis of innovative scientific research practices rich in implications of an epistemological nature[6] in which scientific progress is mainly the fruit of the application of

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[3] See I. AYRES, *Super Crunchers: Why Thinking-By-Numbers Is the New Way To Be Smart*, New York, Bantam Dell., 2007, and the review by E.K. CHENG, *Will Quants Rule the (Legal) World?*, in "Michigan Law Review", Vol. 107, 2009, pp. 967-978.

[4] According to a recent estimate, in 2011 only, humanity has overall produced more than 1,200 billion gigabytes of information compared to 125 billion produced in 2005.

[5] The data deluge is central to a consideration, originating in the scientific domain, that (see, among others, T. HEY, A. TREFETHEN, *The Data Deluge: An e-Science Perspective*, in Berman F., Fox G., Hey A. (eds.), "Grid Computing - Making the Global Infrastructure a Reality", Chichester, Wiley and Sons, 2003, pp. 809-824 and *Nature* of 4 September 2008, which dedicated its cover to so-called "Big data", *Big Data, Science in the petabyte era*) has come to the attention of the non specialised public, as the cover and the articles dedicated to it in the *Economist* of 27 February 2010 show.

[6] In a provocative article of 2008, American physicist and essayist Chris Anderson argues the science that is the descendant of Data Deluge, so-called "Big Data Science", is making scientific method obsolete: "Sensors everywhere. Infinite storage. Clouds of processors. Our ability to capture, warehouse, and understand massive amounts of data is changing science [...] faced with massive data, this approach to science – hypothesize, model, test – is becoming obsolete [...] There is now a better way. Petabytes allow us to say: 'Correlation is enough.' We can stop looking for models. We can analyze the data without hypotheses about what it might show. We can throw the numbers into the biggest computing clusters the world has ever seen and let statistical algorithms find patterns where science cannot" (C. ANDERSON, *The End of Theory: The Data Deluge Makes the Scientific Method Obsolete*, in "Wired Magazine", 2008, http://www.wired.com/science/discoveries/magazine/16-07/pb_theory). Par-

computational heuristics to enormous data sets (Big Data[7]) made possible by the development of computer capacities. In this context, computational social science

> "leverages the capacity to collect and analyze data with an unprecedented breadth and depth and scale"[8].

Recently, *Nature*[9] and the website *Edge* have again returned to look at the matter. The latter gathered together eight conversations – spanning from "Big Data" to "Network Science"[10] – under the title "Computational Social Science".

In defining the state of evolution of computational social science, Claudio Cioffi-Revilla[11] demonstrates how this area of research already actually embraces a substantial number (and potentially growing) of methodologies,

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ticularly interesting, on this matter, see also T. HEY, S. TANSLEY, K. TOLLE, *In The Fourth Paradigm: Data-Intensive Scientific Discovery*, Redmond, Microsoft Research, 2009.

[7] On Big Data see the recent work: V. MAYER-SCHÖNBERGER, K. CUKIER, *Big Data: A Revolution That Will Transform How We Live, Work, and Think*, Houghton, Mifflin Harcourt, 2013; according to the authors (p. 19) "Big data is all about seeing and understanding the relations within and among pieces of information that, until very recently, we struggled to fully grasp" and, moreover, "big data is about three major shifts of mindset that are interlinked and hence reinforce one another. The first is the ability to analyze vast amounts of data about a topic rather than be forced to settle for smaller sets. The second is a willingness to embrace data's real-world messiness rather than privilege exactitude. The third is a growing respect for correlations rather than a continuing quest for elusive causality".

See also the presentation of the book (http://goo.gl/mdPTk) that includes some examples concerning legal data like the analysis of proceedings of the House of Commons in UK and an analysis of the association between the ideology and citation practices of U.S. Supreme Court Justices.

[8] D. LAZER, A. PENTLAND, L. ADAMIC, S. ARAL, A.-L. BARABÁSI, D. BREWER, N. CHRISTAKIS, N. CONTRACTOR, J. FOWLER, M. GUTMANN, T. JEBARA, G. KING, M. MACY, D. ROY, M. VAN ALSTYNE, *Computational Social Science*, cit., p. 722.

[9] Only over the last two years, this journal has gone back five times to the matter, the last time being J. GILES, *Making the Links*, in "Nature", Vol. 488, 2012, pp. 448-450.

[10] See http://www.edge.org/events/-computational-social-science. Up to date, conversations with Dirk Helbing, Nicholas A. Christakis, J. Craig Venter, Cesar Hidalgo, Sandy Pentland, Albert-László Barabási and Tim O'Reilly have been published.

See also, in general terms: B. CASTELLANI, F.W. HAFFERTY, *Sociology and Complexity Science: A New Field of Enquiry*, Berlin-Heidelberg, Springer, 2009 and N. GILBERT, *Computational Social Science*, London, Sage, 2010, that republishes the key articles in this field, brought together within a logical and coherent framework.

[11] C. CIOFFI-REVILLA, *Computational Social Science*, in "WIREs Computational Statistics", Vol. 2, 2010, n. 3, pp. 259-271.

tools and approaches, namely: (i) automated information extraction (algorithmic methods of parsing and coding documents to extract information from data that can be used, amongst other things, for designing computational models or performing advanced statistical analyses[12]), (ii) social network analysis (graph theory applied to social groups and systems[13]), (iii) complexity theory (application of principles, concepts and models of complexity science to the study of social phenomena[14]), (iv) social simulation models (set of different simulation methods spanning from system dynamics to cellular automata and agent-based social simulations[15]), (v) geospatial

[12] This methodology represents an efficacious strategy for using information technology in all the domains of the social sciences, like the law, in which the study and comprehension of the text plays a decisive cognitive role.

[13] Networks, understood as a set of entities (nodes) and a set of relations between entities (links), each defined by a set of attributes, are a phenomenon that can be found in a wide variety of social phenomena. Social network analysis seeks to exploit this characteristic to obtain knowledge of the functional properties of the social phenomenon observed. In doing this, the analysis of the networks is developed in two phases: the construction of a graphic representation (graph) of the phenomenon under investigation and, therefore, the quantitative analysis of the structural characteristics of the graph based on standard methods and metrics. This methodology can provide interesting information regarding the properties of the systems studied, such as resilience, vulnerability, decomposability, functionality. Such information is difficult to derive through simple observation or through more traditional methods. In addition, social network analysis can be applied to design networks that are more reliable and sustainable for public policies, for example in the field of transportation, homeland security, and public health.

[14] The models of the complexity are models based on mathematical concepts and principles aimed at understanding the rules that govern the behaviour of complex phenomena. A complex phenomenon is a phenomenon composed of many elements linked by different kinds of relationships that make it difficult to predict the results produced by these relations. Often complex phenomena are characterised by non-equilibrium dynamics, which are quite often found in challenging research problems across the social sciences. Patterns and regularities of social phenomena like terrorist attacks, wealth and poverty in developing societies and political instability are instances of non-equilibrium dynamics. Complexity models aim at finding regularities of these dynamics in order to comprehend how they evolve and, possibly, predict them.

[15] Simulation models are intended to explain and predict the evolution of complex social phenomena reproducing specific aspects on the computer. The two main simulative techniques used today in the field of social research are system dynamics models and agent-based models. System dynamics models are based on the idea that the evolution of a social system is the result of complex cycles of action and feedback that can be described in mathematical terms. On this assumption, we obtain computer simulations in which the phenomenon under investigation is represented as a set consisting of variables (stocks) and the rates of change (flows) associated with them. Agent-based models are theoretical simulations based on the

analysis (geographic information systems allowing the spatially-referenced analysis of social phenomena[16]).

At the end of 2012 a paper titled "Manifesto of Computational Social Science"[17] was published that described computational social science as

> "a truly interdisciplinary approach, where social and behavioural scientists, cognitive scientists, agent theorists, computer scientists, mathematicians and physicists cooperate side-by-side to come up with innovative and theory-grounded models of the target phenomena"[18].

Regarding this approach,

> "ICT can provide significant help for social science. Not only ICT can help access, analyse and build upon BigData, i.e. new type of massive data, for addressing BigProblems. It can also help provide instruments for BigThinking"[19].

Computational social science is expected to produce effects in different directions. Among these, the impact on science and on society are of particular interest for our purpose. Concerning the impact on science, on the one hand,

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assumption that social phenomena on the macro level (e.g., the emergence of social norms or the spread of the phenomena of racial segregation) are the result emerging from the interactions that, at micro level, are to occur between individuals and between individuals and the environment. An agent-based simulation typically includes a set of actors/agents, a set of interaction rules and an environment where the dynamic, organizational and spatial characteristics are defined.

[16] GIS - Geographic Information Systems permit the representation and display of information located in a geographically referenced context. The application of these systems to social research (social GIS) has found a place in various areas of the social sciences, also in combination with other quantitative techniques that allow us to produce new knowledge about spatial patterns and configurations that would not be otherwise identifiable with statistical or mathematical methods. This methodology is characterized, in particular, by the fact that it offers a synoptic view of different categories of social data obtained thanks to the superposition of multiple layers of information.

[17] See, R. CONTE, N. GILBERT, G. BONELLI, C. CIOFFI-REVILLA, G. DEFFUANT, J. KERTESZ, V. LORETO, S. MOAT, J.-P. NADAL, A. SANCHEZ, A. NOWAK, A. FLACHE, M. SAN MIGUEL, D. HELBING, *Manifesto of Computational Social Science*, in "The European Physical Journal Special Topics 214", 2012, pp. 325-346.

[18] *Ivi*, p. 327.

[19] *Ivi*, p. 331. Furthermore, the Authors stress that "indeed, computational social science can be characterised along two main aspects, which both take advantage, one way or the other, from ICT developments: a) Big Data, and b) the role of computation in inspiring, formalizing and implementing the core scientific concepts, principles, and ideas of computational social science".

> "the combination of the computational approach with a sensible use of experiment will bring the social sciences closer to establishing a wellground link between theory and empirical facts and research. Such links should inform all sciences in which human behaviour is the main object of research or interest"[20];

on the other hand, new tools and methods to be applicable in any instances where Big Data are, or could become, a key ingredient will be developed. Concerning society, the development of computational social science will make it possible to better understand social processes, allowing researchers to take full account of the interdependencies that characterise today's heavily interconnected world. This can support policy makers in their decision making, in order to enable them to efficiently and effectively identify optimal paths for facing the big problems of society from epidemics to financial crises and terrorism[21].

Ultimately, within the space of a very short time, computational social science has taken the form of an unprecedented intersection among social sciences, information sciences and complexity sciences that seems able to lead human sciences, also through new interpretations of the experimental method[22], to the falsifiability, rigour and cumulativeness that have always characterised the study of the physical and biological world[23],

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[20] *Ivi*, p. 341.

[21] *Ivi*, p. 342.

[22] The experimental method, the cornerstone of scientific research in the physical and natural sciences, has now found a place in the social sciences through computer simulations, virtual laboratories for the study of social phenomena. Simulations, in particular, have been the starting point of a new scientific paradigm, presented with regard to the social sciences by J.M. EPSTEIN, *Generative Social Science. Studies in Agent-Based Computational Modeling*, Princeton, Princeton University Press, 2006. According to Epstein, simulations are giving birth to a new kind of science, "generative social science", which can be considered the third paradigm of science along with induction and deduction. Based on the generative approach, to explain social phenomena, you must reproduce, "generate", the phenomena themselves within a computer simulation. On the "epistemolgy of simulation", see also: H. SIMON, *The Sciences of Artificial*, Cambridge, The MIT Press, 1996; J. CASTI, *Would-Be Worlds. How Simulation is Changing the Frontiers of Science*, New York, Wiley, 1997; D. PARISI, *Simulazioni. La realtà rifatta nel computer*, Bologna, Il Mulino, 2001.

[23] In philosophy of science, falsifiability is the quality that belongs to scientific hypotheses and theories that can be tested through empirical experiments and comply, therefore, in the Popperian sense of the term, with the standards of the scientific method. Cumulativeness is the quality of scientific knowledge that increases through successive additions.

"blurring the dividing lines among disciplines and creating a truly interdisciplinary, non-compartmental science"[24].

2. Why discuss the relationship between law and computational social science? The theme seems interesting not only generically, because we are seeing a change that may involve all social sciences, but mostly because this relationship shows promise for reasons related specifically to the nature and function of law and legal science.

Legal phenomena are at the same time the outcome and the ordering factor of social life. The production, interpretation and application of legal rules conceived to regulate social life cannot ignore the scientific knowledge and methodologies illuminating social dynamics at both individual and collective level[25].

From a theoretical point of view, the scientific paradigm underlying computational social science and the nature of the phenomena investigated by it can focus greater attention by lawyers on the empirical dimension of legal phenomena and greater openness to dialogue with other disciplines, two basic conditions for finding appropriate legal responses to the complexity and dynamism of contemporary society[26].

From the methodological point of view, then, computational social science can encourage the appreciation, in the legal field, of a scientific approach (in a Galilean sense) able to offer, through empirical research[27] – the use of

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[24] R. CONTE, N. GILBERT, G. BONELLI, C. CIOFFI-REVILLA, G. DEFFUANT, J. KERTESZ, V. LORETO, S. MOAT, J.-P. NADAL, A. SANCHEZ, A. NOWAK, A. FLACHE, M. SAN MIGUEL, D. HELBING, *Manifesto of Computational Social Science*, cit., p. 341.

[25] For example, knowledge of the conditions that lead to the emergence and evolution of social norms, obtained through the applications of the so-called "distributed artificial intelligence" (artificial societies and social simulations) can usefully be applied in the study of legal issues: see the seminal work of R. AXELROD, *An Evolutionary Approach to Norms*, in "The American Political Science Review", Vol. 80, 1986, n. 4, pp. 1095-1111. On projections of the simulative method in the legal domain, see N. LETTIERI, *Ius in silico. Scienza giuridica ed epistemologia generativa*, in "Sistemi Intelligenti. Quadrimestrale di scienze cognitive e intelligenza artificiale", 2010, n. 3, pp. 419-430; ID., *Artificialia. Intorno a possibili nuovi orizzonti per la scienza giuridica*, in "Scienza&Filosofia", 2010, n. 4, pp. 41-52.

[26] Particularly striking in this perspective is the call for the rehabilitation of the factual and social dimensions aspects of legal phenomenon by Paolo Grossi: see P. GROSSI, *Società, diritto, Stato. Un recupero per il diritto*, Milano, Giuffrè, 2006; ID., *Mitologie giuridiche della modernità*, Milano, Giuffrè, 2007.

[27] See R.M. LAWLESS, J.K. ROBBENNOLT, T.S. ULEN, *Empirical Methods in Law*, Wolters Kluwer, 2010.

statistical and mathematical methods and computational techniques – new tools for understanding phenomena in relation to which the law is called upon to perform its ordering function. Computational social science provides new ways to exploit, even in the legal field, the massive data flow that characterizes the "Big Date Science", offering innovative possibilities to combine qualitative and quantitative research.

In addition, especially through simulation models, computational social science offers legal science a new experimental method by which the modelling of the structural properties of social systems and the exploration of their spatial-temporal development through computer simulations become two basic steps not only to explain complex social dynamics, but also to predict their evolution.

Also the implications of an applied nature seem to be promising: computational social science. provides lawyers with methods and tools that seem to be able to offer a new scientific basis for their activities in the various contexts of interpretation and application of the law and also to the processes of policy and rule making.

3. While, as mentioned above, other disciplines have already widely come closer to the methods and innovative approach of computational social science, the law appears to be still at the beginning of this process[28] which

[28] Purely by way of example, see: S.J. CHANDLER, *The Network Structure of Supreme Court Jurisprudence*, 2005, available at SSRN http://papers.ssrn.com/sol3/papers.cfm?abstract_id=742065; T.A. SMITH, *The Web of Law*, San Diego Legal Studies Research Paper No. 06-11, 2005, available at SSRN http://ssrn.com/abstract=642863; F.B. CROSS, T.A. SMITH, *The Reagan Revolution in the Network of Law*, 2006, available at SSRN http://ssrn.com/abstract=909217; D. BOURCIER, P. MAZZEGA, *Toward Measures of Complexity in Legal Systems*, in "Proceedings of ICAIL 2007", 2007, pp. 211-215; J.H. FOWLER, T.R. JOHNSON, J.F. SPRIGGS, S. JEON, P.J. WAHLBECK, *Network Analysis and the Law: Measuring the Legal Importance of Supreme Court Precedents*, in "Political Analysis", Vol. 15, 2007, n. 3, pp. 324-346, available at SSRN http://ssrn.com/abstract=906827; P.A. HOOK, *Visualizing the Topic Space of the United States Supreme Court*, Indiana Legal Studies Research Paper No. 68, 2007, available at SSRN http://ssrn.com/abstract=948759; U. PAGALLO, *Small World Paradigm and Empirical Research in Legal Ontologies: A Topological Approach*, in Ajani G., Peruginelli G., Sartor G., Tiscornia D. (eds.), "The Multiple Complexity of European Law: Methodologies in Comparison", Florence, EPAP, 2007, pp. 195-210; M.J. BOMMARITO II, D.M. KATZ, *Properties of the United States Code Citation Network*, 2009, available at SSRN http://ssrn.com/abstract=1502927; M.J. BOMMARITO II, D.M. KATZ, J. ZELNER, *Law as a Seamless Web? Comparison of Various Network Representations of the United States Supreme Court Corpus (1791-2005)*, in "Proceedings of the 12th International Conference on Artificial Intelligence and Law (ICAIL 2009)", available at SSRN http://ssrn.com/abstract=1419525;

certainly deserves being developed. In this vein, with this Special Issue of "Informatica e diritto", we want to promote an opportunity for discussion that, starting from experiences that seem very far apart, even because of the heterogeneous origin of the authors, introduces topics that we hope will encourage lawyers to imagine the application of computational social science methods to authentically legal problems.

In more general terms, the intention is to stimulate a reflection on whether and how the law and the way of thinking of a lawyer can be transformed by their encounter with the research paradigm of computational social science.

The first two articles in this Special Issue are introductory because they touch on the question of the relationship between law and science, which we consider preliminary compared with respect to the analysis of our theme, providing lawyers and non-lawyers with a framework within which to place the discussion.

The starting point of Orlando Roselli is his view of the difficulties that the lawyer today meets when faced with the complexity of the global and technologically advanced society. Modern legal culture is faced with an obvious difficulty in performing its principal ordering function when it encounters the plural phenomena of globalisation, the radical ever accelerating transformation of the social tissue, the invasiveness of new technologies, the changing relationship among rules, time and space. The great difficulty to acquire an historically conscious method that enables modern jurists to decipher the consequences of social changes means they have to be open even

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M.J. BOMMARITO II, D.M. KATZ, *A Mathematical Approach to the Study of the United States Code*, 2010, http://arxiv.org/abs/1003.4146; U. PAGALLO, *Power Laws and Levels of Abstraction in Understanding Legal Systems*, in Andrighetto G., Boella G., Pagallo U., Villata S. (eds.), "Combined Proceedings of the International Symposium on Social Network Analysis and Social Norms in MAS", Leicester, De Montford University, 2010, pp. 41-45; P. CASANOVAS, U. PAGALLO, G. SARTOR, G. AJANI (eds.), *AI Approaches to the Complexity of Legal Systems*, LNAI, Heidelberg, Springer, 2010; D.M. KATZ, D.K. STAFFORD, *Hustle and Flow: A Social Network Analysis of the American Federal Judiciary*, in "Ohio State Law Journal", Vol. 71, 2010, n. 3, pp. 457-509; R. WINKELS, J. DE RUYTER, H. KROESE, *Determining Authority of Dutch Case Law*, in Atkinson K.M. (ed.), "Legal Knowledge and Information Systems. JURIX 2011: The 24th Annual Conference", Amsterdam, IOS Press, 2011, pp. 103-112; M. VAN OPIJNEN, *Citation Analysis and Beyond: In Search of Indicators Measuring Case Law Importance*, in Schäfer B. (ed.), "Legal Knowledge and Information Systems - JURIX 2012: The 25th Annual Conference", Amsterdam, IOS Press, 2012, pp. 95-104.

See also the *Computational Legal Studies Blog* (http://computationallegalstudies.com/) founded in 2009 by D.M Katz, M.J. Bommarito II and J. Zelner as "an attempt to disseminate legal or law related studies that employ a computational or complex systems component".

more so than in the past to the contribution of other sciences. Therefore, jurists must broaden the horizon of their research in the understanding that, at the basis of scientific development, there is no presumption of a final result but, rather, a healthy uneasiness that pushes them to rethink their results which they should never assume to be ontologically definitive.

Domenico Parisi examines the same question from the viewpoint of the philosophy of science, also proposing resort to the artificial[29] for legal science (in this case, robots and computer simulation) as a tool for knowledge of reality and of the phenomena under legal regulation. Computational and robotic artifacts are more and more often laboratories for the study of society[30] in which different disciplines converge that study phenomena which in a more or less direct manner influence the dynamics relevant to the law. A robotic science of legal phenomena should be able to reproduce some phenomena and should be able to answer some research questions briefly outlined by Parisi.

This initial and general framework is followed by the articles of Bruce Edmonds and Klaus Troitzsch that identify specific issues relevant to law to which the methods of computational social science may apply, in particular, social simulation which is playing an increasingly important role in the understanding of social phenomena.

In the use of simulation, Bruce Edmonds identifies an ally in understanding how and why law works and, consequently, to decide how to act legally for obtaining certain effects on society and individuals. Edmonds points out that computer simulations can be applied to different legal tasks, namely studying breakdown in norm compliance; preparing the ground for compliance to legislation; bootstrapping away from endemic corruption, and assessing efficacy of different modes of legal rule-making. In this vein, simulations have to be considered *in vitro* experiments that do not replace *in vivo* studies in any way but rather complement them, suggesting possibilities that subsequent empirical studies can investigate and producing precise but complicated models of the existing evidence.

Instead, Klaus Troitzsch, shows us the possible applications of simulation approaches to legislative processes, especially in assessing the impact of alter-

[29] On the concept of "artificial" and its role in science see, *inter alia*, H. SIMON, *The Sciences of Artificial*, cit., *passim*.

[30] See, for example, the research carried out at the Yale Social Robotics Lab where computer science, and in particular robotics, offers a complementary perspective on the study of human behavior, http://www.scazlab.com/.

native political strategies before new legislation would be set into force. The focus of his article is on regulatory impact assessment (RIA) that appears, without doubt, one of the most promising sectors where methods of computational social science can be applied, although it should not be underestimated the author's final comment in which he maintains that all kinds of simulation are and will be unable to make precise predictions of future states of a complex systems or to precisely predict the outcomes of planned policies. The only thing that is possible is foresight in the sense that possible futures can be sketchily described. Policy makers are responsible for the measures taken, but simulation can improve the information on which political decisions rest.

In the field of social simulation, especially agent-based social simulation in which the basic element is the individual or rather his representation as a computational model, a key issue, regardless of the phenomenon to be studied, is the availability of theoretical models that allow the mechanisms underlying the behaviour of individuals and their interactions with others and with the environment to be described in rigorous and scientifically reliable terms. The simulation study of phenomena that have to do with the law assumes an understanding of the cognitive processes that influence the emergence and evolution of social and legal norms. The articles by Castelfranchi, by Cecconi, Andrighetto and Conte, and by Terna offer different points of view on the issue by offering, on the one hand, theories on what are the norms on the level of individual and social cognition and, on the other, models and cognitive architectures to implement in the simulation agents we want to build.

Cristiano Castelfranchi addresses the issue of norm internalization: all norms, from the social and legal, can be seen as mental objects that arise out of individual cognition through processes that can be modelled in a formal way. Castelfranchi proposes an inspiring model of norms, norm adoption and "cognitive processing" of norms in cognitive agents, from the recognition of the input as a normative prescription to the formulation of the intention to conform or to violate.

The work of Federico Cecconi, Giulia Andrighetto and Rosaria Conte presents the use of multi-agent-based simulation as a tool for exploring the dynamics of norm emergence based on mental representations. In their approach, social and legal norms are treated as recognized, represented and reasoned upon prescriptive commands. The agent-based simulations presented aim at understanding what would happen in a world populated by normative agents, able to recognize norms and to reason upon them, compared to other, cognitively, less complex agents, following only their own individual goals.

Finally, Pietro Terna, moves the discussion onto cognitive architectures versus the application aspect, presenting a recent implementation of a software library for agent-based simulation that can be used in modelling social learning dynamics that can play a relevant role in the simulation of normative phenomena. He also dwells on the question whether agent-based simulation could help in a perspective of policy management and law creation.

Two practical examples of simulation that could interest lawyers are proposed by Lettieri and Parisi and by Bonaventura and Consoli.

Nicola Lettieri and Domenico Parisi, present a simple evolutionary agent-based model of the interplay between damaging behaviours, punishment and social mechanisms of learning and imitation. The article is an attempt to show how agent-based simulation can be used to illuminate basic mechanisms underlying social phenomena that are relevant for legal science and to reflect, in an innovative way, on how society, policy and rule makers can deal with such phenomena.

Luigi Bonaventura and Andrea Consoli present an interesting application of agent-based simulation in the field of the organization of criminal justice, demonstrating how it is possible to study "*in silico*" effects on pending cases deriving from the different application of priority criteria applied by a judge in treating procedures. The proposed simulations enable us to assess the effects that different choices have on the reduction in cases pending and on the social cost deriving from delays in dealing with the more serious cases.

Another area of interest for lawyers in which simulation seems to be particularly promising and where theoretical observations and experimentation[31] already exist is the study of the criminal phenomenon. In many respects, the methodologies of computational social science have been demonstrating a significant capacity to address the study of crime and criminal justice to support policy making, with consequences also of considerable applicative impact[32]. The four articles proposed here, coming from criminolo-

[31] See, for an initial view of the matter: L. LIU, J.E. ECK (eds.), *Artificial Crime Analysis Systems: Using Computer Simulations and Geographic Information Systems*, Hershey, IGI Global, 2008.

[32] An interesting example of the applications of computational methods to the study and forecasting of the dynamics of crime is found in PredPol (http://www.predpol.com/) a computer-based program developed by mathematicians, an anthropologist and a criminologist, to implement "Predictive Policing," which uses advanced computation to predict where

gists, computational scientists and sociologists of deviance, demonstrate the interest of different disciplines to the topic and give us a glimpse of interesting future developments.

Fabrizio Caccavale offers a criminologist's brief reflection on the impact that computational social science methods can have on research in the criminology and criminal law domains focusing on the benefits that interaction with other disciplines offers criminology and presenting, in general terms, computational criminology, which involves the use of computational power to identify existent and emerging models of crime.

Federico Cecconi shows how agent-based simulation allows us to obtain reliable computational models for criminal phenomena, making it possible "to simulate the crime". According to the author, agent-based simulation is potentially a very powerful tool for crime study; it increases the empirical understanding of how society works and can help policy makers in designing more effective norms and mechanisms for fighting criminal behaviour.

Valentina Punzo discusses the role of agent-based social simulation in crime research, in particular, criminal policy making offering some suggestions about the utility of applying simulated experiments to crime research. After a review of some examples regarding such type of simulations in predicting and assessing the impact of crime-prevention interventions and policy changes, the specific tasks and purposes of agent-based social simulation along the different stages of the overall policy making process are summarized and discussed.

Finally, Nicolas Malleson, Andrew Evans, Alison Heppenstall and Linda See illustrate how agent-based simulation enables us to reach new levels of analysis to the traditional quantitative analysis of crimes accounting for the individual dimension of criminal behaviour. They present a social simulation model of burglary replicating offender drivers and decision making in a realistic geographical environment, full of potential victims and guardians. Hence, the model offers an interesting way to link aggregate-level crime patterns and individual-level offender behaviour.

A final contribution in the field of simulation is by Migle Laukyte, who discusses the still too limited impact of the multi-agent system approach in the legal field. The author argues that an important reason why the simulation of legal phenomena is not making much headway is a certain language barrier between lawyers and software engineers. To overcome this barrier,

crime will occur. The environment is actually used by Los Angeles Police Department to figure out where crimes will be committed before they take place.

the paper suggests making use of "boundary objects", a sociological concept used to describe the use of the same information or categories by different communities and in different ways. In this vein, the boundary object considered is the autonomy which can be ascribed to an agent within a multi-agent system. In the author's opinion, if we can spell out in a clear enough way what autonomous action means in the law, then we will also have a roadmap we can rely on in developing autonomous agents and building multi-agent systems that would be more effective at simulating or reproducing social interactions in areas of activity which fall within the purview of the law.

The article by Deborah De Felice, Giovanni Giuffrida, Giuseppe Giura, Vilhelm Verendel and Calogero Zarba is the first of three articles dedicated to information extraction and the subsequent processing of information using social network analysis techniques. The authors report and discuss sociological and computational approaches allowing for the characterisation of the social structure of criminal phenomena using large-scale and automated computer tools. The research project they present was based on analysing criminal sentences on organized crime activities in Sicily, pronounced from 2000 through 2006. After having collected the criminal sentences from the various courthouses and stored them into digital format, the texts were examined in order to extract information on the actors involved in the facts and the relationships between them. Finally the network of actors was investigated using social network analysis, in order to capture social network properties.

Nicola Lettieri, Delfina Malandrino and Raffaele Spinelli present an ongoing research exploring applications of computational methods in the analysis of structural and functional features of criminal organisations. Inspired by a sociological study using social network analysis techniques to compare properties of two criminal organisations belonging to the *mafia* and the *camorra*, the research aims at studying tools combining information extraction, network analysis and visualization methods to support investigation and to combat criminal organizations. The paper offers an overview of the results so far achieved from a technical and methodological viewpoint sketching future developments of research that appears to be challenging both for criminology and legal informatics.

Gugliemo Feis presents a theoretical framework called "Network Analysis Formalism" that he proposes as a third way that attempts to rejoin the formalism of legal positivists and the anti-formalism of legal realists by way of relying both on data mining and on network analysis. The article applies this theoretical framework to the concrete problem of taxation, proposing a traceability system for payments. Such a system undoubtedly poses many legal and technical problems, common to all systems that use large quantities of data, sometimes referable to the entire population of a country, on which the author begins to reflect.

Geospatial analysis methodology is also covered in this Special Issue in the contribution of Tamara Bellone, Francesco Fiermonte and Chiara Porporato. They deal with the techniques for transforming plain date, such as normal address lists, into geographic coordinates expressed in latitude and longitude. The issue of access and use of free data or free information for such purposes, also that available on line, is not only technical because the opportunities offered by information sharing and knowledge facilitate individual and collective growth, participatory processes and social justice.

The Special Issue closes with two articles that generally ponder on the possible relations between specific disciplines in the legal and economic-legal area and computational social science. Guido Migliaccio, on the one hand, with reference to business administration, accounting and legal sciences and Ernesto Fabiani, on the other, with reference to civil procedure law, identify some issues that could be studied in accordance with the research perspectives offered by computational social science methodologies. The goal for both is to promote interdisciplinary dialogue, to ask questions and to present specific problems that may be studied in greater depth or from new viewpoints thanks to the contribution offered by computational social scientists.

4. It is likely that, in the near future, as has happened in other areas of the humanities and the social sciences, the relationship between the law and the paradigm of computational social science will intensify. The contributions collected here, on the one hand, confirm this trend and, on the other, suggest pathways to deepen this relationship in various directions, both scientifically and on the level of its application.

Here we limit ourselves to a few concluding remarks. Readers who will wish to walk the finelines between law and computational social science will certainly identify other areas of interest for each one of them.

The approach and methodologies of computational social science have great potential for scientific applications that in order to best be exploited in the field of the law requires the lawyer to identify avenues for research and the appropriate questions to ask. Help in the formulation of these questions may come from the lawyer's comparison with other disciplines that may help to understand, to predict and to manage the phenomena of interest to the law. In this perspective, the ability of ICT to mediate the interaction between different knowledge makes legal informatics the research area ideal for bridging the gap between law and computational social science. The background to what has been said until now is provided by the issue of legal culture and, therefore, a lawyer's training. Albeit with significant differences between the different legal cultures, the world of law is less used to dealing with quantitative approaches and computational tools than other areas of the social sciences such as, for example, economics and sociology. The enhancement of this dimension involves law schools and, more generally, the whole world of legal education. Without giving into *a priori* enthusiasm, it is possible to imagine that many interesting developments in the way in which the law is studied and the way in which the complexity of modern society is handled legally depend on the ability to train new generations of lawyers to seize the opportunities on the horizon in the world of computational social science. The road is now wide open. At a closer look, after all, it is not a matter of inventing anything new: as stated in 1895, by the American jurist, Oliver Wendell Holmes Jr.

> "An ideal system of law should draw its postulates and its legislative justification from science"[33]

and, moreover,

> "for the rational study of the law the black-letter man may be the man of the present, but the man of the future is the man of statistics"[34].

[33] O.W. HOLMES JR., *Collected Legal Papers*, New York, Peter Smith, 2010, p. 139.

[34] O.W. HOLMES JR., *The Path of Law*, in "Harvard Law Review", Vol. 10, 1897, p. 457, http://www.gutenberg.org/files/2373/2373-h/2373-h.htm.

Contributions

The Ever Changing Legal Dimension and the Controversial Notions of Law and Science

ORLANDO ROSELLI*

SUMMARY: *1. The Apparent Paradox of the Difficulty to Define What the Law Is – 2. The Necessary Opening of Legal Culture to Social Transformations – 3. Historicity of Law. Beyond a Concept with Only a Western Matrix – 4. The Change in 'Legality' in Modern Societies Focusing on Pluralism – 4.1. Technological Advances, Changing Factual and Cultural References and the Consequences within the Legal Dimension – 5. The Idea of Science and the Concept of the Completeness or Incompleteness of the Legal Order*

1. THE APPARENT PARADOX OF THE DIFFICULTY TO DEFINE WHAT THE LAW IS

An apparent paradox characterises the work of the jurist: the difficulty of defining the object of his investigation. The most difficult question to find an answer for is precisely what is the law[1].

To understand the nature of the legal dimension, it is necessary to begin with an awareness of that very paradox and the difficulty it brings with it.

For a long time, the dominant legal culture, in particular, in civil law countries, aspired to give a definitive reply to this question: the presumption of the certainty of the law and the completeness of the legal order appeared to be features of the legal dimension that could not be renounced; these are objectives that can be pursued, according to this approach, attributing the monopoly of law-making to the State and reducing the role of the jurist to that of a simple commentator of the legislator's intent[2].

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[1] So much so that it has been said that asking what is the law is a "persistent" question, see H.L.A. HART, *The Concept of Law*, Oxford, Clarendon Press, 1994, II ed. (Italian translation, *Il concetto di diritto*, Torino, Einaudi, 2002), cited in SIMONCINI A., *Cos'è il diritto? Una domanda "persistente"*, in Ventorino F., Barcellona P., Simoncini A., "La lotta tra diritto e giustizia", Genova-Milano, Marietti, 2008, p. 149 ff.

[2] For a critique of this claim, see, for this purpose, the great number of scientific works by P. GROSSI, in particular, *Assolutismo giuridico e diritto privato*, Milano, Giuffrè, 1998, and *Mitologie giuridiche della modernità*, Milano, Giuffrè, 2001.

The foundation and prevalence of such a concept do not have anything to do with the presumed ontological characteristics of the law but rather with its functionality to political-institutional unification processes (understood as a reduction) in national legal orders.

For this purpose, 'legal science' has, indeed, elaborated refined theoretical constructions, but they are often based on prevarication: the presumption being their result expression of the only law imaginable[3], rather than of a very concrete historical process.

In this way, every dominant concept of law has become, in 'psychology' not only that of the jurist but collectively, *the Law*.

This presumption seems to be at the base of the explanations of great theorists who come from a very different cultural approach. These involve concepts of the law that continue according to ideological instead of scientific schemata: that is, the law is what enters into a predefined theoretical schema.

Presuming once and for all to define an a-temporal legal concept has, in this way, lead to the elaboration of refined theories of extraordinary internal consistency but weak (and furthermore: resistant) in grasping the perennial changing of the social dimension.

Frequently, 'legal science' has ended up moving forward by means of great dichotomies: natural law/positive law; common law/positive law; private law/public law and by adhering to one of two opposing poles relegated to the mere fact that all of this is not attributable to it[4]. In this way, yet again, an abstract consistency of legal concepts is preserved at the expense of the heterogeneous, plural, multiform, *real* representation of legal regulation.

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[3] A claim made in a peremptory way at times of consolidation within a legal order (see, P. COSTA, *Lo Stato immaginario. Metafore e paradigmi nella cultura giuridica tra Ottocento e Novecento*, Milano, Giuffrè, 1986) that is threatened during times of transition (see, O. ROSELLI, *Dimensione politica e forma di Stato*, in Caretti P., Grisolia M.C. (a cura di), "Lo Stato costituzionale. La dimensione nazionale e la prospettiva internazionale. Scritti in onore di Enzo Cheli", Bologna, Il Mulino, 2010, p. 117 ff., now in O. ROSELLI, *Riflessioni sulle trasformazioni della dimensione giuridica*, Napoli, ESI, 2011, p. 55 ff.).

[4] See N. BOBBIO, *Dell'uso delle grandi dicotomie nella teoria del diritto*, in "Rivista internazionale di filosofia del diritto", Vol. 47, 1970, p. 187 ff. (and in *Studi in onore di Giuseppe Grosso*, Torino, Giappichelli, Vol. 4, 1971, p. 615 ff.); ID., *La grande dicotomia*, in "Studi in memoria di Carlo Esposito", Padova, Cedam, 1974, p. 2187 ff., now both in ID., *Dalla struttura alla funzione*, Roma-Bari, Laterza, 2007, respectively, p. 101 ff. and p. 122 ff.

2. The Necessary Opening of Legal Culture to Social Transformations

A legal culture that loses its awareness of the historical motives that have lead to the creation of its categories is unfit to grasp the emerging needs governing society. This unfitness appears obvious to everyone in a time of transition like ours, where the system of legal sources is in crisis precisely because it was designed for a society different from the present one which is now in profound transformation. The task of the jurist is to recognise the "signs" of this transformation and to reappraise categories, tools, and legal institutions[5]. If it is not capable of doing this, the law loses part of its function, with consequences that can be dramatic for social coexistence and peace among nations.

Modern legal culture is faced with an obvious difficulty in performing its critical function when it encounters the transformation of our society into multicultural societies; the phenomena of globalisation; the invasiveness of new technologies; the changing relationship among rules, time and space; it is 'disarmed' with respect to the acceleration of transformation processes. Often, we witness the presumption of regulating new social phenomena by using already old legal categories and, sometimes of not recognising the normative nature of social ordering processes.

With regard to plural globalisations, a part of legal authority has expressed doubt about whether we can talk about the existence of a "global" law[6]. In this rejection, we can see the reflection of a concept of static, abstract, self-sufficient law compared to other (social, religious, moral) subsystems.

In the current historical phase, the same fundamental legal categories are transforming because they are suffering the consequences of the momentous change in societies. This change should not surprise us, but instead the disorientation of legal authority that seems to have lost awareness that legal categories have an intrinsic historical dynamism and ability to transform. It

[5] This is the basic teaching of Paolo Grossi (see O. Roselli, *Il progetto culturale e scientifico dei* Quaderni fiorentini per la storia del pensiero giuridico moderno *nelle* Pagine introduttive *dei primi trent'anni*, in "Sociologia del diritto", 2009, n. 3, p. 39 ff., now also in Id., *Riflessioni sulle trasformazioni della dimensione giuridica*, Napoli, ESI, 2011, p. 67 ff.). Naturally, the history of modern legal thinking is full of jurists committed to recognising the signs of social change and their consequences in the legal sphere: intellectually aware jurists are the object of reflection in P. Grossi, *Nobiltà del diritto. Profili di giuristi*, Milano, Giuffrè, 2008.

[6] As mentioned by M.R. Ferrarese, *Prima lezione di diritto globale*, Roma-Bari, Laterza, 2012, p. 5 ff.

almost seems to have forgotten that fundamental notions like sovereignty, legality, source of law have often undergone changes in meaning.

If this awareness had not been lost we would, as jurists, have greater tools available to us for organising an increasingly magmatic reality. Above all, the starting point for legal thinking would not be the presumption to circumscribe the notion of the law by using abstract conceptual categories; the understanding of the phenomena that they want to regulate and the correlation between provisions and facts would be taken as the starting point; there would be greater awareness of the processes of osmosis among social ordering subsystems; there would be greater cognizance that the boundary among the various social subsystems is mobile and non definable once and for all. The error of believing that our epoch is an epoch of crisis in the law would not be made: dated manifestations of the law are in crisis; in fact, modern societies have the need for new and renewed legal circuits.

3. Historicity of Law. Beyond a Concept with Only a Western Matrix

Furthermore, the very historical verifiability that every society requires of the law (*ubi societas, ibi ius*) and of its very varied manifestation of itself testifies how the term 'law' is designated as a congenital phenomenon of the various social dimensions but one whose characteristics are linked to specific historical contexts. For a long time, western culture has been closed within an autarchic concept of the law, not generally going beyond its own historical experience, as though other civilisations had not produced legal orders.

The notion of '*ius*', understood as the birth of legal science, comes to be traced back to the construction of Roman law, even if it was impressive[7], putting the considerable influence of Greek culture and the legal tradition of the *polis* in the shade[8]. The experiences of ancient societies[9] have often been evaluated with the deformed glance of the Romanist model and/or of

[7] A. Schiavone, *Ius. L'invenzione del diritto in Occidente*, Torino, Einaudi, 2005.

[8] Regrets that the teaching of ancient Greek law is "not very wide spread", E. Cantarella, *Diritto greco. Appunti delle lezioni*, Milano, Cuem, 1994, II ed., p. 3.

[9] Obviously, there is no lack of studies on the legal aspects of the most differing ancient civilisations, see, for example, C. Saporetti, *La nascita del diritto. Studi sulle leggi della Mesopotamia antica*, Roma, Aracne, 2010.

modernity; often studied little and almost always badly understanding their originality[10].

The reaction of early western jurists to contact with the 'Celestial Chinese empire' is significant: looking for institutions, categories, organs and organisational models and not finding them in the Chinese system they reached the conclusion that that thousand year old empire had no knowledge of the law[11]. This is a typical reaction of a 'western-centric' culture which means today we have little preparation in understanding the plural dynamics of globalisation. These are dynamics that bring into contact not only capital and goods but people in flesh and blood with different values and cultures and that foster contamination among legal orders, even those of non western tradition[12].

Such contamination is very necessary because it can become a tool for a common language over and above differences among cultures. In this manner, the law sees its role widened, becoming the place where we find a synthesis between even opposing interests and cultures which the crisis in State territoriality is increasingly putting in direct contact.

We quickly need to take into account the social and technological transformations that do not give enough time to be psychologically metabolised

[10] It was a long tradition, in writing entries for encyclopedias and monographs, to reconstruct the history of legal institutions beginning from ancient civilisations, but they are generally not very fruitful reconstructions and are rarely capable of recognising the historical differences.

[11] Marina Timoteo is among Italian jurists who have focused closer attention on the study of Chinese law within the transnational dimension. Here are just some of her works: *Le successioni nel diritto cinese. Evoluzione storica ed assetto attuale*, Milano, Giuffrè,1994, *ivi*, pp. 129-143, sources and bibl.; *Il contratto in Cina e Giappone nello specchio dei diritti occidentali*, Padova, Cedam, 2004, *ivi*, pp. 371-391, bibl.; *Circolazione dei modelli e riforme giuridiche. Il caso est-asiatico*, Bologna, Libreria Bonomo editrice, 2005 (that also concentrates on linguistic problems of the compatibility of western models in Japan). Important for understanding both the original Chinese legal model and the processes of modernisation within that country is the volume by L. MOCCIA, *Il diritto in Cina. Tra ritualismo e modernizzazione*, Torino, Bollati Boringhieri, 2009. The increasing influence of Chinese law in transnational economic relations is pointed out in F. GALGANO, *La globalizzazione nello specchio del diritto*, Bologna, Il Mulino, 2005, *passim*.

[12] Even comparative law studies necessitate a greater opening towards comparison with legal orders belonging to legal families with non-western traditions. Moreover, French legal culture has paid special attention to the study of Islamic legal orders as we can see from a vast number of scientific works and conferences, like the one held in Strasbourg on 25 and 26 March 2010, entitled La *Sharî'a dans le droit d'aujourd'hui*; whilst the American studies on Chinese law are important.

and this is an obstacle to the formation of shared social rules[13]. This also contributes to making it necessary to enhance legislative circuits capable of providing answers to arising needs; circuits that are described as 'legal' not so much and not always in virtue of a constituted power but because of their unmodifiable necessity.

4. The Change in 'Legality' in Modern Societies Focusing on Pluralism

Great jurists of times of transition provide us with invaluable methodological suggestions: to focus special attention on the emergence of those phenomena that move profoundly towards modifying reality, the social context. Thus, between the end of the 1800s and the beginning of the 1900s, for example, some great jurists inferred from social and non legal phenomena, how the birth of popular parties and trade unions would have profound effects on the form of the State, on the fundamental characteristics of the legal order[14].

It is from the observation of the changed social reality that scholars like Santi Romano[15] inferred that not only single institutions were changed but also the organisational processes of the legal dimension that could not be traced back only to the State order. Romano's teaching, historically verified, of the plurality of legal orders, widens the asphyxiated notion of the law and is still valuable today in understanding the plural manifestations of the legal dimension.

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[13] O. Roselli, *Aspetti socio-culturali della globalizzazione*, in "Quaderni AUEL (Amici dell'Università dell'Età Libera)", Firenze, June 2001, p. 12 ff., now in Id., *Riflessioni sulle trasformazioni della dimensione giuridica*, cit., p. 13 ff.

[14] For further in-depth analysis of these matters, see O. Roselli, *La dimensione costituzionale dello sciopero. Lo sciopero come indicatore delle trasformazioni sociali*, Torino, Giappichelli, 2005 and Id., *Il problema degli indicatori delle trasformazioni sociali*, in Poggi A., Roselli O. (a cura di), "Trasformazioni sociali e trasformazioni giuridiche", Napoli, ESI, 2007, p. 27 ff. (now also in O. Roselli, *Riflessioni sulle trasformazioni della dimensione giuridica*, cit., p. 19 ff.).

[15] In the first place, the reference is to *L'ordinamento giuridico* of 1918. On the contribution of Santi Romano to a renewed understanding of the legal phenomenon, see P. Grossi, *Santi Romano: un messaggio da ripensare nella odierna crisi delle fonti*, in "Rivista trimestrale di diritto e procedura civile", 2006 and, more recently, in *Nobiltà del diritto. Profili di giuristi*, cit., p. 669 ff.; Id., *Lo Stato moderno e la sua crisi (a cento anni dalla prolusione pisana di Santi Romano)*, in "Rivista trimestrale di diritto pubblico", 2011, n. 1, p. 1 ff.; N. Bobbio, *Teoria e ideologia nella dottrina di Santi Romano*, in "Dalla struttura alla funzione", cit., p. 139 ff.

"La struttura interna di un ordinamento" is not necessarily the outcome of the activities of the State or, in any case, of a structured power. It may well be the product of

> "una comunità, piccola o grande, che trova il suo fattore di coesione in valori assunti (e condivisi) da ciascuno dei suoi membri quale fondamento ineludibile, quel fondamento che giustifica interamente ogni regola comunitaria e la assolutizza nella coscienza dei socii, imponendone una inderogabile osservanza; quel fondamento che, nella sua tipicità e irripetibilità, identifica quel singolo ordinamento rispetto a ogni altro, lo rende in sé – cioè nel proprio ordine – completo and autosufficiente". "In altre parole, il carattere originario di un ordinamento esprime l'idea che le ragioni o le giustificazioni fondative di questo corrispondano, nel profondo, alla vita della relativa comunità, per come questa, nel suo complesso ma peculiare strutturarsi, sia stata capace di individuare e salvaguardare gelosamente i proprii caratteri e la propria specifica identità"[16].

These considerations of legal historian, Paolo Grossi, point to the congenital pluralism of the legal dimension and are enlightening in understanding today's multiform legislative structuring of very variegated transnational contexts.

Jurists have a difficult task: to understand the differentiated modes for rule-making and the formation of the various legal orders in multiple contexts. That is, by erroneously conjugating in the singular, usually defined globalisation does not, in fact, produce only unifying dynamics but also articulations and sometimes fragmentations that are even more consolidated the more they correspond to aspects characterising reality.

This requires updated training for lawyers, able to provide tools for understanding not only the sources of law produced by States but the others,

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[16] See P. GROSSI, *Sui rapporti tra ordinamento statale e ordinamento sportivo*, in "Diritto amministrativo", 2012, n. 1-2, p. 11: "the internal structure of a legal order" (... may well be the product of) "a community, big or small, that finds its cohesive factor in values assumed (and shared) by each of its members as an ineludible foundation, that foundation that entirely justifies every community rule making it absolute in the consciousness of the members, imposing compliance that cannot be derogated from; that foundation that, in its typical and unique nature, identifies that individual legal order compared to others, makes it in itself – that is, in its own order – complete and self-sufficient". "In other words, the original character of the legal order expresses the idea that the motives or grounds founding it correspond, deep down, to the life of the relative community for the way in which this, in its overall but distinctive organisation, is able to identify and jealously protect its own features and its own specific identity".

in continual expansion, produced by always new communities of actors and the force of economic processes[17].

Legal authority[18], jurisprudence, arbitration awards, custom, the role of jurists in orienting institutions behaviours, large law firms, bodies that we can define as research organisations applied to the law like UNIDROIT, parties like the International Chamber of Commerce in Paris acquire an increasingly important role in modern law making.

The complexity and changeability of relations require professionalism and flexibility. The challenge of globalisations and competition among economic systems is not so much all about the material factors of production but about the capacity of legal culture to put an ever increasingly complex social dimension into order.

4.1. Technological Advances, Changing Factual and Cultural References and the Consequences within the Legal Dimension

Technological advances have very important consequences in legal orders: because they change the relationship of the rules with time and space[19]; they tend to determine an actual anthropological change[20]; they have a bearing on fundamental cultural references and values. With regard to the first two aspects, there is now a lot of well argued material to which the reader is referred.

With reference to the effect of planetary technological development in the entrenchment of millennial cultural references and values it is thought that some talk about of "the death of one's neighbour", believing that one of the characteristics of the "pre-technological world" no longer exists: "neigh-

[17] See O. ROSELLI, *Scritti per una scienza della formazione giuridica*, Napoli, ESI, 2012.

[18] Provided that legal authority knows how to contribute to renewing legal analysis and tools.

[19] There are many contributions on this matter, see, for this purpose, M.R. FERRARESE, *Il diritto al presente. Globalizzazione e tempo delle istituzioni*, Bologna, Il Mulino, 2002.

[20] See, among others, the considerations of the philosopher and psychoanalyst U. GALIMBERTI, *Psiche e techne. L'uomo nell'età della tecnica*, Milano, Feltrinelli, 1999; from the large number of works by the same Author, see, *I miti del nostro tempo*, Milano, Feltrinelli, 2009, in particular, the second part relating to "Collective Myths", p. 205 ff. Among non legal studies that could provide the jurist with interesting ideas, there are some by Marc Augé, who has, amongst other things, looked at the anthropological condition of post-modern man: most recently, M. AUGÉ, *Futuro*, Torino, Bollati Boringhieri, 2012.

Regrettably, within the Italian panorama, there is a trend towards atrophy within studies of legal anthropology.

bourhood". Thus, after the concept of modernity like the 'death of God', that of the 'death of one's neighbour' would affect social perception of the entire biblical commandment "*love God and love thy neighbour as thyself*"[21].

This is a psychoanalytical reconstruction of the condition of post-modern humanity that can well explain wide-spread existential and social disorientation. Even so the outcome of technological advances and globalisation could also be lived not as an extinction of neighbourhood but, on the contrary, of a now general condition of sharing[22]. The perception in a sense ('the death of one's neighbour') or in another ('every human being is now a neighbour') will depend on prevailing cultural trends that will bring with them different incorporations of values into the legal order.

More so than in the past, the legal sphere is situated at a crossroad of other social ordering (social, moral, religious and technical-scientific) subsystems, none of which is exhaustive in determining a *sustainable order*. To a greater extent than in the past, the law is asked to determine that ordering dimension that would otherwise be missing. From all the evidence, it emerges yet again that the function of the law and the responsibility of the jurist class are widening.

A renewal of legal culture proceeding at the same pace as the maximum openness towards other sciences without breaking down in a confused and ineffective eclecticism is required.

The greatest difficulty for the modern jurist is to acquire a method that enables him to decipher the consequences of social transformations; consequences whose effects are manifested at every level of the system of sources, even at constitutional level. In this way, current transformations profoundly change modern societies which influence important aspects of the legal order, even if legislative provisions remains unchanged. So that is why the jurist must be open even more so than in the past[23] to the contribution of other sciences (researching assistance in the most widely differing scientific disciplines). It is significant how in the sphere of sociological studies analyses

[21] L. ZOJA, *La morte del prossimo*, Torino, Einaudi, 2009 (emphasis added by the Author of the book).

[22] Amongst other things, this seems to me to the point of view of scholars like U. ALLEGRETTI, *Diritti e Stato nella mondializzazione*, Troina (EN), Città Aperta, II ed., 2002, p. 302 ff., bibl.

[23] Norberto Bobbio noted how the different legal disciplines have been flanked, in symbiosis, by non legal disciplines, for example: constitutional law by political science, international law by international relations, administrative law by administrative science (N. BOBBIO, *Diritto e scienze sociali*, in ID., "Dalla struttura alla funzione", cit., p. 43).

capable of recognising aspects characterising modern societies have been carried out (like the 'fluidity', precariousness, instability of relationships[24], the constantly wide spread condition of risk[25]) or how the neurosciences[26] influence our knowledge of processes of intent and, all of this makes it necessary for us to reflect again on our fundamental legal institutions.

But the moment when the jurist evaluates the relationship between the provision and the fact[27] (for the comprehension of which he must avail himself of the contribution of different disciplines and sciences other than his own), he must have firmly fixed in his mind the specificity of legal culture[28] (and the role of the law that is historically linked to the form of the State and its evolution). Social change and scientific and technological advances transform the reality that they aim to regulate (of this transformation of reality the jurist must know how to take cognizance), but *conditioning* of the factual context *does not mean automatism of the change of the legislative framework*: there is the role of interpretation (of the judge, arbitrators, the academic jurist, administrative apparatuses, lawyers interested in the application of the

[24] Take, for example, the large number of observations made by ZYGMUNT BAUMAN, of which I will only mention, *Liquid Modernity*, Oxford, Polity Press, Cambridge and Blackwell Publishers Ltd., 2000 (Italian translation, *Modernità liquida*, Roma-Bari, Laterza, 2006, X ed.); *Society under Siege*, Oxford, Polity Press, Cambridge and Blackwell Publishers Ltd., 2002 (Italian translation, *La società sotto assedio*, Roma-Bari, Laterza, 2007, IV ed.); *Liquid fear*, Cambridge, Polity Press, 2006 (Italian translation, *Paura liquida*, Roma-Bari, Laterza, 2008).

[25] I am thinking, in the first place, of the views of Ulrich Beck.

[26] Among the Italian jurists who have dedicated themselves with particular sensitivity to the relationship between neuroscience and the law, I will only mention Eugenio Picozza, Federico Gustavo Pizzetti, Amedeo Santosuosso. For our purposes, it is sufficient to refer to E. PICOZZA, D. TERRACINA, L. CAPRARO, V. CUZZOCREA, *Neurodiritto: una introduzione*, Torino, Giappichelli, 2011; F.G. PIZZETTI, *Neuroscienze forensi e diritti fondamentali: spunti costituzionali*, Torino, Giappichelli, 2012; A. SANTOSUOSSO (a cura di), *Le neuroscienze e il diritto*, Como-Pavia, Ibis, 2009; ID., *Diritto, scienza, nuove tecnologie*, Padova, Cedam, 2011, in part. p. 213 ff., *ivi*, p. 313 ff. bibl. Among more recent meetings, the seminar organized by Nicola Lettieri, Ernesto Fabiani, Sebastiano Faro, *Diritto & Neuroscienze. Temi e proposte per la teoria e la pratica del diritto* (Rome 3 December 2012) is worth mentioning.

[27] Interesting observations about transformations of the legal dimension have been made by M. VOGLIOTTI, *Tra fatto e diritto. Oltre la modernità giuridica*, Giappichelli, Torino, 2007. Written by the same Author, see, *Il tramonto della modernità. Un percorso interdisciplinare*, Giappichelli, Torino, 2008 and ID., *Dalla crisi delle fonti al primato dell'interpretazione: conseguenze sull'insegnamento universitario del diritto*, in Palazzo F., Roselli O. (a cura di), "I professionisti della giustizia", Napoli, ESI, 2007, p. 167 ff.

[28] Caution should be used in automatically transposing sociological analysis into the legal dimension, with specific reference to Bauman's "liquid/solid" notions: P. GROSSI, *Tra fatto e diritto*, in "Quaderni Fiorentini", 2009, n. 38, p. 1903.

provisions) to mediate between the change in reality and the provisions. As Ascarelli[29] teaches us (and the Italian Constitutional Court itself, that has by no coincidence elaborated an articulated type of decisions) only when the provisions are interpreted they turn into rules.

When, for example, we use neurosciences or computational sciences[30] (often an indispensable aid for the fundamental legal profile of the interpretation of the fact), it is then necessary to keep well in mind that

> "Il diritto non ha carattere matematico e l'opera dell'interprete non può ridursi a una deduzione logica: al contrario l'opera dell'interprete non può prescindere da – are Ascarelli's words reported by Bobbio – 'continue valutazioni onde fissare la regola e l'eccezione, determinare nell'unità del sistema la portata di un principio giuridico, valutazioni che hanno luogo in base a tutti i dati logici, storici, politici, economici, risultanti dal sistema, in base alla generale concezione dell'interprete del sistema giuridico e del fenomeno sociale, del suo sviluppo storico, del senso della sua evoluzione'"[31].

Rethinking legal institutions is an indicator of the trend in society and describes the type of cultural priority in giving an answer to "civilisation and its discontents"[32]. This is further evidence of how the legal sphere incorporates not only a fabric of provisions but also the factual dimension interpreted in the light of cultural trends. Evaluation by the jurist of the contribution of other sciences (of any kind, social or 'exact'[33]) cannot be performed by being

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29 N. BOBBIO, *Tullio Ascarelli*, in ID., "Dalla struttura alla funzione", cit., p. 223 ff.

30 See, overall, S. FARO, N. LETTIERI, A. TARTAGLIA POLCINI (a cura di), *Diritto e tecnologie: verso le scienze sociali computazionali. Attualità e orizzonti dell'Informatica giuridica*, Napoli, ESI, 2011.

31 "The law does not have a mathematical nature and the work of the interpreter cannot be reduced to a logical deduction: on the contrary, the work of the interpreter cannot disregard – are Ascarelli's words reported by Bobbio – 'continuous evaluations in order to fix the rule and the exception, to determine within the unit of the system the scope of a legal principle, evaluations that take place based on all the logical, historical, political and economic data resulting from the system, on the basis of the interpreter's general concept of the legal system and of the social phenomenon, of its historical development, of the sense of its evolution'", N. BOBBIO, *Tullio Ascarelli*, cit., p. 209.

32 If you let me borrow (giving it a broad meaning) the title of a 1929 essay by SIGMUND FREUD, *Civilisation and Its Discontents*.

33 In the area of the definition of 'science', there is not even any terminological agreement: thus, exact, experimental, formal, human, social, life, material, cultural and still other sciences are talked about (allow me to refer the reader to: O. ROSELLI, *Scienza, scienza giuridica, scienza della formazione giuridica*, in "Rassegna di diritto pubblico europeo", 2010, n. 2, p. 183 (recently also in ID., *Scritti per una scienza della formazione giuridica*, cit., p. 215 ff.).

flatly mechanical but he must have the greatest understanding of the reality that the law is to regulate.

5. The Idea of Science and the Concept of the Completeness or Incompleteness of the Legal Order

Sometimes, jurists who are meritoriously open to the contribution of other sciences have a sense of cultural inferiority, in particular, in comparison with so-called "exact sciences", almost as if they had introjected a reductionist concept of science, according to which social sciences and humanities are minor sciences because they are deemed to be less able to allow us to acquire certainties and envisage complete systems. With this, a kind of nostalgia for the idea of the certainty of the law and the legal order as complete reality is manifested. These are concepts that are debtors to an idea of the enlightenment of science as a complete system; an idea of science understood as a method for gaining certainties.

But scientific research assumes continual verification of its results, and is structurally aimed at going beyond them. Science is, as Popper tells us, a research method capable of rethinking its results which are never assumed to be ontologically definitive.

"The idea of incompleteness"[34] concerns not only the law, as it "belongs to the very nature of the legal order"[35], but every intellectual sphere. This awareness should aid the jurist in overcoming his sense of inferiority regarding the sciences considered to be 'exact' and the sensation of scientific fragility in coming to terms with a world in whirling transformation.

The challenge to incompleteness does not lie in the presumption of rebuilding definitive certainties but in persevering in research and confrontation.

[34] This is the title of a book by S. Veca, *L'idea di incompletezza. Quattro lezioni*, Milano, Feltrinelli, 2011.

[35] N. Bobbio, *Tullio Ascarelli*, cit., p. 194.

Robotic Societies and Law: A Plea for a Robotic and Simulation Science of Legal Phenomena

DOMENICO PARISI*

Today, computers are everywhere and they are increasingly invading the life of human beings and the functioning of their societies. This has both positive and negative aspects but one certainly positive aspect is that computers can be scientific tools that let us better understand all aspects of reality, including human beings and human societies. Computers can collect enormous quantities of data and find all sorts of regularities in the data but it is not clear that these "big data", although useful, do not really explain reality. A more interesting use of computers as scientific tools is that they can be used to construct artifacts that behave like human beings and live in artificial societies which are like human societies. The artifacts are theories of human behaviour and human societies. Scientific theories of human behaviour and human societies are traditionally formulated by using words but words have unclear and ambiguous meaning, and their meaning remains unclear and ambiguous even when they are defined or re-defined by using other words. Theories as computer-based artifacts are entirely clear and unambiguous because, otherwise, the artifact cannot be constructed and one can always "open" the artifact and see how it is structured and functions. The behaviour of the artifacts are the empirical predictions which are derived from the theory which has been used to construct the artifacts. If the artifacts behave like human beings and reproduce human societies, the theory is confirmed and the artifacts capture what underlies human behaviour and human societies and explains them.

To exploit the advantages of this approach, one should follow the principle "one artifact (one theory)/many phenomena". The same artifact should be able to reproduce (explain) as many different human phenomena as possible. In fact, computers make it possible to develop a non-disciplinary science of human beings and human societies. Reality is a very large ensemble of different phenomena but all these phenomena are connected together and, often, to explain the phenomena which are studied by one discipline, it is necessary to look at the phenomena studied by other disciplines. Hence, to really

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understand human beings and their societies, the same artifact should be able to reproduce phenomena which are studied by the biological sciences, in particular evolutionary biology and the neurosciences, psychology, anthropology, sociology, economics, political science, legal science, and the historical sciences. To explain human behaviour one cannot ignore its biological and, ultimately, physical bases, and therefore the artifacts that reproduce human behaviour and human societies must be robots and collections of robots. Today, most robots are constructed with practical applications in mind. These are robots as technology. What we are talking about here are robots as scientific theories, and the two different goals for constructing robots should be kept separate because they dictate different research agendas.

One significant class of human behaviours and human social institutions are those which are studied by the legal sciences. The system of laws and regulations existing in a society is an important component of the society and we cannot claim to have understood a society unless we have understood and explained its system of laws and regulations. The legal sciences, perhaps more than other scientific disciplines who study human beings and human societies, are both an attempt at knowing and understanding reality and an attempt at identifying how human societies should be regulated in order to function properly and what should be done with respect to behaviours which violate these regulations and therefore damage others - either single individuals or the entire society. Science can be useful to human beings both for understanding reality and for solving their problems but the two goals should not be confused together because science can only know and understand reality if it looks at reality with complete detachment and ignores values and ideologies. One advantage of a robotic science of human beings is that it forces scientists to ignore their values and ideologies because, once you have constructed a robot, the theory incorporated in the robot will generate all the predictions that can be derived from the theory, both those that you like and those that you do not like. But robots as scientific theories should also help human beings to deal with the very difficult problems they face today and will increasingly face in the future and to design what can be called “non-utopian utopias”: artificial worlds which can be analyzed and manipulated like the real world and which, although they are not real, can be made real.

A robotic science of legal phenomena still does not exist, although there are attempts in the field of artificial intelligence and agent-based social simulations, and even in the collection and analysis of “big data”, that produce interesting results and offer useful suggestions. What we will do here is outline some of the phenomena that this science should be able to reproduce and some of the questions that it should be able to answer.

Robot as theories of human behaviour must have a body and a brain, they must have genes which evolve in a succession of generations and that they inherit at birth, they must live in an environment which includes other robots, they must learn in this environment, and they must mostly learn by imitating or by being told by other robots. Furthermore, there must be all sorts of interactions among the robots and all sorts of social organizations and institutions which constrain their behaviour and shape their society. This clearly is a difficult objective to reach but our principle "one artifact/many phenomena" requires that we progressively realize this objective because only if we construct robots that have all these characteristics and exhibit all these behaviours, we can reasonably claim that we have reproduced and, therefore, understood and explained human behaviour and human societies. Which phenomena should these robots reproduce that are studied by students of laws and regulations? We will answer this question by posing a number of research questions.

Human beings sometimes behave selfishly, by doing their personal good while ignoring the good of others, and sometimes they behave altruistically, by doing the good of others even at the expense of their own good. Is selfishness genetically inherited and altruism culturally learned, or the other way round? Are they both genetically inherited and culturally learned? To the extent that selfishness and altruism are culturally learned, what kind of culture and what kind of society will favour selfishness or altruism? Can we construct robots that help us to answer these questions?

Sometimes human beings behave in ways that damage others and, if a society does not find how to contain these other-damaging behaviours, it may collapse because for its members the advantages of living together may be overridden by the disadvantages. Can robots help us explain other-damaging behaviours? Can robots help us distinguish among different classes of other-damaging behaviours? Can robots help us to identify how to contain these different classes of other-damaging behaviours?

Punishment is one way in which other-damaging behaviours can be contained. Punishment is a very important aspect of the behaviour of all animals. If one behaviour is followed by some stimulus which decreases the probability that the behaviour will be executed in the future, the stimulus is a punishing stimulus. (Rewards are stimuli that increase the probability that the behaviour which has been followed by them will be executed in the future). It is evolution which gives punishment or reward value to stimuli and therefore the system of punishment and reward is inscribed in the genes. But, especially in human beings, whose behaviour is mainly learned during life, initially neutral stimuli can become punishing or rewarding because they are associated with stimuli which already are punishing or rewarding. Robots that learn based on punishments and rewards already exist but legal phenomena pose many new problems. Is being punished because of one's other-damaging behaviours different from being punished for behaviours which only damages oneself? Is being punished by "nature" (like touching a very hot object with one's finger) different from being punished by another individual? Some social animals are punished by other individuals. Is being punished by another individual (a conspecific) the same for nonhuman animals and for human beings? Is being punished by another individual in the presence of other individuals the same or different from being punished by another individual in the absence of other individuals - or without that other individuals can be informed of the punishment?

Punishment can have different effects as a function of the nature of the other-damaging behaviour, for example, as a function of whether the other-damaging behaviour was "willed" or "not willed". Can we construct not only robots which, like current robots, do X but also robots that want to do X? How should the two types of robots behave so that we are justified in saying that they are different? How should the brains (artificial neural networks) that control the behaviour of the two types of robots be different? At which age human beings become able to want to do X? Are there pathologies that cause human beings to become unable to want to do X so that they can only do X? What is the role of the ability to predict the consequences of one's actions in wanting to do X - or in being "conscious" of what one is doing or will do? What is the role of being able to linguistically describe to oneself these consequences? What is the role of the ability to evaluate the predicted consequences of one's actions before executing the actions? Does this evaluation takes into consideration only one's advantages and disadvantages or also the advantages and disadvantages (damage) for others? (Robots that predict the consequences of their actions and evaluate these consequences and robots that talk to themselves have already been constructed).

Are there nonhuman animals that want to do what they do? Is there a continuum, which can be illustrated by examining different animals, or a neat separation between simply doing X (for example, in worms) and doing X because one wants to do X (for example, in some nonhuman primates)? If doing X is followed by punishment (especially punishment from others), what are the consequences for robots that only do X and for robots that do not only do X but also want to do X? Should we construct other types of robots, for example, robots that have the intention to do X and robots that are thinking of doing X?

As we have said, most behaviours of human beings are learned from others and human beings tend to imitate the behaviour of the other individuals with whom they interact. Therefore, we should construct communities of robots that include sub-communities made up of robots that interact among themselves more than with robots belonging to other sub-communities. This may lead to the existence to sub-communities of robots who tend to behave without damaging others and other sub-communities made up of robots which tend to damage others. Does the existence of sub-communities of robots that tend to damage others reduce the efficacy of punishment? (Some robots that try to answer this question have been constructed).

Punishment may not be the only mechanism for containing other-damaging behaviours. Other-damaging behaviours can be exhibited because they are the only way to obtain what is needed for one's survival. A community of robots can organize itself so that all members of the community have what is needed for their survival and this may reduce the incidence of other-damaging behaviour. And the community of robots must compare the costs of other-damaging behaviour and of discovering and punishing other-damaging behaviours with the costs of insuring that every member of the community can survive without damaging others. (Robots that answer this question also have been constructed). Other interesting questions are the following. Can we construct robots that can be said to have "rules of behaviour"? Can only robots that want to do X because they predict the consequences of their planned but not executed actions and evaluate these consequences, have rules of behaviour? Is language and talking to oneself necessary? Is being punished not by a single other robot but by the entire community of robots, or by a representative of the entire community, necessary? How rules of behaviour emerge and how are they established? Does violating rules of behaviour automatically damage others because it makes behaviour less predictable and being able to predict the behaviour of others is crucial for living together? Why are some rules of behaviours written? What difference does it makes to have written rules of behaviour? In what types of robotic societies are rules of behaviour written?

As we have said, a robotic science of human beings and human societies should construct robots that progressively reproduce all the different phenomena which are studied by different disciplines. Human beings live in different societies and different cultures and their societies and cultures have different histories. Therefore, a robotic legal science should construct robotic societies with different cultures and compare how other-damaging behaviours are dealt with in these different cultures and how legal systems have changed during history. And it should find how legal systems correlate with the economic, political, and religious institutions of different robotic societies. Furthermore, legal systems are not the only mechanism for containing other-damaging behaviours. Another mechanism is self-punishment which can take the form of religious beliefs or lay morality. A robot punishes itself if it does some other-damaging behaviour or even if it thinks of doing some other-damaging behaviour, and this capacity/tendency to self-punishment can be innate or acquired during life. To the extent that it is acquired during life, we should construct different robotic societies in which the capacity/tendency to punish oneself for other-damaging behaviours is more or less developed.

But, as we have also said, a robotic science of human beings should also help human beings to better understand the many difficult problems they face today and will face in the future and, perhaps, suggest how to deal with these problems. We should construct robotic societies which are like today's societies and we should reproduce how today's societies deal - or should deal - with other-damaging behaviours. Some of the phenomena which characterize today's societies and which are relevant for a socially useful legal science are the following.

Due to advances in the technologies for transporting people, goods, information, and money, human beings are increasingly living in a globalised world. This globalisation is economic and cultural but political sovereignty remains to the states. Since states are responsible for defining the laws and regulations which are to be applied to their citizens, this creates a conflict between globalisation and local laws and regulations which will have to be solved, especially because other-damaging behaviours themselves become globalised. A plurality of robotic states with different legal systems and a variety of economic and cultural relations can be of help in finding and testing possible solutions.

The list of other-damaging behaviours must be constantly up-dated as a function of the changes that occur in societies and ways to contain new types of other-damaging behaviours must be found. Today's societies change very rapidly and, for example, the financial economy, marketing at all levels, and digital technologies have an increasing impact on human life and on the organization of human societies. Simulating financial economies, marketing, and the impact of digital technologies by constructing robotic societies may help legal systems to identify their potential other-damaging impact and how to reduce this impact.

Western culture leads to a decrease in the strength of self-punishment as a way to contain other-damaging behaviours. Religion plays a decreasing role in Western culture and economic and cultural reasons, the reduced role of the family and the fact that an increasing number of people live in cities, lead to forms of extreme individualism in which the consequences of one's behaviour for others are less taken into consideration, unless they are punished by the law. Robotic societies which reproduce Western societies and non-Western societies which are adopting Western culture should help us to examine this phenomenon and its consequences and, if these consequences are negative for the well-being of human beings, to find ways to correct it.

What Social Simulation Might Tell Us about How Law Works

BRUCE EDMONDS*

SUMMARY: *1. Introduction – 2. Computer Simulation of Social Phenomena – 3. Examples – 3.1. Breakdown in Norm Compliance – 3.2. Preparing the Ground for Compliance to Legislation – 3.3. Bootstrapping Away from Endemic Corruption – 3.4. The Efficacy of Different Modes of Legal Rule-making – 4. Conclusion*

1. INTRODUCTION

This paper does not consider the important questions of "How is law made?", "How is it applied in various cases?", nor "Is Law X effective?", but rather some underlying questions that are less often asked, namely: "How does law work?" and "Why does law work?". It will not, in this brief discussion, come up with answers, but rather sketch how a certain technique might help in discovering the answers. That technique is agent-based social simulation – using computer simulations that trace out possible "histories" of interactions between social actors to help understand how social phenomena develop.

It may seem that the answers to the two questions are rather obvious. Law works by force: the state uses its power to either take control of situations it needs to, or punishes those that disobey its published rules. Law works because the state is more powerful than others. However, these explanations are simplistic, at best sketching the ultimate underpinning of complex social processes which include: habit, social norms, imitation, status, self-interest, opportunity, personal power, gossip, reputation, identity, group formation, contextual framing and simple habit. Law "bootstraps" itself upon different mixtures of these in different circumstances, almost never (at least in modern European countries) relying on force alone. Whilst one law (e.g. a road safety law) might rely on a mixture of self-interest, suggestion (via signs), habit and mild threats (fines) another (say a bankruptcy law) might rest upon considerations of reputation and potential loss of power (to easily borrow money in the future).

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Understanding how these different social aspects result in effective law is often mundane; we have an intuitive and common sense insight into the reasons and the processes (e.g. people drive on the right hand side of the road for their own and others' safety). Our every-day knowledge is adequate to explain most of the circumstances of law abidance that we observe, and any exceptions analysed within a natural language discourse. However, it can also be mysterious when things get complicated, for example: when there is a complex mix of countervailing "forces", when it involves many different groupings of actors, when underlying social conditions are changing, or when adherence to a law suddenly breaks down. In order to understand these kinds of situation we would need super-human abilities – being able to trace (or express) multi-dimensional complex and dynamic networks of interaction all at once. In other words, such social outcomes can not be sufficiently understood using thought and natural language alone due to their representational limitations and thus sometimes we are surprised at outcomes that we cannot adequately explain.

2. Computer Simulation of Social Phenomena

Computer simulation complements natural language in its affordances. Whilst natural language is semantically rich, good at abstraction (through the mechanism of analogy) and context-sensitive, computer simulation is precise, holding a mass of simultaneous detail in parallel, good at tracking complex networks of interactions and dynamic processes. This means that it can track complexes of dynamic interactions where the outcomes are not predictable from simple considerations of overall motivations, but rather comes out of the detailed building up of short-term meso-level societal structures[1]. Thus computer simulations that do track interactions down to individual social actors can reveal possible connections between the micro-level of individual actors and their interactions with the macro-level societal outcomes (such as the level of general compliance, or otherwise, to a law). It is possible to use ideas and analogies to explain an observed micro-macro connection but it is then almost possible to know if that is just a "gloss" that rationalises the connection or whether it captures something useful (e.g. something that can result in policy that broadly works). A computer simulation, however, produces precise (but complicated) accounts that show *how* the outcomes

[1] K. Sawyer, *Social Emergence: Societies as Complex Systems*, Cambridge, Cambridge University Press, 2005.

can come about in a way that reveals new questions and issues that can then inform subsequent empirical work. One can summarise this by saying that it generates *real possibilities* and hence can give credibility and precision to explanations of emergent outcomes. Thus computer simulation never supplants natural language but rather works in parallel with it, with a constant interplay between the two systems of representation.

A common, and understandable, objection to the computational simulation of social phenomena is that it inevitably leaves a lot of the original out, simplifying and abstracting. This leaves the worry that some factor or process that is essential to explaining the development of the relevant phenomena has been omitted.

Such fears have been exacerbated by the poor track record in terms of the formal modelling of social phenomena, when the ambitions of the proponents have lead them to make sweeping conclusions purely on the result of very abstract models. A stark example of this is economics, where very strong assumptions (motivated by a desire for analytic tractability) were routinely made to achieve abstract conclusions that coincided neatly with the ideological biases of its proponents (such as the efficiency of free markets). What was missing in these attempts was any good relationship between the models and what is actually observed – either at the micro-level in terms of how people actually think and behave or at the macro-level in terms of the aggregate outcomes (such as the obsession with proving the existence of equilibria even though there is usually no evidence for them). These kinds of model are no more than an analogy expressed in a formal system – "computational analogies". Of course, there is absolutely nothing wrong with analogies, as long as they are not presented as "hard science" and hence having a higher degree of reliability than they merit.

Of course, our everyday experience suggests two things: firstly, that human society is far more complicated than could ever be represented in a computer simulation and, secondly, that even where social interaction does seem to follow certain rules or patterns these can be undermined or abnegated by something that "changes the rules" from the outside (for example when a person who embodies a new goal or ambition is introduced into a society changing people's thinking and motivation). If a computer simulation had to be this comprehensive in terms of its representation to be useful and go beyond being an analogy, then these would be fatal critiques. This is not, of course, something than can be proved in the abstract, but rather something that will (or will not) be demonstrated in practice. However, I would argue that this need not be the case – that there is at least the possibility of useful simulations of society. To do this I look to another science that deals with phenomena which has a commensurable level of complexity to that of social phenomena – cell biochemistry. Within cell biochemistry there is a well-established distinction between *in vivo* and *in vitro* studies. *In vivo* studies are those that investigate living cells, whilst in vitro studies are those that examine the interaction within the artificial environment of the test tube[2]. The point is that, if cell biochemists are to have any hope of unravelling how cell biochemistry works, they need both *in vivo* and *in vitro* studies.

In vitro studies allow one to work out the interactions between a restricted set of cell molecules within a controlled environment. What this tells one is some of the possible interactions between these in the cell, but does not give you the complete picture. What happens in the test tube might well be undermined or overwhelmed by other reactions in a living cell, so conclusions from an *in vitro* study need to be made carefully and checked.

An *in vivo* study will give a realistic picture about the biochemical behaviour in a cell, but the interactions will be so complex, with one process "switching" other processes that any set of data so obtained may not be very helpful in terms of our understanding of that behaviour. This is for two reasons: *firstly*, it will necessarily be a very partial picture of the possible behaviours since the internal self-organisation of the cell does not allow an externally-driven study to reveal the full range of possibilities and, *secondly*, the resulting data will be the result of a very complex set of interactions, appearing "noisy" and making the detection of patterns hard. The first difficulty means that it is not possible to perform targeted experiments to test particular hypotheses or understandings about the internal processes and the second means that any such test may result in very weak correlations, since the target pattern may well be swamped by signals from other, possibly countervailing, processes. Thus trying to understand cell biology from *in vivo* studies alone is hopeless.

Computer simulations are the equivalent of the *in vitro* studies in cell biology. They do not supplant the equivalent of *in vivo* studies, which would be empirical studies of social phenomena (surveys, interviews, analysing tweets, observation, ethnography etc.) but are complementary to these. It allows the exploration of possible interactions and properties of selected subsets of the full range that exist in society. Trying to detangle even a small subset of what

[2] See, e.g., as in S.S. ROTHMAN, *Lessons from the Living Cell: The Culture of Science and the Limits of Reductionism*, New York, McGraw-Hill, 2002.

is happening, relying only on *in vivo* studies and natural language discourse, would be as hopeless for understanding the full complexity of society as it would be to understand the full complexity of cell biology[3] – the phenomena we are considering are so complex that we need all the tools at our disposal, *provided we understand the limitations of each*.

Computer simulations of society thus allow for comprehensive sets of artificial experiments, exploring the "what if" possibilities that are (rarely) accessible from direct *in vivo* studies. They are primarily *possibilistic* in nature rather than *probabilistic*. That is, they reveal some of the possible complex causal chains that may exist rather than the *probability* of any particular possibility. This is appropriate since any probability derived from a simulation would be relative to the set of possibilities in that simulation, which might be a distorted and tiny subset of those observed *in vivo*. Most probabilistic projections of formal models of aspects of society (e.g. economic ones) are concerning the internal dynamics of the model and do not properly refer to likelihoods in reality, since this would require a knowledge of the total space of possibilities there[4].

Of course, if a cell biochemist took a random set of chemicals and did experiments on them, this might be interesting but there would be no reason to suppose any results had anything to do with real cells. Rather, great care is taken to ensure that the chemicals in the test tube are the same as those in the cell. Similarly in the construction of social simulations one needs to ensure that the processes being examined there correspond to those observed in society, otherwise, however interesting the results, there would be no reason to suppose they had anything to do with observed social processes. Whilst clearly we can not simply "take" observed social processes and actors and "drop" them into computer simulations, the closer and more direct the relationship between what is observed and the simulation the better. If there is only a weak, conceptual relationship between the observed and the simulated the best one can hope for is a computational analogy – another way of

[3] There are many reasons to suppose that social systems are as complex, including the presence of both emergent and immergent processes (R. CONTE, G. ANDRIGHETTO, M. CAMPENNÌ, M. PAOLUCCI, *Emergent and Immergent Effects in Complex Social Systems*, in "Proceedings of AAAI Symposium, Social and Organizational Aspects of Intelligence", 2007), and the self organising, "autopoietic", propensities of each (F. VARELA, H. MATURANA, R. URIBE, *Autopoiesis: The Organization of Living Systems, Its Characterization and a Model*, in "Biosystems", 1974, n. 5, pp. 187-196).

[4] F.H. KNIGHT, *Risk, Uncertainty, and Profit*, Boston-New York, Houghton Mifflin, 1921.

"thinking about" the target social processes – but this is a strange use of computer simulation since natural language is much better suited to expressing and exploring analogies. If the relationship is evidence-driven, derived from observations of individuals (however mundane), then the simulation is more likely to be relevant.

Ensuring the correct "ingredients" of an *in vitro* study is but one check upon its relevance, one also seeks to ensure the environment of any experiment is realistic, and then check any results for their plausibility compared to observed data. This is the same with social simulation, one seeks to check the relevance of its processes in as many ways as possible, including: aggregate outcomes, the shapes of distributions that result from it, time series derived from it, the structure of intermediate level groups and networks, and even the "trajectories" of individual agents in it[5]. Thus, whilst constructing and exploring computer simulations may seem a lot easier and cheaper than any *in vivo* studies of society, there is a corresponding effort needed in ensuring their relevance. The formal modelling of social phenomena has been tainted by the over-interpretation of models that, in fact, have no strong relationship to what is observed – a mistake that would not be made by researchers using *in vitro* techniques in cell biochemistry!

