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Invited Commentary

From Big Data to Smart Business:

Some Philosophical Remarks - Revealing the new Era of Smart Data, Deep Learning and Cognitive Computing

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1. PROLOGUE - THE FORMULATION OF HYPOTHESES: A PROFESSIONAL ACTIVITY

The *formulation of hypotheses* is a real professional activity, as in the investigator's' case (police, judges, various experts, and so forth) that, by some indications, must make an assumption about the whole picture of the crime; or in science where *hypotheses* take the form of *laws* that explain natural phenomena. A *Machine Learning* (hereafter ML) challenge is the creation of *artifacts*, such as *software robots* (i.e., programs), or *physical robots* (i.e., personified), able to formulate hypotheses automatically, from observations made under form of a *data set* (hereafter *dataset*). For example, *bioinformatics*, that as a discipline is born in the late seventies of the last century, applies these tools, coming from computer science, to molecular biology, with the aim to provide *models*, or *hypotheses*, able to explain biological phenomena such as the *prediction* of proteins' structures, from a gene sequence; application of considerable importance for the function that some of them will go to cover, in particular, in the etiology of some serious diseases. The physiological function of the protein (either enzyme, receptor, transporter, structural protein), depends entirely on the three-dimensional structure. And some causes of disease are to be found in the errors of *folding*, that is, the transformation in three-dimensional structure of the gene sequence. This is the case of *bovine spongiform encephalopathy*, better known as *BSE*, or other diseases, such as *Parkinson's* and *Alzheimer's*, which could be caused by a malfunction of this biological mechanism. The wide availability of datasets containing gene sequences, for which the protein is known, enables the training of a learning machine to discover new three-dimensional structures. In 1992, GOLEM, a ML program designed by Stephen Muggleton, produced hypotheses, in the form of *rules*, predicting protein structures unknown until then. Before GOLEM, Herbert Simon, with his co-workers, had made BACON, a ML program so named in honor of Francis Bacon and his *inductive method* that, among other applications, has "rediscovered" the Kepler's third law of motion on planets. The Imperial scientist, using only two data, the *distance* of the planets from the Sun, and their *period* of revolution, collected by his schoolmaster Tycho Brahe, thought the existence of "regularities" (*patterns*) connected to these data, finding them after ten years of research. With the same data of Kepler, BACON, using simple *heuristics*, best known as a *rule of thumb*, has "rediscovered" the third law of planetary motion, according to a planet, while abandoning the Sun, takes longer and longer to complete one complete revolution, regardless of its mass. By resorting to this kind of "tricks", BACON was able to discover other laws of nature, such as *Ohm's law* on electrical resistance, other than some laws of chemistry. GOLEM and, before him, BACON, represent two paradigmatic examples of ML. The first belongs to the tradition traced back to Alan Turing, the father of modern computers, makes extensive use of *logic*; in the case of *protein folding*, which has been mentioned, GOLEM induced a *law of nature* in the form of *logical predicates*. BACON, however, is representative of the *psychological tradition* of ML, dating back to Simon, who tries to imitate the strategies of induction as they are carried out, for example, by scientists. According to Donald Gillies (1996), Simons ́ psychological approach to ML, as the one employed by BACON, although it has achieved excellent results in the simulation of the discoveries made by scientists, he has only "rediscovered" laws already known, while learning models of the type used to have GOLEM produced real rules of generalization, in areas which were not previously known. Simon points out, however, that its purpose is to understand, through programs like BACON, the cognitive process (*human thinking*) and not to build powerful artifacts that make use of Artificial intelligence (hereafter AI). Simon's program shows how a *scientific discovery*, as in the case of Kepler, is not the product of some "mysterious processes", the preserve of the scientist, but a problem-solving activity, although complex. Over the past two decades, the most active AI research programs make use of *neural networks*, *genetic algorithms* and *probabilistic reasoning systems*, in other words, methods looking for *inductive inferences* that can treat uncertain information in complex environments. Thus the debate on the two traditions of ML, as well as it was analyzed by Donald Gillies (1996) was enhanced further so that some authors, like Kevin Korb (2004), consider declining the tradition that makes use *logical inductive*, *a` la* GOLEM, especially in light of the success of application of new methodologies. Just think, for example, the use of *neural networks* in the development of the insecticide spinetoram, produced by Dow AgroSciences, which won for its low environmental impact, the Designing Greener Chemicals Award 2008 of the US Environment Protection Agency (Williamson, 2008)[1]. Korb, however, seems to have paid too early a tradition, that of inductive logic, which also continues to enjoy considerable success, theoretical and applied. For example, Saso Dzeroski has demonstrated the usefulness of inductive logic programs for solving differential equations, a theoretical success, and achieved remarkable results in application areas such as *life sciences* and *natural language processing*, where these programs were particularly effective (Blockeel & Dzeroski & Kompare & Kramer & Pfahringer & Van Laer, 2004; D'Avanzo & Lavelli & Magnini & Zanoli, 2003).

