

Information and Communications Technology is Merging Data Science and Advanced Artificial Intelligence Towards the Core of Knowledge Based Society

-Part 3-



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Abstract

*The paper analyses the context and the trends of the actual role/phase of information and communication technology (ICT) advances, for enabling a further progress of the Information Society (IS) towards the Knowledge Based Society (KBS), i.e., to reach a sustainable general development and in the same time avoid undesired evolutions of the Earth ecosystem challenges, like climate changes, Earth resources fading or ... Covid 19 pandemic (without forgetting ...food!). Observing that “evolutions” also suppose now (looking just at climate changes or Covid 19 daily consequences) a **time** critical race, we have emphasized the point where the ICT performances (as speed) meet the need for faster solving/processing the complex problems which actually are associated with the Data Deluge (Big Data), produced at the Earth scale, but complicatedly linking a diversity of domains. This way it is revealed the support expected from the ICT advances, where AI became the most promising instrument to face the complex problems of practically all domains, mainly by machine/deep learning (ML/DL) new models and algorithms, based now on Data Science (DS).*

Consequently, it is essential to deeper analyse how DS/AI/ICT could work together for better and faster results, providing the expected benefits on refined knowledge, but keeping low the undesired consequences such exponentially development could induce when facing challenges like climate changes and Earth resources fading (as most prominent and increasing every day).

*As concrete results of the support for AI gigantic networks, we have presented some issues regarding mechanisms and the core of the relations between the peaks of advanced processors technology and the fundamentals of their limiting factors, including the “46,225 square millimeters” chip that boasts 2.6 trillion transistors, which is in fact the maximal available (entire wafer of silicon) today. These mean that physical limits of technology and also Moore’s Law, we repeatedly have mentioned [18][12], are **one of the fundamental challenges for ICT, needing revolutionary innovations in order to go on**. This way it is explained why these performances are needed for the most advanced actual and future applications areas of AI, confirming the dramatic struggle of actual ICT trends, to achieve bigger chips, but, in the same time, the dimension of this permanent challenge. The benefic results of AI come along with performant processing (IT), but some of **the most complicate optimization problems and eventually AI applications could be found in a diversity of areas of the communications field**, although here they appear less impressive than self-driving cars industry, but it is worth*

to recall the crucial importance and the huge dimension of communications when converging with IT in ICT. On this line, among others, some promising AI applications, as in wireless communications and intelligent self-driving networks, are also presented.

The analysis shows that the general progress of AI/ICT is more and more depending on models and algorithms, confirming also our earlier opinion that the technology advances themselves are not enough, even with the exponential development of hard components of ICT, but they have to be applied considering at every step the refined knowledge that reflects all ICT impact consequences, the fast-changing Data Deluge and the general IS/KBS context at Earth scale. In order to find the optimal matches, a lot of work has to be done on high amounts of available (but usually unstructured) data, but this could be time and energy consuming and this way we have arrived to the core of the relation between the processors performances and the targets of DL/ML/AI, where DS is coming with the expected support, including appropriate methods and algorithms. Each of these methods supposes a deeper approach, which is required to provide the progress in this complex context of AI/ICT/IS/KBS, for better results against more and more difficult actual and future problems at Earth scale. Predictive causal analytics have to consider the premises/causes of involved processes evolutions we have to predict, while the prominent actual method is still represented by prescriptive analytics, as it provides the highest results we are expecting, i.e., to have the optimal decisions after analyses and prediction of the targeted process/context. For example, this method will be benefic for the self-driving cars industry, when deciding what to do in the everchanging complicate traffic processes. All these methods are important and must work together on the general context and this is also true for both machine learning for making predictions (ML-MD) and machine learning for pattern discovery (ML-PD). The applications of ML-MD are based on previous (historical records) relevant data (supervised learning), while ML-PD are following the unsupervised models, where the ML system is looking to find hidden patterns for predictions [2]. One conclusion is that ML-PD and prescriptive analytics could better support the most AI advances in the future more and more complex context to be optimized, in presence of the high levels of uncertainty.

A deeper analysis revealed, considering the first section of the paper, that the DS/AI advances have the potential to improve the general context of ICT/IS/KBS, but the maximal results should necessarily include refined knowledge on multi-criteria optimization. This way, the link between DS/AI advances and the mechanisms of refining knowledge is naturally provided by the updated cyberinfrastructure, which could provide not only the mentioned support of the technology, but also the main level (science and engineering research) and channel to create and spread knowledge and eventually refined knowledge, with maximal efficiency. Research is identified and recognized as the top level of creating and refining knowledge at World scale, it eventually pushing its results everywhere, but the point is that, this way, DS/AI, through cyberinfrastructure, could speed up and enable more efficient the progress of all human activities. One of the most important requirements to be fulfilled in the exponential evolution of the DS/AI/ICT context, in order to get optimized solutions and refining knowledge for the actual challenges involving Big Data and other complicated problems of the Earth ecosystem is the need of standardization when developing such complex and advanced cyberinfrastructures, aiming to provide efficient interoperability and development.

