Witold Marciszewski
University of Białystok

CHALLENGES FOR THE LOGIC OF SOCIAL RESEARCH: TO GRASP RATIONALITY, TO DEAL WITH COMPLEXITY

The two Herculean tasks – to define rationality, as a basis of social order, and to tackle complexity of social phenomena – require harnessing potent forces and resources of logic. One needs 'basic logic', that is, logical calculi to have rules of correct reasonings, then methodological reflexion on the use of mathematical models in social sciences, at last some additions to basic logic. The last involve theoretical computer science to judge the power of algorithms used in modelling, and a study of practical reasoning in social interactions; such a study is provided by the theory of games and decision-making. All that jointly deserves to be called *the logic of social research*[1].

1. Logic, mathematical modelling, and artificial societies

The theory of logic, insofar as we attain to it, is the vision and the attainment of that Reasonabless for the sake of which the Heavens and the Earth have been created. This enthusiastic belief in logic as expressed by Charles Sanders Peirce, is what Evert W. Beth referred to with the motto of his seminal study *Semantic Entailment and Formal Derivability* (Amsterdam, 1955).

In that study Beth succeeded in grasping an essential feature of '*that reasonabless*' which one finds in first-order logic and the accompanying metalogical reflexion. This is just a part of the idea of rationality, but a part significant enough to be taken it as the starting point of discussion.

[1] This paper was supported with financial means of the State [Polish] Committee for Scientific Research as research project no. 2 H01A 030 25: *Nierozstrzygalność i algorytmiczna niedostępność w naukach społecznych* (Undecidability and Algorithmic Intractability in Social Sciences), run in 2003-2006.

ISBN 83-7431-015-4 ISSN 0860-150X

Beth's study, inspired by some Gentzen's idea, offers a very important logical contribution to the notion of rationality. His predicate logic system called *semantic tableaux* is much worth attention for it represents the most algorithmic approach in solving the problem about an inference whether it is logically correct. It is not the only system of this kind but the one which historically was the first in a chain of similar systems, and is a fitting example to represent this whole chain. The problem of whether a formula of predicate logic is logically valid can be solved in different ways. Some of them involve the guessing of premisses from which the formula in question could be deduced; this gives us opportunity to show invention, but does not guarantee success. In other strategies, to which Beth's method belongs, the process of checking validity is guided by a set of algorithmic rules to obtain a result, provided that it is obtainable at all (this not always is the case because of the undecidability of logic). This algorithmic strategy is more rational than the other one, in the sense of being more efficient.

A new level of rationality is attained with metalogical reflexion concerning theoretical tools which one uses in mathematical modelling. A researcher who is aware of metamathematical properties of a theory used for modelling should be acknowledged as more rational than the one who lacks such awareness. The well-known story about Frege who recognized inconsistency of his system of logic after Russell's critique (the antinomy of the set of sets not being their own elements) exemplifies such degrees of rationality; Frege's attitude towards his system was more rational after his learning about the flaw[2]. Completeness of a theory is another subject of such reflexion, still other ones are decidability and computational tractability (decidability in practice).

Such metalogical assessments add new points to the postulate of logical correctness of reasonings. Suppose, there are two researchers in an empirical science. One of them adopts a mathematical model provided by a naive non-formalized theory, whose decidability has not been thus far investigated, while the other employs the same (as to the content) theory stated in a formalized form and enjoying a proof either of decidability or of undecidability. The latter should be appreciated as acting in a more rational way as being more conscious of his tools and methods. Another comparison can be drawn between two theories, one of them being computationally tract-

[2] Though Frege did not intentionally work in a paradigm of modelling, any logical system, including that of him, can perfectly serve as a model of mental processes of reasoning.

able, while the other not, the comparison resulting to the advantage of the former.

The use of mathematical theories to provide models in an algorithmic form, necessary for computer simulation, faces us with two questions, one belonging more to mathematical logic, the other more to computer science. The questions are as follows: (1) the issue of algorithmic decidablity, (2) the issue of computational tractability. The first is concerned with what can be computed in principle, while the second – with what can be computed in practice (i.e., with respect to available resources of time, memory, etc).

These logical explanations of what rationality consists in, are fundamental for building Artificial Intelligence not less than for understanding the natural intelligence of humans and animals. Any inferences we expect, e.g., from agent programs, should conform to the standards of valid deduction and to metatheoretical requirements, before we address the issue, possibly, with more specialized theories of reasoning.