2. SIR POPPER AND LORD BACON ON THE SCIENTIFIC METHOD

In addition to the many practical applications, ML, as used by GOLEM and, earlier, by BACON, may shed light, as claimed by Donald Gillies, on the debate about the *scientific method* developed in philosophy of science, between the *inductivist* party, referring to Francis Bacon, and the *falsificationist* party, referring to Karl Popper (Popper, 1963). As is known, Lord Bacon[2], in the *Novum Organum* (1620) argues that a scientist makes an accurate amount of observations from which it draws the general laws, or hypotheses, able to describe a certain phenomenon (*inductivism*). Bacon explains the *mechanical* nature of his procedure, using the metaphor of the "compass and circle" according to it is "impossible, even for the most gifted artist, drawing a perfect circle freehand, but with a compass everyone can do it". From this concept of a mechanical nature the Lord Chancellor proposes a corollary, very controversial, on the nature of the scientific method, arguing that because of it "science becomes a chore that needs no particular talent or intelligence". Popper, in *Conjectures and Refutations* (1963), radically denies the Baconian position, arguing that there can be no pure observation if it is not guided by any theory and he formulates an alternative conception of the scientific method, the theory of *conjectures* and *refutations*, also known as *falsificationism*. The science is not starting from *observations* but by *conjecture*, and the task of the scientist is to *refute*, or *falsify*, his *conjectures* through a process of criticism and control, for example by making observations or experiments. Popper, unlike Bacon, thinks that the scientific theory, a conjecture, is a product of creative and intuitive thinking of the scientist, not owing to a logical, or automatic, procedure. However, even if the two parties, inductivists and falsificationists, seem so far away each other, Gillies, analyzing the discovery of Kepler, detects both Baconian and Popperian elements. To Gillies, Kepler is a Popperian when employs the *background knowledge*, as a convinced Copernican, connecting the orbit of Mars with the Sun and not the Earth, taking it as a center of power that regulates the orbit of the planets. Kepler is still Popperian when, based on Tycho's data, he rejects the first hypotheses of circular orbit and, instead, resort to intuition to " jump " from the circular orbit to the elliptical one. It is, instead, Baconian when he generates, mechanically, the following assumptions. Where it does not use an induction by simple enumeration, inferred from the observation of a number of similar instances, considered "childish" by the Lord Chancellor, but he considers a form of induction based on "exclusions and rejections", evidently similar to the Popperian "falsifications and refutations". The hypotheses generated by a ML program, as GOLEM, and before BACON, demonstrate, empirically, as the two visions of the scientific method, can actually co-exist. Both programs, in fact, generate hypotheses mechanically, according to the Baconian's wish. And in formulating hypotheses recur constantly to a control on the data, in the spirit of Popper's falsification, "adjusting" the hypotheses generated based on the data available to them. Muggleton when, in 1988, realized the antecedent of GOLEM, in reporting its performance, argued that the program was operating just in the "spirit of the Baconian discussion". Gillies, in analyzing the discovery of Kepler, showed how *intuition*, reputed falsificationist feature, enabled the astronomer to "jump" from the circular hypothesis to elliptical one. Yet BACON has rediscovered the third law of motion without turn, apparently, to this concept, defined by Simon, in the first part of his career, a "mystery" (Frantz, 2003) but then, with the subsequent developments of Artificial Intelligence and Cognitive Science, described by the Nobel laureate as "a label for a process, not an explanation". The process, which traditionally refer Simon, is a "recognition of regularities" (i.e., *pattern recognition*), based on the experiences stored in memory and recalled when needed. Although done on a subconscious level, this process is still analytical and it is "able to provide answers through the recognition of similar situations". For example, a domain expert, as well as having more knowledge of the beginner, can extract more rapidly relevant facts from his memory. This is possible because the knowledge of the expert is like an encyclopedia, with a large index, whose items have cross-references. A chess master, for example, examining the positions of a game in progress, immediately moves his eyes in the most relevant part of the board, proving to see the most important relationships. According to Simon, the performance of the expert is based on knowledge of chess and an act of *subconscious pattern recognition*. And that ability, observed in chess masters or experts decision makers, is what is called *intuition*. In this sense also programs like GOLEM, and before BACON, have recourse to intuition: given a certain task, starting from the background knowledge, suitably encoded in the program, they recognize relevant patterns, performing a search, possibly heuristic, in the space of hypotheses.

