

Information and Communications Technology New Paradigm of Probabilistic Computing Could Inspire our Thinking through a Future World of Uncertainty -Part 1-



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Abstract

The paper analyses the premises of the Information and Communications Technology (ICT) probabilistic computing paradigm, in a critical point of ICT evolution, where it is largely agreed that Moore Law is going to an end and the future solutions for ICT progress are intensely searched, in order to keep the Information society (IS) toward Knowledge Based Society (KBS) progress pace. Also, the analysis considered the main consequences, for humankind, from this new ICT step with unprecedented challenges, including the economical, social, human behaviour and Earth environment ones. ICT, beyond being the main motor of IS/KBS, is an inspiration model of progress for almost all human activity domains, in many ways, revealing the complex and complicate mutual relations between human creation potential and the ICT advances.

The paper analysis and literature quotations confirm, by relevant examples, author's earlier estimations, that living things or biological systems (especially human brain) will be among the main inspirations/solutions for ICT revolutionary advances, including but not restricting to AI/ML. As main examples, the new technologies inspired by human brain model are analyzed, as this approach is manifest and very much exploited in the ICT development, but for surpassing the performances limits of advanced computing and AI, this is quite the most promising direction, including Pohoiki Springs, a data center which is Intel's largest neuromorphic computing system that integrates 768 Loihi neuromorphic chips-inspired from the human brain, but being up to 1,000 times faster and 10,000 times more efficiently than conventional processors. As main advances toward unprecedented ICT performances, the paper approaches the ways that software could bring a decisive contribution to the ICT probabilistic computing paradigm. As a conclusion, the solution for such challenges comes naturally from the same human brain reference way of operation, pointing that our algorithms could mimic what human brain makes having fewer data and computing power. Such complex and relevant dependencies underneath the ICT context led to probabilistic computing and could compensate the uncertainties from rough data. From here, a prominent conclusion is revealed, as it is obvious that the combination of these concepts could further inspire many human processes of thinking/decision – our title main idea. Further, the paper also approached quantum computing, which is one of the most promising technology for ICT future, by pointing its relation with 'probabilistic computing', confirmed by gradually achievements like probabilistic bits (p-bits). It is confirmed that the actual state-of-art of quantum computing is still in the phase of basics and one of the major difficulties of quantum computing development comes from the specific very low temperatures, as Intel started with the silicon existing base, which revealed higher temperatures of operation.

Such examples led to an important conclusion, as the flexibility of approaching diverse techniques/technologies solutions is an inherent feature of the probabilistic computing paradigm that drives this ICT development struggle, due to the logical approach of all events and their chances, in order to select and maximize the expected benefits. The need of flexibility comes also from the complexity and difficulty which characterizes the unprecedented levels of performances of the ICT actual development advances, which are hard to be improved, considering also all their consequences (positive/negative) associated with the context of these evolutions at Earth scale, including IoT, Data Deluge, climate changes, Earth resources fading and social unbalances. This complex and complicate context generates uncertainty, which logically requests a probabilistic approach for almost all decisions and projects, but that is naturally expected to be extended to the individual level, inspiring our thinking by the ways it advances.

The final conclusion of the preliminary analysis and premises, is that a paper farther continuation is to be done, in order to obtain more valuable and detailed information about the consequences of the new ICT probabilistic computing paradigm, through all IS/KBS development and even for people's way of thinking.

Keywords: probabilistic computing paradigm, quantum computing, probabilistic bits, Pohoiki Springs, neuromorphic computing system, Loihi neuromorphic chips, human brain

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

Failure is simply the opportunity to begin again, this time more intelligently
-Henry Ford

1. Inspiration for ICT progress and continuing Moore's Law

Humankind evolution is a continuous fight for survival and progress, in the unique and challenging Earth environment. For decades, Information and Communications Technology (ICT) is the main driving factor of this progress, actually in the phase of the Information Society (IS) aiming the Knowledge Based Society (KBS), but also facing unprecedented challenges, including intrinsic economical/social/human behaviour ones and Earth environment on the other side.

We have already observed this context trends [16][3], but ICT exponential pace of development and its amazing advances, including IoT, AI, Cloud, BIG DATA or nanotechnology, are highly dynamic factors that need to be timely analysed through all their (positive or negative) consequences at Earth scale.