3. EXAMPLES

If, as I have argued above, suitable computer simulations have an indispensable role to play in understanding of social phenomena, including those that involve the law, then the question remains as to what kinds of problem or issue might this technique be helpful with. In the last part of this paper I briefly outline several targets where simulation has the potential for progressing our understanding. These illustrate the sort of questions that computational simulation may help answer. This is not meant in any way to be a comprehensive list but rather highlighting cases where complex simulation might play a particularly crucial role in teasing out the complex interactions between social processes[6].

[5] R.L. AXTELL, J.M. EPSTEIN, *Agent-based Modelling: Understanding Our Creations*, in "The Bulletin of the Santa Fe Institute", 1994, n. 9, pp. 28-32.

[6] For example it misses out more obvious examples such as simulating and mapping burglary using simulations techniques (see, e.g., N. MALLESON, A. EVANS, T. JENKINS, *An Agent-based Model of Burglary*, in "Environment and Planning B: Planning and Design", Vol. 36, 2009, n. 6, pp. 1103-1123; N. MALLESON, A. HEPPENSTALL, L. SEE, *Crime Reduction*

3.1. Breakdown in Norm Compliance

There is rarely a sufficient expression of state power to enforce local compliance, for example damage to property, but rather the existence of group norms ensures that, *usually*, individuals constrain themselves to what is generally acceptable. Here there is a complex combination of forces: social norms that applies to different groupings of actors, the ability of the state to locally back-up the norms, and the self-interest of those concerned. Clearly, in some cases, e.g. the recent UK riots[7]. There these norms either broke down (or did not hold with respect to the groups that locally formed) and the immediate local law enforcement was inadequate. It has been argued that a similar situation now holds in Afghanistan[8]. It seems that a complex feedback loop is behind such breakdowns: a perception that a norm no longer holds free individuals from following that norm[9], self-selection during the formation of groups allows for collections of individuals to form without those that might uphold the norms, the local concentration of power by the group means that state force is (at least temporarily) excluded thus allowing the possibility of ignoring the norm to be established, and the social imitation of actions allows for "seed" individuals to influence many others. It is difficult to tease out the micro-level ordering of these processes from personal accounts and observational evidence since the different processes are happening at different times with different individuals simultaneously. Computational simulation allows for a series of *in vitro* experiments where different micro-level orderings are tried to see if this might have an effect on the macro-level outcomes. This might suggest ways to distinguish the different possibilities from the evidence, ruling out some and revealing distinguishing traits that might be investigated in subsequent *in vivo* research. Knowing more about the micro-level possibilities might allow for more ef-

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through Simulation: An Agent-based Model of Burglary, in "Computers, Environment and Urban Systems", Vol. 31, 2010, n. 3, pp. 236-250).

[7] T. DE CASTELLA, C. MCCLATCHEY, *UK Riots: What Turns People into Looters?*, in "BBC News Magazine", 9 August 2011, http://www.bbc.co.uk/news/magazine-14463452.

[8] A. GELLER, *The Political Economy of Normlessness in Afghanistan*, in Schlenkhoff A., Oeppen, C. (eds.), "Understanding Afghanistan. An Interdisciplinary Approach", London, Hurst & Co., 2008.

[9] C. BICCHIERI, *The Grammar of Society: The Nature and Dynamics of Social Norms*, New York, Cambridge University Press, 2006; C. BICCHIERI, M. MERCIER, *Norms and Beliefs: How Change Occurs*, in Xenitidou M., Edmonds B. (eds.), "The Dynamic View of Norms", Cambridge, Cambridge University Press, forthcoming.

fective intervention strategies, for example the importance of social inclusion strategies compared to crowd dispersal techniques.

3.2. Preparing the Ground for Compliance to Legislation

The reverse case of a breakdown in social compliance is when compliance with a new law is desired (or the need for a more widespread compliance with an existing law is felt to be needed). In the UK, the government campaign against "drink driving" (driving with more alcohol in the blood than the law allows) was broadly successful, helping to change social norms so that it became unacceptable to drink before driving. In contrast, the recent campaign against driving above the speed limit has invoked a lot of hostility and much opposition – even to the extent that some local authorities have since stopped using the automatic speed cameras that they installed. Clearly, in some cases the law seems to lead the development of new social norms and in other cases if it does not follow existing norms it will not. In the later case the introduction of a law might be expensive to enforce and relatively ineffective. This case involves a similar mixture of social processes as the preceding one, since it is the opposite case: the development of a new norm rather than the breakdown of an old one. However, there is no reason to suppose these processes are symmetric: norms seem to get established in a much slower and pervasive manner, whilst they seem to break down in patchy and sudden events. Clearly both are intensely social processes but also involve the perceptions, expectations and assumptions of individuals. Simulation might be able to tease out some of the possible ways in which new norms get established, providing complex but explicit traces of norm establishment. This might help distinguish situations where a population is ready to be "led" by a new law and where the building of a social consensus is necessary first.

3.3. Bootstrapping Away from Endemic Corruption

Social institutions of all kinds seem to have a remarkable persistence once they become established. If owning a house and land becomes established as a key to social status, due to the wealth and power it gives, then such ownership can persist as a sought-after status symbol even after other means to wealth and power predominate. This persistence holds regardless of whether the institution is state-sponsored or is inimical to the state. Thus in societies where corruption is long-established then it is very difficult to shift – simply making it illegal has limited efficacy. Once in place complex webs of expectation, reputation, norms, loyalties and habit help keep it in place. Thus even if one successfully attacks one of these supporting "pillars" the others preserve the phenomena. However, history does show that new institutions can supplant entrenched social institutions if the conditions are right. However it is unclear exactly how this happens or how such a change can be facilitated. Particular historical examples give valuable insights but due to the "density" and embeddedness of social processes it is very hard to separate what was essential to this and what was merely a contributory factor. Thus the analysis of historical examples typically allows for a plethora of alternative explanations for the same events. Computer simulation could help make more precise hypotheses about the importance of each factor that might lead to suggestions of interventions that might then be tried out and monitored. Some simulation that is working in this direction is proposed by Sonzogni and colleagues[10]. As made clear above, any suggestions derived from computer experiments are not guaranteed to succeed but, due to the fact that they are based on precise hypotheses about the interaction between the social processes involved, they might have a greater likelihood of succeeding and, *more importantly*, regardless of their level of success will give far greater insights into how to make such interventions and how they might be improved/modified.

3.4. The Efficacy of Different Modes of Legal Rule-making

Legal processes are a part of the complex web of social processes. They are effective (or otherwise) largely as a result of their embedding and place within the other social processes and institutions that exist. Thus they are also possible subjects for computer simulation. In particular, there is a choice of *how* a legal goal is applied. A precise but complex set of rules may be specified in an effort to cover all possible cases it might apply to; a general principle might be laid down with an obligation to apply it with regard to the local circumstances, leaving it to the discretion of a local authority to interpret taking into regard local conditions; the scope of a law might be left to the development of case law over time, so that gradually a set of exemplars

[10] B. SONZOGNI, F. CECCONI, R. CONTE, *Dynamics of Illegality. The Case of Mafia Systems*, in "Proceedings of the Lisbon European Conference on Complex Systems - ECCS 2010", ISTCE-Lisbon University Institute (Lisbon, 13-17 September 2010); B. SONZOGNI, F. CECCONI, R. CONTE, *On the Interplay between Extortion and Punishment. An Agent Based Model of Camorra*, in "Proceedings of the 2011 Computational Social Science Society of America Annual Conference - CSSSA 2011" (Santa Fe, 9-12 October 2011).

where the law is deemed to hold (or otherwise) can be established as a fuzzy guide to its applicability; or the law could insist on the existence of local processes with a liability for their maintenance (e.g., evacuation procedures in public buildings). Which style is applied in which kind of situation is largely left to the intuition of lawmakers informed by past experiences and existing traditions. However, it seems highly likely that the style of a law has a big impact upon its efficacy and enforcement cost. Computer simulations might give an insight into the possible consequences and drawbacks of each kind, enabling a more informed decision as to how best achieve a social goal using the law. An example of this is where individual firms contextualise abstract rules in a two-way process with the compliance authority[11]. Whilst the kind of computer simulations are not very good at predicting what will happen, they are good at revealing the possible risks of any choice.

4. Conclusion

Social simulation models have a crucial role to play in understanding the possibilities inherent in complex social systems, including those with legal aspects to them. Without modelling how complexes of social mechanisms can play out within society, we will be limited to "broad brush" reasoning concerning the various social "pressures" people are under – which does not work when there are complex mixes of countervailing pressures, and the use of discursive analogies which necessarily miss out the detail of social interaction and hence any emergent social phenomena. Just as in cell biochemistry *in vitro* experiments can help tease apart some of the complex interactions. These do not replace *in vivo* studies in any way but rather complement them, suggesting possibilities that subsequent empirical studies can investigate and producing precise but complicated models of the existing evidence.

[11] B. Burgemeestre, J. Hulstijn, Y.H. Tan, *Rule-based versus Principle-based Regulatory Compliance*, in Governatori G. (ed.), "Proceedings of the JURIX 2009, 22nd Annual Conference on Legal Knowledge and Information Systems", Amsterdam, IOS Press, 2009, pp. 37-46; B. Burgemeestre, J. Hulstijn, Y.H. Tan, *Norm Emergence in Regulatory Compliance*, in Xenitidou M., Edmonds B. (eds.), "The Dynamic View of Norms", Cambridge Univeristy Press, forthcoming.

Legislation, Regulatory Impact Assessment and Simulation

KLAUS G. TROITZSCH*

1. INTRODUCTION

1.1. Overview

This article gives an overview over various possible applications of simulation approaches to legislation. Simulation has been used in legislative processes for several decades, nearly from the time when simulation was first used in the social sciences, particularly in political science. Its main use so far was in assessing the impact of alternative political strategies before new legislation would be set into force. This is why Section 2. of this article first discusses the role of regulatory impact assessment. Sections 3 through 5 are then devoted to a discussion of three of the major approaches to social simulation and their use for impact assessment: static and dynamic microsimulation as well as agent-based simulation. Whereas the two former have a tradition of more than half a century, the latter made its entrance into the repertoire of computational social science only some twenty years ago, although there were several forerunners before the term "agent-based simulation" was coined which used similar techniques.

* The Author is professor emeritus at the Universität Koblenz-Landau (Germany). Section 2. extends the introduction of the earlier paper M. BICKING, K.G. TROITZSCH, M.A. WIMMER, *Regulatory Impact Assessment: Modelling and Simulation to Facilitate Policy Choices*, in Ernst A., Kuhn S. (eds.), "Proceedings of the 3rd World Congress on Social Simulation. Scientific Advances in Understanding Societal Processes and Dynamics - WCSS2010", CD-ROM, Center for Environmental Systems Research, University of Kassel, 2010. Section 5.2. discusses first results of the OCOPOMO project (co-funded by the EU within FP7, contract No. 248128; the European Commission cannot be made liable for any content) directed by Maria Wimmer at the University of Koblenz-Landau. The Author also gratefully remembers the time when he first came into contact with regulatory impact assessment during his membership in the Hamburg state legislature from 1974 till 1978.

1.2. Approaches to Social Simulation

During the long history of applying simulation to social, economic and political phenomena, several simulation approaches have been developed[1]. Some were used to forecast future states of a given target system, others rather had in mind that prediction and forecast should only follow a deep understanding of the system in question and a validation of models used for any kind of prediction. It is a matter of course that even the earliest attempts at forecasting via simulation set up complex models of the respective target systems, but the theory behind them was not in all cases properly validated (perhaps one of the reasons why there is often some skepticism among political decision makers about simulation models). If one follows Zeigler[2] one has to distinguish among three steps of validation: replicative, predictive and structural validation. While replicative validation is satisfied when a dynamic process model replicates data from the past (which can be tested at the time the model is first used), predictive validation can only be performed some time after the use of the model, as one has to wait for the predictions of the model to come true (or not). But even this predictive validation is by no means a guarantee for the structural validity of the model as different models might have predicted the same future state of the target system. We will discuss this issue with several examples of simulation models applied to processes where legislation was involved.

System dynamics and microsimulation are certainly the first among the simulation models used for supporting political decision making as they date back to the 1950s, as the System Dynamics Society and the International Microsimulation Association celebrated the 50th anniversaries of these two approaches in 2007[3]. These two approaches both have their merits in defining and analysing political strategies, but their application areas are entirely different.

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[1] N. GILBERT, K.G. TROITZSCH, *Simulation for the Social Scientist*, Maidenhead, Open University Press, 2nd ed., 2005.

[2] B.P. ZEIGLER, *Theory of Modelling and Simulation*, Krieger, Malabar, 1985. Reprint, first published in 1976, New York, Wiley.

[3] These events were documented in B. EBERLEIN, R. OLIVA, J. STERMAN, J. HOMER, R. SPENCER, *Welcome*, in "Proceedings of the 25th International Conference of the System Dynamics Society and 50th Anniversary Celebration", Albany, 2007, p. 1; see also A. ZAIDI, A. HARDING, P. WILLIAMSON, A. GUPTA (eds.), *Celebrating 50 Years of Microsimulation*, Proceedings of the 1st General Conference of the International Microsimulation Association, Vienna, 2007.

System Dynamics describes its target system as one undivided entity with a large number of state variables (levels) and state change variables (rates) which are connected to each other via a number of feedback loops formalising the dynamics of the system as a whole. Perhaps its first application to policy modelling was in Forrester's Urban Dynamics which (among others) was used to "simulate various classical urban-management programs. ...With these a job program for the underemployed can be introduced, underemployment training can be provided, tax expenditures for welfare and education can be subsidized, and a low-cost housing program can generate housing directly for the underemployed category of the population"[4]. All of these urban-management programs are, of course, subject to legislation, and in the foreword to this book, John F. Collins, former mayor of the city of Boston, acknowledges that it "attempts ...to show how the behavior of the actual system might be modified", i.e. as a guidance to legislators' modifications of the system. As for the replicative validity of Forrester's urban dynamics one would certainly concede that the model with its about 20 level equations describing the state and state changes of the system and with its more than 300 parameters yields approximate replications of a stylised urban area over 250 years. But Forrester himself warns against "tak[ing] these results and act[ing] on them without further examination of the underlying assumptions"[5]. And he repeats this warning after a detailed discussion of his model: "Before accepting the implications as a basis for actions, the reader should satisfy himself that the structure adequately represents the urban system and the particular problems with which he is dealing"[6] – which is doubtful at least in one respect: in system dynamics models it is variables such as "underemployed" (number of persons) or "declining industry" (number of productive units) which interact with each other, and not underemployed persons and employing firms.

Microsimulation offers a diametrically opposed approach as here the number of underemployed persons or declining firms would only be an aggregate variable which is calculated at the end of each simulated period from the decisions taken by underemployed persons and employing firms (for a more detailed example see Section 4.2.). Generally speaking, microsimulation starts from a large database of empirical data collected from a large number of

[4] J.W. FORRESTER, *Urban Dynamics*, Cambridge, MIT Press, 1969, p. 51.
[5] *Ivi*, p. 2.
[6] *Ivi*, p. 38.

households or individual persons or enterprises. This database contains all data per entity which are used to calculate its future state or states, and for this calculation two modes are usually used: either there is a predefined (and usually empirically based) probability, e.g. of dying during the next period, of giving birth to a child, or of entering into a job or into another job, where the probability depends on other states of the same entity, e.g. the person's age or education. Or the state changes according to some equation, e.g. of getting older by the length of the next period or of having to pay a certain amount of taxes according to the annual income. Microsimulation comes in mainly two different forms, static and dynamic.

- In the static case, we are not interested in changes of the state of essential attributes of the individual entities but only in the value of a variable such as tax load according to a modified tax law (whereas variables such as age or gross income remain unchanged). In this case there is no reactivity on the side of the individual entity, we only calculate what would have happened if different regulations had been in force instead of the ones valid in reality. We will give an example in Section 3.2.
- In the dynamic case, all characteristics of the individual entities may in principle change, which means that the individual entities may react on changes on the aggregate level, which also means that the composition and structure of the simulated population in terms of age classes, of employment classes etc. changes over time and can be aggregated to descriptions of the whole population for future periods.

The reactivity and thus the realistic modelling of real world human beings, households and enterprises in the dynamic microsimulation models is still restricted. This is one of the reasons why microsimulation is more and more replaced by agent-based simulation models in which the entities are endowed with additional characteristics beyond just reactivity. Among these additional characteristics[7] are autonomy, proactivity, and social ability which endow software agents representing human actors to modify the rules which govern their behaviour, to strive for goals and to have internal models of other agents. Only these additional characteristics allow for a more realistic modelling of the interactions between legislators and citizens. Whereas most agent-based models in the literature are relatively abstract and model

[7] These were first defined by M. WOOLDRIDGE, N.R. JENNINGS, *Intelligent Agents: Theory and Practice*, in "Knowledge Engineering Review", Vol. 10, 1995, n. 2, pp. 115-152; see also N. GILBERT, K.G. TROITZSCH, *op. cit.*, p. 176.

artificial societies to study emergent phenomena arising from microspecifications, e.g. the sugarscape variants[8], the technique of agent-based modelling can also be used to replicate real social systems in an extension to dynamic microsimulation (see Section 4.2. and Section 5.).

Generally speaking, an agent-based simulation model is a piece of software which creates an environment in which autonomous software agents can move, communicate whith each other, interact with the environment and thereby changing it. The software agents themselves are software agents which behave according to rules which are programmed into them, including rules to change rules. Usually they have a memory in which they can store perceptions which they receive from the environment and from other agents. They are programmed with goals which make them act proactively, i.e. even without a particular stimulus from the environment or from other agents (for more details see Section 4.2.), and usually there is an observer agents which reports what is going on in the model to the modeller.

2. A Short History of Regulatory Impact Assessment

The regulatory impact assessment has substantially changed over the last forty years. Although every bill starting a legislative process used to be accompanied with an explanation of what the potential consequences of setting it into force could be, a formalisation of this kind of explanation is only some 50 years old. As a recent OECD document[9] shows, elements of regulatory impact analysis were introduced in many industrialized countries as early as in the 1970s, in Denmark even in 1966. In Germany there were several forerunner systems before the ones mentioned in this document – which concedes this to Germany only from the 1980s, but under the Brandt government in 1969 and 1970 a system of policy planning was established in the chancellor's office, and academic research begun approximately at the same time under the heading of *Gesetzesfolgenabschätzung*, the German word for Regulatory Impact Assessment (RIA)[10]. In its early days RIA just consisted

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[8] J.M. Epstein, R. Axtell, *Growing Artificial Societies: Social Science from the Bottom Up*, Cambridge, MIT Press, 1996.

[9] Organisation for Economic Co-operation and Development (OECD), *Regulatory Impact Analysis (RIA) Inventory*, Technical report, Paris, 2004, 29th Session of the Committee, 15-16 April 2004.

[10] Pioneering work in Germany was done by C. Böhret, G. Konzendorf, *Handbuch Gesetzesfolgenabschätzung (GFA). Gesetze, Verordnungen, Verwaltungsvorschriften*, Baden-Baden, Nomos, 2001.

of a preface to a legislative bill which described the aims, cost and benefit of the proposed law, but over time the requirements of RIA became more and more detailed. Simulation as a RIA method is not mentioned in the OECD document as this document is not detailed enough to discuss RIA methods in detail. The RIA documents of some countries, however, mention simulation as a possible (but by no means standard) tool for impact assessment, e.g. the RIA Guidelines in Germany[11], but this is rare[12] although – as Sections 3 and 4 show – simulation has been used for impact assessment for decades.

Much earlier, micro analytic simulation[13] had made its entrance into different issue areas (such as tax and transfer policy) in many countries which aimed at a quantitative forecasting of the consequences of different policy strategies. Qualitative tools for the purpose of foresight and for evaluating alternative scenarios were much less widespread in this early area[14], and if they existed they were far from ICT based – perhaps with the exception of a tool developed for the German chancellor's office under the leadership of Horst Ehmke, then minister in the chancellor's office.[15]. This tool was directed at

[11] We owe them to C. BÖHRET, G. KONZENDORF, *Moderner Staat - Moderne Verwaltung*, Leitfaden zur Gesetzesfolgenabschätzung, Federal Ministry of the Interior, July 2000, http://www.bmi.bund.de/SharedDocs/Downloads/DE/Broschueren/2000/Leitfaden_Gesetzfolgenabschaetzung.pdf.

[12] This shows that simulation is still not a widely accepted tool among impact assessors, but at least it shows that RIA guidelines and other published documents are far from being detailed. It is also worth mentioning that most of the web sources listed at the end of the OECD document are difficult or impossible to find.

[13] G.H. ORCUTT, J. MERZ, H. QUINKE (eds.), *Microanalytic Simulation Models to Support Social and Financial Policy*, Information Research and Resource Reports, Vol. 7, Amsterdam, North-Holland, 1986.

[14] Two early examples were C. BÖHRET, *Entscheidungshilfen für die Regierung*, Opladen, Westdeutscher Verlag, 1970, and C. BÖHRET (ed.), *Simulation innenpolitischer Konflikte*, Opladen, Westdeutscher Verlag, 1972.

[15] Ehmke summarised his experience in H. EHMKE, *Planung im Regierungsbereich - Aufgaben und Widerstände*, in Naschold F., Väth W. (eds.), "Politische Planungssysteme", Opladen, Westdeutscher Verlag, 1973, pp. 311-334. Another member of this cabinet, Volker Hauff, parliamentary state secretary in the Ministry of research and technology, wrote his PhD thesis on the use of computers in social research (V. HAUFF, *Möglichkeiten des Einsatzes programmgesteuerter Datenverarbeitungsanlagen zur Analyse, Manipulation und Archivierung von Daten aus dem Bereich der empirischen Sozialforschung*, Freie Universität Berlin, 1968.) and several articles about the use of simulation models (V. HAUFF, F. LATZELSBERGER, *Simulationsmodelle in der soziologischen forschung*, in Gunzenhäuser R. (ed.), "Nichtnumerische Informationsverarbeitung. Beiträge zur Behandlung nicht-numerischer Probleme mit Hilfe von Digitalrechenanlagen", Wien, Springer-Verlag, 1968, pp. 127-147) and particularly about the use of simulating social systems to analyse political alternatives (V. HAUFF, *Simulation sozialer Systeme und politische Alternativen*, in "Atomzeitalter", 1965, n. 3, pp. 80-84).

generating current overviews of the state of all the projects planned under the Brandt government, but its lifetime was rather restricted. Mainly due to the deficiencies of the ICT systems available in the early 1970s, Ehmke's approach was more or less given up under the subsequent Schmidt government which seems to have returned to more traditional tools of policy planning[16]. But strategic planning and governance prove to be an increasingly challenging task, as the latest financial crisis has shown. The world has become increasingly interconnected, complex, and fast-evolving. Consequently, the effects of individual behaviour and of policy choices are much less predictable. At the same time, the amount of data available to governments to learn from monitoring the socio-economic environment has increased.

A special case of regulatory impact assessment which has a very long tradition in legislative studies is the analysis of the consequences of changes in electoral law. Journals such as "Legislative Studies Quarterly" or "Zeitschrift für Parlamentsfragen"[17] are full of articles discussing alternative voting systems or regulations and their effects on the composition of parliaments and other legislative bodies[18].

3. Static Microsimulation for Regulatory Impact Assessment

3.1. Tax and Transfer Regulations

The oldest and still most frequent use of simulation for legislative purpose is static microsimulation of tax and transfer regulations. In this kind of application the entities subject to simulation are not actually potential tax payers

[16] The Planning-Programming-Budgeting System of the 1960s in the US had a similar fate, see the December 1966 and the April 1969 issues of the Public Administration Review, e.g. D. Waldo, *Planning-programming-budgeting System Reexamined: Development, Analysis and Criticism*, in "Public Administration Review", Vol. 29, 1969, n. 2, pp. 111-112, and A. Schick, *The Road to PPB: The Stages of Budget Reform*, in "Public Administration Review", Vol. 26, 1966, n. 4, pp. 243-258.

[17] Most recently see S. Martin, *Electoral Institutions, the Personal Vote, and Legislative Organization*, in "Legislative Studies Quarterly", Vol. 36, 2011, n. 3, pp. 339-361; T. Makse, *Strategic Constituency Manipulation in State Legislative redistricting*, in "Legislative Studies Quarterly", Vol. 37, 2012, n. 2, pp. 225-250, and J. Behnke, *Überhangmandate bei der Bundestagswahl 2009. Eine Schätzung mit Simulationen*, in "Zeitschrift für Parlamentsfragen", Vol. 40, 2009, n. 3, pp. 620-636.

[18] Most recently, the composition of Switzerland's Federal Council if its members would be elected directly by the Swiss people was analysed by T. Milic, A. Vatter, R. Bucher, *Volkswahl des Bundesrates. Eine Simulation der Bundesratswahlen durch das Volk auf der Basis der Wahlen in die kantonalen Regierungen*, Technical report, Universität Bern, Institut für Politikwissenschaft, January 2012.

but tax declarations (or personal accounts of recipients of transfers instead of these recipients themselves). This is because no behavioural changes are modeled and anticipated in this kind of assessment, users of this kind of microsimulation just want to know what would have happened to tax payers or transfer recipients as well to the state budget or the social security budget if the planned legislation had already been in force during the period for which all information about the state of tax payers or transfer recipients was known.

In the optimal case the national finance authority[19] has a database at its disposal which contains a large representative sample of all tax declarations of one year[20]. Assessing the impact of new tax bills then just consists of applying the proposed new rules to all the tax declarations in the sample and calculating the change in the overall revenue as compared to the results of the tax law currently in force and calculating the changes in the average tax load for certain groups of taxable persons (for instance, singles, married couples with and without children, households in different gross-income classes[21]).

3.2. European and National Legislation on Wine

In the mid-1980s the European Commission adopted a new regulation laying down special provisions relating to quality wines produced in specified regions[22] which obliged the Member States "to fix a yield per hectare for each quality wine produced in specified regions (psr) at different levels depending on the sub-region, local administrative area or part thereof, and the vine variety of varieties from which the grapes used are derived (Art. 11 § 1). When this yield is being fixed, account shall be taken of the yields

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[19] Inland Revenue in the UK, *Ministero del Tesoro* in Italy, *Trésor Public* in France, *Ministerium der Finanzen* in Germany, Congressional Budget Office and Office of Managament and Budget in the US, *Agencia Estatal de Administración Tributaria* in Spain.

[20] In Spain for instance this is the "Panel de Declarantes del Instituto de Estudios Fiscales" (see A.F. FERNÁNDEZ, R.G. PÉREZ, *PHOGUE-ECV: ventajas e inconvenientes*, in "I Simposio sobre Reformas Fiscales y Microsimulación", Vigo, 2007) which contained several hundreds of thousands of tax declarations, but was later on replaced by another database.

[21] For examples see N. GILBERT, K.G. TROITZSCH, *op. cit.*, pp. 66-73, or G. REDMOND, H. SUTHERLAND, M. WILSON, *The Arithmetic of Tax and Social Security Reform: A User's Guide to Microsimulation Methods and Analysis*, Cambridge, Cambridge University Press, 1998, Chapter 3.

[22] *Council regulation (EEC) No. 823/87 of 16 March 1987 laying down special provisions relating to quality wines produced in specified regions*, in "Official Journal of the European Commission", L(84), 1987, pp. 59-68.

obtained over the preceding ten years". This obligation in Germany was delegated to the federal states, according to Germany's Basic Law, and it posed a legislative problem for the German federal state of Rhineland-Palatinate[23] whose politicians in charge of viniculture tried to avoid any financial losses on the side of the wine growers due to the quantitative restrictions imposed by the European Commission. So they decided to look for a way to fix the maximum yield for

- all (nine) sub-regions in Rhineland-Palatinate,
- (mainly six) varieties (*Riesling*, *Elbling*, *Müller-Thurgau*, *Silvaner*, *Pinot noir* and others, these aggregated) and
- (four) quality levels (defined in Art. 15 § 2.a of the regulation No. 823/87 – *Qualitätswein b.A.*, *Kabinett*, *Spätlese* and *Auslese*)

such that on an average the wine growers would not suffer from losses due to the rule that any harvest exceeding the maximum yield had either

- to be declassified and marketed at a much lower price or
- carried to the following year if the actual yield was lower then,

which in turn was ruled out in art. 11 § 2 of Regulation No. 823/87.

As a consequence, a static microsimulation model[24] was designed and based on a large sample of wine growers with their actual yields of the years 1983 through 1986, parameterised with different combinations of specific maximum yields for sub-region, variety and quality level. The plausibility of the parameter combinations to be analysed was discussed with stakeholders.

Several of the simulation runs resulted in parameter combinations such that, on an average, wine growers would not suffer from losses. Those whose yield usually exceeds the maximum would have an incentive to prune their vines, those who usually harvest less than the maximum (to obtain higher quality wine) would continue to do so. In the end, on an average the per hectare yield would be reduced and the wine quality raised. It goes without saying that many parameter combinations had similar results such that the final choice may have been more or less arbitrary.

[23] Rhineland-Palatinate grows about two thirds of the German wine production, thus for this federal state the issue was more important than for the neighbouring federal states.

[24] The modelling project carried out by the Institute of Political Science of the University of Koblenz-Landau was funded by the Rhineland-Palatinate Chamber of Agriculture which also organised the data collection from the compulsory reports of the viticultural enterprises. For privacy reasons, all data were deleted shortly after the project ended. The code of the simulation model, too, had to be deleted at the end of the project.

4. Dynamic Microsimulation Supporting Legislation

4.1. Demography and Long-term Welfare Planning

Whereas static microsimulation does not model the behaviour of individuals and thus can only be used for short-term assessment, dynamic microsimulation from its first days used not only "available detailed information about the initial state of microunits such as persons and families" (as does static microsimulation, too), but also "available understanding about the behaviour of entities met in everyday experience"[25]. One can of course discuss whether the understanding derived from everyday experience is sufficient for a valid model of a social process, but beside this everyday experience – perhaps one should talk about stylised facts[26] – statistical material is often available to parameterise state change functions and probabilities. Most dynamic microsimulation models serve the purpose of demographic projection and use transition probabilities to model state changes of modeled individuals, among them, depending on the purpose of the assessment, birth and death, marriage and divorce probabilites, migration probabilities (see Section 4.2.), but also the probabilities of moving elements of the educational sector and between different employments and unemployment. Usually, these transition probabilities are modelled as constant over time, mostly because no information is available why and how these transition probabilities should change over time. Dynamic microsimulation, however, is able to show how, for instance, birth probabilities different between different subpopulations (differential fertility) lead to a changing structure of the whole population such that overall birth rates changes over time even without any changes in the modelled individual behaviour. Thus this technique can unveil hidden heterogeneities and their consequences. This is anyway better than the approach taken by the Study Commission "Demographic Change – Challenges Posed to the Individual and Politics by Our Ageing Society" of

[25] G.H. ORCUTT, *Views on Microanalytic Simulation Modeling*, in Orcutt G.H., Merz J., Quinke H. (eds.), "Microanalytic Simulation Models to Support Social and Financial Policy", cit., p. 14.

[26] This term was coined in N. KALDOR, *Capital Accumulation and Economic Growth*, in Lutz F.A., Hague D.C. (eds.), "The Theroy of Capital", London, Macmillan, 1961/1968, pp. 177-222. See also the analysis of this term in B.O. HEINE, M. MEYER, O. STRANGFELD, *Stylised Facts and the Contribution of Simulation to the Economic Analysis of Budgeting*, in "Journal of Artificial Societies and Social Simulation", Vol. 8, 2005, n. 4, http://jasss.soc.surrey.ac.uk/8/4/4.html.

the German Federal Parliament in the 1990s which just compared different simulations starting from different "plausible" basic assumptions[27].

Although demographic projections do not directly assess legislative decisions they are often used to find out whether a certain aspect of social security measures will be sustainable. A nice example for this is the projection of kinship networks over a period of 65 years, when a German research group, one of the first Targeted Research Projects[28], used dynamic microsimulation to find out how many persons in their retirement age would have younger relatives who could perhaps nurse them when they became needy of help. As persons who would reach retirement age in 2050 were just born at the time of the research done in 1986, it was clear that not only the age structure of the German population had to be projected for a population of which less than one half already lived, but also the future kinship relations of persons who were not even adults at the time when the research was done. The result was that, compared to 1986 when only 9.2 per cent of the population over 60 were without partner and children, this percentage was expected to rise up to 22.3 in 2050, under the (perhaps unrealistic) assumption that death rates, birth rates, marriage and divorce behaviour remain constant at the level of 1982/1983 (data from these two years were used to estimate all these demographic parameters). The author summarised that one could and should expect a drastic decrease of the nursing potential within families[29]. Given that nursing needy old-age persons used to be nursed by their partners or children, relying on in-family nursing had to be considered insufficient in the longer run, thus it seemed necessary to develop other nursing possibilities beside supporting infamily nursing which should be less cost-intensive than current inpatient nursing. Soon after the first results were published in 1990, the Federal Republic of Germany introduced a compulsory long-term care

[27] SCHLUSSBERICHT DER ENQUÊTE-KOMMISSION, *Demographischer Wandel - Herausforderungen unserer älter werdenden Gesellschaft an den Einzelnen und die Politik*, March 28, 2002, pp. 27-30.

[28] This was the so-called *Sonderforschungsbereich* 3, its results discussed here can be found in H.P. GALLER, *Verwandtschaftsnetzwerke im demographischen Modell - Ergebnisse einer Modellrechnung*, in "Acta Demographica", 1990, n. 1, pp. 63-84, and in H.P. GALLER, *Politikanalyse mit Mikrosimulationsmodellen - die Frankfurter Modelle*, in "Mikroanalytische Grundlagen der Gesellschaftspolitik, Band 1, Ausgewählte Probleme und Lösungsansätze. Ergebnisse aus dem gleichnamigen Sonderforschungsbereich an den Universitäten Frankfurt und Mannheim", Berlin, Akademie-Verlag, 1994, pp. 113-135.

[29] H.P. GALLER, *Politikanalyse mit Mikrosimulationsmodellen - die Frankfurter Modelle*, cit., p. 133.

insurance. However, neither the cabinet bill (BT 12/5262, BR 509/93) as of 24 June 1993 nor the bill put forward in the Federal Council by the Länder governed by the SPD (BR 534/91) mentioned these research results explicitly. Perhaps the projection done by the research group was not deemed precise enough to estimate the amount of subsidies necessary in coming years or the contributions to the new insurance system necessary to finance the expenses for needy persons. On the other hand the general trend – decrease of the number of younger persons who could care for their elder needy relatives, changes in the lifestyle and family relationships, increase of the number of one-person households, all of these mentioned in the cabinet bill BT 12/5262, p. 62 – was already obvious without more precise simulation results and taken for granted in the subsequent parliamentary consultations.

The term "dynamic microsimulation" is in a way misleading as the behaviour of the microentities is not actually dynamic: they do not react on the changes in their environment triggered by their own behaviour. In the long-term care insurance example, microunits do not adapt to the results of their behavioural changes – only the macrounit external to the model does by introducing a political measure which is then fine-tuned to meet the needs originating from the results of the changed individual behaviour. Thus, this "dynamic" microsimulation does not get the full dynamics of a society in which human actors change their behaviour when they find out that the consequences of their behaviour are disadvantageous. To cope with this problem, an extension of the classical dynamic microsimulation is necessary, introducing some features of agent-based modelling.

4.2. Urban Planning

The following example[30] extends the dynamic microsimulation approach by introducing a more detailed model of decision making on the level of the microentities when these perceive changes in their environment which are consequences of their own behaviour. The model of urban segregation laid out in Feitosa's thesis models the migration behaviour of households in a city in Southern Brasil (it is these households which are represented by the

[30] This example is taken from the PhD thesis by F. DA FONSECA FEITOSA, *Urban Segregation as a Complex System. An Agent-based Simulation Approach*, Rheinische Friedrich-Wilhelms Universität, Bonn, 2010, http://hss.ulb.uni-bonn.de/2010/2058/2058.pdf and F. DA FONSECA FEITOSA, Q. BAO LE, P.L.G. VLEK, *Multi-agent Simulator for Urban Segregation (MASUS): A Tool to Explore Alternatives for Promoting Inclusive Cities*, in "Computers, Environment and Urban Systems", 2011, n. 35, pp. 104-115.

software agents of this model). Parameters of the model were taken from a large sample survey of some 8,000 households which were asked for their socio-economic status and for some behavioural rules which they would apply to decisions about moving from one housing opportunity to another. From these data, a synthetic sample of some 110,000 households was generated which was quite similar to the overall population of São José dos Campos, and these households, in order to achieve their goal of finding the optimal place where to live, had to make removal decisions in every period of the simulation (a simulation step corresponded to one month, typical simulations run for ten years).

Feitosa's study consisted mainly of three parts (and this should apply to studies like this in any case): model design (describing the microspecification from which a macrophenomenon arises[31]), model validation[32] and use of the model for foresight (which seems justified when the microspecification is based on empirical data and when the replicative validation was satisfactory).

Here, the microspecification describes the decision making process of a household considering a removal to another dwelling with the options: do not move, move to an apartment in the same neighbourhood (which is a parcel of approximately 100x100 meters), move to an apartment in a distant but similar neighbourhood and move to a neighbourhood with features different from the current one. The environment which the agents "live" in and which they have to consider consists of 6,385 of these neighbourhoods, parcels of approximately 100x100 meters. All these (many) options are evaluated for their net utility, and the net utilities are converted into propensities (or, rather, probabilities), and the final decision is made with this probability (such that the best option has the highest probability of being chosen and the worst option has the lowest). The net utility of all these options, of course, depends, among others, on the types of households composing the respective neighbourhood (which is mainly described by the percentages of low-income and high-income households), such that every removal changes the composition of two neighbourhoods.

Replicative validation is done by comparing different segregation indices for the real city and for the simulated city between 1991 and 2000 and finding that not only agregate indices but also the changes of local segregation are satisfactorily similar between reality and simulation.

[31] J.M. EPSTEIN, R. AXTELL, *op. cit.*, p. XI.

[32] This validation is to be understood typically in the replicative sense of B.P. ZEIGLER, *op. cit.*

In the third step, governmental strategies to avoid segregation are introduced into the model, e.g., giving subsidies to poor households such that they can afford a removal to a more affluent neighbourhood or zoning measures which leads to the erection of affordable but well-equipped flats for poor households in an affluent neighbourhood. The study then compares the influence of these governmental strategies on the long term development of the segregation within the city area and thus gives hints at which results these strategies would have led if they were applied to the real city.

In a way, this approach draws on the early urban dynamics studies mentioned above[33] but with two vital differences. First of all, the urban area is not modelled as an indivisible entity, but it has an extension, and it is subdivided into small parcels with very different properties. This allows for a much more detailed picture of the fate of an urban area (in Forrester's model a quality such as segregation could not be modelled at all). Second, its microspecification is much more detailed, as it is not the population which grows or shrinks but the households (father and mother) which give birth to children, dissolve or are fomed. Thus, results of this kind of agent-based microsimulation models gives much more information than even the dynamic microsimulation models discussed before. But still one has to admit that a different microspecification could have generated very similar macrophenomena.

5. Policy Modelling and Agent-based Modelling

5.1. Participatory Modelling Strategies

The approaches discussed so far aim at modelling the state, state changes and perhaps the behaviour of the subjects to legislation, not at modelling the legislative process itself. The legislative process can be seen as a process of negotiations between different groups within parliament, between parliament and cabinet or administration, in many countries also between the two chambers of parliament, but also between government and society. Thus a multitude of stakeholders agents have to be modelled in order to get hold of at least a part of this complicated process. Perhaps one of the first attempts to model the interactions between (local) government, media and the

[33] J.W. Forrester, *op. cit.*

people dates back to 1963[34]. In this attempt the authors modelled the political process of preparing a community referendum about the fluoridation of drinking water (which was an issue in the United States in the early 1960s). Only during the past two decades new efforts were taken to model these interactions, but in the 1990s and in the past decade numerous studies in participatory modelling appeared[35] some of which also relate to agent-based simulation to role-playing games[36].

One of the most recent approaches to participatory modelling and simulation comes from the current project on Open Collaboration for Policy Modelling (OCOPOMO, see Section 5.2.) which tries to combine collaboration platforms for collecting data about stakeholder goals and action rules with software supporting the definition of "consistent conceptual descriptions (CCD) to inform the formal policy models"[37] into which the former

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[34] R.P. ABELSON, A. BERNSTEIN, *A Computer Simulation of Community Referendum Controversies*, in "Public Opinion Quarterly", Vol. 27, 1963, n. 1, pp. 93-122. This seminal paper was reprinted in volume one of N. GILBERT (ed.), *Computational Social Science*, Four-Volume Set, Los Angeles, Sage, 2010.

[35] A selection contains N. BECU, F. BOUSQUET, O. BARRETEAU, P. PEREZ, A. WALKER, *A Methodology for Eliciting and Modelling Stakeholders' Representations with Agent-based Modelling*, in Hales D., Edmonds B., Norling E., Rouchier J. (eds.), "Multi-agent-based simulation III", Proceedings of the 4th International Workshop MABS 2003, Melbourne, Heidelberg, Springer, 2003, pp. 131-148; F. BOUSQUET, O. BARRETEAU, P. D'AQUINO, M. ETIENNE, S. BOISSAU, S. AUBERT, C. LE PAGE, D. BABIN, J.-C. CASTELLA, *Multi-agent Systems and Role Games: Collective Learning Processes for Ecosystem Management*, in "Complexity and Ecosystem Management: The Theory and Practice of Multi-Agent Approaches", Cheltenham, Edward Elgar, 2002, pp. 248-285; T.E. DOWNING, S. MOSS, C. PAHL-WOSTL, *Understanding Climate Policy Using Participatory Agent-based Social Simulation*, in "Proceedings of Multi Agent Based Simulation - MABS", Heidelberg, Springer, 2000, pp. 198-213; D. KOPEVA, M. PENEVA, O. BAQUEIRO, R. FRANIĆ, G. GARROD, B. HAUTDIDIER, N. IVANOVA, M. JELINEK, M. KONECNA, R. LAPLANA, B. MEYER, M. NJAVRO, M. RALEY, A. SAHRBACHER, N. TURPIN, *Critical Analysis and Assessment of EU Policy on Multifunctional Land Use Activities in Rural Areas*, in "Regional and Business Studies", 2011, n. 3, Suppl. 1, pp. 271-287.

[36] In part of the literature, particularly in law studies, simulation is often meant as gaming simulation – which we do not deal here with except in the case where role-playing games are used for collecting data about stakeholder behaviour as in F. BOUSQUET *et al.*, *op. cit.*

[37] M.A. WIMMER, K. FURDIK, M. BICKING, M. MACH, T. SABOL, P. BUTKA, *Open Collaboration in Policy Development: Concept and Architecture to Integrate Scenario Development and Formal Policy Modelling*, in Charalabidis Y., Koussouris S. (eds.), "Empowering Open and Collaborative Governance. Technologies and Methods for Online Citizen Engagement in Public Policy Making", Heidelberg, Springer, 2012, p. 205.

are more or less automatically transformed to become executable simulation programs.

5.2. *Example*

One of the first models generated from the OCOPOMO modelling process[38] is the "model of the Košice case study [which] covers the subject of energy policy: electricity and heating. The focus is on three issues, namely energy efficiency, decrease of energy consumption and utilization of renewable energy sources in the Košice Self-Governing Region (KSR)" in Eastern Slovakia. "The main aim of the prototype model is to capture the behaviours of key stakeholders and the process of decision making in the energy domain. The prototype model is designed to combine interrelations between the local environmental as well as spatial determinants, economic conditions and realistic social dynamics ..."[39]. The main stakeholders represented by agents in this model are households (consumers) and enterprises (both consumers and producers of energy, but also producers of equipment and know-how), interest groups advising the former, governments and municipalities each of whom have different stakes at the energy issue and influence the process of political decision making in different manners while interacting with each other and with their natural, socio-political and economic environment. The natural environment represented in this Košice prototype consists of, for instance, the available biomass or water power; the socio-political and economic environment includes, for instance, the price of imported oil, gas and electricity. Household agents (48 of them in the current version), for instance, "can either buy a new (additional) heating technology, insulate the house/flat, or decrease the room temperature"[40], whereas heat producer

[38] Others are about "a policy of establishing competence centres in order to support the development of industrial clusters within the Campania Region" in Southern Italy, described in S. MOSS, R. MEYER, U. LOTZMANN, M. KACPRZYK, M. ROSZCZYNSKA, C. PIZZO, *Scenario, Policy Model and Rule-based Agent Design*, Technical Report Public Deliverable D5.1, FP7 Project OCOPOMO, January 2011, http://www.ocopomo.eu/results/public-deliverables/OCOPOMO_D5-1.pdf/view, pp. 40-41, and one "concerned with housing policy in London. This is a particularly useful case study in that there are a large number of stakeholders including the Greater London Authority and 33 borough councils as well as central government agencies, housing associations and NGOs (*ivi*, p. 9).

[39] *Ivi*, p. 28

[40] U. LOTZMANN, M. WIMMER, *Provenance and Traceability in Agent-based Policy Simulation*, in Geril P. (ed.), "Proceedings of the 26th European Simulation and Modelling Conference - ESM 2012" (Essen, October 22-24, 2012).

agents (three of them) can decide among several supply and pricing strategies and a regulatory office agent and a government can set limits to these strategies and offer subsidies to producers and/or consumers. “The simulation shows the change of average room temperatures and the investments in heating technology and insulation over time”[41].

What is common in all of these participatory models (and particularly in the OCOPOMO process models) is the multitude of different kinds of agents (which one would not usually find in the more “classical” agent-based models in social science)[42]. One of the cores of these models is the ability of the software agents to design their behaviour with the help of complex rule and fact bases which include assumptions about the rules and facts applied by other agents of the same or different types. This allows them to anticipate future possible behaviour of other agents and to negotiate among themselves in a manner which reflects at least part of the behaviour among parliamentary groups and other political actors. Another important ingredient of OCOPOMO models is the close link between the formal model written in a declarative logic-based language (DRAMS[43]) and the documentation of the interviews with stakeholders and other documentary material which makes sure that every detail of the formal model can be traced back to its empirical basis and that simulation results can be compared to the evidence base for the simulation model.

6. Conclusion

This overview of actual and possible applications of simulation models to support legislation will have shown that there is a large still not exhausted potential of giving legislators insights into the possible consequences or their actions. In Section 5. we could show that a simulation model of the legislatory process could help to better understand the complex processes going on in parliaments and their environments (cabinet, lobbying groups etc.).

On the other hand it goes without saying that all kinds of simulation are and will be unable to make precise predictions of future states of a complex

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41 U. Lotzmann, M.A. Wimmer, *op. cit.*; for more details see also M.A. Wimmer *et al.*, *op. cit.*

42 This refers to the sugarscape-like models, see J.M. Epstein, R. Axtell, *op. cit.*

43 U. Lotzmann, R. Meyer, *A Declarative Rule-based Environment for Agent Modelling Systems*, in “Proceedings of the 7th Conference of the European Social Simulation Association - ESSA 2011”, Montpellier, 2011.

systems or to precisely predict the outcomes of planned policies. What is only possible is a foresight in the sense that possible futures can be sketchily described. Which among several paths into possible futures the real system will take remains unpredictable – even if probabilities can be given for the alternative paths. The responsibility for the measures taken by policy makers remains with these, but simulation can improve the informations on which political decisions rest.

Cognitivizing "Norms". Norm Internalization and Processing

CRISTIANO CASTELFRANCHI*

SUMMARY: *1. Our Perspective and Claims – 2. Norm Internalization – 2.1. Goal-adoption – 2.2. Reasons for Goal-adoption – 2.3. Goal-adhesion – 3. Not Only Prescribed Behaviors But Expected Mental Attitudes – 3.1. Interpersonal Rights – 4. Normative Adhesion – 4.1. Generalized Goal-adoption – 4.2. Spontaneous Norm Monitoring for Strong Reciprocity – 5. Against the Reduction of Norms to Sanctions, Incentives, and "Utility" – 6. "Internalization" (and Why It Matters) – 6.1. Conformity and Punishments as Messages – 6.2. Subjects Not Cooperators: The A-technical, Non-rational Nature of the Deontic "Ought" – 6.3. Educating to Norms – 6.4. The "Alienated" Nature of Norm Adoption – 7. Influencing Devices in a "Prevention Focus" – 8. Norm Processing from Beliefs to Goals and Intentions – 9. From Goal-adoption, Decision, Intention, … to Routines – 10. Norms As Multi-agent Artifacts – 11. Concluding Remarks.*

1. OUR PERSPECTIVE AND CLAIMS

What we present is not an agent-based simulation work[1]; it is more a theoretical contribution to normative cognition, the "psychology" of norms in

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[1] I am sorry to disappoint my reader, but my contribution is not a discussion of the literature (philosophical, sociological, psychological, and AI) on norms and their working. It is more a restatement of the main issues of our work on norms in the last 15 years, work that has significantly contributed to social simulation studies on norms (see LABSS work http://www.istc.cnr.it/group/labss; R. CONTE, G. ANDRIGHETTO, M. CAMPENNÌ (eds.), *Minding Norms. Mechanisms and Dynamics of Social Order in Agent Society*, Oxford Series on Cognitive Models and Architectures, New York, Oxford University Press, forthcoming, and to the Agent and MAS research (see, for example, NorMAS WS and its community, G. BOELLA, P. NORIEGA, G. PIGOZZI, H. VERHAGEN (eds.), *Normative Multi-agent Systems*, Dagstuhl Seminar Proceedings 09121, 2009; G. ANDRIGHETTO, G. GOVERNATORI, P. NORIEGA, L. VAN DER TORRE (eds.), *Normative Multi-agent Systems*, Dagstuhl Seminar Proceedings 12111, 2012; and the Agreement Technology EU Project, http://www.agreement-technologies.eu/wg2, and G. ANDRIGHETTO, C. CASTELFRANCHI (eds.),

a cognitive science perspective, strongly based on the computational modeling of social minds and interactions, on the Artificial Intelligence (AI) model of cognitive autonomous agents, and artificial society.

Our general perspective[2] is the following one:

- Social phenomena are due to the agents' behaviors, but the agents' behaviors are due to the mental mechanisms controlling and (re)producing them.
- It is impossible to understand the efficacy and working of the norms (Ns) without a modeling of how Ns succeed in changing our control system (mind) and regulating from inside our behavior.
- How does a norm (N) change and work through the minds of the agents? How is it "represented"?
- Which are the proximate mechanisms underlying the normative behavior?
- What does it mean to "conform" to a N from a mental – not just a behavioral – point of view? What does it mean to "obey"?
- What kind of mental attitude the N "prescribes" to, and builds into the agents?

1.1. Norms are artifacts, tools for the manipulation and regulation of autonomous cognitive agents' conduct; agents that have their own internal goals and decision processes. This happens thanks to the manipulation of our goals and preferences/choices.

Can we model how N succeed in giving us goals and intentions? They are built for that.

1.2. In many organizational, anthropological, sociological views not only there is a very strong (if not exclusive) emphasis on "sanctions" as necessary and "definitional" for having "norms" (Section 5.), but there is an explicit or implicit view of Ns (of organization, of institutions) as aimed at, having the function of: creating constraints/binds on the agents' behaviors in order to obtain a given coordinated collective behavior ("order").

The other face of Ns is ignored: the purpose and function of "inducing" goals in people, of influencing them to do something: to intend to do something; a goal that was not at all in their mind (Section 2.1.).

Norms, in Ossowski S. (ed.), "Agreement Technologies, Law", Governance and Technology Series 8, 2013.

[2] R. CONTE, C. CASTELFRANCHI, *Cognitive and Social Action*, London, UCL Press, 1995.

Ns are not aimed just at "pruning" possible actions, or "permitting" them; at blocking some possible choice or changing the evaluation by altering the expected outcomes (rewards) of the alternatives. They are also aimed at adding, creating new goals and alternatives.

1.3. In the aforementioned view, it seems (it is implicitly assumed) that: goals (and then intentions) of an agent are all "desires", are all endogenous; and we have just to cut some possible course of action by making some desire practically impossible or non convenient.

It is ignored the fact that "duties" are not "desires"; they are goals from a different source, with a different origin: they come from outside (exogenous)[3], they are imported, "adopted"; they are "prescriptions" and "imperatives" from another Agent (the group, the authority).

Society (and "super-Ego") does not only "block" us, but gives us new goals, shapes our motivation, induce us to do, to pursue, something that might have never been in our mind.

We need a different mind "architecture" not simply based on BDI (beliefs, desires, intentions) models[4].

1.4. A N is not just aimed at regulating our conduct, at inducing us to do or not to do a given action; it is aimed at inducing us to do that action for specific motives, with a given mental attitude. The ideal-typical Adhesion to a N is for an intrinsic motivation, for a "sense of duty", recognition of the authority, because it is right/correct to respect Ns...; and only sub-ideally one should respect for avoiding external or internal sanctions (see Section 3.). Also normative education goes in this direction (see Section 6.3.).

1.5. Ns have to be "impersonal" and depersonalized (and perceived as such) on both sides: the issuer's and the addressee's side. It is not a conflict between me and you; it is not "my" request (for me, for my desires, etc. for my personal will that you have to adopt); and it is not a request to "you". The message is:

- "I do not talk, monitor, sanction, in my name";
- "I am not addressing to you 'ad personam', but as an instance of a class, a member, a citizen, ... like any other in the same conditions". Also for that "You have no reasons for rebelling".

[3] However, see later about the internalization of the "authority", and internal moral imperatives.

[4] On the BDI models and logics see for example http://www.loa.istc.cnr.it/Files/bdi.pdf.

This really is a crucial point in the perception of Ns as Ns; thus it is something that must be signaled in some way (uniform, role symbols, specific documents, ...) or at least contextually presupposed and assumed in the script. The transition from personal power and violence to formal power, from the prince's thugs to policemen, has been a fundamental historical evolution; psychologically and culturally complex and something sham and hypocrite.

1.6. As we said, Ns are social device controlling behaviors through minds but in a specific way; through a partial understanding. They require (for their existence and effectiveness) their explicit mental representation, their (partial) understanding and recognition "as Norms"; specific cognitive representations and motivational processes (*Cognitive Mediators*)[5]; differently from other social phenomena like social functions, that can be played by social actors even without understanding – and even less intending – them[6].

1.7. Ns have to build in us an "ought", a "duty", "you have to"; with a rather constrictive feeling, a negative "frame", an avoidance orientation (even when it elicits "you have to do this action"). And this "ought" is a non-technical "ought", not instrumental to and planned for a given outcome/goal.

This entails a process of Adopting without sharing the "instrumental" nature of the N, and without understanding/adopting its "function" or end. My "plan" is different from the authority's "plan".

Citizens are not real "cooperators" but "subjects". They have to "alienate" their own powers and products (see Section 6.).

1.8. N require different and complementary "roles" with their specific "minds" or "mental attitudes": the subject of the N, the watcher, the issuer (see Section 10.).

And we have to explain how and why a subject of the N also becomes a watcher and an (implicit) issuer of it (see Section 4.).

1.9. We will also argue against
- the reduction of Ns to sanction/incentives and utility;
- the reduction of Ns to reinforcement learning and automatisms;

[5] R. Conte, C. Castelfranchi, *Cognitive and Social Action*, cit.; R. Conte, C. Castelfranchi, *The Mental Path of Norms*, in "Ratio Juris", Vol. 19, 2006, n. 4, pp. 501-517.

[6] C. Castelfranchi, *The Theory of Social Functions. Challenges for Multi-agent-based Social Simulation and Multi-agent Learning*, in "Journal of Cognitive Systems Research", 2001, n. 2, 2001, pp. 5-38, http://www.cogsci.rpi.edu/ ~ rsun/si-mal/article1.pdf.

– the reduction of Ns to mere hardwired impossibility to act. Ns are "norms" only if they presuppose/allow the possibility of "violation".

2. Norm Internalization

Ns are based on a specific process of Goal-adoption or better adhesion; since they have the nature of an "imperative". That is, they are aimed at being "obeyed" for specific motives: not for external rewards, not for benevolence, etc. but for the recognition of authority, role, values, ...

2.1. Goal-adoption

Ns induce new goal through "adoption". Goal-adoption is how an autonomous agent is not an isle but becomes social, or better pro-social[7]; that is s/he does something for the others; puts her/his autonomous goal-pursuing (intentional action), her/his cognitive machinery for that, and her/his powers and resources, into the service of the others and of their interests. How is this possible? Not only economically or evolutionary, but cognitively, that is from the point of view of the working of an autonomous, self-regulated, goal-driven system. What kind of mental representations and operations are needed?

How is it possible that the goal (need, desire, objective, request, order, ...) of another entity succeeds in regulating my own autonomous behavior? How such a goal is "imported" in my regulatory, purposive system?

What is needed is the architecture of a social agent able to import goals from outside (and to influence other agents by giving them goals and relying on him/her) but remaining "autonomous". S/he is able to arrive to intentions not only from her own endogenous "desires", but from imported goals.

Goal-adoption means that:

X believes that Y has the Goal that p (G_y p) and comes to have (and possibly pursue) the Goal that p (G_x p) just because he believes this.

$$\boxed{\text{(Goal-adopt x y p)} =^{def} \text{(R-Goal x p (BEL x(Goal y p))}}$$

[7] Not to be used as synonim of "altruistic", "benevolence", etc. (see below).

"I do something 'for' you" (which does not mean "benevolence"!); I want to realize this since and until you wants/needs this; because it is your goal. Not a trivial notion, to be defined and formalized[8].

2.2. Reasons for Goal-adoption

There are different kinds of Goal-adoption, motivated by different reasons.

a) *Terminal or Altruistic*: Adoption can (rarely) be "altruistic", that is disinterested, non motivated by, non instrumental to higher personal (non-adoptive) calculated advantages (goals);
b) *Instrumental*: Adoption can be instrumental to personal/private returns, part of a selfish plan; like in commerce, where:

> It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interest. We address ourselves, not to their humanity but to their self-love, and never talk to them of our own necessities but of their advantages[9].

   In Adam Smith's perfect characterization of exchange in merely selfish terms it is clear that there is not benevolence at all; and that X has the goals to understand and realize the selfish goal of Y (that *per se* is indifferent – or bad – to X) only in order to satisfy (through Y's reciprocal adoption) his own selfish and personal goal. So having the goal to realize your goal (as what you like and because you like it) is not necessarily altruistic at all.
c) *Cooperative*: it can be instrumental to a personal advantage, but shared with the other: in view of a common goal (strict "cooperation"): X and Y depend on each other for one and the same goal.

One might consider (c) a sub-case of (b) (instrumental adoption) but actually the situation is significantly different. While in (b) it is rational to try to

[8] This formalization might also cover "imitation" ("Since y wants p, me too!"). Goal-adoption is not "doing the same", "doing like the other". It is doing something "for" the other, for realizing her Goal. A better formalization should make clear that:

$$\text{(Goal-adopt x y p)} =^{def} \text{(R-Goal x (OBTAIN y p) (BEL x(Goal y p)))}$$

X has the Goal that *Y realizes her Goal*, that she achieves it. Where the realization of "OBTAIN" implies (Knows y p) = p & (Bel y p).

[9] A. SMITH, *An Inquiry into the Nature and Causes of the Wealth of Nations*, 1776.

cheat and defeat the other; in strict cooperation, where we need each other for realizing one and the same goal, to defeat would be self-defeating.

2.3. Goal-adhesion

A stronger form of G-Adoption is Adhesion:

when I adhere to your (implicit or explicit) "request" (of any kind: prey, favor, order, law, etc.).

In other words, you (Y) have the goal that I adopt your goal p, that I do something (action a of X) realizing that goal, and I adopt your goal p or of doing a, (also) because I know that you expects and wants so.

In Adhesion one of the reasons for Adopting the goal of the other is that the other wants so:

- She also has the (meta)goal that we adopt her goal;
- We Adopt her goal by adopting the meta-goal.

In a sense, there is a double level of adoption (a meta-adoption): I know and adopt your goal that I adopt.

Moreover, in case of Adhesion there is a (presupposed) agreement between X and Y about X's adoption, X doing something as desired by Y. Other forms of adoption (like help) can be unilateral, spontaneous, and even against Y's desire.

3. Not Only Prescribed Behaviors But Expected Mental Attitudes

The aim of a N is not just our behavior; for example, the norm is not satisfied by an accidental conformity.

Ns have very strange claims on our mind: they prescribe also a "mental attitude". A N wants to be followed for an internal mechanism reflecting it; for a goal of following Ns. Moreover, the objective of the N on my mind is that I do not adopt its "request" for whatever reason (higher-goal) (pity, friendship, agreement on the content, personal advantage, fear, …).

I have to Adhere for specific reasons and higher-goals: for an intrinsic motivation (no external rewards), for a non-instrumental goal of respecting the authority and its norms. This is "obedience".

This is the real difference between an "order", a "favor", a "prayer", …; not just social, relational, or pragmatic aspects. In all cases there is a request about an action (or inaction) of yours, but you have to do that for different reasons; I ask you a specific mental attitude towards my expectation and me.

The "order" of a general should not be "obeyed" because of courtesy, sympathy, friendship, pity, agreement about the solution, fear, money, ... but just because it is an "order" of the right person, this is its "ideal" working, its aim[10]. Analogously, N wants:

- my behavior; due to
- my goal; due to
- my adhesion; but,
- motivated by specific higher-goal.

Ns are *not* based on an explicit or implicit "agreement", acceptance of us; the obligation applies and impinges on us in any case; it does not depend on our consent. For that we are "subjects" of the N. Ns do not "ask" us to do something (where we can reject the commitment not only the action); Ns "order/impose" us to do something, and we could "not do" as prescribed but could not "have not to do"; we can refuse to do the action but we cannot cancel the duty.

There is an "acceptance" (which is presupposed in the issuing of norm and in its obedience and real violation) but in another sense. The normative regulation relies on the fact that we "recognize" the N as a norm, and thus "acknowledge" its authority, and treat it accordingly with such assumption, even while disobeying.

Let us give another example of why prescribed mental attitudes matter more than the behavior: the "claim" for the "recognition" of a "right". Later we will say something more about a "duty" attitude (Section 7.).

3.1. Interpersonal Rights

I call "interpersonal rights" those rights that are not necessarily established by some law and imposed by some authority. Let me consider their "psychology". Consider the mental attitudes of two agents when one is claiming a right, and the other is acknowledging it[11].

Suppose that, on a bus, I want you to give me your seat because I think (and I want you to acknowledge) that this is my right (suppose I am a pregnant woman, an old man, etc.); and suppose that there is no official norm

[10] C. CASTELFRANCHI, *Prescribed Mental Attitudes in Goal-Adoption and Norm-Adoption*, in "Artificial Intelligence and Law", Special Issue on Norms in MAS, Vol. 7, 1999, pp. 37-50.

[11] C. CASTELFRANCHI, *Formalising the Informal? Dynamic Social Order, Bottom-up Social Control, and Spontaneous Normative Relations*, in "Journal of Applied Logic", Vol. 1, 2003, n. 1-2, pp. 47-92.

or rule about this. My goal is that you leave your seat, but this is not sufficient. For example, if, for independent reasons (the bus arrived at your bus stop), you leave, your seat is free but my right has not been acknowledged. What is necessary here is Goal-adoption: you have to know and adopt my goal. But even this is not sufficient: I pretend much more from your mind: *I want you to adopt my goal with a specific mental attitude and for specific reasons* (higher-goals, motivations). You might leave your seat just out of pity: this is not "acknowledging my right"; you might do it out of love, sympathy, courtship: but this is not "acknowledging my right" either. You could do it out of fear or interest, because I am very strong and I am threatening you, or because I offered you 2 dollars: again, this is not "acknowledging my right".

Summing up, I do not want you to adopt my goal only. I want you to do this because you believe (agree) that this is my right, that my request/expectation is correct and you perform the action *in order to* respect rights[12].

Why should we be so interested in the mind behind the action, when seemingly what we practically need is that action? The truth is that we do not need only or mainly the required action. In the case of rights it is quite clear which are the very different social consequences of the different attitudes you have in adopting my goal. If you do it for pity, this means that I am inferior and powerless. If you do it out of pity, love, sympathy, generosity, etc., I am in debt, I have to be grateful. On the contrary, if it is my right I am not in debt: it is you that are indebted if you do not respect/satisfy my right. In general, different mental attitudes in compliance not only presuppose very different social relations, but make very different both the probability of the Goal Adoption, its readiness, and the future consequences for the social relations (for example in terms of credits and debts).

4. Normative Adhesion

As we said, Ns exploit and count on *a special process/kind of Goal-adoption*:

- First, they count on Goal-adhesion: that is, on the recognition by the addressee of the will of the issuer, and on an adoption due also to this: I adopt your goal also because I know that you want so.

[12] "Right" in this case means something like: "conform to a moral norm, to a value, to a law". Claiming a right is always searching for a shared value. See M. Miceli, C. Castelfranchi, *A Cognitive Approach to Values*, in "Journal for the Theory of Social Behaviour", Vol. 19, 1989, n. 2, pp. 169-193.

  - "Obedience" in general is a sub-kind of "Adhesion", and norm obedience is a kind of obedience.
- Second, it should ideally be motivated by the sense and respect of the authority and values; not by rewards.
- Third, it is a non "personal", individual request, but it is a generalized request, and should be understood as such and used as such.

4.1. Generalized Goal-adoption

There is an "individual" G-Adoption where

- X has to believe that Y (individual) has the goal that (DOES x A)
- and X comes to have (adopts) the Goal x (DOES x A)

There is a "generalized" G-Adoption where:

- X believes that there is a goal impinging not directly on a single individual but on a class or group of agents:

  (Bel x (Goal y (for any z member of C => (DOES z A))))
- if X believes to belong to that class,
- she believes to be concerned by the norm, and
- she instantiates a Goal impinging on her; adopts it.

However, having adopted the "generalized" goal X does not limits her mind and her behavior to this (self-regulation), she will worry about the others' behavior[13]:

- X is also able to have Goals about the others' behavior: she Adopts the Goal not to do but that for any z (DOES z A).
- Given such an Adoption she has *expectations* (predictions + prescriptions) about the others behavior, and is not only surprised, but "disappointed" by their non-conformity.

4.2. Spontaneous Norm Monitoring for Strong Reciprocity

A punisher has Adopted the goal that the bad guy behaves as prescribed and expected: she is not just "observing" but "inspecting" (surveillance).

She does not only have the mind of the norm-addressee (the "subject") but also the mind of the watcher, caretaker, and in a sense of the (re)issuer of the

[13] Also because she is paying some cost for respecting the norm and the authority, for maintaining the prescribed social "order", which is supposed to be a "common". She wants the other be fair, reciprocate, contribute.

prescription and norm[14]. This is why X also adopts the impinging goal of "punishing": this is not only a personal motive, an affective reaction, but it is also "expected" and prescribed, and approved by the others. And also this goal (to punish) is not only individual and personal, but is generalized:

X also expects that the others of the group would blame Z.

Actually, the famous expiation (penitence, amend) impulse in guilt feeling is the reflexive application of this goal to ourselves:

- the goal to be punished as *any* bad guy;
- and also the self-blame and reproach is already a self-inflicted punishment.

5. Against the Reduction of Norms to Sanctions, Incentives, and "Utility"

Obligations cannot/should not be hardwired, cutting the possibility of that behavior of that choice and agents must be assumed as responsible and free, and a true N presupposes the possibility of intentional violation.

Mental stuff is relevant. Obviously our behavior can be conformable to the norm but we are not "obeying" to it. Ns are not for accidental or mechanic conformity. An external "violation" is not enough for being "guilty" or "blameworthy".

Of course not only (and not always) "intentional" violation are guilty and to be blamed. What really matters is "responsibility"; that is, the counterfactual assumption that:

- "*X might have NOT done what he did*"; he had the possibility for behaving in a different way;
- "*X might have understood the consequences (harm, violation) of what was choosing*".

These, in fact, are the crucial assumptions (beliefs) supporting or eliminating "guilt".

We also reject the reductive "behaviorist" or "economic" views about "conformity" or "violation" just based on rewards, reinforcement learning and evocation, or on prediction of sanctions and rational decision for avoiding them. There are cognitive and social criticisms to that view.

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[14] R. Conte, C. Castelfranchi, *Cognitive and Social Action*, cit.

Actually, sanctions are established and operative only for a sub-ideal world/case. Sanctions are in case of violation; but Norms does not expect/want violation!

Ideally N-Adoption is non-instrumental, not for convenience, just terminal.

The primary function of authority is not to monitor and to provide sanctions (even legal norms violations are weakly/rarely sanctioned (but symbolically they are)) is:

- to be recognized as the authority, to signal the existence of the authority and of the Ns;
- to issue the N as a N (that is "counting as" a N; recognizable as a N, not just a request or an abuse, etc.); is the "proclamation" the N, to be sure that it is common public knowledge and that it is "accepted" (and that there will be distributed social control: reissuing, confirming, monitoring, enforcing).

The second and secondary function of authority is to monitor (and to signal that it is monitoring), to sanction (and to signal that it will and is sanctioning).

The main function of prohibiting and of sanctioning (punishing) is signaling (the message: "this is bad!"), not the penalties (external costs): to stigmatize[15], to educate, to internalize norms and values[16].

In fact, no social control could compete with internal control[17], both, in surveillance (I hardly can hidden myself to myself), and in the certainty of the punishment.

We might have various kinds of normative minds/agents:

[15] S. BOWLES, H. SUNG-HA, *Social Preferences and Public Economics: Mechanism Design When Preferences Depend on Incentives*, in "Journal of Public Economics", Vol. 92, 2008, n. 8-9, pp. 1811-1820.

[16] G. ANDRIGHETTO, D. VILLATORO, *Beyond the Carrot and Stick Approach to Enforcement: An Agent-based Model*, in Kokinov B., Karmiloff-Smith A., Nersessian N.J. (eds.), "Proceedings of the European Conference on Cognitive Science", New Bulgarian University Press, 2011; D. VILLATORO, G. ANDRIGHETTO, R. CONTE, J. SABATER-MIR, *Dynamic Sanctioning for Robust and Cost-Efficient Norm Compliance*, in "Proceedings of the 22nd International Joint Conference on Artificial Intelligence" (Barcelona, 16-22 July 2011); G. ANDRIGHETTO, C. CASTELFRANCHI, *Norm Compliance: The Prescriptive Power of Normative Actions*, in "Paradigmi", forthcoming; F. GIARDINI, G. ANDRIGHETTO, R. CONTE, *A Cognitive Model of Punishment*, in Ohlsson S., Catrambone R. (eds.), in "Proceedings of the 32nd Annual Conference of the Cognitive Science Society", Austin, Cognitive Science Society, 2010, pp. 1282-1288.

[17] R.L. TRIVERS, *Social Evolution*, Menlo Park, Benjamin Cummings, 1985.

- Agents only sensible to legal & economic sanctions (Rational cheaters?)
- Agents (also) sensible to social approval or reputation (Social sanctions)
- Agents (also) sensible to internal rewards or to internal terminal values.

This is the kind of ideal agent Ns are addressed to and try to build. We have to characterize his mind.

6. "Internalization" (and Why It Matters)

Ns have to be internalized, this is a diffused claim. However ... what does this really means? Where is the model of this mental mechanism? Not only of "internalizing", but of doing something for an internalized N?

Does internalization mean a "value"[18], a "terminal goal"? Do Ns provide a "reason" for doing: "I should/I have to"; and why this is different from "I like" "I desire" "I want"...?

Or internalization is just a learned automatic rule? Or is it the calculation of possible sanctions?

Also because punishments, sanctions, rewards in general are not just "external", from the other agent observing us. Punishments are also endogenous and/or self-inflicted.

Moreover, these internal/intrinsic negative rewards

- can be of moral type: self-blame, regret; moral disgust; sense of indignity, lowering self-esteem, disapproval etc. (costs: rumination, etc.). Many (negative) emotions contain negative rewards, punishments.
- can be active "sanctions" that I provide to myself, although not necessarily intentionally (and consciously) but on the basis of an emotional reaction and activation (costs: damages, compensation, expiation,...).

Punishments & sanctions are not aimed just at trivial reinforcement learning, or at intimidating and inducing the agent at avoiding violations just in order to avoid sanctions (an economic reasoning). They are – in humans – mainly aimed at the introjection of a value, of a non-instrumental goal of obeying norms, of respecting the authority (message: "proclaiming" the norm)[19].

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[18] M. Miceli, C. Castelfranchi, *op. cit.*

[19] G. Andrighetto, R. Conte, F. Giardini, *Le basi cognitive della contro-aggressione: vendetta, punizione e sanzione*, in "Sistemi Intelligenti", 2010, n. 3, pp. 521-532; G. Andrighetto, D. Villatoro, *Beyond the Carrot and Stick Approach to Enforcement: An Agent-based Model*, cit.; F. Giardini, G. Andrighetto, R. Conte, *A Cognitive Model of Punishment*, cit.

Ideally the N wants to be adopted for internal motives, not instrumentally to external incentives, not for external pressure and explanations, and for external control; but for and as "recognition" of the authority; and signaling such a recognition and subjection.

The paradox of human normative construction is that we use sanctions (punishments) in order to teach the other to obey to norms not for avoiding sanctions![20]

Only sub-ideally, only in case of violation (the norm has already be violated) we use sanctions. Only sub-ideally we decide to obey the norm just in order to avoid sanctions.

Why this is so important? Not only for the certainty of the monitoring (and eventually of the sanctioning) but because it favors the spreading of the N, not only based on examples but on teaching, shared values, rules, codes, ...And also because this kind of conformity internally driven is much less costly for society both in term of surveillance, violations, sanctions. Moreover, this internalization makes much more stable the recognized authority and the repeated internal "confirmation" of it and of the N.

6.1. Conformity and Punishments as Messages

Punishments and sanctions are mainly "messages"; they are not only aimed at materially and immediately harming you. They are aimed at communicating to you that:

- "We know that!", "We saw you!", "Do not believe that this is ignored, or hidden, or not noticed"
- "We blame this, and you!", "We want you know that we disapprove this as a fault, a defect, a violations; and that we consider you bad";
- "We want to sanction you; that you pay for this; to apply some penalty for this; at least a damage to your social image or reputation"
- "We want to punish you; that is that you learn from this experience, that in the future you avoid this, or you cannot do this again"
- "Your image is compromised; your reputation is in danger"[21].

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[20] C. CASTELFRANCHI, *Emotional Support to Strong Reciprocity*, talk at the Workshop on "Moral Emotions", Roma, CNR, 2008, http://www.academia.edu/2040526/Emotional_Support_to_Strong_Reciprocity.

[21] G. ANDRIGHETTO, C. CASTELFRANCHI, *Norm Compliance: The Prescriptive Power of Normative Actions*, cit.

There are negative emotions just related to each of these meanings and situation: the feeling of be exposed to the other observation and judgment (embarrassment, worry, ...), the feeling of have been "discovered"; the feeling of being blamed; the feeling of a threat, of an incoming aggression; ...

Conformity too is a message (intentional or functional) not only about the attitude and intention of the subject, and his understanding and recognizing the N, being a good guy, etc. but also about the existence and validity of that N itself, its restatement and distributed re-issuing, the generalize expectation about its respect[22].

6.2. Subjects Not Cooperators: The A-technical, Non-rational Nature of the Deontic "Ought"

N claims that we adopt even (and it is even better) without sharing the "instrumental" nature of the N, without understanding/adopting its "function" or end.

My "plan" – as N subject, as adopter – is different from the authority's "plan". Consider as developmental example the mind of a mother pushing her child to brush his theet; and consider the higher goal of this goal into the two minds.

The mother wants her child to brush his teeth every evening, in order to avoid decay. The child adopts the goal (see Fig. 1) in order to obey his mother and to make her happy; he ignores and could not understand the real function of his behavior (the higher goals in the mother's mind). What, relative to the intentional behavior and the mind of the child, is just an external goal and a function, is an intended goal in the mother's mind.

Exactly the same kind of relation often holds between government and citizens[23]. Government pushes citizens to do something it considers necessary for the public utility, for some common interest; but it asks the citizens to do this for mere obedience or by using rewards or sanctions. It does not rely on the citizens' "cooperation", on their understanding of the ultimate functions of their behaviors, and on their motivation for public welfare; it relies on the citizens' motivation for obedience or for money or for avoiding punishment. We are not supposed to "cooperate" but to "obey" and execute!

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[22] *Ibidem*.

[23] C. CASTELFRANCHI, *Scopi esterni*, in "Rassegna Italiana di Sociologia", Vol. 23, 1982, n. 3.

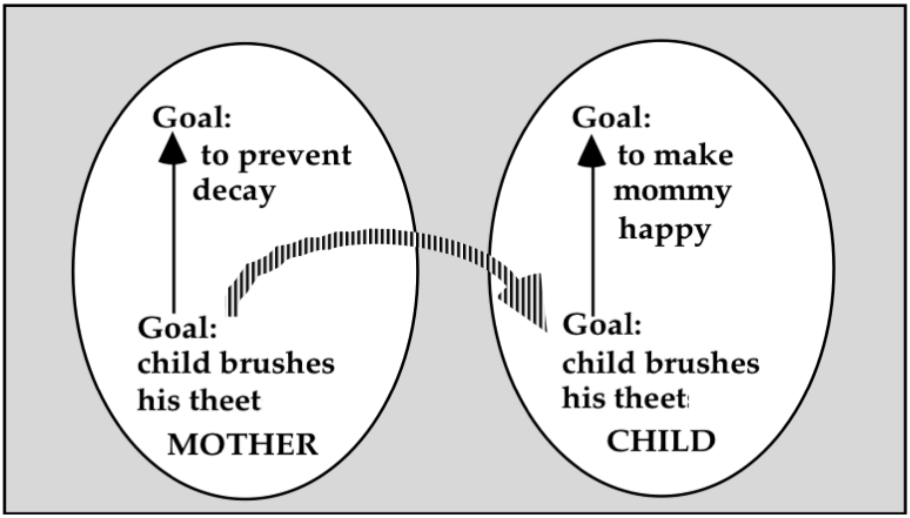

Fig. 1 – Goal-adoption from mind to mind

Both the "ideal" and the "sub-ideal" (for avoiding sanctions) obedience share a fundamental core, crucial for the real nature of the deontic "norm", "ought". A core that differentiate the mind of the normative "subject" S from the mind of the "issuer" or legislator.

S is not supposed to (have to) adopt the N (to "adhere" to the imperative) because s/he understands or agrees about its function, aim.

On the contrary, S is supposed to have to obey even if s/he does not understand the meaning of the N, or disagrees about it. This is true and mere "obedience".

A normative education is precisely an education to obey in any case, and even to not wondering and worry about the validity of the N.

In a sense the deontic "ought" "have to" is a de-technicalized "ought": no longer a necessary means for ...something that you have to want, to choose[24].

The technical ought is: "If you like/want to/in order to ..., you should, have to..." for example: "To open this door you have to...".

The deontic ought just is: "You have to" for what? why?

[24] I am working on this topic with Luca Tummolini (in preparation).

In the mind of the "issuer" the N is on the contrary supposed to be a means, a solution for some problem; he should have in mind the aim and instrumental function of the N.

6.3. Educating to Norms

There are two fundamental kinds of N education:

One based on Understanding & Empowerment/Responsibility: "Did you see what happens if/when ..."; "Do you understand what you have done?"; "You must never do that, otherwise there will be this trouble".

And the most radical and "duty" based one: No understanding/explanation, no sharing.

A radical "normative education" starts when your mother moves from just saying: "*Don't say dirty words!*" "*I don't want that you say dirty words!*" or "*You should not say dirty words!*" to an "impersonal" formulation: "*One should not say dirty words!*" "*Dirty words should not be said!*" "*It is bad ...!*". And when to your protest or question "*Why*?" she does not give any explanation, but just answer: "*Because otherwise I bit you!*" or "*Because I want so!*"; or even better something like "*It is not allowed; and that's all!*" "*You must obey; that's it*" "*Because it is so!*".

That is, she refuses to give you justifications and reasons, and teaches to you that you should do this without specific instrumental reasons (and advantages), terminally; just because it is an order, a norm, of an authority which should be acknowledged; as a terminal "value".

6.4. The "Alienated" Nature of Norm Adoption

Contrary to what supported by the theory of the "extinction of the State" and of the government not over persons but of persons/people (as conscious cooperators and intelligent planners of social dynamics), in my view, it is not really possible the total elimination of this alienated cooperative relation: to cooperate to common good (by conforming to it), without understanding it and thus without intending it.

It is not possible a citizen fully aware and intentionally cooperating with public choices, to whom nothing is thus "imposed" - including imposts. At least partially he will remain a "subject", not sharing the ends but just obedient.

It is not possible for cognitive and cultural limitations of individuals and groups[25]. It is in any case unavoidable a portion of "delegation" and not understanding of the reasons and aims of public/collective choices. Ns and the "authority" of the authority are for that.

Possibly this "delegation" should be based on "trust" towards rulers and institutions, towards the dominating groups, not on the awe of their power and of possible harms.

That the "subject" of the N could not/should not understand (share) the technical sense of the N (that this be irrelevant for her/his obedience and that her/his technical evaluation be irrelevant for the collective) for sure is not a warranty that the N is not oriented at aims different from the "common good".

I, the subject, trust them or the system or anyhow undergo to them, I cannot understand, dominate those issues. Will the N really serve more to the ends of a class or part of the society? Will it protect the interests of the legislators?

There is "alienation"; meaning that the subject alienates his own intellectual capabilities of evaluation, problem-solving, decision, by "delegating" to others them, and the power and the solution. Moreover, he is not in condition to realize that, to understand this process, and behaves without recognizing his own estranged powers and without the possibility of reappropriating them. Perhaps Y – delegated to that – has really found the right solution for our collective problem, but I am not supposed/required to understand it, share, adopt as such. I have to adopt it blindfold.

7. Influencing Devices in a "Prevention Focus"

Norms are influencing devices. In principle they might

- either use a "positive", promoting, promise-based perspective: an attraction perspective,
- or use a duty-based one: ought, responsibility, guilt, punishment: an aversive perspective ("Prevention focus")[26].

[25] For problems of timeliness and regularity in the coordination of distributed and countless behaviors; for the spontaneous psychological prevalence of personal, group, local, and short term interests, on the collective and long term ones, with their necessary compromises and sacrifices.

[26] E.T. Higgins, *Promotion and Prevention: Regulatory Focus As a Motivational Principle*, in Zanna M.P. (ed.), "Advances in Experimental Social Psychology", San Diego, Academic Press, Vol. 30, 1998, pp. 1-46.

Why they generally adopt the second one, and build "obligations", "constraints", "duties", ...?

The logical formulation seem to be equivalent, interchangeable; but they are not at all equivalent from the psychological (cognitive, motivational, affective) point of view[27].

Usually laws and norms do not attract and promise, but present the threat face (on 10 Commandments 8 are prohibitions).

Also because – as we said – they do not want to explain the (instrumental/technical) advantage of the norm, its "utility" (they just want that you want to be "conform", to obey).

There is an asymmetry in the use of threats and promises, sanctions and rewards, blame and bad reputation vs. praises. Why? Why the main tool and artifact for social influencing and social order control adopts such a avoidant/threatening strategy? Betting on the "negative" side ("Prevention focus") rather than on the "positive" one?

(i) "Surveillance"

One reason is precisely the control and in particular the "monitoring". It is necessary to consider the possibility of "violation"; and must be focused and alerted on it, in order to prevent or to sanction it.