The domain of AI has its natural extension in what is called Artificial Societies. AS researchers carry computational simulations of social interactions occurring among artificially intelligent agents. How such simulations are related to logic, can be learnt when reading the quarterly *Journal of Artificial Societies and Social Simulation*, abbreviated as JASSS. An instructive example is found in a recent paper by Maria Fasli, entitled with the question *Formal Systems and Agent-Based Social Simulation Equals Null?*. The author answers in the negative, while asserting that there is a considerable common part of the areas in question, and much space for collaboration. A wide class of logical systems is taken into account as those (to quote the paper) "ranging from classical propositional logic and predicate logic to modal logic, dynamic logic and higher order logics"[3].

This example demonstrates that artificial societies is logicians' business as well. Another argument concerning the use of logic takes into account the usual mathematical modelling in social, including economical, research, its procedures being viewed from a logical point of view. As examples of social phenomena mathematically modelled one can mention population dynamics, group interactions, political transitions, evolutionary economics, urbanisation, etc.[4] As much as there appear conflicting interests among agents in such processes, a formal model to render the situation can be ta-

[3] See Volume 7, Issue 4, 31-Oct-2004; jasss.soc.surrey.ac.uk/JASSS.html.

[4] Cp. Weidlich, Wolfgang: *Sociodynamics: a Systematic Approach to Mathematical Modelling in the Social Sciences*, Harwood Academic Publishers: Amsterdam, 2000; reviewed by Glen Lesins in JASSS, the issue mentioned above.

ken from von Neumann's and Morgenstern's mathematical theory of games which provides us with the fitting model called prisoner's dilemma.

Algorithmic decidability and computational tractability are thoroughly considered by the physicist Stephen Wolfram (especially in his widely discussed book *A New Kind of Science*, 2002) with respect to empirical theories of physics and biology. Wolfram uses the computational model of cellular automata to examine decidability and tractability of some theories in natural science.

The mentioned book by Wolfram, though being a considerable academic event in the US and other Western countries, hardly received (as far as I know) any attention either from logicians or from social scientists in Poland. This seems to be a more general symptom of one's indifference to the issues of decidability of empirical theories. In spite of the enormous achievements of Polish logicians, especially in the period between the two world wars, nowadays their presence at the area of such vital applications of logic is hardly felt.

The realizing of this fact motivated the present author to arrange meetings of logicians and social scientists from main centres of these disciplines in Poland. Such meetings, first, should have yielded a survey of interests, projects and skills, and then should have given an idea of how to enrich future research in Poland with the (neglected thus far) issues of computability. Let me report on two such workshops, as their content closely coincides with the subject of this paper. The two workshops in question belonged to a series of annual meetings devoted to the issues of decidability and computability in a historical perspective[5].

2. A case of social computability: spontaneous order vs central planning

In 2002 there took place the Workshop: *In F. Hayek's 10th Death Anniversary – Free Market as Information-Processing System. On the Problem*

[5] The series of conferences under the name *Workshops in Logic, Informatics and Philosophy of Science* was organized by the Committee for Philosophy of Polish Academy of Sciences in collaboration with the Department of Logic, Informatics and Philosophy of Science, University of Białystok, abbreviated below as DLIPS-UwB, and other partners, including Centre of Market Psychology in Leon Koźmiński Academy of Entrepreneurship and Management, Warsaw, abbreviated below as CMP-LKA, and Higher School of Public Administration in Białystok. A considerable set of Workshop papers, translated into English, is published in this and in the previous issue of this journal. The Workshops have Web documentation at the site www.calculemus.org/.

of Algorithmization in Social Research. Here are the titles (ad hoc translated into English) of invited contributions (for abbreviations of school names – see footnote 5).

1. Hayek on free competition (Justyna Miklaszewska, Jagiellonian University, abr. UJ)
2. Hayek: The idea of self-organization and the critique of constructivist utopia (Wiesław Banach, Adam Mickiewicz University, Poznań)
3. Spontaneous order in social philosophy: from B. Mandeville to F. A. Hayek (Miłowit Kuniński, UJ)
4. The role of instability in dynamic systems (Michał Tempczyk, Polish Academy of Sciences)
5. The stabilizing role of non-linearity (Michał Tempczyk)
6. Chaos in economics (Arkadiusz Orłowski, Informatics Department in Warsaw Agricultural University)
7. Econophysics – a new paradigm? (Arkadiusz Orłowski)
8. On mathematical models used at stock exchange (Bolesław Borkowski and Arkadiusz Orłowski)
9. Market efficiency and the behavioral finance theory (Piotr Zielonka CMP--LKA)
10. Computational tractability and the physics of information (Arkadiusz Orłowski)
11. From genealogy of mathematical economics: Walras, Pareto. Lange (Anna Zalewska, DLIPS-UwB)
12. L. Savage's mathematical theory of decision-making (Dariusz Surowik, DLIPS--UwB)
13. What the central planning cannot do (Andrzej Malec, DLIPS-UwB)
14. The problem of computational tractability of social structures – in the example of the computational power of free market (Witold Marciszewski, DLIPS-UwB).

