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Bounded Rationality Through the Filter of the Lisbon Objectives

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Abstract: Information and Communication Technologies (ICT) have created best conditions for grows of knowledge societies. An emerging global information society serves to building global knowledge societies as source for further development. Conventional paradigms of sciences starts to be more blemish and prone to redefinition of there foundations, understood as scientific knowledge. The perspective of knowledge and ideals of rationality are both heavily influenced by a new contemporary scientific thinking, through tools, inherent of autonomy and uncertainty. A new understanding of the world in terms of open dynamic heterogeneous uncertain systems is needed. Among the conclusions: classical rational reasoning is mainly aiming at effectiveness, not at uncertain knowledge processing, because of its temporality (mainly its ineffectiveness in dealing with future events); a bounded-rationality approach enables both, better economic models and better modelling, being based on trends in economic modelling as well as on agent-oriented software engineering.
Keywords: knowledge society paradigms, bounded rationality, "just in time" paradigm, uncertain knowledge processing.

1 Introduction

The approach proposed in this paper, trials to a better reaction to uncertain and rapidly changing environments as result of ICT implications in the "grows of economy". As far target the paper has three specific aims: (a) Showing that both bounded rationality and agents are, at the same time, unavoidable restrictions, and valuable means when developing applications. (b) Underlining the inadequacy of conventional formal methods with algorithm-based computational techniques applied in AI, in general but firstly for treating uncertainty in applications. (c) Outlining, on this groundwork, an agent-oriented approach to combine synergistically bounded rationality and agents in modelling.

In a society that strives to be progressively technically, technology is becoming a tool for social interaction bridging the strands between online and offline activities, respectively, digital and social behaviour. Studies demonstrate clearly that the Information and Communication Technologies (ICT) experienced in people’s everyday life sets a milestone for an active participation in the Knowledge Society (KS) development [9].

The "*Lisbon Strategy*", developed by the European Council for the time period 2000-2010, aims to make the EU "the most dynamic and competitive knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion, and respect for the environment by 2010" [20] [9] by considering an economic, a social and an environmental pillar.

Information Society policies address core objectives of the Lisbon Strategy: drive productivity growth, create an open and competitive digital economy, and stimulate innovation to tackle changes of globalization and demographic change.

ICT affects economic performance by driving innovation through investment in ICT; improving business processes and reduce companies administration costs; increasing efficiency in public administration; enhance productivity grow and create new markets.

For the period beyond 2010 the EU develops a new strategy to make a recovery from financial crises and speed up towards a greener, more sustainable and innovative economy. In a formal "Consultation on The Future "EU 2020" Strategy" [9] [20] the EU Commission considers that the key drivers of EU 2020 should be focused on the following thematic: Creating value by basing growth on knowledge; Empowering people in inclusive societies; and creating a competitive, connected and greener economy.

Conventional paradigms of sciences starts to be more blemish and prone to redefinition of there foundations understood as scientific knowledge. Accepted aspects are questioned and relocate the place of man in the world. The perspective of knowledge and ideals of rationality are both heavily influenced by a new contemporary scientific thinking, through tools, inherent of autonomy and uncertainty.

Innovative theoretical solutions, such as the approach of complexity, change old fashion models of rationality. [15] [16] The new rationality prioritizes the view of complexity as an essential characteristic of the surrounding reality (social and non-social). The classical ideal of rationality is centred on the supremacy of reason, which is to be overcome by the approach of complexity. A new understanding of the world in terms of dynamic systems is needed, where interaction between the elements of the system and the environment rules.

For the society, education systems are institutional spaces for generation and transmission of complex knowledge. A premise for a global knowledge based society is an adequate amount of highly qualified scientists. The Universities have been aware in the last decades to expend access to higher education. Beside the need fore more graduates (this objective has reached a significant progress since 2000, increasing the number of Mathematics, Science and Technology graduates, by more then 25%. [9]), an even more important issue is to assure that after graduating, lifelong learning takes place in work and leisure time.

The insertions of new ICT and artificial intelligence in the human society, together with the promotion through the Lisbon objectives, have reached, in the last century, every area of human activities, from education and economy to political systems. If we endeavour to undertake any kind of professional research and development (R&D), we have to analyze the applicability and changes brought us through them.