More than these, the recent dramatic consequences of the Covid-19 pandemic, although far from being plenary seen or even estimated, show how important is to rethink our strategies of approaching the World evolution, considering the high uncertainties that rule the real processes in IS/KBS.

In fact, we also pointed [6][9] that ICT, beyond being the main motor of IS/KBS, is also an inspiration model of progress for almost all human activity domains, in many ways, as our paper will present by actual examples, revealing the complex and complicate mutual relations between human creation potential and the ICT advances.

It is sure that these relations are logical, but their complexity and mechanisms are more and more deep and diverse, as ICT influence in IS/KBS and also on humankind behaviour and even evolution is increasing, with consequences that must be timely analysed.

That is why it is important to understand how ICT challenges could be identified and approached, in order to keep the progress pace.

Still, now we are facing a critical point of ICT evolution, as it is largely agreed that Moore Law is going to an end and the future solutions for ICT progress are intensely searched [6][9][17][12].

On this striving road, long time ago we also expressed that living things or *biological systems* (especially human brain) will be among the main inspirations/solutions [21], by learning from nature million years research, as it was also confirmed by [8]:

“A new paper from researchers working in the UK and Germany dives into how much power the human brain consumes when performing various tasks — and sheds light on how humans might one day build similar computer-based artificial intelligences. Mapping biological systems isn't as sexy as the giant discoveries that propel new products or capabilities, but that's because it's the final discovery — not the decades of painstaking work that lays the groundwork — that tends to receive all the media attention.”

Actually, this approach is manifest and very much exploited in the ICT development, but for surpassing the performances limits of advanced computing, AI or networks, this is quite the most promising direction, as many specialists agreed [7]:

“Neuromorphic hardware takes a page from the architecture of animal nervous systems, relaying signals via spiking that is akin to the action potentials of biological neurons. This feature allows the hardware to consume far less power and run brain simulations orders of magnitude faster than conventional chips”

Step by step the solutions toward brain performances are investigated and pointed, aiming answers to the relevant question: How the human brain succeeds to do such much processing with such low energy consuming relative to conventional computers?

Such answers led to the new concept of *neuromorphic computing*, as it is also mentioned by [10]:

„How the Brain Saves Energy by Doing Less ... One of the arguments for neuromorphic computing is the efficiency of the human brain relative to conventional computers. By looking at how the brain works, this argument contends, we can design systems that accomplish more with less power.”

Here, contentions could come from the fact that human brain consumes about 20% of human body, but, compared with conventional computers, its efficiency is quite impressive and that is why the actual trend is to mimic its operating features.

Coming back to the general ICT progress and Moore Law, the concrete research efforts are intended to improve devices/processors performances (speed; power consuming; chip density) with innovative technologies.

Finally, as a good example, Intel, the traditional prominent research leader of technology, appears to have found and implemented a revolutionary solution [4]:

“As impressive as computers are becoming, they still pale in comparison to nature’s version – the brain. As such scientists have started designing computer chips that work in a similar way to the brain, using artificial neurons and synapses. Now Intel has unveiled its most powerful “neuromorphic” computing system to date. Named Pohoiki Springs, this system packs in 100 million neurons, putting it on par with the brain of a small mammal... Intel says that Loihi is as much as 1,000 times faster and 10,000 times more efficient at certain tasks than conventional processors. Just recently, for example, it was put to work identifying and categorizing smells in a new form of electronic nose.”

More than these, Intel progress strategy will continue to inspire new research in the most advanced fields of ICT (as AI is by far) [11], this confirming our above observation about the ways ICT development could inspire humankind activity:

<<The best AI algorithms already use brain-like programs called simulated neural networks, which rely on parallel processing to recognize patterns in data—including objects in images and words in speech. Neuromorphic chips take this idea further by etching the workings of neural networks into silicon. They are less flexible and powerful than the best general-purpose chips, but being specialized to their task makes them very energy efficient, and thus ideal for mobile devices, vehicles, and industrial equipment. The idea of neuromorphic chips has been around for decades, but the technology may finally be ready to find its commercial niche. Across the tech industry, progress in AI has inspired new research into hardware capable of using machine-learning algorithms more efficiently. Chris Eliasmith, a professor who studies neuroscience and computer architectures at the University of Waterloo in Canada, says the biggest challenge with neuromorphic chips in the past has

been scaling them up. “This is one thing I really like about Intel entering the space,” he says. “They have the resources to push things ahead quickly.”>>