(ii) "Punishment" costs and incomes

One of the reasons/functions of this shaping and asymmetry is that it is preferable to support an altruistic cost in order to punish a deviant, a violator, more than wasting resources for praising, reinforcing a good conforming guy. In fact, it is not simply a matter/aim of education and of educational means (where the positive rewarding approach might even been more effective), but it also is a problem of compensation, balancing: who has violated have to "pay" for that, and a sanction (even just blame, emargination, bad reputation) is an harm, a paid penalty.

(iii) A more effective mental frame

Another reasons is due to the supposed greater efficacy or greater weight of the punitive and dutiful approach. It bets on losses, that – with equal amount – worth more than earnings; losses, risks, possible harms have a psychological priority, and more value in evaluation and decision making ("Prospect" theory); they are more binding.

(iv) A "natural" link: punishing for inducing avoidance

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[27] C. CASTELFRANCHI, M. GUERINI, *Is It a Promise or a Threat?*, in "Pragmatics & Cognition", Vol. 15, 2007, n. 2, pp. 277-311.

There is a logical and affective direct relation between a "punishing" experience or threat (which induce an avoidance reaction and feeling) and the aim to build an avoidance attitude towards the violation of the N.

"Duty" is an "avoidance goal"; is a constraining representation.

8. Norm Processing from Beliefs to Goals and Intentions

The ideal path of N in our mind is:

- x is able to *recognize* N, to differentiate what is a N and what is not;
- x is able to *assess* whether s/he is concerned by N;
- x *accepts* N, forms a N-goal corresponding to N;
- x *decides to comply* with N or not;
- x is able to *re-issue* N, to prescribe it to other fellows subject to N, and
- x is able to observe, *monitor* their behaviors with respect to N and react in a positive or negative way to them[28].

In fact, for a N to influence x's behavior, N must become an *intention* of x.

For something to become an intention, it must first become a *goal*, which will be decided upon, planned etc. by x. Finally, for a new goal to be formed, x must form:

- beliefs about its reasons;
- the normative goal (norm acceptance).

Eventually, decide to achieve it (*norm compliance*) (Fig. 2).

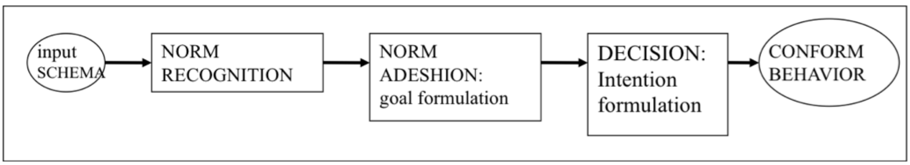

Fig. 2 – Cognitive norm processing

More precisely:

- beliefs: the recognition of that practice or request as a "norm"; and as impinging also on me; the acknowledgment of the "authority";
- beliefs: the instantiation of that N in the current situation and context;

[28] R. Conte, C. Castelfranchi, F. Dignum, *Autonomous Norm Acceptance*, in Mueller J. (ed.), "Proceedings of the 5th International workshop on Agent Theories Architectures and Languages" (Paris, 4-7 July 1999).

- goal Adoption: (N Adhesion) the formulation of the normative goal potentially regulating my action in the situation;
- the activation/consideration of possible Motives (higher-goals) for obeying/conforming or not;
- decision to violate or to obey: possible formulation of the normative Intention;
- intention in action and conform external behavior;
- success or failure (possible non intended violation due to an accident).

Along this path there are several reasons for dropping a N-goal:

- goal-conflict: the N-goal contrasts with another goal of the agent:
    - probability and weight of punishment
    - importance of the goal or value of respecting the norm
    - importance of feelings associated to N-violation
    - importance of the negative consequences of violation
- N-conflict: N contrasts with other Ns accepted by the agent
- irrelevance: x does not believe to be a member of the set X
- material impossibility: x forms a N-goal but cannot comply with it.

9. From Goal-adoption, Decision, Intention, ... to Routines

Our quite rich cognitive characterization of the representations and processes underlying a behavior obedient to a norm, should not however give the idea of behavioral conformity as always based on such a complex "reasoning" and "deliberation".

It is absolutely true that norm conformity and obedience can become a habit, an automatism, a routine behavior, based on simple production-rules or "classifiers".

By default – except one has special reasons and active goals blocking the trivial reaction and routine – one just executes the classifier (like when - while driving a car – one reactively stops to a red light):

Condition ==> Action;

Recognized stimuli ==> Appropriate behavior.

Given that normative behavior is a "regularity" (norms implement and maintain regular and common behaviors), there is a regularity both in perceiving (a fixed schema) and in acting (a fixed behavior in those conditions); thus, reasoning and decision become superfluous (wasting time and resources).

Normative routine behavior, in our model, is just a "shortcut", a functional bypass of the original and "normal/ideal" way, which is assumed to usually be its origin and source, and its cognitive background and justification (Fig. 3).

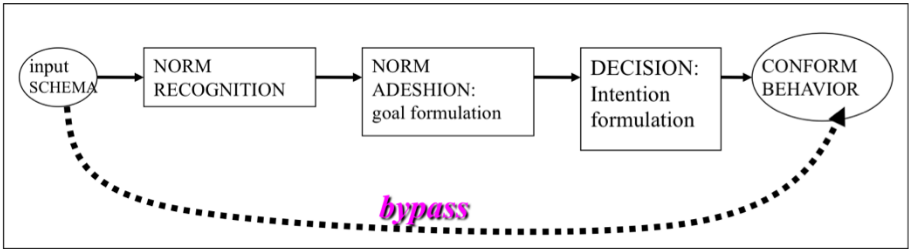

Fig. 3 – Normative routine behavior

This is the simplified schema of reflex “obedience”: like stopping at the red semaphore.

However, there are top-down vs. bottom-up processes, moving from a initial mere reinforcement or imitation based learning to a real deontic representation and awareness, or vice versa, moving from a deep normative understanding and processing to a simplified routine and reaction.

When respecting certain norms is fully routinized and becomes a mere automatic unconscious reflex, the subject is no longer aware of the norm, that is, he does not activate the normative belief (“It is prohibited . . . ”) and the decision.

However, on the one side, even for fully automatic conform behaviors it is always possible the evocation and explicit consideration of the normative beliefs and goals. For example, we automatically stop at the red light, but an ambulance with a loud siren arrives behind us and “asks” us to move, to cross; in that very moment we might explicitly consider that it is red and it is prohibited to cross, but also that it is better to violate that norm.

On the other side, for several norms that level of unconscious automatic obedience is not possible, and we consider the existence of the prescription and take real decisions. For example, stopping for a policeman’ signal is not fully automatic; paying a fine or taxes requires some reflection and a conscious deontic reasoning; and so on.

Moreover, what matters for social order, is that it is “as if” the agent was remembering and considering that there is a norm; we implicitly rely on that.

10. Norms As Multi-agent Artifacts

Ns are social and mental artifacts. As "social" they are a "coordination artifacts", but this coordination works by coordinating agents' minds and mental attitudes. Normative coordination presupposes in fact different normative roles with their minds.

Normative minds: the "Issuer" I; the "Subject" S; the "Monitoring agent" or "Watcher" W.

Those attitudes are complementary to each other, and necessary for the social implementation of Ns:

- In all those "minds" the N is an imperative on a class of agents.
- However, in I and W's minds the N does not concern them; it is not "instantiated" on them.
- S on the contrary is concerned, and should arrive to formulate a conform Intention to do.
- I and W instantiate the N on S, and formulate the Goal (Expectation not just forecast) that S behaves correctly.

We have – in this paper – gone deeply into S's mind and his adoptive process; this was the cognition and internalization we have focused on; but we have also explained how S becomes a (non official, informal) W and I.

11. Concluding Remarks

In sum, to work appropriately Norms must be mentalized. Norms are for influencing "autonomous" agents, that is, agents self-regulated and self-motivated; for inducing goals in them.

Norm working cannot be reduced to sanction/incentives and "utility". Ideally N-Adoption is terminal, non-instrumental; they should not be obeyed because of possible "sanctions".

Norm must be recognized and acknowledged as such; they cannot be only implemented in routines and habits. The N spreading and maintenance is first of all a mental spreading and sharing of values and beliefs.

Norms are a behavioral and mental coordination artifacts, based on different complementary mental attitudes in the various roles.

Expectations about the others' behavior conform to a norm are not just "predictions" built on a regularity; they are full expectations, entailing the fact the we rely on the other behavior and thus want/wish it; we not only predict but prescribe the others' behavior[29].

There is a specific "cognitive processing" of norms in cognitive agents, from the recognition of the input as a normative prescription to the formulation of the intention to conform or to violate.

[29] C. CASTELFRANCHI, L. TUMMOLINI, *Positive and Negative Expectations and the Deontic Nature of Social Conventions*, in "Proceedings of the 9th International Conference on Artificial Intelligence and Law - ICAIL 2003", ACM, 2003.

How Social Norms Can Make the World More Regular and Better

Federico Cecconi, Giulia Andrighetto, Rosaria Conte*

Summary: *1. Introduction – 2. Normative Agents – 3. EMIL-A – 3.1. Norm Recognition Module – 4. Three Colored World – 5. Results – 6. Final Remarks and Discussion*

1. Introduction

Is there any difference between social norms and mere regularities emerging spontaneously from the behaviours of entities that have no norm-based cognition? And if so, which effects do we expect to observe in a world in which agents are endowed with such a type of cognition? In other words, what type of regularities, if any, does such normative cognition establish?

The scientific literature on the subject matter encourages investigation. In a six-year study conducted at the University of Virginia, Turner and collaborators[1] found that exposing college students to information that corrected misperceptions about campus drinking patterns resulted in dramatic reductions in alcohol-related negative consequences[2].

There are different models describing what a social norm is, its properties, modalities of creation and diffusion. They are essentially inspired to two main directions of thought based on two unrelated notions, regularities and obligations. Regularities, or behavioural norms, are spontaneously emerging phenomena[3]. Obligations, or institutional norms, are deliberately

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[1] J. Turner, H. Wesley Perkins, J. Bauerle, *Declining Negative Consequences Related to Alcohol Misuse Among Students Exposed to a Social Norms Marketing Intervention on a College Campus*, in "Journal of American College Health", 2008, n. 57, pp. 85-93.

[2] R.B. Cialdini, R.R. Reno, C.A. Kallgren, *A Focus Theory of Normative Conduct: Recycling the Concept of Norms to Reduce Littering in Public Places*, in "Journal of Personality and Social Psychology", Vol. 58, 1990, n. 6, pp. 1015-1026.

[3] D. Lewis, *Convention: A Philosophical Study*, Cambridge, Cambridge University Press, 1969; H.P. Young, *The Evolution of Conventions*, in "Econometrica", n. 61, 1993, pp. 57-84.

issued prescriptions[4]. Behavioural norms are often found in the pro-social variant, or in the statistical variant, as frequent, normal behaviours. Institutional norms are obligation-based, and collapse on legal norms, issued by specified institutional authorities. Behavioural regularities and institutional obligations are complementary phenomena. None or poor attempt at their integration has been made so far[5]. However, the gap is neither desirable nor inevitable.

In this paper an integrated approach will be proposed, based on mental representations. In this approach, social and legal norms are treated as recognized, represented and reasoned upon prescriptive commands. The main difference between them lies in their

(a) *origin* - spontaneously emerging in social norms, institutionally deliberate in legal norms;
(b) *transmission* - with laws conveyed in written form (*lex posita*), while social norms are only orally or behaviourally communicated; and
(c) *enforcement*, which is unidirectionally effectuated by applying explicitly defined, predictable and equal sanctions in the case of laws, and mutually executed through uncertain and not always predictable forms of social control in the case of social norms.

Although norm addressees perceive these specificities to some extent, the requisites necessary for representing, reasoning and deciding on norms are common to both laws and social prescriptions. Only a theory that explores the impact of norms on the minds of agents can explain the link between these and other typologies – religious, moral, aesthetical and technical – of norms. Necessarily, a theory of this sort will explore a twofold dynamic of norms, which leads to their surfacing in observable behaviours (*emergence*) on the one hand, and to different levels and kinds of mental processing and representation (*immergence*) on the other[6].

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[4] H.L.A. HART, *The Concept of Law*, Oxford, Oxford University Press, 1961; H. KELSEN, *General Theory of Norms*, New York, Oxford University Press, 1979; G.H. VON WRIGHT, *Norms and Action*, London, Routledge and Kegan Paul, 1963.

[5] R. CONTE, *L'obbedienza intelligente*, Bari, Laterza, 1998; R. CONTE, C. CASTELFRANCHI, *From Conventions to Prescriptions. Towards an Integrated View of Norms*, in "Artificial Intelligence and Law", Vol. 7, 1999, pp. 119-125; R. CONTE, G. ANDRIGHETTO, M. CAMPENNÌ (eds.), *Minding Norms. Mechanisms and Dynamics of Social Order in Agent Societies*, Oxford Series on Cognitive Models and Architectures, New York, Oxford University Press, Forthcoming.

[6] See G. ANDRIGHETTO, M. CAMPENNÌ, F. CECCONI, R. CONTE, *The Complex Loop of Norm Emergence: A Simulation Model*, in Takadama K., Cioffi-Revilla C., Deffuant G.

This work is based on a computational methodology, i.e., multi-agent-based simulation[7]. This is an ideal tool for exploring the two-way dynamics of norm emergence, because it must explicitly and completely describe the whole process leading from a no-norm world to one in which regularities of some sort exist. In addition, by using agent-based simulation the relationship between cognition and social dynamics can start to be teased apart in a dynamic manner, and their respective roles accounted for.

In this paper, we present agent-based simulations aimed to understand what would happen in a world populated by normative agents, able to recognize norms and to reason upon them, compared to other, cognitively, less complex agents, following only their own individual goals.

2. Normative Agents

The development of normative architectures is a burgeoning research field[8]. However, architectures of normative agents are predominantly inspired in some way by BDI - *Belief-Desire-Intention* architectures, introduced by the

(eds.), "Simulating Interacting Agents and Social Phenomena", New York, Springer, 2010, pp. 19-35.

[7] N. Gilbert, K.G. Troitzsch, *Simulation for the Social Scientist*, Maidenhead, Open University Press, 2nd ed., 2005; S. Moss, P. Davidsson (eds.), *Multi-Agent-Based Simulation*, LNAI 1979, Berlin, Springer, 2000, pp. 157-166; R. Conte, N. Gilbert, *Computer Simulation for Social Theory*, in Gilbert N., Conte R. (eds.), "Artificial Societies: The Computer Simulation of Social Life", London, UCL Press, 2006, pp. 1-18; J.M. Epstein, *Generative Social Science: Studies in Agent-based Computational Modelling*, Princeton, Princeton University Press, 2006; see also the proceedings of the Multi-Agent-Based Simulation (MABS) Workshops, http://www.pcs.usp.br/ ~ mabs/mabs_intro.html.

[8] R. Conte, G. Andrighetto, M. Campennì (eds.), *op. cit.*; G. Andrighetto, M. Campennì, F. Cecconi, R. Conte, *op. cit.*; J. Broersen, M. Dastani, J. Hulstijn, Z. Huang, L. van der Torre, *The BOID Architecture: Conflicts Between Beliefs, Obligations, Intentions and Desires*, in "Proceedings of the 5th International Conference on Autonomous Agents and Multi Agent Systems (AAMAS)", New York, ACM, 2001, pp. 9-16; N. Criado, E. Argente, V. Botti, P. Noriega, *Reasoning about Norm Compliance*, in "Proceedings of the 10th International Conference on Autonomous Agents and Multiagent Systems", 2011, pp. 1191-1192; B.T.R. Savarimuthu, S. Cranefield, M.A. Purvis, M.K. Purvis, *Obligation Norm Identification in Agent Societies*, in "Journal of Artificial Societies and Social Simulation", Vol. 13, 2010, n. 4, http://jass.soc.surrey.ac.uk/13/4/3.html; F. Lopez y Lopez, M. Luck, *Modelling Norms for Autonomous Agents*, in Chavez E., Favela J., Mejia M., Oliart A. (eds.), "Fourth Mexican International Conference on Computer Science", IEEE Computer Society, 2003, pp. 238-245.

pivotal work of Rao and Georgeff[9], which can be regarded as the point of departure for further developments. The BDI framework is intended to model human intelligent action and decision-making. In the last decade, BDI architectures augmented with obligations, like BOID - *Beliefs-Obligations-Intentions-Desires*[10] or BDOING - *Beliefs, Desires, Obligations, Intentions, Norms and Goals*[11], began to appear.

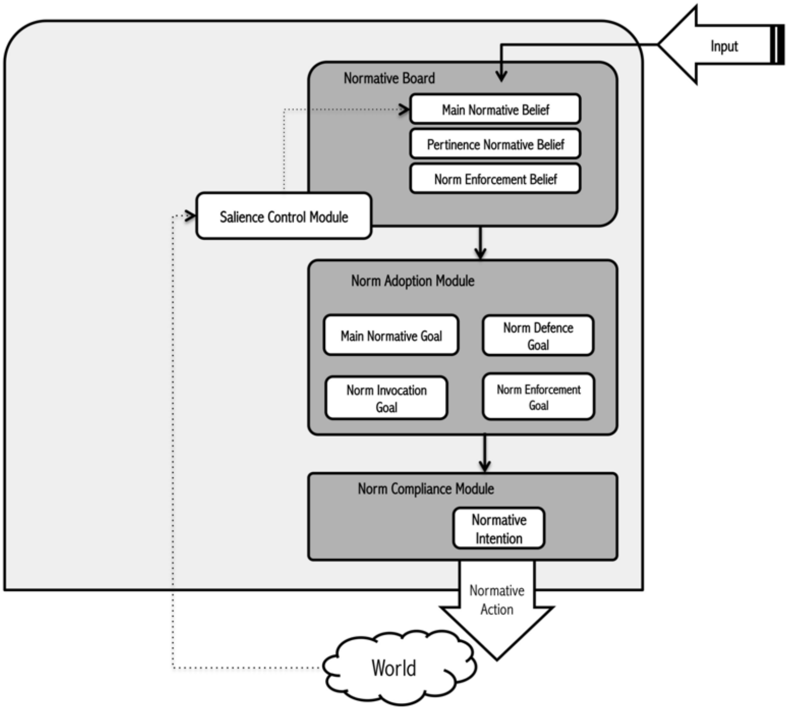

Fig. 1 – Main components and mental dynamics of EMIL-A: the architecture consists of different modules interacting with one another by means of input-output mechanisms

[9] A.S. RAO, M.P. GEORGEFF, *Decision. Procedures for BDI Logics*, in "Journal of Logic and Computation", 1998, n. 8, pp. 293-343.

[10] J. BROERSEN, M. DASTANI, J. HULSTIJN, Z. HUANG, L. VAN DER TORRE, *op. cit.*

[11] F. DIGNUM, D. KINNY, L. SONENBERG, *From Desires, Obligations and Norms to Goals*, in "Cognitive Science Quarterly", Vol. 2, 2002, n. 3-4, pp. 407-430.

The normative architecture we present here, EMIL-A[12], is inspired to BOID and BDOING as it entails the representation of normative beliefs and goals based on obligations.

However, unlike BOID and BDOING, EMIL-A includes a module for norm-recognition allowing agents to process incoming inputs and possibly converting them into norms. This mechanism proves essential when modelling and operationalizing the process of norm immergence[13]. In the next Section a description of the main components and processes of EMIL-A is provided[14].

3. EMIL-A

A sketch of the main components and mental dynamics of EMIL-A is provided in Fig. 1. In particular, it includes:

1. Two types of representations:
   - Normative Beliefs: beliefs that a given behaviour, in a given scenario, for a given set of agents, is either forbidden, obligatory, or permitted[15].
   - Normative Goals: goals[16] relativized to a normative belief. A goal is relativized when it is held because and to the extent that a given world-state or event is hold to be true or is expected[17].
2. Three modules:
   - Norm Recognition, which takes an observed behaviour or a message as an input and possibly turn it into a new normative belief.

[12] This normative architecture has been developed within the EMIL project (EMergence In the Loop: simulating the two way dynamics of norm innovation), a FET-funded European project on the agent-based simulation of the two-way dynamics of norm innovation.

[13] G. ANDRIGHETTO, M. CAMPENNÌ, F. CECCONI, R. CONTE, *op. cit.*

[14] R. CONTE, G. ANDRIGHETTO, M. CAMPENNÌ (eds.), *op. cit.*

[15] R. CONTE, C. CASTELFRANCHI, *The Mental Path of Norms*, in “Ratio Juris”, Vol. 19, 2006, n. 4, pp. 501-517.

[16] A goal is here meant in the very general sense derived from cybernetics, i.e., a wanted state of the world triggering and driving actions (see, G.A. MILLER, E. GALANTER, K.H. PRIBRAM, *Plans and the Structure of Behavior*, New York, Henry Holt, 1960; R. CONTE, C. CASTELFRANCHI, *Cognitive and Social Action*, London, UCL Press, 1995; R. CONTE, *Rational, Goal Governed Agents*, in Meyers R.A. (ed.), “Springer Encyclopedia of Complexity and System Science”, Berlin, Springer, 2009).

[17] P.R. COHEN, H.J. LEVESQUE, *Persistence, Intention, and Commitment*, in Cohen P.R., Morgan J., Pollack M.A. (eds.), “Intentions in Communication”, Cambridge, MIT Press, 1990, pp. 33-71.

  - Norm Adoption, which takes a normative belief as an input and possibly gives a new normative goal as an output.
  - Norm Compliance; which takes a normative goal as an input and possibly puts it into execution, performing a normative action.
3. The norms' salience mechanism, which updates the salience of norms, according to external events.

The Norm Recognition Module is the crucial component by means of which agents are able to infer that a certain norm is in force even when it is not already stored in their normative memory. Implementing such a capacity is conditioned to modelling agents' ability to recognize an observed or communicated social input as normative. It allows agents to form new normative beliefs processing the information received while interacting with or observing the other agents behaving in a common environment. The Norm Recognition Module detects whether or not the received social input refers to a normative belief already stored in the normative board. In the former case, it will update the salience of the corresponding norm accordingly. In the latter case, it will either form a new normative belief, or simply discard the input.

When a new normative belief is formed, the Norm Recognition Module will send information to the Norm Adoption module. This will use such information to decide whether or not to form the corresponding Normative Goal, based on the norm-adoption rule[18]. The general mechanism by which an autonomous agent adopts external requests, called adoption mechanism, has been described at some length in Conte and Castelfranchi[19]. Here, suffice it to say that an agent (the adopter) will adopt another agent's (i.e., the adoptee's) goal as hers, on condition that she, the adopter, comes to believe that the achievement of the adoptee's goal will increase the chances that she will in turn achieve one of her previous goals.

Finally, the new Normative Goal will be inputed to the Norm Compliance Module. This consists in a decision-making procedure that possibly turns the new goal into an intended Normative Action. The procedure will put the goal to execution unless it is already realised or incompatible with more important goals. In the last two cases, the Normative Goal will be suspended until the conditions for its execution will be verified again.

[18] R. CONTE, C. CASTELFRANCHI, *op. cit.*
[19] *Ibidem*.

In this paper, we will describe the implementation only of the first component of EMIL-A, i.e., the Norm Recognition Module (see Fig. 2). This is most frequently involved in answering the question how a new norm is found out, a topic that we consider particularly crucial in norm emergence, innovation and stabilization.

3.1. Norm Recognition Module

The Norm Recognition Module (see Fig. 2) consists of a normative board (on the left), that is a long-term memory, and a two-layer working memory (on the right). The normative board contains normative beliefs, ordered by salience. By norm salience, we refer to the measure that indicates how active a norm is within a group and in a given context[20]. The working memory is where social inputs are elaborated. Agents observe social inputs and receive messages from one another.

Each input is presented as an ordered vector, consisting of four elements:

1. the source (X), i.e., the agent observed or the agent who sends the message;
2. the action transmitted (α), i.e., the potential norm;
3. the type of input (T): it can consist either in a behaviour (B), i.e., an action or reaction of an agent, or in a communicated message, transmitted through the following holders:
   - assertions (A), i.e., generic sentences pointing to or describing a state of the world;
   - requests (R), i.e., requests of action;
   - deontics (D), partitioning situations between good/acceptable and bad/unacceptable. Deontics are holders for the three modal verbs analysed by von Wright[21] "may", indicating permission, "must", indicating obligation, and "must not", indicating prohibition;

[20] See D. VILLATORO, G. ANDRIGHETTO, R. CONTE, J. SABATER-MIR, *Dynamic Sanctioning for Robust and Cost-efficient Norm Compliance*, in "Proceedings of the 22nd International Joint Conference on Artificial Intelligence", 2011, pp. 414-419; G. ANDRIGHETTO, D. VILLATORO, *Beyond the Carrot and Stick Approach to Enforcement: An Agent-based Model*, in Kokinov B., Karmiloff-Smith A., Nersessian N.J. (eds.), "European Perspectives on Cognitive Science", Sofia, New Bulgarian University Press, 2011 for a detailed description of the norm salience dynamics.

[21] G.H. VON WRIGHT, *op. cit.*

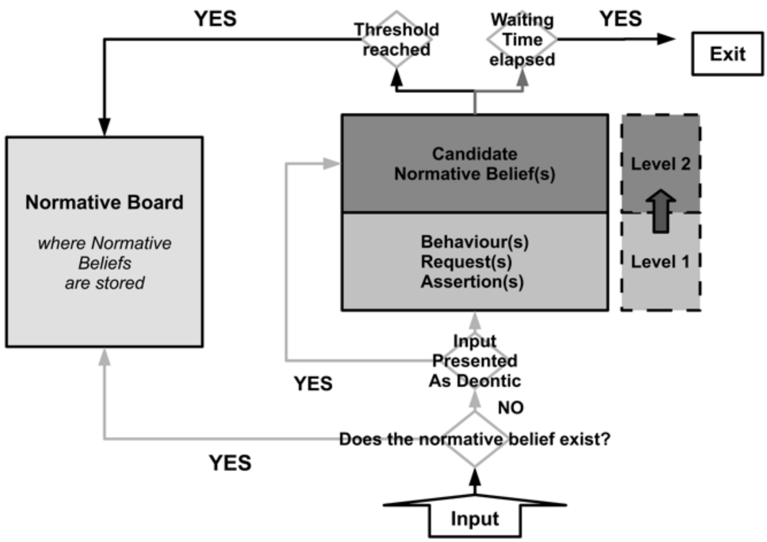

Fig. 2 – The Norm Recognition module

– normative valuations (V), i.e., assertions about what it is right or wrong, correct or incorrect, appropriate or inappropriate (e.g., it is correct to respect the queue).

4. The observer (Y), i.e., the agent who receives the input.

Once the input is received, EMIL-A will compute the information thanks to its norm recognition module. Here follows a brief description of how this module works.

Every time a message containing a deontic (D), for example, "You must answer when asked", or a normative valuation (V), for example "It is impolite not to answer when asked", is received, it will directly access the second layer of the architecture, giving rise to a candidate normative belief "One must answer when asked", which will be temporarily stored. This will sharpen agents' attention: further messages with the same content, especially when observed as open behaviours or transmitted by assertions (A) – for example "When asked, Paul answers" – or requests (R) – for example "Could you answer when asked?" – will be processed and stored at the first level of the architecture. Beyond a certain normative threshold (which represents the frequency of the corresponding normative behaviours observed, i.e., the percentage of the compliant population), the candidate normative belief will be transformed into a new (real) normative belief, which will be stored in the normative board. The normative threshold can be reached in several ways. For example, by observing a given number of agents performing the same action (α) prescribed by the candidate normative belief, e.g., answering when asked. If the observer receives no further occurrences of the same input (action α), the candidate normative belief will leave the working memory (Exit) after a fixed time t.

Exposed to the normative behaviours of others and to their explicit or implicit normative requests, agents acquire normative beliefs. Normative messages or normative requests alone are not sufficient to generate normative beliefs, they have to be confirmed by the compliant conduct of others, which reveals the actual salience and degree of activity of the norm. Thus for a normative belief to be generated, normative prescriptions have to be transmitted and the correspondent normative actions observed.

In the simulation experiments presented in this work, we have implemented a simplified version of EMIL-A, in which the decision-making is driven only by the indications provided by the Norm Recognition Module.

4. Three Colored World

We designed a bidimensional world, divided into regular cells. Agents move on these cells and they can take decisions and modify the states of the cell in which they are (see Fig. 3 and Fig. 4). We refer to this scenario as the three colored world.

In the three colored world there are three kinds of agents (see Fig. 4): (a) agents that are not able to recognize norms, (b) agents able to recognize norms, but at the present stage with no norms able to influence their own behavior (non-active norms), (c) agents endowed with a norm-recognizing mechanism and with active norms.

In this world, agents can *color* the cell of the world where they are, with one of the three colors at their disposal, red, black and grey, and *modify* the propension to follow one of their goals. In particular, the goals agents are endowed with are the following: <goal 1>: minimise interference; <goal 2>: imitate other agents; <goal 3>: normative goal. The propension to follow each of these goals is indicated in terms of probability to use one of the three colors. In details:

- *Goal 1: minimise interference* with the current state of the world. Let us imagine that, starting from a no-color world, each track left on one's cell can produce interference. Within a certain observation window, each agent can count how many cells are already colored by either red, black or grey. Then, depending on the color the cell is left with (which overlays that which was possibly already present in the agent's cell) the interference is calculated as follows: (a) *If RED, interference will be NBlackCells * 2+NGreyCells *0.75, (b) If BLACK, interference will be NRedCells * 2+NGreyCells*0.75, (c) If GREY, interference will be (NredCells+NblackCells)*0.75*. Table 1 shows the three calculations for the same example.

(b) (r) (g)	2*2+1*0.75=4.75
(b) (r) (g)	3*2+1*0.75=6.75
(b) (r) (g)	5 * 0.75=3.75 (grey is the colour that interferes less with the world compared to red and black).

Tab. 1 - Interference of the three colours, black (b), red (r) and grey (g) with the state of the world

- *Goal 2: imitate neighbours*: agents aim to use the same color of their neighbors. In the border between two different color area, this can conflict with the preceding goal.
- *Goal 3*: (for norm detectives only) *use the most salient norm*, which will specify what color to use.

Agents' intelligent decisions are goal based[22]. The type of goals that can be satisfied is the same for all of the agents, but each agent can, at different moments, obey a different goal.

For example, let us imagine four possible goals: go to work, have some sleep, play the piano, go jogging (G1, G2, G3, G4). At each moment, agents

[22] Intelligent agents differ from utilitarian agents as they try to satisfy their most important goals. Goal satisfaction does not imply utility maximization because the advantage of the benefits obtained over the costs sustained to achieve the best goal may be lower than that realized by satisficing the next-best goal option. See R. CONTE, R. PEDONE, *Finding the Best Partner: The PART-NET System*, in "Proceedings of the 1st International Workshop on Multi-Agent Systems and Agent-Based Simulation", 1998, pp. 156-168.

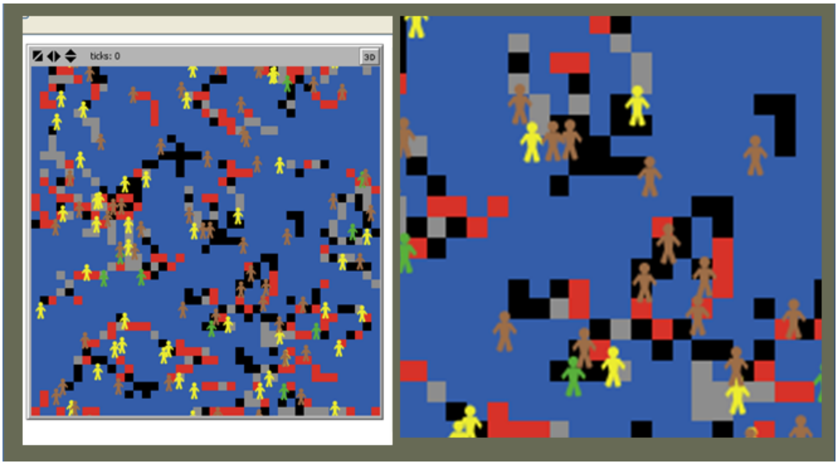

Fig. 3 – Agents and the environment

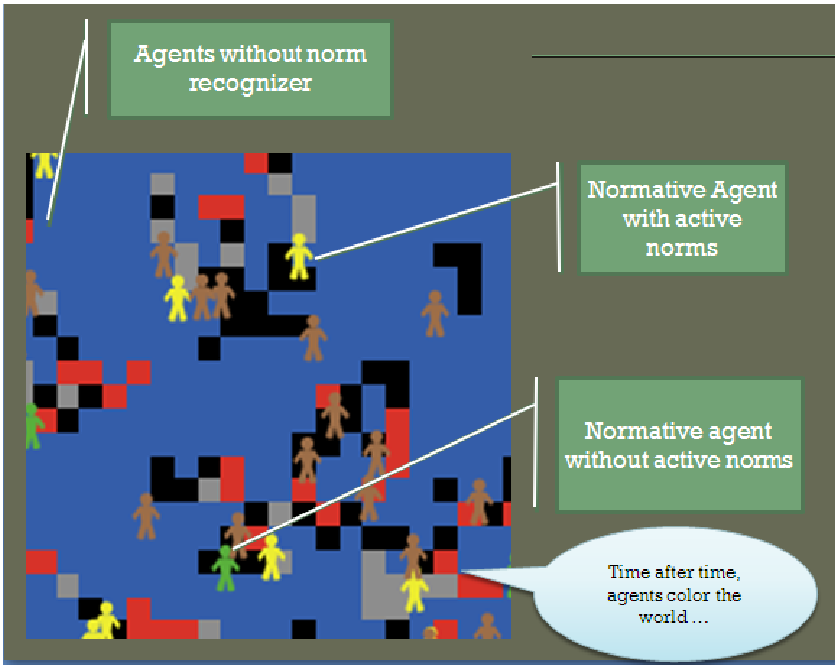

Fig. 4 – Agents' types

Agent	List of probabilities				Behavior
	G1 Work	G2 sleep	G3 play	G4 jogging	
A1	0	0	0	1	With a 100% probability, A1 wants to satisfy the goal to go out jogging. A1 will, thus, follow action b1.
A2	0.5	0	0	0.5	With a 50% probability, A2 wants to satisfy the goal to go to work, and with 50% probability the goal to go out jogging. The selected action is again b1.
A3	0.25	0.25	0.25	0.25	Flip coin.
A4	1	0	0	0	Dual of A1, but the goal to be satisfied is G1, i.e, go to work.
A5	0.9	0.1	0	0	With a 90% probability, A5 wants to satisfy the goal to go to work, and with a 10% probability the goal to have some sleep. A5 is more likely to chose action b1 than anything else.

Tab. 2 - Agents, actions and goals

can choose one out of three possible actions: b1 – going out (useful for satisfying G1 and G4); b2, getting a piano score (useful for satisfying G3); b3, staying home, useful for satisfying G2. The world is populated by five agents, *A1, A2, A3, A4, A5*, each assigned with a list in which the probability of following one of the four goals is indicated:

Agents' actions modify the world and can also modify their own goals. Normative agents can also communicate messages of the form described in the previous Section. Some of those messages contain deontics prescribing the colour to be used "You must use red/black/grey when colouring the world". These messages favour the generation of normative representations. The interaction of the normative representations with the goals results in the agents' behaviour. The simulation has been implemented using a Netlogo platform.

5. Results

The simulation allows us to observe how the world is colored, depending on the number of normative agents introduced in the system since the beginning. The results are the average of thirty repetitions for each condition.

Fig. 5 shows the percentage of grey cells, i.e, the cells that interfere less with the world, for different percentages of normative agents present in the simulation since the beginning.

Fig. 6 shows an interesting regularity: in a world populated by normative agents, the steady state at the end of simulation is not monocromatic. Using normative agents, the number of steady state with two colors increase as a linear function of the percentage of normative agents. This result in not trivial: in fact, norms "in the sense of coordination rules" cannot explain this kind of regularity. In other word, the norms increase "variety" of the world. Be careful: all the steady state with two colors contain grey. Grey is one of the component of bicolor ending of simulations.

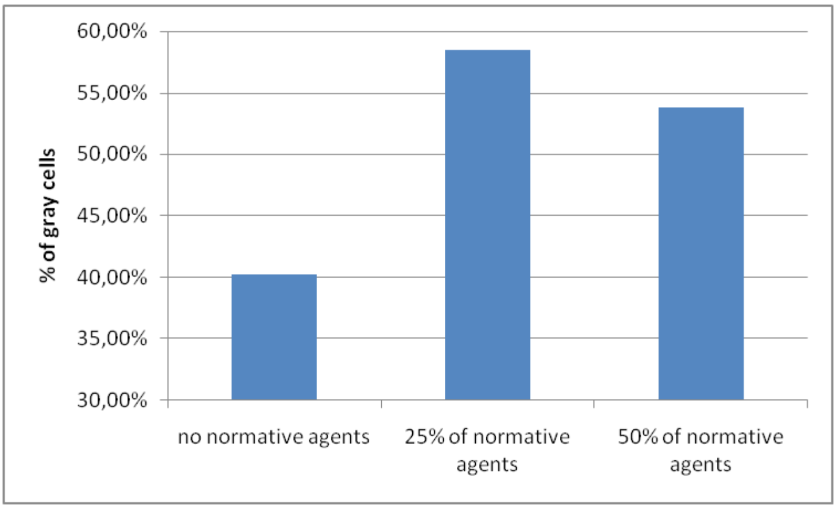

Fig. 5 – Percentage of grey cells at the end of simulations

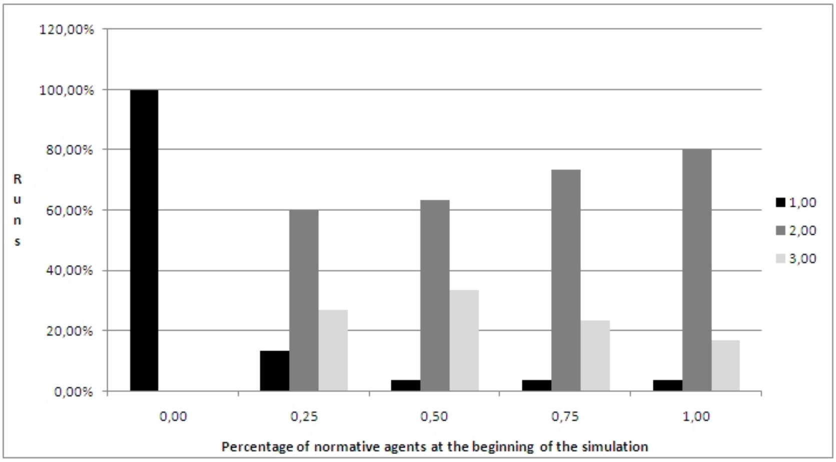

Fig. 6 – The distribution of the colors at the steady state.
Numbers in the legend (1,2,3) indicate the number of colors present in the world.
We show that with no normative agent the world is, at steady state, monocromatic.
On the contrary, using normative agents, the world has two (or three) colors

6. Final Remarks and Discussion

The main result of the experiment concerns the number of grey cells present at the end of the simulation. This varies as a function of the increased number of normative agents: with a non-nul number of agents that are able to recognize norms, the number of grey cells increases. What is more, if normative agents are not around, the simulation converges uniformly on one color, alternatively red, black or grey (the probabilities of occurrence of the three cases directly derive from the degree of grey's interference compared to the other two colors, in our case 0.75 vs 2).

A statistical analysis of the model allows us to conclude that there are no external limits to the convergence on a single color. On the contrary, the presence of normative agents preserves some diversity in the final states.

A second remark is that if the choice of grey is to be preferred to the others for a reason that is external to the model (for example, using the model in a context of social integration we can think that grey is a behavior reducing the probability of contrasts, whilst in an environmental model it may be interpreted as a less disruptive, or more sustainable, behavior), the results show that the presence of normative agents favors such solution, with interesting hints in the study of policies and, partially, of interventions.

Imitation based on a utility function is enough to bring about convergence and regularity, but does not ensure that such regularity corresponds to a socially desirable result. Regularity is useful when trying to achieve a problem of coordination, as in the case of left or wright precedence. Instead, it is not sufficient with social problems in which solutions are not equivalent, and in which the imitation of individually successive strategies may contrast with the socially preferable solution.

Learning Agents and Decisions: New Perspectives

PIETRO TERNA*

"Away! let's go learn the truth of it"
W. Shakespeare, "Measure for Measure"

SUMMARY: *1. Premise – 2. An Example, to Start – 3. Background in Agent-based Models – 4. More on Learning – 5. An Example of Learning and a Crucial Question – 6. Decisions and Actions in Policy and Law: Could Agent-based Simulation Help? – 6.1. European Central Bank – 6.2. Edgeryders, Transition to the Future – 6.3. eGovernment Meets the eSociety – 6.4. Laws in a Bottom-up Process – 6.5. Barabási's Considerations – 7. A Temporary Conclusion*

1. PREMISE

Is it possible to help different form of knowledge to be closer to hard sciences, providing them of experiment capabilities and theory refusal?

One potential reply is that of widening the field of application of agent-based simulation to new disciplines. With agents in a computer, we recreate actual world on an artificial basis, to see the effects of the action and interaction of entities (our agents) built on rules that we give them in an organized arena.

The roots of this proposal are quite old, referring to the cybernetics dream. With Rosenblueth and Wiener[1], being Wiener the actual founder of cybernetics[2]:

> A material model is the representation of a complex system by a system which is assumed simpler and which is also assumed to have some properties similar to those selected for study in the original complex system. A formal model is a symbolic assertion in logical terms of an idealized relatively simple situation sharing the structural properties of the original factual system.
>
> Material models are useful in the following cases. a) They may assist the scientist in replacing a phenomenon in an unfamiliar field by one in a field in

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[1] A. ROSENBLUETH, N. WIENER, *The Role of Models in Science*, in "Philosophy of Science", Vol. 12, 1945, n. 4, pp. 316-321.

[2] The word is inspired from the Ancient Greek term κυβερνήτης, meaning steersman, governor, pilot.

which he is more at home. (...) b) A material model may enable the carrying out of experiments under more favorable conditions than would be available in the original system.

Substitute to the "material model" idea (the actual artifact) an agent-based model (the synthetic artifact), and you have exactly the capacity of making "experiments under more favorable conditions than would be available in the original system".

Doing that, we have to be aware that behind the corner, the trap of the complexity is trying to catch us. With Anderson[3]:

> The reductionist hypothesis may still be a topic for controversy among philosophers, but among the great majority of active scientists I think it is accepted without questions. The workings of our minds and bodies, and of all the animate or inanimate matter of which we have any detailed knowledge, are assumed to be controlled by the same set of fundamental laws, which except under certain extreme conditions we feel we know pretty well.
>
> (...) The main fallacy in this kind of thinking is that the reductionist hypothesis does not by any means imply a "constructionist" one: The ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe.
>
> The constructionist hypothesis breaks down when confronted with the twin difficulties of scale and complexity. The behavior of large and complex aggregates of elementary particles, it turns out, is not to be understood in terms of a simple extrapolation of the properties of a few particles. Instead, at each level of complexity entirely new properties appear, and the understanding of the new behaviors requires research which I think is as fundamental in its nature as any other.

A remark: we have a wonderful tool in our hands, to be handled with care. Let now have a look to an agent model running on line, to verify if the explanations meet the self-communicating capabilities of an example.

2. An Example, to Start

At http://eco83.econ.unito.it/terna/chameleons/chameleons.html we have a simple but provocative example: our agents – one hundred as default, but we can increase or decrease their number with the slider *num*, are chameleons, changing their color in given situations[4].

[3] P.W. Anderson, *More Is Different*, in "Science", Vol. 177, 1972, n. 4047, pp. 393-396.

[4] I have to thank Riccardo Taormina, a former undergraduate student of mine, for developing this kind of application with great involvement and creativity. Many thanks also to Marco Lamieri, a former PhD student of mine, for introducing the powerful chameleon idea.

We are using here SLAPP - *Swarm-like Agent Protocol in Python*[5], to develop this kind of model. The basic code demonstrates that we can implement a rigorous protocol like that of Swarm[6] with a simple coding system[7], consistently with the goals exposed in this premise. At the same SLAPP web address, the Chameleons application may also be found, in both SLAPP and NetLogo[8] versions.

In the starting phase, we have chameleons of three colors: red, green and blue. When two chameleons of different colors meet, they both change their color, assuming the third one. If all chameleons turn the same color, we have a steady-state situation. This case is possible, although rare.

But what if the chameleons of a given color want to preserve their identity? On the other hand, what if they strongly want to change it?

The NetLogo version of the chameleon model has been built just to have the experiment running on-line in an easy way: go to the link above and hit *setup* to create the chameleons and hit *go* to run the code. We can so see the chameleons moving randomly in their space. If we tell a specific type of chameleons (i.e., the red ones, choosing R, for runner, in the *smart_red* "chooser" widget) to be conservative, adopting the mind created via the reinforcement learning technique to avoid contacts, they become capable of increasing their number, with the strategy of decreasing their movement, to remain in zones free from chameleons of other colors, and getting close to subjects with their color.

To counter-verify this interpretation, we substitute the minded moves with the simple imperative actions (i) do not move, with numberStep=0 for the red subjects, or (ii) go closer to subjects similar to you, with closeness that can be defined as near closeness or as absolute, with the switches red_close_to_red and not_too_close.

If the red chameleons do not move, they gain some advantage, although quite a limited one; also, staying close without intelligence does not give any advantage to the conservative group, which is in any case moving around for the internal interactions; the advantage arises only from absolute closeness, which leads to the by-product of immobility.

We can underline the difference between the more sophisticated reinforcement learning behavioral rules and the fixed rules machineries guiding our

---

5 It can be found at http://eco83.econ.unito.it/terna/slapp.

6 See http://www.swarm.org.

7 See http://python.org.

8 NetLogo is a significant simulation tool with an equilibrate compromise between easiness of use and power; we can find it at http://ccl.northwestern.edu/netlogo/index.shtml.

agents. We also verify that the offensive and defensive behavioral mechanisms emerging from the simulation do not correspond to simple rules *à la* Schelling[9], but come from actions based on more sophisticated rules.

In which way they learned? With self-reinforcement trial and error cycles the learning scheme generates a sequence of successful and unsuccessful choices; via a neural network mechanism, i.e. managed with the quick and powerful *nnet* function of R[10], we memorize both situations; using the accumulated experience. The sequence is represented in Fig. 1.

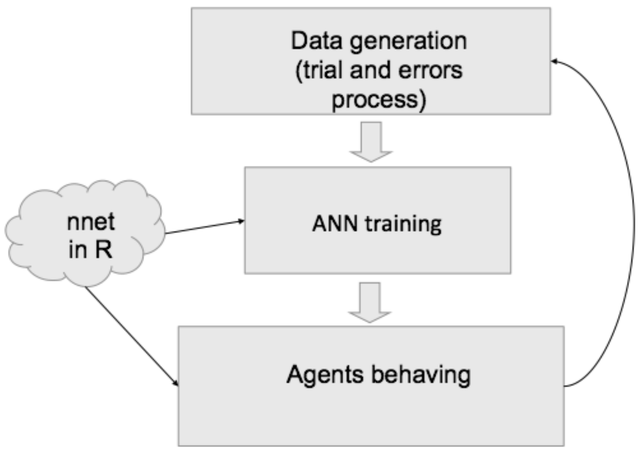

Fig. 1 – The never ending data generation process and the neural network training.

3. Background in Agent-based Models

Following Ostrom[11], and to some extent, Gilbert and Terna[12], in social science, we traditionally build models as simplified representations of reality in two ways: (i) verbal argumentation and (ii) mathematical equations, typically with statistics and econometrics. The first way (i) is absolutely flexible

[9] T. Schelling, *Micromotives and Macrobehavior*, New York, Norton, 1978.

[10] See http://www.r-project.org.

[11] T.M. Ostrom, *Computer Simulation: The Third Symbol System*, in "Journal of Experimental Social Psychology", Vol. 24, 1988, pp. 381-392.

[12] N. Gilbert, P. Terna, *How To Build and Use Agent-based Models in Social Science*, in "Mind & Society", Vol. 1, 2000, n. 1, pp. 57-72.

and adaptable, as in the case of a historical book reporting an analysis of past events, but mere descriptions and discussion, by their nature, preclude tests and verifications of hypotheses. In contrast, the second way (ii) allows for computations and verifications, but suffers from severe limitations in flexibility and adaptation, especially with respect to how agents are expected to operate in the model and when accounting for their heterogeneity and interactions.

There is a third way to build models, (iii) computer simulation, mainly if agent-based. Computer simulation can combine the extreme flexibility of a computer code where we can create agents who act, make choices, and react to the choices of other agents and to modification of their environment – and its intrinsic computability. This allows us to use the descriptive capabilities of verbal argumentation and the ability to calculate the effects of different situations and hypotheses together. From this perspective, the computer program is a form of mathematics. In addition, we can generate time series from our models and analyze them employing statistics and econometrics.

However, reality is intrinsically agent-based, not equation-based[13]. At first glance, this is a strong criticism. Why reproduce social structures in an agent-based way, following (iii), when science applies (ii) to describe, explain, and forecast reality, which is, *per se*, too complicated to be understood?

The first reply is that we can, with agent-based models and simulation, produce artifacts of actual systems and "play" with them, i.e., showing consequences of perfectly known *ex-ante* hypotheses and agent behavioral designs and interactions. Then we can apply statistics and econometrics to the outcomes of the simulation and compare the results with those obtained by applying the same tests to actual data. In this view, simulation models act as a sort of magnifying glass that may be used to understand reality in a better way.

Considering the analysis of an *agent-based simulation model* - ABM as a source of knowledge, there is another "third way view" of these kinds of tools. Referring to Axelrod and Tesfatsion[14]:

[13] For a short, but illuminating discussion of this consideration, see S. WEINBERG, *Is the Universe a Computer?*, in "The New York Review of Books", Vol. 49, 2000, n. 16, http://www.nybooks.com/articles/15762, in his review of Wolfram's book, *A New Kind of Science*.

[14] R. AXELROD, L. TESFATSION, *A Guide for Newcomers to Agent-based Modeling in the Social Sciences*, in Judd K.L., Tesfatsion L. (eds.), "Handbook of Computational Economics. Vol. 2: Agent-Based Computational Economics", Amsterdam, North-Holland, 2005, pp. 1647-1658, http://www.econ.iastate.edu/tesfatsi/GuidetoABM.pdf.

> Simulation in general, and ABM in particular, is a third way of doing science in addition to deduction and induction. Scientists use deduction to derive theorems from assumptions, and induction to find patterns in empirical data. Simulation, like deduction, starts with a set of explicit assumptions. But unlike deduction, simulation does not prove theorems with generality. Instead, simulation generates data suitable for analysis by induction. Nevertheless, unlike typical induction, the simulated data come from a rigorously specified set of assumptions regarding an actual or proposed system of interest rather than direct measurements of the real world. Consequently, simulation differs from standard deduction and induction in both its implementation and its goals. Simulation permits increased understanding of systems through controlled computational experiments.

The considerations above act in a way similar to abduction, or inference to the best explanation, where one chooses the hypotheses that, if true, give the best explanation of the actual evidence. Note that in the ABM perspective, the hypotheses are also related to the rule that determines the behavior of the agents.

4. More on Learning

Things become more and more complicated when we put learning capabilities into our artificial agents. The line of work proposed in the chameleon example is that of generating data via a trial and errors process and then to take note of the successful and unsuccessful replies to the different situations, together with the action done and the related degree of achievement or failure. How to store a huge quantity of information of this kind? In other terms, how to apply the reinforcement learning strategy in a wide sense? We are here referring to the field of machine learning, as perfectly engineered in packages like *mlpy*[15].

A sub set of this wide field of techniques is that of the artificial neural networks; specifically, feed forward ones[16]. The best application of this kind of tools is in classification, mapping an input vector to an output one. A Neural Network (NN) function contains parameters that have to be estimated, but based on which data? This is the key point, because, only if we have data, the estimation of a function like (1) is possible. x is a vector of dimension n containing information and z is a vector of dimension m containing actions. Omitting — in the notation only — the constant input needed to evaluate the

[15] See http://mlpy.sourceforge.net.

[16] C.M. Bishop, *Neural Networks for Pattern Recognition*, Oxford, Clarendon Press, 1995.

so-called bias (same role of the intercept in linear estimations), A matrix has dimension h, $n{+}m$ where h is the intermediary dimension of the function (a vectorial function of vectors) or the so-called number of hidden nodes; B has dimension k, h where k is the number of possible effects.

(1) $y = g(x,z) = f(B\ f(A\ (x',z')'))$

If $z = z_i, \ldots, z_m$ and for each case in the set, we want to evaluate a separate effect, we can also have m eq. of the (2) type, where the index i is 1,…,m, so the action is implicitly inside its related equation.

(2) $y_i = g(x,z) = f(B\ f(A\ (x))$

f is an S shaped function, such as $1/(1 + \exp(-x))$ or similar.

If we have data describing the behavior of each artificial agent, we can estimate A and B in a direct way. The evaluation of the parameter values of NNs is complicated, but technically possible.

We use both techniques close to that of non linear multiple regression or the iterated back correction (so-called back propagation of the errors). In application here, we use the *nnet* function of R prepared by prof. Ripley; the function is described in Fig. 2.

nnet {nnet}

R Documentation

Fit Neural Networks

Description

Fit single-hidden-layer neural network, possibly with skip-layer connections.

Usage

```
nnet(x, ...)
```

Optimization is done via the BFGS method of optim.

Method "BFGS" is a quasi-Newton method (also known as a variable metric algorithm), specifically that published simultaneously in 1970 by Broyden, Fletcher, Goldfarb and Shanno. This uses function values and gradients to build up a picture of the surface to be optimized.

References

Ripley, B. D. (1996) *Pattern Recognition and Neural Networks.* Cambridge.

Venables, W. N. and Ripley, B. D. (2002) *Modern Applied Statistics with S.* Fourth edition. Springer.

Fig. 2 – The nnet function in R and its characteristics.

To evaluate the parameters of the function, which are contained in A and B matrixes, we need data (observations). A rare case is that of having observed the behavior of the agents. As an example, I am building a simulation framework about the behavior of pupils of the primary school. Two young scholars of educational science followed four classes for several weeks, recording movies with a hidden camera; so, we have observations linking *ex-ante* situations and actions done, x and z, to the effects y. Consider two observed subjects, α and β: their data form two tables as in Fig. 3.

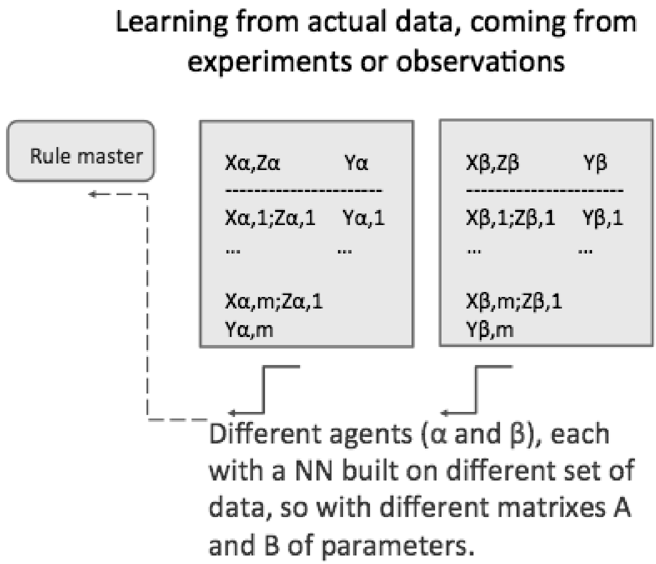

Fig. 3 – Learning from actual data (observation).

Unfortunately, using agent-based models, the commonest situation is that of the absence of observed data at the level of the agents. We have to generate them, as described in Fig. 1. Agents behave, doing actions z, different for each situation x, regardless of the upcoming results; these are evaluated by the simulation environment which we are running, taking into account the actions of each agent and all the consequent interactions.

This way of acting and learning is recapitulated in Fig. 4, where we only better display the analysis reported above. Contemporary, we explicate the way by which the agents chose: executing in each x case, the z action (or actions) giving the y that has the higher effect both in an individual U function (that we can interpret as utility function, if we prefer to reason in this way) of in some societal wellbeing evaluation. In Fig. 4, we underline that laws modify the effects y and so the actions z, while we can interpret that social norms modify U.

The use of NNs in the above construction is a generalization of the usual reinforcement learning schemes[17], where from the experience, we modify some parameter or some possible/forbidden action. With NNs we have to cope with a quite complicated tool, but the effort is paid back by the fact the NN can interpolate a never seen *ex-ante* case x among already known situations (generalization capability), and mainly it is implicitly capable of fuzzy realistic replies about the rewards y.

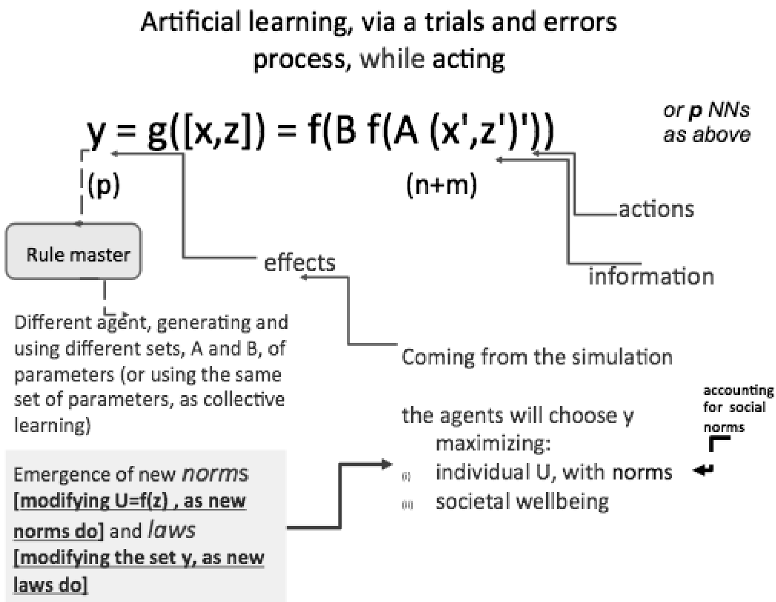

Fig. 4 – Acting, generating effects and learning.

[17] R.S. SUTTON, A.G. BARTO, *Reinforcement Learning: An Introduction*, Cambridge, MIT Press, 1998.

5. An Example of Learning and a Crucial Question

We are currently developing a SLAPP extension for learning[18], based on R function nnet, described in Fig. 2, in which agent act, with errors, and learn from their errors.

As a quick example, we start from a situation of randomly distributed agents in a space, and then we order them to try to learn, via initially random moves and after that with more and more wisely directed actions, to form groups (Fig. 5) or to stay alone (Fig. 6).

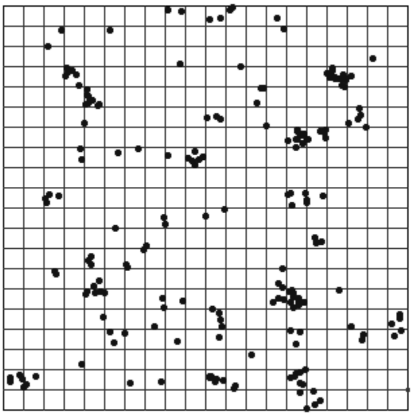

Fig. 5 – Agents forming groups

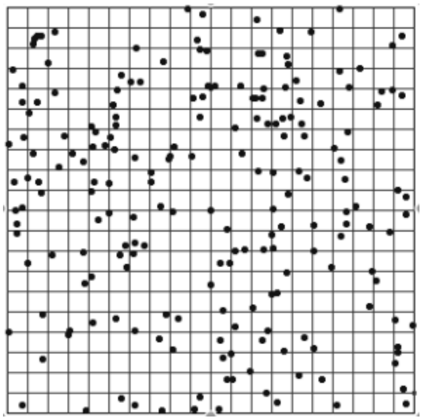

Fig. 6 – Agents staying alone

The crucial question now is: *why* they do that?

Apparently, it is an irrelevant question: they do that because we asked them to learn how to behave to accomplish that action, but we are considering a tiny problem. In a highly complex one, with different types of agents, acting in very distinctive ways, to have the capability of tracing, in our simulator, with precision the kind of behavior that the agents are following and the explanation of their choice is extremely important.

We have to add, in our model, a layer dealing with the so-called *Beliefs Desires Intentions* - BDI agent definition. In SLAPP that layer presently does not exist. We can quite easily refer to an extension of NetLogo, adding BDI

[18] Named z_learningAgents_v.?.?.zip, at http://eco83.econ.unito.it/terna/simoec12/Python_examples/ (November 2012) and in perspective to be included in SLAPP site at http://eco83.econ.unito.it/terna/slapp/.

capabilities, with a few simplifications, as a project of the University of Macedonia, in Greece[19].

This excellent tool[20] uses both the BDI scheme, focusing on Beliefs and Intentions, and a sophisticated formalism to develop messages between agents, based on the FIPA - *Foundation for Intelligent Physical Agents* specifications[21].

Is this construction a not useful added complication? At a first look, it seems to be, but if we use a model of this class, with non trivial agents doing sophisticated action, immediately we understand that we receive a significant added value by having the possibility of being formally informed, by the simulator, of why and in which way agents act. From Sakellariou and colleagues[22], we fully understand that:

> (...) Agent planning, commitment strategies, agent architectures, message passing, cooperation protocol design and evaluation, issues on functional and spatial decomposition of problems, and even team formation and disbanding can be addressed given an appropriate scenario.

We are now in the presence of a very complicated crossroad, with: (i) learning in agents as first element, to be able to understand how agents modify their behavior, (ii) BDI definition to clarify the motivation of that behavior. A very few works exist in that direction[23] and presently no one is used a generalized learning scheme as proposed here. To the cross-road we have to connect two open directions: (a) that of the micro-macro link, which is a key step in understanding the world we are immersed in; a significant reading on that is Chapter 1 "What is agent-based computational sociology all about?"

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19 See http://users.uom.gr/ ~ iliass/projects/NetLogo/.

20 I. SAKELLARIOU, P. KEFALAS, I. STAMATOPOULOU, *Enhancing NetLogo to Simulate BDI Communicating Agents*, in "Lecture Notes in Computer Science", 5138, 2008, pp. 263-275, http://users.uom.gr/ ~ iliass/projects/NetLogo/Papers/Extending_NetLogo_SETN08_SVerlag_Camera_ready.pdf.

21 See http://www.fipa.org.

22 I. SAKELLARIOU, P. KEFALAS, I. STAMATOPOULOU, *MAS Coursework Design in NetLogo*, in "Proceedings of the Educational Uses of Multi Agent Systems (EduMAS 09)", Budapest, 2009, http://users.uom.gr/ ~ iliass/projects/NetLogo/Papers/NetLogoCoursework_EDUMAS.pdf.

23 A. GUERRA-HERNÁNDEZ, G. ORTÍZ-HERNÁNDEZ, *Toward BDI Sapient Agents: Learning Intentionally*, in Mayorga R.V., Perlovsky L.I. (eds.), "Toward Artificial Sapience: Principles and Methods for Wise Systems", London, Springer, 2008, pp. 77–91, http://www.uv.mx/aguerra/documents/2008a-guerra.pdf.

in Squazzoni[24]; (b) the interaction between our agents, mainly if considered as robots (think about algorithmic robots acting in high-frequency trade in stock-markets) and the huge arena of responsibility and law[25].

The research field is huge.

6. Decisions and Actions in Policy and Law: Could Agent-based Simulation Help?

Starting from the field described hereto, the question is what is passing around in the field of policy and collective action, related to simulation and mainly agent-based one. The key idea is now that of defining policy in a participative way, with citizens, and from there to evolve laws and improve social norms in a better understood and shared approach.

Is that a dream or a research field, huger than the previous one? Let us reply with a few existing examples.

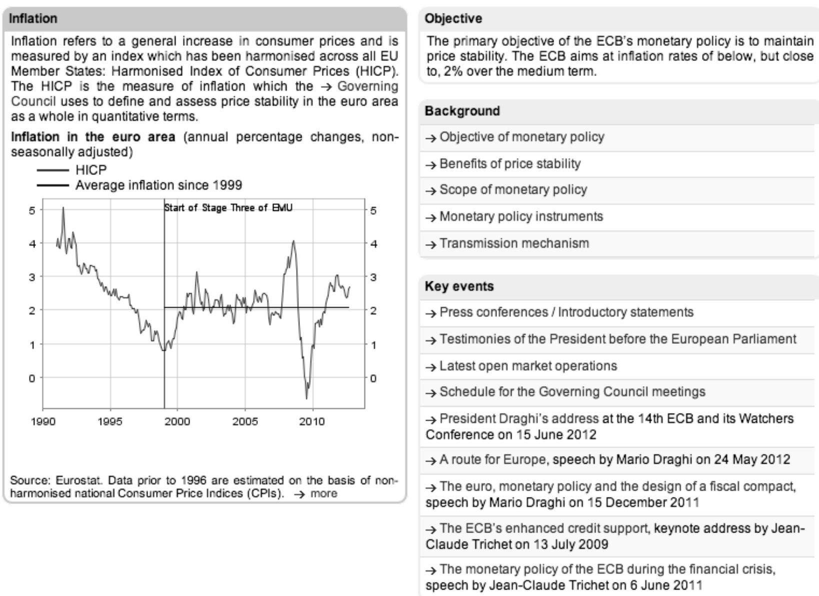

Fig. 7 – The background of the ECB game.

[24] F. Squazzoni, *Agent-based Computational Sociology*, Chichester, Wiley, 2012.

[25] U. Pagallo, *Robotica*, in Durante M., Pagallo U. (a cura di), "Manuale di informatica giuridica e diritto delle nuove tecnologie", Torino, UTET, 2012, pp. 141-158.

6.1. European Central Bank

With €CONOMIA - *The Monetary Policy Game* - we can play to be the president of the European Central Bank. From the web site[26]:

> Ever wondered what monetary policy is? Or how the key interest rate affects inflation? Play €CONOMIA and find out how it works. Your goal: Keep inflation low and stable at just under 2%. Your tool: the key interest rate.

As seen in Fig. 7, the background of the game is extremely well justified and thoughtful.

6.2. Edgeryders, Transition to the Future

Things seem to become more and more complicated in Edgeryders[27], where:

> You are riding the edge to the future, and that makes you an expert on the transition. Inspire European decision makers to take action so that your and others' journey to the future are made a little smoother and faster, and no one gets lost along the way.
>
> Edgeryders is a social game aimed at building a nurturing environment where we get help, inspire one another and make sense of it all. You may wonder what the big deal with the Reputation score is. To make a long story short, you get Rep when you participate, you play Missions, you share what you do with your friends on Facebook and Twitter, you talk to other Edgeryders and comment their posts. Everything that keeps the community healthy should give Rep.
>
> The whole idea about Rep is to make easy for newcomers and expert Edgeryders alike to connect with people who are ready, willing and able to help and play together. This is not a competition, we're all in this together.
>
> Young people everywhere (and quite a few not-so-young people, too) are busy building their lives – and, as they do so, they build our common future, piece by piece.

6.3. eGovernment Meets the eSociety

A further step, close to be tangible, at wegov (where eGovernment meets the eSociety)[28], where we read that:

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[26] See http://www.ecb.int/ecb/educational/economia/html/index.en.html.

[27] See http://edgeryders.ppa.coe.int.

[28] See http://wegov-project.eu.

> Social networking technology provides major new opportunities for policy makers (eGovernment) to engage with the community (eSociety).
>
> We will develop a toolset that allows full advantage to be taken of a wide range of existing and well established social networking sites (Facebook, Twitter, Bebo, WordPress etc.) to engage citizens in two-way dialogs as part of governance and policymaking processes. The tools will make it possible to detect, track and mine opinions and discussions on policy oriented topics.
>
> The tools will allow discussions to be seeded and stimulated through injection of policy discussion points into relevant communities in a secure and managed way. The tools will allow the origins, bias and evolution of opinions to be tracked to provide auditable records of provenance, guard against misuse, and ensure trust and privacy for all involved.

6.4. Laws in a Bottom-up Process

Finally, at http://gigaom.com/europe/online-crowdsourcing-can-now-help-build-new-laws-in-finland, we read about an actual living agent application of bottom-up true democracy:

> Who makes laws? In most of the democratic world, that's the sole preserve of elected governments. But in Finland, technology is about to make democracy significantly more direct.
>
> Earlier this year, the Finnish government enabled something called a "citizens' initiative", through which registered voters can come up with new laws – if they can get 50,000 of their fellow citizens to back them up within six months, then the Eduskunta (the Finnish Parliament) is forced to vote on the proposal.

6.5. Barabási's Considerations

Is all that a sort of science-fiction literature? Is all that only positive or contains dangerous elements? A conversation of Barabási[29] opens new perspectives, in a concrete way:

> One question that fascinated me in the last two years is, can we ever use data to control systems? Could we go as far as, not only describe and quantify and mathematically formulate and perhaps predict the behavior of a system, but could you use this knowledge to be able to control a complex system, to control a social system, to control an economic system?

[29] A.-L. BARABÁSI, *Thinking in Network Terms. A Conversation with Albert-László Barabási*, http://www.edge.org/conversation/thinking-in-network-terms, 2012.

7. A Temporary Conclusion

We are back to the crossroad presented above, and to the question if agent-based simulation could help in this perspective of policy management and law creation or norm emergence. Following the assessments introduced here, adding the network framework, in the Barabási's sense, to agents is a big significant open issue, still to be improved in spite of not being a novelty[30].

A program of future work is: the integration of learning capabilities in SLAPP; the creation of a BDI layer for SLAPP; the creation of a learning BDI version; the use of networks to connect the agents in simulation frameworks.

[30] E. Bonabeau, *Agent-based Modeling: Methods and Techniques for Simulating Human Systems*, in "Proceedings of the National Academy of Sciences of the United States of America", Vol. 99, 2002, n. 3, pp. 7280-7287.

Exploring the Effects of Sanctions on Damaging Actions through Artificial Societies: A Simulation Model

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SUMMARY: *1. Introduction – 2. The Target Phenomenon: Other-damaging Behaviours – 3. Three Mechanisms for Containing Other-damaging Behaviours – 4. A Simple Simulation Model of the State-level Mechanism for Containing Other-damaging Behaviours – 4.1. Simulation 1: Effects of Punishment – 4.2. Simulation 2: Subcommunities – 5. Summary and discussion*

1. INTRODUCTION

After the invention of electronic computers, the role played by computational techniques in social sciences (here defined in a broad sense as the complex of disciplines investigating human and social dynamics at all levels of analysis, from individual cognition to international organizations) has become more and more important. From the second half of the 20th century, social scientists have progressively learned to exploit advanced instruments of computation to gain a deeper understanding of the social world. The emerging methodological paradigm of computational social science[1], a "fledging interdisciplinary field at the intersection of the social sciences, computational science, and complexity science"[2], is gradually changing the way in which social phenomena are investigated and managed. The set of computational social science methods is wide and encompasses differents techniques: automated information extraction; social network analysis;

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1 D. LAZER *et al.*, *Computational Social Science*, in "Science", Vol. 323, 2009, n. 5915, pp. 721-723.

2 C. CIOFFI-REVILLA, *Computational Social Science*, in "Wiley Interdisciplinary Reviews: Computational Statistics", Vol. 2, 2010, n. 3, pp. 259-271; see also ID., *Scienza sociale computazionale e scienza giuridica*, in Faro S., Lettieri N., Tartaglia Polcini A. (a cura di), "Diritto e tecnologie: verso le scienze sociali computazionali. Attualità e orizzonti dell'Informatica giuridica", Napoli, ESI, pp. 205-227.

geospatial analysis; complexity modeling and social simulations models each of which has several specialized branches.

In this paper we focus on agent-based simulation models (ABM), a specific kind of social simulation[3] that can be considered, from a technical point of view, the result of a turning point in the history of artificial intelligence: the rise of Distributed Artificial Intelligence[4]. In general terms, ABM can be defined as a "computational method that enables a researcher to create, analyze, and experiment with models composed of agents that interact within an environment"[5]. Based on the identification of the scientific explanation with the reproduction *in silico* (i.e. in a computer simulation), of social processes being investigated, ABM has contributed to promote a generative approach to social science research: social macro-dynamics and structures are interpreted, described, reproduced and explained as the result of micro interactions between computational entities (agents) simulating the behaviour of real individuals[6]. In this perspective, modelling the structural properties of social systems and exploring their spatio-temporal development via computer simulation are crucial steps to provide explanations of complex social outcomes, In ABM researchers model agents as distinct parts of a computer program that may contain heterogeneous variables, parameters, and behaviour. Agents interact by exchanging information, react to the environment (programmed to mimic the real social world in more or less detail), learn, adapt, and change rules of behaviour showing cognitive and behavioural properties typical of human agents.

Epistemological consequences of agent-based modeling are relevant. ABM is establishing the primacy of modelling for social science descriptions and theorizing, in contrast with the prevalent use of narrative descriptions and un-formalized theorizing that dominate (with the exception of economics) most social science discourse[7]. Moreover ABM has strengthened an "issue-

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[3] R. CONTE, R. HEGSELMANN, P. TERNA (eds.), *Simulating Social Phenomena*, Berlin-Heidelberg, Springer, 1997.

[4] G.M.P. O'HARE, N.R. JENNINGS (eds.), *Foundations of Distributed Artificial Intelligence*, New York, John Wiley & Sons, 1996.

[5] N. GILBERT, *Agent-based Models*, London, Sage Publications, 2007.

[6] J.M. EPSTEIN, *Generative Social Science: Studies in Agent-based Computational Modeling*, Princeton, Princeton University Press, 2006; F. SQUAZZONI, *Epistemological Aspects of Computer Simulation in the Social Sciences*, Berlin-Heidelberg, Springer, 2009.

[7] R. FRANK, *The Explanatory Power of Models. Bridging the Gap between Empirical and Theoretical Research in the Social Sciences*, Dordrecht, Kluwer Academic Publishers, 2002.

oriented" style of research that is "favouring trans-disciplinary collaboration and stepping over the classic social science disciplinary boundaries"[8]. According to this approach, a growing community of social scientists investigates topics spanning from cooperation[9] to reputation[10], from the emergence of conventions[11] to the evolution of institutions[12] and the emergence of norms[13], with interesting results.

The potentials of ABM are not only limited to analytical purposes as they provide insights of social behaviours that can inform the design of policy solutions: as a matter of fact, an interesting feature of agent-based model is their capacity to support the development of innovative and policy instruments. Traditional policy models often fail their purpose being unable to grasp and forecast complex social processes including the reaction of agents to policy decisions, the aggregate effect of their interactions and their consequences on large spatial-temporal scales[14].

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[8] F. SQUAZZONI, *The Impact of Agent-based Models in the Social Sciences after 15 Years of Incursions*, in "History of Economic Ideas", Vol. 18, 2010, n. 2, pp. 197-233.

[9] R. AXELROD, *The Complexity of Cooperation. Agent-based Models of Competition and Collaboration*, Princeton, Princeton University Press, 1997.

[10] R. CONTE, M. PAOLUCCI, *Reputation in Artificial Societies: Social Beliefs for Social Order*, Dordrecht, Kluwer, 2002.

[11] G.M. HODGSON, T. KNUDSEN, *The Complex Evolution of a Simplex Traffic Convention. The Function and Implications of Habits*, in "Journal of Economic Behavior and Organization", n. 54, 2004, pp. 19-47; J. CARPENTER, *Evolutionary Models of Bargaining: Comparing Agent-based Computational and Analytical Approaches to Understanding Convention Evolution*, in "Computational Economics", Vol. 19, 2002, n. 1, pp. 25-49.

[12] C. CIOFFI-REVILLA, S. LUKE, D.C. PARKER, J.D. ROGERS, W.W. FITZUGH, W. HONEYCHURCH, B. FROHLICH, P. DE PRIEST, C. AMARTUVHIN, *Agent-based Modeling Simulation of Social Adaptation and Long-term Change in Inner Asia*, in Terano T., Sallach D. (eds.), "Advancing Social Simulation: The First World Congress in Social Simulation", Berlin, Springer Verlag, 2007.

[13] R. CONTE, C. CASTELFRANCHI, *Understanding the Functions of Norms in Social Groups through Simulation*, in Gilbert N., Conte R. (eds.), "Artificial Societies. The Computer Simulation of Social Life", London, UCL Press, 1995, pp. 252-267; M.J. EPSTEIN, *Learning to Be Thoughtless: Social Norms and Individual Competition*, in "Computational Economics", Vol. 18, 2001, pp. 9-24; R. CONTE, R. FALCONE, *ICMAS '96: Norms, Obligations, and Conventions*, in "AI Magazine", Vol. 18, 1997, n. 4, pp. 145-147.

[14] S. MOSS, *Policy Analysis from First Principles*, in "Proceedings of the National Academy of Sciences of the United States of America", Vol. 99, 2002, n. 3, pp. 7267-7274; F. SQUAZZONI, R. BOERO, *Complexity-friendly Policy Modelling*, in Ahrweiler P. (ed.), *Innovation in Complex Social Systems*, London, Routledge, 2010, pp. 290-299.

Even if belonging to the area of social sciences, legal science has substantially fallen behind in the research about agent-based models. Yet, as we will highligth below, there are various reasons for legal scientist to look at ABM: not only, in general terms, because they can contribute to illumitate social dynamics that are relevant for law but also, more specifically, because legal issues and procedures (norm making, regulatory impact analysis) are important parts of policy making ABM may support. It is therefore important to promote in legal field the design and implementation of simulation models in order to take confidence with this technique. In this prospect, the goal of this paper, is to show how agent-based simulation can be used not only to illuminate in an innovative way the basic mechanisms underlying social phenomena, but also to reflect on how society can deal with them. Even when extremely simplified, social simulations model can indeed provide ideas for designing new policies and for examining the possible consequences of these policies.

2. The Target Phenomenon: Other-damaging Behaviours

In order to show the potential of ABM, we propose a simulation model of a wide class of human behaviours that we define "other-damaging behaviours". Human beings often exhibit behaviours that damage others and societies must find ways to contain these behaviours to avoid disintegration in that the costs of living together become greater than the benefits. As noted by Hoebel[15], "social norms are mental constructs" but we prefer to avoid mental constructs and to choose a more operational approach that postulates only more directly observable entities and processes. Social norms[16], with the exception of written laws and regulations, cannot be directly observed and therefore we prefer not to use the notion of social norm. Furthermore, there is a "variety of concepts of norms"[17] and, instead of defending our own definition, we try to more directly capture with our model the empirical phenomena that the concept is intended to explain.

[15] A.E. Hoebel, *The Law of Primitive Man. A Study in Comparative Legal Dynamics*, Harvard, Athaeneum, 1954.

[16] M. Hechter, K.D. Opp (eds.), *Social Norms*, New York, Sage, 2001.

[17] M. Neumann, *Homo Socionicus: A Case Study of Simulation Models of Norms*, in "Journal of Artificial Societies and Social Simulation", Vol. 11, 2008, n. 4, http://jasss.soc.surrey.ac.uk/11/4/6.html; M. Neumann, *Norm Internalisation in Human and Artificial Intelligence*, in "Journal of Artificial Societies and Social Simulation", Vol. 13, 2010, n. 1, http://jasss.soc.surrey.ac.uk/13/1/12.html.

The concepts in terms of which we will analyse the phenomena we are talking about are “other-damaging behaviour” and “social punishment”. “Other-damaging behaviours” are behaviours that reduce the well-being of specific other individuals or of the entire community. “Social punishment” is any behaviour on the part of other individuals or of some central authority that decreases the probability that an individual will exhibit other-damaging behaviours in the future.

To better understand the importance of containing other-damaging behaviours for the continuing existence of a society, we have to consider the benefits of living socially. Many animals live socially, with frequent interactions among individuals and socially coordinated behaviours, but human beings are perhaps the most social of all animal species. They do not only constantly interact with one another and exhibit socially coordinated behaviours but, unlike nonhuman animals, they obtain most of what they need not from nature but from other individuals through exchange and they benefit from the knowledge and judgment of other individuals. In addition, human communities create a “central store” of resources, the State, to which all individuals in the community contribute and from which all individuals benefit[18]. And, finally, human beings are cultural animals, that is, they learn most of their behaviours from others, and learning from others allows them to behave in similar ways, which is important in order to be able to predict how other individuals will behave and how they will respond to one’s behaviour.

But an intense social life has its problems. Human beings may exhibit behaviours that increase the well-being of their authors but damage, i.e., decrease the well-being of either specific other individuals or the entire community. These “other-damaging” behaviours, if left unchecked, can become so frequent and diffuse that the advantages of living together may be exceeded by the disadvantages of being damaged by others, and this may put the very existence of the society into question. Therefore, for any minimally complex human society it is necessary to include mechanisms that induce its members to refrain from exhibiting behaviours that damage others.

While other-damaging behaviours exist in all human societies, these behaviours and the mechanisms for containing them vary in different societies and in different epochs. Furthermore, many different disciplines study other-damaging behaviours and the different mechanisms used by societies to

[18] D. PARISI, *What to Do with a Surplus?*, in Conte R., Hegselmann P., Terna P. (eds.), “Simulating Social Phenomena”, New York, Springer, 1997, pp. 133-151.

contain these behaviours, from psychology to anthropology, from sociology to political science, from history to legal science and criminology.

Legal scientists should especially be concerned with the dynamics discussed in this paper, at least the ones inspired by those schools of thought that are interested in the empirical aspects of legal phenomena and try to approach them with and interdisciplinary orientation, such as Legal Realism[19] and Institutionalism[20]. Legal science, on the other hand, should not be interpreted only as the exegesis of written norms or the definition and systematization of abstract legal concepts, but also as the analysis of the empirical processes which underlie legal phenomena. In this prospect agent-based models, with their ability to support the understanding of social and economic dynamics seem able to help devising more effective legal systems in that social and economic factors can increase or reduce the effectiveness of laws and regulations[21].

The idea of using computational artifacts for the investigation of socio-legal phenomena dates back to the '40s of the last century[22] and computer simulations have been described as a viable tool for legal analysis[23] and for the study of empirical phenomena linked to the functioning of legal systems and institutions[24], and, especially, in the more empirically oriented discipline

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[19] K. LLEWELLYN, *Jurisprudence. Realism in Theory and Practice*, Chicago, Chicago University Press, 1962.

[20] M. HAURIOU, *Aux sources du droit: le pouvoir, l'ordre, et la liberté*, Paris, Bloud & Gay, 1933; N. MC CORMICK, O. WEINBERGER, *An Institutional Theory of Law*, Dordrecht, D. Reidel, 1986; M. LA TORRE, *Institutionalism Old and New*, in "Ratio Juris", Vol. 6, 1993, pp. 190-201.

[21] E.A. POSNER, *Law and Social Norms*, Cambridge, Harvard University Press, 2000; B.Z. TAMANAHA, *A General Jurisprudence of Law and Society*, Oxford, Oxford University Press, 2001.

[22] L. LOEVINGER, *Jurimetrics*, in "Minnesota Law Review", Vol. 33, 1949, pp. 455-493; H.W. BAADE (ed.), *Jurimetrics*, New York, Basic Books, 1963.