3. MACHINE LEARNING AND PHILOSOPHY OF SCIENCE: BESIDES THE SCIENTIFIC METHOD

Although the scientific method is one of the topics of investigation privileged by the Philosophy of science, as we know, it is not the only one. On the other hand GOLEM, and before him BACON, are only examples for the interaction that exists between Philosophy of Science and Machine learning.

Such interaction is considered by some "mutual" and "dynamic" (Williamson, 2004) and other seen as a first step towards the merger of the two disciplines (Korb, 2004). In 2004, the journal *Minds and Machines* devotes a special issue to the relationship between the two disciplines and Kevin Korb, in its editorial, detects similarities. As well as "Machine learning strategies inductive study performed by the algorithms" says Korb, the same way the "Philosophy of science studies the inductive strategies as they appear in scientific practice". The author analyzes the practice of philosophers of science which, he says, often prefer the use of historical cases of science to define their own theories, such as the discovery of Kepler analyzed by Gillies. Korb (2004), however, hopes the claims of Paul Taghard in Computational Philosophy of Science (1988), according to the implementation of different inductive algorithms allows, for the first time, an experimental philosophy of science. Taghard had proposed a test of methodological rigor whereby any hypothesis must be expressed in a language that could lead to its implementation in a computer program. A topic that he found many objections. Just think of (Dreyfus, 1992), according to many human abilities, including scientists, are not algorithmic. Programs like BACON show, however, the plausibility of Taghard's thesis. And although the same Korb had doubts about the methodology of BACON, that would treat the noisy data using ad hoc procedures, a program like GOLEM shows how to discover the laws of nature unknown before, without using ad hoc strategies. In fact, for Korb, even if a methodology is not executable by a computer program, the test of methodological rigor proposed by Taghard has a normative value: the translation into computer program of any one methodology represents a good demonstration of its rigor, providing, at the same time, a test of merit or demerit. In support of a possible "merger" between the two disciplines, Korb uses an argument of David Hume, who had argued that no inductive strategy can be considered, universally, better than the others. In particular, the author points out that machine learning, after about 200 years, has not only realized the importance of this result, but it also gave a demonstration. In 1997, in fact, Wolpert (1997) and Macready have proved a theorem according to "two algorithms are equivalent when their performance is assessed on the average of all possible problems". In other words, if a learning algorithm obtains superior results on some problems, it will realize lower results on other tasks. For Korb, this result is the starting point for analyzing the problem of meta-learning, according to, abandoning the ambitious universal learning algorithm, we must grope to find a heuristic to select an inductive algorithm able to solve a particular problem. For Korb, addressing the issue of meta-learning as part of machine learning means facing, in descriptive terms, the problem of induction in philosophy of science, trying to figure out how the inductions of a scientist takes place. And here the clear convergence between Korb and Simon: both use artificial intelligence as a tool for understanding cognitive phenomena. In support of the unity between the two disciplines Korb analyzes Occam's Razor, which, as is known, requires to postulate only entities strictly necessary. The principle, when applied to the induction, aims for the simplest theory that can explain the evidence; this assumption is at odds with many approaches being used in Machine Learning who prefer, as the sole epistemological criterion seeing how the theory can explain the data. The formulation of a more complex hypothesis, that is, as much as possible adapted to the data, produces as a result a more complex model that, although could explain the existing data, does not allow to describe new data in a satisfactory manner, losing its predictive power. This extreme "attention" to the data is known as overfitting. According to the Occam's principle, however, we can introduce more complex hypotheses only when they are actually justified on the basis of evidence. On the other hand, if you formulate a priori hypothesis complex, without the complexities were induced by the evidence, then it would have been introduced without a guide of thumb: "it would be as realistic as any other hypothesis dictated by pure fantasy".