For knowledge refining, other features have to be also considered, because, in all cases where human mind is involved in the Earth ecosystem (knowledge must be studied in a particular context), the role of human intelligence is and must remain fundamental even in the DS/AI advances context, including the revealed link of knowledge with learning. In the same time, it is recognized that **refining knowledge is a difficult and critical process of obtaining added value, where DS/AI and ICT will leverage knowledge towards the core of knowledge based society.**

We argued that if this knowledge is properly associated with human intelligence and innovative actions, sometimes an added value could come from it more than from technology. Using this idea and the digital transformation/disruption trends, we could witness miracle changes of the business models, based on human potential and labor but using ICT advances with unprecedented efficiency. Presenting some simple examples, another iceberg tip of ICT was revealed, as indeed they forecast a new World, which will surprise us not mainly by the technology advances, but especially by the ways ICT could leverage the innovation in the modes of impacting the human thinking and of using ICT when refining knowledge.

The final conclusion is that we have to timely watch and analyse DS/AI and generally the ICT advances, in order to optimally achieve the refined knowledge that could provide the sustainable progress of IS/KBS.

Keywords: Data Deluge, Big Data, knowledge refining, data science, artificial intelligence, prescriptive analytics, machine/deep learning, wafer of silicon, Self-Driving Networks

JEL Classification: L63; L86; M15; O31; O33

“The only true wisdom is in knowing you know nothing”
— Socrates

1. Data Science and future artificial intelligence

From their first steps, humans tried to shorten their path toward reaching what they are looking for (beginning with food), but the World evolution created so many paths and so many purposes, as today is more and more difficult to think at all of them in the same time.

We could say that space and time are only the most prominent dimensions where our intelligence has to better perform, but it is clear that although we have reached to “step” on other planets and the computers speeds hide from our usual perception unprecedented time divisions, space and time are far from being our only actual optimization goals when facing World challenges like climate changes, Earth resources fading or ... Covid 19 pandemic (without forgetting ...food!).

Still, time and a huge diversity of paths generalizing the “space” are the core of performances we have to improve, but it is more than obvious that today this is really not possible to conceive that without the crucial support of the information and communication technology (ICT), which generally became, *by its services, products, applications and systems*, the main driving factor of the *Information Society (IS) towards the Knowledge Based Society (KBS)*.

In fact, as many other human visions on life progress, the idea of generally improving (time, space etc.) performances is also going to be not enough accurate, just because of the actual complexity and performance levels we have to face, in almost all domains of ICT/IS/KBS, in order to finally obtain the knowledge and further the refined knowledge which have to reflect the exponential development and impact of ICT on Earth ecosystem.

This way we can better understand the actual role/phase of ICT advances, for enabling a further World progress, **in all areas**, i.e., to reach a sustainable general development and in the same time avoid catastrophic evolutions of the mentioned Earth ecosystem challenges.

Step by step, considering that “evolutions” also suppose now (looking just at climate changes or Covid 19 daily consequences) a **time critical** race, we have just arrived to the point where the ICT performances (as speed) meet the need to faster processing of the complex problems which actually are associated with the data deluge (Big Data), produced at the Earth scale, but complicatedly linking a diversity of domains.

Here comes the support expected from the ICT advances, where AI became the most promising instrument to face the complex problems of practically all domains, by machine learning (ML) or deep learning (DL) new models and algorithms, based now on Data Science (DS) [3][9].

Consequently, it is essential to deeper analyse how DS/AI/ICT could work together for better and faster results, providing the expected benefits on refined knowledge, but keeping low the undesired consequences such exponentially development could induce when facing challenges like climate changes and Earth resources fading (as most prominent and increasing everyday) [18].

The ways DS, AI and generally ICT may be developed and optimized on complex criteria could be observed by some relevant cases, intended to relieve the intimate relations of these interdependent domains of ICT/IS/KBS and further the main directions of improvement.

Perhaps a recent technology achievement could bring a straightforward picture of these complex dependences, actually linking the core of ICT with the peaks of DS/AI [1]:

<< *Almost from the moment Cerebras Systems announced a computer based on the largest single computer chip ever built, the Silicon Valley startup declared its intentions to build an even heftier processor. In April, the company announced that its next-gen chip, the Wafer Scale Engine 2 (WSE-2), will be available in the third quarter of this year. WSE-2 is just as big physically as its predecessor, but it has enormously increased amounts of, well, everything. The goal is to keep ahead of the ever-increasing size of neural networks used in machine learning. “In AI compute, big chips are king, as they process information more quickly, producing answers in less time—and time is the enemy of progress in AI,” Dhiraj Mallick, vice president of engineering and business development, said in a statement.*>>

This amazing achievement (boasts 2.6 trillion transistors) is relevant not only by “enormously increased amounts of, well, everything” needed in the most advances domain of AI, but here the main direction of actually improving AI it is pointed (ever-increasing size of neural networks used in machine learning) and also is time, as the limiting factor (enemy) of “progress in AI”.