It is sure that this achievement, will stepwise show many implications, as it will be developed, but for now it is more important to understand the ways it learned from human brain – a road that ICT and other domains have to find more on, generally from the biological world [1]:

<<Today, Intel announced the readiness of Pohoiki Springs, its latest and most powerful neuromorphic research system providing the computational capacity of 100 million neurons. The cloud-based system will be made available to members of the Intel Neuromorphic Research Community (INRC), extending their neuromorphic work to solve larger, more complex problems. “Pohoiki Springs scales up our Loihi neuromorphic research chip by more than 750 times, while operating at a power level of under 500 watts. The system enables our research partners to explore ways to accelerate workloads that run slowly today on conventional architectures, including high-performance computing (HPC) systems.” –Mike Davies, director of Intel’s Neuromorphic Computing Lab.>>

Here we have to notice the speed and the dimensions of revolutionary Loihi chips applications, mainly by scaling – IT most prominent feature we repeatedly emphasized[19][23] as generating the exponential pace of ICT devevelopment:

„Pohoiki Springs is a data center rack-mounted system and is Intel’s largest neuromorphic computing system developed to date. It integrates 768 Loihi neuromorphic research chips inside a chassis the size of five standard servers. Loihi processors take inspiration from the human brain. Like the brain, Loihi can process certain demanding workloads up to 1,000 times faster and 10,000 times more efficiently than conventional processors. Pohoiki Springs is the next step in scaling this architecture to assess its potential to solve not just artificial intelligence (AI) problems, but a wide range of computationally difficult problems. Intel researchers believe the extreme parallelism and asynchronous signaling of neuromorphic systems may provide significant performance gains at dramatically reduced power levels compared with the most advanced conventional computers available today.”

Further, a relevant comparison of the *Loihi* smallest system application with the living things computing capacities could just suggest its future evolution/potential:

„What the Opportunity for Scale is: *In the natural world even some of the smallest living organisms can solve remarkably hard computational problems. Many insects, for example, can visually track objects and navigate and avoid obstacles in real time, despite having brains with well under 1 million neurons. Similarly, Intel’s smallest neuromorphic system, Kapoho Bay, comprises two Loihi chips with 262,000 neurons and supports a variety of real-time edge workloads. Intel and INRC researchers have demonstrated the ability for Loihi to recognize gestures in real time, read Braille using novel artificial skin, orient direction using learned visual landmarks and learn new odor patterns– all while consuming tens of milliwatts of power. These small-scale examples have so far shown excellent scalability, with larger problems running faster and more efficiently on Loihi compared with conventional solutions.”*

Our future of learning from nature is further justified, as we can see how the *mammal species brain evolution* followed similar patterns of scalability, from where actual innovations could surely get benefic inspiration:

„...This mirrors the scalability of brains found in nature, from insects to human brains. With 100 million neurons, Pohoiki Springs increases Loihi’s neural capacity to the size of a small mammal brain, a major step on the path to supporting much larger and more sophisticated neuromorphic workloads. The system lays the foundation for an autonomous, connected future, which will require new approaches to real-time, dynamic data processing...Intel’s neuromorphic systems, such as Pohoiki Springs, are still in the research phase and are not intended to replace conventional computing systems. Instead, they provide a tool for researchers to develop and characterize new neuro-inspired algorithms for real-time processing, problem solving, adaptation and learning.“

Observing this ICT potential, one could think that its future development and performances advances will continue without problems, but here we have to recall our approach of ICT progress perception and in IS/KBS context, as an elusive iceberg tip [16], because of its increasing complexity and inherent challenges.

This way we have just arrived to the title main issue, concerning probabilistic computing, because **the complicate processes of ICT progress and the struggle to continuously improve performances, while extending applications at Earth scale, is a challenging evolution in an everchanging context that inherently generates uncertainty and probabilistic approaches.**

2. ICT’s new paradigm of probabilistic computing

In the short history of ICT evolution, at least in the last decades, the role of software components had an increasing impact, which became prominent lately by its overwhelming importance for soft defined devices, equipments or even networks.