[23] D.A. DEGNAN, C.M. HAAR, *Computer Simulation in Urban Legal Studies*, in "Journal of Legal Education", Vol. 23, 1970, pp. 353-365; J. DROBAK, *Computer Simulation and Gaming: An Interdisciplinary Survey with a View Toward Legal Applications*, in "Stanford Law Review", Vol. 24, 1972, n. 4, pp. 712-729; M. AIKENHEAD, R. WIDDISON, T. ALLEN, *Exploring Law through Computer Simulation*, in "International Journal of Law and Information Technology", Vol. 7, 1999, n. 3, pp. 191-217.

[24] P. VAN BAAL, *Computer Simulations of Criminal Deterrence: From Public Policy to Local Interaction to Individual Behaviour*, Den Haag, Boom Juridische Uitgevers, 2004; T. BOSSE, C. GERRITSEN, *Social Simulation and Analysis of the Dynamics of Criminal Hot Spots*, in "Journal of Artificial Societies and Social Simulation", Vol. 13, 2010, n. 2, http://jasss.soc.

of criminology. However, agent-based models still appear to be outside the cultural horizon of most legal scientists.

3. Three Mechanisms for Containing Other-damaging Behaviours

As we have said, to stay together all communities of individuals have to implement some mechanism for containing other-damaging behaviours. Very schematically we distinguish, in this paper, three such mechanisms. All three mechanisms involve some punishment of the individual that has damaged others, that is, some consequences for the individual which, by causing some kind of loss or affliction, will reduce the probability that the individual will exhibit the damaging behaviour in the future. However, the three mechanisms operate at different levels: at the State or institutional level, at the social level and at the individual level.

a) *State level*. The first mechanism for containing other-damaging behaviours is a central structure which is part of the State and which has the task to identify the behaviours that damage other individuals or the entire community and to punish these behaviours according to explicitly formulated laws and regulations. This central structure includes police, investigative bodies, and the judiciary system. The central structure relies on statements (laws and regulations) that specify the different types of other-damaging behaviours and the nature and quantity of punishment to be administered for each different type. Laws and regulations can specify behaviours that *should not be exhibited* or behaviours that *must be exhibited*, and violations of laws and regulations are punished in both cases. The central structure is implemented by specialized organizations that have the task to detect other-damaging behaviours, to classify these behaviours according to the written laws and regulations and previous similar cases, and to decide and administer the appropriate punishment. If we interpret the state as a central store of resources for the community, the existence and appropriate functioning of this central structure is one of the most important resources provided by the State to the community.

b) *Social level*. The second mechanism existing in human communities for reducing the probability of occurrence of other-damaging behaviours

surrey.ac.uk/13/2/5.html; L. Liu, J.E. Eck (eds.), *Artificial Crime Analysis Systems: Using Computer Simulations and Geographic Information Systems*, Hershey, IGI Global, 2008.

is the social circulation of information concerning the other-damaging behaviour exhibited by an individual. This socially circulated information induces other individuals to refrain from doing things which benefit the damaging individual and even from interacting with the individual, which is an important type of punishment for such highly social animals as human beings. This second mechanism is called reputation[25] and is an informal one: any individual can contribute to the reputation of any other individual.

c) *Individual level*. The third mechanism consists in the internalization of prohibitions to exhibit other-damaging behaviours which causes psychological pain if the prohibitions are violated or if one even thinks of violating them, and is therefore a form of self-punishment. This third mechanism can be part of a moral education imparted by parents, teachers, and other social authorities, or it can be part of a religious faith or, more generally, of a religious attitude towards reality.

All three mechanisms may obtain the result of limiting the occurrence of other-damaging behaviours not only as a consequence of being actually punished, or self-punished in the case of the third mechanism, but also because human beings can anticipate punishment and this is often sufficient for them to refrain from exhibiting other-damaging behaviours. Furthermore, it is also possible that punishing one individual for his/her other-damaging behaviour will decrease the probability that the other-damaging behaviour will be exhibited not only by the punished individual but by other individuals who are informed that a punishment has taken place.

A community of individuals make recourse to different degrees to the three mechanisms for containing other-damaging behaviours, but if none of them functions adequately, other-damaging behaviours will become common and this may endanger the very existence of the community.

[25] C. CASTELFRANCHI, R. CONTE, M. PAOLUCCI, *Normative Reputation and the Costs of Compliance*, in "Journal of Artificial Societies and Social Simulation", Vol. 1, 1998, n. 3, http://www.soc.surrey.ac.uk/JASSS/1/3/3.html.

4. A Simple Simulation Model of the State-level Mechanism for Containing Other-damaging Behaviours

In this paper we describe some computer simulations (realized using the agent-based modelling environment *Netlogo*[26] and accessible on line at http://goo.gl/yRQ9r) that reproduce the effects of other-damaging behaviours and how a society can try to contain them with the first of the three mechanisms we have distinguished, the mechanism of laws, regulations and sanctions which operates at the State or institutional level. The simulations are extremely simplified and abstract with respect to the actual phenomena but we hope they capture some of the basic underlying principles and can help us to think more clearly about these phenomena. Agent-based simulations should be used not only to explain existing empirical data but also to illuminate the "core dynamics" and to "discover new questions"[27]. Another important advantage of computer simulations is that they make it possible to go beyond disciplinary divisions. As we have said, other-damaging behaviours are studied by a number of distinct disciplines (the disciplines of law, sociology, psychology, etc.) and computer simulations can show how the phenomena studied by these different disciplines work together and influence each other. And, finally, agent-based simulations can be used as tools for evaluating current policies and for designing and evaluating new policies, although one must be aware of the limitations of simple and abstract simulations such as those described in this paper for policy analysis and prediction.

Our simulations are agent-based simulations[28] but our agents are very simple and have very limited interactions. More specifically, our agents are not cognitive agents in the sense that their actions are not determined by the interplay among complex cognitive constructs (i.e. BDI - *Beliefs Desires and Intentions*[29], BOID - *Beliefs, Obligations, Intentions and Desires*) but they can

[26] E. Sklar, *NetLogo, A Multi-agent Simulation Environment*, in "Artificial Life", Vol. 13, 2007, n. 3, pp. 303-311.

[27] J.M. Epstein, *Why Model?*, in "Journal of Artificial Societies and Social Simulation", Vol. 11, 2008, n. 4, http://jasss.soc.surrey.ac.uk/11/4/12.html; T. Grüne-Yanoff, P. Weirich, *Philosophy and Epistemology of Simulation: A Review*, in "Simulation and Gaming", Vol. 41, 2010, n. 1, pp. 20-50.

[28] N. Gilbert, *Agent-based Models*, cit.; J.M. Epstein, *Generative Social Science: Studies in Agent-based Computational Modeling*, cit.

[29] A.S. Rao, M.P. Georgeff, *BDI-agents: From Theory to Practice*, in "Proceedings of the 1st International Conference on Multiagent Systems - ICMAS '95", San Francisco, 1995.

only execute one of two possible actions according to the probabilities of these two actions which are associated with each agent.

Another characteristic of our simulations is that, while the goal of many agent-based simulations is to discover what emerges from the interactions among many agents, the focus of our simulations is on how agents learn to behave as they behave. We use a genetic algorithm[30] to simulate learning, where learning occurs across a succession of generations of agents rather than during an agent's life. We interpret our genetic algorithm not in biological but in cultural terms[31]. An agent is a "model" which is imitated by a greater or smaller number of imitators that add some random variation to what they learn. We describe two sets of simulations. In the first set (Simulation 1) an agent learns from its "model" at the beginning of its life and then its behaviour remains the same for the agent's entire life. In the second set of simulations (Simulation 2) an agent, in addition to imitating its "model" at the beginning of its life, may also learn by imitating the agents with which it interacts during its life.

A third characteristic of our model is that while agent-based models tend to be concerned with how cooperation and altruistic behaviour can emerge in populations of selfish individuals[32], our model is concerned with selfish behaviours that damage others – behaviours that increase the well-being of the agent and reduce the well-being of other agents – and with how societies try to contain these behaviours. Our simulations have some similarity to Gary Becker's attempt at explaining criminal behaviour in economic terms[33] but they avoid the complex theoretical apparatus of the science of economics as based on rational choice theory.

[30] M. MITCHELL, *An Introduction to Genetic Algorithms*, Cambridge, MIT Press, 1998.

[31] R. REYNOLDS, *An Introduction to Cultural Algorithms*, in "Proceedings of the 3rd Annual Conference on Evolutionary Programming", Singapore, World Scientific Publishing, 1994.

[32] R. AXELROD, *The Evolution of Cooperation*, New York, Basic Books, 1984; H. GINTIS, S. BOWLES, R.T. BOYD, E. FEHR (eds.), *Moral Sentiments and Material Interests: The Foundation of Cooperation in Economic Life*, Cambridge, MIT Press, 2006; D.B. CORNISH, R.V. CLARKE (eds.), *The Reasoning Criminal: Rational Choice Perspectives on Offending*, New York, Springer, 1986; J. HEINRICH, N. HEINRICH, *Why Humans Cooperate. A Cultural and Evolutionary Explanation*, Oxford, Oxford University Press, 2007; M. TOMASELLO, *Why We Cooperate*, Harvard-Cambridge, MIT Press, 2009.

[33] G.S. BECKER, *Crime and Punishment: An Economic Approach*, in "The Journal of Political Economy", Vol. 76, 1968, pp. 169-217; D.B. CORNISH, R.V. CLARKE (eds.), *The Reasoning Criminal: Rational Choice Perspectives on Offending*, cit.; T. HIRSCHI, *Causes of Delinquency*, Berkeley, University of California Press, 1969.

4.1. Simulation 1: Effects of Punishment

Imagine a society of 200 agents which live for a fixed length of time and are then replaced by a second generation of 200 agents, and so on for a number of generations. The agents of each generation learn how to behave from the agents of the preceding generation. Each agent can exhibit one of two possible behaviours: it can exhibit a behaviour which does not damage other agents (for brevity, “honest” behaviour) or it can exhibit a behaviour that damage another randomly selected agent (“dishonest” behaviour). Each agent has one number associated with it which describes the probability that the agent will behave dishonestly and, if an agent does not behave dishonestly, it will behave honestly. For example, if an agent has an associated number of 64, in each time cycle of its life the agent will have a 64% probability of behaving dishonestly and a 36% probability of behaving honestly. We call the agents that have a greater probability of acting dishonestly “dishonest agents” (DH agents) while we call the agents that have a greater probability to act honestly “honest agents” (H agents). A DH agent will generally act dishonestly but, since we are talking about probabilities, in some more or less rare occasions a DH agent may act honestly and an H agent dishonestly.

Each agent has associated with it a level of well-being and the agent’s level of well-being changes with the behaviours exhibited by the agent and with the behaviour of other agents. Honest behaviour increases by some quantity the level of well-being of the agent that behave honestly without changing the level of well-being of other agents. Dishonest behaviour also increases by some quantity the level of well-being of the agent that behaves dishonestly but, in addition, it decreases by the same quantity the level of well-being of another randomly selected agent. Dishonest behaviour can be punished with some probability, which means that, if punishment occurs, the level of well-being of the agent which exhibits dishonest behaviour is decreased by some quantity. These quantities and the probability of punishment for dishonest behaviour are all parameters that are varied in different simulations.

What determines the probability of honest or dishonest behaviour on the part of any particular agent? At the beginning of the simulation the number associated with each agent is chosen randomly with the only restriction that half of the agents must be honest and half dishonest (100 and 100). All agents live for the same number of cycles and in each cycle an agent exhibits either an honest or a dishonest behaviour according to the number (probability) associated with it, and its level of well-being is changed in accordance with this behaviour. At the end of their life the agents are replaced by a second generation of agents with the same total number of members as the first generation (200). The agents of the second generation learn how to behave from the agents of the first generation. Each agent of the second generation "inherits" the number associated with its "model" (probability of exhibiting dishonest behaviour) with some random variation which may either increase or decrease the number. Hence, each agent of the second generation will behave more or less in the same way as the agent of the first generation chosen as its "model" (one limitation of our simulations is that, by assuming that the individuals of one generation have the same length of life and are simultaneously replaced by the individuals of the next generation, we have not included a generational overlap in our simulations which may play an important role in learning from others).

What is crucial is that the "models" to be imitated are chosen as a function of their level of well-being, with the agents that have a higher level of well-being (as a result of their behaviour) being more likely to be chosen as "models" by the agents of the second generation. As we have already said, each generation is made of 200 agents. The best 50 agents of each generation are chosen as "models" to be imitated and each "model" is imitated by 2 agents of the next generation. (These values have been chosen arbitrarily and they can have an influence on the results of the simulations). Therefore, while the first generation of agents includes 100 honest and 100 dishonest agents, these numbers can change in the succession of generations of agents. The simulation goes on for 30 generations and at the end we determine what is the number of DH agents in the society.

Before we describe the results of our simulations we want to comment on the meaning of their parameters, that is, on the aspects of social reality that the simulation parameters try to capture (of course, in a hugely simplified way).

a) *Payoff of honest behaviour*. The parameter of the increase in one's level of well-being that can be obtained with honest behaviour (payoff of honest behaviour) refers to how much can be gained by living an honest life, i.e., how easy is to find an honest occupation and what is the level of well-being that can reached by working "honestly" (through salaries, wages, profits, buying and selling goods, etc.). In practice, we define as "honest" any behaviour that does not damage others.

b) *Payoff of dishonest behaviour*. The parameter of the increase in one's level of well-being that can be obtained with dishonest behaviour (payoff of dishonest behaviour) refers to how much can be gained from dishonest behaviour, i.e., how much one's level of well-being can be increased by engaging in behaviours that damage others.
c) *Severity of punishment*. The parameter of the quantity of punishment which is received if one behaves dishonestly refers to how severe are the written laws and the sanctions of the state. In our simulations punishment can be fair, severe, or lax, where "fair" means that, when it gets punished, a DH agent loses the same quantity of resources which it has obtained with its dishonest behaviour, while "severe" and "lax" mean that the DH agent loses twice or half, respectively, the quantity of resources obtained with its dishonest behaviour. The role of this parameter can be better understood if we add another parameter to the simulation. In addition to specifying the probability of dishonest behaviour on the part of the agent, the characteristics of an agent may also specify the amount of damage caused in another agent if the agent behaves dishonestly, with a corresponding variation in the quantity of resources obtained by the damaging agent with its dishonest behaviour. In other words, a DH agent can "decide" the amount of resources subtracted to the damaged agent, and if the agent becomes a "model" for the agents of the next generation it will teach them to reduce the well-being of the damaged agent by the same quantity (with some random variation of this quantity). If we add this new parameter to our simulations, we can study two other phenomena: what are the consequences of severity of punishment and of punishment commensurate to the gravity of "crimes", and how the variation of the other parameters influences the gravity of the "crimes" committed by DH agents.
d) *Probability of punishment*. Finally, the parameter of the probability that a dishonest behaviour is punished refers to how probable is that dishonest behaviour is discovered and punished by the state. As we have said, in real societies there may be many different factors that determine the probability that dishonest behaviours will be discovered and punished: the effectiveness of the punishing system, the nature of the crime (against specific individuals or against the entire community), the existence of organized crime, etc. All these factors are summarized by the parameter of probability of punishment.

4.1.1. The Quantity of Damage Caused by Dishonest Behaviour Is Fixed

In one first group of simulations DH agents do not decide the quantity of damage inflicted with their dishonest behaviour, and therefore the quantity of resources they obtain with this behaviour, but the value of this parameter is decided by us.

Societies tend to invest in punishing DH agents in order to contain dishonest behaviour but the level of investment can vary, and this variable investment results in different probabilities that DH agents will be punished. In our simulations we have varied the probability that DH agents are punished from 1% (very little investment: DH agents are almost never punished), to 5% (little investment: DH agents are rarely punished), 50% (somewhat more investment: DH agents are punished half of the time), and 100% (full investment: DH agents are always punished). We have examined the consequences of level of investment in punishing DH agents in three types of societies:

a) societies in which the payoff of dishonest behaviour is twice or three times as great as the payoff of honest behaviour (2 or 3 units vs. 1 unit);
b) societies in which the payoff of dishonest behaviour is the same as the payoff of honest behaviour (1 unit of additional resources gained with both honest and dishonest behaviour);
c) societies in which the payoff of dishonest behaviour is only half as great as the payoff of honest behaviour (1 unit vs. 2 units).

Another variable that we have manipulated is severity of punishment. Punishment of dishonest behaviour can be fair, i.e., identical to the damage inflicted to the other agent and therefore to the payoff for dishonest behaviour (for example, 1 unit of damage, 1 unit of punishment) or it can be severe (1 unit of damage, 2 units of punishment) or lax (1 unit of damage, half unit of punishment).

The results of the simulations show (Fig. 1) that in a society in which the payoff of dishonest behaviour is twice as great as the payoff of honest behaviour (2 units vs. 1 unit) DH agents (almost) disappear from the society only if the level of investment of the state in punishing DH agents is so high that DH agents are always punished (100% probability). Even if probability of punishment is 100% but severity of punishment is low (half the payoff for dishonest behaviour, i.e., 1 unit), at the end of the simulation DH agents are still somewhat more numerous than H agents. If the level of investment is lower so that DH agents are punished with only a probability of 50%, DH agents disappear only if punishment is severe (twice the payoff for dishonest behaviour, i.e., 4 units). If punishment is commensurate to the payoff of dishonest behaviour (2 units), DH agents continue to constitute half of society as at the beginning of the simulation. And if level of investment in punishing DH agents is even lower so that DH agents are rarely punished (probability of being punished of 5% or 1%), DH agents colonize the entire society, that is, all agents become DH agents.

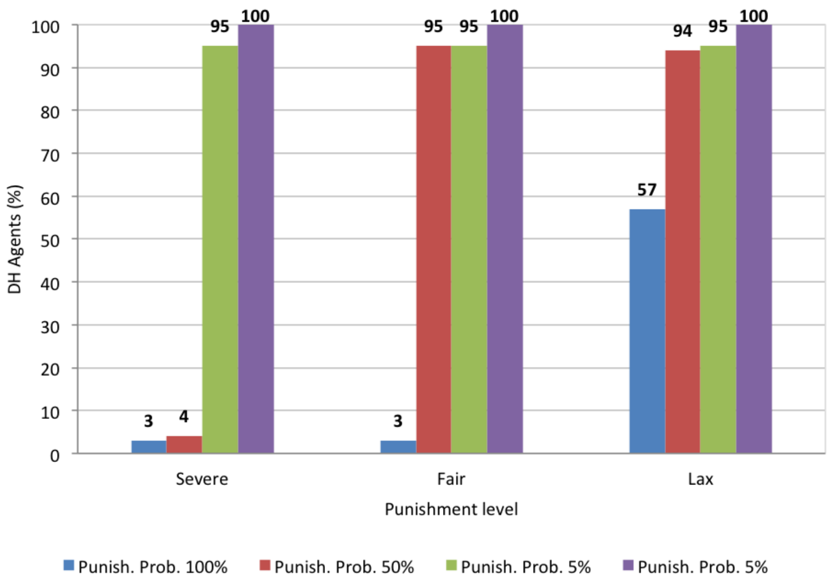

Fig. 1 – Percentage of DH agents with H payoff of 1 unit and DH payoff of 2 units

Of course, containing dishonest behaviours is even more difficult if the payoff of dishonest behaviour is three times as great as the payoff of honest behaviour. DH agents disappear only if the investment in punishing them is at maximum level (100% probability of punishing DH agents) and punishment is fair or severe, or if probability of punishing DH agents is 50% but punishment is severe. In all other types of societies, DH agents again colonize the entire society.

We now turn to societies in which the payoffs of honest and dishonest behaviours are the same (1 unit). In these societies (Fig. 2) DH agents disappear only if level of investment on the part of the society in punishing dishonest behaviour is great enough so that DH agents are punished with a probability of 100% or 50%. However, if the probability is only 5%, DH agents are almost completely eliminated only if punishment is severe (2 units), while a small minority of DH agents remain if it is fair or lax. If probability of punishment is lower (1%), this minority of DH agents is somewhat greater.

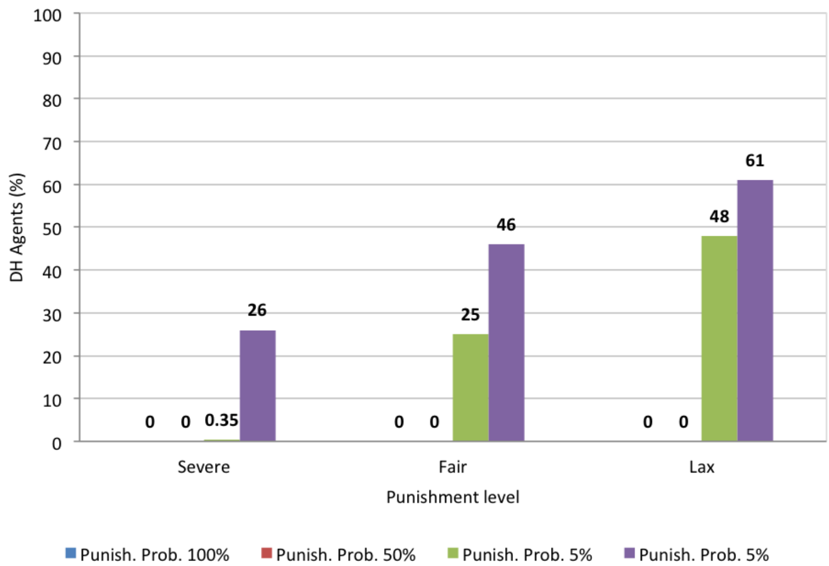

Fig. 2 – Percentage of DH agents with H payoff of 1 unit and DH payoff of 1 unit

Finally, in the third type of society in which the payoff of honest behaviour is greater than the payoff of dishonest behaviour, i.e., 2 units for honest behaviour vs. 1 unit for dishonest behaviour, DH agents are eliminated whatever the level of investment in punishing them (even with 1% probability of punishing them) and whatever the severity of punishment (even with lax punishment).

4.1.2. DH Agents Vary the Quantity of Resources They Obtain with Their Dishonest Behaviour and Therefore the Quantity of Damage Produced by Their Actions

In the simulations we have described DH agents do not decide the payoff of their dishonest behaviour but this payoff is decided by us. This is not very realistic since dishonest behaviour may vary with respect to its payoff for the DH agent and therefore to the quantity of damage caused in another agent. In a second group of simulations we have given DH agents the freedom to "choose" the seriousness of the damage caused in another agent and therefore the payoff of their dishonest behaviour (remember that in all our simulations the payoff of other-damaging behaviours is identical to the damage caused by these behaviours). We have associated to each agent another number that specifies the extent of the damage caused in another agent by the dishonest agent's behaviour. This number also is learned by the agents from their "model", with some random variation that can slightly increase or decrease its value.

Unlike the preceding simulations, in these new simulations DH agents can be different from one another in the quantity of damage inflicted to another agent with their dishonest behaviour, and therefore in their payoff, and the average quantity of damage inflicted to others with dishonest behaviour can change from one generation to the next. In the first generation all agents are assigned a number randomly selected between 1 and 10 (of course this number becomes effective only for agents behaving dishonestly).

We have run three sets of simulations by varying the payoff of honest behaviour from 1 to 2 to 5 units, and for each set we have varied the other two parameters, i.e., probability of punishment and severity of punishment, in the same way as in the simulations with a fixed payoff for DH agents.

When the payoff for honest behaviour is small, i.e., 1 unit, the results are similar to those obtained with a payoff of honest behaviour of 1 unit and a payoff of dishonest behaviour of 3 units. DH agents are eliminated from the society only when the probability of punishment for dishonest behaviour is 100% and the level of punishment is fair or severe or when probability of punishment is 50% and the level of punishment is severe (cf. the preceding simulations). This also happens if the payoff for honest behaviour is somewhat higher, that is, 2 units. On the other hand if the payoff for honest behaviour is significantly higher, i.e., 5 units, we return to the situation of the preceding simulations in which the payoff for honest behaviour was 2 units and that for dishonest behaviour was 1 unit. In all circumstances, i.e., with all probabilities of punishment and with all levels of punishment, DH agents are eliminated from the society.

If we look at the average quantity of damage inflicted to other agents by DH agents in the various simulations, we find the following.

In the simulations with 1 or 2 units of payoff for honest behaviour, when DH agents colonize the entire society the quantity of damage caused in other agents and therefore their payoff is very high. In contrast, in the simulations in which DH agents are eliminated from society (that is, when probability of punishment is 100% and level of punishment is fair or severe or when probability of punishment is 50% and level of punishment is severe), the average quantity of damage inflicted by DH agents is medium or low. When the payoff for honest behaviour is higher, i.e., 5 units, so that DH agents are eliminated from the society for all levels of probability of punishment and for all levels of punishment, DH agents tend to disappear but until they disappear they tend to commit serious crimes if probability of punishment is low and somewhat less serious crimes only if the probability of punishment is very high (100%) and the level of punishment is severe.

4.2. Simulation 2: Subcommunities

In Simulation 1 a society is a set of individuals and, when an individual damages another individual, the damaged individual is chosen randomly. But societies are not just sets of individuals. They are networks of nodes where a node is an individual and a connection between two nodes indicates that the individuals represented by the nodes interact with each other. A network has a topology that specifies who interacts with whom. The topology may not be homogeneous but there may exist sub-networks of more densely interconnected nodes which are more sparsely connected with other sub-networks. What are the consequences of this property of societies for the ability of the state to contain other-damaging behaviours?

In the simulations we have already described, the only interactions among the agents take place when an agent learns whether to behave honestly or dishonestly by imitating an agent of the preceding generation. In the new simulations, in addition to this type of learning there is a second type of learning: an agent also learns how to behave by imitating the agents with which it interacts during its life. This implies that the honesty or dishonesty of an agent may not remain identical for the entire life of the agent but it may change because of the social interactions of the agent with other agents.

There are two differences between learning by imitating an individual of the preceding generation and learning by imitating the individuals with whom one interacts during life.

The first difference is that an individual chooses the model to imitate among the individuals of the preceding generation on the basis of their well-being while the individual imitates the individuals with which it interacts during its life independently of their well-being.

The second difference is that imitation due to social interaction is reciprocal. If two agents are connected together, each agent will tend to adopt the type of behaviour, honest or dishonest, of the other agent. Notice that since societies are networks of nodes that may include more densely interconnected sub-networks, this second type of learning will take place mainly within these sub-networks of nodes.

At the beginning of the simulation the agents have an average number of randomly assigned bidirectional connections which is 1.5 in one set of simulations and 5 in another set. During an agent's 100 cycles of life an agent tends to imitate the agents with which it is connected, i.e., to become more honest if it interacts with an honest agent and more dishonest if it interacts with a dishonest agent, and therefore the agent's behaviour may change during its life. The probability that an agent will imitate another agent is 0.01 but we have also tried a smaller probability of 0.001 for a sub-set of the simulations. In all other respects the new simulations are identical to the simulations already described. An agent has a certain inherited level of well-being and this level is changed by the agent's behaviour, honest or dishonest, by the behaviour of other (dishonest) agents, and by the action of the state which, with some probability and with more or less severity, reduces the quantity of resources of the agents which act dishonestly. At the end of life each agent has a certain level of well-being and the agents with the highest level of well-being are selected as "models" by the agents of the next generation. The simulation goes on for 30 generations.

What determines the structure of the network of nodes (agents)?

As we have said, at the beginning of the simulation, the connections between pairs of nodes are randomly assigned with the constraint that the average number of connections per node has to be 1.5 or 5 in two distinct sets of simulations, and this constraint remains throughout the simulation. However, the topology of the connections changes in the successive generations of the simulation. When an agent is selected as a "model" to be imitated by two agents of the next generation, the two "imitator" agents are necessarily connected together. Hence, they will act similarly, either honestly or dishonestly, not only because they are both "imitators" of the same agent of the preceding generation but also because they imitate each other. This tends to create sub-communities (sub-networks) of agents that act in the same way.

The results of the simulations indicate that the presence of sub-communities of similar agents creates a new obstacle to the action of the state aimed at containing other-damaging behaviours.

The variables whose role we have explored in the preceding simulations still play a role in determining the percentage of dishonest agents in the society. As in the preceding simulations, this percentage increases with a decreasing probability of being punished and with a decreasing severity of punishment but the main variable that determines the percentage of dishonest agents in the society is the payoff of honest vs. dishonest behaviour.

However, in all conditions the existence of social imitation during life increases the percentage of dishonest agents, and this increase is greater when the average number of links is 5 (Fig. 3) rather than 1.5 (Fig. 4), that is, when there are more opportunities to interact with other agents.

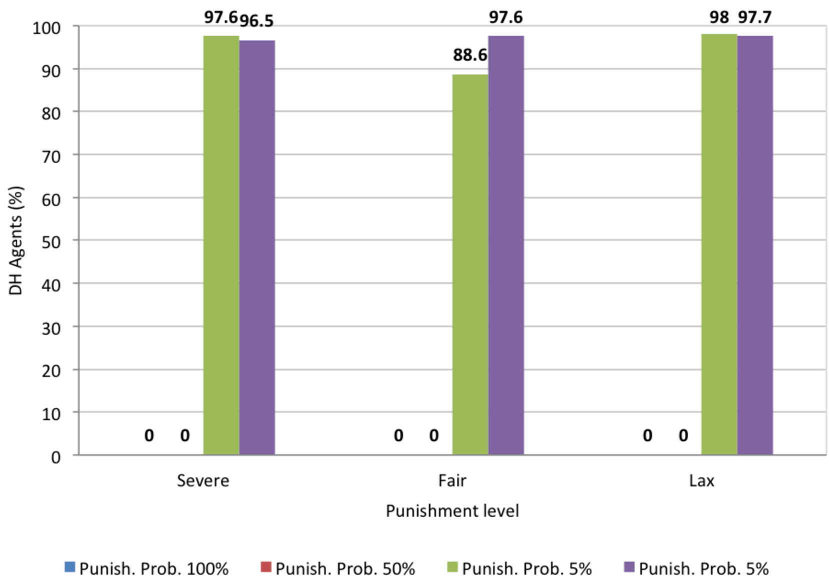

Fig. 3 – Percentage of DH agents with H payoff of 1 unit, DH payoff of 1 unit and strong social influence (average number of connections = 5)

5. Summary and discussion

In this paper we have made an attempt at analyzing some social phenomena that are usually interpreted by using the concept of social norm without using the concept. The only concepts that appear to be necessary to

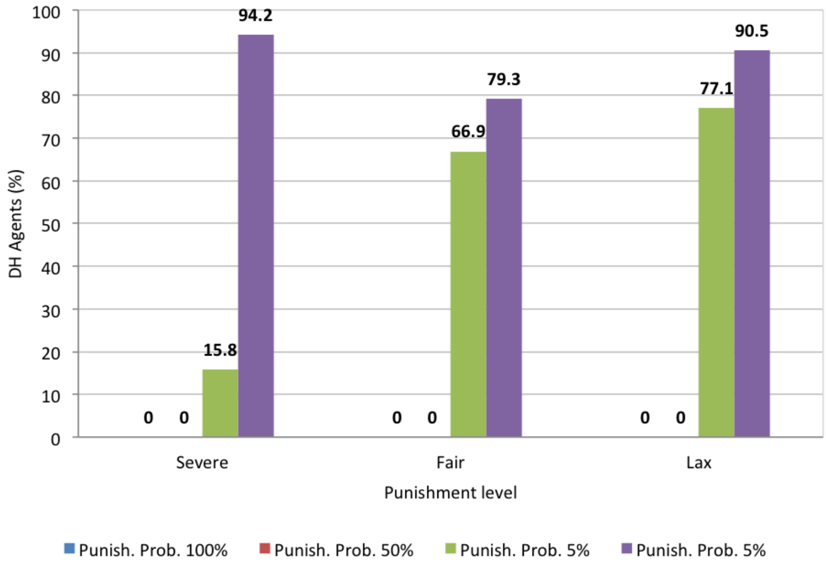

Fig. 4 – Percentage of DH agents with H payoff of 1 unit, DH payoff of 1 unit and weak social influence (average number of connections = 1.5)

analyze the phenomena are the concepts of other-damaging behaviours, i.e., behaviours that reduce the well-being of other individuals or of the entire community, and punishment, interpreted as the behaviour of an individual or a central structure which causes a reduction in the well-being of the individual who has exhibited a other-damaging behaviour and therefore makes this behaviour less probable in the future. We might define a social norm as the description of a behaviour whose exhibition or nonexhibition is socially punished but, clearly, in this case the notion of social norm would be redundant and not necessary.

Furthermore, the notion of (verbal) description, at least if we interpret it literally and not metaphorically, only applies to one of the three mechanisms that societies use to reduce the incidence of other-damaging behaviours, the mechanism of written laws and regulations which is implemented by the state.

Unless societies find ways to contain other-damaging behaviours, they risk dissolution because for the members of the society the costs of participating in the society may become greater than the benefits. Although we have identified three such ways, the formal system of law at the state level, the informal system of reputation at the social level, and the system of self-punishment at the individual level, we have addressed with our simulations only the first of these three mechanisms, the formal system of laws and regulations. In our simulations we have manipulated a number of variables and we have tried to show how these variables influence the capacity of the mechanism to contain other-damaging behaviours (we are examining the role of the second and third mechanisms for containing other-damaging behaviours in some simulations currently underway).

The results of our simulations suggest that the best policy for eliminating dishonest behaviour is not to increase the probability that dishonest behaviours will be punished or to increase the severity of punishment but to create opportunities for the members of the society to live well with honest behaviour. Only if this strategy is adopted, DH agents are almost completely eliminated from the society, independently of the probability of punishing them and of the severity of punishment. On the contrary, if the payoff of dishonest behaviour is as great as or greater than that of honest behaviour, it is possible to eliminate dishonest behaviour only if there is a very high probability of discovering and punishing dishonest behaviours. The tentative conclusion that can be drawn from our simulations is that the best strategy for containing other-damaging behaviours is for the state to invest so as to increase the payoff of nondamaging behaviours, and this conclusion is in accordance with Merton's[34] idea that individuals tend to behave criminally when the society does not provide them with the possibility to realize their aspirations by behaving honestly. However, based on empirical data whether the state should invest in "jobs or jails" remains an open question[35].

However, both investing in discovering and punishing other-damaging behaviours and investing in creating the conditions for the non-emergence of other-damaging behaviours are strategies that require the employment of significant economic resources on the part of the state. The problem here is the problem of all types of spending on the part of the state: the state may not have sufficient resources (obtained through the fiscal system) to spend so that the mechanism for discovering and punishing other-damaging behaviours may function with the required very high level of effectiveness or the average agent can get a sufficiently high payoff from honest behaviour.

[34] R.K. MERTON, *Social Theory and Social Structure*, New York, Free Press, 1949.

[35] W. SPELMAN, *Jobs or Jails?*, in "Journal of Policy Analysis and Management", Vol. 24, 2005, n. 1, pp. 133-165.

Another problem for the state is that there may exist sub-communities of interacting dishonest individuals (we define them "criminal sub-cultures") which, as shown by the results of our second set of simulations, can reduce the efficacy of the action of the state aimed at containing other-damaging behaviours. Today this problem may be more serious because while traditional criminal sub-cultures tended to be territorial, that is, they were restricted to specific geographical regions, advances in the technologies of information and communication make it possible for people to interact independently of the physical location of the interacting individuals, and this offers new opportunities for criminal sub-cultures to expand globally.

The second set of simulations shows the importance of cultural factors in determining whether an individual will behave honestly or dishonestly. This is in contrast with a view of social behaviour as based on the individual's rational choices and it is in accordance with Durkheim's idea that the characteristics of the social environment impose themselves to the individual with or without the individual's acceptance[36]. Other links can be found with the idea that the attachment of an individual to the other members of his/her group will lead the individual to behave like them, and with the differential association theory[37] according to which criminal behaviour is learnable and learned in interaction with other persons. This is also linked to various theories of social control[38].

The general conclusion that can be drawn from our simulations is that if the only mechanism for containing other-damaging behaviour is the system of legal sanctions which is implemented by the state, it is very difficult to avoid that other-damaging behaviours exist and are widespread in the society. Other-damaging behaviours can only be eliminated if the state invests enough resources to make the probability of punishment for dishonest behaviour very high or to increase the payoff of honest behaviour for the av-

[36] E. DURKHEIM, *The Rules of Sociological Method*, New York, Free Press, 1964; D. MATZA, G.M. SYKES, *Juvenile Delinquency and Subterranean Values*, in "American Sociological Review", Vol. 26, 1961, pp. 712-719.

[37] E. SUTHERLAND, *The Professional Thief*, Chicago, University of Chicago Press, 1937; ID., *Principles of Criminology*, Philadelphia, J.B. Lippincott, 1947; T. HIRSCHI, *Causes of Delinquency*, cit.

[38] E. DURKHEIM, *The Rules of Sociological Method*, cit.; R. SAMPSON, J. LAUB, *Crime in the Making: Pathways and Turning Points through Life*, Cambridge, Harvard University Press, 1993; R. SAMPSON, *How Does Community Context Matter? Social Mechanism and the Explanation of Crime Rate*, in Sampson R., Wikstrom P.H. (eds.), "The Explanation of Crime. Context, Mechanism, and Development", Cambridge, Cambridge Univ. Press, 2006.

erage citizen or in other positive ways and, as we have said, this is not very realistic for purely economic reasons. In addition, as Cesare Beccaria already observed more than two centuries ago[39] and as many recent studies have confirmed[40], our simulations suggest that the level of severity of punishment does not play a significant role as a strategy for containing other-damaging behaviour. Other factors which tend to decrease the effectiveness of the action of the state aimed at containing other-damaging behaviours are the particular difficulty of discovering and punishing behaviours that damage the entire community rather than specific individuals and the existence of criminal sub-cultures which today are greatly helped by globalisation.

The simulations described in this paper address in a very simplified form the relations among some of the variables that play a role in determining the effectiveness of the action of the state aimed at containing other-damaging behaviours. We plan to develop these simulations in order to address other phenomena such as the differences among different categories of other-damaging behaviours, and in particular between behaviours that damage specific individuals and behaviours that damage the entire community, the existence of criminal organizations, and how globalisation may affect other-damaging behaviours and their containment. If we interpret the results of the simulations as the predictions derived from the model incorporated in the simulations, these predictions should be verified with various classes of empirical data such as data on the different types of criminal behaviours and on the geographical distribution of criminal behaviours. But, as we have already mentioned, our simulations should be used not only to explain existing empirical data but also to illuminate the basic mechanisms underlying other-damaging behaviours and how society can deal with them and, notwithstanding their extreme simplicity and exploratory nature, they should provide ideas for designing new policies concerning other-damaging behaviours and for examining the possible consequences of these policies.

[39] C. BECCARIA, *On Crimes and Punishments and Other Writings*, Bellamy R. (ed.), Cambridge, Cambridge University Press, 1995 (1st ed. 1764).

[40] R.L. AKERS, C.S. SELLERS, *Criminological Theories*, Los Angeles, Roxbury, 2004.

Priorities for Backlog of Criminal Cases Pending in Courts: A Computational Agent-based Model

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SUMMARY: *1. Introduction – 2. An Analysis of the Justice System in Literature – 3. The Model Set-up – 4. The Simulation of the Model – 4.1. With a Low-productivity Function – 4.2. With a High-productivity Function – 5. Conclusions*

1. INTRODUCTION

The practice of establishing criteria of priority for reducing the backlog of trial procedures has been widespread for some time, although not always made clear. In both investigating and judging departments, the limited resources available have made organizational decisions necessary in order to answer the need to improve the justice system.

With reference to the Public Prosecutor's office, this subject has often led in Italy to animated discussions on the consistency of such criteria with the principle of compulsoriness of penal action, since the decision regarding which cases to bring before the court, whether made by those responsible for the offices or by the single Public Prosecutor, represents in any case a concession to discretionary power. Moving from the nineties, in any case, public and previous priorities stand out in investigation and prosecution, as in the US experience of *guidelines*: at first, with local ventures of chief prosecutors; later, with court sentences (see Disciplinary decision No. 105/97 of *Consiglio Superiore della Magistratura* - the Italian Council of Judiciary). In spite of mandatory prosecution the budget constraint of investigation has necessarily led to the use of guidelines connected to the seriousness of the crime and concrete injury resulting from behaviour.

Possibly less at the centre of the Italian political debate, but equally important for its consequences, is the definition of criteria of priority operated by the judging offices. Increasing the immediacy of a judicial reaction to crime constitutes an important instrument, adding to the deterrent effect and the social value of repression. A series of guidelines exists in these offices (since it is communicated to the Ministry of Justice) containing the criteria of assignment among the different sections according to the topic and a criterion

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for the internal assignment of cases among the different magistrates in each section. It is simply left to the discretion of the individual judge to organize his own order of hearings; only in certain circumstances is this shared by means of protocols established together with the Councils of the Order of Attorneys and with the legal associations.

A recent investigation carried out by Eurispes[1], in agreement with the Union of Criminal Chambers, represents the first study of an organic nature on how criminal hearings are organized, contributing to a clearer definition of the reasons why a criminal case appears to be paralyzed by bureaucracy and formalities which offer no guarantee of a high standard of efficiency. This investigation brought to light that the average duration of proceedings is 226 days, while the average time spent in court hearing is only 18 minutes for a trial celebrated before a monocratic judge (i.e., single judge) and 52 minutes for one celebrated with a panel of judges. A little over two-thirds of the cases (69.3%) each brief considered is remanded for a further hearing for physiological reasons (prosecution of the debatement inquiry, deferment for discussion, etc.) or pathological ones (logistic problems, absence of the judge, impediment of the parties, absence of a summons or failure to appear of witnesses, etc.). The average length of deferment is 139 days for trials taking place in a monocratic court and 117 days for a panel of judges. The percentage of full hearing trials celebrated in ordinary proceeding is 90.6% while 9.4% are celebrated in alternative proceeding (5.4% in abbreviated form, 4% by settlement)[2].

In the light of these data, it is easy to understand the need to introduce criteria of priority in organizing the hearing sessions. An important step in this direction was taken by the so-called "security package"[3], whose effectiveness however has never yet been tested by the competent authorities. With the explicit aim of speeding up the reply of the court system to the request for penal justice, the measure in fact establishes that in the drawing up of schedules for the hearing and debate of cases, absolute priority must be ensured for

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[1] EURISPES, *Rapporto sul processo penale in Italia*, Roma, 2008.

[2] Monitoring in the Court of Catania has revealed that the average duration of a hearing and debatement trial is only ten minutes before a monocratic judge, while with a collegiate panel of judges the time dedicated to the investigative debate is 21 minutes. In 93.9% of the cases an ordinary trial procedure is adopted, in 2,9% an abbreviated procedure and in 3.2% a settlement. Delays and postponements represent the typical outcome of hearings with average delays of 149 days for a monocratic judge and 113 days for a panel of judges.

[3] Law No. 125 of 2008, in Art. 2-*bis* regarding some modifications of the enacting, coordinating and transitory rules of the code of criminal procedure.

certain types of crime considered particularly serious and belonging to categories considered socially dangerous, as well as for those for which a term of imprisonment of not less than four years is foreseeable. The same measure assigns to the directors of the judging offices the task of adopting criteria of priority in debating procedures and in the drawing up of hearing schedules, on the basis of the concrete offensiveness of the crime. In other words, it is as if the legislator had aimed to build a social cost function for every type of crime, considering most harmful to the interest of collective society the more serious crimes (or those of a specific type) and the most recent ones. If, in fact, the social cost is connected with the threatened penalty (which constitutes the predetermination of public interest to repression) and with the length of time necessary for the procedure to be completed and the penalty carried out, the result is that a timely repression of the more serious and more recent crimes adds to the deterrent effect and reduces the social costs of crime.

This paper takes the before mentioned "security package" as a starting-point with the purpose of analyzing the effect on the reduction of cases pending and on the lower social cost deriving from the application of the different criteria of priority. Some categories of crime consistent with those included in the package are analyzed in order to simulate the management of the backlog of cases pending of a monocratic judge who finds it necessary to organize his calendar using various criteria of priority in dealing with the cases assigned to him.

The paper is organized as follows: Section 2. contains an analysis of the relevant literature and the theoretical framework of reference; in Section 3. the structure of the model is described; in Section 4. the results of the simulation are presented; Section 5. contains the conclusions.

2. An Analysis of the Justice System in Literature

Economic analysis of criminal jurisdiction, more than civil jurisdiction, has not yet moved in a widespread fashion towards evaluating the productivity of its structures. Also the data processing centres and the specific departments within the Ministry of Justice often limit their activity in this field to the collection of statistical data and the creation of generalized indicators of the quality of the services offered[4]. Similarly, in literature, a univocal

[4] Among these, the so-called *Dashboard Procedure* adopted in 2001 with which it was decided to apply to the judicial sector some quantitative modelling techniques of the back-

methodology has not been defined for assessing the efficiency of the justice systems, or for the single organizational units of which it is made up. Various techniques of economic analysis of law have been widely used to form both a theoretical and an empirical assessment of some proposals for the reform of the justice system. Attention has been focused, for example, on the length of waiting time determined by the single trial institutions in different judicial realities[5]. With reference to the penal system alone, a more systematic picture of the process is supplied by Easterbrook[6]: this author uses a marginalistic approach comparing public decisions in favour of safeguarding civil rights and liberties on the one hand and crime deterrence on the other, to define the trial as a combination of constraints and incentives in which the weight of the threatened punishment must be balanced against the private and social value of the crime committed.

A number of works on the subject of efficiency in judicial decisions have been published over the last fifteen years[7]. All these authors have aimed to define a series of indicators of assessment of the various values underlying every trial procedure.

Italian authors have focused more on exploring Court management with the aim to extend to judicial productivity some more typically economic

log of pending cases in order to assess the effects of every potential change in the organization. The *Progetto Strasburgo*, see http://www.qualitapa.gov.it/index.php?id=794&tx_wfqbe_pi1%5Buid%5d=1459, is more recent and still under development, and is coordinated for Italy by the Tribunal of Turin.

5 See W.M. LANDES, *An Economic Analysis of the Courts*, in "Journal of Law and Economics", Vol. 14, 1971, n. 1, pp. 61-107; W.M. RHODES, *The Economics of Criminal Courts: A Theoretical and Empirical Investigation*, in "The Journal of Legal Studies", Vol. 5, 1976, n. 2, pp. 311-340; R.A. BOWLES, *Economic Aspects of Legal Procedure*, in Burrows P., Velijanovski G., "The Economic Approach to Law", London, Butterworths, 1981; G.M. GROSSMAN, M.L. KATZ, *Plea Bargaining and Social Welfare*, in "The American Economic Review", Vol. 73, 1983, n. 4, pp. 749-757; R. ADELSTEIN, J.M. MICELI, *Toward a Comparative Economics of Plea Bargaining*, in "European Journal of Law and Economics", 2001, pp. 47-67.

6 F.H. EASTERBROOK, *Criminal Procedure as a Market System*, in "The Journal of Legal Studies", Vol. 12, 1983, n. 2, pp. 289-332.

7 M. KOSMA, *Measuring the Influence of Supreme Court Justices*, in "The Journal of Legal Studies", Vol. 27, 1998, p. 333; W.M. LANDES, L. LESSING, M.E. SOLIMINE, *Judicial Influence: Citation Analysis of Federal Courts of Appeals Judges*, in "The Journal of Legal Studies", 1998, n. 27, pp. 272-332; S.J. CHOI, G.M. GULATI, *Choosing the Next Supreme Court Justice: An Empirical Ranking of Judicial Performance*, in "Southern California Law Review", Vol. 3, 2004; S.A. LINDQUIST, F.B. CROSS, *Measuring Judicial Activism*, Oxford, Oxford University Press, 2009; S. GOLDBERG, *Judging for the 21st Century: A Problem-solving Approach*, Ottawa, National Judicial Institute, 2005.

criteria of evaluation[8] or on the ratio between performance of the judicial administrative system and levels of entrepreneurship[9]. Still less systematic is the study of qualitative profiles of the judicial product and its characteristics.

The political debate has also concentrated on inefficiencies reported in the judicial system, and the undesirable negative record that Italy holds for its critical sentences pronounced by the European Court of Human Rights is often linked to a supply which is under-dimensioned with respect to demand. The result of this, as for every other excess of demand, should lead to the definition of some corrective measures, to an increase in supply[10] or to a system for filtering demand[11].

In order to respond also to the growing public interest in the efficiency of jurisdiction, some legislative measures[12] have attributed to the Italian National Institute for Statistics - ISTAT, as well as the usual function of data collection, also the task of elaborating methods for measuring costs and results, based on the reconstruction of standards to be determined also on the basis of cross-section observations.

3. The Model Set-up

The model adopted simulates the desk of a criminal judge, on which are placed a number of procedures, divided according to the type of crime featured. Three distinct categories of crime are considered, distinguished on the basis of their gravity and of the maximum penalty to be expected. In relation

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[8] L. Marini, *Gli indicatori di efficacia ed efficienza nell'amministrazione della giustizia*, in "Rivista trimestrale di scienza della amministrazione", 2000, n. 2, pp. 143-168; G. Guarda, *La qualità del servizio giustizia: la "lista di controllo" realizzata dalla CEPEJ*, in "Quaderni di giustizia e organizzazione", Vol. 4, 2009, n. 5, pp. 85-111; L. Lepore, *Efficienza, efficacia ed equità nell'amministrazione della giustizia*, in "Azienda pubblica", Vol. 22, 2009, n. 3, pp. 429-448.

[9] M. Bianco, S. Giacomelli, *Efficienza della giustizia e imprenditorialità: il caso italiano*, in "Economia e politica industriale", Vol. 31, 2004, n. 124, pp. 89-111.

[10] It would be possible to increase supply by employing more resources, with a more costly spending policy. Nevertheless, this is not an obvious choice for the public decider to make: collective resources are limited, while collective needs are potentially limitless.

[11] It is theoretically not difficult to limit demand, unless this is done by means of a massive de-penalization since, in general, the levels of demand are physiological: it increases with an increase in population and with the complication of social relations. Moreover, further measures which may be considered an appreciable instrument for containing demand could be represented by instruments alternative to jurisdiction.

[12] Starting from the Legislative Decree No. 29 of 1993.

to each type of crime three groups (populations) of procedures are defined: *red* (N_r), *yellow* (N_y), and *green* (N_g), on the judge's desk, in order of severity ($r > y > g$). This system reproduces the model of a queue, and as such is defined by:

- a process of arrivals of the procedures (the mathematical model of which is known);
- an accumulation buffer, represented by the judge's desk;
- a process of service or a function of reduction of the backlog of cases pending;
- a flow of concluded procedures exiting from the system (a statistic description of which is obtained).

The diagram in Figure 1 shows the structure of the model, where the procedures N_i enter the system and are piled up on the judge's desk. He then deals with the queue following a criterion of priority (*Pr*) and generating an output flow (*S*).

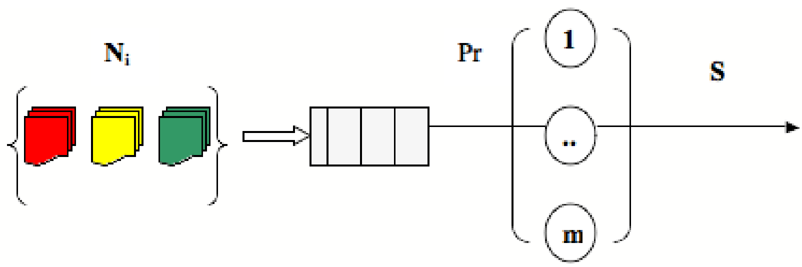

Fig. 1 – Flowchart of the model

Simplifying the operation in order to underline only the most important features of the problem analyzed, a single judge's desk (server) is shown, on which the number of new cases added is expressed by a rate (λ_i) different for each category of crime. The productivity function of reducing the backlog of cases pending is constant over time and irrespective of the type of procedure; it selects the population according to the criteria of priority adopted, and, within this group, on *FIFO* (First In, First Out) criterion. We define:

$$N_i(t) \text{ number of procedures of the } ith \text{ population in time } t.$$

$$\lambda_i(t) \text{ rate of arrival per time unit of the population } i.$$

In the simulation two functions will be used for the reduction of the backlog of proceedings per time unit (with $t = 1$ day) with high (v_h) and low

(v_l) productivity. This choice is justified by the analysis of Coviello and colleagues[13] in which it is observed that in the labour sections of the Tribunals of Milan and Turin the total duration of trials can vary between the quickest judges and the slowest ones by as much as twice the rate.

Many other factors, besides the efforts of the magistrate, are involved in determining this rate of elimination of trials, such as the number of hearings necessary to close a case, the number of cases active at the same given moment and, as we aim to prove in this study, also the criterion of priority adopted by the judge in reducing the cases pending. The functions of elimination of the backlog are therefore:

$$v_h(t) = (\frac{1}{2}n_i) \cdot t$$

$$v_l(t) = (\frac{1}{5}n_i) \cdot t$$

In a period of time $h \in [0, t]$ we will obtain $\lambda_i N_i(t)h$ new arrivals for the population N_i and $v(h)$ procedures dealt with.

So the difference in the overall number of procedures in a time interval h will be:

$$N(t+h) - N(t) = \sum_{i=r,y,g} \lambda_i N_i(t)h - v(h)$$

Dividing by the time passed h we have an overall rate of growth of all the procedures present in the system:

$$\frac{N(t+h) - N(t)}{h} = \sum_i \lambda_i N_i(t) - \upsilon$$

We assume that $\sum_i N_i(t)$ varies continually, in other words it may assume all the real values. This type of hypothesis is reasonable when the population consists of a large number of procedures. We may pass on to the limit for h which tends towards 0:

$$lim_{h \to 0} \frac{N(t+h) - N(t)}{h} = N'(t) - \upsilon = \sum_i \lambda_i N_i(t) - \upsilon$$

[13] D. Coviello, A. Ichino, N. Persico, *Giudici in affanno*, in “Annuario di diritto comparato e studi legislativi”, 2009.

Given $\epsilon = \sum_i \lambda_i$ the total rate of growth of the populations, it is possible to verify that the equation (first order linear differential) has as its solutions all the functions $N(t) = ke^{\epsilon t} - \upsilon$, for $k \in \mathbb{R}$. In particular, if the population at time t_0 consists of $N(t_0)$ individuals, its evolution with time is given by the solution:

$$N(t) = N(t_0)e^{\epsilon(t-t_0)} - \upsilon$$

If $\epsilon > \upsilon$, that is if the number of new cases arriving is higher than the number of cases dealt with, the population suffers an exponential growth. But if $\epsilon < \upsilon$, the number of procedures on the waiting list will diminish rapidly.

Finally, the model evaluates the social cost of the system, by means of a function weighting the different types of crime in relation to the sentence expected (γ) and to the time it remains in the system. The procedures of the population N_r have an expected sentence equal to γ_r, those of the population N_y have an expected sentence of γ_y and finally those of the population N_g have an expected sentence of γ_g (where $\gamma_r > \gamma_y > \gamma_g$).

The social cost function has the following form:

$$\Pi_t = \textstyle\sum_{t=0}^{\infty}(n_{it} t_i) \cdot \gamma_j$$
$$j, i \in (r, y, g)$$

4. The Simulation of the Model

The simulation was carried out on NetLogo[14] on the basis of the ISTAT data for the years 2004-2005 regarding the Tribunal of Catania. In the initial situation, the judge uses the *FIFO* criterion, that is, the cases which arrive first on his desk are dealt with first, regardless of the gravity or extension of the crime. Following the most recent legislative orientations the effects of other criteria of priority will be simulated. Applying the priority of *gravity*, the cases concerning the most serious crimes (with expected penalties of 4 or more years) will be dealt with first, while procedures for less serious offences will go to the bottom of the list. Applying that of *diffusion*, the crimes that are most widespread over the territory will be selected first. In this latter case, the judge will give priority to the procedures regarding the most widespread crimes and/or those with the highest rates of growth.

[14] The code is available from the Authors on request.

Social, economic and cultural variables, first of all, determine the composition and number of crimes committed in a given area. As well as by these variables, they are also influenced in a considerable way by the deterrent function of the entire system of repression and punishment adopted by the Authorities. In this perspective, the choice of the criterion of priority applied by the judge assumes a role that is by no means secondary. By choosing the *gravity* criterion of the crime, for example, he will speed up the procedures regarding the more serious crimes and "signal" to the (criminal) world at large that he is paying more attention to this type of crime, increasing the probabilities of reaching a sentence (and a punishment) in a short time.

Given the populations and the relative growth rates, the judge may choose the criterion of priority with which to deal with each single case. The simulation was carried out with the use of the three criteria: *FIFO*, *gravity* and *diffusion*.

Using the ISTAT data contained in Table 1 with regard to the crimes of handling stolen goods (r), fraud (y) and harm to persons or goods (g), reported to the Judicial Authorities (JA), the rate of arrival for each category of crime was estimated in the time unit and they were divided by the number of judges present in the section[15]. The model was simulated over a period of one year ($t = 365$).

	harm (g)	fraud (y)	handling (r)
2004	4122	1081	2090
2005	4833 (+17,2%)	1155 (+6,8%)	2108 (+0,8%)

Tab. 1 – Crimes reported (and % variation) to the Tribunal of Catania for which the JA has undertaken penal action [Source: ISTAT (2004-2005)].

4.1. With a Low-productivity Function

In this example the number of cases arriving on the judge's desk ($\sum \lambda_i N_i$) is higher than the number of cases dealt with, given by the function of elimination $[v_l(t) = (\frac{1}{5} n_i) \cdot t]$ resulting in a progressive accumulation on the desk

[15] Four criminal sections are present in the Tribunal of Catania, each of which consisting of six judges (excluding the president). Dividing the flow of entry of proceedings by the number of judges, we obtain the rate of growth for each crime for each judge: $\lambda_r(t) = 0.068$; $\lambda_y(t) = 0.0086$; $\lambda_g(t) = 0.172$.

of all the categories of crimes and therefore an increase in the social cost. Table 2 presents a synthesis of the percentage variations in the number of cases for each choice criterion.

	fraud	handling	harm	total	social cost
FIFO	8,9	0,7	15,2	10,6	7,4
Gravity	4,5	0,3	17,2	10,6	6,2
Diffusion	6,7	0,3	15,4	9,8	6,4

Tab. 2 – Percentage variations in the number of procedures and the social cost. Simulation with $(\sum \lambda_i N_i > v_h)$.

It may be noted that the *gravity* criterion, which obtains the smallest growth in social cost, does not prove the best in terms of the increase in backlog. In particular, if the aim is a reduction in backlog the *diffusion* criterion proves the most effective, while the *gravity* criterion is the most effective in containing social cost. The *FIFO* criterion proves the worst in terms of both increase in backlog and social cost.

The case with a low productivity function for backlog reduction is a closer reflection of the real flow situation of the judge's workload. In the Tribunal of Catania, as in the rest of Italy, the entry flow of cases is higher than the exit flow and this, added to the waiting times in dealing with cases, is the main cause of congestion and of the lengthening of the time necessary to come to judgement.

In a perspective of reform policies, therefore, it is necessary to read the results of the simulation carefully before drawing conclusions regarding the choice of a priority criterion. If the main objective were a reduction in the social cost, then the choice of the *gravity* criterion would prove the most satisfactory. But if there is also a desire to reduce the backlog of cases pending, then the assessment is a different one and the *diffusion* criterion prevails. In the light of the results which emerged from the simulation, we may conclude that the *diffusion* criterion represents the best compromise between the two objectives. By comparing the two criteria, in fact, we may observe an increase in social cost of a mere +0.2% for the *diffusion* criterion, but a reduction in the backlog of cases pending of -0.8% compared to the *gravity* criterion. In other words, the *diffusion* criterion limits the growth in social cost with better results on the overall backlog of cases pending.

4.2. With a High-productivity Function

Simulating the model with the high-productivity function $[v(t) = (\frac{1}{2}n_i) \cdot t]$, that is with a case examined every two days, the results are partly different from those obtained in the previous example. Obviously, there is an overall reduction in the backlog of cases pending ($\sum \lambda_i N_i < v_h$), for all the choice criteria applied. The results presented in Table 3, however, show that the trends of the backlog of cases pending for the different categories of crime are in some ways contradictory. In particular, we observe that the *gravity* criterion is able to reduce the backlog of fraud cases to zero and the backlog of handling cases by a large amount, but that there is an increase of16, 24% in the cases pending for harm to persons or property.

The *diffusion* criterion obtains the best results in terms of the overall reduction in backlog. Applying this criterion, it is possible to reduce to zero the procedures for harm, which represent the most voluminous backlog of cases and which have a higher growth rate than the other categories in Catania. The contradiction lies in the fact that we observe an overall reduction of -34% in spite of an increase in the backlog of procedures for fraud and handling.

Finally, the effects on the social cost confirm the results already obtained with the low-productivity function. There is a reduction in the social cost with all the criteria applied but with a clear prevalence of the *gravity* criterion, where the reduction in social cost is 67, 3%, almost double that of the *FIFO* criterion (34, 9%) and considerably higher than the *diffusion* criterion (12, 6%).

	fraud	handling	harm	total	social cost
FIFO	-37,3	-37,8	-28,1	-31,7	-34,9
Gravity	-100	-88,4	+16,24	-30,7	-67,3
Diffusion	+6,7	+0,01	-62,5	-34	-12,6

Tab. 3 – Percentage variations in the number of procedures and the social cost. Simulation with ($\sum \lambda_i N_i < v_h$).

The case with high productivity function for reducing backlog represents the ideal situation, in which there are no problems of eliminating the accumulation of cases pending and the productivity of the judge is higher than the overall volume of cases to be examined. In this situation, all the choice criteria obtain a good performance in reducing the backlog of cases pending, with a slight preference for the *diffusion* criterion, while the *gravity* criterion is preferable for reducing social costs.

5. Conclusions

The principal aim of this paper is to offer some new guidelines for dealing with cases pending, in order to render the judicial service more rapid and especially attentive to those crimes considered to have a strong social impact. Some criteria of priority are suggested, as an alternative to the *FIFO* criterion, based on the order of arrival of cases. The individual *modus operandi* of a single judge in criminal law is also analyzed, thus confirming the theory that the application of one criterion of priority instead of another leads to a variation in results, in terms of a reduction in both the backlog of cases pending and social costs.

The effects of two criteria of priority were tested: *gravity* and *diffusion*. The main considerations that may be drawn from the simulations of criteria for dealing with backlog vary according to the objective pursued. In particular, if the main objective is to reduce social costs, and therefore, to reduce delays in bringing before the court those crimes with the highest social impact, the *gravity* criterion answers this requirement most effectively, albeit with the disadvantage of an increase in the overall volume of cases pending. On the other hand, the criterion of priority based on the diffusion of the crime proves more effective in reducing the overall backlog of cases pending albeit at a higher social cost.

We argue that although the results obtained are based on data obtained from a single section of the Tribunal of Catania, they may prove useful for a more generalised debate on problems of justice in Italy. An analysis of the work of a single magistrate has been carried out in the civil field (labour section) by other authors[16] who have underlined how the organizational decisions involved in dealing with procedures – "in sequence" rather than "in parallel" – appears to favour a reduction in the backlog of cases pending by accelerating the magistrate's work. The results of the present study are closely connected with this, since it identifies the choice of the criterion of priority applied by the judge as one of the causes of the accumulation of cases pending and of the relative costs for society. It may be advisable to think twice before declaring that the problems of justice in Italy derive principally from

[16] D. Coviello, A. Ichino, N. Persico, *Giudici in affanno*, cit.

the lack of resources or from the inadequate dimensions of the law-courts. Our simulations suggest that the individual decision of the judge regarding which criterion of priority to apply in treating cases has a strong impact on the reduction in cases pending and on the social cost deriving from delays in dealing with the more serious cases.

Perspectives of the Computational Approach as a Method for Criminological Research

FABRIZIO CACCAVALE*

SUMMARY: *1. Statistics as a Consolidated Tool of Criminological Research – 2. Data Processing and Their Interpolation: The Computer Tool – 3. The New Frontiers of the Computational Method in the Criminology Domain*

1. STATISTICS AS A CONSOLIDATED TOOL OF CRIMINOLOGICAL RESEARCH

In criminological research methodology, the use of quantitative methods plays a very important role contributing to the very spirit of the subject matter. Studies with a sociological matrix on crime, already existing from the 1800s, try to explain the essence of it through the analysis of the "ultimate cause" of its manifestations, and the use of systematised data for its description becomes a significant moment in the research. In fact, "the image of criminology as a synthetic science is justified if it is understood in terms of empirical science, characterised by the inductive method and founded on observation, that is, if criminology is considered the result of a systematisation of assertions that describe observations and if we believe that criminological knowledge must be built on the basis of principles of observatism"[1].

The studies carried out by Quetelet (from Belgium) and Guerry (from France) are recognized as the first important statistical studies[2], and these became of utmost importance in the criminological domain for qualitative and quantitative knowledge of delinquency, for both verifying the interpretations of this phenomenon offered on a theoretical level and for offering measures aimed at preventing and containing its spread.

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[1] M. COCO, F. MICHELUZZI, G. PISAPIA, *Criminologia. Norme e regole*, Torino, UTET, 2003, pp. 11-12.

[2] Adolphe Quetelet and Andrè-Michel Guerry are recognised as the founders of moral statistics, embryo and founding element of criminal sociology, and promoters of the Cartographic or Geographic School who interpret the delinquency phenomenon with a statistic geographic representation of its distribution analysing the relationship existing between sociodemographic factors and fluctuations in crime indexes (*amplius*, A.J. QUETELET, *Physique sociale ou Essai sur le développement des facultés de l'homme*, Bruxelles, Hayez, 1835; A.-M. GUERRY, *Essai sur la statistique morale de la France*, Paris, Grochard, 1833).

The main source, and also the one more easily accessible, from which to obtain these data is represented by the official measurements furnished by formal and social control agencies and ordered by bodies in charge of the study of the spread of the behaviour and attitudes of the collectivity throughout the national territory[3]. However, the most important limit that weighs on research conducted by using official statistical data derives from the fact that that they are only representative of those kinds of behaviour that are known to the social control agencies. The reality, instead, is also made up of a whole series of crimes which, eluding the spotlights of the institutional system of the control of the crime, remain within the cone of shade of the unknowable and, therefore, hidden. Hidden crime, therefore, constitutes the deficit of official knowledge, and can be defined as a set of those crimes that have effectively been committed but not recorded. To overcome the limits to research deriving from this so-called "dark number" of criminality[4],

[3] In Italy, for example, the *Istituto Nazionale di Statistica* (National Institute for Statistics) which collects and processes data in the legal domain, by gathering up-to-date information on the fundamental data and flows of the demand for justice in Italy and on the capacity of the system to respond. As far as specifically criminal matters are concerned, they include: statistics of criminal activities, crime statistics, statistics of accused persons who have been convicted, statistics of criminal proceedings and statistics of criminal military proceedings.

[4] The index of dark crime, that is, the relationship between crimes effectively committed and officially recorded, varies over time and according to the type of crime and concern, above all, those which, due to their nature, can only be brought to attention through criminal charges, which if encouraged by individual factors or favourable situations (hope of recovering the stolen goods, compensation from insurance, aiding the criminal's capture, the victim's civic conscience, faith in the authorities, etc.), are often not presented for a series of reasons, for instance, fear of reprisals, of a public scandal, the code of silence, or even compassion for the criminal, justification of his/her action for ideological or religious reasons, or political solidarity towards the criminals. But not only. The size of the number of hidden crimes may also depend both on the manner in which a certain behaviour is defined as criminally significant and the ways in which this definition is applied in practice by the institutional apparatus responsible for social control. On the amount of the "dark number" and, in particular, on the variables that motivate it and condition its entity, cfr., among others, S. AMBROSET, G.V. PISAPIA, *Numero oscuro della devianza e questione criminale*, Verona, Bertani, 1980, pp. 38-39; L. RADZINOWICZ, J. KING, *La spirale del crimine. L'esperienza internazionale*, Milano, Giuffrè, 1981, pp. 46 ff.; G. FORTI, *Tra criminologia e diritto penale. Brevi note su "cifre nere" e funzione generalpreventiva della pena*, in Marinucci G., Dolcini E. (a cura di), "Diritto penale in trasformazione", Milano, Giuffrè, 1985, p. 67 ff.; N. WEINER, M.E. WOLFGANG, *Le fonti dei dati in criminologia*, in Ferracuti F. (a cura di), "Trattato di criminologia, medicina criminologica e psichiatria forense", Milano, Giuffrè, 1987, 1 (Le radici, le fonti, gli obiettivi e lo sviluppo della criminologia), pp. 125-126; S. CORRADO, *Statistica giudiziaria*, Rimini, Maggioli, 1993, p. 154.

and to better quantify the spread of the delinquency phenomenon in time or space – considering that the data officially coming from the selective action of the social control agencies are only representative of a modest part of the real numeric size of the criminality – noteworthy scientific efforts have been made: also through social science techniques, methods for detecting committed crimes, provided with greater reliability and penetration compared to traditional methods, are basically "self-report research" – that concern potential authors of deviant behaviours – and "victimisation surveys" – that look at possible victims of a crime. In *self-report studies*, whose origins go back to the end of the 1940s in the United States and spreading subsequently to many European and non-European countries, sample surveys are conducted that usually use structured self-administered and anonymous questionnaires, or else the interview system, through which certain social groups are invited to report any participation in delinquent activities and, if so, to provide information about its frequency and characteristics, as well as, possibly, the social and judicial reactions resulting from it. *Victimization surveys* became especially popular in English-language speaking countries from the second half of the 1960s and involve questionnaires given to representative samples of the population in order to identify whoever among those interviewed or their families had been a victim of crime within a specific period of time, to learn about any complaints made, to collect information about the dynamics of the act and the consequences it had.

Going into more detail into the advantages deriving from these research techniques as well as the problematic nodes they present fall outside the scope of this contribution[5]; here, it is sufficient to keep in mind that the "institu-

[5] On controversial issues regarding the methodology of self report researches, see, among others, D.S. ELLIOTT, S.S. AGETON, *Reconciling Race and Class Differences in Self-reported and Official Estimates of Delinquency*, in "American Sociological Review", 1980, n. 45, p. 95 ff.; M. HINDELANG, T. HIRSCHI, J.G. WEIS, *Measuring Delinquency*, Sage, Beverly Hills, 1981; D.P. FARRINGTON, R. LOEBER, M. STOUTHAMER-LOEBER, W.B.V. KAMMEN, L. SCHMIDT, *Self-reported Delinquency and a Combined Delinquency Seriousness Scale Based on Boys, Mothers and Teachers: Concurrent and Predictive Validity for African-Americans and Caucasians*, in "Criminology", 1996, n. 34, p. 493 ff.; D. JOLLIFFE, D.P. FARRINGTON, J.D. HAWKINS, R.F. CATALANO, K.G. HILL, R. KOSTERMAN, *Predictive, Concurrent, Prospective and Retrospective Validity of Self-reported Delinquency*, in "Criminal Behaviour and Mental Health", 2003, n. 13, p. 179 ff. In relation to victimisation surveys, see, SKOGAN W.C. (ed.), *Sample Surveys of the Victims of Crime*, Cambridge, Ballinger, 1976; R. SPARKS, *Research on Victims of Crime: Accomplishment, Issues, and New Directions*, Washington, U.S. Government Printing Office, 1982; J.G. WEIS, *Crime Statistics. Reporting Systems and Methods*, in Kadish S.H. (ed.), "Encyclopedia of Crime and Justice", New York, The Free Press, Vol. 1,

tionalistic" approach is that of those who argue that the most valid data are those collected by official institutions since crime and the criminality are only significant formulations at the time in which they are formally recognised. This is in contrast with the "realist" position which leans towards the need for an integrative supplement of official statistics rather than their institutional validation. This latter approach, in fact, is concerned with the statistical description of delinquency that is as close to reality as possible compared to the former which focuses on the use of criminal statistics as the output of agencies dealing with criminal complaints.

2. Data Processing and Their Interpolation: The Computer Tool

Initially, the computer was timidly adopted for processing, classifying and displaying numeric data; subsequently, with the development of proper software and greater computing power, it increasingly became more widespread, up to the point of profoundly and inescapably taking root in the operational modes of criminological research. However, apart from requiring advanced technical skills, software in use often necessitated exhaustive study and appropriate exercise to be effectively applied.

In particular, in the final decade of last century, I used a personal computer to store data relating to a study on authorisations to proceed in the Italian Parliament: a very large mass of knowledge and information (parties that the persons under investigation belonged to, place of their electoral college, type of crime they were accused of for which an authorisation to proceed was sought, etc.) that allowed me to describe and assess the actual qualitative and quantitative extent of the "parliamentary delinquency" phenomenon and its effective evolution, above all in the medium- and long-term. In practice, it was an investigation that acquired raw data and reprocessed to provide, apart from an initial and general classification, their organic and periodic quantisation[6].

1983; U. Gatti, M.I. Marugo, G. Fossa, V. Materazzi, *Le inchieste di vittimizzazione: problemi metodologici e primi risultati di uno studio-pilota condotto nella città di Genova*, in "Rassegna italiana di criminologia", 1991, n. 4, p. 363 ff.; M. Barbagli, *Immigrazione e criminalità in Italia*, Bologna, il Mulino, 1998.

[6] M. D'Aniello, F. Sclafani, with the collaboration of F. Caccavale, *Autorizzazioni a procedere. Analisi del fenomeno nel Parlamento italiano 1948-1991*, Napoli, ESI, 1991; F. Sclafani, M. D'Aniello, F. Caccavale, *Le autorizzazioni a procedere nel Parlamento italiano. La Camera dei Deputati*, in "Medicina legale - Quaderni camerti", 2002, p. 485 ff.

Subsequently, this type of research and analysis of criminality regarding its extent has been refined by a statistics-type analysis: dedicated software has, on the one hand, offered an ever increasing number of processing possibilities and, on the other, it has undergone a progressive process of simplification in use, that has enabled frequent and repeated use from the time the user has also been able operate without the assistance of specialised personnel. As a result, "multivariate data analysis" and "calculation of Chi-squared distribution on the significance of the correlation of factors", for example, represent terminological names, an expression of statistical techniques by now firmly acquired by scholars in criminology and which they find difficult to exclude in giving a more complete and consistent representation of the (criminal) reality they intend to investigate.

In this regard, forgive me if I once again refer to a recent study I carried out relating to Naples that was part of a wider ISRD 2 international research project (*International Comparative Self-Report Delinquency Study*) promoted and organised by the Research and Documentation Centre of the Dutch Ministry of Justice, in which numerous European countries participated. In particular, as far as Italy is concerned, given that in Italy there are marked difference in social phenomena from region to region, with high economic, social and cultural specificities, in the various geographical areas, the research was carried out in 15 cities selected on the basis of the number of inhabitants and their geographical position appertaining to the north-south axis. The statistical data was processed using the *SPSS 15.0 for Windows*, a powerful and flexible software that allowed extremely deep and wide analysis[7].

From what has already been discussed, it emerges that the use of computer tools - so far having occurred essentially for processing statistics – has taken an ancillary place compared to traditional criminological goals: the method consisted of collecting data from concrete reality through its direct observation; their interpolation and combination through the use of the computer, then, for obtaining a statistical-type logical representation of them for learning about criminality, its prevention and validating the relative interpretation theories.

[7] F. CACCAVALE, *I comportamenti devianti dei giovani nella realtà napoletana*, in Gatti U., Gualco B., Traverso S. (a cura di), "La delinquenza giovanile in Italia. I risultati di una ricerca multicentrica", Lecce, Pensa Multimedia Editore, 2011, p. 185 ff.

3. The New Frontiers of the Computational Method in the Criminology Domain

In the early 1990s, the epistemological transformation due to the spread of computational approaches gave birth to a new methodology. And if the legal sciences as a whole showed themselves to be substantially indifferent to this metamorphosis, Criminology, on the contrary, particularly in the United States, has shown a certain interest in this approach. This is due to the opportunities offered by computational social science methods to disciplinary contexts where the scholar's attention is concentrated not only on abstract rules but also on the interaction of the latter with social dynamics.

It has been the origin, therefore, of what has been defined as *computational criminology*: a hybrid mixture of criminology, computational sciences and applied mathematics, that aims at finding answers to social uneasiness and alarm deriving from the commission of criminal offences, from the least serious (but not less worrying) like crimes included in micro-criminality, to forms of crime featuring a higher level of danger, such as organised crime and international terrorism. In particular, computational criminology involves the use of the power of computer processing to identify existent and emerging models; explore crimino-genetic and crimino-precipitating factors; identify terrorist networks, organised crime and social gangs; clarify the contours of computer crime. The algorithms are developed by using various exclusively mathematical and statistical techniques, like computational topology, the hypergraph, the discovery of knowledge in databases (KDD), the social networks analysis (SNA), agent-based simulations, the dynamic analysis of information systems, and so on[8].

Amongst these, which therefore represent the new way to use the computer, in particular, one of considerable interest stands out: *agent-based social simulation*. Originating from the encounter of suggestions coming from a heterogeneous set of research sectors, the objective of agent-based simulation is to study society through computational models directed towards discovering how single individuals or groups of persons, by interacting among themselves, bring about complex social phenomena. They can be described, explained or predicted – according to this approach – by reproducing the dynamics that generate them within artificial societies simulated by the computer. *Agent-based simulations are, in fact, true virtual reconstructions that*

[8] P.L. Brantingham, *Computational Criminology*, Paper presented at the European Intelligence and Security Information Conference - EISIC (Athens, 12-14 September 2011).

permit a real phenomenon to be modelled and all the possible evolutions of it to be studied based on changes in the variables in play. Through this new model of knowledge, the most varied phenomena can, in this way, be studied: economic processes, cultural and market trends, emergence and spread of social rules; and this with a methodology that, for its intrinsic characteristics (high level of formalisation, use of computational techniques, resort to experiments), offers social sciences the advantages traditionally linked to the practice of the scientific method: theory falsifiability, inter-subjective communicability, cumulativity of results. The study of delinquency and criminal policy, in particular, has been marked by how, in order to prove the need for complementariety between the experimental and the simulation approach, the use of simulation would appear to be especially useful in all those cases where empirical research is hampered by difficulties deriving from experiments being performed in the field and it would constitute a kind of comparatively inexpensive pre-test for evaluating *ex ante* the different crime prevention programs for the purpose of suggesting any changes before effectively carrying out the empirical test[9]. And, in this regard, it should be noted that the quantitative datum used for processing statistics in the criminal domain only permits an ex post representation of the crime: the mapping described in this way gives us a photograph of delinquency rebus sic stantibus, fixed in the immobile static nature of that particular moment in history coinciding with the act of its acquisition, which can indeed serve in terms of prevention or in the unveiling of the ways in which delinquent processes unfold, but does not offer a concrete, dynamic and articulated vision of social reality and the crimes that occur in it. Agent-based computational science, with the possibility of a simulation approach - which exploits data interpolating them dynamically, together with other socio-environmental factors, in order to obtain a sort of their temporal projection also extending into the future - manages instead to make social dynamics "live", enabling an interpretation of prevention that can take advantage of the knowledge in real-time of the action-reaction links, albeit only in simulated terms between human forms of behaviours and between them and their surroundings[10].

[9] V. PUNZO, *Scelta razionale e sociologia del crimine. Un approccio critico e un modello di simulazione ad agenti*, Milano, Franco Angeli, 2012, pp. 194-195, that represents one of the early attempts in Italy to unite the sociological explanation of crime with the modelling of the behaviour of social actors.

[10] On this matter: "Like other modeling approaches, simulation modeling involves the creation of a simplified representation of a social phenomenon (...). The most familiar type

Asking the question in these terms, the agent-based computational approach presents advances of great interest to criminological science. Thus, in the United States, pioneering work that has adopted agent-based simulation dates back to 2001. Since 2004, in particular, the use of this methodology in the field of environmental crime (which can briefly be defined as the study of crime, criminality and victimisation primarily with reference to certain places, and secondly, as the way in which individuals and organizations create space for their activities, being influenced and influencing in turn that same environment). There are two basic objectives to be achieved: on the one hand, to formalise and test specific theories of deviance, complete in their abstract definition, also to highlight any conceptual gaps or to further hone them before empirical validation, and on the other, to serve as a tool for the analysis and evaluation of policies on the fight against crime and the prevention of deviant behaviour.

Some scholars believe simulation is the solution for conducting research in the social sciences domain, in addition to the more traditional verbal and mathematical/statistical representation of theories; and if the simulation and statistical models have the same ratio to better understand a social phenomenon[11],

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of model is a statistical one (e.g., a regression model) in which input data are 'run' via a statistical program and values are output that describe the relationships among the input data. In contrast, simulation models are themselves computer programs that incorporate the critical aspects of the social phenomenon being modeled. The program is run and the output data are analyzed using standard statistical techniques. Some advantages of simulation models include the ability to examine the 'entire dynamical history of the process under study' since information about the dynamics can be collected as the model runs (...). In addition, simulation allows heterogeneity among individuals that more closely approximates the variety found in everyday life and is able to accommodate the non-linear relationships present in dynamic and complex interactions" (E.R. GROFF, *Simulation for Theory Testing and Experimentation: An Example Using Routine Activity Theory and Street Robbery*, in "Journal of Quantitative Criminology" 2007, n. 23, p. 78).

[11] "The logic of developing models using computer simulation is not very different from the logic used for the more familiar statistical models. In either case, there is some phenomenon that we as researchers want to understand better. This is the 'target'. We build a model of the target through a theoretically motivated process of abstraction (this model may be a set of mathematical equations, a statistical equation, such as a regression equation, or a computer program). We then examine the behavior of the model and compare it with observations of the social world. If the output from the model and the data collected from the social world are sufficiently similar, we use this as evidence in favor of the validity of the model (or use a lack of similarity as evidence for disconfirmation)" (N. GILBERT, P. TERNA, *How to Build and Use Agent-based Models in Social Science*, Discussion Paper of 18 May 1999, http://web.econ.unito.it/terna/deposito/gil_ter.pdf, pp. 3-4).

the former presents a series of advantages compared to the latter: in the first place, the possibility of examining the entire dynamic history of the process under investigation as the information about it can be collected during the processing of the simulation itself[12]; secondly, the simulation allows for heterogeneity among simulated agents which more closely resembles the variety of real world and is able to represent non-linear relations present in dynamic and complex interactions[13]; thirdly, the simulation model can be used in situations where there is little or even no empirical data available whilst statistical models require empirical or simulated data[14]. Then, the additional advantage is that in comparison to empirical research, the simulations have a minimal cost[15].

However, the methodology in question has some limitations, the first of which is that which emerges from these kinds of research is that it is constrained by the assumptions and rules on which the model is based. Thus, agent-based models reflect the quality of the available theoretical and empirical research, data sources and the choices on the basis of which they are implemented in the model. In particular, the represented relations, data sources, the values of the parameters and decision-making rules within the model affect the observed relations within it and their results. In fact, agent-based models rest on random numbers and random numeric distributions for providing a stochastic element for the simulation. Similarly to the choice of the values of the parameters, the choice of the distribution (for example, uniform, normal, etc.) and the time of the distribution (for example, average, standard deviation, etc.) have repercussions on the results of the model. Another limitation concerns the meaning of that which emerges from an arti-

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12 "Since the model is 'solved' merely by executing it, there results an entire dynamical history of the process under study". (R. AXTELL, *Why Agents? On the Varied Motivations for Agent Computing in the Social Sciences*, Working Paper, November 2000, http://www.brook.edu/es/dynamics/papers/agents/agents.pdf, pp. 2-3).