More than these, we could have this way a flavour about the mechanisms and the core of the relations between the peaks of advanced processors technology and the fundamentals of their limiting factors:

“Training neural networks takes too long—weeks for the big ones when Andrew Feldman cofounded the company in 2016. The biggest bottleneck was that data had to shuttle back and forth between the processor and external DRAM memory, eating up both time and energy.”

Now it is obvious why these performances are needed for the most advanced actual and future applications areas of AI:

“With gigantic networks for natural-language processing, image recognition, and other tasks on the horizon, you’d need a really big chip. How big? As big as possible, meaning the size of an entire wafer of silicon (with the round bits cut off), or 46,225 square millimeters.”

Finally, we may also understand the dramatic struggle of actual technology to achieve “a really big chip”, but, in the same time, the dimension of this permanent challenge launched by AI: “How big? As big as possible, meaning the size of an entire wafer of silicon”.

In addition, we have to point that “46,225 square millimeters” is in fact the maximal available (entire wafer of silicon) today, meaning that physical limits of technology and also Moore’s Law, we repeatedly have mentioned [18][12], are **one of the fundamental challenges for ICT, needing revolutionary innovations in order to ... go on!**

That is why the progress of AI/ICT/IS/KBS has to be supported also by other leveraging factors of the context, as DS is.

Still, it is important to see how DS will further be developed to provide the maximal results associated with every phase of AI/ICT/IS/KBS and correlated with the Data Deluge (Big Data), as it is approached by [2]:

“The main focus was on building a framework and solutions to store data. Now when Hadoop and other frameworks have successfully solved the problem of storage, the focus has shifted to the processing of this data. Data Science is the secret sauce here. All the ideas which you see in Hollywood sci-fi movies can actually turn into reality by Data Science. Data Science is the future of Artificial Intelligence...”

In reality, the way from fiction to concrete results is long, even with the usual high speed of AI/ICT, due to the complex context of Data Deluge and consequently this have to be step by step analysed:

“Data Science is a blend of various tools, algorithms, and machine learning principles with the goal to discover hidden patterns from the raw data. But how is this different from what statisticians have been doing for years? The answer lies in the difference between explaining and predicting.”

From the beginning we have to observe that the general progress of AI/ICT is more and more depending on models and algorithms, confirming also our earlier opinion that the technology advances themselves are not enough, even with the exponential development of hard components of ICT, but they have to be applied considering at every step the refined knowledge that reflects all ICT impact consequences and the general IS/KBS context at Earth scale [3][12].

In fact, it is clear that the power of hard (ICT) could not be exploited without the appropriate advances of the models and algorithms, which have to also match the applications and the fast-changing Data Deluge context.

In order to find the optimal matches, a lot of work has to be done on high amounts of available (but usually unstructured) data, but this could be time and energy consuming and this way we have just arrived to the core of the relation between the processors performances and the targets of DL/ML/AI, where DS is coming with the above-mentioned expected support as it is further explained:

“... a Data Analyst usually explains what is going on by processing history of the data. On the other hand, Data Scientist not only does the exploratory analysis to discover insights from it, but also uses various advanced machine learning algorithms to identify the occurrence of a particular event in the future. A Data Scientist will look at the data from many angles, sometimes angles not known earlier. So, Data Science is primarily used to make decisions and predictions making use of predictive causal analytics, prescriptive analytics (predictive plus decision science) and machine learning.”

Each of these methods supposes a deeper approach, as all the progress in this complex context of AI/ICT/IS/KBS is naturally requiring for better results against more difficult actual and future problems at Earth scale.

Predictive causal analytics have to consider the premises/causes of involved processes evolutions we have to predict.

The prominent actual method is still represented by prescriptive analytics, as it provides the highest results we are expecting, i.e., to have the optimal decisions after analyses and prediction of the targeted process/context. For example, this method will be benefic for the self-driving cars industry, when deciding what to do in the everchanging complicate traffic processes.

As it is easy to suppose, all these methods are important and must work together on the general context and this is also true for both machine learning for making predictions (ML-MD) and machine learning for pattern discovery (ML-PD).

The applications of ML-MD are based on previous (historical records) relevant data (supervised learning), while ML-PD are following the unsupervised models, where the ML system is looking to find hidden patterns for predictions.