Still, in the context of the above presented advances toward unprecedented ICT performances, it is quite interesting to see that software could bring a decisive contribution to the next paradigm of ICT [5]:

“Today machine learning is rigid and requires massive amounts of data. But AI researchers are attempting to emulate the low-data fluidity and rich representations of human thinking... In nature and in life, more is not necessarily better. A gentle rain is good for the grass, but if it lasts for five days, you may get a raging flood. Rising temperatures can be pleasant, even optimal, until the heat burns, the droughts sear and the polar ice caps start to melt. A long-popular finance theory argues that companies with too much cash on hand will begin to do stupid things. This also applies to data. We are awash in data, and it’s growing at an exponential rate. It often seems as if this tidal wave of data is a necessary prerequisite for computer programs designed to learn. Today’s machine learning programs require huge amounts of data to discover what toddlers can master by crawling around and playing with blocks or simply observing the strange behavior of adults. In fact, an excess of data can quickly overwhelm the ability of human brains to function properly. Humans need a lot less data than machines to generalize about and draw conclusions on matters large and small, simple and complex.”

Perhaps a long list of iceberg tips, like the above quoted examples suggest, could be confusing, but we have to recall that the mentioned elusive iceberg tip of ICT context includes a socio-psychological component, which is successfully emphasized by too much cash or data cases, i.e. a clear link with the Data Deluge context where ICT/AI/ML are actually applied.

Now it seems that we have come back to the point, linking the computer and human brain performance toward the above desired asymptotic evolution of ICT/AI (*the art of the possible*), as it is further detailed:

“For instance, training a deep learning algorithm to recognize a category of objects — say, chairs or dogs — with great accuracy is not easy, but distinguishing Person A from Person B is even harder and requires even more data. If you teach an artificial intelligence (AI) program that a robin, an eagle and a duck are all birds, the program still may not recognize a cardinal or a peacock as one of our feathered friends. That would require feeding the algorithm tens or even hundreds of thousands of images, capturing a massive amount of variation in size, shape, profile, texture, lighting and angle. Handling large amounts of data is cumbersome, slow and expensive. Anyone who has tried training a convolutional neural network (CNN), which analyzes visual imagery, or a generative adversarial network (GAN), which pits two neural networks against each other in a zero-sum game, knows the large computational effort and multiple passes of training data required to achieve a robust level of accuracy.”

As a conclusion, the solution for such challenges comes naturally from the same human brain reference way of operation:

“It would be much more efficient if an algorithm could develop ideas about what makes a human with less data and computational power, easily test them and learn from successes and failures.”

It is also surprising and very interesting, how shortly we can arrive to such complex and relevant dependencies underneath the context iceberg, as the promising strategies of ICT progress are there finally found:

“One answer to this challenge is probabilistic computing, an increasingly vital component of AI and a way of addressing the uncertainties inherent in so-called natural data — the kind of real-world data that humans continually process, often without conscious intent. Advances in probabilistic computing make it increasingly likely that we’ll soon be able to build machines that are capable of understanding, predicting and making decisions with limited amounts of data.”

With simpler words, both *probabilistic computing* paradigm and *uncertainties* of real/future World context are here splendidly revealed, as it is obvious that the combination of these concepts could further inspire many human processes of thinking/decision – our title main idea.

More than these, the same quotation brings together the unique capacity of human brain to efficiently process complex data/scenarios, otherwise than computers.

Still, here we have to mention that *probabilistic computing* is a very general concept, linking probabilistic approaches of different techniques/technologies, as it will be further presented and also emphasized by the MIT Probabilistic Computing Project [18]:

“We aim to improve our ability to engineer artificial intelligence, reverse-engineer natural intelligence, and deploy applications that increase our collective intelligence and well-being. We do this by integrating probabilistic inference, generative models, and Monte Carlo methods into the building blocks of software, hardware, and other computational systems. For example, we have developed high-level probabilistic programming languages, automated Bayesian data modelling systems, Bayesian inverse graphics approaches to 3D computer vision, and near-optimal algorithms, circuits, and hardware architectures for Monte Carlo. We test our results by collaborating with domain experts on practical applications.”