Premises for the research described here, as well as for other research surveyed in this paper: a) In the last decade most non-trivial IT applications are meant for, and hosted by, open, dynamic, and uncertain environments. b) Ever more services have to be provided in line with the "just in time" (JIT) paradigm; c) developing applications for JIT services implies both bounded rationality (fact of life) and artificial intelligence (powerful IT instrument) as cardinal design-space dimensions. [3] [22] [8] The basic idea is that the dynamics of every facet of our society (first of all, economy) are so intense that no field of study could afford a slower development pace.

Present-day IT environments, except for some irrelevant applications, move fast from limited, homogeneous, changing slowly, deterministic (even if partly approximated or even unknown) towards (OHDUE). That means: "open and heterogeneous (the resources involved are unalike and their availability is not warranted), dynamic (the pace of exogenous and endogenous changes is high) and uncertain (both information and its processing rules are revisable, fuzzy, uncertain and intrinsically non-deterministic" [22] [8] - as most environmental and almost all human stimuli generators).

This paper is organized as follows: After summarizing the history of the undertaking and revising basic concepts, (Section 2), its rationale and approach are outlined in (Section 3) together with considerations highlighting the disadvantages of conventional IT, because of inadequate interaction in dynamic environments. Decision making in from the perspective of bounded rationality is suggested. Conclusions and future work (Section 6) close the paper.

2 History and basic concepts

Conventional IT undertakings relaying on formal methods of computation used for modelling economic systems [10], showed the limitations of the conceptual bases. The rather rigid character and incapability to adapt over time to a rapid changing environmental context, has been addressed afterwards by introducing "total fuzzy grammars" [12].

Trying to manage non deterministic intelligent systems, from economic modelling [12] [10] to natural language processing for ChatBots [11], with intrinsic deterministic tools, proved the be inadequate of this kind endower. Tools unable to deal with a certain degree of uncertainty are not worth to be considered in any kind of modelling real life scenarios.

The approach from [22] addresses bounded-rationality and enables better economic modelling, being based on trends in economic modelling as well as on agent-oriented software engineering.

Uncertainty was analyzed with regard to approximation and undecidability [22] [3] and emphasis that they are two incommensurable kinds of uncertainty: approximation is deterministic and atemporal and undecidability is nondeterministic and has basic temporal dimension. Thus, approximation aims at optimization and efficiency and doesn't fit as instrument for uncertainty. On the other hand, undecidability has to deal with future events in any decision making process and can not be treated exclusively through approximation or other conventional prediction methods (probabilistic, stochastic, etc.)

Research directions on *non-algorithmic* approaches begun in 2007 and have the role to support the approach in this paper. Since the conclusions from [21] [4] are general, they can be easily adapted to real world applications by further investigations and development.

Information and knowledge. The essence of communication in KS is the message to be transmitted. To clarify the meaning used in this paper, of three overlapping and often misleadingly used concepts, regarding message transmission, we consider answering the following questions: What is (will be) passing through modern electronic pipelines? Data, Information or Knowledge?

Data alone caries no meaning and as such represents the lowest level of abstraction. It is used as carrier for collections of numbers, characters, images, bits and bytes etc. Data represents "qualitative or quantitative attributes of a variable or set of variables" (http://en.wikipedia.org/wiki/Data). For data to become information they have to be interpreted in such way that it gets associated with a meaning. Information bears a diversity of meanings from everyday usage to technical settings and is depending on the context of use. Hence, we can see it as second level of abstract while the highest one will be knowledge.

According to Oxford English Dictionary, knowledge is defined as: a) expertise, and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject, (2) what is known in a particular field or in total; facts and information; c) awareness or familiarity gained by experience of a fact or situation. Though, the defining of knowledge is subject for several ongoing philosophical debates.

Putting al three terms together we can say that information is the result of processing data such that it enlarges the knowledge of a person. Therefore, trough the pipelines are passing a mix of all three, decisive being the nature of sender and receiver.