A usual algorithm used for pattern discovery is *clustering* [2], which aims to identify, in absence of previous relevant data, the solutions that fit the context/process. Examples of such **applications could include transport, placement or distribution processes, irrespective the objects or entities involved, which could apply to energy, materials, values or ... signals/information.**

We can observe that finally ML-PD and prescriptive analytics could better support the most AI advances in the future more and more complex context to be optimized, in presence of the high levels of uncertainty.

A deeper step of the analysis could provide concrete applications examples of DS/AI methods, algorithms and achievements, above presented.

Some of **the most complicate optimization problems and eventually applications could be found in a diversity of areas of the communications field**, although here they appear less impressive than self-driving cars industry, but it is worth to notice from the beginning the crucial importance and the huge dimension of communications converging with IT in ICT.

A relevant approach of such applications, just as a signal for the potential of DS/AI in these communications areas, is given in [4]:

“The six papers in this special section address the application of artificial intelligence, machine learning, and data analytics at different layers and different applications of different types of communications networks. The objective of using these tools is the optimal design and improved operation of networks. These articles feature new opportunities to develop and advance various areas of communications through the use and applications of AI/ML/ deep learning technologies.

Research in artificial intelligence (AI) has been active for several decades, but lately, and with the exponential increase in the amounts of available data, new directions of AI, such as machine learning (ML) and data analytics that learn from data, have emerged and have impacted many fields in science and engineering.”

Although a new and not very much extended area of communications, *Spectrum Intelligent Radio*, just fits the above-mentioned prescriptive analytics methods of DS/AI, as it is given by [4][5]:

<<The first article, “Spectrum Intelligent Radio: Technology, Development, and Future Trends,” is authored by P. Cheng, Z. Chen, M. Ding, Y. Li, B. Vucetic, and D. Niyato, and deals with machine learning applications at the physical layer in wireless networks. The article addresses the significant spectrum strains imposed by information collection and decision making in Industry 4.0, which is also known as the fourth industrial revolution. The article focuses on machine-learning-based intelligent radios as a viable solution to this problem and proposes a new radio architecture consisting of three hierarchical forms: perception, understanding, and reasoning. The purpose of these three forms is accurate

spectrum sensing, accurate prediction of primary users' coverage, and optimal idle channel selection.>>

A larger view of the wireless networks, with impact in the huge and emergent IoT, is also presented as an optimal solution for the massive areas of sensors, which will cover the Earth, including self-driving cars complex context [4] [7]:

<<The second article, “Toward an Intelligent Edge: Wireless Communication Meets Machine Learning” by G. Zhu, D. Liu, Y. Du, C. You, J. Zhang, and K. Huang, also deals with wireless networks in an environment with massive numbers of edge devices that collect data and upload this data to edge servers that learn from the data and distill intelligent decisions. Examples of such scenarios include sensors in IoT networks, auto-driving cars, and so on. The article proposes a framework that includes a set of new design guidelines for wireless communications in edge learning, which is referred to as learning-driven communication. The article discusses research directions emerging under this framework and provides illustrative examples that cover key communication aspects including multiple access, resource allocation, and signal encoding.>>

On the other hand, we suppose that a relevant corollary of the above DS/AI methods and algorithms, along with the unprecedented increase of the complexity in communications networks, the advanced model of Intelligent Self-Driving Networks could be considered [4] [8]:

<<The fifth article, “Machine Fault Detection for Intelligent Self-Driving Networks,” by H. Huang, L. Zhao, H. Huang, and S. Guo, deals with self-driving networks (SelfDNs), which are autonomous networks that are capable of making predictive and adaptive responses to their environment. The article focuses on fault detection in SelfDNs, and proposes a new fault detection architecture for SelfDNs. Under this architecture, an algorithm, named Gaussian Bernoulli restricted Boltzmann machines (GBRBM)-based deep neural network with autoencoder (i.e., GBRBM-DAE), is proposed with the objective of transforming the fault detection problem into a classification problem. Several classification mechanisms are considered and compared using traces from real-world experimental results, and it is shown that the proposed algorithm outperforms other popular machine learning algorithms, such as linear discriminant analysis, support vector machine, and pure deep neural network.>>

It is now obvious that some of the most efficacy and needed impact applications of the DC/AI advances will be in the areas of communications, without mentioning the complex interdependent relations and mechanisms which will transfer the benefic consequences of such applications towards all integrated products, services and systems of the ICT context and eventually towards IS/KBS.

More than these, above all achievements and promising perspectives, we have to notice that the overall results of using DS and AI will provide in fact the needed knowledge in all fields of activity and eventually the refined knowledge to support a sustainable progress at Earth scale and generally for humankind evolution.