13 J.M. EPSTEIN, R. AXTELL, *Growing Artificial Societies*, Washington, Brookings Institution Press, 1996.

14 E.R. GROFF, *'Situating' Simulation to Model Human Spatio-temporal Interactions: An Example Using Crime Events*, in "Transactions in GIS", Vol. 11, 2007, n. 4, p. 507 ff. In particular, "simulation modeling can be used in situations where little or no empirical data are available. Statistical models require data, either empirical or simulated" (p. 508).

15 E.R. GROFF, *Simulation for Theory Testing and Experimentation: An Example Using Routine Activity Theory and Street Robbery*, cit., p. 79.

ficial society: in fact, it is not an empirical test of the theory but rather the extent to which the theory is plausible[16].

Precisely it is this last statement that focuses on the crux of the whole matter, or on what the real contribution of computational simulation is to the path of criminological development in research into the mechanisms explaining delinquent behaviour. Already R. Penrose claims he is able to decree the demise of the theory that machines are able to imitate human thought and practices and in his essay *The Emperor's New Mind*[17] proposes an argument of an algorithmic nature whereby certain characteristics of human intelligence - amongst others, creativity, intuition and consciousness, or rather self-consciousness - cannot be trapped in patterns, or to be more precise, in patterns of an algorithmic nature. The answer seems to be that scholars declare that which they are effectively working at is to teach machines to solve specific problems of a cognitive nature, which if solved y humans, require some degree of intelligence. Today, in fact, it is actually possible to talk about intelligence in agent-based simulation, where everyone does not have a general picture of the environment and of the other agents, but is able to act and coordinate with neighbours, sometimes without an initial target, subsequently discovering it in collaboration with those neighbours.

If all this is true, then it is the creation of a new intelligence, that, most probably, has a different nature from human intelligence. The multidisciplinary context proposes a synthesis which is not merely the sum of disciplines, but a truly new field of study, namely, knowledge with its own ontology that, before proposing solutions to problems, gives the possibility to model them. And it is precisely at this point that agent-based modelling arose, that which can be defined as an artificial vision integrated with existing disciplines. Ultimately, today we have the ability to manipulate multidisciplinary knowledge that has its own *status quo* and is able to continue on its own two feet.

In this way, a series of research horizons are unlocked, whose borders are still now difficult to trace, that are exciting for their amplitude and for the wealth of discoveries it is possible to obtain. The risk, however, is that social simulation, with the creation of an "artificial" world that overlaps the "natural" world, complicate research, and a great deal: how far is it worthwhile devoting resources in terms of economics and intelligence, to the understanding

[16] *Ibidem*.

[17] R. PENROSE, *The Emperor's New Mind: Concerning Computers, Mind and the Laws of Phisics*, Oxford, Oxford University Press, 1989.

and interpretation of a wide range of dynamics that are and remain internal to virtual agents, that are, nevertheless, “other” than human agents?

Simulating Crime: Models, Methods, Tools

FEDERICO CECCONI*

"To me the most interesting aspect of the law and economics movement has been its aspiration to place the study of law on a scientific basis, with coherent theory, precise hypotheses deduced from theory, and empirical tests of the hypotheses ..."[1]

1. INTRODUCTION

Since the advent of computers, the natural and engineering sciences have enormously progressed. Computer simulations allow one to understand interactions of physical particles and make sense of astronomical observations, to describe many chemical properties *ab initio*, and to design energy-efficient aircrafts and safer cars. Today, the use of computational devices is pervasive. Offices, administrations, financial trading, economic exchange, the control of infrastructure networks, and a large share of our communication would not be conceivable without the use of computers anymore.

Hence, it would be very surprising, if computers could not make a contribution to a better understanding of social and economic systems. While relevant also for the statistical analysis of data and data-driven efforts to reveal patterns of human interaction, we will focus here on the prospects of computer simulation of social and economic systems by ABS - Agent-Based Simulation.

It is well-known that the ways in which social scientists analyze human behavior, social interactions, and society vary largely. The methods range from qualitative to quantitative ones, and among the quantitative ones, some communities prefer detailed models with many variables and parameters, while

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[1] R.A. POSNER, in Faure M., Van den Bergh R. (eds.), "Essays in Law and Economics", Antwerpen, Maklu, 1989.

others prefer simple or simplified models with a few variables and parameters only. Overall, each method has its justification, and the choice of the proper method very much depends on the respective purpose. For example, the elaboration of applications such as new systems designs often requires a quite realistic and, hence, detailed description of all relevant aspects. In contrast, simple models may be used to get a better understanding of how social mechanisms work. They serve to reduce the complexity of a given system to an extent that allows to guide our thinking and provide an intuition how certain changes in the system would affect its dynamics and outcome. The application of computational models is currently not common in the social and economic sciences. This is perhaps because many people consider them as intransparent and unreliable (as compared to analytical methods) and/or as unsuitable for prediction[2].

Besides, the benefit of computational models is not restricted to prediction. Joshua Epstein discusses 16 other reasons to build models, including explanation, guiding data collection, revealing dynamical analogies, discovering new questions, illuminating core uncertainties, demonstrating tradeoffs, training practitioners, and last but not least decision support, particularly in crisis situations. In fact, computer models can naturally complement classical research methods in socio-economic sciences. For example, they allow one to test whether mechanisms and theories used to explain certain observed phenomena are sufficient to understand the respective empirical evidence, or whether there are gaps or inconsistencies in the explanation. Morever, they allow one to study situations, for which analytical solutions cannot be found anymore, and to go beyond the idealizations and approximations of simple models. Without the exploration of model behaviors that can only be numerically determined, scientific analysis is often restricted to unrealistic models and to situations which may be of little relevance for reality. For example, the financial crisis may have been the result of approximations and simplifications of economic models, which were not sufficiently justified[3].

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[2] H. SIMON, *The Architecture of Complexity*, in "Proceedings of the American Philosophical Society", Vol. 106, 1962, n. 6, pp. 467-482.

[3] J.M. EPSTEIN, R. AXTELL, *Growing Artificial Societies: Social Sciences from the Bottom Up*, Cambridge, MIT Press, 1996.

An ABS is a class of computational models for simulating the actions and interactions of artificial autonomous agents[4] (both individual or collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole. ABSs simulate the simultaneous operations and interactions of multiple agents, in an attempt to re-create and predict the appearance of complex phenomena. The process is one of emergence from the lower (micro) level of systems to a higher (macro) level. A central tenet is that the whole is greater than the sum of the parts. Individual agents are typically characterized as boundedly rational, presumed to be acting in what they perceive as their own interests, such as reproduction, economic benefit, or social status, using heuristics or simple decision-making rules. ABS agents may experience "learning", adaptation and reproduction. Most agent-based simulations are composed of:

1. numerous agents specified at various scales (typically referred to as agent-granularity);
2. decision-making heuristics;
3. learning rules or adaptive processes;
4. an interaction topology; and
5. a non-agent environment[5].

2. ABM - Agent-based Modeling and Crime

In recent years, there has been a growing interest on theoretical, methodological and empirical work to develop analytical and computational models of crime pattern formation. Computational crime models forms a key feature of current approaches to understanding offender behavior and is a tool used increasingly by police departments and policy makers for strategic crime prevention, to guess new policy to prevent crime, to tackle organized crime. However, despite the availability of sophisticated digital mapping and

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[4] With *artificial autonomous agent* we refer to procedures that *runs* into a computer. It is not necessary that the agents are physical agents that move in environment (robots).

[5] R. Axelrod, *The Complexity of Cooperation: Agent-based Models of Competition and Collaborations*, Princeton, Princeton University Press, 1997; R. Axelrod, L. Tesfatsion, *A Guide for Newcomers to Agent-based Modeling in the Social Science*, in Judd K., Tesfatsion L. (eds.), "Handbook of Computational Economics", Amsterdam, Elsevier/North Holland, Vol. 2, 2005; M. Wooldridge, *An Introduction to Multiagent Systems*, New York, John Wiley & Sons, 2002.

analysis tools (see Fig. 1[6]) there is a substantial gap in our understanding of how low-level behaviors of offenders lead to aggregate crime patterns such as crime hot spots. Thus, for example, we are unable to specify exactly why directed police action at crime hot spots sometimes leads to displacement of crime in space but, surprisingly, often can also lead to hot spot dissipation and a real reduction in crime incidences. ABM offers a potential avenue for developing a quantitative understanding of crime hot spot formation built from the bottom-up around offender behavior. Agent-based models are not only more consistent with the scale of decisions that offenders actually take, but they also open the door to the development of custom statistics that are designed to answer specific behavioral questions less tractable in general statistical models. However, there is also concern that agent-based simulations can lead to erroneous results either because of poor model design or errors in model implementation that go undetected. A solution to this problem is to design simulations around well-studied analytical models where the model behavior can be tested against sound analytical expectations. Only following such testing should simulation models be extended into areas that cannot be treated analytically and, only subsequent to this, into applied contexts.

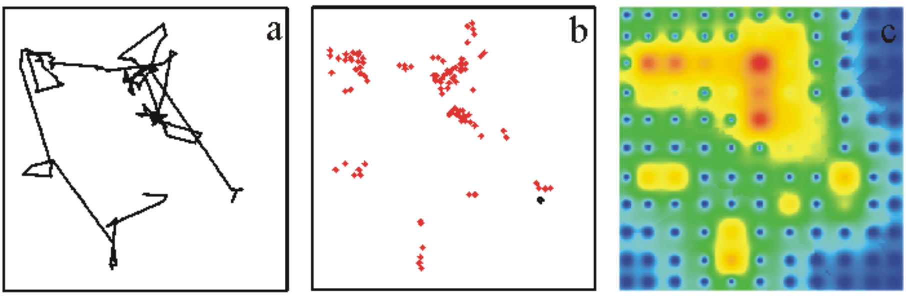

Fig. 1 – Simulated offender movement and abstract mapping of crime locations

The possibilities are many: you could study relationships between criminal behavior, criminal opportunities and policing and may provide insight into how to design better crime prevention strategies, contributing to a broader

[6] In this Figure the following phenomena are represented: (a) Simulated offender following a Lévy mobility strategy. Lévy mobility shows clusters of short distance flights interspersed with longer distance flights. (b) Mapped crime locations assuming that criminal opportunities are uniformly distributed in space and that offenses occur only at the end points of Lévy flights. (c) Inverse distance weighted interpolation of offense locations showing crime hot spots generated by the underlying Lévy mobility strategy.

dialog on homeland security. Simultaneous development of mathematical and simulation models, as well as continuous empirical testing, will provide a guide for the experimental use of these tools in the social sciences, while the broad interdisciplinary foundation of the project will provide a model for collaboration between mathematicians and social scientists. The educational component will provide an excellent venue for developing the research careers of students and postdoctoral associates at all levels.

3. Simulating Crime: Methods

The basis of the ABM applied to criminal study is the assumption that people involved with the legal system act as rational maximizers of their utility. Since most of the time the choice of the individuals involves uncertainty – the result of a crime is not given as certain beforehand – the relevant economic theory analyzes the decision making in uncertain conditions[7]. Assuming rationality in economics studies or when it is applied to crime, only means that people act on purpose in the search of objectives individually chosen; it means, more specifically, that people prefer more to less, of the things they desire. Economists use the framework of rationality as a description of human behavior, and as a way of identifying the foreseeable reaction of the average individual that composes the group. The *key* for the method is all in the next statement, i.e.

> ...I can draw the criminal activity as the interaction of individual activities, which can individually describe, and the interaction of these with an environment. We are talking about ARTIFICIAL agents (i.e. described by procedures into a computer) and ARTIFICIAL environments (that are described by other procedures).

Sometimes, the rational individual (agent) contrasts with the reasonable individual in what refers to the tradition of legal theory – an individual, who is socialized in the norms and conventions of a community, and whose behavior corresponds to these norms. Laws, as a consequence, should reflect

[7] I. Ehrlich, *Crime, Punishment and the Market for Offenses*, in "The Journal of Economic Perspectives", Vol. 10, 1996, n. 1, pp. 43-67; G. Fiorentini, S. Peltzman (eds.), *The Economics of Organised Crime*, Centre for Economic Policy Research, Cambridge University Press, 1997; P.W. Kingston, R. Hubbard, B. Lapp, P. Schroeder, J. Wilson, *Why Education Matters*, in "Sociology of Education", Vol. 76, 2003, n. 1, pp. 53-70; A.M. Law, W.D. Kelton, *Simulation Modeling and Analysis*, New York, McGraw-Hill, 1982.

these norms and conventions and therefore, be obeyed by reasonable individuals. In this way, those who engage in illegal activities (theft, kidnapping, murder, etc.) are seen as having a deviate behavior in the sense that they have violated or broken those norms and conventions. This approach poses problems in terms of computational modeling. An ABM admits that individuals are capable of criminal activity through social interaction. Such models facilitate deeper analysis regarding the differentials of criminality indexes among regions. In the next Section we will deal with this question. This particular remark is also addressed within the context of the architecture of the agent-based model and how the rules of individual behavior are conceived in order to design an artificial society.

Now we can give a more formal definition of an ABM:

> ...In agent-based modeling (ABM), a system is modeled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules. Agents may execute various behaviors appropriate for the system they represent – for example, producing, consuming, or selling. Repetitive competitive interactions between agents are a feature of agent-based modeling, which relies on the power of computers to explore dynamics out of the reach of pure mathematical methods. At the simplest level, an agent-based model consists of a system of agents and the relationships between them. Even a simple agent-based model can exhibit complex behavior patterns and provide valuable information about the dynamics of the real-world system that it emulates. In addition, agents may be capable of evolving, allowing unanticipated behaviors to emerge. Sophisticated ABM sometimes incorporates neural networks, evolutionary algorithms, or other learning techniques to allow realistic learning and adaptation[8].

3.1. An Example

We could try to make these arguments more solid. We take such a model of Berger and colleagues[9]. The model seeks to establish dynamically the relationship between micro and macroeconomic variables. Each singular behavior of any agent within the environmental framework subject to analysis will have an associated cost of transaction. Agents' interaction alters ran-

[8] Citation from E. BONABEAU, *Agent-based Modeling: Methods and Techniques for Simulating Human Systems*, in "Proceedings of the National Academy of Sciences of the United States of America", Vol. 99, 2002, n. 3.

[9] L.M. BERGER, D. BORENSTEIN, G. BALBINOTTO NETO, *The Agent Based Model Applied to Crime: Theory and Evidence*, 2011, in "Economic Analysis of Law Review", Vol. 1, 2011, n. 1, pp. 140-152.

domly their conditions during simulation process and, therefore, the overall macroeconomic performance.

The basic strategy used by agents when engaging (or not) in criminal activity within a given context is Becker's formulae[10] which states formally:

$g > p(f + \lambda t)$

Where:

g = gain a party obtains by engaging in harm-creating activity;

p = probability of detection;

f = fine;

t = length of the imprisonment term;

λ = disutility borne by a prisoner per unit of the imprisonment term.

The model is built upon three agents (or set of agents) that dynamically and randomly interact with each other and with the environment, simulating, as close as possible, real criminal events. The model is conceived as follows:

- *Citizen Agent*. This agent represents some probable perpetrator. It must be stressed that the model does not assume prior criminal condition from the agent. That condition will be given by the simulation process and depends upon the probability distributions more suitable for the case. Therefore, the engagement in criminal activity is a decision the agent takes during the simulation process, depending upon the particular conditions regarding the crime committed, whereas it may be an assault, battery, rape, manslaughter, murder and so forth. The incoming data that feed the simulator parameters is modeled for each particular case, or criminal act.
- *Opportunity Agent*. This agent represents the specific target of criminal activity that is protected by law over which the citizen agent might be interested in. This agent models the specific right, protected by law, subject to simulation. In this study, the agent is represented by vehicles once it intends to model car theft. In this particularly case, the opportunity agent is *a property belonging to another*, according, for instance, to the British law regarding the subject.
- *State Agent*. Represents the Public authority in charge to address enforcement of criminal legal rules. The initiatives or actions taken by state agents may be not just criminal fighting through police means,

[10] G. BECKER, *Crime and Punishment: An Economic Approach*, in "Journal of Political Economy", Vol. 76, 1968, n. 2, pp. 169-217.

but interventions in many social circles that may have intense effect on criminal rates. The agents' interactions regarding the enforcement of law can be seen in the way the citizen agent and the opportunity agent are connected.

3.2. *One Result*

The authors have not yet begun to exploit the potential of their model (I have chosen to quote this for the clarity with which the agents are defined...). Anyway, we can test the correctness of the code by this simple analysis. In Fig. 2, the x-axis gives the probability of detection (and punishment) p. The y-axis gives the crime rates obtained with the simulation experiments. In accordance to Becker's equation, as increases p, crime rates decrease proportionally, making the results consistent with Becker's framework. Also, as the experiments were performed for agents with different income levels, the simulation tests show a proportional decrease in crime rates as agents' marginal income increases, as theoretically expected.

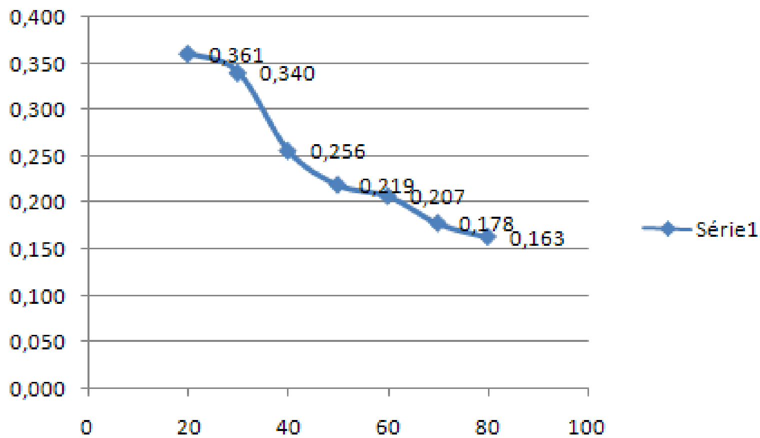

Fig. 2 – One (obvious) results coming from ABM model. Increasing punish, the crime rates decrease

The simulator-operating console with typical NetLogo (see next Section) features is shown in Fig. 3, which allow performing various kinds of experiments, particularly, simultaneous interaction among microeconomic variables and the macroeconomic outcome. All along the simulation process, the probability functions used to generate random entry data can be fully controlled.

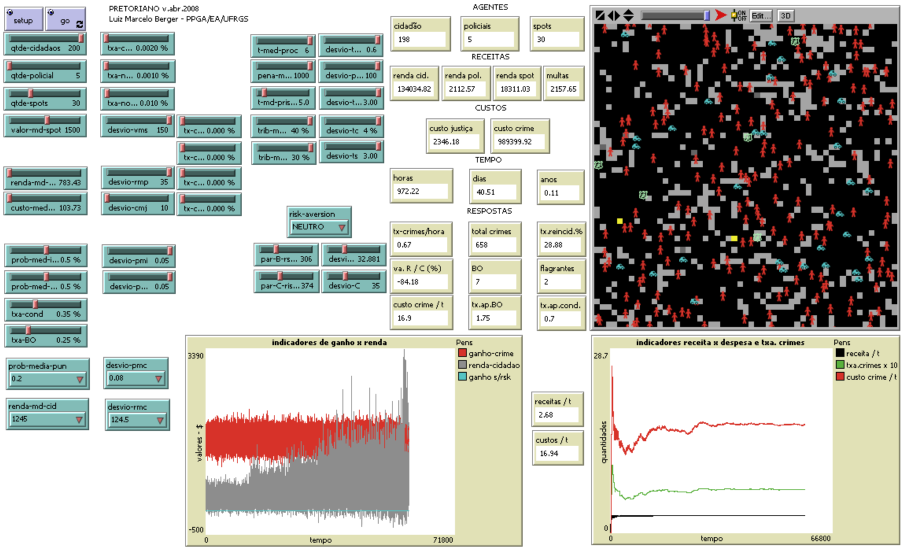

Fig. 3 – The simulation interface

4. Tools

Here is the sketch description of three of the most popular agent-based modeling simulation environments. Except for NetLogo, you need to know Java programming language to write a simulation. Java is a programming language based on objects, that is currently most widespread and general used. This fact gives to NetLogo, rather than the other two environments, an incomparable immediacy of use. So as to make possible the creation of ABM in teams without a specific informatics skills[11].

- MASON is a fast discrete-event multiagent simulation library core in Java, designed to be the foundation for large custom-purpose Java sim-

[11] U. Wilensky, *Center for Connected Learning and Computer-based Modeling*, Evanston, Northwestern University, 1999, http://ccl.northwestern.edu/netlogo/; P. Winotto, *An Agent-based Simulation on the Market for Offenses*, AAAI Technical Report WS-02-10, 2002; W.B. Arthur, *Out-of Equilibrium Economics and Agent-based Modeling*, in Judd K., Tesfatsion L. (eds.), “Handbook of Computational Economics”, Amsterdam, Elsevier/North Holland, Vol. 2, 2005.

ulations. MASON is a single-process discrete-event simulation core and visualization library aimed at multiagent simulations with large numbers of agents. The system is written in pure Java and is intended for experienced Java coders who want something general and easily hackable to start with, rather than a domain-specific simulation environment. Some features:

- Simulations can be serialized to checkpoints (freeze-dried and written to disk), which can be recovered from at any time, even to different Java platforms and new MASON visualization toolkits.
- MASON can be set up to be guaranteed duplicatable, meaning that the same simulation parameters will produce the same results regardless of platform.
- Libraries are provided for visualizing in 2D and in 3D (using Java3D), to manipulate the model graphically, to take screenshots, and to generate movies (using Java Media Framework).
- While the visualization toolkits are fairly large, the core simulation model is intentionally very small, fast, and easy to understand.

- NetLogo. A cross-platform multi-agent programmable modeling environment. NetLogo (release 5.0), is a flexible programming suite to design, simulate, and study agent-based models. The main data structures of NetLogo is the same of the other language (unidimensional vectors, lists, arrays, and tables); it is possible to declare, to initialize, and to manipulate them by creating user-defined procedures and functions; NetLogo has main control structures (branching points and loops). The main feature of Netlogo is the agent-oriented side: it is possible to create Netlogo autonomous entity (patches, turtles, and links) and to invoke them by using "agentsets".
- Repast. Repast Simphony 2.0, released on 5 March 2012, is a tightly integrated, richly interactive, cross platform Java-based modeling system that runs under Microsoft Windows, Apple Mac OS X, and Linux. It supports the development of extremely flexible models of interacting agents for use on workstations and small computing clusters. Repast Simphony models can be developed in several different forms including the ReLogo dialect of Logo, point-and-click flowcharts, Groovy, or Java, all of which can be fluidly interleaved. NetLogo models can also be imported.

5. Conclusions

Agent-based modeling is potentially a very powerful tool for crime study[12]:

- it increases the empirical understanding of how society works and help to exploit the emergence of regularities;
- it increases the normative understanding, since the computing models can help design good norms and mechanisms for many kinds of criminal behavior;
- it increases the methodological tools since they give to researchers a new powerful method to study complex social systems when individuals are cooperative or non-cooperatives at the same time, and when norms and incentives dynamically change; and finally
- it can attain insights to researchers about methods and tools, concerning the functioning of complex systems and societies.

This kind of framework developed is still in its infancy, there is much more work to do, but the insight is very valuable to anyone interested in economics of crime and the implication of law and economics. In other words, agent-based model applied to crime is important to study complex societies and their evolution[13].

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[12] R.V. Clarke, *Situational Crime Prevention, Crime and Justice*, in "Building a Safer Society: Strategic Approaches to Crime Prevention", Vol. 19, 1995, pp. 91-150; L.E. Cohen, M. Felson, *Social Change and Crime Rate Trends: A Routine Activity Approach*, in "American Sociological Review", Vol. 44, 1979, August, pp. 588-608; R. Cooter, T. Ulen, *Law and Economics*, Boston, Addison Wesley Longman, 3rd ed., 1999.

[13] N. Mercuro, S.G. Medema, *Economics and the Law: From Posner to Post-Modernism*, Princeton, Princeton University Press, 1997; S. Russel, P. Norvig, *Artificial Intelligence: A Modern Approach*, Prentice Hall Series in Artificial Intelligence, 2nd edition, 2003; J.A. Scheinkman, E.L. Glaeser, B. Sacerdote, *Crime and Social Interactions*, in "The Quarterly Journal of Economics", Vol. 111, 1996, n. 2, pp. 507-548; S. Shavell, *Foundations of Economic Analysis of Law*, Cambridge, Harvard University Press, 2004; S. Shavell, A.M. Polinsky, *The Economic Theory of Public Enforcement of Law*, in "Journal of Economic Literature", Vol. 38, 2000, n. 1, ABI/INFORM Global, p. 45.

Agent-based Approach to Crime and Criminal Justice Policy Analysis

VALENTINA PUNZO*

SUMMARY: *1. Introduction – 2. Agent-based Modeling and the Bottom-up Approach to Computer Simulation – 3. Agent-based Modeling and Crime Analysis: Using Simulated Experiments in Crime Prevention – 4. Agent-based Models of Crime Prevention and Criminal Justice Policies – 5. Conclusions*

1. INTRODUCTION

Agent-based Social Simulation (ABSS) has increasingly been proving to be successful for the study of crime and criminal justice policies[1]. The use of techniques belonging to the field of computer simulation in policy modelling is also actually increasing[2].

Early applications of simulative approach to crime analysis appeared in the field of Environmental Criminology[3]. In 2008, a special issue of the "Journal of Experimental Criminology" was entirely devoted to current applications of simulation methods to the study of crime and criminal justice policies[4]. As regards crime research, it was suggested how this technique

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[1] L. LIU, X. WANG, J.E. ECK, J. LIANG, *Simulation Crime Events and Crime Patterns in RA/CA Model*, in Wang F. (ed.), "Geographic Information Systems and Crime Analysis", Singapore, Idea Group, 2005, pp. 197-213; X. WANG, *Spatial Adaptive Crime Event Simulation with RA/CA/ABM Computational Laboratory*, Geography Cincinnati, University of Cincinnati, 2005; L. LIU, J.E. ECK (eds.), *Artificial Crime Analysis Systems: Using Computer Simulations and Geographic Information Systems*, Hershey, IGI Global, 2008; D.J. BIRKS, S. DONKIN, M. WELLSMITH, *Synthesis over Analysis: Towards an Ontology for Volume Crime Simulation*, in Liu L., Eck J.E. (eds.), "op. cit.", pp. 160-192.

[2] M.A. WIMMER, K. FURDIK, M. BICKING, M. MACH, T. SABOL, P. BUTKA, *Open Collaboration in Policy Development: Concept and Architecture to Integrate Scenario Development and Formal Policy Modeling*, in Charalabidis Y., Koussouris S. (eds.), "Empowering Open and Collaborative Governance", Berlin, Springer Verlag, 2012.

[3] P.L. BRANTINGHAM, P.J. BRANTINGHAM, *Computer Simulation as a Tool for Environmental Criminologists*, in "Security Journal", Vol. 17, 2004, n. 1, pp. 21-30; P.L. BRANTINGHAM, E.R. GROFF, *The Future of Agent-based Simulation in Environmental Criminology*, in "Proceedings of the American Society of Criminology Conference", Nashville, 2004.

[4] E. GROFF, L. MAZEROLLE, *Simulated Experiments and Their Potential Role in Criminology and Criminal Justice*, in "Journal of Experimental Criminology", Vol. 4, 2008, pp. 187-193.

could be useful to advance, test or refine theory[5], to anticipate consequences accruing from one type of intervention over another[6], and to provide new policy evaluation tools[7]. As a consequence simulation can also supply informed policy guidance to crime control agencies[8].

Recently several international conferences on artificial intelligence and multi-agent systems hosted lots of contributions about applications of computer simulation to the crime problem[9].

There are many reasons why it is appropriate to investigate the relationship between ABSS and crime analysis. The principal argument in criminology is the need for complementarities between the experimental or quasi-experimental approach and the simulation one[10]. The use of agent-based computational method would be considered particularly beneficial in cases where empirical research is limited by the inability to conduct field trials[11].

[5] E. GROFF, *Simulation for Theory Testing and Experimentation: An Example Using Routine Activity Theory and Street Robbery*, in "Journal of Quantitative Criminology", Vol. 23, 2007, n. 2, pp. 75-103; E. GROFF, *Adding the Temporal and Spatial Aspects of Routine Activities: A Further Test of Routine Activity Theory*, in "Security Journal", Vol. 21, 2008, pp. 95-116.

[6] R.A. BERK, J. BOND, R. LU, R. TURCO, R.E. WEISS, *Computer Simulations as Experiments: Using Program Evaluation Tools to Assess the Validity of Interventions in Virtual Worlds*, in Bickman L. (ed.), "Donald Campbell's Legacy (Vol. II): Contributions to Research Design", Newbury Park, Sage Publications, 2000.

[7] P. PEREZ, A. DRAY, *SimDrug: Exploring the Complexity of Heroin Use in Melbourne*. Drug Policy Modelling Project Monograph Series, Fitzroy: Turning Point Alcohol and Drug Centre, 2005, http://www.turningpoint.org.au/research/dpmp_monographs/dpmp_monograph11.pdf; A. DRAY, L. MAZEROLLE, P. PEREZ, A. RITTER, *Drug Law Enforcement in an Agent-based Model: Simulating the Disruption to Street-level Drug Markets*, in Liu L., Eck J.E. (eds.), "op. cit.", pp. 352-271.

[8] D. REIS, A. MELO, A.L.V. COELHO, V. FURTADO, *Towards Optimal Police Patrol Routes with Genetic Algorithms*, in Mehrotra S., Zeng D.D., Chen H., Thuraisingham B., Wang F.-Y. (eds.), "Intelligence and Security Informatics", Proceedings of the IEEE International Conference on Intelligence and Security Informatics, 2006, pp. 485-491.

[9] See the Proceedings of ACM Symposium 2007 http://www.acm.org/conferences/sac/sac2007/, AAMAS 2008 http://www.aamas-conference.org/Proceedings/aamas08/ and ICAART 2009 http://www.informatik.uni-trier.de/ ~ ley/db/conf/icaart/icaart2009.html.

[10] J.E. ECK, L. LIU, *Contrasting Simulated and Empirical Experiments in Crime Prevention*, in "Journal of Experimental Criminology", Vol. 4, 2008, n. 3, pp. 195-213.

[11] E. GROFF, L. MAZEROLLE, *op. cit.* For a review, see also V. PUNZO, A. FICI, *Modelli ad agenti e sociologia del crimine e della devianza. Aspetti teorici e metodologici*, in Faro S., Lettieri N., Tartaglia Polcini A. (eds.), "Diritto e Tecnologie. Verso le scienze sociali computazionali", Napoli, Edizioni Scientifiche Italiane, 2011, pp. 271-294.

In some cases, simulation can be viewed as a sort of pre-test of certain crime prevention programs, able to suggest any changes before their empirical test[12].

There is also a strong evidence that agent-based simulation allows to implement the Coleman's casual macro-micro-macro "transitions"[13]. It allows researchers to create artificial societies[14] and to explore how individual-level criminal action might translate into observable macrolevel crime patterns. An important challenge within the field of criminology is to investigate the spatio-temporal dynamics of crime[15]. Within this area, the key object is the study of crime, criminality, and victimization as they relate to particular places and how offenders, targets (victims), and guardians (control agents) shape their activities spatially[16]. For example, a relevant question is which factors influence the emergence of so-called hot spots – areas in which many crimes occur[17] – and how the displacement of criminal hot spots can be predicted and prevented[18]. Computer simulation of criminal patterns is implemented to identify potential hot spots and flashpoints. It can be usefully used for supporting police forces which can allocate resources to areas where particular crimes are most likely to occur[19].

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[12] E. GROFF, L. MAZEROLLE, *op. cit.*

[13] F. SQUAZZONI, *The Micro-Macro Link in Social Simulation*, in "Sociologica", Vol. 1, 2008, n. 8.

[14] J.M. EPSTEIN, R. AXTELL, *Growing Artificial Societies: Social Science from the Bottom-up*, Cambridge, MIT Press, 1996.

[15] L. LIU, J.E. ECK (eds.), *op. cit.*; T. BOSSE, C. GERRITSEN, *Social Simulation and Analysis of the Dynamics of Criminal Hot Spots*, in "Journal of Artificial Societies and Social Simulation", Vol. 13, 2010, n. 2, http://jasss.soc.surrey.ac.uk/13/2/5.html.

[16] S. JOHNSON, *Repeat Burglary Victimisation: A Tale of Two Theories*, in "Journal of Experimental Criminology", Vol. 4, 2008, pp. 215-240.

[17] L. SHERMAN, P. GARTIN, M. BUERGER, *Hot Spots of Predatory Crime: Routine Activities and the Criminology of Place*, in "Criminology", Vol. 27, 1989, n. 1, pp. 27-55; J.E. ECK, S. CHAINEY, J. CAMERON, M. LEITNER, R. WILSON, *Mapping Crime: Understanding Hot Spots*, National Institute of Justice, U.S. Department of Justice, 2005, http://www.ojp.usdoj.gov/nij/pubs-sum/209393.htm.

[18] T. BOSSE, C. GERRITSEN, *op. cit.*; V. FURTADO, A. MELO, A. COELHO, R. MENEZES, *A Crime Simulation Model Based on Social Network and Swarm Intelligence*, Proceedings of the 2007 ACM Symposium on Applied Computing, Seoul, 2007.

[19] See for example the IBM system known as CRUSH - *Criminal Reduction Utilising Statistical History*, http://www-03.ibm.com/press/us/en/pressrelease/32169.wss. The software is being tested in UK and has been tested in Tennessee, where the police department credits CRUSH as the key factor behind a 31% reduction in overall crime and a 15% fall in violent crime.

The knowledge and techniques that can be ascribed to ABSS are, in effect, demonstrating a significant capacity to contribute to criminal justice policy making.

This paper aims at presenting the potential intersections between ABSS and crime research by focusing on policy making issues. The goal is to clarify how ABSS can specifically support the elaboration of criminal justice policies by making the policy evaluation tools more effective.

2. Agent-based Modeling and the Bottom-up Approach to Computer Simulation

The employment of Agent-based Social Simulation (ABSS) in the social sciences has increased over the past ten years[20] and has proved as a powerful computational tool to formalize models of social outcomes and to modelling crime[21]. The main purpose of agent-based modelling is to analyze the properties of social systems by explicitly representing individuals (called "agents"), interactions between them and the (geographical, spatial, economic, institutional) environment in which they are situated[22].

In crime modelling, agents represent offenders, potential victims, police and/or others informal control agents. Agents make decisions about movement and actions in a local environment (e.g. a street network, social network or some other representation of space). The environment can include features such as buildings, where potential victims might be situated, or barriers to movement or communication.

The bottom-up approach to computer simulation on which agent-based social simulation relies means that starting from a few, simple, theory-based rules that inform the behavior of individual agents (and their interactions), the model generates macro-level patterns (they often acquire the property of emergence which refers to unexpected consequences)[23].

The interactions of agents with each other and the environment are governed by set of rules, following a sequence of the "what if" – questions. As

[20] N. Gilbert, K. Troizsch, *Simulation for the Social Scientist*, Maidenhead, Open University Press, 2005; N. Gilbert, *Agent-based Models*, London, Sage, 2008.

[21] D.J. Birks, S. Donkin, M. Wellsmith, *op. cit.*

[22] J.H. Miller, S. Page, *Complex Adaptive Systems. An Introduction to Computational Models of Social Life*, Princeton-Oxford, Princeton University Press, 2007; F. Squazzoni, *op. cit.*; N. Gilbert, *Agent-based Models*, cit.

[23] J.M. Epstein, R. Axtell, *op. cit.*; N. Gilbert, K. Troizsch, *op. cit.*

underlined by Elffers and Van Baal it means: what happens if "acts" ("behavior") of a number of "agents" are fully governed by certain "law-like processes"? These law-like processes state completely which specific act an agent will perform, in a given situation[24]. For example, a rule such this could state: "If an offender agent occupies the same location as a target agent, then the offender robs the victim", otherwise "If a police agent is within a set distance of an offender agent then no crime occurs". Rules govern the transition from one state to another – for example, the state with no crime to the state with a crime.

Usually these law-like processes are specified by means of a mathematical formula (a decision rule that in many cases includes probabilistic elements) that identifies what behavior will be performed by that actor, given his situation (often the situation is characterized by the availability of other actors).

Moreover, the environment may change during the simulation according to a related law-like process as well (under the influence of higher order rules for adapting, such as learning models, neural network models, etc.) and agents may be capable of evolving, based on experience, allowing unanticipated behaviors to emerge.

Simple problems of this type sometimes can be analytically solved through mathematical analysis. However, simulation becomes indispensable as soon as the complexity of the problem is analytically intractable with mathematical or statistical models. As already Squazzoni highlighted, social scientists can grasp within a formalized model those relevant features of the complexity of social systems: autonomy and heterogeneity of agents, adaptive rationality, spacial and local interactions, non-equilibrium dynamics[25]. Even a simple agent-based model can exhibit complex behavior patterns and provide valuable information about the dynamics of the real-world system that it reproduces[26].

In the field of crime research, for example, the spatial nature of crime and interaction between agents (criminal, police, victim, etc.) often requires

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[24] H. ELFFERS, P. VAN BAAL, *Spatial Backcloth Is Not That Important in Simulation Research: An Illustration from Simulating Perceptual Deterrence*, in Liu L., Eck J.E. (eds.), "op. cit.", p. 20.

[25] F. SQUAZZONI, *op. cit.*

[26] F. SQUAZZONI, R. BOERO, *Towards an Agent-based Computational Sociology: Good Reasons to Strengthen Cross-fertilization between Complexity and Sociology*, in Stoneham L.M.(ed.), "Advances in Sociology Research", New York, Nova Science Publishers Inc., Vol. 2, 2005, pp. 103-133; J.H. MILLER, S. PAGE, *op. cit.*; N. GILBERT, *Agent-based Models*, cit.

the agent-based models to include space and time[27]. It becomes important overcoming some of the limitations which characterize the traditional research methods in criminology bounded both temporally and spatially. In this framework, simulation method represents a third way between the more established research approaches[28] of carrying out social science, in addition to argumentation and formalization. In contrast to other methods "with computer simulations, it is possible to carry out experiments and observe the occurrence of emergence"[29].

3. Agent-based Modeling and Crime Analysis: Using Simulated Experiments in Crime Prevention

For the purpose of this paper we focus our attention on agent-based simulation as a different, but complementary approach, to existing methodologies applied in the study of crime. Especially we refer to the use of agent-based modelling as a virtual laboratory to conduct "virtual experiments"[30]. In regard, Eck and Liu[31] stated that simulated experiments of crime prevention interventions are an important class of research methods that fits within the empirical experimental paradigm widely used in criminology.

A simulation works as a computational laboratory when you manipulate a, so-called, experimental condition[32]. Agent-based models can be used

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[27] D.G. Brown, M. North, D. Robinson, R. Riolo, W. Rand, *Spatial Process and Data Models: Toward Integration of Agent-based Models and GIS*, in "Journal of Geographical Systems", Vol. 7, 2005, n. 1, pp. 25-47; E. Groff, *Characterizing the Spatio-temporal Aspects of Routine Activities and the Geographic Distribution of Street Robbery*, in Liu L., Eck J.E. (eds.), "op. cit.", pp. 226-251.

[28] N. Gilbert, *Simulation: A New Way of Doing Social Science*, in "American Behavioral Scientist", Vol. 42, 1999, n. 10, p. 1487.

[29] N. Gilbert, P. Terna, *How to Build and Use Agent-based Models in Social Science*, in "Mind & Society", Vol. 1, 2000, p. 58.

[30] L. Liu, J.E. Eck (eds.), *op. cit.*; M. Townsley, D.J. Birks, *Building Better Crime Simulations: Systematic Replication and the Introduction of Incremental Complexity*, in "Journal of Experimental Criminology", Vol. 4, 2008, n. 3, pp. 309-333.

[31] J.E. Eck, L. Liu, *Contrasting Simulated and Empirical Experiments in Crime Prevention*, cit.

[32] C. Dibble, *Theory in a Complex World: GeoGraph Computational Laboratories*, Santa Barbara, University of California, Department of Geography, 2001, p. 165; D.C. Parker, T. Berger, S.M. Manson, *Agent-based Models of Land-use/land-cover Change*, LUCC Report Series No. 6, LUCC Focus 1 Office Anthropological Center for Training and Research on Global Environmental Change, Indiana University, 2001; L. Tesfatsion, *Guest Editorial:*

to investigate the relative impact of one or more components of a system through several manipulations. Simulations implemented in the framework of a computational laboratory offer the advantage of being able to control aspects of interest about agents and/or the landscape, varying the values of the parameters related to one or both of them[33].

This feature provides a level of control difficult to achieve using traditional social science methods[34]. First of all, the combination of heterogeneous agents which interact in different local environments enables the researcher to conduct several "virtual" experiments in different experimental conditions (also applying various prevention scenarios) and then evaluate the simulated outcomes[35]. Simulation "offers social scientists an analogue to controlled experiments for examining social phenomena. In a simulation researchers can alter factors normally beyond their control, implement interventions perfectly, and explore dose–response relationships beyond logistic and financial constraints"[36].

By contrasting empirical and computational experimentation within criminology, Eck and Liu[37] state that simulated experiments provide a bridge between theoretical explanations and empirically inferred representations of crime patterns[38]. Simulated experiments help criminologists to face the weakness of theoretical explanations of crime (mainly written in common languages and often subjected to multiple interpretations), because they provide a rigorous formalization of a certain theory for empirical testing and experimentation. Indeed simulation requires that the theory's assumptions must be operationalized as a computer algorithm that is consistent with the theory. The result is a more formalized theory[39]. In other words, agent-

Agent-based Modeling of Evolutionary Economic Systems, in "Computation", Vol. 5, 2001, n. 5, pp. 437-441.

33 E. GROFF, L. MAZEROLLE, *op. cit.*

34 J.M. EPSTEIN, R. AXTELL, *op. cit.*; N. GILBERT, *Simulation: A New Way of Doing Social Science*, cit.

35 E. GROFF, *Simulation for Theory Testing and Experimentation: An Example Using Routine Activity Theory and Street Robbery*, cit.; E. GROFF, L. MAZEROLLE, *op. cit.*

36 M. TOWNSLEY, D.J. BIRKS, *op. cit.*, p. 310.

37 J.E. ECK, L. LIU, *Contrasting Simulated and Empirical Experiments in Crime Prevention*, cit.

38 *Ivi*, p. 196.

39 I. BENENSON, P. TORRENS, *Geosimulation: Automata-based Modeling of Urban Phenomena*, New York, Wiley, 2004; J.M. EPSTEIN, *Generative Social Science: Studies in Agent-based Computational Modelling*, Princeton, Princeton Univ. Press, 2006; P. HEDSTRÖM,

based simulation requires the researcher to specify the causal mechanisms[40] by which a hypothesized independent variable gives rise to the dependent variable, according to the theory incorporated into the simulation model.

The process of decomposing theories into computational formalisms "such as the rules that govern agent behaviour, is useful in that it provides researchers greater insight and demands that they specify theories and concepts in explicit terms. This can highlight potential inconsistencies or shortcomings and, by doing so, contributes to the subsequent strengthening of theory[41].

Once the theory has been operationalized as a computer code, the next step is to observe whether the model (and then the theory on its basis) is sufficient to generate an outcome that looks like the empirical distribution of the dependent variable observed. According to the principles of the generative explanation[42]: if the simulation outcomes do not match the empirical data related to the phenomenon in question, the theory is falsified, otherwise we have identified at least one process that grows the phenomenon (and how theory explains it).

It is for its ability to falsify that simulation might help improving theorizing in criminology[43]. As stated by Eck and Liu "because simulations can falsify theory, they are not simply a method for theory elaboration but can also be used for experimentation"[44]. Criminological theories can be made testable.

Unlike statistical explanations of crime, generative explanation reached through the mean of agent-based simulation focuses on the mechanisms that give rise to the phenomenon. Specifically, crime pattern simulations allow researchers to examine not only the mere distributions of crime patterns (e.g. the dislocation of hot spots within a certain spatial environment) but also how they develop (the mechanisms that give rise to crime patterns or that prevent crime from clustering)[45].

Anatomia del sociale. Sui princìpi della sociologia analitica, Milano, Bruno Mondadori, 2006; J.H. MILLER, S. PAGE, *op. cit.*.

[40] P. HEDSTRÖM, *op. cit.*

[41] M. TOWNSLEY, D.J. BIRKS, *op. cit.*, p. 311.

[42] P. HEDSTRÖM, *op. cit.*; J.M. EPSTEIN, *op. cit.*

[43] D.J. BIRKS, S. DONKIN, M. WELLSMITH, *op. cit.*

[44] J.E. ECK, L. LIU, *Contrasting Simulated and Empirical Experiments in Crime Prevention*, cit., p. 198.

[45] *Ivi*, p. 196.

The utility of applying simulated experiments in crime research also derives from data limitations. Crime studies rely on poor and misleading empirical data. This is a matter of fact. Data sources are in fact highly unreliable where people involved with crime know little about what occurred or have a self-interest to say nothing about it (for example in the case of offenders) or to misrepresent the truth in particular circumstances. Inductive reasoning, based on inherently faulty data, is likely to lead to invalid explanations[46]. In the case of crime there is also the problem of the so-called "dark number" which implies that a certain amount of crimes are inherently undetectable.

Data and theory limitations show the weakness of many criminological theories[47]. In addition, computer experiments provide us with an approach that overcomes some of the current limitations of the traditional research methods which deal with real-world settings, real subjects or even with laboratories. There are indeed many limits to manipulate multiple independent variables through field experiments or test their effects independently. In field experiments it is difficult to create many experimental conditions. Where field experiments in crime prevention or criminal justice are difficult and highly costly, "simulations allow the testing of innovative interventions prior to their being taken into the field"[48]. With simulations, an extensive range of interventions can be applied by varying parameters. As underlined by Townsley and Birks "Simulation models allow repeated experiments under identical conditions, save for differences selected by the researcher"[49]. Moreover, each experimental condition can be replicated hundreds or thousands of times[50] and once the model has been built, further adjustments are simple to perform.

Simulations can then be used to select the range of conditions and in some cases they may be usefully employed as pre-tests in order to screen out the least plausible innovations[51].

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[46] *Ivi*, p. 201.

[47] D. WEISBURD, A.R. PIQUERO, *How Well Do Criminologists Explain Crime?*, in Tonry M. (ed.), "Crime and Justice: An Annual Review of Research", Chicago, University of Chicago Press, Vol. 37, 2008.

[48] J.E. ECK, L. LIU, *Contrasting Simulated and Empirical Experiments in Crime Prevention*, cit., p. 198.

[49] M. TOWNSLEY, D.J. BIRKS, *op. cit.*, p. 311.

[50] J.M. EPSTEIN, *op. cit.*

[51] E. GROFF, *Simulation for Theory Testing and Experimentation: An Example Using Routine Activity Theory and Street Robbery*, cit.; J.E. ECK, L. LIU, *Contrasting Simulated and Empirical Experiments in Crime Prevention*, cit.

There are also moral boundaries to empirical experimentation that operates with human subjects. Simulations might then be considered when ethical issues preclude random assignment of people to certain control conditions. For example, while police might not "strike" for long periods of time in real life, they can do so in an artificial society.

Simulated experiments could also shed light on some important police functions that are very unlikely to be studied with field experiments, for example the effect of police rapid response on crime[52].

Finally, computational laboratories allow to change the physical environment, that is not possible in real-world settings, for example it is thus possible to alter street patterns experimentally, on a large scale, to see their effects on crime patterns[53].

A critical note with regard to simulated experiments relates to the actual implementation of an intervention in a real environment. Only after the actual implementation of a policy intervention indeed it will create the post-implementation data used in empirical experiments. In simulated experiments the implementation data of a certain intervention are hypothetical, created in a "virtual" setting. On the one hand this fact reduces the credibility of simulated experiments, on the other "it has the advantage that we can 'bench test' policies prior to their implementation, or even test arrangements that cannot be tested in the field"[54].

Next Section will focus on the advantage of crime simulation for criminal justice policy modeling. We will review several agent-based models implemented for this purpose.

4. Agent-based Models of Crime Prevention and Criminal Justice Policies

Criminologists have recently been exploring how agent-based simulation models can inform the study of crime[55].

52 J.E. Eck, L. Liu, *Contrasting Simulated and Empirical Experiments in Crime Prevention*, cit.

53 *Ibidem*.

54 *Ivi*, p. 204.

55 P.L. Brantingham, P.J. Brantingham, *op. cit.*; P.L. Brantingham, E.R. Groff, *op. cit.*; L. Liu, J.E. Eck (eds.), *op. cit.*

The early works are the studies by Epstein and colleagues[56] on civil violence and by Wilhite[57] on crime protection. Both studies show how interactions between individual agents appear to be linked to the emerging pattern of violence or protection at the collective level. Crime simulations allow researchers to examine how crime patterns develop and to explore the mechanisms that give rise to crime patterns[58].

It is possible to distinguish different types of agent-based models on crime, starting from their purposes. They range from theorizing, to policy testing and program planning[59]. Starting from assumptions drawn from different criminological theories, several simulations explore theoretical problems in crime[60]. In each case, researchers are interested in determining whether commonly observed crime patterns could arise from simple processes. If the simulations can mimic real world phenomena, by using a limited set of simple processes, this suggests that the theories encapsulated into the software may be sufficient to explain the phenomena.

Experimenting with these artificial crime models may help formulate hypotheses about how crime is produced[61]. After theoretical hypotheses/ex-

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[56] J.M. EPSTEIN, J.D. STEINBRUNER, M.T. PARKER, *Modeling Civil Violence: An Agent Based Computational Approach*, Washington D.C., Center on Social and Economic Dynamics, Brookings Institution, 2001, working paper.

[57] A. WILHITE, *Protection and Social Order*, in "Computational Economics and Finance Meeting", Yale University, 2001.

[58] L. LIU, J.E. ECK (eds.), *op. cit.*

[59] J.E. ECK, L. LIU, *Varieties of Artificial Crime Analysis: Purpose, Structure, and Evidence in Crime Simulations*, in Liu L., Eck J.E. (eds.), "op. cit.".

[60] X. WANG, L. LIU, J.E. ECK, *A Spatial Dynamic Simulation of Crime Using Agent-based Modeling*, Proceedings of the Association of American Geographers Conference, Philadelphia, 2004; E. GROFF, *Simulation for Theory Testing and Experimentation: An Example Using Routine Activity Theory and Street Robbery*, cit.; E. GROFF, *Characterizing the Spatio-temporal Aspects of Routine Activities and the Geographic Distribution of Street Robbery*, cit.; T. BOSSE, C. GERRITSEN, M.C.A. KLEIN, *Agent-based Simulation of Social Learning in Criminology*, Proceedings of the International Conference on Agents and Artificial Intelligence (ICAART), Porto, 2009; V. PUNZO, B. SONZOGNI, F. CECCONI, *Social Networks and Deviant Leisure Choices. An Agent-based Simulation Model*, in Lo Verde F.M., Modi I., Cappello G. (eds.), "Mapping Leisure across Borders", Cambridge Scholars Publishing, forthcoming; D. BIRKS, M. TOWNSLEY, A. STEWART, *Generative Explanations of Crime: Using Simulation to Test Criminological Theory*, in "Criminology", Vol. 50, 2012, n. 1, pp. 221-254.

[61] X. WANG, *op. cit.*; X. WANG, L. LIU, J.E. ECK, *Crime Simulation Using GIS and Artificial Intelligent Agents*, in Liu L., Eck J.E. (eds.), "op. cit.", pp. 209-225; E. GROFF, *Characterizing the Spatio-temporal Aspects of Routine Activities and the Geographic Distribution of Street Robbery*, cit.

planation mechanisms have been identified they must then be tested using empirical data[62].

Other studies acquired a simulative approach to examine prospectively the likely effects of policy changes[63].

Some authors suggested the use of agent-based simulation as a policy evaluation tool[64]. Deepening the aspects related to the impact of various anti-crime policies, Wilhite and Allen[65] for example showed that, although the intensification of the anti-crime measures tends to reduce crime, the impact of incarceration is ambiguous, as a high rate of detention may lead to increased crime in the long term. In general, the increase in time of incarceration can reduce crime, as a mechanical effect, but this reduction may be due to a steady increase in the prison population, and this may suggest that incarceration may not be a solution in a long-term perspective. The results achieved by Wilhite and Allen show that the deterrent effect of the anti-crime (in particular the increase in length of the penalties) and incarceration varies between short and long term.

Other studies employed agent-based models to test policies or to compare crime prevention strategies[66]. Szakas and colleagues, for example, illustrate a simulation of police patrolling that would allow to test various police patrol methods[67]. Simulations such as presented by Szakas and colleagues could help in planning a certain intervention (in the case study it is a police intervention) by narrowing the range of options available and aiding in the selection of the options with the greatest promise. Specifically, the authors suggested that police simulations might be particularly useful for planning police interventions for emergency situations (e.g. natural disasters, terrorist

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[62] J.E. ECK, L. LIU, *Contrasting Simulated and Empirical Experiments in Crime Prevention*, cit.

[63] K. AUERHAHN, *Using Simulation Modeling to Evaluate Sentencing Reform in California: Choosing the Future*, in "Journal of Experimental Criminology", Vol. 4, 2008, n. 3, pp. 241-266.

[64] P. PEREZ, A. DRAY, *op. cit.*

[65] A. WILHITE, W.D. ALLEN, *Crime, Protection, and Incarceration*, in "Journal of Economic Behavior and Organization", Vol. 67, 2008, pp. 481-494.

[66] T. BOSSE, C. GERRITSEN, *Comparing Crime Prevention Strategies by Agent-based Simulation*, 2009 IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology, 2009.

[67] J. SZAKAS, C. TREFFTZ, J.R. RAMIREZ, E. JEFFERIS, *Development of an Intelligent Patrol Routing System Using GIS and Computer Simulations*, in Liu L., Eck J.E. (eds.), "op. cit.", pp. 339-351.

attacks, and mass accidents). Similarly, the agent-based model described by Bosse and colleagues illustrates the usefulness of simulation as an analytical tool to investigate the effectiveness in crime prevention of various guardianship policies and to develop policing deployment strategies, the so-called hot spot policing[68].

According to Eck and Liu "planning simulations are very similar to the use of simulations to test policies, but they are less specific about the changes being implemented"[69]. For example, a planning simulation might ask what would happen to court backlogs if arrests were increased (but would not specify how arrests are increased). Instead, a policy testing simulation might ask whether changing a particular policing practice results in more arrests[70].

An approach similar to the planning simulations relates to the use of simulations to test the impact of programs prior to implementation[71]. In this framework, simulations form the basis of decision support systems (DSS)[72], a popular class of computer-based information or knowledge based systems that support decision making activities. Specifically, Intelligent DSS often use multiple intelligent agents interacting based on decentralized coordination models to assist decision makers in analyzing a situation[73].

Contextualizing its interest to a specific policy sector, the agent-based model developed by Dray and colleagues[74] examines the likely impact of crime-prevention interventions looking at the effects of forms of policing on heroin related harms. The study describes an agent-based model that

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[68] T. BOSSE, H. ELFFERS, C. GERRITSEN, *Simulating the Dynamical Interaction of Offender, Targets and Guardians*, in "Crime Patterns and Analysis", Vol. 3, 2010, n. 1, pp. 51-66.

[69] J.E. ECK, L. LIU, *Varieties of Artificial Crime Analysis: Purpose, Structure, and Evidence in Crime Simulations*, cit., p. 416.

[70] *Ivi*, p. 416.

[71] P.L. BRANTINGHAM, U. GLÄSSER, P. JACKSON, B. KINNEY, M. VAJIHOLLAHI, *Mastermind: Computational Modeling and Simulation of Spatiotemporal Aspects of Crime in Urban Environments*, in Liu L., Eck J.E. (eds.), "op. cit.", pp. 252-281.

[72] L. FANG, K.W. HIPEL, D.M. KILGOUR, X. PENG, *A Decision Support System for Interactive Decision Making. Part I: Model Formulation*, in "IEEE Transactions on Systems, Man and Cybernetics", Part C, Vol. 33, 2003, n. 1, pp. 42-55; L. MIKHAILOV, M.G. SINGH, *Fuzzy Analytic Network Process and Its Application to the Development of Decision Support Systems*, in "IEEE Transactions on Systems, Man and Cybernetics", cit., pp. 33-41.

[73] J.N.D. GUPTA, G.A. FORGIONNE, T.M. MORA (eds.), *Intelligent Decision-making Support Systems: Foundations, Applications and Challenges*, New York, Springer, 2006.

[74] A. DRAY, L. MAZEROLLE, P. PEREZ, A. RITTER, *Drug Law Enforcement in an Agent-based Model: Simulating the Disruption to Street-level Drug Markets*, cit.

aims at comparing three different law enforcement strategies (policing strategies), exploring the relative impact of each (standard patrol, hotspot policing, and problem-oriented policing) on an archetypal street-based illicit drug market. Researchers simulate the relative effectiveness of these different drug law enforcement approaches, analyzing several outcome indicators (such as the number of committed crimes, dealers' and users' cash, overdoses and fatal overdoses). Simulative results show that problem-oriented policing is the most effective approach to disrupting street level drug markets in a simulated urban environment[75].

The study shows how simulated policy experiments can examine situations that are impossible to be examined using empirical research methods. In fact an experiment on three types of policing strategies simultaneously throughout the same city would be impossible to conduct in the real world.

Within the field of Criminology, the spatio-temporal dynamics of crime are an important subject of study. Typical questions, in this area, are how the emergence and displacement of criminal hot spots can be explained and predicted. In this regard, an interesting question is whether simulation models of criminal displacement can be useful for anticipatory policies strategies (e.g. to increase the number of guardians at locations where hot spots are likely to emerge, instead of at the present locations of hot spots). Some agent-based models have been implemented to this purpose, comparing between a number of policy strategies (varying from merely reactive to more anticipatory policies)[76]. In all these cases researchers highlight the implications of simulated experimentation in terms of policy indications.

An interesting and recent approach that looks at the use of computer simulation in policy modelling is the so-called *participatory agent-based social simulation*[77]. Participatory modeling aims at closely involving potential users and stakeholders in model specification, design, testing and use. The development of agent-based social simulation models is realized in conjunction with users and stakeholders. They can repeat decisions made under differing

[75] *Ibidem*.

[76] T. BOSSE, C. GERRITSEN, *Comparing Crime Prevention Strategies by Agent-based Simulation*, cit.

[77] A. RAMANATH, N. GILBERT, *The Design of Participatory Agent-based Social Simulations*, in "Journal of Artificial Societies and Social Simulation", Vol. 7, 2004, n. 4, http://jasss.soc.surrey.ac.uk/7/4/1.html; M.A. WIMMER, K. FURDIK, M. BICKING, M. MACH, T. SABOL, P. BUTKA, *op. cit.*

scenarios and strategic conditions[78]. This method can provide support for decision making in a relatively cost effective way[79]. A group of researchers at the University of Koblenz (Germany) have recently been designing and implementing a software tool to support participatory simulation and policy modeling[80]. The software is intended to provide a platform for formalizing various kinds of agent behavior representations[81] and to support models of political negotiations between different groups of stakeholders[82]. The use of participatory simulation as a technique that enhances understanding of tasks and communication among stakeholders is also receiving increasing attention in the field of criminal justice policy research[83].

5. Conclusions

In the present paper we have discussed how agent-based social simulation (ABSS) can address the study of crime and how it can support criminal justice policy making. Crime simulation is a methodological approach to formalizing and testing criminological theory and to conducting "virtual" experiments on crime-prevention strategies.

One of the advantages of simulated experiment is its ability to create a counterfactual (it does not have to use randomization because it can go back in time and recreate the same society upon which to apply a different intervention)[84].

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[78] E. Bonabeau, C. Meyer, *Swarm Intelligence: A Whole New Way to Think about Business*, in "Harvard Business Review", Vol. 79, 2001, n. 5, pp. 107-114; B. Hannon, M. Ruth, *Dynamic Modelling*, 2nd ed., New York, Springer-Verlag, 2001.

[79] T. Wickenberg, P. Davidsson, *On Multi Agent Based Simulation of Software Development Processes*, in Sichman J., Bousquet F., Davidsson P. (eds.), "Multi-Agent-Based Simulation - MABS 2002", Bologna, 2002, pp. 104-113.

[80] See the "Open Collaboration in Policy Modelling - OCOPOMO" project, funded by the EU under the FP7.

[81] U. Lotzmann, R. Meyer, *A Declarative Rule-based Environment for Agent Modelling Systems*, in "Proceedings of the 7th Conference of the European Social Simulation Association, ESSA 2011", Montpellier, September 2011.

[82] OCOPOMO is currently developing a methodology to convert the mental models of stakeholders (which usually come as verbal description of their world views) into formal models, accumulated in a DRAMS description of a simulation model.

[83] See the "The Global Dynamic of Extortion Racket Systems - GLODERS" project, funded by the EU under the FP7.

[84] R.A. Berk, J. Bond, R. Lu, R. Turco, R.E. Weiss, *op. cit.*

As far as the field of criminology is concerned, agent-based social simulation is useful in many circumstances, specifically when opportunities to conduct empirical experiments with real subjects are challenging or impossible[85]. For example, simulations might be considered when ethical concerns prevent the random assignment of people to the so-called "control conditions". Simulations are also useful as a comparatively inexpensive way to evaluate a certain program and suggest some changes before it is properly tested empirically. The cost of running 'virtual' experiments is inferior of the costs involved in empirical field trials. Simulation may play a significant role in vetting and strengthening programs prior to their empirical testing[86], "then we may be able to weed out interventions prior to their application in the field for empirical testing"[87].

Within criminology, ABSS has been usefully employed to projecting the likely impact of crime-prevention interventions[88] and to evaluating the potential of a certain criminal justice policy strategy[89].

As far the application of crime simulation to policy making, several researchers have been developing agent-based models to study policy problems in different policy sectors and with different purposes. In Fig. 1 we synthesized the way in which agent-based social simulation can be usefully applied within the policy process, showing, for each stage of the policy cycle, the specific purposes of agent-based models.

As already seen in previous Sections, agent-based social simulation can support the overall policy making process along its different stages: from the original problem definition; to the phase of implementation (in which agent-based models can be used to test the relative impact of a certain policy and to highlight what is going wrong); to policy evaluation, in which agent-based models can be used to test the overall impact of a certain policy.

During the first phase of the policy cycle (problem definition), for example, simulations could help improving the theoretical explanation (which justifies the definition of a certain issue as a problem that needs to be solved),

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85 E. GROFF, L. MAZEROLLE, *op. cit.*

86 *Ibidem*; J.E. ECK, L. LIU, *Varieties of Artificial Crime Analysis: Purpose, Structure, and Evidence in Crime Simulations*, cit.

87 J.E. ECK, L. LIU, *Varieties of Artificial Crime Analysis: Purpose, Structure, and Evidence in Crime Simulations*, cit., pp. 209-210.

88 A. DRAY, L. MAZEROLLE, P. PEREZ, A. RITTER, *Drug Law Enforcement in an Agent-based Model: Simulating the Disruption to Street-level Drug Markets*, cit.

89 T. BOSSE, H. ELFFERS, C. GERRITSEN, *op. cit.*

by requiring a higher degree of theory formalization. Formalization reveals logical inconsistencies of a theory that must be eliminated before planning useful policy interventions. If crime prevention interventions can be simulated, then we may be able to weed out interventions prior to their application in the field for empirical testing. Several agent-based models address this question and allow for the examination of the outcomes of different crime-prevention interventions (e.g. police patrolling strategies).

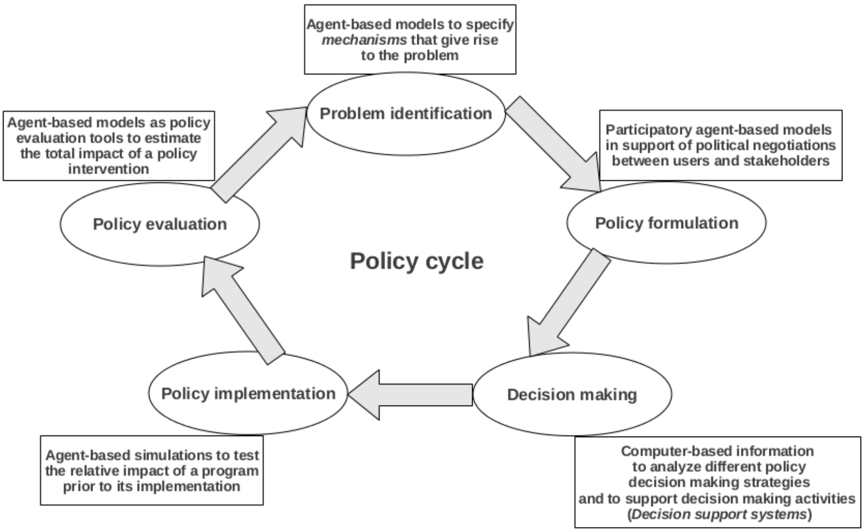

Fig. 1 – The employment of agent-based simulations along the policy making process

Moreover simulations could reveal how much time must pass between the implementation of a policy intervention and the appearance of its outcomes, for example in terms of crime reduction or increase of the safety of the population. This also means that simulation helps us to measure the impact of a policy intervention. This could also allow to improve the planning of empirical experiments and avoid using experiments that measure impact prior to its occurrence[90].

Finally, simulations could help us estimate the conditions in which a certain intervention is likely to wear off[91]. It is then possible to use simulated

[90] J.E. ECK, L. LIU, *Varieties of Artificial Crime Analysis: Purpose, Structure, and Evidence in Crime Simulations*, cit.
[91] *Ivi*, p. 210.

experiments to estimate the total impact of the intervention, by using various experimental scenarios in which you manipulate parameters related to the social, cultural or economic environment in which the policy is implemented and then to observe the consequences in the model. It may allow to give realistic measures of a program's impact and to provide effective, reliable, and replicable instruments for evidence based policy making.

The Leeds Burglary Simulator

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ALISON J. HEPPENSTALL, LINDA M. SEE*

SUMMARY: *1. Introduction – 2. Overview – 2.1. Purpose – 2.2. State Variables and Scales – 2.3. Process Overview and Scheduling – 3. Design Concepts – 4. Details – 4.1. Initialisation – 4.2. Input – 4.3. Submodels – 5. Simulation Experiments*

1. INTRODUCTION

Quantitative analysis of crimes often proceeds at an aggregate level, utilising environmental and crime statistics aggregated over both time and space. However, the drivers of crime are, more often than not, individual, as are the decision-making processes (here we exclude organised crime, though the same techniques are ultimately appropriate). Agent-based modelling offers the opportunity to step away from traditional aggregate analyses, and concentrate on the detailed actions of individuals within an environment. Agent modelling additionally allows more sophisticated modelling of individual drivers, decision making, and history. These models thus represent an excellent opportunity to bring a greater level of depth to crime modelling, and the last ten years has seen a slow rise in crime models of this type[1].

Burglary, particularly theft from private houses, is a major criminal issue in Britain, where these crimes tend to be perpetrated by individuals or small informal groups, and where a major driver is the purchasing of drugs. Burglary is inherently spatial, controlled as it is by the location of offenders, the demographic patterns of potential victims in a city, and the location of guardians like the police and passers-by. These spatial ties cause aggregate hotspots that can be analysed on a predictive basis for policing purposes and primary crime prevention. What is harder, however, is predicting quantitatively how these hotspots will respond to policing, or how criminals might

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[1] For a review, see N. MALLESON, A.J. EVANS, A.J. HEPPENSTALL, L.M. SEE, *Crime from the Ground-up: Agent-based Models of Burglary*, in “Geography Compass”, forthcoming.

react and/or be removed from the crime system. Work on crime displacement and offender decision making is harder at the aggregate level because of the very individually-driven nature of the crimes. Burglary is, therefore, a clear candidate for agent-based modelling. An agent-based model of burglary promises to provide a predictive analysis for primary crime prevention, but also a framework for modelling detailed criminal, victim, and guardian behaviour, with a concomitant ability for modelling secondary responses to prevention efforts.

With this in mind, this paper describes a sophisticated model of individual-level criminal behaviour. The paper utilises the OOD protocol[2] to describe the model and its validation. We then introduce, very briefly, some of the results from the model.

2. Overview

2.1. Purpose

The model is designed to a) allow for spatio-temporal predictions of burglaries at the city scale, both under current conditions and "what if" policy and other changes, and b) provide a framework for modelling and testing our understanding of the criminal system. The model does not, currently, predict the number of crimes, but runs to a fixed number of criminal events (usually the current crime figures) or for a fixed period or stopping criteria (usually until the spatial pattern of crimes stabilises). Predicting crime numbers would require an additional model relating agent histories to economic predictions. As the relationship between these elements of the crime system are far from well understood, the model currently assumes crime drivers are entirely based on individual-level steady-state economics (that is, each agent has a fixed non-crime income that does not vary) and the needs of the individuals that the income must satisfy (drugs, socialising), along with key biological drivers (in this case, sleep). The drivers have diurnal variations –

[2] V. Grimm, S.F. Railsback, *Individual-based Modeling and Ecology*, Princeton, Princeton University Press, 2005; V. Grimm, U. Berger, F. Bastiansen, S. Eliassen, V. Ginot, J. Giske, J. Goss-Custard, T. Grand, S.K. Heinz, G. Huse, A. Huth, J.U. Jepsen, C. Jørgensen, W.M. Mooij, B. Müller, G. Pe'er, C. Piou, S.F. Railsback, A.M. Robbins, M.M. Robbins, E. Rossmanith, N. Rüger, E. Strand, S. Souissi, R.A. Stillman, R. Vabø, U. Visser, D.L. DeAngelis, *A Standard Protocol for Describing Individual-based and Agent-based Models*, in "Ecological Modelling", Vol. 198, 2006, pp. 115-126.

the desire for sleep, for example, is stronger overnight – however we do not currently consider than these are nuanced enough for daily crime rates to be used to give realistic crime rates that could act as an indication of monthly or yearly total crime figures.

In addition, there is no notion of punishment or capture – offenders are not removed from the system, nor are their drivers adjusted by any kind of punishment. While guardianship and other variables will control whether a property is chosen for a crime, once a target is chosen, the crime is successful. There is also no communication between agents; all offenders are currently lone individuals without a shared understanding. The model generates a spatial distribution of crimes, taking into account a variety of offender behaviours, environmental factors, and victim and guardian attributes.

2.2. State Variables and Scales

The model is comprised of agents representing offenders. Victims and guardians are currently represented through environmental variables (for example, a probability as to whether a house is occupied), but current efforts are directed at an agent-based representation of victim behaviour[3].

The attributes for the offenders fixed at initiation are:

- Household: this is derived from real offender data. Agents are randomly allocated within their real postal codes.
- Drug supplier: allocated randomly from a pool of potential drug suppliers in the area (established using data on approximate locations of convicted drug dealers).
- Socialisation space: allocated randomly from all areas (socialisation biased on distance from home and the demographic similarity of the target area to the agent's home area).
- Period of sleep needed: 8 hours a day.

The model includes a fixed cost for purchasing drugs and socialising. Variables which change during the model run are then:

- Desire for sleep: varies throughout the day (see Fig. 1).
- Desire for drugs: builds after last intake.

[3] Cf. N. MALLESON, A. HEPPENSTALL, L. SEE, *Crime Reduction through Simulation: An Agent-based Model of Burglary*, in "Computers, Environment and Urban Systems", Vol. 31, 2010, n. 3, pp. 236-250.

- Desire for socialisation: highest in the evenings.
- Desire for wealth: varying diurnally (see Fig. 1).

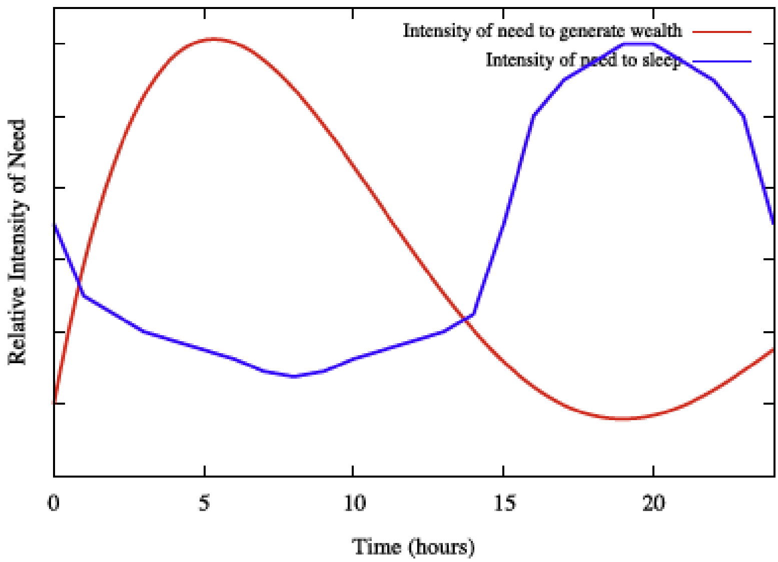

Fig. 1 – Examples of the variation in two variables

Each of the desire variables fluctuates throughout the day but can be zeroed by being satisfied. Each one additionally has a weight associated with it which represents the importance of this driver for a specific agent. Currently the agents are homogeneous with regards to their weights and variable change rates, however both could be varied as one way of introducing personality or other behavioural traits (e.g. level of drug addiction). Again, work on more heterogeneous agents is underway within a project looking at modelling burglar types.

- Wealth: this is dependent on the additions from burglaries and subtractions for drugs and socialising. One burglary will provide sufficient income for one day's drug use and socialising.
- Awareness space: this is a map of areas familiar to the agent, which builds up as they go about their daily business and is used in choosing target houses for burglary.

Objects within the environment build up a substrate which the agents act within. There are three types of objects: roads, a public transport network, and buildings. These then have attributes that subdivide them. Roads and public transport links have a type that controls the speed of movement of the agents along them. Buildings have a type that determines if they are houses, drug-dealer houses, socialisation spaces, or employment properties (some model versions incorporate the possibility of temporary legitimate employment). Houses have attributes which are taken from the area they are in or from their geographical properties (building footprint) and which control the likelihood of burglary.

The associated fixed values are:

- Geometry of the objects (e.g. house and garden dimensions): taken from British Ordnance Survey data.
- Type of object: taken from British Ordnance Survey data and the National Land Use Database. Drug dealer locations are based on real data, but randomised within their postcode areas.

The presence/absence of guardians associated with the house is represented by a score giving the house's attractiveness as a target. This is composed of variables associated with internal guardians (that is, the likelihood of occupation) and external guardians (passers-by, neighbours, etc.), and centred on the Rational Choice Perspective of Clarke and Cornish[4] and Routine Activities Theory of Cohen and Felson[5].

Occupation estimates are based on the works structure of the household, that is:

- Employment type of adults in the household: taken from employment distributions in the census, or
- Unemployment type: taken from unemployment, retirement, and studentship statistics in the census, and
- Family structure: taken from census statistics.

These variables are used to construct a probability of occupancy for each house, which varies during the day. For example, a household occupied by a worker will be unoccupied during the day but is fairly likely to be occupied in the evening, whereas one occupied by a student will have some probability

[4] R.V. CLARKE, D.B. CORNISH, *Modeling Offenders' Decisions: A Framework for Research and Policy*, in "Crime and Justice", Vol. 6, 1985, pp. 147-185.

[5] L. COHEN, M. FELSON, *Social Change and Crime Rate Trends: A Routine Activity Approach*, in "American Sociological Review", Vol. 44, 1979, pp. 588-608.

of being occupied during the day, but less likelihood of occupation in the evening.

This probability is then used within a further variable to fix the attractiveness of the house as a target. Additional variables used in this attractiveness score represent the likelihood that external guardians will prevent a burglary. These are:

- Collective efficacy: calculated from deprivation and demographic variation.
- Traffic volume: calculated using traffic estimates and space syntax.
- Accessibility: calculated using number of exterior property walls not shared by properties (window/door proxy).
- Visibility: estimated from garden dimensions and house arrangement.
- Security: given a default value initially (which has no effect on attractiveness) but then adjusted in a fixed radius around each burgled property for a set time period to represent temporary increased vigilance. This value decays with a half-life of one week based on expert advice.

In addition to these individual objects, there are also community areas. These are based on census geography areas (British Output Areas in this case) which have an attractiveness score associated with them. If burglars know the area they can use the attractiveness score to decide whether to travel to the area to search for target houses.

Area attraction is a combination of:

- Deprivation disparity: the disparity between the deprivation (measured using the UK government-published Index of Multiple Deprivation) of the agent's home location and the area they are considering to burgle – less deprived areas are more favourable.
- Inverse of the distance (in travel time) from the agent's current location – closer areas are more favourable.
- Comfort: assessed between the target area and the area in which the offender lives, using census-derived socio-economic groups. This gives an indication of how much a burglar will feel they 'stand out' in an area.
- Number of previously successful burglaries in the area.

Each of these variables has a weight associated with it as an attraction component, the value of which is calibrated in the final model.

As noted above, the number and location of offenders and drug dealers is taken from real data provided by local police partnerships. The model is usually run to the current annual crime numbers, to match annual reporting statistics and distributions, or until the spatial patterns of crime stabilise. The model runs on one minute time steps (1,440 iterations per simulated day), though there is no expectation that a year's crime numbers will currently take a year of model time to generate.

The environment is made of vector objects, largely derived from British Ordnance Survey datasets. A typical example of the original data is given in Fig. 2 (the model looks very similar when running). The model is usually run on the sub-city scale because of the computational demands of running for larger populations. Independent of this, the model areal size is not a limiting factor, and resolution is only important in giving sufficient detail to calculate object geometry.

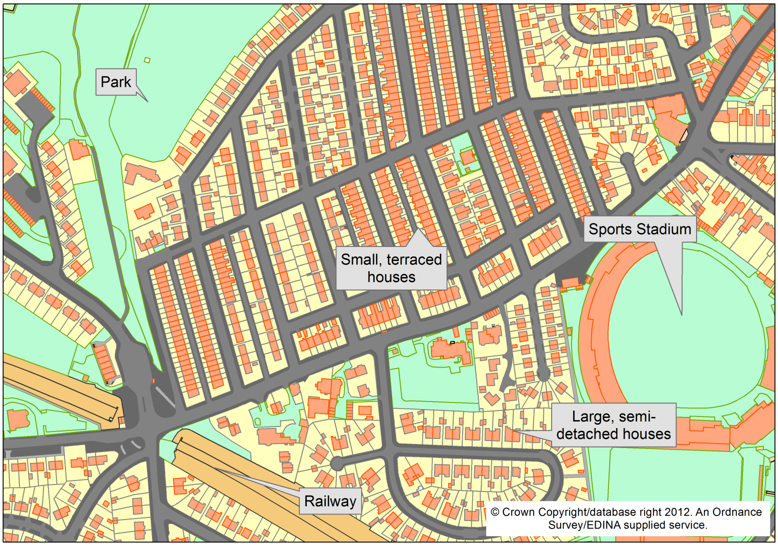

Fig. 2 – Ordnance Survey Mastermap

2.3. Process Overview and Scheduling

The model is initialised with data that allocates offenders to households, attributes to buildings and transport components, and initialises the state variables of the offenders. Offenders start with nothing in their awareness space. At each time step, all offenders decide on actions determined by their internal states. The sequence of offenders is random.

Offenders are modelled using the PECS framework (Physical conditions; Emotional states; Cognitive capabilities; Social status)[6]. At each time step they assess their desires (sleep, use drugs, socialise) and respond to the dominant one. If they need to, they will then opt for a wider plan of action and travel to an appropriate destination (drug dealer; burglary target; socialisation space).

If the desired action cannot be financed with current resources, the offender will burgle. Offenders identify a community area that will contain targets, based on areas they know and area attractiveness. Their awareness space is built up during their daily routines visiting anchor points associated with work, socialisation and drug buying (based on the Geometric Theory of Crime of Brantingham and Brantingham[7]). Target households within each area have an additional attractiveness that includes the ease of burglary. Agents travel to the identified target area by the shortest route weighted for ease of travel, searching as they go for easy target households. Once in an area they will randomly chose a house and use a search pattern that expands outwards, termed a "bulls-eye" search[8]. They take larger risks on targets (attack less easy targets), probabilistically dependent on the desperation of their driving need. If they do not find anywhere suitable in a given time, they pick a new area and repeat the process. If they do find somewhere suitable, the crime is assumed to be successful. The attractiveness of areas where a crime has been achieved increases for the burglar, however, the security of the burgled house and its neighbours also goes up for a period after the crime.

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[6] B. SCHMIDT, *The Modelling of Human Behaviour*, Erlangen, SCS Publications, 2000; B. SCHMIDT, *How to Give Agents a Personality*, in "Proceedings of the 3rd Workshop on Agent-based Simulation" (Passau, 7-9 April 2002); C. URBAN, *PECS: A Reference Model for the Simulation of Multi-agent Systems*, in Suleiman R., Troitzsch K.G., Gilbert N. (eds.), "Tools and Techniques for Social Science Simulation", Chapter 6, pp. 83-114, Heidelberg-New York, Physica-Verlag, 2000.

[7] P.L. BRANTINGHAM, P.J. BRANTINGHAM, *Notes of the Geometry of Crime*, in Brantingham P.L., Brantingham P.J. (eds.), "Environmental Criminology", Prospect Heights, Waveland Press, 1981, pp. 27-54; P.L. BRANTINGHAM, P.J. BRANTINGHAM, *Mobility, Notoriety, and Crime: A Study in the Crime Patterns of Urban Nodal Points*, in "Journal of Environmental Systems", Vol. 11, 1981, n. 1, pp. 89-99; P.L. BRANTINGHAM, P.J. BRANTINGHAM, *Environment, Routine, and Situation: Toward a Pattern Theory of Crime*, in Clarke R., Felson M. (eds.), "Routine Activity and Rational Choice", New Brunswick, Transaction Publishers, 1993; P.L. BRANTINGHAM, P.J. BRANTINGHAM, *Crime Pattern Theory*, in Wortley R., Mazerolle L. (eds.), "Environmental Criminology and Crime Analysis", Cullompton, Willan Publishing, 2008.

[8] G. RENGERT, *The Geography of Illegal Drugs*, Boulder, Westview Press, 1996.

3. Design Concepts

Agents have limited self-awareness and learning in this model. Character is attributed to the agents through adjustment to the weightings of their desires, the progressive changes to these desires on a repeating timescale (usually diurnal), and their starting environments. From the decisions made on these bases, and interaction with the spatial configuration of the urban environment and its attributes, patterns of crime emerge at the urban scale. The underlying behaviours are based on crime theory, as outlined above. Such theories predict specific abstract patterns of crime. The novelty of the model results come, in general, from two sources: the urban configuration, and from the comparison of the model results with real crime distributions that would not be predicted by these criminological theories.

In addition to making predictions, the model is thus useful for testing criminological theories against current crime data. It represents an experimental framework that encapsulates the theories of environmental criminology and allows their quantitative assessment and manipulation. This includes examining the behaviour of individual agents: in general the model is designed to produce a spatial distribution of individual crime events, however, individual agents do record their tracks over time, and these can be presented as spatio-temporal paths individually outside of the model. The current implementation of the model runs inside the Repast Simphony environment, and therefore has access to the geographical and graphical displays associated with that, but alternative datasets, such as individual paths, can be exported for external analysis.