Each of these items in a way contributes to the explaining of the key notions of this essay as appearing in the title: 'to grasp rationality, to deal with complexity'. Let me hint at connexions.

Papers 1–3 introduce some crucial ideas due to Hayek, while the remaining ones provide a conceptual apparatus to develop these ideas. *Free competition, self-organization, spontaneous order*, discussed in those papers, are phenomena which Hayek, especially in his polemics with Oskar Lange (cp. items 11 and 14), considered with respect to the issues of complexity and computability. Contrary to Lange, Hayek claimed the advantage of free market over central planning (cp. item 13) with respect to power of computation.

Items 4–7 are to direct attention to the theory of complex dynamic systems as explaining some sources of unpredictability of social processes. This is an approach to complexity which is complementary to that addressing the notion of algorithmic complexity.

Items 8–13 deal with models of economic processes, treated as that representation of social processes which best exemplifies problems of applicability of mathematical models and algorithms. Item 11 sheds light on a methodological aspect of socialist economics. Oskar Lange, who was a strenuous advocate for mathematical models and computerized calculations in socialist economics, referred to the school of economics initiated by Walras and Pareto; it is the context in which his ideas of socialist economy become more conceivable. When taking into account extreme simplifications in Walras and Pareto models for economy, one fully appreciates the role of the concept of computational tractability. Even if socialist economy had a consistent model, the real economic life, when compared with such models displays complexity which exceeds any algoritmic capabilities and computational resources necessary for socialistic central planning. This was intuitively grasped by Ludwig von Mises and Friedrich Hayek, while a precise formulation of their ideas is nowadays possible due to the theory of computational complexity; this was the point of the closing item 14.

To put the thing in a nutshell: free market is a computational device which for at least three reasons is more efficient than central planning; this is due to the use of computing which is distributive, interactive and analog.

Owing to *distributivity*, which means that each market agent processes the data necessary for his own business alone, the volume of data to be processed is enormously smaller (than in central planning). Thus computational complexity does not exceed computational capacities.

Interactivity means that a system is able to learn data-processing from its feed-back interactions with the environment (as entrepreneurs do). It does not need to be fully preprogrammed, what would require unimaginably more memory space and computing time. For, instead of programs and databases preparing a system to meet all possible situations, only a program for self-learning is needed.

Analog computation proves more efficient since it does not require rendering all the process with symbols. This spares time and makes data processing possible also in these situations in which impulses cannot be strictly measured, being only approximately felt by individual receivers. Often such approximations are sufficient for rational decision-making, being at the same time dramatically swifter and more economic than any symbolized and digitalized data-processing. And this is that much sensitive way free market agents run their bussiness, in contradistinction to central planning officials who are unable to handle any data if not recorded in symbols.

A social order arranged according to the above three principles of data-processing usually emerges spontaneously as a result of long evolution, that is, a trial and error self-organizing process. This is what Hayek called *spontaneous order*, and saw it in free market, the development of language, democracy, self-governance, etc. Usually, spontaneous order involves an ethical code that outlines acceptable behavior within the unit or group.

As testified by the fitting forecasts of liberal thinkers (Friedrich Hayek, Karl Popper, Ralf Dahrendorf, Richard Pipes et al.), the concept of spontaneous order has a considerable predictive force. In particular, it implies the collapse of those systems which are extremely hostile to spontaneous order, and introduce instead artificially constructed centralized systems which have no chances when faced with complexity of real life. This was the basis of prediction which Richard Pipes made regarding the Soviet Union. In his autobiography *Memoirs of a Non-Belonger*, 2003, (Chapter 2, Section on Historical Revisionism) Pipes claims that only liberalism, as decentralizing decision-making, is able to handle the complexity of the contemporary world. Pipes, an outstanding historian of Russia and the Soviet Union, is no theorist of computational complexity. Nevertheless, on the basis of historical experience, he arrives at the view like Hayek's that the tractability of complexity is the main political challenge. This idea belongs to the very core of liberalism, on the same footing as the respect for freedom and human rights.

3. The theory of games and computational tractability

In 2003 the Workshop devoted to the above theme was entitled *Computational Power for Social Research. Von Neumann's Ideas – in the Centenary of His Birth*. On account of the Centenary celebration, the program included also talks on some von Neumann's merits beyond the scope of social research, as his contributions to quantum theory and other branches of physics (A. Orłowski), meteorology in the context of Chaos (M. Tempczyk), metamathematics (R. Murawski, J. Pogonowski). The main stream of Workshop involved the theory of games with utility theory, cellular automata as models of social phenomena, and mathematical modelling related to these both subjects. Here are the titles.