In spite of the complexity revealed by the above examples, **the highest challenge will come just when approaching the refined knowledge complicate processes, where the diverse criteria and context dynamic will be the hardest conditions to face.**

2. Refining knowledge as best of knowledge we could actually have

Perhaps the most relevant way to link the above-mentioned achievements and promising perspectives of DS/AI with the **fundamental need of sustainable progress of IS toward KBS, including the wellbeing of the human race on Earth**, by providing at every step of DS/AI/ICT development the necessary refined knowledge, is to come back to the crucial impact of communications in this complex and dynamic context.

With simpler words, we have to recall the role of communications, irrespective the historical phase of human evolution we could consider, but especially when they contributed more and more to expand the information and knowledge that promoted the unprecedented progress of humanity in every activity field, either by books, phones or Internet – to mention just some of the milestones.

As we have already repeatedly presented [21][22], the advances of communications provided the multiplication of the useful information/knowledge, including innovation and best practice everywhere.

If such observations could be considered already obvious, as we are used with the enabling role of communications, this is just the floor where the Data Deluge (Big Data) just exploded, creating for the ICT/IS/KBS context one of the most prominent challenges to be analysed and optimally solved [17][16][21][22].

A deeper analysis could reveal, considering the above section of the paper, that the DS/AI advances have the potential to improve the general context of ICT/IS/KBS, but the maximal results should necessarily include refined knowledge on multi-criteria optimization. This way, the link between DS/AI advances and the mechanisms of refining knowledge is naturally provided by the updated cyberinfrastructure [16][9], as it is also confirmed by [10]:

“A confluence of technology-push and science and engineering research-pull activities and possibilities makes this the right time. Researchers are ramping up their use of computing resources, starting to store enormous amounts of information, and sharing it. Distributed computing, large clusters, data farms, and broadband networks (typified by Internet, Grid and Web Services directions) have moved from research to practical use. We anticipate a phase change, where direct attention to this opportunity can have a highly desirable and nonlinear effect”

Here we have to observe not only the mentioned support of the technology, but also the identification of the main level (*science and engineering research*) and channel to create and spread knowledge and eventually refined knowledge with maximal efficiency.

Research (*Science and Engineering*) is identified and recognized as the top level of creating and refining knowledge at World scale, it eventually pushing its results everywhere, but the point is that, this way, DS/AI through cyberinfrastructure could speed up and enable more efficient the progress of all human activities.

Although not very new, this signal of the (*National Science Foundation=NSF*) is more and more actual as the object of these observations, DS/AI/ICT and Big Data context, is advancing as complexity and potential impact:

“Effective use of cyberinfrastructure can break down artificial disciplinary boundaries, while incompatible tools and structures can isolate scientific communities for years. Groups are building their own application and middleware software without awareness of comparable

needs elsewhere, both within the NSF and across all of science. Much of this software will be of limited long-term value absent a consistent computer science perspective. Time and talent will be wasted that could have led to much better computing and much better science. Dramatic changes are coming in computing and application architectures; lack of consideration of work in other sciences and in the commercial world could render projects obsolete before they deliver. Much of the effort under way to use cyberinfrastructure for collaborative research is not giving adequate attention to sociological and culture barriers to technology adoption that may cause failure, even after large investments. The time is ripe for NSF to accelerate the revolution for the benefit of society.”

Covering the Earth ecosystem, when observing also the *sociological and culture barriers to technology adoption*, this vision is more than a signal due to the practical indirect hints and to the identification of the fundamental relation between DS/AI/ICT and the processes where knowledge could be optimally created and refined (*share insights, software, and knowledge, to reduce wasteful re-creation and repetition*):

„We envision an environment in which raw data and recent results are easily shared, not just within a research group or institution but also between scientific disciplines and locations. There is an exciting opportunity to share insights, software, and knowledge, to reduce wasteful re-creation and repetition. Key applications and software that are used to analyze and simulate phenomena in one field can be utilized broadly. This will only take place if all share standards and underlying technical infrastructures.”

Here we have to notice one of the most important requirements to be fulfilled in the exponential evolution of the DS/AI/ICT context, in order to get optimized solutions and refining knowledge for the actual challenges involving Big Data and other complicated problems of the Earth ecosystem: **the need of standardization** when developing such complex and advanced cyberinfrastructures, aiming to provide efficient interoperability and development.

More than these, as we also presented [18], an inherent (but less desired) feature of the exponential evolution of the ICT, concerning *market size and technological risks*, is confirmed pointing the same crucial role of refining knowledge:

“Although many of the mechanisms to support the best scientific computing are becoming available through commercial channels, there continue to be special needs that the commercial sector is unlikely to meet directly because of the market size and technological risks. Scientists must have easy access to the finest tools from the commercial and advanced research sectors, without dampening their creativity and ardor to do even better. Individual researchers expend too much effort, frequently with insufficient knowledgeable computing assistance, to create and re-create computing resources; to access, reformat, and save information; to protect the data and software assets.”