4. Details

4.1. Initialisation

The model can be initialised with a wide variety of real or imagined data. In general, real data is utilised where possible. Details of the data utilised can be found in Malleson and colleagues[9]. Parameters controlling variable weights and behaviours are calibrated, either based on expert advice, the literature, or by hand. Hand-calibrated parameters are calibrated to minimise errors against a real dataset. Details of the calibration and verification of the

[9] N. Malleson, L. See, A. Evans, A. Heppenstall, *Implementing Comprehensive Offender Behaviour in a Realistic Agent-based Model of Burglary*, in "Simulation", Vol. 88, 2010, n. 1, pp. 50-71.

model can be found in Malleson[10] and Malleson and colleagues[11]. Work is currently underway on a parallel version of the model that will be calibrated by a genetic algorithm for comparison and exploration. Once calibrated, the model can be run with different urban and offender configurations.

In general the model produces spatial predictions, which are compared with real distributions for validation, and individual behavioural histories, which are examined for qualitative realism and quantitatively compared with aggregate dynamics, like average travel-path lengths.

4.2. Input

There are no dynamic inputs into the model. The parameters do not change during model runs, nor, in general, is new data injected into the model, though the capability exists. In general, socio-economic models like this could be greatly improved by the dynamic data assimilation techniques seen in other modelling fields[12]; however, a community response to the ethical issues involved in implementing data assimilation within social models would need addressing first[13].

4.3. Submodels

Submodels are extensive and described in detail elsewhere[14]. Information on the agent drivers and decision making can additionally be found in Malleson and colleagues[15]. Decision making for choosing victims can be found in

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[10] N. MALLESON, *Agent-based Modelling of Burglary*, PhD Thesis, School of Geography, University of Leeds, http://www.geog.leeds.ac.uk/fileadmin/downloads/school/people/postgrads/n.malleson/thesis-final.pdf, 2010.

[11] N. MALLESON, L. SEE, A. EVANS, A. HEPPENSTALL, *Implementing Comprehensive Offender Behaviour in a Realistic Agent-based Model of Burglary*, cit.; N. MALLESON, A. EVANS, A. HEPPENSTALL, L. SEE, *Evaluating an Agent-based Model of Burglary*, Working Paper of the University of Leeds, School of Geography, n. 10, 2010, pp. 1-84.

[12] A.J. EVANS, *Uncertainty and Error*, in Heppenstall A.J., Crooks A.T., See L.M., Batty M. (eds.), "Agent-based Models of Geographical Systems", Springer, 2012.

[13] A.J. EVANS, *A Sketchbook for Ethics in Agent-based Modelling*, Association of American Geographers (AAG) Annual Meeting (New York, 23-26 February 2012), http://www.geog.leeds.ac.uk/presentations/12-2/12-2.pptx.

[14] N. MALLESON, *Agent-based Modelling of Burglary*, cit.

[15] N. MALLESON, A. HEPPENSTALL, L. SEE, *Crime Reduction through Simulation: An Agent-based Model of Burglary*, cit.; N. MALLESON, L. SEE, A. EVANS, A. HEPPENSTALL,

Malleson and colleagues[16]. Search pattern generation can be found in Malleson and colleagues[17]. Data layer construction and use can be found in Malleson[18]. For transport routing, see Malleson[19].

5. Simulation Experiments

As this paper is a general description of the model, it is not our intention to present detailed results from the model, nor validation statistics, here. However, the reader may find it useful to have to hand a brief description of where these details can be found.

Early thinking on the model can be found in Malleson and colleagues[20], which set out to build an agent-based model of crime flows replicating earlier experiments in crime modelling that used spatial microsimulation and spatial interaction models[21].

A very full and detailed description of the data preparation and the model design process can be found in Malleson[22]. Details of the PECS model implementation and the drivers behind agent decision making are summarised in Malleson and colleagues[23]. Details of the model calibration and validation can be found in Malleson and colleagues[24].

Implementing Comprehensive Offender Behaviour in a Realistic Agent-based Model of Burglary, cit.

16 N. Malleson, L. See, A. Evans, A. Heppenstall, *Implementing Comprehensive Offender Behaviour in a Realistic Agent-based Model of Burglary*, cit.

17 *Ibidem*.

18 N. Malleson, *Agent-based Modelling of Burglary*, cit.

19 N. Malleson, *Using Repast to Move Agents Along a Road Network. Agent-based Crime Simulation*, 2008, http://crimesim.blogspot.co.uk/2008/05/using-repast-to-move-agents-along-road.html.

20 N. Malleson, A.J. Evans, T. Jenkins, *An Agent-based Model of Burglary*, in "Environment and Planning B: Planning and Design", Vol. 36, 2009, pp. 1103-1123.

21 C. Kongmuang, G.P. Clarke, A.J. Evans, *A Spatial Microsimulation Approach to Modelling Crime*, Proceedings of the British Society of Criminology Conference (Leeds, 12-14 July 2005); C. Kongmuang, G.P. Clarke, A.J. Evans, D. Ballas, *Modelling Crime Victimisation at Small-Area Level Using a Spatial Microsimulation Technique*, Paper presented at the RSAIBIS 35th Annual Conference (Stratford-upon-Avon, 17-19 August 2005).

22 N. Malleson, *Agent-based Modelling of Burglary*, cit.

23 N. Malleson, A. Heppenstall, L. See, *Crime Reduction through Simulation: An Agent-based Model of Burglary*, cit.

24 N. Malleson, L. See, A. Evans, A. Heppenstall, *Implementing Comprehensive Offender Behaviour in a Realistic Agent-based Model of Burglary*, cit.; N. Malleson, A. Evans, A. Heppenstall, L. See, *Evaluating an Agent-based Model of Burglary*, cit.

Applications of the model to validating current crime theory and "what if" simulations can be found in Malleson[25], Malleson and colleagues[26] and Malleson and Brantingham[27]. Results for simulations applied to the Leeds area have been the most successful. The model was able to suggest some *individual houses* that might have an increased risk of victimisation following a large urban regeneration scheme[28].

Issues with the application of the model to sub-optimal datasets can be found analysed in Malleson[29] and Malleson and Brantingham[30], while a discussion of the ethical issues associated with agent-based crime modelling can be found in Evans[31]. A comparison of the pros and cons of the model in relation to other agent-based models of burglary and other crimes can be found in Malleson and colleagues[32]. On-going work on the model can be found in Malleson and Birkin[33] and at http://crimesim.blogspot.co.uk/. Finally, a copy of the model, along with a stripped down version of the model suitable for building into other urban simulations (RepastCity), can be found at http://code.google.com/p/repastcity/.

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25 N. MALLESON, *Agent-based Modelling of Burglary*, cit.

26 N. MALLESON, L. SEE, A. EVANS, A. HEPPENSTALL, *Implementing Comprehensive Offender Behaviour in a Realistic Agent-based Model of Burglary*, cit.

27 N. MALLESON, P. BRANTIGHAM, *Prototype Burglary Simulations For Crime Reduction and Forecasting*, in "Crime Patterns and Analysis", Vol. 2, 2009, n. 1, pp. 47-66.

28 N. MALLESON, L. SEE, A. EVANS, A. HEPPENSTALL, *Implementing Comprehensive Offender Behaviour in a Realistic Agent-based Model of Burglary*, cit.

29 N. MALLESON, *Agent-based Modelling of Burglary*, cit.

30 N. MALLESON, P.L. BRANTIGHAM, *Prototype Burglary Simulations For Crime Reduction and Forecasting*, cit.

31 A.J. EVANS, *A Sketchbook for Ethics in Agent-based Modelling*, cit.

32 N. MALLESON, A.J. EVANS, A.J. HEPPENSTALL, L.M. SEE, *Crime from the Ground-up: Agent-based Models of Burglary*, cit.

33 N. MALLESON, M. BIRKIN, *Towards Victim-oriented Crime Modelling in a Social Science e-Infrastructure*, in "Philosophical Transactions of the Royal Society A", Vol. 2011, n. 1949, pp. 3353-3371.

An Interdisciplinary Approach to Multi-agent Systems: Bridging the Gap between Law and Computer Science

MIGLE LAUKYTE*

SUMMARY: *1. Introduction – 2. Law and the Development of MASs – 3. The Interdisciplinary Idea of Boundary Objects – 3.1. Communities of Practice as Users of Boundary Objects – 3.2. Lawyers and Computer Scientists: Two CPs on Different Sides of the Same Boundary Object - The Artificial Agent – 4. Autonomy as an Interface between Law and Computer Science – 4.1. The Concept of Autonomy – 4.2. The Concept of Autonomy in Law – 4.3. The Legal Autonomy of Artificial Agents – 5. Closing Remarks*

1. INTRODUCTION

Research in Multi-agent Systems - MASs has given rise to new issues in sociology, psychology, philosophy, and other social sciences, all the while providing new insights into some abiding issues. But legal science has not quite responded to these developments: the computational simulation of legally relevant social activities and phenomena is a research area that has yet to hit its stride. Why is that so? And what can be done to encourage the development of such simulation?

This paper attempts to answer these questions by developing two related ideas that, if brought to fruition, could change the current situation for the better: the first is the interdisciplinary idea of a boundary object; the second, that of an agent's autonomy.

As concerns the first idea, that of boundary objects, I argue that an important reason why the simulation of legal phenomena is not making as much headway as legal scholars and computer scientists would like is a certain language barrier that lawyers and computer scientists (in particular, software engineers) have to overcome if they are to achieve the sort of fluent communication needed to create a successful legal MAS. I do not speculate about the *causes* of this language barrier, but I do point out that one way in which it can be taken down is through an approach that – by bringing to bear the sociological concept of a boundary object, understood as an interactive object lying at the boundary between different disciplines – makes it possible for the

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relative research communities to relate to one another and work together in a mutually beneficial way (here, in building a legal MAS).

The second idea I bring into play and develop is that of the autonomy which can be ascribed to an artificial agent within an MAS. I work out a *legal* concept of autonomy by setting out the conditions satisfying which an agent's action can be deemed autonomous, in effect identifying a threshold of autonomous action that would trigger legal consequences. I argue that artificial agents have yet to reach this threshold, and I discuss the legal considerations that would have to be taken into account in light of this future development.

With that done, I tie this idea of autonomy to the previous discussion on boundary objects by treating autonomy itself as a boundary object. In other words, I illustrate how, if we can spell out in a clear enough way what autonomous action means in the law, and what the legal approach to such action ought to be, then we will also have a roadmap we can rely on in developing autonomous artificial agents and building MASs that would be more effective at simulating or reproducing social interactions in areas of activity which fall within the purview of the law. Autonomy so conceived would count as a boundary object by virtue of its lying at the intersection of law and computer science, but what is even more important is that the two broad communities (lawyers, jurists, and legal scholars on the one hand, computer scientists on the other) would be able to share ideas and solutions in working toward MASs "staffed" by artificial agents whose autonomy makes them at once practically intelligent (in replacing human agents) and legally cognizant.

2. Law and the Development of MASs

I take a broad view of MASs as any computational system made of artificial agents that interact and communicate with one another and with their environment, and where the system's overall behavior is more important than that of its single agents[1], and I take an equally broad view of artificial agents as any computational entity that has a role and can "do something" within such a system. An important application in this regard is the use of MASs to simulate or actually *do* the work that humans do in coordinative enterprises, meaning any task requiring some kind of coordinated action or relational interactivity: this kind of simulation has been attempted, for ex-

[1] A. Omicini, *Challenges and Research Directions in Agent-oriented Software Engineering. Autonomous Agents and Multi-agent Systems*, in "Challenges for Agent-based Computing", Special issue, Vol. 9, 2004, n. 3, pp. 253-283.

ample, in psychology[2], cognitive science[3], generative science[4], biology[5], economics[6], geography[7], political science[8], and transportation and logistics[9].

The common denominator to all these applications is that they all require different artificial agents to interact toward a common goal. Now, I would not go so far as to say that a legal system is driven by a common goal (other than that of peace and stability among equals[10]), but I would say that if anything can be identified as the object of law, that would have to be the interactive component of human endeavors, meaning that law arises wherever different people have to interact in such a way that one person's goals do not come into conflict with another's. Of course, this is a minimal, stripped down definition of law, and I do not so much pretend as to solve the abiding jurisprudential problem "What is law?" But at least this much can be

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2 S. BANDINI, S. MANZONI, G. VIZZARI, *A Multi-agent System for Remore Psychological Profiling with Role-Playing Games-based Tests*, in "Proceedings of the 2003 ACM Symposium on Applied Computing", New York, ACM, 2003, pp. 33-37.

3 C. CASTELFRANCHI, *The Theory of Social Functions: Challenges for Computational Social Science and Multi-agent Learning*, in "Cognitive Systems Research", Vol. 2, 2001, n. 1, pp. 5-38; C. CASTELFRANCHI, F. DE ROSIS, R. FALCONE, S. PIZZUTILO, *Personality Traits and Social Attitudes in Multiagent Cooperation*, in "Applied Artificial Intelligence", Vol. 12, 1998, n. 7-8, pp. 649-675.

4 J.M. EPSTEIN, *Generative Social Science: Studies in Agent-based Computational Modeling*, Princeton, Princeton University Press, 2011.

5 C.E. SANSORES, F. REYES, H.F. GÓMEZ, J. PAVÓN, L.E. CALDERÓN-AGUILERA, *BioMASS: a Biological Multi-agent Simulation System*, in "Proceedings of the Federated Conference on Computer Science and Information Systems - FedCSIS", IEEE Explore Digital Library, 2011, pp. 675-682.

6 A. SCHWAIGER, B. STAHMER, *SimMarket: Multiagent-based Customer Simulation and Decision Support for Category Management*, in Schillo M., Klusch M., Müller J., Tianfield H. (eds.), "Proceedings of the 1st German Conference on Multiagent Technologies (MATES 2003)", Lecture Notes in Artificial Intelligence, Berlin-Heidelberg, Springer Verlag, 2003, pp. 74-84.

7 A.U. FRANK, S. BITTNER, M. RAUBAL, *Spatial and Cognitive Simulation with Multi-agent Systems*, in Montello D. (ed.), "Spatial Information Theory – Foundations of Geographic Information Science", Berlin-Heidelberg, Springer Verlag, 2001, pp. 124-139.

8 T. YU, S.-H. CHEN, *Agent-based Modeling of the Prediction Markets for Political Elections*, in Villatoro D., Sabater-Mir J., Sichman J.S. (eds.), "Multi-agent Based Simulation", LNAI 7124, Berlin-Heidelberg, Springer Verlag, 2012, pp. 31-43.

9 M.P. LUCK, MCBURNEY, O. SHEHORY, S. WILLMOTT, *Agent Technology: Computing as Interaction. A Roadmap for Agent Based Computing*, http://www.agentlink.org/roadmap/al3rm.pdf, 2005.

10 See R.A. MANN, B.S. ROBERTS, *Essentials of Business Law and the Legal Environment*, Mason, South-Western Cengage Learning, 2010, p. 3.

agreed on, that wherever you have human interaction on a large scale (anything larger than face-to-face contact), there you have law, or the need for law, and wherever such a need arises, there also arises a need for rules. Rules are precisely the bread and butter of law, "the most pervasive and developed normative system"[11], the system we rely on to regulate human interaction (whether by design or by custom, or a combination thereof). So the question is: If law is so centrally concerned with regulating human interactions, and if MASs are so centrally concerned with simulating these interactions, why is there not much of an effort to design legal MASs, or MASs capable of simulating legally relevant social activities?

Such simulation could be put to use in different areas of law (civil, administrative, criminal, labour, family, etc.), drawing on the expertise of lawyers and legal philosophers alike, who in turn would find an interest in working out the ramifications of the activity in question. And, in fairness, some attempts have been made in working toward this goal[12]. But there is still much work to be done, and I speculate that the reason for this lies in part in a certain language barrier that is making it difficult for lawyers and computer scientists to work together. So, my idea is that if some common ground can be found – or a framework through which scholars and researchers who would not otherwise interact can do so – then we will have at least created the conditions for cooperation toward a common goal. It is here that the

[11] R. CONTE, R. FALCONE, *Introduction: Agents and Norms: How to Fill the Gap?*, in "Artificial Intelligence and Law", Vol. 7, 1999, p. 1.

[12] Examples are (*i*) the cadastral system described in A.U. FRANK, S. BITTNER, M. RAUBAL, cit., pp. 124-139, designed to simulate the transfer of rights in land, among other purposes, though the authors agree that in the future we will have to further investigate the way "simulations with multi-agent systems can help to explore how technical systems and legal requirements interact"; (*ii*) the crime-prevention model described in T. BOSSE, C. GERRITSEN, *A Model-based Reasoning Approach to Prevent Crime*, in Magnani L., Carnielli W., Pizzi C. (eds.), "Model-based Reasoning in Science and Technology Abduction, Logic, and Computational Discovery", Berlin-Heidelberg, Springer Verlag, 2010, pp. 159-177, which also makes policy recommendations based on the model; (*iii*) the development of MASs having the requisite of legal capacity to form binding contracts and carry out other legal transactions, see G. BOELLA, L. VAN DER TORRE, *Contracts as Legal Institutions in Organizations of Autonomous Agents*, in "Proceedings of the 3rd International Joint Conference on Autonomous Agents and Multiagent Systems", Washington, IEEE Computer Society, Vol. 2, 2004, pp. 948-955; and, more generally, (*iv*) the development of normative MASs, or agent-based systems whose functioning is based on social norms, though it must be stressed that this line of research is still in its infancy, see A. ROTOLO, L. VAN DER TORRE, *Rules, Agents and Norms: Guidelines for Rule-based Normative Multi-agent System*, in Bassiliades N., Governatori G., Paschke A. (eds.), "Rule-based Reasoning, Programming, and Applications", Lecture Notes in Computer Science, Berlin-Heidelberg, Springer Verlag, 2011, pp. 52-66.

idea of a boundary object comes into play, for I view such objects as key to any cross-disciplinary endeavor. This will be the subject of the next Section, where I introduce boundary objects so as to illustrate how they apply to the case at hand.

3. The Interdisciplinary Idea of Boundary Objects

The idea of a boundary object was first introduced more than two decades ago, in 1989 by Susan Leigh Star and James Griesemer[13], the former a psychologist and sociologist interested in information technology and science, and the latter a philosopher interested in biology. What they meant by the term "boundary object" was any object that different communities of practice use and conceive in different ways while still recognizing the object for what it is. Objects of this kind are liable to take on a variety of meanings depending on who is using them and for what purposes. This may seem to make it more difficult for us to deal with such objects, but it is actually an advantage, for otherwise everything in the world would consist of "rigid" objects each of which boxes us into a single use of it according to its proper conception. A boundary object, by contrast, is at once stable and plastic, or malleable: it is solid enough at its core that the different communities using it will still know they are essentially dealing with the same object, but it is "soft" around the edges, and in this way we can fashion it into different "shapes" depending on what we are trying to do with it and how. If you are now thinking, in light of this description, that *anything*, even the apple you are about to eat, can be a boundary object, you are right, because the term to a good extent describes not so much a kind of object as an *attitude* we take toward objects (the attitude I hope to encourage). In fact the idea has undergone its own evolution over the years, expanding its range to include, among other things, processes and even human beings: the only "requirement is that they be able to span boundaries separating social worlds, so that those on either side can 'get behind' the boundary object and work together toward some goal"[14]. That is precisely the idea I want to stress, and the corresponding collaborative attitude I would like to foster, in discussing

[13] S.L. Star, J. Griesemer, *Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39*, in "Social Studies of Science", Vol. 19, 1989, n. 3, pp. 387-420.

[14] T.F. Gieryn, *Boundaries of Science*, in Jasanoff S., Markle G.E., Petersen J.C., Pinch T. (eds.), "Handbook of Science and Technology Studies", London, Sage Publications, 1995, pp. 414-415. I should note here that Star and Griesemer themselves used the term *social world*, though they did not mean it to be coextensive with the idea of a community of practice.

the idea of a boundary object. But let us see how it all works by considering who the intended "users" of boundary objects are, the previously mentioned communities of practice.

3.1. Communities of Practice as Users of Boundary Objects

There are different conceptions of what a community of practice is[15], but perhaps the most comprehensive discussion of this idea is the one offered by Wenger[16], for whom a community of practice (or CP) is an "organic, spontaneous and informal"[17] group of people bound together by their expertise, interests, and goals, among other things. What makes them a community is (a) a shared interest in working on common problems and developing certain themes and (b) a shared repertoire of resources that they can draw on in that pursuit. The community would typically set out goals by involving its members in discussions and asking for contributions from them, but this does not mean that all members share the same goals. On the contrary, the landscape for action is wide, and so much latitude is afforded to the members to specifically frame their own goals within the broad outline. It follows that the goals framed by the community as a whole can be thought of as belonging at the same time to its members individually, precisely because each member is free to contribute to the community in an individual way. This introduces a dynamic nature of CP in that a CP evolves with and through its members, who do share common interest and a common store of knowledge, but they also shape that interest and carve that knowledge in specific ways, so that as a group they can engage in mutually reinforcing activities. As Wenger[18] puts it, "communities of practice create a dynamic form of continuity that preserves knowledge while keeping it current".

One can already see the basic analogy between this description of a CP and the previous description of a boundary object: just as a CP is bound by a core interest that each member develops in individual ways, so a boundary object can be said to have a core shape (that makes it recognizable as such) whose contours can be fashioned in different ways. And just as virtually

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[15] For an overview see A. COX, *What Are Communities of Practice? A Comparative Review of Four Seminal Works*, in "Journal of Information Science", Vol. 31, 2005, n. 6, pp. 527-540.

[16] E. WENGER, *Situated Learning: Legitimate Peripheral Participation*, Cambridge, Cambridge University Press, 1991; E. WENGER, *Communities of Practice: Learning, Meaning and Identity*, Cambridge, Cambridge University Press, 1998.

[17] E. WENGER, *Communities of Practice: The Organizational Frontier*, in "Harvard Business Review", 2000, Jan.-Feb., p. 140.

[18] E. WENGER, *Communities of Practice: Learning, Meaning and Identity*, cit., p. 252.

anything can be thought of as a boundary object, so virtually any group of people can be thought of as a CP: lawyers can form a CP just as moms can, for example, or even neighbors. Also, any person is likely to be in several CPs at once, at different levels of engagement, and for this reason no CP can be conceived as an isolate: CPs exist only as so many parts of the extensive, overarching social network. Wenger[19] expresses this idea by presenting CPs as "histories of articulation with the rest of the world", arguing that CPs "take the responsibility for the preservation of old competencies and the development of new ones, for the continued relevance of artifacts, stories, and routines, for the renewal of concepts and techniques, and for the fine tuning of enterprises to new circumstances"[20]. So let us consider a specific example of a CP, so that we can then see in practical terms how boundary objects fit into the discussion: let us take the community of artists. This community is made of people who share

- an interest in making art (expressing content through form and color) and
- a common vocabulary and general store of knowledge that they draw on in pursuing that activity.

The activity of making art is carried out in a dynamic way: it evolves, and furthermore, it does so by virtue of the mutually reinforcing engagement through which different artists go about their work. And it is here that boundary objects come into play: the vocabulary, materials, techniques, and ideas forming the common stock of resources that artists draw on in making art are themselves the boundary objects that enable artists to make art, or create, both as individuals and as a community.

How so? To see this, we need only to go back to the idea of a boundary object as something defined by a hard core enveloped in a soft shell. Suppose the object in question is art itself. We may not be able to define art, but at least we can recognize it when we see it. And that is precisely what boundary objects do: they enable the members of different CPs (artists, critics, consumers) to recognize them as objects of a certain kind (a work of art, a cubist painting, a watercolor), all the while making it possible for each CP to fashion and conceive the object in different ways, this (a) depending on what a particular CP is trying to achieve, and (b) by sharing knowledge and ideas with others in the same community (with other artists, critics, or consumers of art).

[19] *Ivi*, p. 103.
[20] *Ivi*, p. 252.

As can be surmised from the example just made, boundary objects are something of a double-edged sword: they can promote collaboration among different communities, but they can just as easily be a source of dissension, precisely because each such object is amenable to a variety of uses and interpretations. In fact, each CP is liable to assert its own understanding of a given boundary object, rejecting all other conceptions of it as irrelevant or even wrongheaded. This is an inherent risk but not necessarily a disadvantage: as I am trying to argue, diversity of interpretation can be an asset, rather than a liability, because it can support a dynamic of mutual reinforcement among different CPs.

A final point is that the multiplex nature of boundary objects holds not only for abstract entities (like art, color, form, and realism) but also for more concrete ones, like color contrast, *chiaroscuro*, and even oil color. In other words, just as we can all recognize something as art even though we may disagree on its way of "capturing" that concept, so we can all recognize oil color as such while making different uses of it depending on what purposes we are driven by in that regard. For example, a painter and a manufacturer might have an equal interest in the permanence and stability of a given oil color but will be driven by different purposes, the former looking to achieve the color effect with which to express himself, the latter instead looking to market a product recognized for its quality. So, in summary, a boundary object does not just admit of different uses and corresponding interpretations, but would not even exist without a constellation of CPs revolving around it, that is, without different communities using it in different (possibly mutually empowering) ways.

3.2. Lawyers and Computer Scientists: Two CPs on Different Sides of the Same Boundary Object - The Artificial Agent

Let us see how the concepts just illustrated can be brought to bear on the idea of agents as boundary objects providing an interface between lawyers and computer scientists. The point of the discussion is, of course, to show how the two communities might be able to work closer together, to the degree that one would expect given the legal implications of what it means to use artificial agents to simulate human interaction in various areas of activity.

At first glance, the two CPs – lawyers on the one hand, computer scientists on the other – seem quite removed from one another, the former working in what might be termed a social science, or at least a human science, and the latter in an exact science, especially as concerns software engineering[21]. So let us see how two apparently unrelated CPs might be able to come together and collaborate in dealing with artificial agents (the building blocks of a MAS).

To begin with they need to identify a common interest, or a broad problem that they work on in tandem. This was hinted at earlier on in the discussion when it was pointed out that every MAS is an interactive system and that interaction – or rather, the *rules* by which interaction among artificial agents is regulated – is a central concern of law. This introduces at least two lines of research centered on the idea of a rule. The first of these can be captured in the question (*a*) How can artificial agents be designed to simulate the actual working of legal rules, or the legal effects of human action and interaction? This line of research can in turn be broken down into two strands, concerned with the simulation of either (*a.1*) acts *in* the law or (*a.2*) acts *of* the law, the former class comprising any "act that is intended to create, transfer, or extinguish a right and that is effective in law for that purpose; the exercise of a legal power (also termed *juristic act*, *act of the party*, *legal act*)", and the latter "the creation, extinction, or transfer of a right by the operation of the law itself, without any consent on the part of the persons concerned (also termed *legal act*)"[22]. And the second line of research can instead be encapsulated in the question (*b*) How are we to work out the legal implications of what artificial agents do *as artificial agents*, rather than as agents designed to simulate *human* action and interaction under the law?

And now, having identified a common interest between two otherwise unrelated CPs, we will have to identify a shared vocabulary. We do so by identifying the appropriate boundary objects, and two candidates immediately suggest themselves in this respect: the first is the concept of a rule (as just considered) and the second that of an agent. The former concept I will not take up here: it is a subject best discussed at some length in a dedicated investigation. The latter concept, that of an agent, is likewise a boundary object in that the two CPs clearly use the same term in different ways – the term *agent*, designating *artificial* agents for one CP, and someone acting on another's behalf for the other – but they also recognize that at some level they are dealing with the same thing. One might justifiably ask here how

[21] C.A.R. HOARE, *An Axiomatic Basis for Computer Programming*, in "Communications of ACM", Vol. 12, 1969, n. 10, pp. 576-583.

[22] S.v. "Act in the law" and "Act of the law" in B.A. GARNER (ed.), *Black's Law Dictionary*, 7th ed., St. Paul, West Group, 1999.

that is possible, considering the distance that separates the two CPs, but remember that a boundary object always has a solid core, and I submit that this solid core lies in the idea of autonomy, in that nothing can be described as an agent unless it is to some extent capable of autonomous action.

That is an idea to which we turn in the next Section. But in the meantime I should note that what applies to *agents* as boundary objects also applies to *artificial* agents as such objects. Here, too, we can see that software engineers and lawyers will approach artificial agents from different angles, the former with an interest in developing MASs designed to carry out complex, interactive tasks, the latter with an interest in working out the legal consequences that flow from such activity (research line *b* above). Software engineers accordingly treat artificial agents as abstract entities forming part of an overall interactive complex of elements, each driven by a goal functional to the broader goal for which an MAS is developed[23]. And lawyers, for their part, see artificial agents as fictions, that is, they create the legal fiction of an artificial agent as an *actual* agent (a person) so as to apply to that entity the rules that would apply to any other subject in a similar position under the law; or they see artificial agents as products, with a corresponding interest in product liability and the law that applies to products as works of authorship (copyright) or as inventions (patent law)[24]. But even here, where artificial agents are concerned, we can take the concept of an agent's autonomy as the core content through which different communities can relate in dealing with artificial agents[25]. And so an artificial agent can be understood as a boundary object having autonomy as a core property through which different CPs can interface so as to complement each other's work, in that the concept of

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[23] On artificial agents as abstractions, see M. WOOLDRIDGE, P. CIANCARINI, *Agent-Oriented Software Engineering: The State of the Art*, in Ciancarini P., Wooldridge M. (eds.), "Agent-Oriented Software Engineering", Berlin-Heidelberg, Springer Verlag, 2001, pp. 1-28.

[24] For an overview of the legal perspective on artificial agents, see G. SARTOR, *Cognitive Automata and the Law: Electronic Contracting and the Intentionality of Software Agents*, in "Artificial Intelligence and Law", Vol. 17, 2009, pp. 253-290; and S. CHOPRA, *Rights for Autonomous Artificial Agents?*, in "Communications of the ACM", Vol. 53, 2010, n. 8, pp. 38-40.

[25] This core content has been extended to also include intelligence and intentionality. The list can be extended even further (see, for example, S. WILLMOTT, *Illegal Agents? Creating Wholly Independent Autonomous Entities in Online Worlds*, 2004, http://www.lsi.upc.edu/dept/techreps/llistat_detallat.php?id=695), but the point, where we are concerned, is not so much to agree on a list of core properties as to see in these properties points of contact enabling different CPs to work on joint projects.

autonomy informs the vocabulary of both lawyers and software engineers. Let us see, then, if we can flesh out this idea a little further.

4. Autonomy as an Interface between Law and Computer Science

We will be considering in the rest of this discussion how the concept of autonomy – especially as applied to artificial agents within an MAS – can offer a platform for collaborative action between two areas of practice: law and computer science. To see this, we will first briefly consider the concept of autonomy in philosophy and will then work out a *legal* concept of autonomy so as to set out the conditions satisfying which an agent's action can be deemed autonomous, in effect identifying a threshold of autonomous action that would trigger legal consequences (research line *b* above). I argue that artificial agents have yet to reach this threshold, and I discuss the legal considerations that would have to be taken into account in light of this future development. With that done, I tie this idea of autonomy to the previous discussion on boundary objects by treating autonomy itself as a boundary object and arguing that if law and computer science will look at autonomy in this light, positive results will come out of research on MASs.

4.1. The Concept of Autonomy

One way to broach the subject of autonomy is to consider all the terms that scholars in the humanities have associated with this concept: we find freedom, liberty, independence, choice, decision-making, dignity, integrity, authenticity, the self, individuality, personality, rationality, reflexivity, and strength of will, among others[26]. This gives us a flavor for what autonomy can involve, and since there is much disagreement about the role that each of these terms plays in shaping the concept of autonomy, Dworkin has come to the conclusion that "the only features held constant from one author to another are that autonomy is a feature of persons and that it is a desirable quality to have"[27].

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[26] The longer list, with an account of how each of these terms is related to autonomy, can be found in D. Milligan, W. Watts Miller (eds.), *Liberalism, Citizenship and Autonomy*, Aldershot, Avebury Ashgate Publishing Ltd., 1992.

[27] G. Dworkin, *The Theory and Practice of Autonomy*, Cambridge, Cambridge University Press, 1988, p. 6.

I take the stronger view of autonomy as a core property of agency, or personhood, because (among other reasons) I am interested in finding a basis on which different communities can work collaboratively in reasoning about agents. For this purpose I turn to Kant, not only because he gave us the modern conception of autonomy such as it applies to us as practical moral agents[28], but also because in so doing he set out a broad framework that can be used to shed light on the different areas of practice where autonomy has a role.

Kant bound together in a tight knot the ideas of freedom, autonomy, and moral personality. He essentially said that to be a moral person (in essence a *person*) is to be autonomous, and that what it means to be autonomous is to govern oneself according to the moral law, a law we receive from our common human reason and impose on ourselves by self-legislation: this is something we *choose* do to, that is, we are free to follow the moral law (freedom of will)[29], but if we choose not to, then we shed our humanity, that is, we can no longer be said to exist as moral agents. Thus moral personality (or personhood) implies autonomy, which in turn implies freedom (free will), but we can only be free if we follow the moral law of common human reason[30]. Two points here bear comment. The first of these is that autonomy is a twofold concept, on the one hand it requires freedom, but then this freedom resolves itself into our ability to follow the moral law (to be our own law-givers), from which it follows that autonomy cannot just be equated with freedom: it is freedom responsibly exercised in accordance with the moral law, thus taking into account the *consequences* of our actions. And the second point is that the moral law, as a principle we find in our common human reason, is something through which we can relate to others according to what is right. The thrust of these two points is that autonomy in Kant can be understood as an

[28] The Kantian account figures prominently, for example in the political philosophy of John Rawls (J. RAWLS, *A Theory of Justice*, Cambridge, Harvard University Press, 1971) and also informs the work of O'Neil (O. O'NEIL, *Autonomy, Coherence and Independence*, in Milligan D., Watts Miller W. (eds.), "Liberalism, Citizenship and Autonomy", cit., pp. 203-225).

[29] "What else can freedom of will be but autonomy – that is, the property which will has being a law to itself?". See I. KANT, *Groundwork of the Metaphysic of Morals*, London-New York, Routledge, 2001 (1st ed. 1785), p. 107.

[30] It is through this common human reason that we can distinguish right from wrong in practical matters: "The commonest intelligence can easily and without hesitation see what, on the principle of autonomy of the will, requires to be done". See I. KANT, *Critique of Pure Reason*, Mineola, Dover Publications, 2004 (1st ed. 1781), p. 38.

inherently *relational* concept: it is not just our choosing a course of action on our own, but our doing so consistently with what *others* are doing.

This shows how the concept of autonomy can easily find its way into the law, for law itself is an inherently relational device, by which I mean that law is the primary technique we have for "getting along" even in contexts where we are perfect strangers to one another. And just as autonomy as a moral concept requires us to follow a moral law that takes others into account, so as a legal concept it can be construed as the basic attribute through which to ascribe responsibility, in that we can only be held responsible for something we did willingly on our own (autonomously), and to be held responsible in the law is to be made to recognize the consequences our actions have on others. But let us see in greater detail what it means to be autonomous in a legal sense, for in this way we can draw up a list of characteristics an artificial agent should satisfy to be counted as autonomous in that sense.

4.2. *The Concept of Autonomy in Law*

Law was earlier described as "the most pervasive and developed normative system"[31], but the full description reads, "and it is typically concerned with the government of autonomy". This should not strike us as surprising if we consider the idea in light of the foregoing discussion: if autonomy is central to a moral person's agency, and hence to practical reasoning at large, and if practical reasoning informs different areas of human activity – one of which is the law – then it only makes sense that autonomy should also be central to law. This is easily grasped as a general proposition, that law is called on to regulate our interaction as autonomous agents, but how is such autonomy understood as a specifically legal concept?

It should be noted, before we begin, that because we are considering autonomy in law proceeding from a philosophical account of autonomy, that account will inevitably inform the legal concept we wind up having: we will end up with a legal-philosophical rather than a strictly legal concept of autonomy considered from a lawyerly legal-positivist perspective. We do this precisely because, in this way – by taking a broader perspective than that of the law itself – we can hope to see solutions that would not otherwise be available from that more circumscribed perspective.

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[31] R. CONTE, R. FALCONE, *Introduction. Agents and Norms: How to Fill the Gap?*, cit., p. 2.

With that said, I begin by noting that autonomy can take on any of several meanings in law depending on the area of law we are dealing with (contract, labor, family, tort, international private and public law, etc.), on who the specific *subject* of law is (a citizen, a worker, a spouse, or an organization or a nation, etc.), and on what interests are being protected (freedom of contract, freedom of speech, occupational safety, etc.). So it is doubtful that there can be such a thing as "*the* legal concept of autonomy", but some commonalities can be found, and indeed Lapidoth[32] has distilled three broad meanings of autonomy in law: autonomy can be understood as (*a*) the right to act according one's own beliefs (positive freedom); (*b*) the ability to act independently of a centralized system (negative freedom, noninterference); or (*c*) the exclusive power of an entity to administer and rule on certain issues (regulatory and adjudicative power).

We can briefly consider the first of these three characterizations of autonomy (the right to act according one's own beliefs), for it seems to act conceptually as a condition for the second and the third one and can thus be construed as more foundational. Three features of this definition stand out. The first of these is that autonomy is defined as a right. This is somewhat startling, as it suggests that we have a right to be autonomous: What is the sense, one might ask, of stipulating a *right* to do what we already have the *power* to do as practical agents? But, as we will see shortly, the bewilderment goes away once we realize that rights are essentially the technical device the law uses to body forth the idea of autonomy: they are the legal implementation of autonomy. The second feature that stands out is how vague the definition is, for it does not specify what it means to act according to one's own beliefs: these could be religious (freedom of conscience) or they could be epistemic beliefs about the world or about what the best course of action is for us to take given what our goals are (autonomy as rationality). But here we can see that the vagueness is grounded in the conceptual difficulty (and inadvisability) of offering a one-size-fits-all definition of autonomy. And this in turn brings out the connection with philosophical accounts of autonomy, with the underlying idea of freedom of choice: consider, for example, Raz, for whom "a person is autonomous only if he has a variety of acceptable options open to him to choose from and his life became as it is through his

[32] R. LAPIDOTH, *Autonomy: Potential and Limitations*, in "International Journal on Group Rights", 1993, n. 1, p. 277.

choice of some of these options"[33]. And the third feature relates to the idea of autonomy as a right: it is widely known that rights in the law are correlative to duties[34], in that one person's right entails another's duty, and this means that autonomy is not just the right to freely make our own choices but also takes into account what those choices entail once acted upon. This goes back to Kant's conception of autonomy as something that binds together freedom and the moral law as a law that takes other agents into account. And the same basic principle is at work in the law as a relational device: the moment we speak of the rights one holds as an autonomous agent, we must thereby consider the consequences that follow from one's use of those rights and the responsibility that comes with that use[35] whence comes the whole cluster of legal concepts that includes liability, tort, damages, redress, restitution, and "making someone whole".

What the three foregoing features point to is that autonomy in law can be constructed as the *legal* implementation of a broad *philosophical* concept of autonomy: a practical agent's autonomy is implemented in the law by ascribing *rights* to that person; the moral power through which we exercise these rights is in law our *legal* capacity; and the same rights exist not in isolation but in the relational context of society, a context which brings into play the *consequences* attendant on our exercise of rights, and which in turn brings in the correlative idea of a duty (e.g., the duty or obligation to pay damages for violating another person's property rights).

Legal capacity is something the law ascribes to natural persons (human beings) or to artificial persons, understood entities created by natural persons and treated by law as if they were actual persons[36]. Examples are corpora-

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[33] The whole line of communitarian philosophy has raised strong objections to the idea of the moral agent as an autonomous individual with a number of options to choose from in the abstract, because every individual is embedded in a social context, and that context acts as a force in shaping our lives and persons. These are serious objections, to be sure, but we need not take them up here because they will not help us clarify the idea of autonomy such as it figures in the working of the law. See J. RAZ, *The Morality of Freedom*, Oxford, Oxford University Press, 1986, p. 204.

[34] See W.N. HOHFELD, *Some Fundamental Legal Conceptions as Applied in Judicial Reasoning*, in "The Yale Law Journal", Vol. 23, 1913, n. 1, pp. 16-59.

[35] Therein lies another similarity with the philosophical account of autonomy. Lucas, for example, argues that "I and I alone am ultimately responsible for the decisions I make and am, in that sense, autonomous" (J.R. LUCAS, *Principles of Politics*, Oxford, Clarendon Press, 1966, p. 101).

[36] S.v. "Artificial person" in S.M. SHEPPARD (ed.), *The Wolters Kluwer Bouvier Law Dictionary*, compact edition, New York, Wolters Kluwer Law & Business, 2011.

tions and partnerships, but what about artificial agents? Do they have the legal capacity the law ascribes to artificial persons? And does that make them autonomous in the eyes of the law? And what would be the implications of such an ascription? These questions I briefly discuss in the final Section below, where I also underscore that autonomy itself can be construed as a boundary object making it possible for different CPs (lawyers and computer scientists) to interact in working out the legal consequences of developing autonomous artificial agents (research line *b* above, as specified in Section 3.2.) and developing MASs that will simulate the actual working of legal rules (research line *a*).

4.3. The Legal Autonomy of Artificial Agents

In the foregoing discussion we considered two key concepts that, if cast in the right way, can serve as a platform enabling lawyers and computer scientists to work together in thinking about and designing artificial agents and MASs. These concepts are that of an agent and that of autonomy. We worked out the relation between these two concepts by arguing that autonomy can be construed as the core content of any entity which can be described as an agent. It was also argued that in this way we can conceive agents – and by extension *artificial* agents – as boundary objects, because once we have agreed on the idea of an agent as an autonomous entity, we have a criterion on which basis to tell an agent apart from a nonagent, and we can also proceed on this basis to design different types of agents and fit them into a legal scheme.

But it was further pointed out that the inquiry is not complete until we also have a notion of autonomy. We thus considered the idea of autonomy as a philosophical concept providing a basis for understanding what an agent's autonomy might mean in the law. The philosophical concept was analyzed as having the core content of self-government understood as an agent's ability to make its own decision about how to act. And it turned out that there are two sides to this feature of autonomy (the ability to set one's own course of action), for on the one hand it means that autonomous agents enjoy freedom of action, but on the other hand this freedom entails responsibilities, in that an autonomous agent is really free to determine its own action, and on a Kantian conception is authentically autonomous, only insofar as it takes into account the way in which *others* stand to be affected by such action. It was finally argued that these features of autonomy have been implemented in what might be described as the *legal* understanding of autonomy (however much this may be a misnomer, considering that the idea of autonomy takes a variety of inflections in the law depending on the area of law involved and on the subject or person to whom autonomy is ascribed): an autonomous person is one who is recognized as having legal capacity, namely, the freedom to do juristic acts understood as acts *in* the law (Section 3.2.), such as voting and entering into contracts; such legal capacity confers rights on the person recognized as having such legal capacity; and with these rights also come duties and responsibilities, because no person in the law is understood as an isolate but as someone living in the interactive context of society.

I should now point out that this makes autonomy itself a boundary object, precisely because we can identify in it a core meaning amenable to different implementations: its core meaning is what enables different CPs to recognize an autonomous agent as such, while its amenability to interpretation allows the same CPs to fashion the concept in different ways. And because none of these inflections can depart so much from the core content of autonomy as to prevent one CP from recognizing another CP's autonomous agent as such, we know that the two CPs can understand and work with each other on common projects.

The projects we are specifically concerned with are those that revolve around artificial agents and MASs, and we can now ask: When can an artificial agent be said to be autonomous in a legal sense? Because depending on how we answer that question we may need to work out a legal scheme through which to regulate the use of artificial agents[37] – an endeavor that would fall under research line *b* above – and it is only through a proper understanding of legal autonomy that software engineers can design MASs capable of simulating acts *in* the and acts *of* the law (research line *a*).

The first thing to consider as we turn to the question of what attributes an artificial agent will have to exhibit in order to be considered autonomous in a legal sense is what computer scientists themselves think about an artificial agent's autonomy. I would note in this regard that software engineers are not ready to consider artificial agents properly autonomous entities[38]. And

[37] G. SARTOR, *Cognitive Automata and the Law: Electronic Contracting and the Intentionality of Software Agents*, cit.; E.A.R. DAHIYAT, *Intelligent Agents and Liability: Is It a Doctrinal Problem or Merely a Problem of Explanation?*, in "Artificial Intelligence and Law", Vol. 18, 2010, pp. 103-121; F. ANDRADE, P. NOVAIS, J. MACHADO, J. NEVES, *Contracting Agents: Legal Personality and Representation*, in "Artificial Intelligence and Law", Vol. 15, 2007, pp. 357-373.

[38] T. SMITHERS, *Autonomy in Robots and Other Agents*, in "Brain and Cognition", 1997, n. 34, pp. 88-106.

I would further note that software engineers have a view of autonomy very much attuned to what was earlier identified as the core idea of autonomy as both a philosophical and a legal concept, namely, the idea of self-government, i.e., choosing one's own course of action. In Sycara, for example, an artificial agent's autonomy is defined as an agent's ability to control its actions and the internal states through which it deliberates on these actions[39]. However, in contrast to the idea we have of the autonomy ascribable to a subject of law having legal capacity, an artificial agent's control over its own internal states is limited to its ability to establish the means of getting to an end without also choosing the end itself[40]. In other words, at the current state of technology, artificial agents are autonomous in determining *how* to do something but not in determining *what* to do.

I believe that in this distinction lies a bright-line test for determining whether an artificial agent can be regarded as autonomous for the purposes of the law: an artificial agent can be so regarded – as an agent with legal capacity – only if designed so that it can make determinations about the *ends* of its own action (rather than only about the means of action). And I further believe that in combination with that criterion we should also consider the *range* of ends an artificial agent can decide to pursue: if that range is a finite, predetermined set, the computational entity in question cannot be deemed autonomous in a legal sense (just as no human person can be deemed autonomous in the law if he or she is acting under duress, a circumstance under which the person would no longer be held accountable for those actions). So, if we combine these two criteria, we would come out with this broad rule: an artificial agent can be deemed autonomous under the law, or an artificial person with legal capacity, if (*a*) it can choose its own ends of action (rather than only the means to such ends) and (*b*) these ends are not a finite set[41].

5. Closing Remarks

If we can agree on a legally relevant idea of autonomy, we will have a basis on which to work in setting out a corresponding set of rights and responsi-

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39 K.P. Sycara, *The Many Faces of Agents*, in "AI Magazine", Vol. 19, 1998, n. 2, pp. 11-12.

40 D.J. Calverley, *Imagining a Non-biological Machine as a Legal Person*, in "Artificial Intelligence and Society", Vol. 22, 2008, n. 4, pp. 523-537.

41 Computer scientists speak in this latter sense of autonomous artificial agents as capable of interacting with their environment (in a reactive as well as in a proactive way) and of learning from experience.

bilities. The two-part test offered in the previous Section can serve as a basis for thinking about such rights and responsibilities (a task that computer scientists have already entrusted to lawyers[42]). And it makes sense to think, as a matter of principle, that the more an artificial entity becomes autonomous – indeed the more it resembles a natural person with the moral power to act *for a reason*, or else to distinguish right from wrong and to act accordingly – the greater will be the cluster of rights and duties ascribable to this entity and to those it interacts with.

But the broader comment I would like to make as we wind down is that a good way to think about these issues is the interdisciplinary approach we can take by viewing our basic concepts as boundary objects: this holds not only for the concepts of agent and autonomy, but also for the related concepts of person, moral capacity, rights, and responsibility, among others. If we can think in those terms, we can take down the barriers that might divide different areas of practice: we can do so by finding a vocabulary that makes sense to the communities in these different areas, and in this way we can foster the sort collaborative enterprise needed to attack problems such as those we have been considering in connection with MASs and artificial agents.

[42] See P.M. ASARO, *What Should We Want from a Robot Ethic?*, in "International Review of Information Ethics", Vol. 12, 2006, n. 6, pp. 9-16.

Information Extraction and Social Network Analysis of Criminal Sentences. A Sociological and Computational Approach

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1. INTRODUCTION

A main objective of our research is to obtain a description of the socio-economic environment characterizing a trial leading to a criminal sentence, as well as the differences in the conduct of the trial between different jurisdictional administrations.

In this paper we study the juridical response to organized crime activities in Sicily[1], Italy, by analyzing a *corpus* of criminal sentences using computational techniques of information extraction and social network analysis. In particular, the analyzed criminal sentences were pronounced in the four courthouses of Sicily from 2000 through 2006, and were declared irrevocable for at least one defendant. A first element of originality of this paper is in the choice of the source of sentences: criminal sentences are tools of social regulation (although as outcome of a trial), and are used as a "magnifying glass" to study mechanisms and contexts from which one can deduce the real

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[1] C. PENNISI, G. GIURA, *Un'analisi empirica della giurisprudenza sulla criminalità organizzata e di tipo mafioso*, in "Antigone", 2009, n. 2-3, pp. 125-162.

balances of power and value hierarchies established by the institutional response to organized crime and mafia-related crimes. A second element of originality is the synergy, pursued since the phase of data retrieval, between computer scientists and social scientists when it comes to methodology and the approach of the research team.

By using direct (expert-based) knowledge of the semantic importance of the source of sentences, we made a preliminary coding and performed statistical exploration of a *corpus* of sentences. To the same *corpus*, we designed and applied automatic textual extraction algorithms trained using computational machine learning techniques. A result of using this approach, especially compared to the source of judiciary statistics, has the following advantages: a larger variety of the information material contained in the sentences, greater reliability of the classification of the crime categories dealt by the sentences, greater versatility of the information to the cognitive requirements of the researcher rather than that of the administrative monitoring requirements of the judiciary machine.

We use all of these advantages and report here on our results of information extraction and social network analysis between actors (pairs of actors that repeatedly co-occur in the text). An outcome of our result is the study of a social network with several familiar properties, which suggests that the combination of information extraction and social network analysis may provide novel insights on crime as a social phenomenon.

In this paper we describe the first example in Italy of a large digital archive of criminal sentences and demonstrate how a computational structural analysis can be performed on the *corpus* of data.

1.1. Criminal Sentences from a Sociological Perspective

In the analysis of the jurisprudence a sentence is the result of a reconstruction process of reality that depends on the purpose for which such reconstruction is made (that is to judge), and on the (juridic) technique used in order to arrive to the qualification of the facts.

The judge must evaluate using the current law, and therefore his action is limited to the possibilities contemplated by the law. This inevitably implies, on the one hand, that the qualificatory process influences the way that the reality is reconstructed in the sentence and, on the other hand, that the outcome of the sentence will depend upon what the judge will deem significant for the application of the relevant norm to the concrete case. Moreover, difficulties stem because, on the one hand, juridical constructs live on infrequency, that is, they are not ascribable to dogmatic constructs in which one can make out methodologies and objectives, and on the other hand, they are the result of a juridical culture that uses proximity models followed by the judge.

Until now, the reflections on the jurisprudence as a topic of research, with an explanatory focus of the interplay between juridical and social dimensions in the judiciary institutions are limited, especially in Italy, both in the juridic doctrine and in the philosophic and sociologic analysis. Little is known, since these analyses suffer from a lack of empirical studies. Considered as a meeting point of different philosophies coming from different interests coming from different interests in the social system, juridical decisions can represent a significant magnifying glass of mechanisms and phenomena that, although still considered within the "area" of the process, are a precious source of information for those which are motivated by heuristic needs: the juridic decision, "because of its attitude to become an immediate tool of social regulation, can form an indicator [...] of the real balances of power [...] existing in a society"[2]. The construction of the juridical reality as expression of the complexity of a social phenomenon that comprises, or at least, interacts with the juridical phenomenon is far from being ascribable to a paradigm oriented for the understanding of basic mechanisms; it is rather mainly oriented to the construction of meta-theorization which tends to overlook the observation of the phenomena. In this context, however, the debate exhibits a consciousness raising of the unilateral perspective employed until now in the formulation of possible theories on the juridical phenomenon in its entirety (be it that of the judge, of the legislator, or of the citizen), thus considering the different roles and the different perspectives of the analysis.

From this point of view, a perspective of socio-juridical analysis may be fertile; pointing out that the scientific character of sociology of law, today, is the employment of methodological tools that allow it to understand and describe in a scientifically-founded way, on one hand, the proper function of the modern jurisprudence, and on the other hand, the empirically observable reality of the behavior of jurisprudence operators or subjects interacting with the juridical system.

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[2] O. ABBAMONTE, *Le ragioni del decidere. Per un possibile studio della giurisprudenza e della mentalità del giudice*, in "Sociologia del diritto", Vol. 28, 2001, n. 2, pp. 5-44.

The incremental development of the analysis of sentences has mainly considered the areas of civil jurisprudence and the case law of the Court of Cassation (more than in the penal area), favoring an analytic-classificatory approach. The techniques of analysis are the classic ones of the traditional dogmatic investigation (given a sentence, analyze citations as well as massive basic comments from jurisdictional authorities to see what differs from the regularity of many previous pronounced sentences) applied to the study of the juridic material. Also, the common methodology of investigation is suited to the formation and cultural interests of the jurists that use it. Moreover, the examination of the sentences and of the tendencies of the jurisprudence is almost always inside the source, that is analyzed in its structural and argumentative components, with notably lucid results for knowing what and how the judge has pronounced and how much reliable and reasonable his conclusions are, on the basis of the logic coherence of the arguments contained in the decision. In this sense, the decisions, which fully enter in the "material sources" of the positive jurisprudence, would constitute the written document to interpret using as a key reading the linguistic signs that compose it. According to Abbamonte[3], the limit of this kind of methodological orientation is that a significant part of the cognitive contribution that the analysis of the juridical material could supply remains unexplored. He argues over the importance of the historicization, of the juridical decisions with respect to the connections with the political, economic, social, and ideological contexts that could have caused them, in order to "have access" to the qualifying moments of the juridical source (namely that define the characteristics of the jurisprudence source), and to search in the depths of the politics that the jurisprudence pursues. In other words, the question arises as to reconsider our understanding of the law, since this vision implies a process in which the so-called "internal legal culture" moves, communicates, both to its members and to the so-called "external legal culture", a perspective of reality that it is substantially theoretical in nature. This means that this reality, so represented, is disconnected both from the social and cultural contexts in which it originated and from the facts in which it is produced, because it is a result of logical constructs that can be good for each "historical time". The problem of rethinking the way of understanding the jurisprudence arises in many ways in the debate faced by the sociology of law. With a growing attention to the trial, to the mechanisms, and to the relation between the roles as a measure to observe

[3] *Ibidem*.

the real balances of power and relational hierarchies the sentence becomes a natural ground of the possible explanatory and observing these phenomena.

1.2. Outline of This Work

Although the *corpus* of criminal sentences is limited in both time and space, the results of the analysis are significant for three main reasons: there is not yet in the literature a comparative analysis of criminal sentences pronounced at the four Sicilian courthouses or in the rest of Italy: the present one is hence at the best of our knowledge a seminal work; there is not yet a digital database collecting data on the institutional response to the phenomenon of organized crime activities in Sicily: the present work may hence be used as a starting experience toward the creation of such knowledge base; in the case of organized crime activities, the Sicilian jurisprudence *de facto* orients the Italian jurisprudence and it is hence relevant to better investigate the internal working of this activity.

Our research is organized into three main stages[4]. In the first stage, we collected the criminal sentences from the courthouses of Sicily. Since there is not yet a digital archive of criminal sentences in Sicily, all sentences had to be collected in their paper format. The paper sentences have been scanned into digital format, and then converted into plain text files by means of computer-based OCR technology. Furthermore, we have constructed a codebook, which is basically a collection of well-thought variables to be devised from the text of each criminal sentence. This is described in Section 2. and Section 3.

In the second stage, the text files were analyzed using information extraction technology, in order to extract from the text of the sentences the actors involved in the facts and the relationships between them. In particular we extracted information on the judge, the members of the court, the prosecutor, the defendants, the lawyers, and the other people involved in the sentence facts. Relationships between actors were also extracted. The information extraction has been performed by implementing opportune *finite state transducers*, automatons capable to recognize specific patterns in an input string. This is described in Section 4.

[4] D. De Felice, G. Giuffrida, G. Giura, C. Zarba, *La descrizione dei reati di criminalità organizzata e di tipo mafioso nel testo delle sentenze*, in "Quaderni di Sociologia", Vol. 54, 2010, n. 54, pp. 57-80.

In the third stage, we constructed a social network using the information extracted so far. The social network consists of the nodes that are actors and edges denote repeated co-occurrence in *corpus* texts. The resulting network was inspected in order to detect central nodes as well as communities. These nodes should be relative to pivotal character of the trials. This is described in Section 5.

We also discuss limitations as well as possible avenues of our research and conclude our paper. This is done in Section 6.

2. Data Collection

We have restricted the analysis of criminal sentences according to the following criteria:

- the sentences describe only mafia crimes: these are those encompassed by the Italian criminal procedure code, Article 51.3-bis;
- all sentences were declared final and irrevocable for at least one defendant;
- all sentences have been pronounced by Sicilian judicial authorities between January 1, 2000 and December 31, 2006.

Since in Italy there is not yet a unified digital database of criminal sentences, it was necessary to perform a complex and time-consuming data collection activity in order to gather the criminal sentences required for our analysis. The entire process took more than two man-years work. Specifically a preliminary interrogation to the Italian computerized archive RE.GE. – the general register of criminal proceedings – has been performed. This interrogation has been parametrized with the criteria above and produced a list of about 1,200 criminal sentences satisfying our query. Then a formal request to the applicable Sicilian courthouses has been made in order to gain physical access to the paper printed criminal sentences. After the authorizations were granted, we went physically to the various Sicilian courthouses in order to obtain copies of the files. Eventually we collected 1,147 sentences; we performed an extensive manual data quality verification process. Due to misleading classification in the RE.GE. archive, only 728 criminal sentences really satisfied all our criteria. For instance, about 90% of the non-pertinent criminal sentences were initially recorded in the RE.GE. as concerning illicit drug smuggling. These sentences were later assessed as concerning the less grave crime of Art. 73 of the same DPR (*Decreto del Presidente della Repubblica*, a statute law), but without this correction being made in the RE.GE.

The entire remaining set of criminal sentences is made of about 55,000 pages, and the sentence length varies from a minimum of 2 pages to a maximum of 3,268 pages. Every page has been scanned producing digital (pdf) files, and processed with computerized (OCR) technology in order to produce plain text files suitable to automatic computerized analysis.

The collected sentences can be classified according to authority, degree of judgement and proceedings format, as shown in the following tables, where the rows indicate the authority entitled, the degrees (first three for the first degree and last two for the second degree) of judgements in the Italian judicial system, while the columns indicate the proceedings format (Tab. 1).

Authority	Standard	Abbreviated	Plea	Total
GIP/GUP	0	147	117	264
Tribunale	115	2	6	123
Corte d'Assise	11	2	0	13
Corte d'Appello	89	10	62	161
Corte d'Assise d'Appello	90	4	73	167
Total	305	165	258	728

Tab. 1 – The collection of 728 sentences on which the rest of the analysis is based

3. The Codebook

While analyzing the collected criminal sentences, we specified a codebook, whose purpose is to organize the results of the analysis. More precisely, the codebook consists of a table that contains one row for each criminal sentence. The columns denote classificatory variables that describe the features of the criminal sentences that are important for the analysis[5].

The process leading to the specification of the codebook started with an initial *a priori* definition of the variables. Then, each sentence has been read by human experts and analyzed in order to fill the codebook. While the criminal sentences were analyzed, the specification of the variables of the codebook has been gradually refined. Many sentences had to be re-analyzed several times. This manual approach is satisfactory to meet the designed goals, but it definitively limits additional analysis based on different variables. The lesson learned at this stage has been, hence, that an automatic process to har-

5 A. Bruschi, *Metodologia delle scienze sociali*, Milano, Bruno Mondadori, 1999; A. Bruschi, *Metodologia della ricerca sociale*, Roma-Bari, Laterza, 2005.

vest variables from free text is imperative in order to avoid long repetitive manual processes.

At the end of the analysis, the final codebook is made of 44 variables belonging to four categories: temporal, procedural, social, and environmental.

The *temporal* dimension includes variables describing the durations of each phase of the trial process, starting from the registration to the RE.GE., including the pronouncements of the verdicts at each degree of judgement, and terminating with the final declaration of irrevocability of the sentence. Therefore, the total duration of the trial process can be ascertained. The *procedural* dimension includes variables describing the legal events occurring during the temporal dimension. These events include custody measures, proceedings formats, contested crimes, modifications and integration of contested crimes, recognition of extenuating circumstances, and the final verdict. The *social* dimension includes variables describing the occupation or profession of the defendants, as well as their social and economic conditions. The *environmental* dimension includes variables describing the geographic, political, and institutional, aspects of the events discussed in the sentence. They also identify the economic sector that is harmed by the contested crimes, and report the official quantification of the economic cost suffered because of the contested crimes.

Making observations efficiently depends on the data being relatively structured, and the variables outlined above indicates the information which is possible to collect. However, making observations from the text in general would be a cumbersome manual process due to the size of the material. We proceed to describe an attempt to automatically extract structural information from the *corpus* of 728 sentences.

4. Information Extraction

Information extraction is generally the process of extracting structured data from "unstructured" (or explicitly less structured) observation. In this research we consider the extraction of relational data from natural language documents[6]. Typically, given a document written in natural language, there are four kinds of information that can be extracted: entities, attributes, relations, and events. Entities can be individuals, things, dates, or measurements. Attributes are features associated to entities. For instance, an individual has

[6] S. Sarawagi, *Information Extraction*, in "Foundations and Trends in Databases", Vol. 3, 2007, n. 1, pp. 261-377.

attributes like birthdate, birthplace, profession, education, title, telephone number, email address. Relations are associations between entities. Events are relations where time is of primary importance.

There are two main approaches to information extraction: deep and shallow. Deep information extraction is based on natural language processing. Information is extracted from the document by lexical analysis, semantic analysis, and the interpretation of the discourse[7]. Deep information extraction can be quite effective, but in some cases computationally too slow. Furthermore, the (manual) construction of the model necessary to carry out the interpretation of the discourse is complex and laborious. Shallow information extraction does not aim at a human-like comprehension of the document, but aims only at filling the relational tables. This is done using a pipeline consisting of a finite number of finite state transducers (FSTs). A finite state transducer takes a sequential input and, if some conditions are verified, returns an output that depends on the input and on the internal state of the transducer[8]. Essentially, a finite state transducer performs a simple linguistic task. The idea is that a finite number of simple linguistic tasks is sufficient in order to fill the relational tables.

4.1. Information Extraction from Criminal Sentences

We have implemented an automated analyzer that performs information extraction from our *corpus* of criminal sentences. Given a criminal sentence, our analyzer extracts the following entities representing individuals: judges, members of the court, defendants, lawyers, prosecutors, and other people involved. Our analyzer also extracts the crimes mentioned in the criminal sentence. Furthermore, it extracts, for each defendant, the lawyers(s) that represent them, and whether the defendant is convicted or acquitted. Finally, our analyzer extracts associations between entities representing individuals, by detecting when two distinct individuals co-occur in the same phrase of a criminal sentence. The extraction is performed by means of a pipeline of finite state transducers, and exploits the fact that Italian criminal sentences

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[7] K. HUMPHREYS, R. GAIZAUSKAS, S. AZZAM, *Event Coreference for Information Extraction*, in "Anaresolution '97, Proceedings of a Workshop on Operational Factors in Practical, Robust Anaphora Resolution for Unrestricted Texts", Stroudsburg, Association for Computational Linguistics, 1997, pp. 75-81.

[8] S. BRIN, *Extracting Patterns and Relations from the World Wide Web*, in Atzeni P., Mendelzon A., Mecca G. (eds.), "The World Wide Web and Databases", Berlin-Heidelberg, Springer, 1999, pp. 172-183.

are written following a relatively standard structure. We next describe this standard structure, and afterwards we describe the finite state transducers implemented.

4.2. Standard Structure of an Italian Criminal Sentence

An Italian criminal sentence always start with the denomination of the legal authority, and the wording "Repubblica Italiana", followed by "In nome del popolo italiano". The names of the members of the court follow. The first name mentioned is always that of the judge. Then, the other members of the court. Then another section starts, where the defendants are listed. Each defendant has to be properly identified by his/her biographical data such as birthplace and birthday. In the criminal sentence, the defendant name is typically followed by the wording "nato a" (i.e., born in). The name of each defendant is followed by the name(s) of the defending lawyer(s). The name of each lawyer is preceded by the title "avv.". The name of the prosecutor is preceded by the acronym "PM". The first name that is not preceded by "avv." or "PM", and is not followed by a "nato a" statement indicates the end of the defendant list, and this name is an involved part in the events discussed by the sentence (for instance, it could be an injured party or a witness). The verdict of the sentence is always preceded by the acronym "PQM" or "PTM". For first-degree sentences (GIP/GUP), each defendant is either convicted or acquitted. In second-degree sentences, before the acronym PQM/PTM and after the defendant list, the first-degree verdict is described. Then, after the acronym PQM/PTM, it is explained how the first-degree verdict is modified.

4.3. The Finite State Transducers

We now list and describe the finite state transducers implemented in order to perform information extraction on our *corpus* of criminal sentences.

People-FST. This transducers uses a dictionary of Italian first names and family names in order to recognize individuals. If necessary, the user can extend the dictionary. An individual is considered as a sequence of at least two names, or as a capital letter followed by a point, a space, and a name.

Defendants-FST. Each defendant is always accompanied by its birthplace and birthday. If an individual is followed by the wording like "nato a", then we assume that he/she is a defendant.

Lawyers-FST. Lawyers are individuals preceded by their title "avv.".

Judge-FST. If at this point the first individual appearing in the text of the sentence is not a defendant, then it must be the judge. If the first individual is a defendant, then the information about the judge is unavailable.

Court-FST. If the name of the judge has been extracted, then all individuals comprised between the judge and the first defendant must be members of the court.

Prosecutor-FST. The prosecutor is an individual preceded by the abbreviation "PM".

Other-FST. At this point, all individuals that are not the judge, members of the court, assistants, defendants, or lawyers, are categorized as "other people involved".

Defendants-lawyers-FST. This transducer associates each defendant to the list of lawyers that represent him/her.

Crimes-FST. This transducer recognizes the crimes disputed in the trial using regular expressions.

Verdict-FST. This transducer attempts to deduce if a defendant has been condemned or absolved. This is done by analyzing the text of the sentence following the acronym "PQM" or "PTM", and looking for words such as "condanna" or "assolve" written before the name of the defendant.

Associations-FST. This transducer detects when two individuals co-occur in the same phrase anywhere in a criminal sentence. When this happens, we say that there is an association between the two individuals. These associations are then used in order to construct a graph, which will be then analyzed using techniques of social network analysis, as described in the next section.

5. Social Network Analysis

We now turn to reporting the social network analysis we performed on the *corpus* of criminal sentences. Social network analysis uses the mathematical theory of graphs, in order to define and quantify various measures of network structure. This leads to the possibility to explain and describe sociological concepts such as social capital by describing the role of individuals and groups in social networks. The various quantitative concepts measure both properties on the network, taken as a whole, as well as properties of the individual and her position in the network. For an introduction to the field, see e.g. Scott's book[9].

[9] J. Scott, *Social Network Analysis: A Handbook*, London, SAGE Publications, 2000.

More precisely, we have analyzed a network graph generated using the information extracted using our computer-based tools. The nodes are the individuals and their relationship, their co-occurrence in sentences, extracted with the set of finite-state transducers (as described in Section 4.3.).

5.1. A First Look: Pre-processing the Data

Presented with a *corpus* of many associations, with the possibility of two names co-occurring only a few times, one must make a distinction between noise and interesting data. In order to reduce the possibility to observe occurrences by chance, we performed pre-processing of data before the analysis in three main steps. First, we eliminate self-cycles, i.e. a name occurring with itself in phrases. It is straightforward that a person co-occurring with itself is uninteresting for studying the social relations between actors. Second, we need to distinguish between a casual co-occurrence of names and an unambiguous indication in the text of an actual relationship. At this point, we chose to discard co-occurrences between pairs of nodes that co-occur less than 5 times in the *corpus*. Out of $67,586$ extracted edges (co-occurring associations between two distinct individuals) from the *corpus*, discarding weights less than 5 led us to discard $49,498$ edges (73%) of the available associations. Third, we chose to discard nodes representing names that had no co-occurrences to other names. Out of $5,280$ names extracted out of the *corpus*, this led us to discard $2,990$ (57%) nodes from the network.

5.2. Overview of the Network

After the pre-processing of the data, what remains is a network of $2,290$ persons with $18,088$ associations (occurring at least 5 times in the same phrase). In mathematical terms, we are thus studying a graph with weighted and undirected edges, with weights being at least 5 and relationships going in both directions between nodes. Furthermore, all nodes lack self-cycles and are connected to at least another node, thus having a degree of at least 1. The components of this network are visualized in Fig. 1, from which one can see that the network consists of many small but only one “giant” component ($1,497$ persons).

The quantitative properties of these components, as well as the giant component separately, are summarized in Tab. 2 and Tab. 3, as well as the degree distributions in Fig. 2. We note, first, that a qualitative inspection of the

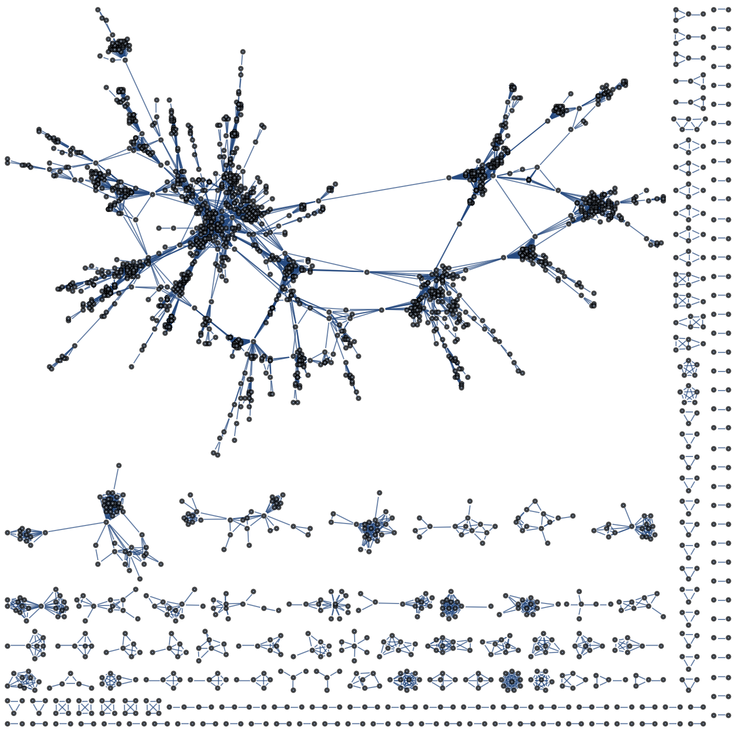

Fig. 1 – The various components in 2,290 out of 5,280 persons in the data set (the remaining 2990 nodes are isolated). The giant component contains 1,497 *persons, followed by sizes of* 52, 32, 23 *and* 20 *(the* 5 *largest components, in ascending order)*

network directly suggests that smaller components are possible to analyze by hand. Second, we also note that there appears to be a clear community structure with sub-groups of nodes where there are dense connections among nodes compared to that to the rest of the nodes in the graph. Third, individual nodes appear to play a significant role in linking up groups into the connectivity of the giant component. These observations lead us to analyze the network both from the perspective of groups (communities) as well as individuals.

For the rest of the analysis, we will focus on the single giant component.

All components (N=2290)	
Average degree	7.89
Density	0.003
Diameter	∞

Tab. 2 – Basic statistics for the full network

Giant component (N=1497)	
Average Degree	9.88
Density	0.006
Diameter	16

Tab. 3 – Basic statistics for the single giant component

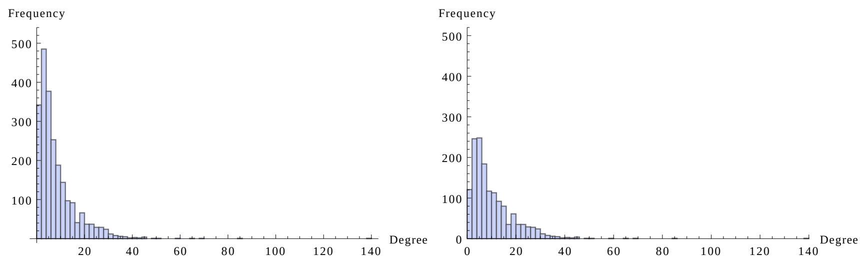

Fig. 2 – Degree distributions of the full network (N=2,290 persons, to the left) and the giant component (N=1,497, to the right). An upward shift of the average degree can be expected, as the smaller components are degree-bounded by available number of nodes

5.3. A Central Core in the Giant Component

Is there a dense core in the network, where everyone is associated in some way to everyone? To study this question, but with the more reasonable criterion that "many know many" in such a group, we apply the *k*-core algorithm[10]. This method iteratively eliminates nodes with a low degree, similar to removing "outliers". An iteration leads to the removal of nodes with a degree less than *k*, and the method is repeatedly applied to the graph until no more elimination of nodes (and their associated edges) can be done. The result is presented in Fig. 3.

[10] M. NEWMAN, *Networks: An Introduction*, Oxford, Oxford University Press, 2009.

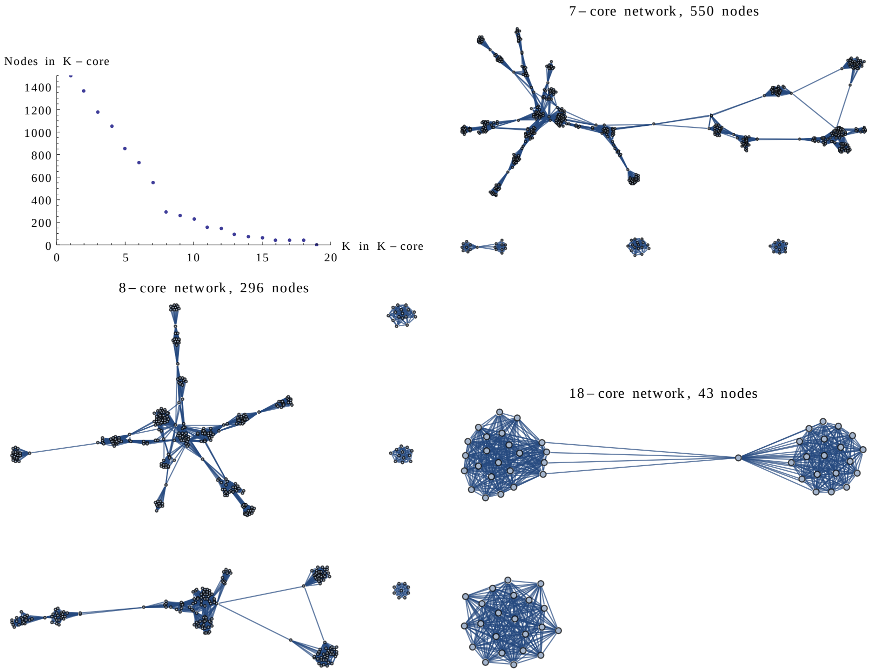

Fig. 3 – Application of the K-core algorithm to the giant component, varying k. The most dense core has at least 18 *in-group associations, and is a set of 43 nodes*

5.4. Community Structure

We proceed to perform a community structure analysis on the giant component with $N = 1,497$. Community detection[11] consists of dividing the nodes of a network into distinct, or possibly overlapping, groups of nodes that are relatively dense to the rest of the network. As argued above, smaller components also indicate a natural idea of community structure (that of being densely connected as well as relatively isolated), but on the level of the network they are less ambiguous when it comes to visual inspection.

11 A. CLAUSET, M.E.J. NEWMAN, C. MOORE, *Finding Community Structure in Very Large Networks*, in "Physical Review E", Vol. 70, 2004, n. 6.

Focusing on the main component, we use the *modularity* metric[12], a quantitative description aiming to capture the intuition of communities as being both dense (nodes in a community have most neighbors within that community) as well as relatively isolated (there are few edges leaving the community). The modularity of a graph takes its value between -1 and 1. We execute a fast greedy algorithm that attempts to maximize modularity[13] by splitting the network into communities. In principle, modularity can be maximized in various ways[14], where we use a direct way by iteratively joining single nodes into bigger groups and evaluate what maximizes modularity change. This results in 33 different communities and a modularity value of 0.884, which is relatively high (as compared to other networks). While getting high modularity scores can be consistent with several different divisions into communities[15], with different solutions possibly giving similar modularity values, a high modularity demonstrates that the network structure is relatively easily split into communities. The resulting network contains $7,028$ out of $7,400$ edges *inside* the communities, i.e. only 5% of the relations are directed outside the community to which an individual is classified. The resulting communities are displayed in Fig. 4, and their size in Fig. 5.

5.5. *Important Nodes in the Network*

The previous results on community structure suggests the possibility to study nodes that appear important for the overall network connectivity. Due to the high modularity value, with most edges inside the communities, we can expect a relatively small number of nodes to act as "bridges" between different communities in the network. In order to assess this quantitatively, we calculate the *betweenness centrality*[16] for the nodes in the giant component.

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[12] M. NEWMAN, *Modularity and Community Structure in Networks*, in "Proceedings of the National Academy of Sciences", Vol. 103, 2006, pp. 8577-8582.

[13] U. BRANDES, D. DELLING, M. GAERTLER, R. GÖRKE, M. HOEFER, Z. NIKOLOSKI, D. WAGNER, *On Finding Graph Clusterings with Maximum Modularity*, in Brandstädt A., Kratsch D., Müller H. (eds.), "Graph-Theoretic Concepts in Computer Science", Berlin-Heidelberg, Springer, 2007, pp. 121-132.

[14] M. NEWMAN, *Networks: An Introduction*, cit.

[15] B.H. GOOD, Y.-A. MONTJOYE, A. CLAUSET, *Performance of Modularity Maximization in Practical Contexts*, in "Physical Review E", Vol. 81, 2010, n. 4, p. 19.

[16] Betweenness centrality is a standard metric, attempting to quantify the intuitive notion that there can be "bottlenecks" or "bridges" in social networks that connect separate subgraphs.

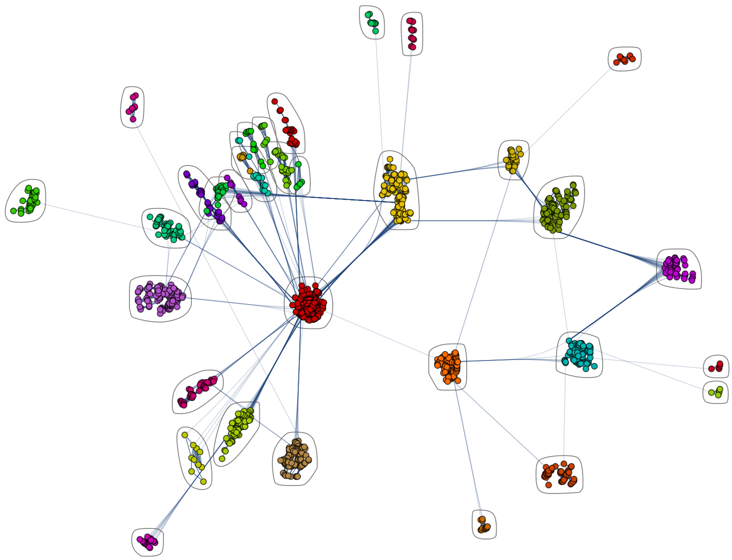

Fig. 4 – Community detection applied to the giant component. Using modularity maximization, the method suggests 33 distinct communities with a high modularity value of 0.884. 95% *of the edges stay within the classified communities*

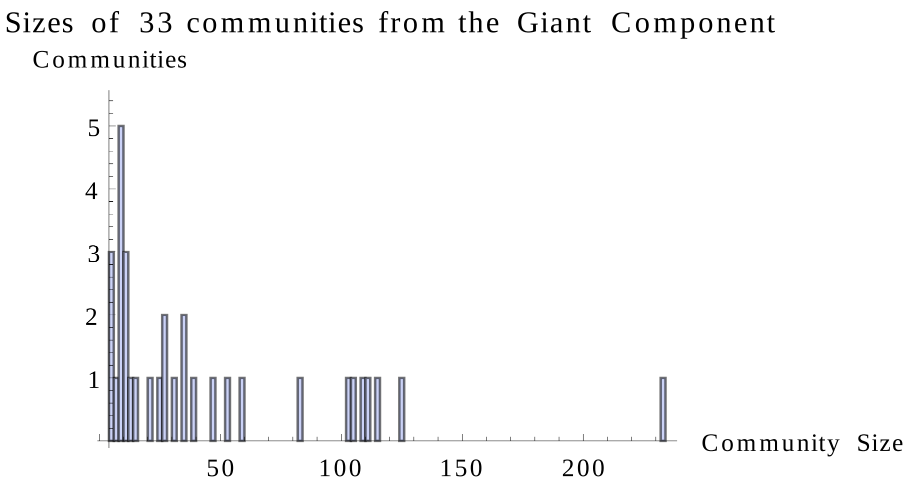

Fig. 5 – Distribution of the 33 community sizes of the giant component

The result can be found in Fig. 6. We find that this measure varies widely, which is consistent with the findings above.

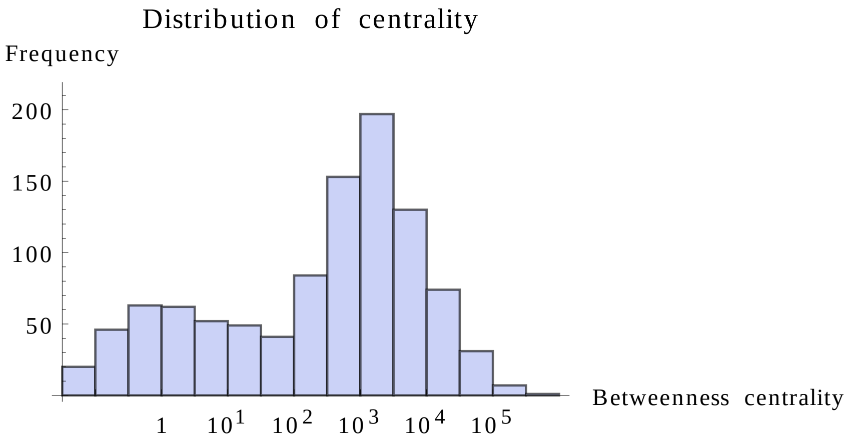

Fig. 6 – Distribution of betweenness centrality measure in the giant component. The values take a wide range, showing how nodes vary to a big extent in the connectivity of the giant component

6. Conclusion

In this paper we have described the first example in Italy of a large digital archive of criminal sentences accompanied by a structural analysis of response to organized crime. We set out to describe the socio-economic environment of criminal sentences by using automatic tools of information extraction. We extract information for social network analysis of the different actors in the jurisdictional system (judges, members of the court, defendants, lawyers, prosecutors, etc.). Our results are very reasonable in terms of what is typically found in a social network: some highly connected nodes, a giant component, community structure as well as varying dependence on the connectivity among individual nodes[17].