Now it is important to notice that inspiring from human brain is not the only source for ICT general progress and especially for AI/ML expected advances, but it will be more than obvious that the ways the natural evolution optimized it, provides many learned lessons which could be useful for other strategies leading to probabilistic approaches.

Quantum computing is one of the most promising technology for ICT future, but it is interesting to observe its relation with ‘probabilistic computing’, as it expressed by [13]:

“Even as the quantum computing community chases reliable systems, innovation continues around developing techniques that ‘mimic’ some of quantum computing’s capabilities but run on less complicated machines. Welcome to ‘probabilistic computing’ or at least a step in that direction. Researchers from Purdue University and Tohoku University published a proof-of-concept study in Nature last week in which they created and used probabilistic bits (p-bits) to factorize integers up to 945. The work, led by Kerem Casmari (Purdue) and Shunsuke Fukami (Tohoku), seems to be well suited for classes of optimization (energy cost) problems. If this sounds a bit like adiabatic quantum annealing, you’re correct, although the authors say it can be also used to emulate gate-based quantum computing.”

In the same time, we have to mention that quantum computing is just at the study phase (and p-bits are poorer q-bits), although mainstream companies like Intel or IBM are very advanced in creating clusters of q-bits [2]:

<<Intel today reported (Nature) successful control a ‘silicon spin’ qubit at 100 degrees Kelvin – that’s a relatively balmy departure from the frigid milliKelvin environment most qubits require. Last week, the National Science Foundation and IBM, AWS, and Microsoft launched a pilot program to provide expanded access to their quantum platforms. Yesterday, quantum tool-maker Q-CTRL announced added funding from In-Q-Tel, the not-for-profit strategic investor that identifies technology solutions to support the national security communities of the U.S. “Our demonstration of hot qubits that can operate at higher temperatures while maintaining high fidelity paves the way to allow a variety of local qubit control options without impacting qubit performance,” said Jim Clarke, director of quantum hardware, Intel Labs, in the announcement.>>

Here we could also see which are the concrete (rough) expectations for the development to get over the studies phase, with the private and public support this promising technology already has:

“Given the amount of public and private effort now being poured into quantum development, it may be reasonable to expect practical advances will occur sooner rather than later – a couple of years versus a decade”

We further observe that, beyond the fundamental difficulties of the domain, it could be interesting, on the other side, that the technological/commercial competition is, in this race for supremacy, very intense:

“...here’s an interesting perspective from noted quantum researcher and blogger Scott Aaronson (UT, Austin) from an excellent talk[I] two weeks ago on quantum computing generally and Google’s work to achieve Quantum Supremacy: [Finding practical applications] is a major, major focus of quantum algorithms research right now because we know that we’re going to have these noisy devices with 50 or 100 or 200 qubits over the course of the next decade. And we don’t really know what they’re good for. This demonstration of quantum supremacy, which Google just did, was great, but of course it would be even better if we could do something useful.”

Although there are many signals in the last decade, the actual state-of-art of quantum computing is still in the phase of basics, as it is further commented from the same (recent!) source:

“I think the best shot that we have for doing something useful with these noisy near-term devices is going to be to do some kind of quantum simulation, probably of some materials of some condensed matter system. Although, [if] we’re really lucky then maybe even in chemistry. That will tell the scientists in the relevant area – the material scientists, that condensed matter physicists, the chemists – something interesting about their system that they didn’t already know. That would be a tremendously exciting next milestone. And it is possible that we could achieve that using noisy devices.”

A similar stage is confirmed for the area of possible applications of the expected advances of quantum computing, although AI/ML is among the most probable targets of the higher performances:

<< *“There’s a lot of talk about other applications for near-term quantum computers, like, for example, for optimization and machine learning. It is crucial for everyone to understand that those applications are very, very speculative, meaning that even if you have a perfect quantum computer, we still don’t know what kind of speed-ups [they] are going to give you [over classical systems].”* So is the glass half-full or half-empty? >>

We can also observe from these comments that one of the major difficulties of quantum computing development comes from the specific very low temperatures and this is why the researchers from Intel started with the silicon existing base, which revealed higher temperatures:

“Let’s start with Intel. One advantage it has by working with silicon dots is it leverages existing semiconductor manufacturing and packaging methods. So far Intel has said little about its quantum processor but it has suggested it too will eventually provide access via the web. The recent work QuTech[II] demonstrates steady progress and potentially an area of advantage over competing superconducting approaches...”