In a simpler expression, we have to watch over all consequences of ICT fast pace, as the time for evaluate the long-term impact on IS/KBS is very short, considering the ever-increasing complexity of this context, i.e., the refining of knowledge should include the sustainable solutions for ICT/IS/KBS development and Earth ecosystem.

That is why **refining knowledge and generally the optimal evolution of IS toward KBS are easier said than done and consequently a complex problem and a subject of timely analyses.**

Perhaps the difficulty of refining knowledge comes first just from itself, as it is recognized that generally knowledge is a dynamic concept, repeatedly analysed [18][12] and largely debated [10][19][13][20], while refining knowledge is consequently even more complicated to be precisely defined, as it also confirmed and detailed by [11]:

<<In this paper, the relationship between information and knowledge travels in both directions: knowledge is made explicit and becomes information, while information is internalized and becomes knowledge ... The distinction between tacit and explicit is probably the one most frequently referred to in the knowledge management literature ... For Polanyi (1962, p. 601-602, emphasis in the original) any activity has two dimensions of knowledge: (1) knowing a thing by attending to it, in the way we attend to an entity as a whole and (2) knowing a thing by relying on our awareness of it for the purpose of attending to an entity to which it contributes. The latter knowledge can be said to be tacit... We may call “knowing by attending to” a focal knowing, and “knowing by relying on” a subsidiary knowing... What is subsidiarily known is tacitly known; but it seems appropriate to extend the meaning of “tacit knowing” to include the integration of subsidiary to focal knowing...>>

If these opinions could initially appear only theoretical issues, far from the practical problems of optimization we have mentioned above, here we could notice that the intimate mechanisms of generating knowledge and the fluent relations with data and information, through the human perceptions and actions, are more actual and useful as the circle of ICT innovation and its impact on IS/KBS, we have also presented[12], is faster changing in a complex context, where humans are in the same time causes and consequences (for the purpose of attending to an entity to which it contributes):

<< Firstly, knowledge is embodied in the individual and secondly, as a consequence, knowledge must be studied in a particular context. The individual processes the data, the information, and adds to the information his/her own previous knowledge, beliefs, values, etc. In Piaget’s terms, the schemata are in the human mind, and it is in the human mind that the schemata have to adapt to new realities. Knowledge is something that one constructs by him/herself in an interaction with the environment and with others. Articulated explicit knowledge is, therefore, public in the sense that it is accessible to anyone who can understand the code in which it is written, as opposed to knowledge that is private (such as tacit knowledge), which is only inside one’s head. In other words, knowledge becomes information when it is made explicit. Explicit knowledge and specific information, as defined by Mårtensson (2000), are two sides of the same coin. When I am writing, or talking, I articulate my knowledge; that is, I am “externalizing” tacit knowledge into explicit knowledge. However, the receptor of my explicit knowledge, in this case the patient reader, is reading information, and only if s/he adapts (assimilates or accommodates) this information into his/her schemata or theory will the information become knowledge.>>

Here we can easily recognize not only the scientific and technical processes of ICT evolution where information and knowledge are generated, but in all cases where human mind is involved in the Earth ecosystem (*knowledge must be studied in a particular context*), because the role of human intelligence is and must remain fundamental even in the DS/AI advances context, as we have also presented [9] and now detailed and further confirmed:

<<This knowledge acquisition process is, therefore, an individual process, since it is the reader who will or will not process the information read. Knowledge, by definition, is in

someone's head, and when it is not in someone's head it is information or data ... Further, it is important to note that the information can never be a perfect replica of the knowledge the individual has, and different individuals will have different ways of approaching the same information ... The different terms and differentiations that knowledge management literature has provided in the conceptualization of knowledge have been presented. Knowledge is in people's heads, it differs from information or data, it is individual, and in some instances it can be made public or shared as information. In addition, the difference between various types of knowledge has been explained in terms of content. Andriessen (2006, p. 97) identifies six different metaphors in his analysis of the treatment of knowledge in key publications of the knowledge management field: knowledge as something physical, as a wave, as a living organism, as thought and feelings, as a process and as a structure.>>

It is important to notice that such detailed and intimate features of the ways to perceive the data, information and eventually achieve associated knowledge, beyond the real benefic impact on all human activity fields we have also mentioned [12], could be useful instruments of better designing and exploiting the AI/ICT products, applications, services and systems, just due to the better understanding of knowledge and human mind processes.