1. Evolution of the concept of utility (Tadeusz Tyszka, CMP-LKA)
2. A brief history of Game Theory (Jaideep Roy, CMP-LKA and Indian Statistical Institute, New Delhi)

3. The concept of utility. Should it be revisited? (Janusz Grzelak, University of Warsaw, abbr. UW)
4. The theory of social choice – from Arrow to the current state (Grzegorz Lissowski, UW)
5. The Nice voting system vs. Convention System. An application of power index (Mikołaj Jasiński, UW)
6. An empirical example of limited rationality (Honorata Sosnowska, Warsaw School of Economics)
7. The modelling of the influence of two basic inclinations of investors upon stock indexes (Piotr Zielonka, CMP-LKA)
8. Temporal logic and game theory (Dariusz Surowik, DLIPS-UwB)
9. Dynamic minimalism: the role of computer simulations with cellular automata in studying social processes (Andrzej Nowak, UW and Florida Atlantic University)
10. Social influence modelled in cellular automata: basic research and applications to economic processes in Poland (Andrzej Nowak)
11. Theory of cellular automata in simulating social processes (Katarzyna Zbieć, DLIPS-UwB)
12. Some applications of cellular automata in constructing self-learning systems (Paweł Borkowski, WSP, Częstochowa)
13. The concept of rational action with Max Weber (Radosław Oryszczyszyn, UwB)
14. Empirical aspects of computability theory. That is: does the Universe compute better than (thoughtless) man? (Jerzy Mycka, Maria Skłodowska-Curie University, Lublin)
15. On how the methodology of social sciences meets the issues of computational complexity (Witold Marciszewski, DLIPS-UwB).

The main stream of the conference was concerned with (A) game and utility theories (items 1–8), the second to it was (B) the issue of cellular automata, for short CA (items 9–12), the third – (C) the issue of rationality as escaping algorithmicity (items 13–15).

Streams A and B are closely interconnected not only because of the fact that both game theory and CA theory derive from John von Neumann's works (an advantageous fact in celebrating his Centenary), but also for their being recently combined in social modelling. This combining is nicely exemplified in Andrzej Nowak's own research as reported by him in 9 and 10; some results of other authors were mentioned in communication 11.

CA theory is surprisingly fit to be combined with such paradigmatical cases of game theory as the Prisoner's Dilemma (for that Dilemma see item 3, discussed by J. Grzelak in this issue of *Studies*). The cells in the space of a game in natural way can be regarded as players, while the dilemma in question consists in conflicting interests of theirs. Rules of behaviour in such a dilemma can be easily stated as strategies being chosen by individual cells which react to impulses from the envirnoment. In those social processs which are modelled as iterated games (i.e., played many times), the players can learn from observing results of strategies adopted by them and those adopted by partners[6]. What is specially interesting in studying social evolution, it is the phenomenon of cooperative strategies. These emerge either from social-oriented (altruistic) reactions, or even from one's self-interest when collaboration proves more advantageous for an egoist. CA rules display that astonishing property that even when being very simple, after some number of steps they lead to unexpected results, thus proving their predictive value. In such a context there arise some issues of decidability, for instance, whether the following problem is decidable: suppose that from a given point of time a strategy established itself as dominating: will it remain dominating forever? (Cp. Grim 1997 in Literature).

The third stream of the Workshop, represented by items 13–15, was rather marked than fully developed. Let it be advanced a bit further now, in the next Section. Item 13 from the list of topics yields a convenient starting point.

4. Value-oriented rationality as a basis for social predictions

The famous among sociologists Max Weber's distinction between what is goal-oriented rational (zweckrational) and value-oriented rational (wertrational) requires elucidation. Weber did not succeed in explaining the latter. Moreover, it got blurred with Weber's sermon claiming that social researchers should refrain from any valuations, thus forbidding them to resort to one of those acknowledged by him sorts of rationality. The thing grows even dimmer when Weber himself uses some phrases in an evaluating tone, e.g. when contrasting as opposities the eternal *auri sacra fames* (abominable greed for gold) and the rational motive of gain, the latter seeing as characteristic of modern capitalism and apparently more valuable than that old greed. Thus it is up to the present writer to offer some explanations, while appreciating Weber's merits for calling the issue to mind.

This calling to mind is topical and timely after some successful political predictions, ones of the great consequence, have been made on the basis of axiological assumptions. For instance, Richar Pipes – the renowned historian

[6] Compare the Workshop on *Agents that Learn from Other Agents* held as part of the 1995 *International Machine Learning Conference*. See www.cs.wisc.edu/shavlik/ml95w1/.

of Russia and Ronald Reagan's influential adviser – foretold the collapse of the Soviet Union after having realized the extent of moral ruin of the Soviet system and Soviet people, such a ruin resulting in economic, political and material collapse.