4. THE INTERACTION BETWEEN MACHINE LEARNING AND PHILOSOPHY OF SCIENCE WITH THE ADVENT OF BIG DATA

As seen, a Machine Learning program uses a number of observations, collected in a dataset, to automatically extract a predictive model which, if applied to scientific discovery, as in the case of GOLEM for protein folding, it is also explanatory: that is, it works as a scientific law (Williamson, 2008). Another vision of the scientific method suggests hypotheses' formulation of on the basis of a wide range of evidence, like a scientist, using the variety of available datasets. In this case, the dominant paradigm contemplates the extraction of as many patterns, one for each dataset, then aggregated into a single model. This operation, known as *forecast aggregation*, presents a series of limitations such as, for example, to ignore qualitative evidence, or that of the choice of the final model, usually based on an average of the individual ones. Williamson (2008), in trying to overcome the limitations of the process of forecast aggragation, proposed the construction of a single model which integrates the totality of the evidence available in the different datasets (*evidence integration*), supporting it as a third way to the scientific method, able to reconcile the inductivist vision with the falsificationist one. In this sense, it has shown particular utility, the way traced by Bayesian epistemology, from the twentieth century, although the discipline goes back to Reverend Thomas Bayes, who lived in the eighteenth century. The basic idea of the Bayesian method is that many quantity, apparently unknown, possess a probability distribution, updateable based on new evidence soon as available. The procedure, known as a *Bayes' the- orem*, or *Bayes' rule*, states that the *posterior probability* (distribution in the light of new evidence) is proportional to the *prior probability* (the distribution you had before the contribution of new evidence) multiplied by the likelihood:

4.1. Posterior Probability of the Hypothesis ∝ Prior Probability x Likelihood

Where the *likelihood* indicates how likely the new evidence, admitted that the prior probability was correct. For example, using Bayes' rule, Williamson has tested the *evidence integration* in a case of cancer prognosis, where the evidence from different sources, also includes qualitative data. The physician should decide the post-operative treatment that is more effective the more aggressive. It is therefore important that the degree of belief of the physician, in the recurrence of the disease, is adequately assessed on the basis of evidence. In this case the available data concerning other patients, are of three types: a dataset regarding the clinical symptoms, genomic datasets on the presence of molecular markers, and datasets containing studies that establish causal relationships between some variables. The author, through the Bayesian procedure, showed how to use molecular markers and clinical symptoms to predict patient survival, although none of the datasets, by themselves, before the integration, contained information on these variables. The Bayesian approach to the hypotheses formulation is a response to Humean skepticism, according to inductive inferences cannot be justified because they are based on the assumption that the future will be like the past. The Bayesian method, instead, allows to change the hypothesis based on the data, then contemplating falsifiability, which is so conjectural and subject to change, *à la* Popper. According to the the Bayesian view, the probability measures the strength of a hypothesis, and, in general, of a *belief*, as, for example, "I'm sure that 2% of the population is diabetic" differing from *frequentist* view that, instead, considers the probability as a statement of fact about the world, that, in turn, represents core of the *objectivism*. Prerequisite of *frequentism*, and its limit, is the infinite repeatability of an experiment, where an attraction of the *Bayesianism* is the possibility to treat individual events, such as, for example, assigning a probability to the hypothesis that a smoker of forty years may have a heart attack in the next year, although it is not a sample available with examples of the same type. New evidence, when available, as some genetic characteristics, make it possible to modify and updating the initial hypothesis. Many authors believe that Bayesianism is a *normative* model of rationality to aspire to, maybe training appropriately a decision maker who is not familiar with this procedure; or through the use of automatic systems that can support an operator need thereof, as in the case of the physician who must decide the treatment to be administered. Other research (Gopnik & Glymour & Sobel & Schulz & Kushnir & Danks, 2004) provide experiments that demonstrate how children seem to use a Bayesian learning model, showing its cognitive plausibility. These investigations run through the tradition, within Machine Learning, began with Simon, who, as mentioned earlier, sees Artificial Intelligence as a tool for understanding the cognitive process. They show how *satisficing* inductive strategies, according to Simon's *model of bounded rationality* (employed with limitations of *time* and *knowledge*), and plausible from a cognitive point of view, if they are simulated through a computer program, in the performance of certain tasks, they show performance similar, or exceeding, inference procedures, such as *multiple regression*, which respect, however, the classical principles of *normative rationality* (Gigerenzer & Goldstein 1996). With the explosion of information on the Web, users are forced to read a good part of a page, encountering many difficulties, before deciding on its relevance to their needs and their objectives. One option to reduce this problem is to resort to summaries, automatically extracted and/or generated, to guide the behavior of navigation (*browsing behavior*). Recent studies show how summaries, as well as reducing the *cognitive overload* of the user, increase the knowledge of the analyzed page. In particular, some investigations, conducted while users were browsing, show that reading a text takes place with "snap" movements of the eyes, irregular or "jerky", which focus on *keywords* or *keyphrases* for about 250 milliseconds. A summary that is too large is likely in turn to produce in the user cognitive overload; vice versa, summaries short and concise, as those constituted by sets of keywords, may reduce them substantially. Also in this case, as shown by the experiments, the Bayesian procedures are particularly useful (D'Avanzo & Kuflik, 2005). The dataset used to train the machine learning program are composed of documents for each of which the user provides the keywords most appropriate, according to him, to describe the text. The program employs this material to extract the hypothesis, that in this case consists in classifying one keyword as *relevant* or *not* for the text, using *attributes* such as *the position of the word* in the document, its *linguistic features* and so on. The extracted model is applied automatically to the new texts for which the keywords that make up the summary are unknown. The Web is a real laboratory where different datasets, such as biomedical ones, can be integrated to automate the formulation of scientific hypotheses. For instance, Don Swanson (1997), with his collaborators, has suggested that new information can be "unearthed" investigating systematically scientific literature seemingly unrelated. The method, which extracts *knowledge* (*knowledge mining*) from documents, consists in finding two scientific literatures, "complementary but disjoint", *AB* and *BC*, where *A*, *B* and *C* are concepts of interest. For example, if *C* is the literature on migraine and *A* the literature about magnesium, then performing a search in the titles of the publications in MEDLINE, one of the largest databases of biomedical literature, we can find relevant titles for each of the concepts *A* and *C*, but also a list *B* of terms common to *A* and *C* that may suggest hypotheses unusual as the physiological effects of the insufficiency of magnesium on migraine. Hypotheses that can be confirmed or disproved by experimental tests, as clinical ones. A demonstration of the feasibility of his method, Swanson has found evidence for relationships already known as those between magnesium and migraine, or that between fish oil and Raynaud's syndrome (Bekhuis, 2006). Some variants of Swanson's method extract knowledge from the summaries of documents, as well as from the titles, or resort to techniques that capture the main concepts of a text, collected, for example, in keywords/keyphrases, such as those described above. Other methods employ ontologies or more sophisticated Natural Language Processing techniques, belonging to the wider discipline of Text Mining, which tries to extract relevant patterns of text, for example strings of nucleotides, or clinical concepts, in distributed databases on the Web (D'Avanzo & Kuflik & Lytras, 2008). Just the abundance of information in digital format, from the molecular and cellular biology, has made possible the emergence of *conceptual biology* as a discipline (Blagosklonny & Pardee, 2002). The new discipline formulates hypotheses from this data just using methods of Text Mining, assisting in the development of automation of scientific discovery of which GOLEM, and before him BACON, are illustrious forerunners. Together, these areas of research have opened new perspectives that were unedited until a few years ago. The aim of these new unpaved ways is to build agents, with increasing degrees of autonomy, which, however, they must always serve the uncertainty and bias of the information they have on their respective worlds. These scenarios require analysis of ethical and epistemological more frequent and thorough.

5. REVEALING THE NEW ERA OF BIG DATA, MACHINE LEARNING AND COGNITIVE COMPUTING

With all the previous philosophical remarks in mind it is critical to provide a context for the new era of computing where the ultimate milestone of computer science about the provision of efficient artificial intelligence in the daily life of human looks more possible than ever. With initiatives like OpenAI and the provision of full environments for the development of Intelligent agents and beyond like IBM Watson, as well as many new areas of development like Intelligent Bots and technologies like SPARQL or Apache Storm, our world is entering to a new era of computing. It seems that a new enriched experience of human computer interaction will be enabled by new personalized, customizable, scalable and reliable environments.