It is also possible to keep important assumptions and limitations in mind. The structure of this network is gathered from a specific representation of reality, created by the jurisdictional system in terms of written sentences. Specifically, the concept of relating actors by repeated co-occurrence in text depends on a number of decisions by a number of people in the jurisdictional

[17] M. Newman, *Networks: An Introduction*, cit.

system. In this research we have worked on a particular representation when it comes to understanding a network. The problem of the representation of the structured data is particularly important and is not completely defined, since it is influenced by the kind of analysis that one may decide to apply to the *corpus* of data. In any case, whichever will be its final form, the current activity of entity and relation extraction is necessary to avoid too large manual efforts. The sociological approach and the computational approach both have virtues and limitations, as well as the risks originating from the potentially increasing level of abstraction that one may achieve using more sophisticated computer models. The application of computer science gets its power from the large-scale capability of symbolic manipulation of the information, upon which it exercises its capabilities using imposed models, in need of simplified assumptions rather than real correspondence between what is real and what is represented. Obviously, while providing the power of simplicity, only studying text co-occurrence cancels out many other possible relations that could be read out manually from the text. The task of the social scientist is often exactly the opposite than finding restrictive assumptions: to highlight the differences, i.e. of the relations, because only through understanding these crucial differences, it is possible to, if not explain, then at least fully describe the phenomena that are the subjects of study. This task is easier when the information is structured, and the structure, when a large *corpus* of data is present, can also use the contribution of applied computer science. This fact is an additional reason that makes the project of interest to both the scientific communities.

The main challenges of additional research will be to overcome the difficulty to perform information extraction on the *corpus* of available sentences and classify in a sociologically correct way the different nodes we have found out using social network analysis. At another level, challenges also exist for the OCR software, with e.g. some of the sentences containing not only typed text, but also some handwriting, and the OCR is unable to satisfactorily process the handwriting. Future progress of this research will therefore need to use more sophisticated OCR tools, specifically tailored to the kind of criminal sentences that need to be analyzed. In general, there remain a number potentially fruitful ways to apply methods from network analysis and improve our knowledge about this system.

Text and Social Network Analysis as Investigative Tools: A Case Study

NICOLA LETTIERI, DELFINA MALANDRINO, RAFFAELE SPINELLI*

1. INTRODUCTION

This paper explores the intersections between the law and the computational social science (CSS) paradigm by focusing, in particular, on text and social network analysis. We will present ongoing research about the applications of computational methods in the analysis of structural and functional features of criminal organizations. Inspired by a sociological study using network analysis techniques to compare the characteristics of two criminal organizations belonging to Sicily's *mafia* and Campania's *camorra*, the research aims at studying tools combining information extraction, network analysis and visualization methods to support investigation and the fight against criminal organizations. After a brief introduction to social network analysis (SNA) and its applications in the legal field, the paper offers an overview of the results so far achieved from a technical and methodological point of view sketching future developments that appear to be challenging both for criminology and legal informatics.

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2. Social Network Analysis

Social network analysis is a theoretical and methodological approach to the study of social phenomena[1] whose origins can be traced back to the 1930s. Ideally stemming from the intuitions of the sociologist Georg Simmell[2] and of the psychosociologist Jacob Levi Moreno[3], SNA aims at analyzing and understanding forms of social life as distinct from their content: instead of focusing on individuals and their attributes (gender, age, instruction, economic status, opinions, etc.), or on macro social structures, it centers on the *relations* between individuals, groups, or social institutions.

In the SNA perspective, to study society is to study social actors within the network of relations in which they are emerged, seeking explanations

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[1] The birth of SNA is connected with the growth, over the 20th century, of different scientific communities sharing the same basic idea: to understand human and social phenomena focusing more on the role played by social structures than on individuals and their attributes. Among the most relevant schools of thought, we can mention the School of Sociometry lead by Jacob Moreno, the Harvard Sociological School of Lloyd Warner and the anthropological research group at the University of Manchester (Max Gluckman, John Barnes). The bibliography on network analysis is extremely wide. Among others see: B. WELLMANN, S.D. BERKOWITZ (eds.), *Social Structures: A Network Approach*, Cambridge, Cambridge University Press, 1988; S. WASSERMANN, K. FAUST, *Social Network Analysis, Methods and Applications*, New York, Cambridge University Press, 1997; D. KNOKE, S. YANG, *Social Network Analysis*, Thousand Oaks, Sage, 2008. Interesting insights about the role of networks in social dynamics are offered in: A.-L. BARABÁSI, *Linked: How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life*, New York, Plume Books, 2003; N.A. CHRISTAKIS, J.H. FOWLER, *Connected: The Surprising Power of Our Social Networks and How They Shape Our Lives*, New York, Little, Brow and Company, 2009.

[2] With his Formal Sociology, Georg Simmel pioneered many concepts of SNA. According to Simmel, relationships that individuals create in their continuous interactions clearly influence the action of the subject. Therefore, the task of sociology is to isolate the forms of social life abstracting them from their concrete content. Simmel wanted to develop a geometry of social life in order to investigate it in a quantitative and operational way: "Geometric abstraction investigates only the spatial forms of bodies, although empirically these forms are given merely as the forms of some material content. Similarly, if society is conceived as interaction among individuals, the description of the forms of this interaction is the task of the science of society in its strictest and most essential sense", see G. SIMMEL, *The Study of Societal Forms*, in Wolff K.H. (ed.), "The Sociology of George Simmel", Glencoe, The Free Press, 1950, pp. 21-22.

[3] Jacob Levy Moreno is known, among other things, for being the father of Sociometry, the quantitative method for measuring social relationship. In 1937, he began to publish the journal *Sociometry: a Journal of Inter-Personal Relations*. On the sociometric paradigm, see J.L. MORENO, *Sociometry, Experimental Method and the Science of Society. An Approach to a New Political Orientation*, New York, Beacon House, 1951.

for social behaviors in the structure of these networks rather than simply in the individuals. According to this approach, social relationships are conceptualized, represented and studied as graphs, static pictures consisting of nodes (actors) and ties (connections between actors). Once a graph is generated according to a given metric (e.g., mapping friendship, kinship, cultural exchanges, organizational position, etc.), several measures are then used to analyze structural and functional features both of the network and its components. The study of *Centrality*[4], one of the most relevant measures in SNA, is used, for example, to assess issues such as the dominance, subordination, influence or prestige of social actors. Just to give an idea of the meaning and role of SNA metrics, we would like to mention here the main centrality measures: *degree, closeness and betweenness centrality*.

Degree centrality is defined as the number of direct links a node *k* has:

$$C_D(k) = \sum_{i=1}^{n} a(i,k),$$

where *n* is the total number of nodes of the network, and *a(i,k)* is a binary variable indicating whether a link exists between nodes *i* and *k*. *Degree centrality* is used to measure the activity of a particular node: a node with a high degree is likely to be a leader or a "hub" within the group.

Closeness centrality is the sum of the length of the geodesics between a particular node k and all the other nodes in a network and is defined by the expression:

$$C_C(k) = \sum_{i=1}^{n} l(i,k),$$

where *l (i, k)* is the length of the shortest path connecting nodes *i* and *k*. Closeness allows us to measures how far away one node is from other nodes.

Betweenness centrality of a node *k* is the number of shortest paths between all the vertices of the network (geodesics) and passing through it and is defined by the expression:

[4] In network analysis, the centrality of a node within a graph is a measure that allows us to determine the importance of a social actor, that is, how influential a person is within a group. About *centrality* and its measures see L. FREEMAN, *Centrality in Social Networks: Conceptual Clarification*, in "Social Networks", 1979, 1, pp. 215-239.

$$C_B(k) = \sum_k^n \sum_j^n g_{ij}(k),$$

where g_{ij}(k) indicates whether the shortest path between two other nodes *i* and *j* passes through the node *k*. The *betweenness* measures the centrality of a node: a node with high *betweenness* is probably a "broker", a good intermediary within communication or market dynamics (flow of goods, opinion spread).

By means of these and other measures[5], SNA is offering new insights for many social sciences, such as sociology, anthropology, economics and has been used effectively in the study of extremely various phenomena[6], finding applications in the physical, biochemical, genetic and computer sciences, while maintaining conventionally the name social in memory of its origin. Even if originally thought of for the analysis of human relationships, SNA metrics and techniques have spread to studying relations between the most diverse entities from documents to computers: the recurrence of the term "SNA" in scientific literature over the last ten years shows an exponential growth in the use of this representation of social phenomena[7].

3. Social Network Analysis in the Legal Field

In its more recent life, SNA has shown interesting potentialities in providing new insights also into legal and socio-legal issues. The application of network analysis techniques to the study of legal documents has become the

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[5] For a general introduction to SNA measures, metrics and techniques see J. SCOTT, *Social Network Analysis. A Handbook*, Thousand Oaks, Sage, 2000; M.E.J. NEWMAN, *Networks: An Introduction*, Oxford, Oxford University Press, 2010.

[6] Over time SNA has been applied in the study of extremely various phenomena. See, i.a.: J. DIESNER, K.M. CARLEY, *Using Network Text Analysis to Detect the Organization Structure of Covert Networks*, in "Proceedings of the North American Association for Computational Social and Organizational Science Conference", 2004, http://goo.gl/nwWzM; R. POPPING, *Text Analysis for Knowledge Graphs*, in "Quality and quantity", Vol. 41, 2007, pp. 691-709; P.A. STOCKOWSKI, *Leisure in Society, a Network Structural Perspective*, London, Mansell Publishing, 1994; B. ERICKSON, *Culture, Class and Connections*, in "American Journal of Sociology", 1996, n. 102, pp. 217-225; N.A. CHRISTAKIS, J.H. FOWLER, *The Spread of Obesity in a Large Social Network over 32 Years*, in "New England Journal of Medicine" Vol. 357, 2007, pp. 370-379; R.M. CHRISTLEY, G.L. PINCHBECK, R.G. BOWERS *et al.*, *Infection in Social Networks: Using Network Analysis to Identify High-risk Individuals*, in "American Journal of Epidemiology", Vol. 162, 2005, pp. 1024-1031.

[7] See D. KNOKE, S. YANG, *Social Network Analysis*, cit., p. 1.

basis of several studies aiming at capturing the structural and dynamic properties of specific legal phenomena from legislation to case law.

In 2005, Thomas A. Smith from the University of San Diego published on this topic a position paper[8] claiming the possibility of identifying in the relations between legal documents (cases, statutes and other legal authorities, and the citations that link them together) the typical topology of the network structure[9] and, consequently, proposing to apply network analysis measures to law and legal issues. After a brief introduction to the basic concepts of network science, the paper presents the results of citation study based on the analysis of nearly four million American legal precedents, showing how the study of the network made up by cases and their mutual relations could help to shed light on how the legal system evolves. According to Smith, such a kind of analysis allows us not only to empirically measure the degree of integration between different legal systems (e.g., state and federal laws) and its evolution over time but also to analyze the emergence and decline in the authority of precedents over the years. In this perspective, the analysis of cases can be integrated with that of legal authority to verify their mutual relations.

Since 2005, many works focusing on the application of SNA techniques to case law and legislation have been published. As to the analysis of case law, it is worth mentioning, among the others, research from Chandler[10] and Fowler[11], who used network analysis to study relationships between precedents of the Supreme Court of the United States in order to capture information on the relevance of judgments that cannot be detected by simply counting the number of citations[12].

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[8] T.A. SMITH, *The Web of Law*, San Diego Legal Studies Research Paper, 2005, n. 06-11, available at SSRN: http://ssrn.com/abstract=642863.

[9] "…the overall topology, or mathematical structure, of the Web of Law closely resembles that of the World Wide Web. Both the World Wide Web and the Web of Law are "directed" networks, have grown organically to a large size, and evince striking features of self-organization", T.A. SMITH, *The Web of Law*, cit., p. 2.

[10] S.J. CHANDLER, *The Network Structure of Supreme Court Jurisprudence*, University of Houston Law Center, No. 2005-W-01, available at SSRN: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=742065.

[11] J.H. FOWLER, T.R. JOHNSON, J.F. SPRIGGS, S. JEON, P.J. WAHLBECK, *Network Analysis and the Law: Measuring the Legal Importance of Supreme Court Precedents*, in "Political Analysis", Vol. 15, 2007, n. 3, pp. 324-346.

[12] See also M.J. BOMMARITO II, D.M. KATZ, J. ZELNER, *Law as a Seamless Web? Comparison of Various Network Representations of the United States Supreme Court Corpus (1791-*

With regard to the analysis of legal texts, we can report a work from Katz and Bommarito[13] on the United States Code of which a representation formalized in terms of a network is proposed in order to measure the direction and the magnitude of the changes suffered by the Code itself over time. The French Environment Code has been the subject of an analysis of the same kind carried out by Boulet and others[14], who considered the network formed by citations in the Code that, as suggested by the analysis conducted, presents structural properties different from those of other codes of French law[15].

Another interesting application of the analysis of networks, particularly relevant for studies on judicial organization, is offered by Katz and Stafford[16] that, based on biographical information about a set of 19,000 law clerks (assistants of judges and federal prosecutors), study the U.S. federal courts as a social system for the purpose, *inter alia*, of providing criteria for measuring the authoritativeness of the careers of the actors of the system and to understand the reasons that generate the differences between the different components of social network.

The list could go on, as in the last few years, the number of publications about SNA and law has grown rapidly[17]. In general terms, we can say that

2005), in "Proceedings of the 12th International Conference on Artificial Intelligence and Law (ICAIL 2009)", available at SSRN: http://ssrn.com/abstract=1419525.

[13] M.J. BOMMARITO II, D.M. KATZ, *A Mathematical Approach to the Study of the United States Code*, 2010, http://arxiv.org/abs/1003.4146; M.J. BOMMARITO II, D.M. KATZ, *Properties of the United States Code Citation Network*, 2009, available at SSRN: http://ssrn.com/abstract=1502927.

[14] R. BOULET, P. MAZZEGA, D. BOURCIER, *Network Analysis of the French Environmental Code*, in Casanovas P., Pagallo U., Sartor G., Ajani G. (eds.), "AI Approaches to the Complexity of Legal Systems", Heidelberg, Springer, 2010, pp. 39-53.

[15] Always with regard to French law, it is worth mentioning the suggestive graphical representation of the network of the relationships between the Articles of the French *Code civil*, offered online by the project Lexmex: http://lexmex.fr.

[16] D.M. KATZ, D.K. STAFFORD, *Hustle and Flow: A Social Network Analysis of the American Federal Judiciary*, in "Ohio State Law Journal", Vol. 71, 2010, n. 3, pp. 457-509.

[17] See, among the others, F.B. CROSS, T.A. SMITH, *The Reagan Revolution in the Network of Law*, available at SSRN: http://ssrn.com/abstract=909217; P.A. HOOK, *Visualizing the Topic Space of the United States Supreme Court*. Indiana Legal Studies Research Paper No. 68, available at SSRN: http://ssrn.com/abstract=948759; U. PAGALLO, *Small World Paradigm and Empirical Research in Legal Ontologies: A Topological Approach*, in Ajani G., Peruginelli G., Sartor G., Tiscornia D. (eds.), "The Multiple Complexity of European Law: Methodologies in Comparison", EPAP, Firenze, 2007, pp. 195-210; R. WINKELS, J. DE RUYTER, H. KROESE, *Determining Authority of Dutch Case Law*, in Atkinson K.M. (ed.), "Legal Knowledge and Information Systems. JURIX 2011: The 24th Annual Conference", Amsterdam,

the spread of network analysis is yielding interesting new insights into the overall structure of the law and into socio-legal phenomena that are relevant in the legal field.

4. Text and Social Network Analysis as Investigative Tools

Among the various application contexts of SNA that are arousing the interest of legal scientists and practitioners, one of the most promising is the study of the social underpinnings of legally relevant phenomena, or, more in detail, the analysis of criminal groups and networks from a structural and functional point of view.

The social dimension plays a crucial role in the evolution of crime: a large part of criminal phenomena from drug networks[18] to international terrorism[19]; from pornography trafficking[20] to hacking and other cybercrimes[21], is strongly conditioned (inhibited or facilitated[22]) by relational dynamics. Criminals are not isolated: they are nested within communities, drawing support from members of the community. In this context, the SNA approach, thanks to the potentialities shown in mapping and measuring the social landscape, is becoming more and more interesting.

Nowadays, the achievement of results by SNA techniques is facilitated by the boundless amount of digital by-products (e-mails, mobile phone calls,

IOS Press, 2011, pp. 103-112; M. van Opijnen, *Citation Analysis and Beyond: in Search of Indicators Measuring Case Law Importance*, in Schäfer B. (ed.), "Legal Knowledge and Information Systems - JURIX 2012: The 25th Annual Conference", Amsterdam, IOS Press, 2012.

[18] K. Murji, *Markets, Hierarchies and Networks: Race/ethnicity and Drug Distribution*, in "Journal of Drug Issues", Vol. 37, 2007, n. 4, pp. 781-804; Bruinsma, Gerben, Bernasco, Wim, *Criminal Groups and Transnational Illegal Markets: A More Detailed Examination on the Basis of Social Network Theory*, in "Crime Law and Social Change", Vol. 41, 2004, n. 1, pp. 79-94.

[19] V. Krebs, *Mapping Networks of Terrorist Cells*, in "Connections", Vol. 24, 2002, n. 3, pp. 43-52.

[20] J. Johnson, *To Catch a Curious Clicker: A Social Network Analysis of the Online Pornography Industry*, in Boyle K. (ed.), "Everyday Pornographies", London, Routledge, 2010.

[21] D. Décary-Hétu, B. Dupont, *The Social Network of Hackers*, in "Global Crime", 2012, available at SSRN: http://ssrn.com/abstract=2119235.

[22] E. Patacchini, Y. Zenou, *The Strength of Weak Ties in Crime*, in "European Economic Review", Vol. 52, 2008, n. 2, pp. 209-236; D.L. Haynie, *Delinquent Peers Revisited: Does Network Structure Matter?*, in "American Journal of Sociology", Vol. 106, 2001, n. 4, pp. 1013-1057.

credit-card operations, Internet searches, interactions mediated by social networks) generated by social life in the modern world: the digital data-stream and advances in technology are pushing both scholars and law enforcement agencies to figure out new tools and methodologies to illuminate the structures and dynamics of criminal networks.

The idea has recently gained growing popularity: over the past 10 years[23], there has been an increasing number of experiences in the development and in the use of SNA-based investigative software. Criminal Network Analysis[24] (CNA) is a flourishing research area in which criminology, organized crime research, social network theory and computer science converge with other disciplines[25] to offer new insights into crime by means of innovative data mining tools and applications working to unveil hidden patterns in large volumes of crime data and investigative documents.

5. The Case Study

Taking a cue from the scientific scenario so far sketched, we have decided to explore the application of CSS (in particular, information extraction and SNA) techniques in criminal investigation. In this vein, fundamental inputs came from the collaboration with Italian deputy prosecutors that highlighted two circumstances relevant for our research:

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[23] X. Shang, Y. Yuan, *Social Network Analysis in Multiple Social Networks Data for Criminal Group Discovery*, in "International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery", 2012, pp. 27-30; J.A. Johnson, J.D. Reitzel, *Social Network Analysis in an Operational Environment: Defining the Utility of a Network Approach for Crime Analysis Using the Richmond City Police Department as a Case Study*, IPES, Coginta and DCAF Working Paper No. 39, 2011; N. Memon, H.L. Larsen, *Investigative Data Mining Toolkit: A Software Prototype for Visualizing, Analyzing and Destabilizing Terrorist Networks*, in "Visualising Network Information", http://www.dtic.mil/dtic/tr/fulltext/u2/a477075.pdf; Y. Lu, M. Polgar, Y. Cao, *Social Network Analysis of a Criminal Hacker Community*, in "Journal of Computer Information Systems", Vol. 51, 2010, n. 2, pp. 31-41; J. Xu, H. Chen, *CrimeNet Explorer: A Framework for Criminal Network Knowledge Discovery*, in "ACM Transactions on Information Systems", Vol. 23, 2005, n. 2, pp. 201-226; J. Xu, H. Chen, *Criminal Network Analysis and Visualization*, in "Communications of the ACM", Vol. 48, 2005, n. 6, pp. 100-107.

[24] For a compelling introduction to the research area of criminal network analysis, see C. Morselli, *Inside Criminal Networks. Studies of Organized Crime*, Berlin-Heidelberg, Springer, 2010.

[25] K. von Lampe, *The Interdisciplinary Dimensions of the Study of Organized Crime*, in "Trends in Organized Crime", Vol. 9, 2006, n. 3, pp. 77-95.

- If we put aside more "traditional" information systems (databases containing complaints, criminal records, police reports, etc.), criminal investigation remains primarily a manual process. Available computational tools do not provide either advanced information extraction functionalities or structural analysis of network knowledge from criminal justice documents. Furthermore, investigative information, even when in digital format, is not structured.
- Tools allowing us to gather, analyze, visualize and extract information from investigative documents produced by the prosecutor's office and police would be considered extremely useful. Particular attention has been aroused by visual and "scientifically grounded" tools illuminating not only the extension, the topology and the patterns of groups of people involved in illegal activities, but also the role of specific individuals within the organization. After all, knowledge about the structural and functional properties of criminal networks is fundamental for both investigation and the development of effective prevention strategies.

Starting from the consideration of these circumstances, we have initiated a project in which domain experts (lawyers and judges) collaborate with computer scientists to develop and test an integrated environment based on social network analysis techniques able to:

- support the automatic retrieval and marking up of information necessary for performing network analysis of criminality;
- generate and analyze graphs of criminal networks under investigation;
- provide a diachronic view of the evolution of criminal networks;
- organize and manage visually the investigative material;
- make predictions about the potential of an individual to belong to a criminal group.

In the light of the guidance given by the prosecutors involved in the project, an environment of this kind not only could offer insights into criminal phenomena difficult to obtain in any other way, but could also have an impact in the dynamic of the investigation and trial. The graphs and the results of analysis carried out on them could be a tool to facilitate information sharing and collaboration between the judges and the investigating police; moreover, they could be used to support requests for commital for trial with the evidence of a scientific kind with particular value for the argumentation.

In the part of the project carried out so far, after having examined the characteristics of the documents produced in the course of the investigation by prosecutors, we have focused our attention on the extraction of information from a particular type of pleading (request for an arrest warrant) and the consequent application of SNA metrics to this information.

The starting point of the project was offered by an interesting research[26] by a sociologist of deviance who not only brought us closer to the use of SNA in the study of criminal phenomena but also aided us in the retrieval of documents on which to start experimenting. Oriented towards purely scientific purposes, the work of Scaglione was to analyze the characteristics of the social network emerging from the wire-tapping reported in two requests for precautionary measures[27] to be taken that had been subjected to the manual tagging of parts of the texts deemed to be relevant.

Using one of the procedural documents examined by Scaglione, we started our case study, by posing as its first objective the replication of his findings in the study of the criminal network and, at the same time, beginning to implement the various components of the tool supporting investigations imagined.

In our case study, whose properties are listed in Tab. 1, the analyzed document contains two kinds of information source:

- *Telephone tapping*: this is a transcript of a phone call started or reaching a person under investigation.
- *Wiretap*: a transcription of dialogues in an environment, there is not a person who starts the call. In this case, we assume that each person that is shown in the conversation is communicating with any other person involved in wiretap.

5.1. Implementation

Before starting with details about the implementation, we have to emphasize that an obstacle in this area is the difficulty of finding scanned documents, or other documents that are readily convertible into formats that can then be adapted to automatic analysis.

As anticipated, we have analyzed the remand document used by Scaglione for his work on the comparison of criminal organizations. This document contains information about nearly 150 criminals classified in two *Families*:

[26] A. SCAGLIONE, *Reti mafiose. Cosa Nostra e Camorra: organizzazioni criminali a confronto*, Milano, Franco Angeli, 2011.

[27] Data used for the construction of the graph by Scaglione were manually extracted from unstructured documents. No consideration has been given to the content of the calls: the data taken into account for the construction of the graphs have only been the following: calls (two nodes are connected if there is no communication between them); the number of contacts; the direction of phone call (who calls who).

Characteristics	Value
Document type	Remand document
Organization name	Clan Cava
Organization class	Camorra
People involved	73
Location	Quindici, Avellino, Italy
Pages of the document	ca 3000
Number of telephone and wiretap	2791
Number of phone under tapping	300

Tab. 1 – Properties of the case study

the *Cava Family* from Quindici (Avellino) and the *Rinzivillo Family* from Gela (Caltanissetta).

To represent the crime network described by Scaglione we have used a graph, one of the already well-known ways to represent and investigate criminal network[28]. A graph is composed of a pair of sets, called nodes and edges, where edges link the nodes together. Nodes represent people, groups or organizations (but also vehicles, building and so on), that are connected through social ties (that is, the edges) in which a variety of resources are exchanged or used. In order to build our crime network we have taken into account the following information:

- telephone tapping and wiretap (nodes are connected if there was a communication between them)
- the phone call direction (who calls whom)

The phone call direction could be interesting for deriving the importance of members of the organizations. We have to emphasize that we did not consider the content of the call, as our main and initial interest was in the structure of the resultant network. We have organized the work of information extraction and analysis in three different phases, as shown in Fig. 1.

Firstly, we needed to apply an initial "*Text Filtering*" phase to make official documents suitable for the subsequent automatic "*Information Extraction and Graph Generation*" phase. In this second phase, the remand documents were automatically processed to analyze behaviors and relationships

[28] J. XU, H. CHEN, *Criminal Network Analysis and Visualization*, cit.; J. SCHROEDER, J. XU, H. CHEN, *CrimeLink Explorer: Using Domain Knowledge to Facilitate Automated Crime Association Analysis*, in "Proceedings of the 1st NSF/NIJ conference on Intelligence and security informatics", 2003, pp. 168-180.

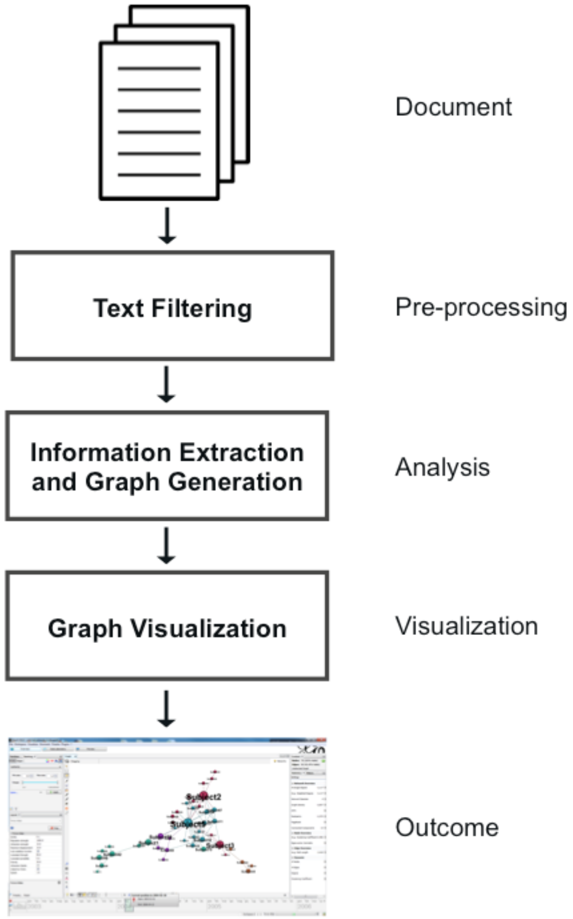

Fig. 1 – Case study workflow

in order to produce, in the last phase (namely, *Graph Visualization*), the corresponding visual representation.

The way we analyzed and visualized the network can be classified according to a taxonomy defined by Klerks[29] who has analyzed and evaluated the approach for criminal network analysis, classifying them in:

- *First generation*
  A completely manual task. It uses a matrix where each row and column represents a person (an offender) and the value is the number of established contacts. Eventually an image can be drawn from the matrix.
- *Second generation*
  Can automatically visualize a representation of the criminal network, adjusting the position of nodes to achieve a better visualization.
- *Third generation*
  An evolution of the second that moves the focus onto the social context. Focusing on the social context could help the investigators in their search for high ranked members of the organization, to find out how much power members have within the organization, important intermediate or even weak points in the organization structure. Furthermore, it could help to clarify how recruitment works and how the order and/or knowledge are transferred by one member to another.

The third generation approach makes it easier to give answers to qualitative questions, for example, how much the member of the organization communicates before and after committing a crime, and what are the hot topics in their conversations. Our approach can be classified as a third generation approach.

5.2. Text Filtering

In this phase, we filtered out unnecessary information and marked some specific parts needful for the network analysis. To this end, we have developed, in Perl[30] a simple parser that extracts entities (name, surname, telephone number, etc.) relevant for the graph. It was not possible to completely

[29] P. KLERKS, *The Network Paradigm Applied to Criminal Organisations: Theoretical Nitpicking or a Relevant Doctrine for Investigators? Recent Developments in the Netherlands*, in "Connections", Vol. 24, 2001, n. 3, pp. 53-65.

[30] Perl is a high-level, general-purpose programming language providing powerful text processing facilities.

process the documents automatically because of their nature. In fact, they are known to suffer from the following critical deficiencies[31]:

- *Incompleteness*: sometimes some information about nodes and relations are missing, making ii impossible to construct a the global vision of the network that resembles as much as possible the real one. Examples include the minimization of the criminals' interactions to avoid attracting police attention and the hiding of their interactions behind various illicit activities.
- *Incorrectness*: Incorrect data regarding criminals' identities, physical characteristics, and addresses may result either from unintentional data entry errors or from intentional deception by criminals. These types of errors can be easily addressed.
- *Inconsistency*: Information about a criminal who has multiple police contacts may be entered into law enforcement databases multiple times. These records are not necessarily consistent, involving inaccuracies when building the network.

5.3. Information Extraction and Graph Generation

In this phase, all entities have to be extracted and used to find out relations between the members of the organization. To do that, our software firstly extracts from the remand document (in a specific section) the list of people involved in the judiciary investigation. They will represent the nodes of our network. Next, the rest of the document is parsed and for each wiretap transcription:

1. We check if the people involved match against the previously defined list
2. If a match exists, we add a new edge between the corresponding entities in the graph.

Our software produces an XML file representing the network and complying with the GEXF file format specifications[32], a language for describing complex networks structures, their associated data and dynamics.

[31] J. XU, H. CHEN, *Criminal Network Analysis and Visualization*, cit.

[32] See http://gexf.net/format.

5.4. Graph Visualization

This last phase allowed us to visualize the resultant graph. We loaded the produced GEXF file into a framework for graph analysis and visualization named *Gephi*[33], a framework that incorporates and offers a wide range of algorithms from Graph Theory literature, including: algorithms for extracting metrics (statistical properties); algorithms for group discovery; algorithms for visualization.

Once loaded our graph, we also computed some statistics, such as, for example, the importance of the organizations' members. The graph representing our case study is shown in Fig. 2. Nodes represent members (we used Subject IDs instead of real full names) and their color and size give information about group membership and authoritativeness, respectively.

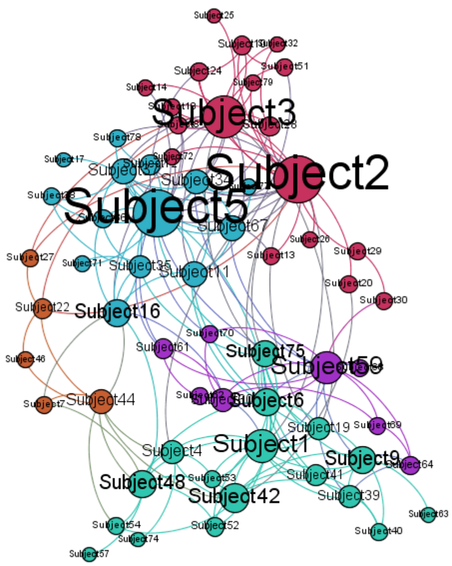

Fig. 2 – Criminal network graph

[33] M. Bastian, S. Heymann, M. Jacomy, *Gephi: An Open Source Software for Exploring and Manipulating Networks*, in "International AAAI Conference on Weblogs and Social Media (2009)". Other tools used in social network analysis include Ucinet, Pajek, NetMiner, Stocnet, NodeXL. For a general overview about network analysis tools see A. Trobia, V. Milia, *Social Network Analysis. Approcci, Tecniche, Applicazioni*, Roma, Carocci, 2011, p. 165.

Another interesting feature of the tool so far developed is the possibility to switch from a static to a dynamic version of the graph (see Fig. 3 and Fig. 4). Taking into account the date associated to every wiretap, the software is able to generate different overviews of the organization under investigation allowing researchers to examine the evolution of the criminal group over time, identifying temporal patterns and trends (growth, decline of criminal groups).

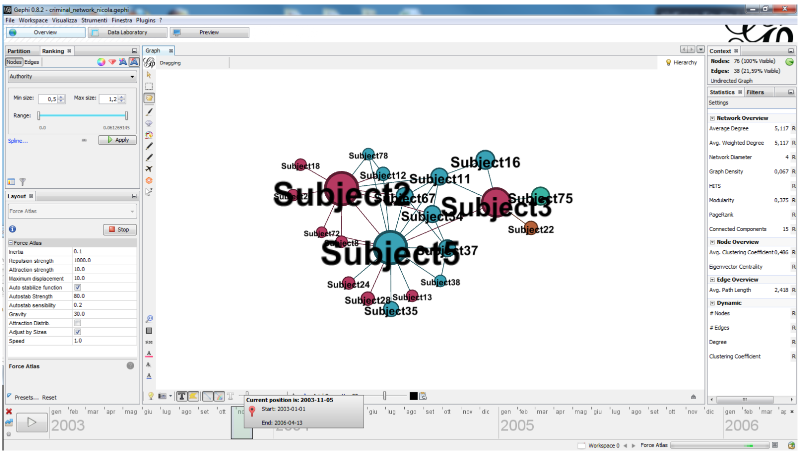

Fig. 3 – Screenshot of Gephi interface with timeline slider

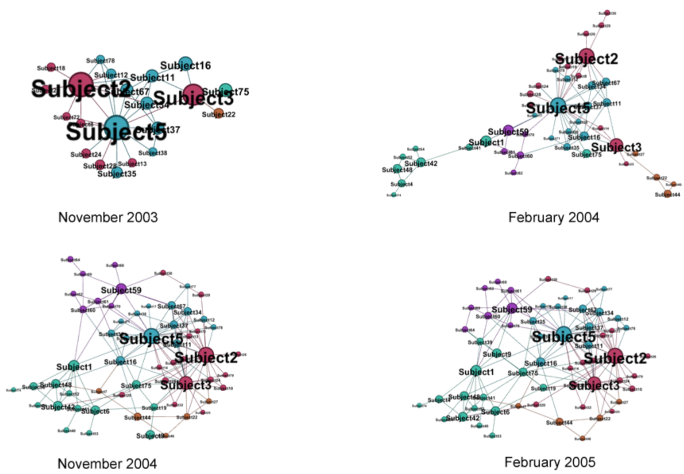

Fig. 4 – Evolution of a criminal network over time

6. Conclusions

Although in progress, experiments have given some preliminary outcomes. The most tangible results are found on the level of implementation. The work done so far has allowed us to explore the issues related to the parsing of unstructured investigative and prosecution documents and to obtain useful information on the processing of these kinds of documents. The analysis carried out are encouraging in terms of reliability in extracting relevant information: data derived from automatic analysis and the subsequent processing of the documents fit with the trial evidence and have generated graphs whose measures are essentially comparable to those resulting from the work of Scaglione that was taken as a reference. To all this, always on the application level, there is also the implementation of timeline for the diachronic view of the criminal network. From the point of view of the analysis of the phenomenon being investigated, the research suffers from a number of limitations arising primarily from the characteristics of the documentary material used: a first limit is represented by the fact of having used a single document even if meaty, another aspect – that is not secondary – is the nature of the information processed. The number and the direction of phone calls used for the construction of the graph, by itself, is not sufficiently and univocally meaningful: depending on the group, the region and the culture considered, a person playing a secondary role in a criminal organization can be the recipient of a large number of phone calls. The issue that came out during the discussion with the prosecutors emphasized how that which turns out to be relevant on the scientific level of a sociological-type study, albeit inspiring, often may not be significant for investigation purposes. According to this consideration, it clearly emerged how the creation of a support tool for carrying out an investigation requires not only increasing the amount and variety of information processed to build up graphs (e.g., gathering data from criminal justice databases) but also refining criteria used in processing judicial and police information trying to "embed" the inquirer's know-how in information extraction procedures. In this perspective, it will be useful to use reliable methods to weigh the impact that investigative information gathered have on the probability that an individual is part of a group or a criminal organization.

The most interesting result, however, is found on the methodological level; the interdisciplinary collaboration regarding crime analysis technologies is showing that it can have an impact on the development of interdiction and law enforcement strategies.

The research will continue in two directions devoting itself, on the one hand, to a deepening of the scientific issues linked to social and criminal network analysis and, on the other, to the design and implementation of new tools for the collection and analysis of investigative data. A crucial first step in this direction seems to be to design a tool that allows us to collect and mark up *ab initio* with the necessary metadata information to be used for building graphs.

The road ahead seems to be challenging both, on the one hand, for Criminology and Criminal law, and, on the other hand, for Legal informatics. For Criminology and Criminal Law, information technologies and SNA techniques represent an opportunity for methodological enrichment through an accentuation of the quantitative dimension of the study of crime. For Legal informatics, the topic not only represents a new application context but also the opportunity to build on and improve the knowledge already produced in processing legal information and documentation. In the future, moreover, there is the possibility of integration with other CSS methods, for example, with social simulations that may serve to combine SNA with the generative perspective of simulations to which the law has also begun to approach[34]. The study of crime and, eventually, the prediction of its evolution can be based not only on the techniques of inferential statistics applied to large amounts of data[35] but also on methods that take better account of the cognitive, social and institutional processes underlying criminal phenomena[36].

34 See, for example, the special Issue dedicated to *Simulation, Norms and Laws*, of "Artificial Intelligence and Law", Vol. 20, 2012, n. 4 and Vol. 21, 2013, n. 1.

35 A particularly suggestive example of this technique is provided by *PredPol*, a software environment for "predictive policing" developed under the guidance of anthropologist P.J. Brantingham of UCLA (http://www.predpol.com/).

36 As numerous and recent publications demonstrate, not only is the intersection between social simulations and network analysis a reality (for an interesting example regarding market dynamics see K. LEE, S. KIM, C.O. KIM, T. PARK, *An Agent-Based Competitive Product Diffusion Model for the Estimation and Sensitivity Analysis of Social Network Structure and Purchase Time Distribution*, in "Journal of Artificial Societies and Social Simulation", Vol. 16, 2013, n. 1, http://jasss.soc.surrey.ac.uk/16/1/3.html and the bibliography cited in it) but also the simulation study of crimes for the purpose of prediction (see, i.a., M. FONOBEROVA, V.A. FONOBEROV, I. MEZIC, J. MEZIC, P.J. BRANTINGHAM, *Nonlinear Dynamics of Crime and Violence in Urban Settings*, in "Journal of Artificial Societies and Social Simulation", Vol. 15, 2012, n. 1, http://jasss.soc.surrey.ac.uk/15/1/2.html; N. MALLESON, P. BRANTINGHAM, *Prototype Burglary Simulations for Crime Reduction and Forecasting*, in "Crime Patterns and Analysis", Vol. 2, 2009, n. 1, pp. 47-66).

Network Analysis Formalism and the Construction of a Traceability System for Payments. A Sketch of Its Legal and Sociological Aspects

GUGLIELMO FEIS*

SUMMARY: *Introduction – Part I: Philosophical Motivations: Law & Informatics Towards a Network Analysis Formalism (NAF) – 1. Method and Organization of Part I – 2. The Relationship between the Theoretical Framework of NAF and the Applied Example of the TS for Payments – 3. The Theoretical Framework of Network Analysis Formalism (NAF) – 3.1. The Possible Objection of Killing Legal Activities through NAF and a Reply – 4. Conclusions on NAF – Part II: Introducing the Problem of the Traceability System (TS) – 5. Method and Organization of Part II – 5.1. Some Lexicon – 6. The General Principle – 6.1. Presuppositions of the General Principle – 7. The Applied Principle – 7.1. Presuppositions of the Applied Principle and its Consequences – 7.2. Going Forward Social Consequences – 7.3. Going Forward Legal Consequences – 8. Implementing the Applied Principle: Data Mining and Database Organization – 8.1. Introducing the Asymmetry – 8.2. The Mining Problem – 9. Case Studies: Recorded Future and Tassa.li – 9.1. Tassa.li – 9.2. Recorded Future – 10. Security – 11. Conclusions on the Traceability System – 12. General Conclusions*

INTRODUCTION

This paper is two-folded: in the first part, I will approach the theoretical problem of the relationships between law and computational social sciences, putting forward a framework that I call network analysis formalism (NAF); in the second part, I will discuss an applied problem concerning the technical and legal aspects of developing a full traceability system (TS) for payments and investigate this problem backward and forward on the temporal axis.

The second part can be seen as an example of the NAF framework presented in the first part that shows how the theoretical proposal of the sociologically aware weak formalism – NAF – can be used to solve some real life legal problems, in the present case, the ones related with structuring a system to track all the economical transactions.

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PART I: PHILOSOPHICAL MOTIVATIONS: LAW & INFORMATICS TOWARDS A NETWORK ANALYSIS FORMALISM (NAF)

1. Method and Organization of Part I

In this part of my paper I will present (Section 2.) how the NAF framework relates to the case of developing a traceability system (TS) that is going to be discussed in the second part. Then, after solving this methodological issue, I will sketch my NAF framework (Section 3.) and reply to a possible objection according to which NAF has nothing to do with legal science (Section 3.1.). Before moving on to part two, in Section 4., I will draw the conclusions on NAF.

2. The Relationship between the Theoretical Framework of NAF and the Applied Example of the TS for Payments

In the second part of the paper I will investigate the possibility of developing a traceability system (TS) for payments. Besides the problem of the TS in itself – i.e., how to organize the TS and how to investigate what are its legal and social upshots – the issue is interesting because we can see the TS problem as the applied counterpart of more philosophical questions, namely: what are the relationships between informatics and the new resources of technological progress and the law? What can we gain in terms of "legal welfare" from the increasing computability power of our computers as well as from the spreading of mobile devices that can always connect us to a network?

I will first address these broad questions outlining the framework of network analysis formalism, then I will move to its application considering the TS problem.

3. The Theoretical Framework of Network Analysis Formalism (NAF)

My thesis is that entering technological devices, procedures of acquisition of relevant legal data and tech-aware legal agents[1] can help us to reconcile two approaches to the law that, from a theoretical point of view, are perceived and presented as opposed: the (neo)positivistic formalism and the realist antifor-

[1] I.e., agents that are active part of the legal system, that can easily achieve an average use of technologies such as credit cards, Internet banking and smartphones.

malism[2]. Getting closer to the point, I think that the possibility to mine data – legal data in particular – can bring us closer both to the leibnizian *calculemus*[3] dream and to the anti-formalist idea of some legal realists that stressed the importance of the sociological context in which legal action takes place.

Before going on, I have to say a few words on the two conflicting thesis – the formalist and the anti-formalist – and on the idea of an instrument I would like to use to reduce the gap between the two positions, i.e., informatics in general and data mining in particular.

I propose to call my attempt to rejoin formalism and antiformalism "network analysis formalism" (NAF) and to classify this approach as a "socially aware formalism". You may object that once you let society, the empirical world and some other kind of context or some other facets of the *Sein* enter the picture of formalism you lose a pure formalist approach. By "socially aware weak formalism" I mean that the abstract types of legal situations are constantly monitored and checked (confirmed or disconfirmed) by the data. These data tell us how and in which way, if any, the law is affecting our daily life.

The idea of data mining comes from informatics and is the way of organizing huge amounts of data in order to discover patterns inside them. The aim of data mining is somehow pretentious: it is not only to describe a structure, but also to use the described structure to make further predictions. The formalists' idea is that the legal system is complete, that is, it can handle every possible situation: all we need to know is the fact, then the judges need only to be the voice of the law, that is, find the right law that fits that fact and apply it. This is enough to sentence.

On the other hand, the antiformalists deny this dictatorship of the law, saying that we need to be realist and stick to what happens in real trials: the judges have a lot of power; there is no way to predict a sentence just by way of knowing what happened (the facts) and what should have happened (the relevant laws), legal interpretation cannot be avoided. The anti-formalists stressed this point by saying that what you need, in order to know the law, is predicting judges' behaviors and decisions (this led to the provocative idea of "digestive jurisprudence" held by some American legal realists).

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[2] This is probably an oversimplified contraposition that does not bring into account the distinctions between American legal realists and Scandinavian legal realists. Despite this inaccuracy, I think it helps to get my point in characterizing NAF.

[3] G.W. LEIBNIZ, *The Art of Discovery*, 1685.

Despite these conflicting views, I claim that, on the descriptive side, gathering data by way of data mining can help you both to discover what the relevant laws are (getting closer to Leibniz's *calculemus*) and what the past histories of similar cases were (giving the legal realists and the anti-formalists much more data and statistics they imagined when they talk about predicting judges behavior upon the dishes they have eaten).

Thus, on this very general level, I claim that the introduction of tools that can help us in providing a better description of legal practices will help both the formalists and the anti-formalists.

The prospective used to bring closer these different paradigms is empirical and sociological. In the context of legal philosophy, my proposal can be described as Hartian[4], if you interpret the Hartian rule of recognition and the external point of view as a way to bring sociology into play.

My proposal is the following: I rely on the Hartian idea of an empirical recognition of the elements of a legal system, then I extend it by way of mining that part of legal data that is relevant for the legal system (financial data in the case of the TS, data concerning judges, sentences and litigation in case of the formalists vs. anti-formalists dispute concerning trials and legal interpretation and so on).

This is where data mining and informatics come in handy. I think modeling the data using statistics and network analysis[5] could be really helpful: you can discover patterns and graphs of tax evasion in the case of the TS or have statistics concerning how different judges and different courts solve similar controversies around the world. Collecting and extracting such information will enable us to access a lot of relevant information concerning prejudice and specific courts ideology: are we more severe in punishing a theft committed by an immigrant with no VISA and low income rather than a theft committed by a young citizen? Such data will give us an opportunity to find out if really "the law is the same for everybody" – as it is written in the Ital-

[4] H.L.A. HART, *The Concept of Law*, Oxford, Oxford University Press, 1961, introduced the rule of recognition as a secondary rule to empirically recognize what is the *corpus* of a positive legal system.

[5] (Social) network analysis studies the interaction of individuals, groups and organizations with the tools of graph theory. For an introduction on its tools see D. EASLEY, J. KLEINBERG, *Networks, Crowds, and Markets: Reasoning about a Highly Connected World*, Oxford, Cambridge University Press, 2010. Considering the issue of the TS, network analysis can study the relevant behaviors related to tax payments and goods exchanges and provide models and patterns suggesting possible violation of taxation laws.

ian courts – no matter what is the color of your skin, your income, or how many degrees of separation you are away from a political leader.

The NFA approach tries to take into account every single case in its individuality and, in this regard, it is closer to the realists' perspective. On the other hand, the data acquired can be used to reinforce a weak formalist perspective: in order to know what will happen in the legal system, you need to know the law and how the law is statistically applied. Thus, data and computation provide an *a posteriori* pattern – close to the Hartian tradition but compatible with the realists' approach – and not an *a priori* formalist ideal of the *Sollen* or the Ought of the normative world.

3.1. The Possible Objection of Killing Legal Activities through NAF and a Reply

One of the first reactions to my proposal could be this: "this is no longer jurisprudence! You are killing legal activity! There is no room left for interpretation in your NFA model!". You may go even further by saying that NAF is not a weak formalism but, indeed, is the strongest form of formalism ever, whose aim is to replace judges with machines.

Nonetheless, this picture is wrong. Judges are still part of the model: they provide and shape the data that will be the input of the NFA system. Judges are still making decisions, deciding controversies, sentencing and so on. Network analysis is used only to grasp what is going on in legal activities trying to have a larger scale view that cannot be obtained only by way of citing some paradigmatic case. After years, the data collected through a NFA approach might be relevant for legal decision making but, this is something that needs to be stressed, the legal decisions are still realized by bone and flesh human beings, not by siliceous computers.

Computers are useful only in sorting out how the law is used by humans and how a particular law is performing in the achievement of its goals. If we expect some benefits for a society due to the introduction of certain new laws, we can track whether we are gaining such benefits or not (I will show this aspect later, while describing the positive outcomes of the implementation of the TS). The evaluation is done by way of machines, nonetheless, every time the law is applied, there is a human behind it and not a computer. The computer is there just to keep a record of that particular decision.

4. Conclusions on NAF

I presented NAF as a methodological proposal that enables us to find something like a third way between formalism and anti-formalism. The idea is that computers are not to be feared and that there is no gap between humanities and computer sciences or between the law in books and its creation, evaluation and application.

Computational social sciences can provide a great load of useful information to evaluate and monitor how the good intentions and purposes that motivate a law are doing in the world both in mapping the consequences of a law (think about a law designed to improve the assumption of young workers) and in mapping how a law has been applied (think about criminal laws related with cultural influenced murders or high debated and vagueness-affected laws concerning issues of bioethics that are highly influenced by the judges' personal beliefs).

PART II: INTRODUCING THE PROBLEM OF THE TRACEABILITY SYSTEM (TS)

In this second part I will present a TS for payment as an example of applied NAF. I want to show how the philosophical considerations exposed in part one can be used as a framework that can be applied to solve problems of our everyday life. I think the issue of payments and tax is a fairly good example: we deal with payments and money in quite a familiar and easy way, despite the fact that there are many problems and legal consequences attached to such phenomena that are by far less intuitive (e.g.: tax regulations).

I will engage an interdisciplinary approach trying to handle the philosophical and legal problems as well as the economical and technical problems related to the security and the possibility of realizing the TS sketched in the paper.

5. Method and Organization of Part II

Here I will discuss the technical and legal aspects of developing a full traceability system (TS) for payments and then investigate it backward and forward on the temporal axis.

Going backward, I will consider what should be the conditions that allow us to build such a system and the benefits given to the society by the implementation of such a TS. These benefits, I claim, will be both social and economical.

Going forward, I will concentrate on legal and technical aspects of detecting and mining personal data concerning earnings and expenses. The most relevant issues, I think, are related to privacy, especially concerning the (non) anonymity of the collected data.

The two questions that guide my research are the following:

1. What are going to be the legal upshots of a TS for every payment made in a community?
2. What might be the practical consequences of such a TS?

I think the main reasons to justify the development of a TS for payments can be the following:

1. it provides a solid base to collect taxes[6];
2. if the data are somehow publically available, it may also provide good data to drive financial economy (trading and investing) avoiding financial bubbles.

After providing some lexicon (Section 5.1.), I will first (Section 6.) state a general principle ("all economic transactions should be traced") and then (Section 7.) I will move on to consider an applied principle ("economic transactions should be traceable and the data should be accessible in order to prompt the development and provide resources to combat tax evasion"). For both principles, I will analyze the presuppositions for the principle to work and the practical upshots of its application. In dealing with the general principle, I will address the problems only at an abstract level.

I will then go deeper into the development of a TS starting from the applied principle (Section 8.), present some case studies concerning already existing traceability systems (Section 9.) and, after a brief consideration on security (Section 10.), draw the general conclusions.

5.1. Some Lexicon

Here I will introduce some terminology that I will adopt during the paper. I will refer to the ones that have to pay the taxes as *tax payer* (TP) while, on the other hand, I will call *tax collector* (TC) the other part of the model that has to collect the data concerning expenses and payments. These will be the two agents of the traceability system (TS).

[6] Establishing the principles of the taxation system is not a part of the present paper.

Tax collectors also have the burden of directly or indirectly collecting and organizing the data: their final goal is to use these data to increase everybody's welfare and eventually make the data publically available[7].

6. The General Principle

The general principle, which expresses the idea behind the TS proposal in the most naïve way is the following:

[*general principle*]: all economic transactions should be traced.

From the point of view of the motivations and goals for adopting a traceability system (see Section 5.1.), the general principle works mainly on the first one: it provides a solid base in order to apply taxation. As it does not say anything concerning the accessibility of the data, it cannot be used to obtain the second goal[8].

6.1. Presuppositions of the General Principle

The conceptual presuppositions of the general principle are at least the following:

1. There should be – on TCs part – a standard model to register and keep the data of all the transactions;
2. There should be – on TPs part – a standard way to enter the data, so that it will be easy for every TP to help TCs contributing to the "traceability game".

The most problematic presupposition, i.e., the one that is most likely to end up being inefficient, is (2). As the principle is general, we do not have to investigate the effective requirements the society needs to have in order to embrace the principle.

7. The Applied Principle

It is now time to move to a more concrete scenario and consider the "applied principle":

[7] I leave open whether the TC is the state or some more specific institution.

[8] Note that, stated in this way, the general principle is still compatible with the circulation of paper money. The general principle does not imply that paper money is to be dismissed or declared illegal.

[*applied principle*]: economic transactions should be traceable and the data should be accessible in order to prompt the development and provide resources to fight tax evasion.

7.1. Presuppositions of the Applied Principle and its Consequences

The conceptual presuppositions of this second principle are the same as the general principle, i.e.:

1. There should be – on TCs part – a standard model to register and keep the data of all the transactions;
2. There should be – on TPs part – a standard way to enter the data, so that it will be easy for every TP to help TCs contributing to the "traceability game".

Then, we also need to presuppose the two following things:

1. the realization of an archive for the collected data available to the public;
2. a policy stating who can access what kind of information.

The going backwards presupposition related to the society is a well developed technological infrastructure (wi-fi and Internet access) that is needed in order to not exclude people from accessing the data[9].

Considering the going forward analysis, the upshots of an implementation of the applied principle will result in a better accessibility to the Internet and, inside the European Union, it may help to meet the Digital Agenda[10].

7.2. Going Forward Social Consequences

A TS for payments will help us to detect tax evasion and presupposes high level services to the citizens who need to be given at least:

1. some sort of bank account, credit card or mean of payment almost for free: TPs join the traceability game and should suffer no major

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[9] Of course, there should also be the possibility to request a paper version of the data (for a fair price or for free).

[10] What I have in mind are the following points of the Digital Agenda: 2.1.1. Opening up access to content; 2.1.3. Building digital confidence; 2.2.1. Improving ICT standard-setting; 2.3. Trust and security; 2.4.1. Guarantee universal broadband coverage with increasing speeds; 2.4.3. Open and neutral Internet; 2.6.1. Digital literacy and skills; 2.7.4. eGovernment. See *A Digital Agenda for Europe* 2010, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0245:FIN:EN:PDF.

expenses. It is up to the TCs to enable the TPs to enter the game (see the tassa.li case study below in Section 9.1.);

2. some new technological instruments that will make it easy for the TPs and TCs to enter and track the data: e.g., mobile phones with some sort of paying system connected to some sort of governmental expenses and tax tracking network;
3. the possibility of accessing the Internet almost for free: the collected information are a value not only for the TCs, but for the whole society, so every TP needs to have a quick access to (some of) them in the fastest way. Until now, the best way to give data accessibility is the Internet[11].

7.3. Going Forward Legal Consequences

The legal upshots of these preconditions may be:

1. a clear statement of the right to access the Internet: it emerged from the previous point 3 in Section 7.2.;
2. new problems concerning privacy and the accessibility of financial data: the TS knows everything of the economy of a state. This means a great deal of information that leads to the following question: what is or should be accessible and what is not? What are the criteria to choose what has to be accessible and what is not;
3. new transparency standards for corporations, political parties, governments: TPs will be given the power of raising their voice when a government wastes public money or when corporations make speculations or fraudulent tax declarations.

Determining *a priori* the full spectrum of legal consequences is not possible and, in the rest of the paper, I will just hint at some of the points.

8. Implementing the Applied Principle: Data Mining and Database Organization

The third presupposition of the applied principle is the one that will shape the organization of the TS. We can imagine the TS as a big spreadsheet or excel file, accessible through the Internet. TPs send all the data to TCs, then TCs track everything.

[11] The physical access to the place where the data gained through the TS are stored is by far less efficient. It would be like obliging every people to go to the bank instead of using online services for paying.

The main problem, as the TS is able to provide a full database of the economic transactions, is: *who may access (and mine) what?* This requires to state better what a TP is and what information are associated to each TP's profile.

TPs are going to be all the agents of an economic environment: from individuals buying goods to corporations paying salaries or buying other corporations.

Every TP profile associates to the specific data (i.e., the money paid or received) any relevant data concerning who the TP is (proper name or corporation name), what are the earnings of the corporation or of the individual, education and profession of the individual (founding statute of the corporation and list of the employees for the corporation) and possibly other data.

These data will help the TCs to:

1. mine the data and recognize patterns of illicit activities (some corporations or workers could be more likely to evade taxes, we may find out what are the most used accounting tricks to make money disappear, etc.);
2. improve the general economy providing accurate data concerning (un)employment rate, average salaries compared with age or geographical area or type of job and, last but not least, balances of the corporations.

This will avoid a lot of "numbers wars" disputes between politicians and worker unions or between different political parties and, hopefully, may avoid financial bubbles.

A lot of problems arise at this point: does this mean that every company can see the names of its customers and all the items of the company that a particular customer has purchased? Does this mean that a company can know all the purchases of a TP as well as its name? Does it mean that Apple and Microsoft can see how much Google pays for its server maintenance[12]?

8.1. Introducing the Asymmetry

I think these problems can be solved by making the TS *asymmetrical* both in storing the information related to the different subjects (individual TP or corporation TP) and in giving access to the information collected by the TCs.

[12] If you read S. LEVY, *In the Plex. How Google Thinks, Works and Shapes Out Lives*, New York, Simon & Shuster, 2001, you will find out that this is one of the strategic data that Google cares the most not to reveal.

Concerning the asymmetry in storing the data, individual TPs contributions will always be anonymously registered by the other part of the TCs - i.e., by the other TP who sold the good or the service[13]. On one hand, the TC is the only kind of subject entitled to visualize the whole profile of all the transactions of any TP (full name, age and so on) for (tax) investigative purposes only.

The TCs can also elaborate statistics concerning relevant TP information and ought to produce the official statistics (unemployment rate, salaries by age, income compared to education and so on). These elaborations will be made publically available to everyone and the TCs will grant that, in elaborating the data, there will be no privacy infringement.

On the other hand, corporations and single TPs are not entitled to earn for free a full non anonymous customer profile for every TP, knowing that TP John Smith bought such and such from them in a year. A transaction between John Smith and a (Big) Corporation will be thus registered as "JS to BC" for John Smith but for the Big Corporation it will be a "General Customer to BC"[14].

Inside the TS, accessible only to TCs, there is also the nominal transaction made by John Smith to the Big Corporation. This is needed in case John Smith complains about the services and wants his money back: before giving him his money, the Big Corporation needs to know that it was TP John Smith to buy the good and not somebody else, otherwise the Big Corporations will have to give money away automatically for every complaint they received.

Concerning the exchanges between corporations or shops, I think that they should be symmetrically recorded: the owner of shop A knows that shop B bought something from him and the other way round.

Concerning the asymmetry in giving access to the information collected by the TCs, I think full reports of units sold during a year by corporations should be public and accessible to all the citizens as well as corporate balances. This will provide reliable data for the economy and let everybody

[13] Here I am assuming goods selling as the paradigm. Of course, when positive law requires something different (such as in some kinds of contracts) it is possible for both the seller and the buyer to register the transaction with the full name of the buying TP. A supermarket works and sells in a different way than a lawyer.

[14] The same goes for shops or other commercial activities. This is to ensure that business activities are not given by the TS a full customer's profile for free: they have promotion cards for it.

interested in the performances of a corporation know how many units were sold by a company, helping citizen and financial markets to have a better understanding of how firms are performing; I hope that knowing these information will lessen the frequency of financial bubbles. Collecting these data will also enable the state and the market to have more instruments to review corporations' budgets.

I think that, in order to keep free market going, the relevant information concerning strategic issues and for market competition between corporations have to be removed from these budgets (I think operative cost of infrastructure maintenance might be omitted, but here is where the problems will rise)[15].

8.2. The Mining Problem

Another relevant legal issue is how far the different subjects (TCs, corporations and individual TPs) can go into mining the public available data. Should data be profiled by age, race, education, geolocalized and so on?

As I told before, I think that it is up to the TCs to produce the relevant statistical analysis of the collected data, granting both TPs' privacy and data accessibility.

I also think that TCs should make a public register of all the exchanges of a certain TP (both individuals and corporations) that shows how much money they have spent and received without any specification concerning the item bought or the sum of money received. I propose to call this open access database, the *anonymous in/out database* (the "anonymous" refers to the fact that, even if we know the name of the TP we are considering, we do not know the name of the other part in the selling and buying process, but just the sum exchanged)[16].

[15] One of the most complicated issue concerns the (non) publicity of private deals such as the price of acquisition of a society or the sum received by an individual TP after suing and winning against a corporation or another TP. Hopefully, this will be ruled somewhere in the legal system the TS will be embedded into. Concerning companies, I think they can omit how many employees are working on a single project or department, but not their total employees' number.

[16] The difference with what is inside the TC database is that they know both the seller, the buyer, the value of the transaction and the good exchanged. In the *anonymous in/out database* we know just one of the two between the seller and the buyer (it depends on the role that our considerer TP had in the transaction) and the value.

Here problems arise: what other relevant information should be included and attached to the name of the single TP in this *anonymous in/out database*? This is a crucial point because what we will include here will also determine the information that could be mined.

My idea is that researches for every demographic category should be possible. What becomes problematic is to add more information concerning the TP status and to allow for more complicated searches. An example might help: find out what is the average monthly expense of a man or woman seems to be a question worth answering and it is positive to have a statistical answer to it. The statistic given by the TS is the result of the access to all the relevant data, so it is a very good one. It becomes problematic if you ask the same question but add to the data of the average expense an X for the age of the person, a Y for the region, a Z for education or, even worst, if you add a certain type of goods.

I think that this is a great problem for the development of a TS and it has to be ruled by both TCs and TPs. Whatever the criteria are going to be – the discussion is going to be on what should be the different types and combinations of anonymous information, trying to find the limit of whether anonymity is no longer warranted by the data[17] – I think that there should be a public accessible database giving non-anonymous information on who run searches on the *anonymous in/out database*[18]. This will enable both TCs and TPs to spot any suspect query in the system and to locate possible queries resulting in non-anonymous results (as the foreign student example in note 17). These data will be used to have an evolution of the system and to keep controlling the TS.

9. Case Studies: Recorded Future and Tassa.li

Here I will present two case studies that are interesting to see how traceability systems have been employed and the issues they arose. The first re-

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[17] Imagine that you know that 1 student out of 10 comes from a foreign country. If a professor puts in his evaluation form a local/foreign box, filling the evaluation form will no longer be anonymous for the foreign student. The TS should avoid such situations.

[18] I.e., there is a list of all the searches done by a TP on the TCs *anonymous in/out database*. This will enable you to know that the shampoo seller John Smith did some research on the wages of the TPs near his shop trying to sort out all the relevant data. I think it is useful to have such an archive in order to spot mining activities that may go against the privacy standards set inside the TS.

gards money: I will present the "Tassa.li" smartphone application that was designed to construct a map of evaded taxes in Italy.

The second regards human behavior in general, but has relevant financial application. The software is called "Recorded Future" and its mission is to predict the future mining the data available on the Internet. This latter case study is important both for its financial applications (it seems that you can have bigger profits in trading if you just mine the data from Twitter) as well as for the issue of how far you can go in mining public data.

9.1. Tassa.li

Tassa.li[19] is a smartphone app(lication) developed in Italy to cope with the problem of tax evasion (cafes not making the bills, workers performing jobs without giving you any receipt and so on). It employs a volunteer and non automatic system for tracing the money that is evaded. Tassa.li users voluntarily download the app and, whenever they do not receive the receipt or the bill, they – again voluntarily – submit a record of the evaded sum that is geolocalized and stored anonymously and displayed on the tassa.li website. As the site claims: "the data that we collect will be used to draw a tax evasion map, available to everybody on our website".

Concerning anonymity, they say that "your name will never appear on the map, neither in any area of the website nor in any field of the application. The name of the tax evader will not be reported as well"[20].

Another important thing concerns the chance of other people knowing that we are participating into the "tassa.li game". Instead of what happens inside the TS, "nobody will ever know that you are using tassa.li, unless you connected the tassa.li activity with Facebook or Twitter". Even in this case, the app will never reveal private information and will only post on your social network wall a message saying "I reported a tax evasion case using tassa.li – take a look at the tax evasion map".

This case shows that we need no tremendous computational power to obtain results, all we need is a way of integrating the processes of legal data acquisition into our daily life.

[19] See http://tassa.li.

[20] This and the following quotes are translations of the Frequently Asked Questions of tassa.li, http://tassa.li/faq.

9.2. Recorded Future

Recorded Future - RF[21] is a company that produces forecasts using public data mined from the web. You pay money to use the service and can ask their algorithm to perform a big variety of searches. RF idea is that the web has enough information to answer our concerns and enables us to make predictions about many different subjects.

Recorded Future is already doing something that the TCs in the model will do: they are mining publically available data, i.e., the whole web.

This is different from what the TCs will do because TCs will mine only some selected data (i.e., the one contributed by the TPs) but investigating RF may give us insights on the problems related with the mining of all the data of the *anonymous in/out database* produced by the TCs.

Before listing possible problems, there are differences between the two databases to be outlined:

1. information on the RF database are less controlled: not all the Internet users are well aware of the consequences of publically sharing information and the laws concerning the Internet are still to be fully figured out (think about the right to online oblivion or the right to access the Internet for free);
2. in the *anonymous in/out database* compiled by the TCs, all the users have a clear awareness of the kind of data they are contributing to and there is a clear positive law concerning its organization (there are different forbidden mining combination, the TCs will be responsible of privacy infringements when issuing their reports and so on).

With these differences in mind, we can get more information on how RF works by reading their blank paper on data mining[22]. I think these are the questions raised by the RF actions:

1. what do we have to do if the data processed and stored through the algorithm are no longer on the Internet?[23];

[21] See http://www.recordedfuture.com.

[22] S. TRUVÉ, *Big Data for the Future: Unlocking the Predictive Power of the Web*, 2011, https://www.recordedfuture.com/assets/RF-White-Paper.pdf.

[23] It is not quite clear to me from the RF paper what they do in analyzing the different daily slices of the data. It seems that they record and track day by day. So, if you remove on day 2 what you wrote on day 1, they will keep having and tracing also the information of what you wrote on day 1 also on day 3, day 4, ..., day n.

2. what if RF algorithm comes to mine information that are secret or somehow highly protected (by this I mean something more than a book copyright, such as a patent of a product or a military secret)?;
3. how can RF impact on censorship?

I think that RF can claim that "what is public is public" and they have no limits in mining it. Concerning 3, RF may claim that the fact that they store information once online and kept them stored, no matter what happens to the original source, is a way to contrast censorship.

The upshots of debating the RF case may end up being relevant to questions such as: should there be someone able to control the public access of the data (for RF the Internet, for TS the accessibility of the anonymous database compiled by TCs and the log of the activities on it)?[24]

10. Security

The problem of security for a TS has to be faced on all the levels of security: physical security of the infrastructures, security in the code lines of the TS and security of its content (the TP data). I think that, concerning physical and software level, this enterprise has to face the same danger of storing anagraphical data or credit card data and it will be up to the law to provide extra warrants for the contents (and we have seen that, in sketching the asymmetries of the TS, we had the law granting some extra legal protection to the TPs' privacy).

One of the biggest problem in realizing an effective TS is sociological: at least in Italy you need to win the fear of the web (people prefer to give their credit card to a waiter, giving him all the time to copy the data – credit card's number and code –, then typing them into an online form, and make people more aware of what it is like to share information or access the Internet and what is it like to be a victim of social engineering)[25].

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[24] This relates to the questions of the web access as a human right and having UNO controlling the web. In his talk at Mobile World Congress 2012, Google's CEO Eric Schmidt denies the need of United Nations to safeguard the Internet (http://www.youtube.com/watch?4DKLSO8wYzk at minute 36.20). I do not think that the introduction of TS and the *anonymous in/out* minable TC database will give reasons for a central control. On the contrary, it should give extra reasons for a transparent access to it.

[25] For an introduction of how a social engineering works you can see K.D. MITNICK, *The Art of Deception*, Indiana, Wiley, 2002.

11. Conclusions on the Traceability System

Having all transactions archived and available to the tax collectors will give an enormous data set that will enable the creation of a model that can be improved through time (an integration of tassa.li into RF may well be a first good hypothesis).

Of course, this will not solve the problem of evasion if money transactions are not registered. Nonetheless, provided the full implementations of the applied principle plus the elimination of paper money, the only way to have evaded taxation will be going back to barter or introducing parallel money[26].

The TS can be seen as a passive form of e-democracy: it teaches all the good practice of e-democracy (transparency and participation to the taxation game) but does not ask us to make a political choice (direct democracy: voting and proposing law).

The last question to be asked is: how far are we from the adoption of a TS for payment in our ordinary life? Unfortunately, this question deserves another paper to be addressed properly.

12. General Conclusions

In this paper I provided a methodological framework – NAF – in which computational social science can help legal science to be more effective and obtain control on how the law is performing in the world.

In the second part I investigated a possible application of the framework dealing with the development of a traceability system for payments. I think that the NAF framework can be further extended with the implementation of tools and conceptual resources from sociology, psychology and economics.

[26] There may be parallel money used to escape the TS, but it will be difficult for the parallel money to spread without being recognized and introduced into the TS. Maybe non durable goods may be used as such money. On this see T. Kawagoe, *Can Chocolate Be Money As a Medium of Exchange? Belief Learning vs. Reinforcement*, in "Learning", 2009, n. 5, pp. 279-292.

From "Free Information" to Its (Geo)referencing and Analisys: The "Costs" of Open Source

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SUMMARY: *1. Introduction – 2. From Data to the Geo-referred Information – 3. Geocoding – 4. Geo-data Mining – 5. Geographic Knowledge Discovery and Participatory Mapping – 6. Conclusion*

1. INTRODUCTION

In principle, within a "participatory decision-making"[1] all actors into play can "collaborate" because they share – preferably jointly – the information required to properly manage data flows and processes called for the contingent situation. To ensure to "communicate", students should also use the same codes for the same conventional signs, which are coded and universally recognizable, also using identical or at least easily recognizable "instruments" for a "standardized format" – through simple computing processes.

Mapping – also in its ultimate form, the digital one – is not an exception to the "rules" described above. The signs that appear on a paper must be clearly understood and shared to ensure an absolutely immediate reading without misunderstandings. Even before caring for the "visual" aspect it is essential to step back. It is essential, therefore, to find and use "official" data sets widely meta-documented and fit for purpose. In this context, during recent years in Europe, several projects and directives have been involved to specify and formalize not just the "representation" – a topic that remains open and of not immediate solution – but the methodology required to "share" catalogs of data on a large scale, in order to:

(a) tackling unnecessary and harmful phenomena of duplication - which also generate problems of "certification" and "official nature" of sources, among other things;

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[1] T. BELLONE, A. CITTADINO, F. FIERMONTE, *Participatory Mapping. Information Sharing on the Web*, in "Proceedings of the Conference Cartographic Challenges. Movement, Participation, Risk" (Bergamo, 23-24 April 2009).

(b) promoting processes of "derivation" and sharing, for example, for a given scale, a certain amount of data layers should not exist to represent the administrative units (country, regions, provinces and municipalities in the Italian case), but only one from which you can reach the others, even through the information sharing through the display of services such as WMS - Web Map Service, WFS - Web Feature Service, WCS - Web Coverage Service and so on, officially recognized and certificated;
(c) ensuring the free use of the information, encouraging public participation and access to justice (in court proceedings in relation to the environment)[2].

For example, we can mention the INSPIRE project[3] and the SEIS[4] Directive, to which we refer for completeness.

The problem of the availability of "official data" should be resolved or at least the path taken takes out to be correct. As far as this subject is concerned, we highlight the efforts taken up by the *Regione Piemonte* with the project *Dati Piemonte* (public data are of everyone) that provides a valuable informative wealth. However, the sources not always fully satisfy the requirements of analysis and research. Increasingly, in fact, we ourselves need to create geo-referred/geo-related data also starting from textual information available online. It is known that any set of information, with full address, can be "transferred" to a map description crossing road databases with the address books of interest. The process is called "indirect geo-referencing". However, how easy is to deal with it? What are the problems and the "costs" that one must endured in "open source" environments and "open source" tools? This paper will attempt to analyze the problems inherent in such operations, highlighting the key points and the critical issues identified.

2. From Data to the Geo-referred Information

To look up information it may be sufficient to start from a search engine (for example Google, Bing or other) or, even better, making reference

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[2] Aarhus Convention, *Citizens Right to Access Environmental Information*, http://ec.europa.eu/environment/seis/citizens_rights.htm.

[3] Acronym that stands for Infrastructure for Spatial Information in Europe. See European Community, *SEIS - Shared Environmental Information System*, http://ec.europa.eu/environment/seis.

[4] Acronym that stands for Shared Environmental Information System.

to official records. In the first analysis all the feedback in PDF format can be left out, especially if protected by a password, as it avoids making copies of records to be processed. Therefore, if possible, it is better to use directly the accessible information published in spreadsheets (OpenOffice Calc), databases (OpenOffice Base) or text files, preferably the structured ones (CSV - Comma Separated Value).

About the previously cited shared formats, we found the ability to download – in addition to the already mentioned geo-referred data – CSV information (for example, among others, the "List of shopping malls") on the Dati.Piemonte.it site[5]. In order to correctly decode such information, however, additional software tools such as, for example, Google Refine[6] are required. If this is not enough, it is possible to use a simple text editor (with a good computer skill), procedures that is clearly described on the Dati.Piemonte site. Similar situations, although they require free add-in type, however, extend the pre-processing time and lead to higher costs (man/days) concerning the geo-referencing process.

3. Geocoding

The information, in order to be properly managed and represented in its correct component spatial reference, shall be added to addresses, preferably if it is normalized. As it is known, a hypothetical toponym, such as "Verdi", should be correctly ascribed to get a truthful control for localization. Giuseppe Verdi, the composer, is obviously different from Mario Verdi, hypothetical hero of the Italian Risorgimento. After having been normalized, namings should be divided, if necessary, in basic components: street, preposition, street name, area, etc. in order to allow a "(semi-)automatic process" from instruments of "massive geocoding" such as Batch Geocoder[7]. This online tool, which is "free for limited numbers of records", returns the coordinates (WGS84 geocentrics), expressed in latitude-longitude, beginning from the addresses and from their civic numbering. We are facing, even in this case, with processing simplifications. The coordinates, in fact, are returned by interpolating the house numbering on single road arcs – between intersection and intersection – and with a range of house numbers on the left and right (left-right/from-to). This is obviously a process which, in

[5] Regione Piemonte, *Dati Piemonte*, http://www.dati.piemonte.it/.

[6] See https://code.google.com/p/google-refine/.

[7] See http://www.BatchGeocode.com.

addition to all the typical limitations of the starting databases (update, reliability, quality, length of road between two intersections, etc.. . .) also suffers from inherent problems of "understanding", such as accented letters or abbreviations of place names, that, if not managed properly to the source, may render ineffective a large part of the work.

Broadly speaking, any GIS - Geographic Information System type software application "is able", starting from the coordinates of the points just obtained, to return graphically the "correct" location of the points that appear then to be geo-referenced in all respects. Unfortunately the situation is not optimal as it seems and does not allow to be certain of the results because a lot of the steps are performed by hand or using procedures offered unseen sight and with no means to intercept and handle the error. On a limited number of recognizable objects (by their area, shape or size) we can verify the correct correspondence using a certified document (such as "technical map" or "orthophotomap"). However, it is a question of long and not always feasible checks. A school building, for example, could not be so "evident" or "recognizable" onto the map or seen from above. Generally, the unidentified locations are then assigned to "coordinates zero" and therefore it is necessary to investigate and to work out adequately what is left "pending", if possible.

4. Geo-data Mining

Why is it so important to think about DM - Data Mining[8], especially referring to the "geographic information"? Maybe, just for a simple consideration: the amount and the volume of (geographic) data are grown a lot in the last decade and they are increasing day after day in a massive way[9]. No possibilities, therefore, exist to use the "data" correctly without converting them into "structured information" or simple creating "information from

[8] For a description about the concept, see Wikipedia at http://en.wikipedia.org/wiki/Data_mining.

[9] "Geographic data collection devices linked to LATs - Location-Aware Technologies, such as the global positioning system, allow field researchers to collect unprecedented amounts of data. Other LATs such as cell phones, in-vehicle navigation systems and wireless Internet clients, can capture data on individual movement patterns", see J.P. Wilson, A.S. Fotheringham (eds.), *Geographic Data Mining and Knowledge Discovery*, in "Handbook of Geographic Information Science", Blackwell Publishing, 2008, http://www.geog.utah.edu/ ˜ hmiller/papers/Handbook_GIS.pdf.

data"[10]. For this reason, if thinking about a specific "geographic location" (and all that is close to it) is relevant, considering its historical background is also strategic. Such analisys can measure or explain the land consumption, or simply show where should be the "optimal place" for a new kindergarten. So, what is DM? We can answer in a simple way: DM is not a Google (Advanced) Search. DM is, instead, the process of analyzing data to identify "patterns" or "relationships". To do this task, it is important to use almost two softwares, a spreadsheet and a statistical analysis package, for example OpenOffice Calc and Orange[11] to "join" some of these data together. A GIS software (an open source one is better, of course) is also required to perform all the (geo)spatial analisys of interest (Quantum GIS, for example). Data mining is also known as KDD - Knowledge Discover in Databases[12]. And knowledge means "all that is interesting" and not known *a priori*.

How many "data" exists? How many of them is it possible to convert into "information", much better if reusable and upgradable in time? From KDD to GKD - Geographic Knowledge Discovery, and its core sector, the GDM - Geographic Data Mining, the way is not so easy. In fact, we have to notice that "Spatial" concerns any phenomenon where the objects can be embedded within some "formal space" that generates implicit relationships among the objects[13]. So, the matter is: "how discover knowledge from databases"? How use data mining to create and manage "information"? Using a sentence by Wilson and Fotheringham, "data mining involves the application of techniques for distilling data into information or facts implied by the data" if we have to:

- understand the world that surrounds us (according to literature, we can call it the "background knowledge");

[10] K.-H. ANDERS, *Data Mining for Automated GIS Data Collection*, in Fritsch D., Spiller R. (eds.), "Photogrammetric Week '01", Heidelberg, Wichmann Verlag, 2001, pp. 263-272.

[11] See http://orange.biolab.si/ and T. CURK, J. DEMŠAR, Q. XU, G. LEBAN, U. PETROVIČ, I. BRATKO, G. SHAULSKY, B. ZUPAN, *Microarray Data Mining with Visual Programming*, in "Bioinformatics", Vol. 21, 2005, n. 3, pp. 396-398.

[12] M. ESTER, H.-P. KRIEGEL, J. SANDER, *Spatial Data Mining: A Database Approach*, in "Proceedings of the 5th International Symposium on Large Spatial Databases - SSD '97", Berlin, Springer-Verlag, 1997, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.18.4661&rep=rep1&type=pdf; U.M. FAYYAD, G. PIATETSKY-SHAPIRO, P. SMYTH, R. UTHURUSAMY, *Advances in Knowledge Discovery and Data Mining*, Menlo Park, AAAI/MIT Press, 1996, pp. 1-34, http://www.kdnuggets.com/gpspubs/aimag-kdd-overview-1996-Fayyad.pdf.

[13] J.P. WILSON, A.S. FOTHERINGHAM (eds.), *op. cit.*

- verify, organize[14] and clean the data (that always must be followed by their own metadocumentation) before starting any operations and analisys;
- according to our need, choose the appropriate "data mining type" to perform the analysis or the research (such as the correct classes, associations, rules, clusters, outliers and trends discussed in more detail below).
- "build (and consolidate) the Knowledge" using all the input data (and their spatial relationship).

Of course, the KDD process is not a linear one, with a sequenced starting and ending point: "analyst will re-sequence and even revisit steps based on the sought knowledge and the nature of the information uncovered within the process"[15].

Data mining should reveal, among the others, the patterns of interest and to perform this we have to consider several steps to "organize" the input. So, broadly speaking, we have to classify the data, analysing their association and make prediction (if possible) about their correlations and effects, perform "cluster analysis"[16] and "outlier analysis"[17].

5. Geographic Knowledge Discovery and Participatory Mapping[19]

GDK - Geographic Knowledge Discovery is the process of extracting information and knowledge from massive geo-referenced databases[20]. How-

[14] Geographic data must share the same GCS.

[15] J.P. Wilson, A.S. Fotheringham (eds.), *op. cit.*

[16] Techniques for classifying data objects into similar groups.

[17] Outliers are data objects that appear inconsistent with respect to the remainder of the database[18]. While in many cases these can be anomalies or noise, sometimes these represent rare or unusual events to be investigated further. For example, outlier analysis has been used in detecting credit fraud, determining voting irregularities or severe weather prediction. See S. Shekhar, P. Zhang, Y. Huang, R. Vatsavai, *Trends in Spatial Data Mining*, in Kargupta H., Joshi A., Sivakumar K., Yesha Y. (eds.), "Data Mining: Next Generation: Challenges and Future Directions", AAAI/MIT Press, 2003.

[19] M.F. Goodchild, *Citizens as Voluntary Sensors: Spatial Data Infrastructure in the World of Web 2.0*, in "International Journal of Spatial Data Infrastructures Research", Vol. 2, 2007, pp. 24-32, http://www.geoinformatics.cn/wp-content/uploads/citizensasvoluntarysensors.pdf.

[20] SDWs - Spatial Data Warehouses are data warehouses that also include both "spatial and aspatial data", J.P. Wilson, A.S. Fotheringham (eds.), *op. cit.*

ever, to do this (for the nature of geographic entities, relationships and data) the "standard of the KDD techniques is not sufficient" to explain the complexity of real world and to reflect it into related schemes to build structured information[21]. We have to think also at the spatial relationship and at proximity rules. These can be defined and understood using terms such as location (where is it?), distance (how far is it?), direction (on which direction?) and/or topology to manage data integrity, shared geometry, adjacent and connected features. Last, but not least, we are compelled to think about the relations among data, spatial relationship and timeline series.

The goal is to arrive into a new geographic visualization, that someone calls GVis - Geographic Visualization, that is "the integration of scientific visualization with traditional cartography"[22].

Probably, participatory mapping is not the last, neither the least, nor the first argument of this short paper but, without raising and sharing the "information", it could be not even start. The accessibility to the official data, such as the lists of street maps (certified toponyms), for examples, and procedures apt to the verification and standardization of the addresses, restricting the preliminary operations of cleaning and recognition, would allow to obtain, in less time, a better quality output. The use of "open source" instruments, of course, limiting the costs of basic software, allows to share instruments and resources and to invest in training on alternative procedures and on freely available tools.

In the last years, in spite of all the efforts made for greater sharing and participation, from a point of view of the ordinary user, the view has not substantially changed.