This Pipes' idea is by no means new. It goes back to the Old Testament prophets, as well as the old Romans who believed that moral virtues supported political power; its visible traces can be found in Polish patriotic literature (Jan Kochanowski, Adam Mickiewicz), and in nowadays folk sociology. However, that an idea is old and common among people does not diminish its chances to be true.

On the other hand, the fact that someone inferred from it a prognosis that proved true does not warrant the truth of the premiss. I do not mean to argue that the idea of value-oriented rationality is right; this would exceed the scope of the present paper. Instead, I offer something like a test so that anybody interested might to get aware of his own opinion. One of the views resulting from the test should help in clarifying the notion of value-oriented rationality; those who do not accept that view may device arguments against it. The test runs as follows. Suppose you have two options.

A. To greatly help a honest person being in need at a little expense on your part.

B. To ruin somebody at the same expense as above, with no gain for you except a pleasure of dominating through inflicting pain.

Suppose the only motive of choice you consider is doing what is more right. Now decide which option is regarded more right by you, and express the choice in a verbal Statement, say (as I may guess):

[S] A is more right than B.

Now there is time for the next decision. Do you regard S as a genuine sentence in declarative mood, that is, *a mood that represents the act or state as an objective fact* (as defined in grammar)?

If you answer in the afirmative (what, possibly, is not the case if you are an orthodox neopositivist), this means that you assert S as true. Think once more whether you like regarding S as true, because if you stick to that, you have to acknowledge the state of something being more right than something else 'as an objective fact' (according to the quoted definition); and this, by no means, is either psychological or physical fact, it is rather a 'metaphysical fact'. So be cautious, if you are afraid of engaging yourself into metaphysics. But, think again. If you withdraw your opinion of S as being true, what do you offer in return? You should have a positive suggestion, including the explanation what a grammatical kind of sentence would be disguised in the indicative form of S.

Now, the sequel is addressed to those who accept S as true, thus qualifying it as an indicative sentence. If so, then there may be a logical following of an empirically testable sentence (as being indicative too) from such propositions as S; let us call them *estimates*, be them moral, esthetic, or alike. Thus an empirical prediction may logically follow from a set of premises including estimates. In order to create such a nexus between empirical propositions and estimates, we need some principles of the kind like the following Principle of Axiology:

[PAx] *In a long run, any social system to survive needs axiological foundations, that is a set of non-empty basic axiological concepts to be used in estimates.*

They are basic in the sense that they do not derive from any other concepts but are primitive, like concepts occurring in axioms of a deductive system. Such are the notions of justice, freedom, credibility, loyalty, dignity. That they are so basic as if they were inborn to human minds, could be observed in the Ukrainian protest against iniquities of the political establishment such as falsified results of election in 2004. Similar obviousnesses were felt by those Polish, Russian or Czech people who earlier resisted the communist regime in the period of its absolute dominance.

Such events yield a direct exemplification of PAx. The total lack of axiological foundations makes totalitarian regimes unstable – contrary to the cynical opinion (of dictators and their followers) that brute power which does not respect any moral principles is the most reliable means of lasting dominance and stability.

PAx is just that principle which for people like Richard Pipes became one of two main premisses in forecasting the collapse of the Soviet Union block. The other premiss, already mentioned above, was to the effect that the extreme centralization of economy and politics is a ground of weakness bringing about the collapse of a system.

Thus we obtain an evidence that there are principles, those like PAx, which may function as premisses in reasonings about social affaires. At the same time, we obtain an example what value-oriented rationality may be like (thus filling a gap in Weber's exposition). And it is also the case of a challenge facing the logic of social research, as signalled in this paper's title.

That logic should explain the following question: is it possible for a social theory built on principles like PAx to have a mathematical model in algorithmic form? Should the answer be in the negative, we are to choose between two alternatives. Either there is a mathematical model but not algorithmic one, that is, one that does not imply algorithmic computability (algorithmic decidability), or there is no mathematical model. The former option is one that would engage us into a new, unconventional and little known field called hypercomputation, that is computation beyond the limits of Turing machine; this is the subject dealt with in a contribution to von Neumann Workshop (see item 14 as listed in Section 3, and the corresponding contribution to this issue). The latter option (no mathematics) might belong to what Weber called *understanding sociology*, that is, a discipline which explains social phenomena by resorting to the notion of rationality; in this case it would be value-oriented rationality (this, however, is a matter for further discussion, as other interpretations of the understanding sociology programme, reconciling it with a mathematical approach, may be considered).

The challenge is here just recorded, not responded. However, in the moment such a mere recording is a step forward – the more needed, the less its need is obvious for community of scholars.