Information and knowledge society. Information Society refers to a society where information and ICT are explicitly ruling. A common vision on the Information Society, "where everyone can create, access, utilize and share information and knowledge, enabling individuals, communities and peoples to achieve their full potential in promoting their sustainable development and improving their quality of life...", was settled by the World Summit on the Information Society (WSIS, Declaration of Principals, Geneva phase 2003).

The idea of Information Society is based on technological breakthroughs while the Knowledge society encompasses much broader social, ethical and political dimensions.

Historically, the Information Society concept was overtaken rapidly by the idea of the Knowledge Society. The main issues of settling for the idea of Knowledge Society were that the Information Society was to restricted for policy and knowledge is more usable than information.

"Knowledge is today recognized as the object of huge economic, political and cultural stakes, to the point of justifiably qualifying the societies currently emerging." [25] A KS is "a society that creates shares and uses knowledge for the prosperity and well-being of its people".

New dynamics have emerge since the "Third Industrial Revolution" (that of new technologies) and constantly evolved from education, science and technique to cultural aspects. Knowledge is central to these changes. The need for an accepted diversity means that knowledge societies will have to be societies of shared knowledge. ICT, especially by the emergence of the internet to a public network, carries new opportunities for a universal access to knowledge. Consequently, it is unacceptable that ICT should lead to a fatalistic technological determinism.

The changes in sciences and implicitly in everyday life produced a revolution in the conception of man by the means of how to regard and produce knowledge and sciences. The long term impact of ICT to knowledge production is described by Manuel Castells as "application of such knowledge to knowledge generation and information processing/communication devices, in a cumulative feedback loop between innovation and the uses of innovation." [18]

3 Rationale and Approach

The acknowledgement of the systemic nature of the world implies a vision of the complex reality together with there diverse interrelationships. It is necessary to adopt methods which allow working from a holistic perspective in order to address adequately complex problems.

Now, more then ever, in the Knowledge Society, any activity is affected in one way ore another by ICT tools. Scientists are able to create state of the art technologies designed for collaboration and transdisciplinarity.

The paper proposes an approach for achieving and promoting the Lisbon objectives through the ICT perspective by narrowing the gape between the technologic perspective and the anthropocentric one. In this endower we consider three paradigms as main pillars for sustainable development in new societies:

- Open Heterogeneous Dynamic Uncertain Environment (OHDUE) - as natural real world environment;
- Bounded Rationality (BR) - as kind of rationality in decision making;
- Just in time paradigm (JIT) - as limit of perception.

We concentrate now on ICT paradigms impulsed by the Lisbon objectives to absorb the speed of change in/for the KS, to sustain the pillars considered above. Since the required change of mentality is profound and urgent, the approach must avoid "solutions in search of a problem". Hence, total pragmatism to begin with: a) To validate the approach - at least in ovo - a relevant, cardinal, and for the most part ill-defined real-world problem is focused on: decision making in economic modelling. b) The solution must reduce complexity: b1) cognitive; that means obvious functionality, no sophisticated concepts or instruments (agents, temporal logics, explicit uncertain information processing, computability theory and computational complexity theory, Bayesian methods, certainty factors, etc.); b2) structural; that means simple mechanisms, immediate applicability in current designs; conventional software engineering. [8]

IT paradigms shift from "client-server" to "computing as interaction". However, since the prevalence of older paradigms are still active and the issue is central to this paper, a historical perspective is helpful: For over 40 years, determinism and bivalent logic were the pillars of Computer Science; likewise, algorithms were the backbone of computer programs, complying with their etymon: pro-gramma = what is written in advance. When early real-time applications (firstly, operating systems) required less autistic programs, algorithms tried to adapt accepting "unsolicited input", to fit the incipient non-determinism due to user free will. Bivalence not only survived, but also, strongly backed by hardware, grew in importance. In the early 70's, the role of bivalent logic transcended the borders of narrow data processing, penetrating "Computer-Aided x", where x stays for almost any intellectual activity (including decision-making). [22] [5]

Uncertainty as epistemic concept. The relationship between uncertainty and non-determinism is intricate but irrelevant in decision-making context, because uncertainty can appear in deterministic problems too (playing chess is a manifest example: certainty about the best move is given up to speed - better said, to inexorable time restrictions). Thus, research can avoid non-determinism and focus only on uncertainty, its species and degrees. Due to its vital role in any kind of decision-making, a subsection in [7] is dedicated to this topic.