5.1. The Reference Domains

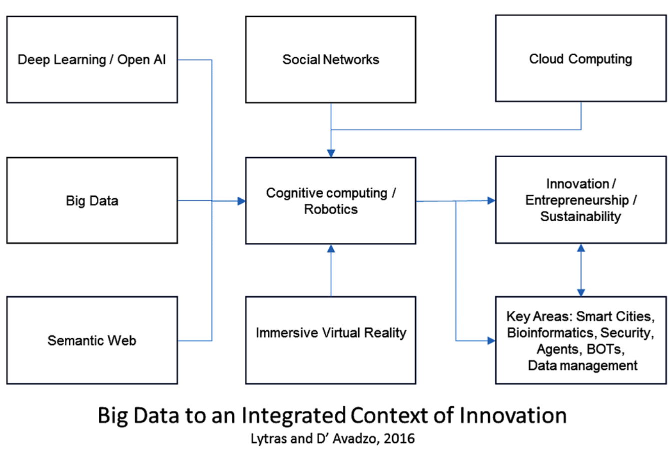
The evolution of this new era, will require a very speedy integration of many computing approaches, but also the consideration of complex social factors. Thus the new era of computing will be more than ever Sociotechnical.

The current literature review provides a very interesting and complementary overview of the integrative aspects of the phenomenon. In figure 1, we provide our perception for the integrated context of exploitation.

In our perception Cognitive Computing and Robotics will require an integration of various complementary approaches that recently emerged as new value adding propositions in computing, while many of them exist in relevant scientific areas for many years.

- **Deep Learning**: A new fresh approach to Machine Learning with advanced Neural Networks and complicated Reinforcement algorithms provides already an evolution to the domain. If we add to this perspective the capacity of several algorithms to learn with less data, then it is a great challenge to investigate how Big Data can inform more effective decision making and personalized services. The OpenAI initiative is another bold example of the things that will

Figure 1. The big data research to an integrated context for innovation



have a great impact in the near future of computing and why BigData Research is a very partial aspect of the entire phenomenon that very shortly will invent a new covering umbrella concept to integrate the full perspective and the dynamics.

- **BigData,** with different considerations and technical perspectives seem that is move fast to the analysis of the supporting business scenarios. With a variety of technological components already dominating in the industry including Apache Hadoop, and Apache Storm, SPARQL for open linked data and querying, seems that the business scenario needs further elaboration.
- **Semantic Web**: It is rather hard to differentiate the discussion bout Big Data from a thorough analysis of ontological and semantic aspects. It is trough that the initial Semantic Web vision provided by Tim Berners Lee it is timely, but the other approached discussed here and presented in figure 1, have emerged and provide a holistic approach to the new era of computing. The evolution of Cognitive Computing is in fact the new context for the realization of the semantic web
- **Social Networks Research**: The current decade dominated by enormous research and a great evolution of social Networks. This trend will continue and social Networks will continue to diffuse a variety of intelligent applications and additionally agents or bots will emerge as a key component of the next generations of Social Networking platforms. The key shift will be related to the maturity and the complexity or the computational capacity of the new versions of social networks. We will face a tremendous empowerment of the services and also of the intelligence of these structures.
- **Immersive Virtual Reality**: Undoubtedly this is one of the most interesting additions to the overall landscape. Wearable technologies and advanced approaches to virtual realities promote big data development and consumption. The analysis of the business case for virtual reality goes beyond the traditional value proposition for domains like health or training. E-commerce will also enter to a new generation adopting some cutting edge technologies of VR/AR/MR (virtual/ augmented/ mixed) reality.
- **Cloud Computing:** cloud technologies are here for a long time. In the traditional consideration of software as an infrastructure, software as a service, platform as a service and infrastructure as a service, shortly we will revisit also the business as a service. One of the greatest challenges of the next thread of entrepreneurship would be to integrate various cloud services for supporting their innovation mix.
- **Cognitive Computing / Robotics:** it is the new big Thing in computing. Integration of Cognition and advanced reasoning capabilities to computer systems will boost the world economy. The players in the market as well as research institutes around the world are getting ready offering new development environments. IBM Watson and OpenAI are two good examples.
- **Innovation, Entrepreneurship and Sustainability:** Without new robust methodologies for collaborative innovation none of the previous technological development will conclude to sustainable businesses. It is one of the most critical requirements for the new era of computing to prove that the integration of Intelligent Devices and systems in Production will move Post-Industrial Humanity to the Smart Technology Era, with respect to the right of humans to prosperity and work. It sounds like a pulp fiction scenario but these questions will ask for a demanding answer very shortly. Thus there is a challenge for the educational system to reconsider its priorities and the kind of knowledge and skills that will be promoted.
- **Key Areas:** A number of key areas are of great importance for the Knowledge Society Vision. Smart Cities, Healthcare Domain, Public Service, Security and many other set the exploitation context.