5. Does brain's complexity surpass that of human-devised algorithms?

Janusz Grzelak in the contribution to this volume ends his discussion on the concept of utility with an optimistic statement which runs as follows.

> The concept of utility is growing more complex, but the measurement possibilities of contemporary psychology appear to match its level of complexity.

However, the unavoidability of principles like PAx (introduced in previous Section) appears to hint at the contrary. The complexity of moral drives as permeating societies in some periods of their histories (as in the struggles for moral values against communist regimes) seems to exceed explanatory power of nowadays sociology or social psychology. In a remarkable way, the simple mind of Ronald Reagan (derided for that simplicity by intellectuals) proved more understanding and foreseeing than scientifically looking theories of numerous Sovietologists. Here is a fitting characterization of the latter given by Richard Pipes[7].

[7] See an excerpt from Richard Pipes's *Memoirs of a Non-Belonger* (Yale University Press 2003) reprinted at the website http://hnn.us/articles/1836.html.

> Insisting that moral judgments have no place in science (and they considered themselves scientists) the Sovietologists treated societies as if they were mechanisms. One of their basic premises held that all societies performed the same "functions", even if in different ways, on which grounds they interpreted in familiar terms all those features of the communist regime which to a mind untutored in social science appeared outlandish. One such "expert", for example, found no significant difference between the way New Haven was administered and any city of similar size in the Soviet Union. (2) The net result of this methodology was to depict communist societies as not fundamentally different from democratic ones: a conclusion that reinforced the policy recommendation that we could and should come to terms with them.

Moral judgments in science, alien to the content of Sovietological theories, seem inopportune also to some other scholars for reasons which are purely methodological. May be, they are right when refuse to accept as scientific something which is not capable of being measured and mathematically modelled. But then they should acknowledge the superiority of a non-scientific mind, like Reagan's, whose intuition in foreseeing social processes has turned out more powerful than predictive force of scientific theories. Thus it seems that if the theorists do not like appearing useless, they should reconsider their refusal of including value-oriented rationality into the paradigm of social sciences. Such a turn might be justified in the following way.

There may be a cognitive power in some brains which surpasses the scope of what can be recorded in a language and then expressed in a theory. Therefore theories have to resort to simplifications. This can be a good strategy, provided that simplifications get overcome if necessary and justice is done to greater complexity. Such a process in which complexity of a theory increases in order to match the complexity of the phenomena under study, can be traced in the story (in this volume) *Historic and contemporary controversies on the concept of utility* by Joanna Domurat and Tadeusz Tyszka. First, the notion of rationality in John von Neumann's and Oskar Morgenstern's game theory is in that paper described, then we learn that one of its simplifications was remedied by Savage's definition of subjective probality, then another one by D. Kanehman and A. Tversky's prospect theory; the last amends the previous game-theoretical simplifications with taking into account reference points (e.g., some previous experiences) which influence one's utilities.

This story is thought-provoking since it reveals how preverbal insights must precede improvements of a theory. Before a new or improved theory is stated, the mind has to realize a discrepancy between the old theory and a newly observed feature of reality, while the old theory does not render that feature in its verbal statements, e.g., its axioms. Thus the question arises about superiority of mind/brain pretheoretical processes over those going on with the use of a theory.

To address the problem, let me start from quoting an inspiring hypothesis going back to von Neumann[8].

> It is only proper to realize that language is largely a historical accident. The basic human languages are traditionally transmitted to us in various forms, but their very multiplicity proves that there is nothing absolute and necessary about them. Just as languages like Greek or Sanscrit are historical facts and not absolute logical necessities, it is only reasonable to assume that logic and mathematics are similarly historical, accidental forms of expression. They may have essential variants, i.e., they may exist in other forms than the ones to which we are accustomed. Indeed, the nature of the central nervous system and of the message systems that it transmits indicate positively that this is so. [...] Thus logic and mathematics in the central nervous system, when viewed as languages, must structurally be essentially different from those languages to which our common experience refers.

The problem so raised involves four more particular questions.

(1) Is the logic and mathematics of brain subject to restrictions of limitative theorems concerning undecidability (computability in principle)?

(2) If so, is the scope of undecidable problems identical with that constraining the Turing machine?

(3) If not identical, then how should it be defined?

(4) Is there any superiority of the brain over Turing machine embedded in digital electronic computers in respect of computational tractability (practical computability)?

The last problem obtained an answer quite recently. In a contribution entitled *The Code of Mathematics: John von Neumann's "The Computer and the Brain" (1958)* (in the forthcoming book, 2005, by Dirk Baecker (Ed.), *Key Works of Systems Theory*, Opladen: Westdeutscher Verlag) Loet Leydesdorff (Amsterdam School of Communications Research, University of Amsterdam), when summing up some earlier results, writes as follows[9].