"Data sharing" (or "participatory mapping" as you prefer) in order to function, needs (at least) of three levels + 1 of interoperability[23]

- technical (communication through shared "interfaces");
- semantic (standards related to content and meta data documentation)

[21] For example, we could think about "the complexity of spatial objects and relationships as well as their transformations over time, the heterogeneous and sometimes ill-structured nature of geo-referenced data, and the nature of geographic knowledge" J.P. WILSON, A.S. FOTHERINGHAM (eds.), *op. cit.*; see also S. SHEKHAR, P. ZHANG, Y. HUANG, R. VATSAVAI, *op. cit.*

[22] J.P. WILSON, A.S. FOTHERINGHAM (eds.), *op. cit.*

[23] M. SALVEMINI, *La direttiva INSPIRE: punti fermi, priorità, impegni per i governi nazionali*, 2004, http://151.100.2.84/wordpress/wp-content/uploads/2008/02/salvemini-la-direttiva-inspireasita-2004.pdf.

- institutional (collaboration and sharing aimed at overcoming the institutional barriers);
- training (activities designed to increase the geographical culture);

In this latter respect, the extension of ECDL[24] certification in GIS environment (Geodesy, Cartography, commercial or open source software and tools) and the strengthening of training offer, that such certification requires, are extremely important.

6. Conclusion

In conclusion, to facilitate the consolidation of a "participatory mapping", leading to the birth of an "ACTIVEsharing" (in Italian "partecipAttiva", Active_and_Participatory) mapping, it is highly desirable to succeed in:

- "standardizing" the mapping component in the access pages, for example by sharing the same prefix or suffix;
- making cartographic inventories, related resources and applications running on the Internet "more visible" or "not hidden" to search engines[25];
- publishing lists of WebGIS, WMS, etc. services, taking care of including the main functionalities of each one (e.g., downloading data: yes/no);
- increasing availability of downloadable datasets (including meta documentation) locally;
- guiding the user to a "conscious" use of data, even through the use of distance learning instruments of e-Learning (e.g., Moodle);
- promoting and supporting ECDL GIS certification;
- allowing users to have the possibility to consult the Web pages and the services offered by it in the language of the state of the country of belonging as well as in English.

We want to conclude our paper with an Italian example about a possible use of geo-referencing. An Italian research team from the Politecnico of

[24] The european GIS certification (Geographic Information System) is a program designed to demonstrate the professional knowledge on the use of GIS systems and of their main components and functions. It is addressed to all those who are called, in their professional area, to work with systems (GIS) that correlate the phenomena or variables to the territorial dimension, creating thematic maps and analytical reports in various formats, http://www.ecdlgis.it.

[25] Appropriate bookmarks drowned in the code (meta tags) make resource easily recognizable.

Torino is purposing to geo-reference the information for teaching[26]. This new approach could increase the appeal of some scientific disciplines. Moreover, it could be a user-friendly tool, for the new students generation, the BIT generation, in addition to the traditional ones commonly used for studying. In particular, the group realized two study cases: about the biography of Sir Isaac Newton and Ernesto Schiapparelli. The information about these two scientists, using a timeline, was geo-referenced on maps and visualized on Google Earth. Going into details, these researchers developed a tool that is able not only to geocode the information, translating it into KML format (and view it into Google Earth) but also to create an html page with CSS style language[27] file in order to browse all the data using a compatible hypertext client software.

[26] A.C. SPARAVIGNA, R. MARAZZATO, *Georeferenced Lives*, 2012, http://arxiv.org/abs/1203.0500v1.

[27] See http://en.wikipedia.org/wiki/Cascading_Style_Sheets.

Computational Sciences, Business Management, Accounting and Law: Potential Intersections

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SUMMARY: *1. Introduction – 2. Interdisciplinary Relations between Computational Sciences and Economics – 3. Summary and Conclusions*

1. INTRODUCTION

The origins of Accountancy are linked to the natural human need to record significant events, especially those related to the economic dimension of man's existence[1]. Subject matter and methods have however, evolved over time, thus defining the various areas of application[2].

In effect, in its practical application, the "praxis" of Accounting has always involved "the art of book keeping" and keeping accounts has always constituted the main tool for detecting and recording data relative to events under investigation.

Notwithstanding, Accounting can be contextualized within the history of scientific economic thought, science and history, and therefore from the

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[1] S. CORONELLA, *L'economia aziendale e la ragioneria*, in Ricci P. (a cura di), "L'economia dell'azienda: paradigmi e declinazioni", Milano, Giuffrè, 2012, p. 749 ff.

[2] On the historical evolution of the subject, see also: A. AMADUZZI, *Storia della ragioneria. Percorsi di ricerca tra aziende e contabilità, dottrine e professioni*, Milano, Giuffrè, 2004; S. CORONELLA, *Compendio di storia della ragioneria*, Roma, Rirea, 2010; M. COSTA, *Le concezioni della ragioneria nella dottrina italiana. Profili storici e storiografici nella sistematica delle discipline aziendali*, Torino, Giappichelli, 2001; O. GAVROVEC MEI, *Il linguaggio contabile. Itinerario storico e metodologico*, II ed., Torino, Giappichelli, 1999; B. SIBONI, *Introduzione allo studio di storia della ragioneria attraverso il pensiero e le opere dei suoi maestri*, Milano, Franco Angeli, 2005. In terms of subject content and research method instead, among many publications, see: P. ONIDA, *Le discipline economico-aziendali. Oggetto e metodo*, Milano, Giuffrè, 1947; M. PUGLISI, *Economia aziendale e dibattito scientifico. Alcune significative relazioni in un tentativo di lettura in chiave epistemologica*, Palermo, Palumbo, 1996; S. VICARI (a cura di), *Metodo e linguaggio in economia aziendale*, Milano, Egea, 1992; R. FERRARIS FRANCESCHI, *Il percorso scientifico dell'economia aziendale. Saggi di analisi storica e dottrinale*, Torino, Giappichelli, 2010; P. LIZZA, *Sul metodo di ricerca in economia aziendale*, Milano, Giuffrè, 1998; G. PAOLONE, *L'economia aziendale e la ragioneria nella teoria e nelle specializzazioni*, Milano, Franco Angeli, 2011.

perspective of doctrine can be delineated in terms of a natural pathway leading to the more recent and familiar discipline of Business Administration[3]. The theoretical approach distinguishes diverse historical periods, ranging from fragmentary[4] to systemic[5], from the phases of General Accountancy and Administrative Technology[6] to culminate in Business Administration *tout court*[7].

Gradually, starting from separate studies focusing mainly on technical and administrative computation and the keeping of accounts, more consistent theories were devised delineating the enterprise, its internal dynamics and its relations with the environment[8], in the awareness of business as an open system interacting with its supply markets and outlets.

Accounting has thus become part of the broader and more recent discipline Business Administration[9], collocated[10] alongside more general[11] empirical[12] disciplines which investigate real life scenarios in order to create optimal models of corporate behaviour.

Its object of analysis, the enterprise, in its guise of privileged instrument of production and consumption, designed and managed to satisfy and respond to human needs, places Business Administration within the social sciences with which praxis it has numerous elements (conditions, processes, behaviour, organization, institutions) in common. The logic of combining scarce resources to create multiple goods and services, furthermore, associates the discipline with Economic Science of which Political Economy - to

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[3] A. AMADUZZI, *L'azienda nel suo sistema e nell'ordine delle sue rilevazioni*, Torino, Utet, 1987, p. 47 ff.

[4] From 1200 to 1800.

[5] First decades of the 1800's.

[6] Especially the second half of 1800.

[7] Studies carried out in 1900.

[8] Physical-natural, technological, cultural, legal, social, political, legislative, etc.

[9] The valuable insights of Zappa reported in the vast bibliography are unanimously held to underpin the origins of the Economic enterprise. In particular, the famous inaugural address made on November 13, 1926, on the occasion of the inauguration of the academic year 1926/1927 at the National Institute of Economic and Commercial Sciences of Venice (Ca' Foscari) is considered the beginning of the new discipline. See G. ZAPPA, *Tendenze nuove negli studi di ragioneria*, Milano, Soc. An. Istituto Editoriale Scientifico, 1927.

[10] E. ARDEMANI, *L'impresa, economia, controllo, bilancio, gestione straordinaria*; Vol. 1: *L'economia delle imprese*, Milano, Giuffrè, III ed., 1989, p. 1 ff.

[11] Formulating laws derived by uniformity of behavior-consequence relationship.

[12] Investigating reality also for operational purposes.

which it is intrinsically linked - has long been part. Such multiple relations moreover, are entwined with various other disciplines of a quantitative[13], sociological[14], psychological[15] nature. In particular, longstanding relations are firmly in place with Legal Sciences: civil law, commercial law, bankruptcy, labour and tax law, as consolidated practice and the acquired knowhow of scholars, professionals and operators testify: economic activities have constantly required regulatory dispositions to underpin the economic system in its explicating of effective instances of economic policy and for regulating production processes in which person-company-State relations are core components.

However, a factor that remains to be verified – the main purpose of these notes – is the potential interrelations of economic practice with the most recent methods of computational science and the latter's contribution to consolidating and improving current relations in act between economics and the law. In the wider perspective, computational sciences include any area of science which uses computerized calculations to resolve problems inaccessible to man in terms of real time. One specific segment, *System Dynamics*, studies the behaviour of systems, underlining the extent to which the rapport between policies, decision-making structures and time scales influences dynamic phenomena[16]. Accounting, collocated at the centre of the wider business information system - whose main function is to collect basic data for transforming into information after laborious and complex processing by means of online computational methodologies - also makes use of quantitative processing related to economic and business issues. This contributes to reducing the margin of error on the part of top management given that their

[13] Business management sometimes uses algebraic algorithms and geometric representations.

[14] The markets affected by the evolution of relationships between individuals that guide consumption.

[15] The organization of work should consider the aspirations of each operator, also to increase productivity.

[16] The analysis is based on two concepts: – the division between state variables (stock) and the dynamics of these (flow) – the presence of the feedback loop. A feedback loop exists when the state of a system stimulates a decision that results in action and causes a change in the original state of the system, thus creating the basis for future decisions. Two basic assumptions, then: a) the interweaving of decision-making processes, information flows and relationships within companies, emerging structures made up of feedback loops concatenated b) the behavior of the systems are the result of structural features that take such combinations of feedback loops that regulate the rate of accumulation or erosion of the variables level (stock) included in such. See http://www.systemdynamics.it.

decision making is generally based on available information, or on purely intuitive processes that are incompatible with current environmental complexity[17]. Consequently, the advent of information technology has definitively characterized the evolution of Social Sciences and in particular of Accounting, by virtue of processes that are increasingly faster and more accurate than in the past.

In this context, the main purpose of this paper is to highlight the potential uses of the methods of Computational Science in Economics and Business Accounting in order to: propose new governance tools to facilitate management in decision-making processes; promote the dissemination of instruments of predicting, planning and control to allay liabilities, financial crises or bankruptcy; monitor to verify that rules and regulations in the business context are respected and misconduct sanctioned; explore corporate requirements to regulate economic activity in an organic and efficient manner; interpret corporate behaviour, eventually using socio-economic analysis, to regulate corporate relations.

2. Interdisciplinary Relations between Computational Sciences and Economics

Areas of potential application of computational science methodologies in Economics coincide with the main areas of business research and application. For each[18] area, theoretical elements and applications are set out below, specifying, where feasible, potential links with Legal Sciences.

(a) Automated information extraction. Academic and professional methodological approaches typical of this area of Computational Sciences facilitate research relative to the *quantitative* and *qualitative* composition of budgets[19].

[17] "For efficacious and knowledgeable action, management and organizations need to use data and information deriving from within the company or from the environment in which it operates. Knowledge is a key factor that all actors working in a company have to deal with in a rapidly changing environment": G. Airoldi, G. Brunetti, V. Coda, *Corso di economia aziendale*, Bologna, Il Mulino, 2005, p. 275.

[18] As illustrated in C. Cioffi-Revilla, *Scienza sociale computazionale e scienza giuridica*, in Faro S., Lettieri N., Tartaglia Polcini A. (a cura di), "Diritto e tecnologie verso le scienze sociali computazionali. Attualità e orizzonti dell'Informatica giuridica", Napoli, Esi, 2012, p. 203 ff.

[19] For application in business to report results from the financial statement using the typical methodology of computational linguistics. In this context, see L. Dibattista (a cura di), *Storia della scienza e linguistica computazionale. Sconfinamenti possibili*, Milano, Franco

To date, their comparability has always been considered crucial for improving processes of analysis relative to the capital, economic and financial structure of a business and for reporting adequately on individual enterprises. In more general terms, it is possible to create standard budget models as benchmarks to obtain sector mean indices of reference that can contribute to devising economic policies for industrial and local development.

Specific requirements of comparability underpin the Legislative Decree No. 127/1991 which implements Eec Directive IV, 78/660 relative to the issue of annual corporate reporting.

Civil legislation however, still in force, imposes rigid budget parameters and guidelines which only in exceptional cases, can be slightly modified when the need for greater clarity arises[20]. This has encouraged mechanisms of comparison including the collecting and comparing of numerous industrial production reports. One outcome of such practice has been the creation of specific databases of recorded statement input collected in specialist software. This has facilitated the process of collecting and processing regulatory financial information and its depositing with the Chamber of Commerce in electronic format – Xbrl – which stands for eXtensible Business Reporting Language[21].

In this vein, with the relaxing of the rigid schemes of financial statements, as regulated by the Ias/Ifrs[22], reporting methodologies currently in use risk

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Angeli, 2009, reporting the proceedings of a Conference held in Bari, Italy, in 2008. Speakers included historians of science, computer scientists, linguists and researchers attempting to cross cultural borders of disciplines such as scientometrics, computational linguistics and history of science.

[20] On the subject, see G. MIGLIACCIO, *Gli schemi di rendicontazione economico-patrimoniale di imprese ed enti locali: profili evolutivi e comparativi*, in “Esperienze d’impresa”, 2007, n. 2; ID., *Verso nuovi schemi di bilancio. Note su evoluzione e prospettive di forme e strutture del bilancio d’esercizio*, Milano, Franco Angeli, 2007.

[21] The Xbrl format was introduced at international level to promote the exchange and communication of accounting and financial information, defining a flexible and shared data encoding process facilitating the analysis of financial statements and therefore the financial assessments of credit institutions for the Inland Revenue Agency. The issue of its undoubted interdisciplinary value is dealt with in A. FRADEANI (a cura di), *Xbrl: il nuovo linguaggio dei bilanci*, Milano, Ipsoa, 2009; ID. (a cura di), *Xbrl il presente ed il futuro della comunicazione economico-finanziaria*, Milano, Giuffrè, 2009; ID., *La globalizzazione della comunicazione economico-finanziaria. IAS/IFRS e XBRL*, Milano, Giuffrè, 2005.

[22] Today only the largest listed companies or those belonging to specific economic sectors (banking and insurance); in future to be extended to all companies, including small and medium size enterprises.

encountering total inefficacy. The wide margin allowed in drawing up financial statements at international scale, in terms of form, content and format imposes the need for new methods of automated information extraction to which purpose Computational Sciences can provide tools.

The current complex scenario (i.e. the unorthodox coexistence of statements drawn up on the basis of opposing logics) requires investigation by means of adequate algorithms. From the outcome of investigations, new legislation can then be proposed to regulate future policy choices, particularly if the current formal anarchy of financial reporting continues to create difficulties in interpreting financial accounting or in any event, to represent an obstacle to necessary business interrelations.

A fundamental element to take into account is the fact that statements, reports and other documentation accompanying balance sheets and income statements are becoming more and more relevant. At the same time, electronic analysis of the content of such documentation is becoming crucial for detecting salient information that may not emerge from mainstream reporting. In short, computational science methods can contribute to revealing the presence of common elements or evident differences or, even indicate factors that might have been overlooked or not exploited adequately when interpreting vast columns of figures.

In conclusion, comprehension of the large corpus of highly analytical, Ias/Ifrs international accounting standards documentation, can be facilitated by means of an It based platform of information detecting techniques, as can the interpretation of all the relevant sources of legislation and jurisprudence.

(b) Social network analysis. Any enterprise, public or private, for-profit or not for profit, can be considered a "social network". Companies establish numerous relations with other companies, they create, in other words, an open system requiring feedback, i.e., input-output with other institutions.

The importance of computational science methodologies to monitor the extent and form of reporting and the relations characterizing each firm is therefore fundamental, not least in terms of comparison mechanisms and benchmarks both to identify potential inefficiencies and to plan new earning potential.

Methods of computational science in this context can serve internal needs by focusing on the relations characterizing different departments, offices or functions and meet external requirements related to the wider input-output relations of each structure.

It would be slightly more complex, but desirable, the analysis of the relations involved in the production process and trading of a business and the social and cultural system in which it operates and with which it regularly and systemically[23] interacts.

In the same way, in depth studies would be useful that analyze the rapport between private sector enterprise and the consolidated presence of the private sector in the public administration (more or less pronounced in relation to the policy decision making context): public authorities would also benefit from such information in order to plan facilities, events and processes which effectively meet collective needs[24].

One significant advantage would derive from identifying potential alliances between companies that are often difficult to detect within the intricate series of complex relationships, embedded or otherwise.

The above described benefits in terms of potential growth in productivity would also have particular repercussions and implications from a legal perspective. For instance, conflicts between companies dominating the international economic news require resolving within national and supranational legal frameworks that comply with the changing needs of business production. On a smaller scale, in house relations frequently generate conflicts between employees or between the latter and the company and such issues require resolution and regulation by Labour or Industrial Relations Laws that take into account contingent events. However, accountability of the effects on the environment and on social groups, of manufacturing and trade policies is also fundamental in order to promote a discipline that induces respect for natural resources, individuals and associated groups. Analyses both of en-

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[23] Consider, for example, the social effects of advertising messages.

[24] The volume of G. FIORANI, *System thinking, system dynamics e politiche pubbliche*, Milano, Egea, 2010, suggests the dissemination of systemic thinking and system dynamics methodology in the definition and evaluation of public policies. These methods would be useful for regional and local authorities strategic planning, alongside the tools of public management traditionally used. On this subject, with special reference to depressed areas respectively, dock areas and water as a public good, see: C. CUCCURULLO, *Il ruolo della pubblica amministrazione nelle politiche di sviluppo delle aree depresse: un'analisi system dynamics*, in "Azienda pubblica", Vol. 18, 2005, n. 2, pp. 231-250; F. CARLUCCI, A. CIRÀ, *Le politiche di pianificazione degli investimenti in infrastrutture portuali: un approccio di system dynamics*, in "Economia dei servizi", Vol. 4, 2009, n. 3, pp. 329-343; C. BIANCHI, E. BIVONA, A. COGNATA, P. FERRARA, T. LANDI, P. RICCI, *Applying System Dynamics to Foster Organizational Change, Accountability and Performance in the Public Sector: A Case-Based Italian Perspective*, in "Special System Dynamics Issue of the International Journal Systems Research & Behavioural Science", Vol. 27, 2010, n. 4.

vironmental impact and of the social effects of promoting and distributing particular products of a specific company would facilitate identification of illicit or unethical conduct and outcomes of such analyses could function in terms of facilitating the updating of legislative norms which often remain anchored to scenarios that are no longer pertinent or relevant.

In this respect, it should be considered that administrative law could also facilitate the creation of more efficient relations between productive units and the public administration where computational science methods would clearly demonstrate the extent of unnecessary and cumbersome bureaucratic relations.

Finally, the emanating of more flexible but at the same time more effective commercial and fiscal laws to safeguard all the stakeholders involved could result from the analysis of intra-group relations or those between subsidiaries and associates. Thus attacks of instability such as the detraction of resources could be prevented and above all, illicit conduct such as tax evasion impeded.

(c) Geospatial Analysis. Social GIS (Geographic Information System), linked to the spatial-statistical analysis field, might, at first sight, appear the exclusive competence of socio-economic geographers who analyze the deployment of the main productive territorial resources.

The issue, however, has typical interdisciplinary connotations by virtue of the fact that business economics and its related disciplines of management, analyze, study and develop theories and devise projects related to corporate location strategies.

The current global economic situation, in effect, allows greater freedom of investment and favours free choice in the location of production plants, even those quite distant from the area of start up of the original business.

The findings from specific research, i.e., the outcomes of different methods of computational science in these areas, would facilitate the promoting of international laws and/or the stipulating of specific agreements between nations. In addition, national legislation could exploit data obtained to plan a more appropriate economic and social use of the territory[25] with updated legislation regulating the location of factories and commercial activities in re-

[25] R.M. PULSELLI, P. ROMANO, *Dinamiche dei sistemi urbani - Urban system dynamics*, Firenze, Alinea, 2009. The results of a "census" of the population of a small area covered by the research are illustrated in the volume: citizen density was measured, the facilities and services in the city quantified. The information was considered essential in order to address issues related to the management of services, infrastructure and mobility systems.

lation to residential areas. Town planning laws, in this respect, would clearly also benefit.

(d) Complexity Modeling. As is well known, models inspired by the complexity theory provide systems based on quantitative analysis of non-equilibrium dynamics. Some such models are also applicable to business needs.

The lifetime (potential duration) of the business system can be measured by calibrating the company to conditions approaching economic, capital and financial balance. Management has to concentrate efforts on addressing the achieving of such balance which is constantly threatened by both internal and external dynamics.

The extent of corporate disequilibrium can result in critical situations which if not properly dealt with, can lead to business break up. The reasons for such imbalance are numerous and lie both within and outside the company. External causes include recessions, hostile social and cultural environments and/or a negative corporate image or reputation. Internal causes impact equally and concern: overinvestment or insufficient or modest competences or skills, inadequate trade policies and so on.

Calibrating current algorithms of computational science methodologies to recessional paradigms is not simple given that the former are addressed mainly to statistical issues relative to the composition of societies, i.e., the distribution of wealth among countries, distribution of foreign aid and the geography of terrorism that often follows in their wake.

In any event, the context provides a number of valid reasons favouring the statistical analysis of causes of corporate crises as a basis for putting in place adequate quantitative estimating or predicting systems for crisis prevention. Outcomes would encourage the onset of steady employment and at the same time, contribute towards increasing Gdp at national scale. Quantitative studies linked to the dramatic circumstance of the current economic and corporate crisis would also be of extreme relevance to the Legal Sciences attributing them the remit of monitoring and verifying balance sheets and where necessary, of resolving scenarios related to businesses afflicted by recession and related consequences or, in the worst case, the remit of regulating their closure. Productive enterprises consequently, ought to be considered a resource of public interest even if they do constitute private sector companies. There is no doubt that corporate survival benefits the whole community which derives directly or indirectly, economic benefits from viable, productive businesses.

It goes without saying that Corporate legislation, a branch of wider economic legislation, cannot be limited merely to the management of routine situations, but should also be charged with predicting and regulating scenarios that often herald interpersonal conflicts between individuals with contrasting interests. Thus legal institutions are needed that can detect the early stages of crisis and which are in a position to move rapidly to address and remedy the same.

Even detracting such responsibility from seemingly incompetent management in order to preserve a firm's survival status should also be governed and regulated. Likewise, the dramatic scenario of receivership and forced liquidation of assets requires regulating by legislation processes that truly reflect the praxis and scenarios investigated and clarified by computational analyses.

(e) Social Simulation Models. The application of *system dynamics* models, already a reality in business studies, is especially designed to improve corporates performance.

They constitute therefore, applications that have already generated extensive international and national literature[26]. By means of methods of computational social sciences, they seem to facilitate a company's internal system

[26] See: F. BARNABÉ, *Governare la supply chain tramite modelli di simulazione: un caso aziendale da prendere 'al volo'*, in "Controllo di Gestione", Vol. 5, 2008, n. 3, pp. 45-56; ID., *Balanced Scorecard e System Dynamics*, in Busco C., Riccaboni A., Saviotti A., "Governance, strategia e misurazione delle performance", Arezzo, Knowità, 2007; ID., *System Dynamics e percorsi di apprendimento in contesti economico-aziendali*, Padova, Cedam, 2005; ID., *La System Dynamics negli studi economico-aziendali: un'analisi longitudinale*, in "Contabilità e cultura aziendale", Vol. 3, 2003, n. 2, pp. 173-192; C. BIANCHI, *Processi di apprendimento nel governo dello sviluppo della piccola impresa. Una prospettiva basata sull'integrazione tra modelli contabili e di system dynamics attraverso i micromondi*, Milano, Giuffrè, 2001; ID., *Modelli contabili e modelli "dinamici" per il controllo di gestione in un'ottica strategica*, Milano, Giuffrè, 1996; ID., *Modelli di system dynamics per il controllo di gestione: l'analisi dei margini*, in Antonelli V., D'Alessio R. (a cura di), "Casi di controllo di gestione", Milano, Ipsoa, 2004; ID., *Enhancing Strategy Design and Planning in Public Utilities through 'Dynamic' Balanced Scorecards: Insights from a Project in a City Water Company*, in "System Dynamics Review", 2008, n. 2; ID., *Il governo dello sviluppo aziendale attraverso modelli di system dynamics*, in "Controllo di gestione", Vol. 6, 2009, n. 3, pp. 2-19; ID., *Modelli di system dynamics per il miglioramento della performance aziendale. Verso un sistema di programmazione e controllo per lo sviluppo sostenibile*, Milano, Ipsoa, 2009; E. SUPINO, *Elementi di system dynamics per il budget d'impresa*, Bologna, Dupress, 2011; ID., *Modelli dinamici per il controllo multidimensionale. Integrazione tra system dynamics e balanced score card*, Bologna, Dupress, 2008; G.M. GOLINELLI, *Viable Systems Approach (VSA). Governing business dynamics*, Padova, Cedam, 2010. This paper illustrates the VSA - Viable System Approach, an original concept of systems approach delineating a coherent set of principles and tools for managing businesses and other complex organizations.

of planning and control, contributing to its wider goal of sustainable development.

Traditional techniques of budgeting employ electronic simulation models for short-medium term and long-term strategic planning. When decisive factors are identified, they determine potential mutations of economic and financial parameters in the event of changing variables. This applies to both static and flow data.

In short, organizational theories have reaped the benefits in recent decades from techniques similar to those analyzed, constituting a specific branch of management science where scientific and quantitative methods are applied to decisional processes in order to ensure rationality. To this purpose, any business problem is broken down into constituent parts.

Such theories have become part of the larger information system which uses operational tools derived from mathematical statistics, such as linear programming, game theory, theory of probability. This has resulted in a large scale model, that has attempted to connect the internal variables to the main external factors through complex quantitative processing. However, it has not always achieved desired goals.

Simulation techniques are part of corporate predictive processes put in place by management. However, no laws can regulate this phase as it depends on managerial creativity. Legislation could intervene merely in terms of encouraging the diffusion of such methods, for instance by regulating public subsidies to encourage investment in adequate computer facilities and the training of personnel.

3. Summary and Conclusions

The above analysis of the potential intersection between methods of computational science and economics and corporate sciences, highlights the many areas in which interdisciplinary relationships are desirable for the benefit of corporate information systems. This would enable companies to monitor better the ambits in which they operate.

For instance, in the planning phase, a pre-start-up analysis of locations would help to identify ideal sites. In addition, growth and development processes could exploit territorial research for selecting new areas in which to establish manufacturing plants and/or retail points.

Diffusion of quantitative models for simulation, based on the prediction, anticipation and quantitative estimating of the potential consequences of specific decision making, is useful for management and has positive repercussions on budgeting logics.

Furthermore the constant assessment and evaluation of environmental effects and the social impact of specific policies or commercial production contribute to improving relations with the productive environment and with the marketplace, at the same time promoting corporate image and reputation.

Frequent comparisons with same sector companies through comparative budget analysis promotes early detection of inefficiencies needing remedy in order to prevent disequilibrium and crises. Computational results are most valuable in analyzing the semiotics of disequilibrium, where they contribute to preventing bankruptcy and encourage turnaround processes[27].

Both public and private sector companies would benefit indirectly from an adequate legislative framework for promoting productivity. The applied methods of computational science would provide the necessary quantitative information for legislators to plan and regulate the ideal territorial distribution of productive initiatives, the essential relations between firms and public administration, the relations between companies and workers to prevent and resolve conflicts, intra and inter group relations, i.e. between subsidiaries and associates; economic statements of account and social balance which could have implications in terms of more equitable tax policies.

In short, a positive virtuous circle could thus be set in motion, grounded on clearly visible and transparent economic and social scenarios, quantified by methods of computational science and regulated by the legislative bodies in agreement with companies. Currently, the main obstacle seems to be either ignorance or underestimation of the potentially useful information that can be gleaned from methods of computational science. In effect, its modest diffusion to date, can be traced to inexperience, lack of training and the few skills available, not to mention the result of extremely low investments in the past in education and training in segments of science that certainly hold more appeal at present, taking into account the fact that available technologies can be obtained at costs significantly lower than in the past.

[27] Business plan for restructuring and reorganization, which involves, primarily, the elimination of the causes of crisis and the adoption of a recovery plan that allows a return to efficiency.

Law and Computational Social Science: Brief Notes of a Civil Procedure Law Scholar

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Recently, relationships between law and science[1] have witnessed the development of an area of great importance and interest represented by computational social science (hereinafter CSS), understood as "the integrated, interdisciplinary investigation of social systems as information-processing organizations and through the medium of advanced computational systems"[2].

Research methodologies that characterize contemporary science (statistics, mathematics and computation) have already played an important role in all social sciences, including an area, like the law, where this may seem less obvious. Just think, as a mere example, about the contribution statistics have made, and continue to make, in this field[3].

In this context, further research perspectives have been opened up by CSS. As pointed out by Cioffi-Revilla "computational social scientists are learning to exploit the advanced and increasingly powerful instruments of computation to see beyond the visible spectrum of more traditional disciplinary analyses"[4], and it is interesting to look at (current or potential) applications for legal science of each of the five basic CSS research methods, namely automated information extraction, social network analysis, geospa-

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[1] See, overall, also for further references: N. BOBBIO, *Diritto e scienze sociali* in ID., "Dalla struttura alla funzione. Nuovi studi di teoria del diritto", Roma-Bari, 2007, p. 31 ff.; S. RODOTÀ, *Diritto, scienza, tecnologia: modelli e scelte di regolamentazione*, in "Rivista critica di diritto privato", 2004, p. 357 ff.; G. OPPO, *Scienza, diritto, vita umana*, in "Rivista di diritto civile", 2002, I, p. 11 ff.; A. SANTOSUOSSO, *Diritto, scienza, nuove tecnologie*, Padova, Cedam, 2011; O. ROSELLI, *Scienza, scienza giuridica, scienza della formazione giuridica* in ID., "Scritti per una scienza della formazione giuridica", Napoli, ESI, 2012, p. 215 ff.

[2] C. CIOFFI-REVILLA, *Computational Social Science*, in "WIREs Computational Statistics", Vol. 2, 2010, n. 3, p. 259 ff., p. 259.

[3] Examples might be different, but I think it is enough to remember that, as particularly significant, at least from a more strictly procedural point of view, the Italian Supreme Court has for a long time widely used statistics for extracting multiple data, concerning proceedings pending before it, that are of undoubted importance – in several respects – both in the civil and criminal matters.

[4] See C. CIOFFI-REVILLA, *op. cit.*, p. 260.

tial analysis (socio-GIS or social GIS), complexity modelling and social simulation models[5].

A very recent contribution on the matter[6], drawing on research in which these methods are used as much to study the law as to deepen knowledge of social phenomena relevant to the law, underlined the fact that the application of CSS methodologies can lead to promising developments in at least four directions: (i) the analysis of structural and functional aspects of legal systems, (ii) the analysis of procedures regulated by law, (iii) the analysis of criminal phenomenon, and (iv) the analysis of the structure and dynamics of international relations and organizations.

In the light of these considerations, I believe it is advisable for lawyers to start looking, closely and with interest, at these research methods, trying to understand, from an interdisciplinary perspective, what are the areas of law where the use of CSS can (at least potentially) be more profitable.

It is what I would like to do here, in a tentative way, focusing on the area of law I have been working in for years: civil procedure law. From this viewpoint I would like to identify, based on personal intuition, some issues of civil procedure law which appear to demonstrate the greatest number of points of contact with CSS. The goal is to offer a contribution to interdisciplinary dialogue by identifying legal problems that can result in just as many research questions for the computational social scientist.

At first glance, civil procedure law seems able to benefit, in various ways, from CSS methods, which appear to offer, in general terms, new interpretations of civil proceedings[7].

Looking at some of the best known among introductory writings published on the subject, one gets the feeling that CSS cannot only provide a better understanding of proceedings, but also suggest, based on this understanding, solutions for changing and improving existing rules and procedures.

In the light of this premise, the research objects could be even more varied: rules of civil procedure; actors who apply the rules (judges, judicial of-

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[5] *Ibidem*.

[6] S. FARO, N. LETTIERI, *Diritto e computazione: modelli e metodi delle scienze sociali computazionali nel diritto*, in "Ciberspazio e diritto", Vol. 13, 2012, n. 2, pp. 185-204, p. 191 ff; see also N. LETTIERI, S. FARO, *Computational Social Science and Its Potential Impact upon Law*, in "European Journal of Law and Technology", Vol. 3, 2012, n. 3, http://ejlt.org//article/view/175/267.

[7] See on this point, on the one hand, with more specific reference to the social simulation and, on the other, more generally concerning the law B. EDMONDS, *What Social Simulation Might Tell Us About How Law Works*, in this Issue.

ficials, court clerks, etc..), and, more generally, that particular type of "organization" on which the so-called justice administration rests.

In legislation and in procedural acts (including court orders and, above all, the judgment), techniques for automated information extraction and automated text analysis may allow the user to obtain interesting information about the concepts therein and the relations that link the various entities evoked in the text[8]. In this case, the study, understanding and analysis of the text plays an important cognitive role; in particular, I have in mind the possibility of acquiring relevant information and inferences regarding: 1) the evolution in legislation and/or case law, which occurred in relation to certain procedural institutions, as also evidenced by research in this direction that has already been carried out in other legal systems[9]; 2) the evolution of drafting techniques and content of the parties' pleadings (for example, in terms of the greater use of the citation of legal precedents over time) or court documents (for example, in parallel, in terms of more space and/or weight dedicated to case law in the judgment; or, I should say, with even more interesting and meaningful prospects in terms of the content and the way the court drafts a judgment, if necessary, with a parallel comparison between the trial court and the Supreme Court[10]). In relation to the procedural acts, research of this kind would also encourage the availability of the relevant texts in electronic format, and a certain "standardization" in relation to their structure and content. From this point of view, especially for court orders, the final introduction of electronic civil proceedings, still at an experimental stage into the Italian legal system, may prove particularly important.

Regarding specific institutions of civil procedure law, the use of CSS research methodologies, where necessary suitably combined, seems to make it possible to acquire information and make inferences that are very important for a better understanding of them, especially in their realm of application,

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[8] See C. CIOFFI-REVILLA, *op. cit.*

[9] See J.H. FOWLER, T.R. JOHNSON, J.F. SPRIGGS II, S. JEON, P.J. WAHLBECK, *Network Analysis and Law: Measuring the Legal Importance of Precedents at the U.S. Supreme Court*, http://papers.ssrn.com/sol3/papers.cfm?abstract-id=906827.

[10] In this regard, I am convinced that quantitative and qualitative indications could emerge that would no longer constitute only the result of a mere sensation of a scholar of civil proceedings but rather the result of a "scientific measurement". We could, for example, study the differences in the way the Supreme Court motivates its judgment with respect to the trial court and the way in which the Court exercises its judicial review on the facts in cases brought before it.

highlighting at the same time limits, if any, which could then be subjected to intervention by the legislator and/or when they are interpreted or applied.

Just to give a simple but concrete example linked to the Italian legal system, consider a forced sale (or, in other words, the legal tool that allows the process of forcible expropriation to transform an asset owned by a debtor into a sum of money – i.e, the money paid by a third party to purchase the goods – based on which the creditor can be satisfied), which the court can delegate to a notary public and even to a lawyer or an accountant[11].

Here, the use of computational methodologies seems to allow the researcher to acquire a range of information and inferences regarding the way in which this institution is applied by the various Italian courts and its greater or lesser functionality in practice because of the different possible operation (and combination with each other) of a series of especially significant variables, such as:

- the court's use or not of the institution of the delegation of the sale (given that there are areas in Italy where the court does not use the institution of the delegation for forced sales but carries out this activity itself, or uses it in a very limited and circumscribed way);
- the delegation of all sales transactions or only part of them to one or more professionals (given that different possibilities can be imagined, which are also reflected in the practices of Italian courts);
- delegation to a single professional (for example, a notary public) or more than one professional (for example, lawyers and accountants);
- the delegation to professionals working or not as part of an association together with other professionals that was specially created to work in this sector (given that there are areas in Italy where certain associations have been active for some time providing results that seem particularly valuable in terms of time, costs, etc.);
- the choices made by the court and/or the delegated professional regarding certain pivot points of the sales process (assuming that, even on this point, there are different practices among the various Italian courts, even significantly different from each other).

Concerning the justice administration as a whole, network analysis and geospatial analysis (if appropriate, in combination with each other) appear to be of noteworthy interesting. My impression is that these methods can

[11] See, on the point, E. FABIANI, *Delega delle operazioni di vendita in sede di espropriazione forzata immobiliare*, in "Digesto delle Discipline Privatistiche, Sezione civile, Aggiornamento 5", Torino, Utet, 2010, p. 456 ff.

help the user acquire very detailed information and inferences on the functionality of this special type of organization[12], understood broadly speaking, to be used not only to reach more thorough knowledge of the operation of it, but also for possible interventions to amend or improve it. Consider, for example, the spatial distribution of the seats of courts (including branches) and the optimization of the same, the distribution of workloads within individual offices within the courts, etc.

Finally, the predictive dimension that characterizes CSS research methods and, in particular, social simulation models (system dynamics models[13], agent-based models[14] or hybrid models[15]) is even more fascinating for law[16].

In fact, in conformity with the characteristics of (social) simulations[17], one could imagine using them not only to achieve a better understanding

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[12] See, on this point, C. CIOFFI-REVILLA, *op. cit.*, p. 264 which illustrates, in particular, how "Social network analysis (SNA) has many computational applications across the social science disciplines - not just for visualizing network structures - and is supported by a large family of metrics and exact methods. For example, SNA can provide insightful information and inferences on the functionality of an organization, given its structural pattern of nodes and relations. Such properties as resilience, vulnerability, decomposability, functionality, and others provide insightful information and knowledge not available through plain observation or through more traditional methods". The analysis of network systems began to be applied in the study of the fundamental structure of many phenomena that affect the law: organizations, procedures, international alliances and agreements, for example, are sets of entities linked by relationships.

[13] See C. CIOFFI-REVILLA, *op. cit.*, p. 268.

[14] *Ibidem*.

[15] That is models that, concerning an individual case, aim to make the most of the characteristics of the two different types of social simulation models mentioned above (namely, models of system dynamics and agent-based models). See, overall, the use of a hybrid model in the field of legal science, S. BOYLE, S. GUERIN, D. KUNKLE, *An Application of Multi-agent Simulation to Policy Appraisal in the Criminal Justice System*, in Chen S.-H., Jain L., Tai C.-C. (eds.), "Computational Economics: A Perspective from Computational Intelligence", Hershey, Idea Group Publishing, 2005.

[16] See, *i.a.*, D.M. KATZ, *Quantitative Legal Prediction – or – How I Learned to Stop Worrying and Start Preparing for the Data Driven Future of the Legal Services Industry*, in "Emory Law Journal", Vol. 62, 2013, available at SSRN http://ssrn.com/abstract=2187752.

[17] Simulations have been used, or are beginning to be used, in all fields of science, and "are an important tool for the analysis of the problems of human society and for the identification of possible solutions," given that "simulations are tools for the knowledge of reality, but are also tools of analysis of these problems and for testing solutions" (D. PARISI, *Simulare per capire* in Faro S., Lettieri N., Tartaglia Polcini A. (a cura di), "Diritto e tecnologie. Verso le scienze sociali computazionali. Attualità e orizzonti dell'Informatica giuridica", cit., pp. 231-232).

of the dynamics of civil proceedings but also to predict the likely impact of legislative reforms and/or the practical implications of different possible interpretations of a procedural rule[18].

Merely as an example, for civil proceedings, it would seem to me to be very interesting to be able to "measure" the possible reactions of individuals, in terms of access to legal protection against certain procedural reforms aimed at discouraging such access, when faced with specific cases, with the intention, more generally, of reducing the total number of civil proceedings which ordinary civil courts have to contend with (as a whole or, in a more limited sense, those dealing with a specific type of disputes).

[18] With regard to criminal proceedings see, L. BONAVENTURA, A. CONSOLI, *Priorities for Backlog of Criminal Cases Pending in Courts: A Computational Agent-based Model*, in this Issue.

Appendix

Abstracts

Sebastiano Faro, Nicola Lettieri
Walking Finelines between Law and Computational Social Science (p. 9)

The article introduces the relationship between law and computational social science identifying the reasons that make it promising. Besides allowing for a contact to be made between law and the scientific and application opportunities offered by computation and its technologies, this relationship can aid jurists in various ways. As a matter of fact, computational social science not only offers new research methods that can, *inter alia*, contribute to rediscovering the social dimension of legal phenomena but also represents a framework for dialogue between law and other scientific disciplines able to contribute to the understanding of phenomena relevant for the law. The article briefly discusses these questions as an introduction to the Issue and its contents.

Orlando Roselli
The Ever Changing Legal Dimension and the Controversial Notions of Law and Science (p. 27)

An apparent paradox characterises the work of the jurist: the difficulty of defining the object of his investigation. The most difficult question to find an answer for is precisely what is the law. For a long time the dominant legal culture, in particular in civil law countries, aspired to attribute the monopoly of law-making to the State and reduce the role of the jurist to that of a simple commentator of the legislator's intent. In times of transition, of profound social transformations, the great legal theories reveal their inadequacy. Modern legal culture is faced with an obvious difficulty in performing its principal ordering function when it encounters the plural phenomena of globalisation; the radical ever accelerating transformation of the social tissue; the invasiveness of new technologies; the changing relationship among rules, time and space. The task of legal culture is to recognise the "signs" of these transformations and to reappraise categories, tools, and legal institutions able to provide answers to the legislative needs of post modern societies. In contemporary law-making, legal authority, jurisprudence, arbitration awards, custom, and the role of jurists in directing the way institutions, large law firms, bodies that are created to promote, in both the scientific and operational field, a common legal language take on an increasingly important role. The complexity and changeability of social relations require adequate training, professionalism and flexibility. The challenge of globalisations and competition among economic systems plays not so much on all the material factors of production but on the capacity of legal culture to put an ever increasingly complex social dimension into order. Planetary technological development produces an actual anthropological mutation and poses very real problems relating to the protection of fundamental rights. The greatest difficulty for the modern jurist is to acquire an historically conscious method that enables him to decipher the consequences of social changes. For this purpose, the jurist must be open even more so than in the past to the contribution of other sciences, he must broaden the horizon of his research in the understanding that, at the basis of scientific development, there is no presumption of a final result but, rather, a healthy uneasiness that pushes him to rethink his results which he should never assume to be ontologically definitive.

DOMENICO PARISI

Robotic Societies and Law: A Plea for a Robotic and Simulation Science of Legal Phenomena (p. 39)

Robots, like computer simulations, can be constructed to express theories of human behaviour and human societies. If a robot (or an artificial agent) behaves like a human being or a collection of robots functions like a human society, then the way in which the robots are constructed explains the phenomena of human behaviour and human society. Phenomena studied by the legal sciences are an important class of human phenomena and a robotic theory of human beings should be able to replicate these phenomena: how a society deals with behaviours that damage others, how doing X is different from intentionally doing X, how being punished by others is different from being punished by nature, how a system for containing other-damaging behaviours can function properly. A robotic and simulation science of human beings and human societies is a non-disciplinary science and this is an important advantage because reality is an ensemble of different phenomena which are all connected together and one cannot understand one class of phenomena without invoking the phenomena studied by other disciplines. Hence, a robotic and simulation legal science will deal with phenomena studied by biologists, psychologists, anthropologists, economists, sociologists, and historians.

BRUCE EDMONDS
What Social Simulation Might Tell Us about How Law Works (p. 47)

This paper sketches how agent-based models – computer simulations that trace out possible "histories" of interactions between social actors to help understand how social phenomena develop – might help in discovering the answers to a series of relevant questions about law, namely: How does law work? and Why does law work? Also by means of some meaningful examples, the paper underlines that social simulation models have a crucial role to play in understanding of social phenomena, including those that involve the law.

KLAUS G. TROITZSCH
Legislation, Regulatory Impact Assessment and Simulation (p. 57)

This article gives an overview over various possible applications of simulation approaches to legislation. Simulation has been used in legislative processes for several decades. Its main use so far was in assessing the impact of alternative political strategies before new legislation would be set into force. In this vein, the article first discusses the role of regulatory impact assessment and then three of the major approaches to social simulation and their use for impact assessment: static and dynamic microsimulation as well as agent-based simulation.

CRISTIANO CASTELFRANCHI
Cognitivizing "Norms". Norm Internalization and Processing (p. 75)

In order to work appropriately norms must be mentalized. In fact, norms are for influencing "autonomous" agents, that is, agents self-regulated and self-motivated; norms aim is inducing goals in them. Norm working cannot be reduced to sanction/incentives and "utility". Ideally Norm-Adoption is terminal, non-instrumental; they should not be obeyed because of possible "sanctions". Norm must be recognized and acknowledged as such; they cannot just be implemented in routines and habits. Norms spreading and maintenance is first of all a mental spreading and sharing of values and beliefs. Expectations about the others' behavior conform to a norm are not just "predictions" built on a regularity; they are full expectations, entailing the fact the we rely on the other behavior and thus want/wish it; we not only predict but prescribe the others' behavior. There is a specific "cognitive processing" of norms in cognitive agents, from the recognition of the input as a normative prescription to the formulation of the intention to conform or to violate. Norms are a behavioral and mental coordination artifacts, based on different complementary mental attitudes in the various normative roles.

FEDERICO CECCONI, GIULIA ANDRIGHETTO, ROSARIA CONTE

How Social Norms Can Make the World More Regular and Better (p. 99)

Is there any difference between social norms and mere regularities emerging spontaneously from the behaviours of entities that have no norm-based cognition? And if so, which effects do we expect to observe in a world in which agents are endowed with such a type of cognition? The agent-based simulations presented here are aimed to understand what would happen in a world populated by normative agents, able to recognize norms and to reason upon them, compared to other, cognitively, less complex agents, following only their own individual goals.

PIETRO TERNA

Learning Agents and Decisions: New Perspectives (p. 115)

The proposed structure of learning facilities is self-developed via a trial and errors process: the reinforcement learning model is built upon the SLAPP - Swarm-Like Agent Protocol in Python, a recent implementation of the standard Swarm function library for agent-based simulation, written using Python, a powerful and quite simple language. We introduce also a very complicated crossroad, with: (i) learning in agents as first element, to be able to understand how agents modify their behavior, (ii) BDI (Beliefs, Desires, Intentions) definition to clarify the motivation of that behavior. To the cross-road we have to connect two open directions: (a) that of the micro-macro link, which is a key step in understanding the world we are immersed in; (b) the interaction between our agents, in networks. Finally, we go to the question if agent-based simulation could help in a perspective of policy management and law creation or norm emergence. Several examples help to deepen the discussion.

NICOLA LETTIERI, DOMENICO PARISI

Exploring the Effects of Sanctions on Damaging Actions through Artificial Societies: A Simulation Model (p. 131)

Agent-based social simulation is an expanding research field lying at the intersection between social and computer sciences that aims at exploring processes underlying complex social phenomena by means of artificial societies. After a brief description of social simulation paradigm and its impact on social sciences, the paper presents a simple evolutionary agent-based model of the interplay between damaging behaviors, punishment and social mechanisms of learning and imitation. The goal is twofold: to show how agent-based simulation can be used to illuminate basic mechanisms underlying social phenomena that are relevant for legal science and to reflect, in an innovative way, on how society, policy and rule makers can deal with such phenomena.

LUIGI BONAVENTURA, ANDREA CONSOLI

Priorities for Backlog of Criminal Cases Pending in Courts: A Computational Agent-based Model (p. 155)

The aim of this study is to analyze the effects of priority criteria on pending criminal trials. The article focuses on the quantitative effects on cases pending of criteria of priority applied by a judge in treating procedures differentiated according to the type of crime and the level of offence. Starting from the Italian National Institute for Statistics data on cases pending in the criminal section of the Tribunal of Catania (Italy), agent-based simulation is used to verify the effects of the following criteria: FIFO (First In, First Out), gravity and diffusion. Finally, the social cost of applying these criteria of priority is assessed. Our simulations suggest that the individual decision of the judge regarding which criterion of priority to apply in treating cases has a strong impact on the reduction in cases pending and on the social cost deriving from delays in dealing with the more serious cases.

FABRIZIO CACCAVALE

Perspectives of the Computational Approach as a Method for Criminological Research (p. 169)

The article offers a criminologist's brief reflection on the impact that computational social science methods can have on research in the criminology and criminal law domains. After a brief analysis of the role that quantitative methods play in the study of criminal phenomenon, the work focuses on the benefits that interaction with other disciplines offers criminology. Computational criminology, which involves the use of computational power to identify existent and emerging models of crime, is presented in general terms: it explores crimino-genetic factors, it identifies terrorist networks, organised crime and social gangs, and clarifies the contours of computer crime. Special attention is paid to agent-based social simulation: benefits and limitations of applying it to criminological science are highlighted.

FEDERICO CECCONI
Simulating Crime: Models, Methods, Tools (p. 181)

Computer simulations allow one to understand interactions of physical particles and make sense of astronomical observations, to describe many chemical properties *ab initio*, and to design energy-efficient aircrafts and safer cars. Hence, it would be very surprising if computational modeling could not make a contribution to a better understanding of social and economic systems, including criminal behavior and criminal structures. In this paper I will try to show how a new computational technique, agent-based simulation (ABS), allows to obtain reliable computational models for criminal phenomena, making it possible "to simulate the crime". An ABS is a class of computational models for simulating the actions and interactions of artificial autonomous agents (both individual or collective entities such as organizations or groups) with a view to assessing their aggregated effects. Agent-based simulation is potentially a very powerful tool for crime study; it increases the empirical understanding of how society works and can help policy makers in designing more effective norms and mechanisms for fighting criminal behavior.

VALENTINA PUNZO
Agent-based Approach to Crime and Criminal Justice Policy Analysis (p. 193)

The knowledge and techniques that can be ascribed to agent-based social simulation (ABSS) have been demonstrating a significant capacity to address the study of crime and to support criminal justice policy making. The paper discusses the role of ABSS in crime research, in particular criminal policy making; some suggestions about the utility of applying simulated experiments to crime research are implemented. By focusing on the potential intersections between ABSS and policy making issues, our goal is to clarify how ABSS can specifically support the elaboration of criminal justice policies by making the policy evaluation tools more effective. As far as the application of crime simulation to policy making is concerned, several agent-based models have been developed in different policy sectors and with different purposes. Some examples regard ABSS in predicting the likely impact of crime-prevention interventions, in evaluating the potential of a certain criminal justice policy strategy, in providing new policy evaluation tools and in assessing experimentally the likely consequences of some policy changes. After a review of these models, the specific tasks and purposes of agent-based social simulation along the different stages of the overall policy making process are summarized and discussed.

NICOLAS S. MALLESON, ANDREW J. EVANS
ALISON J. HEPPENSTALL, LINDA M. SEE
The Leeds Burglary Simulator (p. 211)

Quantitative analysis of crimes is often completed at an aggregate level, using environmental and crime statistics aggregated over both time and space. However, the drivers of crime are, more often than not, individual, as are the decision-making processes. Agent-based modelling offers a way to link these scales, giving aggregate-level patterns and understanding based on individual-level drivers. Here we present the details of an agent-based model of burglary. The model replicates offender drivers and decision making in a realistic geographical environment, filled with potential victims and guardians. It can simulate both aggregate-level crime patterns and individual-level offender behaviour.

MIGLE LAUKYTE
An Interdisciplinary Approach to Multi-agent Systems: Bridging the Gap between Law and Computer Science (p. 223)

Research in multi-agent systems (MASs) has given rise to new issues in sociology, psychology and other social sciences. But the effect on legal science has not been quite the same: the computational simulation of legally relevant social activities and phenomena is a research area that has yet to come into its own. Why is that so? And what can be done to encourage the development of such simulations? This paper attempts an answer to these questions by developing two related ideas that could change the current situation for the better: the first is the interdisciplinary idea of boundary objects;

the second, that of an agent's autonomy. As concerns boundary objects, I argue that an important reason why the simulation of legal phenomena is not making much headway is a certain language barrier between lawyers and software engineers. One way in which this barrier can be taken down is through an approach that – by bringing to bear the sociological concept of a boundary object – makes it possible for the relative research communities to relate to one another and work together in building a legal MAS. The second idea is that of the autonomy which can be ascribed to an agent within a MAS. I work out a legal concept of autonomy and identify a threshold of autonomous action that would trigger legal consequences. With that done, I tie this idea of autonomy to the previous discussion on boundary objects by treating autonomy itself as a boundary object. In other words, I illustrate how, if we can spell out in a clear enough way what autonomous action means in the law, then we will also have a roadmap we can rely on in developing autonomous agents and building MASs that would be more effective at simulating or reproducing social interactions in areas of activity which fall within the purview of the law.

DEBORAH DE FELICE, GIOVANNI GIUFFRIDA
GIUSEPPE GIURA, VILHELM VERENDEL, CALOGERO G. ZARBA
Information Extraction and Social Network Analysis of Criminal Sentences. A Sociological and Computational Approach (p. 243)

Administrative sources on crimes (statistics on felonies and crimes) have in many cases shown to be unsatisfactory for the purpose of a scientific description of the criminal phenomenon. Specifically in the context of organized crime in Italy (and *mafia* in particular) these sources show significant limits in terms of reliability and quality of the information due to specific recipients of data and to the difficulty in collecting and comparing data, as consequence of the speed of legislative changes and changes in criteria used to classify the data. This paper reports a research project based on analyzing criminal sentences on organized crime activities in Sicily, pronounced from 2000 through 2006. For this case study we split the analysis of a 1,147 document textual *corpus* into three main stages. First, we collected criminal sentences from the various courthouses. Since there is not yet a unified digital archive of criminal sentences in Sicily, we collected them in their paper format and stored into digital format, then into plaintext, by means of computer technology. In the second stage, the text was examined in order to extract the actors involved in the facts and the relationships between them.

The actors have been labelled with the following roles: judge, members of the court, prosecutor, defendants, lawyers. Actors not labelled have been purged from the analysis. Relationships between actors were also extracted in terms of close co-occurance in the text, and the network was investigated using social network analysis, leading to a social network of typical properties. In this paper, we report and discuss the sociological and computational approaches to characterize the social structure of criminal phenomena, using large-scale and automated computer tools.

NICOLA LETTIERI, DELFINA MALANDRINO, RAFFAELE SPINELLI

Text and Social Network Analysis as Investigative Tools: A Case Study (p. 263)

The paper presents an ongoing research exploring applications of computational methods in the analysis of structural and functional features of criminal organisations. Inspired by a sociological study using social network analysis techniques to compare properties of two criminal organisations belonging to Sicily's *mafia* and Campania's *camorra*, the research aims at studying tools combining information extraction, network analysis and visualization methods to support investigation and the fight against criminal organizations. The paper offers an overview of the results so far achieved from a technical and methodological viewpoint sketching future developments of a research that appears to be challenging both for criminology and legal informatics.

GUGLIELMO FEIS

Network Analysis Formalism and the Construction of a Traceability System for Payments. A Sketch of Its Legal and Sociological Aspects (p. 281)

In this paper I will present a theoretical framework that I call Network Analysis Formalism (NAF). NAF proposes itself as a third way that tries to rejoin the formalism of legal positivists and the anti-formalism of legal realists by way of relying both on data mining and on network analysis. With NAF the abstract types of legal situations are constantly monitored and checked (confirmed or disconfirmed) by the data. These data tell us how and in which way, if any, the law is affecting our daily life and whether or not it is succeeding in reaching the aims that motivated its enforcement. In the second part of the paper I will apply such a theoretical framework to the concrete problem of taxation. The result is the proposal of an asymmetrical traceability system (TS) for payments. I then survey the technical and legal aspects of developing a full traceability system (TS) for payments and then investigate it backward and forward on the temporal axis.

TAMARA BELLONE, FRANCESCO FIERMONTE, CHIARA PORPORATO

From "Free Information" to Its (Geo)referencing and Analisys: The "Costs" of Open Source (p. 299)

Is it possible, starting from free data or free information, also available online, to get a representation of them on paper, consequently highlighting the real spatial component? How to handle normal address lists and to achieve their transformation into geographic coordinates, expressed in latitude and longitude? What difficulties come up against and how can we face and overcome them? This contribution, trying to return an updated image of the current situation, highlights potential and critical points of mechanisms and procedures rarely accessible in an effective manner. Finally, it dwells on the opportunities offered by information sharing and knowledge since they facilitate the individual and collective growth, the participatory processes and the social justice.

GUIDO MIGLIACCIO

Computational Sciences, Business Management, Accounting and Law: Potential Intersections (p. 309)

The main purpose of this paper is to identify potential relations in act between Business Administration, Accounting, Legal Sciences and methods of Computational Sciences with a view to perfecting existing legislation. Accounting makes frequent use of quantitative processes which are core to the corporate information system within the context of data collecting and processing. This contributes to reducing the errors of top management. The potential applications of the methods of Computational Science to Accounting and Business Management and Economics coincide with mainstream areas of research and application. For each area we outline theoretical aspects and possible applications, specifying, where feasible, possible links with the Legal Sciences.

ERNESTO FABIANI

Law and Computational Social Science:
Brief Notes of a Civil Procedure Law Scholar (p. 321)

This article reflects on possible intersections between computational social science methods and the civil procedure law. Taking cue from the observation of the results achieved so far in other areas of the social sciences, some issues of civil procedure law are identified that could be studied in accordance with the new research perspectives offered by computational social science methodologies. The aim is to contribute to interdisciplinary dialogue by identifying legal problems that can result in just as many research questions for the computational social scientist.

Riassunti

SEBASTIANO FARO, NICOLA LETTIERI
Ai confini fra diritto e scienze sociali computazionali (p. 9)

L'articolo introduce il rapporto tra diritto e scienze sociali computazionali identificando le ragioni che lo rendono promettente. Oltre a rappresentare una occasione di contatto tra il diritto e le opportunità scientifico-applicative offerte dalla computazione e dalle sue tecnologie, questo rapporto può supportare il giurista in più modi. Infatti, le scienze sociali computazionali non solo offrono nuove metodologie di ricerca, in grado tra l'altro di contribuire al recupero della dimensione sociale del fenomeno giuridico, ma rappresentano anche un contesto per il dialogo con altri saperi scientifici in grado di contribuire alla comprensione dei fenomeni rilevanti per il diritto. L'articolo discute brevemente questi profili introducendo il numero speciale della Rivista e i suoi contenuti.

ORLANDO ROSELLI
La mutevole dimensione giuridica e le controverse nozioni di diritto e scienza (p. 27)

Un apparente paradosso caratterizza il lavoro del giurista: la difficoltà di definire l'oggetto della propria indagine. La domanda più difficile a cui dare risposta è proprio quella di che cosa sia il diritto. Per lungo tempo la cultura giuridica dominante, in particolare nei Paesi di *civil law*, ha preteso di ricondurre l'intera dimensione giuridica nell'ambito del monopolio della produzione del diritto da parte dello Stato e ridurre il ruolo del giurista a semplice esegeta della volontà del legislatore. Nelle epoche di transizione, di profonde trasformazioni sociali, le grandi teorie del diritto svelano la loro inadeguatezza. La cultura giuridica contemporanea incontra una evidente difficoltà nello svolgere la propria funzione ordinante di fronte ai plurali fenomeni di globalizzazione; al radicale sempre più accelerato trasformarsi del tessuto sociale; alle invasività delle nuove tecnologie; al mutare del rapporto tra le norme, il tempo e lo spazio. Il compito della cultura giuridica è quello di cogliere i "segni" di tali trasformazioni e ripensare categorie, strumenti, istituti capaci di dare risposte alle esigenze ordinamentali delle società posmoderne. Nella formazione del diritto contemporaneo acquistano un ruolo sempre più rilevante la dottrina, la giurisprudenza, i lodi arbitrali, le prassi, il ruolo dei giuristi nell'orientare l'operato delle istituzioni, i grandi studi professionali, organismi preposti a promuovere sul terreno sia scientifico che operativo un comune linguaggio giuridico. La complessità e mutabilità delle relazioni sociali richiede adeguata formazione, professionalità e flessibilità. La sfida delle globalizzazioni, la competizione tra sistemi economici, si gioca non tanto sui fattori materiali della produzione quanto sulla capacità della cultura giuridica di ordinare una dimensione sociale sempre più complessa. Il planetario sviluppo tecnologico produce una vera e propria mutazione antropologica e pone rilevantissimi problemi di tutela degli stessi diritti fondamentali. La difficoltà maggiore per il giurista contemporaneo è acquisire un metodo, storicamente consapevole, che lo renda capace di decifrare le conseguenze delle trasformazioni sociali. A tal fine, il giurista deve aprirsi ancora più che nel passato all'apporto delle scienze più varie, deve allargare l'orizzonte delle proprie indagini nella consapevolezza che alla base dello sviluppo scientifico non vi è la pretesa di un risultato definitivo ma una salutare irrequietezza che spinge sempre a ripensare i propri risultati mai presupposti come ontologicamente definitivi.

DOMENICO PARISI

Società di robot e diritto:
per una scienza robotica e simulativa dei fenomeni giuridici (p. 39)

I robot, come le simulazioni informatiche, possono essere concepiti e utilizzati per esprimere teorie del comportamento dell'uomo e delle società umane. Se un robot (o un agente artificiale) simulato al computer si comporta come un essere umano o, ancora, un insieme di robot funziona come una società umana, allora il modo in cui sono costruiti i robot spiega i fenomeni del comportamento dell'uomo e della società stessa. I fenomeni di interesse per la scienza giuridica rappresentano una parte significativa dei fenomeni umani e una teoria robotica degli esseri umani dovrebbe essere in grado di replicare questi fenomeni, e quindi: il modo in cui una società si confronta con comportamenti con cui un individuo danneggia altri individui; la diversità tra un'azione intenzionale e una non intenzionale; gli effetti della punizione applicata dalle istituzioni giuridiche e sociali; il funzionamento di un sistema di contenimento dei comportamenti dannosi che sia in grado di operare efficacemente. Una scienza robotica e simulativa degli esseri umani e delle società umane è una scienza non-disciplinare e questa caratteristica rappresenta un vantaggio importante perché la realtà è un insieme di fenomeni diversi tutti collegati tra loro e non si può capire una classe di fenomeni senza considerare i fenomeni studiati da altre discipline. Quindi, una scienza giuridica robotica e simulativa dovrà necessariamente confrontarsi con biologi, psicologi, antropologi, economisti, sociologi e storici.

BRUCE EDMONDS
Cosa possono dirci le simulazioni sociali su come funziona il diritto (p. 47)

Questo articolo discute brevemente come i modelli basati su agente – simulazioni al computer che descrivono diversi possibili sviluppi delle interazioni tra attori sociali allo scopo di aiutare a capire come evolvono i fenomeni sociali – potrebbero contribuire a dare risposta a una serie di rilevanti interrogativi relativi al fenomeno giuridico e in particolare: "Come funziona il diritto?", "Perché il diritto funziona?". Il lavoro pone in evidenza, anche attraverso una serie di esempi significativi, come i modelli di simulazione abbiamo un ruolo cruciale da giocare nella comprensione dei fenomeni sociali, compresi quelli rilevanti per il diritto.

KLAUS G. TROITZSCH
La legge, l'analisi di impatto della regolazione e la simulazione (p. 57)

Questo articolo fornisce una panoramica su varie possibili applicazioni degli approcci simulativi al processo legislativo. La simulazione è stata usata nei processi legislativi per diversi decenni; fino ad oggi il suo utilizzo principale è stato quello di valutare l'impatto di strategie politiche alternative prima dell'entrata in vigore di una nuova disciplina normativa. In tale ottica, l'articolo discute inizialmente il ruolo dell'analisi di impatto della regolazione per poi affrontare tre dei principali approcci alla simulazione sociale e il loro uso in questo specifico contesto: microsimulazione statica, microsimulazione dinamica e simulazione basata su agente.

CRISTIANO CASTELFRANCHI
Cognitivizzare le norme. Internalizzazione ed elaborazione dei costrutti mentali normativi (p. 75)

Per funzionare in modo appropriato le norme devono essere mentalizzate. A ben vedere, le norme sono concepite per influenzare agenti "autonomi", agenti, cioè, i cui comportamenti sono condizionati da regole e motivazioni mentali interne; le norme mirano a indurre in loro degli obiettivi.

Il funzionamento delle norme non può essere ridotto ai concetti di sanzione/incentivo e "utilità". In termini teorici, l'adozione delle norme è un obiettivo in sé, non uno strumento; le norme non dovrebbero essere osservate a causa di possibili sanzioni. Le norme devono essere riconosciute e accettate come tali, non possono essere semplicemente ridotte a *routine* e abitudini. La diffusione e la permanenza in vita delle norme è innanzitutto una diffusione mentale e condivisione di valori e credenze. Le aspettative relative al fatto che un altro individuo si conformi ad una norma non sono solo "predizioni" basate sull'osservazione di una regolarità; esse sono vere e proprie aspettative che implicano il fatto che noi contiamo sul comportamento di un altro individuo e perciò lo vogliamo, lo desideriamo; noi non ci limitiamo a predire ma prescriviamo il comportamento degli altri. Esiste uno specifico "trattamento cognitivo" delle norme negli agenti cognitivi, dal riconoscimento di un *input* come una prescrizione normativa, alla formulazione dell'intenzione di osservare o violare la stessa. Le norme sono artefatti comportamentali e mentali finalizzati alla coordinazione tra gli individui, basati su differenti attitudini mentali complementari nei diversi ruoli normativi.

FEDERICO CECCONI, GIULIA ANDRIGHETTO, ROSARIA CONTE

Come le norme sociali possono rendere il mondo più ordinato e migliore (p. 99)

C'è qualche differenza tra norme sociali e semplici regolarità che emergono spontaneamente dai comportamenti di entità che non hanno alcuna forma di cognizione normativa? E se sì, quali effetti ci aspettiamo di osservare in un mondo di agenti che sono dotati di un tale tipo di funzioni cognitive? Le simulazioni basate su agenti qui presentate hanno l'obiettivo di comprendere le differenze tra un mondo popolato da agenti normativi, in grado di riconoscere norme e di ragionare su di esse, e un mondo popolato da agenti, cognitivamente meno complessi, che seguono solo i loro obiettivi individuali.

PIETRO TERNA

Agenti che apprendono e decidono: nuove prospettive (p. 115)

Questo articolo propone un'architettura per l'implementazione di funzioni di apprendimento in agenti artificiali che si sviluppano in maniera autonoma attraverso processi di prove ed errori: il modello di apprendimento basato su rinforzo è costruito sullo SLAPP - *Swarm-Like Agent Protocol in Python*. Si tratta di una recente implementazione della libreria di funzioni standard *Swarm* per le simulazioni basate su agente, scritta in *Python*, un linguaggio di programmazione potente e abbastanza semplice. Viene anche presentata l'intersezione molto complessa tra: (i) l'apprendimento negli agenti come primo elemento per essere in grado di capire come gli agenti modificano il loro comportamento, (ii) la definizione dell'architettura BDI (credenze, desideri, intenzioni) per chiarire la motivazione di tale comportamento. A questa intersezione si ricollegano due temi da esplorare: (a) il collegamento micro-macro, che è un passaggio fondamentale nella comprensione del mondo in cui siamo immersi, (b) l'interazione tra i nostri agenti, in una rete. Infine, si discute, anche attraverso una serie di esempi, la questione se la simulazione basata su agente possa essere di aiuto nella prospettiva dell'emersione delle norme sociali, della produzione delle norme giuridiche e della gestione delle politiche pubbliche.

NICOLA LETTIERI, DOMENICO PARISI

Esplorare gli effetti della sanzione sui comportamenti di danno attraverso società artificiali: un modello di simulazione (p. 131)

La simulazione sociale basata su agente è un campo di ricerca in espansione, che si colloca all'incrocio tra le scienze sociali e l'informatica, che si propone di esplorare, per mezzo di società artificiali, i processi che sottendono fenomeni sociali complessi. Dopo una breve descrizione del paradigma della simulazione sociale e del suo impatto sulle scienze sociali, l'articolo presenta un semplice modello ad agente evoluzionistico delle interazioni tra comportamenti di danno, sanzioni e meccanismi sociali di apprendimento e imitazione. L'obiettivo è duplice: mostrare come la simulazione possa essere utilizzata per illuminare i meccanismi fondamentali alla base di fenomeni sociali rilevanti per la scienza giuridica e riflettere, in modo innovativo, su come la società, i decisori politici e il legislatore possono gestire tali fenomeni.

LUIGI BONAVENTURA, ANDREA CONSOLI

Criteri di priorità nella gestione dei carichi pendenti nei tribunali penali: un modello di simulazione basata su agente (p. 155)

Questo studio mira ad analizzare l'impatto che i criteri di priorità nell'ordine di trattazione dei casi hanno sull'accumulo dei processi penali pendenti. L'articolo si concentra sugli effetti quantitativi dei criteri di priorità adottati dal giudice che gestisce procedure differenziate in base al tipo di reato e al grado di offensività. Partendo dai dati ISTAT relativi ai casi pendenti dinanzi alla sezione penale del Tribunale di Catania, viene utilizzato il metodo della simulazione basata su agente per verificare gli effetti dei seguenti criteri: priorità temporale (FIFO), gravità dei reati, diffusione dei reati. Infine, viene valutato il costo sociale dell'applicazione di tali criteri. Le simulazioni effettuate evidenziano come la scelta del giudice in merito al criterio di priorità da applicare svolga un ruolo cruciale rispetto alla riduzione dei carichi pendenti e al costo sociale derivante da ritardi nel trattare i reati più gravi.

FABRIZIO CACCAVALE

Le prospettive dell'approccio computazionale come metodo della ricerca criminologica (p. 169)

L'articolo propone la breve riflessione di un criminologo sull'impatto che i metodi delle scienze sociali computazionali possono avere sulla ricerca criminologica e penalistica. Dopo una breve analisi del ruolo che i metodi quantitativi giocano nello studio del fenomeno criminale, il lavoro si sofferma sui vantaggi che l'interazione con altre discipline offre alla criminologia. Viene presentata in termini generali la criminologia computazionale che prevede l'uso della potenza di calcolo informatico per identificare modelli del crimine esistenti ed emergenti, esplorare i fattori criminogenetici, individuare reti terroristiche, della criminalità organizzata e delle gang sociali, chiarire i contorni della criminalità informatica. Particolare attenzione viene dedicata alla simulazione sociale basata su agente, della cui applicazione alla scienza criminologica vengono evidenziati vantaggi e limiti.

FEDERICO CECCONI

Simulare il crimine: modelli, metodi e strumenti (p. 181)

Le simulazioni al computer permettono di comprendere le interazioni delle particelle fisiche e di dar senso alle osservazioni astronomiche, di descrivere molte proprietà chimiche *ab initio* e di progettare aerei a basso consumo energetico e automobili più sicure. Sarebbe quindi sorprendente se la modellazione al computer non fosse in grado di contribuire a una migliore comprensione dei sistemi sociali ed economici, tra cui il comportamento e le strutture criminali. L'articolo mira a mostrare come una nuova tecnica computazionale, la simulazione basata su agente, permetta di ottenere affidabili modelli computazionali di fenomeni criminali, rendendo possibile "simulare il crimine". Una simulazione basata su agente è un tipo di modello computazionale concepito per simulare le azioni e le interazioni di agenti artificiali autonomi (individui o entità collettive come organizzazioni o gruppi) al fine di valutare i loro effetti su scala aggregata. La simulazione basata su agente è potenzialmente uno strumento molto potente per lo studio della criminalità in quanto capace di accrescere la comprensione empirica di come la società funziona e di aiutare i decisori potici nella progettazione di norme e meccanismi di lotta alla criminalità più efficaci.

VALENTINA PUNZO
Un approccio *agent-based*
all'analisi del crimine e delle politiche criminali (p. 193)

Le conoscenze e le tecniche riconducibili all'area delle simulazioni sociali basate su agente (SSBA) hanno mostrato una notevole capacità di contribuire allo studio del crimine e di supportare l'elaborazione delle politiche di contrasto alla criminalità. L'articolo discute il ruolo della SSBA nella ricerca criminologica e, in particolare, nella messa a punto delle strategie di lotta al crimine proponendo alcune riflessioni circa l'utilità di impiegare esperimenti di tipo simulativo nella ricerca sul crimine; l'obiettivo è quello di chiarire come la SSBA possa sostenere in modo specifico l'elaborazione di politiche di giustizia penale, rendendo gli strumenti di valutazione delle politiche più efficaci. Diversi modelli basati su agenti sono stati sviluppati in diversi settori della politica criminale e con scopi differenti. Alcuni esempi riguardano l'uso delle simulazioni per predire l'impatto di interventi di lotta alla criminalità, per valutare il potenziale di una certa strategia di politica criminale, e, ancora, per fornire nuovi strumenti capaci di valutare sperimentalmente le probabili conseguenze di alcuni cambiamenti delle politiche stesse. Dopo una presentazione di tali modelli, vengono riassunti e discussi i compiti e le finalità specifiche dei modelli di simulazione sociale nelle diverse fasi del processo complessivo di elaborazione delle politiche criminali.

NICOLAS S. MALLESON, ANDREW J. EVANS
ALISON J. HEPPENSTALL, LINDA M. SEE
Il *Leeds Burglary Simulator*: una simulazione
del fenomeno del furto con scasso nella città di Leeds (p. 211)

L'analisi quantitativa dei reati è spesso integrata utilizzando statistiche ambientali e criminali aggregate in base a criteri sia spaziali sia temporali. Tuttavia, tanto i fattori criminogeni quanto i processi decisionali sono il più delle volte individuali. L'uso di modelli basati su agente permette di collegare questi diversi livelli della realtà, offrendo sia una visione delle regolarità osservabili sul piano aggregato, sia una comprensione basata sulle motivazioni individuali. L'articolo si concentra su un modello basato su agente del furto con scasso. Il modello replica le motivazioni e il processo decisionale dei criminali in un'area geografica descritta in maniera realistica in cui sono presenti le potenziali vittime e le forze di polizia. La simulazione permette di esplorare sia le configurazioni assunte a livello aggregato dalle azioni criminali sia il comportamento del singolo criminale.

MIGLE LAUKYTE
Un approccio interdisciplinare ai sistemi multi agente: un ponte fra diritto e informatica (p. 223)

La ricerca sui sistemi multi agente (MAS) ha sollevato nuove questioni in sociologia, psicologia e nelle altre scienze sociali. L'effetto sulla scienza giuridica, tuttavia, non è stato esattamente lo stesso: la simulazione al computer di fenomeni e attività sociali giuridicamente rilevanti è un'area di ricerca che deve ancora dare i suoi frutti. Perché è così? Cosa si può fare per incoraggiare lo sviluppo di questo genere di simulazioni? L'articolo cerca di dare una risposta a queste domande sviluppando due idee correlate: la prima è rappresentata dal concetto interdisciplinare di *boundary object* o "oggetto di confine" (concetto sociologico utilizzato per descrivere l'uso, da parte di comunità differenti e in modi differenti, delle stesse informazioni o categorie); la seconda è data, invece, dal concetto di autonomia di un agente. Per quanto riguarda gli oggetti di confine, la tesi qui sostenuta è che un motivo significativo per cui la simulazione di fenomeni giuridici non sta facendo progressi è in una certa misura l'esistenza di una barriera linguistica tra giuristi e informatici. Uno dei modi in cui questa barriera può essere abbattuta è il ricorso ad un approccio che, portando ad adottare il concetto sociologico di oggetto di confine, permetta alle rispettive comunità di ricerca di relazionarsi e lavorare insieme nel costruire sistemi multi agente destinati allo studio di fenomeni giuridici. La seconda idea è quella dell'autonomia ascrivibile a un agente all'interno di un sistema multi agente. L'articolo esamina il concetto giuridico di autonomia e identifica la soglia di autonomia delle azioni cui può essere riconosciuta rilevanza giuridica. Fatto ciò, il lavoro collega il concetto di autonomia appena definito alla discussione precedente relativa agli oggetti di confine trattando l'autonomia stessa come oggetto di confine. In altri termini si illustra come, se siamo in grado di spiegare in modo abbastanza chiaro cosa si intenda per azione autonoma in ambito giuridico, allora avremo anche una tabella di marcia su cui poter contare nello sviluppo di agenti autonomi e nella costruzione di sistemi multi agente più efficaci nel simulare interazioni sociali in aree di attività che rientrano nella sfera di competenza del diritto.

Deborah De Felice, Giovanni Giuffrida
Giuseppe Giura, Vilhelm Verendel, Calogero G. Zarba

Estrazione di informazioni e *social network analysis* applicate a sentenze penali. Un approccio sociologico e computazionale (p. 243)

Le fonti amministrative sulla criminalità (statistiche sui reati) hanno mostrato in molti casi di essere insoddisfacenti ai fini di una descrizione scientifica del fenomeno criminale. Specificamente, nel caso della criminalità organizzata in Italia (e in particolare della mafia) queste fonti mostrano limiti significativi in termini di affidabilità e qualità delle informazioni a causa della particolare natura dei destinatari cui i dati raccolti vanno inviati e della difficoltà nel raccogliere e confrontare i dati in ragione del susseguirsi delle modifiche legislative e dei cambiamenti dei criteri di classificazione dei dati stessi. Questo articolo presenta un progetto di ricerca basato sull'analisi di sentenze penali relative ad attività della criminalità organizzata in Sicilia, pronunciate dal 2000 al 2006. Per questo studio l'analisi di un *corpus* di 1.147 documenti testuali è stata suddivisa in tre fasi principali. In primo luogo, sono state raccolte le sentenze penali dai diversi tribunali. Dal momento che non esiste ancora un archivio digitale unificato delle sentenze penali in Sicilia, queste sono state raccolte nel loro formato cartaceo e archiviate in formato digitale come *file* di testo. Nella seconda fase, il testo è stato esaminato per estrarre informazioni relative agli attori coinvolti nei fatti e alle relazioni esistenti tra loro. Gli attori sono stati etichettati con i seguenti ruoli: giudice, membri della corte, pubblico ministero, imputati, avvocati. Gli attori non etichettati sono stati eliminati dall'analisi. Sono state estratte anche informazioni sulle relazioni fra gli attori, sulla base della loro compresenza nel testo, e la rete è stata studiata utilizzando tecniche di *social network analysis*, che hanno condotto alla rappresentazione grafica di una rete sociale con caratteristiche peculiari. In questo articolo sono presentati e discussi gli approcci sociologici e computazionali che permettono di evidenziare le caratteristiche dei fenomeni criminali, utilizzando strumenti informatici che operano in maniera automatica su ampie quantità di documenti.

NICOLA LETTIERI, DELFINA MALANDRINO, RAFFAELE SPINELLI
Analisi del testo e delle reti sociali come strumenti investigativi: un caso di studio (p. 263)

Il lavoro presenta una ricerca in corso avente ad oggetto l'applicazione di metodi computazionali per l'analisi delle caratteristiche strutturali e funzionali delle organizzazioni criminali. Ispirato da uno studio sociologico che sfrutta tecniche di *social network analysis* per confrontare le proprietà di due organizzazioni criminali appartenenti alla mafia siciliana e alla camorra campana, la ricerca mira a studiare strumenti che combinano estrazione di informazioni, analisi delle reti e metodi di visualizzazione per supportare lo svolgimento di attività investigative e la lotta alla criminalità organizzata. L'articolo offre una panoramica dei risultati finora conseguiti sul piano tecnico e metodologico ed abbozza futuri sviluppi di una ricerca che sembra offrire spunti interessanti sia per la criminologia sia per la ricerca informatico-giuridica.

GUGLIELMO FEIS
***Network Analysis Formalism* e costruzione di un sistema di tracciabilità dei pagamenti. Note sugli aspetti giuridici e sociologici** (p. 281)

In questo articolo viene presentato un quadro teorico definito come *Network Analysis Formalism* (NAF) che si propone come terza via che cerca di conciliare il formalismo del positivismo giuridico e l'anti-formalismo del realismo giuridico, affidandosi al *data mining* e alla *network analysis*. Con il NAF i tipi astratti delle fattispecie giuridiche sono costantemente monitorati e controllati (confermati o smentiti) dai dati. I dati ci dicono se e come il diritto influenza la nostra vita quotidiana e riesce a raggiungere gli obiettivi che hanno motivato la sua applicazione. La seconda parte dell'articolo è dedicata all'applicazione di questo quadro teorico al problema concreto della tassazione. Il risultato è la proposta di un sistema di tracciabilità dei pagamenti asimmetrico. Vengono poi analizzati gli aspetti tecnici e giuridici dello sviluppo di un tale sistema, le condizioni che lo rendono possibile e i risultati attesi.

TAMARA BELLONE, FRANCESCO FIERMONTE, CHIARA PORPORATO

Dalla "informazione libera" alla sua (geo)referenziazione e analisi: i "costi" dell'*open source* (p. 299)

È possibile, a partire da dati o informazioni libere, disponibili anche in rete, ottenere una loro rappresentazione grafica che ne metta in evidenza la reale dimensione spaziale? Come gestire semplici liste di indirizzi e ottenere la loro trasformazione in coordinate geografiche, espresse in latitudine e longitudine? Quali difficoltà si incontrano e come si possono affrontare e superare? Questo contributo, cercando di offrire un quadro aggiornato della situazione attuale, mette in evidenza le potenzialità e i punti critici di meccanismi e procedure volti a ottenere questi risultati. Infine, vengono sottolineate le opportunità offerte dalla condivisione di informazioni e conoscenze in quanto possono agevolare la crescita individuale e collettiva, i processi di partecipazione e la giustizia sociale.

GUIDO MIGLIACCIO

Le scienze computazionali, l'economia aziendale, la ragioneria e il diritto: alcune possibili intersezioni (p. 309)

La finalità principale di questo articolo è individuare le possibili relazioni tra economia aziendale, ragioneria e metodologie delle scienze computazionali, anche al fine di migliorare la legislazione. Anche la ragioneria, infatti, si avvale di elaborazioni quantitative. Essa è al centro del più ampio sistema informativo aziendale: deve raccogliere dati per trasformarli in informazioni dopo una complessa elaborazione al fine di ridurre gli errori del *top management* aziendale. I possibili ambiti di applicazione delle metodologie delle scienze computazionali all'economia aziendale coincidono con le sue principali aree di ricerca ed applicazione. Per ogni area si delineano aspetti teorici e potenzialità applicative precisando, ove possibile, i nessi con la scienza giuridica.

ERNESTO FABIANI

Diritto e scienza sociale computazionale: brevi note di uno studioso del processo civile (p. 321)

L'articolo propone una riflessione sulle possibili intersezioni tra i metodi delle scienze sociali computazionali e il diritto processuale civile. Traendo spunto dall'osservazione dei risultati conseguiti sinora in altre aree delle scienze sociali, vengono identificati alcuni temi del diritto processuale civile che potrebbero essere studiati secondo le nuove prospettive di ricerca offerte dalle metodologie delle scienze sociali computazionali. L'obiettivo è quello di contribuire al dialogo interdisciplinare identificando problemi giuridici che possano tradursi in altrettante domande di ricerca per lo studioso di scienze sociali computazionali.

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