Uncertain knowledge processing. Since "in the knowledge-based process planning system, the attribute values are usually miscellaneous, heterogeneous and uncertain" and in "manufacturing process planning, experts often make decisions based on different decision thresholds under uncertainty [...], a novel approach to integrating fuzzy clustering is proposed" in [28] able to "discover association rules more effectively and practically in process planning with such thresholds".

Due to the characteristics of this century, when speed and efficiency are vital in all fields of interest, decision making plays an important role in almost every domain of human activity. In such tasks, alternatives are considered and there outcomes are measured until a certain threshold is reached, at which time the solution is found. Human do not use explicit probabilistic/stochastic thinking when they make time constrained decisions [22] [3] [8].

Undecidability. Definitions on the Web: a) "property of knowledge representation language that the truth of some of the true statements within that language cannot be established by any algorithm" (www.dbmi.columbia. edu/homepages/wandong/KR/krglossary.html); b) "Undecidable has more than one meaning in mathematical logic: b1) A decision problem is called (recursively) undecidable if no algorithm can decide it, such as for Turing's halting problem. b2) "Undecidable" is sometimes used as a synonym of "independent", where a formula in mathematical logic is independent of a logical theory if neither that formula nor its negation can be proved within the theory." (en.wikipedia.org/wiki/Undecidability). Obviously such definitions are too "full of mathematics" to be thoroughly comprehended in common decision-making. On the contrary, the definition "Within a system, a statement is said to be undecidable when it cannot be shown to be either true or false." (ddi.cs.uni-potsdam.de/Lehre/TuringLectures/Math Notions.htm is relevant for this paper. Indeed, even when the fact that accurate numeric data are hard to get is accepted, the emphasis is on approximated, predicted, evaluated by rule of thumb, or even on intrinsically fuzzy data, rather than on missing ones (lacking sensor or market information, delayed previous decisions, server crash etc.). However, decisions are difficult because a relevant event not happened yet, not because a result is imprecise.

Approximation. A web definition of approximation states "inexact representation of something that is still close enough to be useful. Although approximation is most often applied to numbers, it is also frequently applied to such things as mathematical functions, shapes, and physical laws." (en.wikipedia.org/wiki/Approximation). These definition is relevant as regards: a) both the commonsensical and the scientific (mainly, mathematical) meanings of approximation; b) its role as degree of uncertainty (as "measure" of: imprecision, difference between a reported value and a real one, possible error or range of error, etc.); c) its major function as optimization tool. Indeed, approximation, seen as a "don't care"-like uncertainty, can speed up remarkably data processing in key IT subdomains (e.g., image processing, form and motion recognition, surface design, web classification, networks). [3] [22] But on the other hand: approximation is inherently unsuitable for "don't know" - like uncertainty, not even in deterministic contexts. [8]

Bounded Rationality. The very principle of bounded rationality had been developed a half-century ago by the Chicago School and endorsed brilliantly by Simon [24]. Rubinstein describes "models in which procedural aspects of decision making are explicitly included" in [23]. Kahneman received a Nobel Prize for seeing bounded rationality as a means to improve economic modelling [16] linking it to psychological processes or to communication faults that could explain (or not) ill-applied statistical thinking in decision-making. Gigerenzer proposed alternatives for decision making, based on simple heuristics [15] that "lead to better decisions than the theoretically optimal procedure" (en.wikipedia.org/wiki/Bounded rationality); for instance, priority heuristics [18]). A more recent advance by Edward Tsang presents the Rubinstein approach in a computational point of view, referred as CIDER (Computational Intelligence Determines Effective Rationality) theory. This way of interpreting BR enables to reason about economic systems when the full rationality assumption is relaxed. [26]

The problem is that none of the aspects mentioned above are taken into account sufficiently, neither in economic modelling, nor in decision-making. Moreover, ignoring the fact that bounded rationality is "a form of behaviour associated with uncertainty where individuals do not examine every possible option open to them" (www.pestmanagement.co.uk/lib/glossary/glossary_b.shtml), the mathematical tools still recommended for modelling economic processes (taking place in OHDUE) are ill-applied when they try to deal with undecidability and complexity.