Finally, all these observations lead to a practical and comprehensive image of the subtle ways/processes the refining knowledge is achieved in a realistic interaction with the environment, with an optimal involvement of human personality:

<< Knowledge, understood both as content and as schema, will therefore be constructed during this process of adaptation through its interaction with the environment. When we are presented with data (facts, impressions), we will examine that specific information (which has some meaning and structure for us) with the knowledge that we already have. In fact, the previous knowledge will guide the type of data that we seek, or beyond that, the information we seek and are capable of understanding. If that specific information content (either know-what, why, how or who) appears in adequate conditions of motivation, interest and attention, the content will be "absorbed" into the mental model (or theory) that we are applying to that specific context. The new content might not produce much change in the structure of the mental model (alpha answer), it might produce partial modification (beta answer) or it might result in a critical modification (gamma answer, significant learning or conceptual change). These changes in our schema constitute, in fact, learning.>>

Here, the subtle (vicious) circle of interdependences, we have mentioned for ICT/IS/KBS, is sensed at the core of process of refining knowledge, as we will examine that specific information (which has some meaning and structure for us) with the knowledge that **we already have.**

We also have to notice the pointing of the **fundamental features which link knowledge with learning**, but in the same time it is recognized that **refining knowledge is a difficult and critical process of obtaining added value** (*The new content might not produce much change in the structure of the mental model*), **just like pearls or diamonds collecting from deepness!**

Now we could better understand not only the deep relations and processes where DS/AI and ICT leverage knowledge **towards the core of knowledge based society**, but also the emerging trends of providing added value from that knowledge, as it is detailed in [13]:

<<Knowledge-based society is a strategic term which – like “postmodern society“, “postindustrial society“, “experience society“, “consumer society“, “risk society“, “media society“ or “information society“ and similar terms – aims to divert attention to a certain aspect. Aspects that are particularly highlighted by the term ‘knowledge-based society’ are knowledge and education. It is said that knowledge, besides capital, will become an increasingly significant production factor of the modern society. Knowledge exists in the material form as technology. Inventiveness and science have flown into it. It is controlled by means of titles of ownership over patents and usage rights.>>

If this knowledge is properly associated with human intelligence and innovative actions, as we also presented [6][15]), sometimes an added value could come from it more than from technology:

“However, knowledge has also a major role in the utilization of living labor. The thesis of the knowledge-based society even claims that this role obtains an increasing significance: Many economic processes cannot be mastered any longer by the mere execution of well-defined tasks, but increasingly also through involvement and self-responsibility. In this situation, it is not a matter of having more economically independent persons but rather enabling that the dependent employees do not work in a culture of command-obedience but in one of cooperation, as well as of process and result responsibility.”

Using this idea and the digital transformation/disruption trends, we witness miracle changes of the business models, based on human potential and labor but using ICT advances with unprecedented efficiency:

“An increasing number of companies are no longer oriented towards the production of mass-products, but rather towards complex system solutions which are to be found only through the utilization of the subjectivity of living labor or through living knowledge which – as opposed to materialized knowledge (in technology) – is hard to control by the employer and to a certain extent needs to be introduced voluntarily. Example: The automobile industry still produces automobiles. However, today’s task is increasingly not a matter of selling a physical product, i.e. automobile, but satisfying the customers’ mobility requirements. People do not want to necessarily own the car, but to use it in places where a bike, train or bus does not suffice. The solution of these issues – e.g. by car-sharing linked with further usage possibilities – requires communicative and logistical services that very much go beyond the manufacturing of physical products. It is a matter of communication and cooperation with customers who in a certain way become the co-producers of the mobility options“

These simple examples (opposed to materialized knowledge) could only show another iceberg tip of ICT, as we repeatedly presented [15][12][6], but indeed they forecast a new World, which will surprise us not mainly by the technology advances, but especially by the ways ICT could leverage the innovation in the modes of impacting the human thinking and using ICT when **refining knowledge**.

Consequently, we have to timely watch and analyse DS/AI and generally the ICT advances, in order to optimally achieve the refined knowledge that could provide the sustainable progress of KBS.

3. Conclusions

We have considered the context and the trends of the actual role/phase of ICT advances, for enabling a further World progress, **in all areas**, i.e., to reach a sustainable general development and in the same time avoid undesired evolutions of the Earth ecosystem challenges, like climate changes, Earth resources fading or ... Covid 19 pandemic (without forgetting ...food!). Observing that “evolutions” also suppose now (looking just at climate changes or Covid 19 daily consequences) a **time critical** race, we have emphasized the point where the ICT performances (as speed) meet the need for faster solving/processing the complex problems which actually are associated with the Data Deluge (Big Data), produced at the Earth scale, but complicatedly linking a diversity of domains. This way we have revealed the support expected from the ICT advances, where AI became the most promising instrument to face the complex problems of practically all domains, mainly by ML or DL new models and algorithms, based now on DS.

Consequently, it is essential to deeper analyse how DS/AI/ICT could work together for better and faster results, providing the expected benefits on refined knowledge, but keeping low the undesired consequences such exponentially development could induce when facing challenges like climate changes and Earth resources fading (as most prominent and increasing everyday).