5.2. The Revisited Research Problem

From the previous philosophical discourse and the elaboration on the key aspects for the phenomenon of Big Data within the greater vision of Cognitive Computing, it is clear that the new era of computing will set new priorities and challenges to research and business. To our opinion one of the first significant implications will be the promotion of Smart Business. A new context for competition and market differentiation where cognitive components will provide advanced experiences to humans, customers, citizens, learners, patients, tourists. Any human activity will have to be reconsidered in order to incorporate the implications of millions of transparent, ubiquitous, pervasive services and applications. There will be for the first time in the history of Humanity, a critical artificial intelligent component that will boost the economy but at the same time will also put pressure to inefficiencies of traditional business.

5.3. Research Variables

The research variables in the new era of computing are more complicated and refer to the socio-technical nature of the phenomenon. Without a balanced consideration of human, technical, social and business aspects any approach will be partial.

In Table 1, we provide an introductory context for a variety of variable categories in the context of the new computing vision. İt is the first draft of a research tool we are going to use in an international survey we will run in 2017 in ten countries, aiming to uncover the potential of Cognitive computing.

5.4. Research Questions and Hypothesis

This is a next milestone in our research. We are going to communicate in a next article as a follow up to this special issue 50 research questions and hypothesis that can guide master or PhD degrees.

6. CONCLUSION

The Era of Smart Data, Deep Learning and Cognitive Computing is not a provocative inquiry. It is a matter of few more years of research. Currently we are part of a revolution in the capacity of Information Systems to support the Knowledge society vision. We do believe than in less than 15 years what we tried to describe in this visioning paper will be the daily practice. The convergence of Deep Learning, Semantic Web, Social Networks, Immersive Virtual Reality, Cognitive Computing / Robotics and Cloud Computing will be the new context for Innovation, Entrepreneurship, and Sustainability. This conclusion has multiple implications for Higher Education, Policy Makers and Industry. Our recommendation is to face this emerging era of computing as an opportunity and not as a threat. A slide effect is that for this new era we will need a better Computer Science, Information Systems, Management and, Innovation, Entrepreneurship and Business Education Strategy.

Table 1. Research variable taxonomy for cognitive computing

Variables	Technical Aspects	Social Aspects	Business Aspects
Deep Learning	• New Algorithms • Advanced Neural Networks • Training algorithms	• Effect on Human behavior • Human Learning • Isolation	• Business Potential • Business Intelligence • Agents as a business service • Integration to Enterprise Computing
Semantic Web	• Querying • Reasoning • Trust	• Sharing of Semantics • Security	• Ontological engineering • Integrated Business scenarios
Social Networks	• Connectivity • Represeentation • Visualization • Knowledge Extraction • Recommendation Services	• Isolation • Fear • Bullying • Fraud	• Intelligent Bots in Social Networks • Technology enabled Innovation • Business models • Microfinance
Immersive Virtual Reality	• Visualization • Interactivity • Motion • Integrated Werable Technologies to human activity	• Isolation • Technostress • Cognition • Digital Personality	• VR e-commerce megastores • Virtual Labs • Virtual Thematic Mega Spaces • Crowdfunding
Cognitive Computing / Robotics	• Reasoning • Recommendation • Knowledge Bases and Rules • Integration of Semantics • Collective Intelligence	• Interaction • Integration to human life • Perception • Behavior • Meaning • crowdsourcing	• Cognition Startups • Open Artificial Intelligence Solutions • Intelligent Agents as businesses
Cloud Computing	• Security • Reinforcement • Business as a service	• Security • Collaboration	• Technology-enhanced community
Innovation, Entrepreneurship, sustainability	• Innovation Labs • Meetups • Innovation Infrastructure • Sustainability	• Inclusion • Entrepreneurship of people in disability	• International collaborations • Knowledge society • Smart Business
Domain Specific	• Smart Cities Application • Healthcare Informatics	• Context Un-awareness	• Problem solving oriented

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ENDNOTES

[1] It is the case to refer to some recent successful example of the *Deep Learning*.
[2] Francis Bacon was ...