---

[8] The quoted passage is the last paragraph in the last von Neumann's work *The Computer and the Brain*, Yale University Press, 1958. The book is a record of a lecture series that von Neumann delivered at Yale University in 1956.

[9] The excerpt is copied from the page users.fmg.uva.nl/lleydesdorff/vonneumann/. The items referred to in abbreviations are as follows.
– Adleman, L. M. (1994). "Molecular Computation of Solution to Combinatorial Problems", *Science* 266 (11), 1021-1024.

> Von Neumann noted that the mechanism of using shorter code may also work the other way round: the material substance may contain mechanisms which are different from our common mathematics, but which are able to solve problems by using shorter code. This prediction has come true. For example, the so-called "traveling salesman problem" which is virtually impossible to solve using normal computation (because it is NP complete), can be solved by using DNA strings in a laboratory setting thanks to the properties of this material (Adleman, 1994; Liu et al., 2000; cf. Ball, 2000). The biochemistry of the system must be understood in addition to the mathematical problem. The recombination of formal and material insights provides us also with new mechanisms for the computation of complex problems. Thus, the mathematics can function as a formal bridge between the special theories that remain otherwise specific.

The notion of short codes is due to Alan Turing. Such a code enables a second machine to imitate the behavior of another, fully coded, machinery. Short codes were developed to make it possible to code more briefly for a machine than its own system would allow. This consists in treating it as if it were a different machine with a more convenient, fuller system of instructions which would allow simpler, less detailed and more straightforward coding.

The message (in the Leydesdorff's passage quoted above) which is crucial for our discussion of game theory as this theory pretends to provide algorithmic models of decision-making and of social processes (competition, collaboration, etc.) runs as follows:

— *There is a NP-complete problem being solvable by a short code in the brain, namely the Travelling Salesman Problem (TSP).*

This premiss should be combined with another one, belonging to the so-called theory of coherence (to be mentioned later).

The above result (italicized) implies that in dealing with complexity of TSP the brain by far surpasses computational capabilities of the digital electronic computer. Here is in order to recall that NP-problems are those

— Ball, P. (2000). *DNA computer helps travelling salesman*, at http://www.nature.com/nsu/000113/000113-10.html.
— Liu, Q., Wang, L., Frutos, A. G., Condon, A. E., Corn, R. M. and Smith, L. M. (2000). "DNA computing on surfaces", *Nature* 403, 175.

This message was found by me at the last stage of writing the present paper. In an earlier version there was a passage in which I wrote about this von Neumann's hypothesis as one waiting for empirical confirmation. Fortunately, a confirmation is now the case. As for the Travelling Salesman Problem, a lot of information can be found at Web, when using this phrase as an entry.

which are (for electronic computers) uncomputable in practice, and they are so since algorithms needed for their solving work in exponential time, this trait being the measure of problem's complexity. When a problem is called NP-complete this means its belonging to the hardest problems in the NP category, that is (let me repeat), the category of problems whose solving requires exponential algorithms[10].

The discovery of so enormous advantages of brains over computers sheds light on game-theoritical algorithms when compared with capabilities of human intuition, the latter, presumably, being due to the brain's equippment. The bridge between the above TSP issue and game-theoretical models is to be conceived as follows. The process of decision-making involves considering all the possible outcomes of actions (which could be taken by the decision-maker) in order to check which incomes are mutually coherent. This is the MCO problem:

(MCO) *How to Maximize Coherence in the set of all possible Outcomes of the actions considered before choice.*

Thus in models of decision-making we need an algorithm for searching outcomes. For n outcomes the number of possible combinations equals 2^n, say 2^{100} with 100 outcomes (in the worst case), what is no unrealistic situation. A problem requiring such an exponential algorithm for exhaustive search belongs to the NP-complete category. It is the same as the category of TSP. Hence any device capable of solving TSP is capable of solving MCO. Since the brain is a device which solves TSP (according to the result reported above), it can solve MCO as well, while for the electronic computer both problems are in practice unsolvable.

From psychological side, that biological capability should be, plausibly, identified with what people used to call intuition and what proves to be a potent tool to deal with complexity. In turn, that intuition, when concerned with rationality, is what the understading sociology relies on. Thus, *via* game theory and algorithmic complexity theory we return to the old venerable programme, mainly due to Max Weber. When taking his idea in the above way, based on these modern, reliable and flourishing disciplines (complexity theory and neurobiology), we may have chance to build the understanding sociology on solid logico-empirical foundations.

---

[10] For this terminology see, e.g. db.uw/aterloo.ca/alopez-o/comp-faq/faq.html, or www.nist.gov/dads/HTML/npcomplete.html.