Bounded rationality is defined as concept that decision makers (irrespective of their level of intelligence) have to work under three unavoidable constraints: (a) only limited, often unreliable, information is available regarding possible alternatives and their consequences; (b) human mind has only limited capacity to evaluate and process the information that is available, and (c) only a limited amount of time is available to make a decision.

Therefore even individuals who intend to make rational choices are bound to make satisfying (rather than maximizing or optimizing) choices in complex situations. Consequently, considering bounded rationality in modelling, would have two convergent, major beneficial effects: reducing attempts in the counterproductive direction (i.e., treating undecidability) and promoting efforts in the valuable course (i.e., offering "just in time" answers). Thus, the paradox of approximation complexity in modelling would fade away.

Inaccurate complexity management. Due the growing information complexity encountered in every research fields, machine learning techniques gain increasing popularity. Software tools (like Weka and RapidMiner) offer state of the art feature selection techniques and a large number of similarity functions allowing clustering and instance based learning techniques, respectively to deal with height dimensional domains. When complexity is overwhelming (requiring unaffordable resources), instead of simplifying the model, subsymbolic paradigms - mainly artificial neural networks (ANN) or evolutionary algorithms (EA) - are used, ignoring their general weaknesses (no explanations, weak convergence, poor reliability because of inadequate exploitation/exploration ratio) or specific ones: need for training example sets (for ANN) or endogamic limitation (for EA). For instance, what responsible human will make critical (e.g., macroeconomic) decisions without any justification?

Modern Artificial Intelligence. In an historical early phase of intelligent system development, when expert systems based on the Newell-Simon hypothesis ("A physical symbol system has the necessary and sufficient means for general intelligent action") where "on vogue", they start to disappoint in all nuances of the world. A prompt reaction upon the limits of the symbolic paradigm came timely by replacing "GOFA" (Good Old-Fashioned AI) with "BIC" (Biologically Inspired Computing). Bringing all paradigms together, "modern artificial interlace" means now agents [17] [29] [1]. By a formal standard [14] the agent is now acknowledged as process.

The user impact of agent technology through ICTs [6] [5] breaks up from reversing the three questions: "What for?" - the aim; "What?" - the architecture; "How?" - the structure. Redressing the balance from an end user viewpoint to a user centered one, the three questions become a different interpretation: "What for?" - to get easy and fast help; "What?" - new applications domains become affordable; "How?" - by imposing user needs and not ICT ones. "Technological determinism" for "technology pushed" users is not distinctive for agents, it is just a matter of impact measurement.

4 Conclusions and future work

In the last century we witnessed an explosive growth in the number and diversity of networked devices and portals as main communication channels bringing a height degree of mobility, heterogeneity, and interactions among devices connected to global networks. Knowledge is the engine for sustainable growth. In a fast-changing world, what makes the difference is education and research, innovation and creativity. Building on its strengths in technology and knowledge, Europe should tap fully the potential of the digital economy.

Economic models cannot anymore avoid the consequences of bounded rationality. It has to accept undecidability as concept and to resort to approximation as means. To be relevant, the endower should always address real world problems and not artificially models born and living in abstracted laboratory simulated conditions.

Software agents will be seamlessly integrated in our everyday life and therefore they have to constantly sense and react to the environment. Great opportunities for agent oriented software architecture are opened by the dynamic and heterogeneous environmental character.

Negative impacts of ICTs are partially rooted in the uncertainty coming from the inability to assimilate the complexity, diversity, magnitude and space of the ICT world. Positive impacts increase the possibility of communication by significantly widening the filed of existing applications and facilitates the emergence of new ones. In this context, the negative or positive impact is wrongly attributed to the technology itself, and rather to there applications.

The gape between the user expectations and the technological offer is deepened due insufficient innovation and lake in use of new agent oriented potential.

The future research will focus on agent oriented software engineering as powerful just in time solution in an environment striving toward a knowledge society, where traditional rationality has to be replaced (ore at least heavily supported) by bounded rational approaches, in order to be able dealing with the increasing complexity of real life scenarios.

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