As concrete results of this support for AI *gigantic networks*, we have presented some issues regarding mechanisms and the core of the relations between the peaks of advanced processors technology and the fundamentals of their limiting factors, including the “46,225 square millimeters” chip that *boasts 2.6 trillion transistors*, which is in fact the maximal available (entire wafer of silicon) today. These mean that physical limits of technology and also Moore’s Law, we repeatedly have mentioned [18][12], are **one of the fundamental challenges for ICT, needing revolutionary innovations in order to go on**. This way it is explained why these performances are needed for the most advanced actual and future applications areas of AI, confirming the dramatic struggle of actual ICT trends, to achieve “*a really big chip*”, but, in the same time, the dimension of this permanent challenge.

The benefic results of AI come along with performant processing (IT), but some of **the most complicate optimization problems and eventually AI applications could be found in a diversity of areas of the communications field**, although here they appear less impressive than self-driving cars industry, but it is worth to recall the crucial importance and the huge dimension of communications when converging with IT in ICT. On this line, we have presented, among others, some promising AI applications, as in wireless communications and intelligent self-driving networks.

Another conclusion is that the general progress of AI/ICT is more and more depending on models and algorithms, confirming also our earlier opinion that the technology advances themselves are not enough, even with the exponential development of hard components of ICT, but they have to be applied considering at every step the refined knowledge that reflects all ICT impact consequences, the fast-changing Data Deluge and the general IS/KBS context at Earth scale. In order to find the optimal matches, a lot of work has to be done on high amounts of available (but usually unstructured) data, but this could be time and energy consuming and this way we have just arrived to the core of the relation between the processors’ performances

and the targets of DL/ML/AI, where DS is coming with the expected support, including appropriate methods and algorithms.

Each of these methods supposes a deeper approach, which is required to provide the progress in this complex context of AI/ICT/IS/KBS, for better results against more and more difficult actual and future problems at Earth scale. Predictive causal analytics have to consider the premises/causes of involved processes evolutions we have to predict, while the prominent actual method is still represented by prescriptive analytics, as it provides the highest results we are expecting, i.e., to have the optimal decisions after analyses and prediction of the targeted process/context. For example, this method will be benefic for the self-driving cars industry, when deciding what to do in the everchanging complicate traffic processes. All these methods are important and must work together on the general context and this is also true for both *machine learning for making predictions* (ML-MD) and *machine learning for pattern discovery* (ML-PD). The applications of ML-MD are based on previous (historical records) relevant data (supervised learning), while ML-PD are following the unsupervised models, where the ML system is looking to find hidden patterns for predictions [2].

One conclusion is that ML-PD and prescriptive analytics could better support the most AI advances in the future more and more complex context to be optimized, in presence of the high levels of uncertainty.

A deeper analysis revealed, considering the first section of the paper, that the DS/AI advances have the potential to improve the general context of ICT/IS/KBS, but the maximal results should necessarily include refined knowledge on multi-criteria optimization. This way, the link between DS/AI advances and the mechanisms of refining knowledge is naturally provided by the updated cyberinfrastructure, which could provide not only the mentioned support of the technology, but also the main level (*science and engineering research*) and channel to create and spread knowledge and eventually refined knowledge, with maximal efficiency. Research is identified and recognized as the top level of creating and refining knowledge at World scale, it eventually pushing its results everywhere, but the point is that, this way, DS/AI, through cyberinfrastructure, could speed up and enable more efficient the progress of all human activities.

One of the most important requirements to be fulfilled in the exponential evolution of the DS/AI/ICT context, in order to get optimized solutions and refining knowledge for the actual challenges involving Big Data and other complicated problems of the Earth ecosystem is **the need of standardization** when developing such complex and advanced cyberinfrastructures, aiming to provide efficient interoperability and development.

For knowledge refining, other features have to be also considered, because, in all cases where human mind is involved in the Earth ecosystem (*knowledge must be studied in a particular context*), the role of human intelligence is and must remain fundamental even in the DS/AI advances context, including the revealed **link of knowledge with learning**. In the same time, it is recognized that **refining knowledge is a difficult and critical process of obtaining added value**, where **DS/AI and ICT will leverage knowledge towards the core of knowledge-based society**.

We argued that if this knowledge is properly associated with human intelligence and innovative actions, sometimes an added value could come from it more than from technology. Using this idea and the digital transformation/disruption trends, we witness

miracle changes of the business models, based on human potential and labor but using ICT advances with unprecedented efficiency. Presenting some simple examples, another iceberg tip of ICT was revealed, as indeed they forecast a new World, which will surprise us not mainly by the technology advances, but especially by the ways ICT could leverage the innovation in the modes of impacting the human thinking and of using ICT when **refining knowledge**.

Consequently, we have to timely watch and analyse DS/AI and generally the ICT advances, in order to optimally achieve the refined knowledge that could provide the sustainable progress of IS/KBS.

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