So far only the last of the four problems listed at the start of this Section (after quoting von Neumann's text) was discussed. Even when being treated in a very sketchy way, this item required a considerable space. Much more would require every of the remainig issues, which besides have the drawback that no empirical results, comparable with those concerning the capabilities of brain DNA have been attained so far. However, the very stating of problems, even without hints toward solution, seems to be of use as a small preliminary step. Hopefully, not before long greater and more conclusive steps in that direction will be made.

Literature

The list of Literature below contains items recommended for reading as useful guides to the issues which are discussed in this paper. As for items used for references, they are quoted inside the paper, either in the main text or in footnotes.

Selmer Bringsjord, Michael Zenzen: Toward a Formal Philosophy of Hypercomputation. *Minds and Machines*, Volume 12 Issue 2, May 2002.

Jerzy Brzeziński et al. (Eds.): *Creativity and Consciousness. Philosophical and Psychological Dimensions*, Rodopi, Amsterdam – Atlanta 1993.

Jack Copeland: The Broad Conception of Computation, *American Behavioral Scientist*, 40, 1997, 690-716.

Jack Copeland [2000, Copyright]: *Turing's O-Machines*, www.alanturing.net /turing_archive/pages/Reference%20Articles/referencearticlesindex. html

Jack Copeland: Accelerating Turing Machines. *Minds and Machines*, Volume 12 Issue 2, May 2002.

Jack Copeland: Hypercomputation. *Minds and Machines*, Volume 12, Issue 4, November 2002.

M. L. Hogarth: Non-Turing computers and non-Turing computability. vol. 1, PSA, 1994.

Patrick Grim: The Undecidability of the Spatialized Prisoner's Dilemma, *Theory and Decision* 42, 1997, 53–80.

J. Hartmanis and R. Stearns: On the computational complexity of algorithms, *Transactions of the AMS* 117, 1965, 285–306.

J. Hartmanis: Gödel, von Neumann and the P=?NP problem, *Bulletin of the European Association for Theoretical Computer Science* 38, 1989, 101–107,

David R. Henderson: *Biography of Friedrich August Hayek (1899–1992)*, www.econlib.org/library/Enc/bios/Hayek.html

Andrzej Nowak and Maciej Lewenstein: Modelling social changes with cellular automata. In: Rainer Hegselmann (ed.), *Modelling and Simulation in the Social Science from the Philosophy of Science Point of View*, pages 249–285. Kluwer Academic Publishers, Dordrecht, 1996.

Oracle machine – entry in *Brainy Encyclopedia* www.brainyencyclopedia.com/encyclopedia/o/or/oracle_machine.html

Roger Penrose: *The Emperor's New Mind: Concerning Computers, Minds, and the Laws of Physics*, Oxford Univ. Press, Oxford etc. 1989.

Roger Penrose: *Shadows of the Mind*, Oxford University Press, New York 1994.

Oron Shagrir: Super-tasks, accelerating Turing machines and uncomputability. *Theoretical Computer Science*, Volume 317, Issue 1–3, June 2004.

Hava T. Siegelmann: Neural and Super-Turing Computing. *Minds and Machines*, Volume 13, Issue 1, February 2003.

Alfred Tarski, in collaboration with Andrzej Mostowski and Raphael M. Robinson: *Undecidable Theories*, North Holland, Amsterdam 1968 (Studies in Logic and the Foundation of Mathematics).

Alan Turing: On computable numbers, with an application to the Entscheidungsproblem, *Proc. of the London Math. Society,* Series 2, 42, 1936, 230–265.

Alan Turing: Systems of logic based on ordinals, *Proc. of the London Math. Society*, Series 2, 45, 1939, 161–228. Cytowane jako Turing [1938].

John von Neumann and Oskar Morgenstern: *The Theory of Games and Economic Behavior*, 3rd ed., Princeton University Press, 1953.

John von Neumann: *The Computer and the Brain,* Yale Univ. Press, New Haven 1958.

Max Weber: *Wirtschaft und Gesellschaft. Grundriss der verstehenden Soziologie.* Fünfte, revidierte Auflage. J. C. B. Mohr (Paul Siebeck), Tübingen 1972.

Peter Wegner: Why interaction is more powerful than algorithms. *Communications of the ACM*, v. 40 n. 5, p. 80–91, May 1997.

Stephen Wolfram: Undecidability and Intractability in Theoretical Physics, *Physical Review Letters* 54, 1985, 735–738.

Stephen Wolfram: *A New Kind of Science*, Wolfram Media, Inc., 2002.

James A. Yunker: Post-Lange Market Socialism. An Evaluation of Profit--Oriented Proposals, *Journal of Economic Issues*, September 1995.

[Author's name lacking] *The Socialist Calculation Debate* cepa.newschool.edu/het/essays/paretian/social.htm