Quoting from the information released by QuTech, which is the advanced research center for Quantum Computing and Quantum Internet, a collaboration founded in 2014 by Delft University of Technology (TU Delft) and the Netherlands Organisation for Applied

Scientific Research (TNO), the same source [2] found confirmation for the silicon approach advantages:

“[L]eading solid-state approaches function only at temperatures below 100 millikelvin, where cooling power is extremely limited, and this severely affects the prospects of practical quantum computation. Recent studies of electron spins in silicon have made progress towards a platform that can be operated at higher temperatures by demonstrating long spin lifetimes, gate-based spin readout and coherent single-spin control. However, a high-temperature two-qubit logic gate has not yet been demonstrated. Here we show that silicon quantum dots can have sufficient thermal robustness to enable the execution of a universal gate set at temperatures greater than one kelvin.”

Regarding the expectations for the first devices to be developed based on quantum computing, we notice that, even for the elementary *high-temperature two-qubit logic gate*, the implementation phase is still waiting, without speaking about the aimed concrete (high) speed which the devices should provide.

On the other side, it is fair to mention that all the last decade analyses on quantum computing showed very optimistic estimates about higher speeds compared with conventional computers, due to inherent physics advantages at atomic level, as the more impressive expectations are in the quantum cryptography domain [3][2][17][25].

For understanding the complexity and *uncertainties* of the winding road of ICT advances, from the high tops it is already sitting, here in the difficult evolution of quantum computing revolution, the development step by step, along with the probabilistic approach, is essential [14]:

“As the amazing progress enabled by the continued miniaturization of the field-effect-transistor slows down, there is developing interest in non-traditional computing as a path to energy-efficiency and increased functionality ... such path based on the concept of probabilistic or p-bits that can be scalably built with present-day technology used in magnetic memory devices ... p-bits can be robustly placed in between deterministic bits that are at the heart of digital computers and quantum bits that are at the heart of quantum computers ... these p-bits can be used as building blocks for constructing autonomous p-circuits that can accelerate many current applications like optimization, invertible logic and machine learning algorithms, while providing a bridge to the Noisy-Intermediate-Scale Quantum (NISQ) era quantum computers...”

Following the gradual approach of the development difficulties, in the case of this p-bit intermediate technological innovation, a first concrete achievement, due to the algorithm's optimization, is further announced as:

“...a recent experimental demonstration of an 8-bit p-computer implementing a quantum-inspired optimization algorithm. An underlying theme throughout this work is an Atoms to Systems approach that includes emerging materials and novel phenomena (e.g. spintronics, quantum materials), transport theory and device physics, circuit simulation, system-level behavioral synthesis (e.g. using FPGAs), and an understanding of Machine Learning and Quantum Computing algorithms that drive the search for new and specialized devices.”

Considering these steps, we can still notice that they are built with realism, pointing from the beginning *emerging materials, transport theory, device physics, circuit simulation,*

system-level behavioural synthesis or even *Machine Learning and Quantum Computing algorithms*, i.e. the implementation phases which have to be progressively done.

Also we can observe the needed flexibility of the ICT development strategies, in this époque where diverse techniques/technologies are approached, like *magnetic memory devices, p-bits, deterministic bits that are at the heart of digital computers and quantum bits that are at the heart of quantum computers*, without missing a future *bridge to the Noisy-Intermediate-Scale Quantum era quantum computers*.

In fact, this flexibility is an inherent feature of the *probabilistic computing* paradigm that drives this ICT promising development direction, due to the logical approach of all events and their chances, in order to select and maximize the expected benefits.

In our opinion, the need of flexibility comes also from the complexity and difficulty which characterizes the unprecedented levels of performances of the ICT actual development advances, which are hard to be improved, considering also all their consequences (positive/negative) associated with the context of these evolutions at Earth scale, including IoT, Data Deluge, climate changes, Earth resources fading and social unbalances.

Perhaps now it is obvious that this complex and complicate context generates uncertainty, which logically requests a probabilistic approach for almost all decisions and projects.

This probabilistic approach necessity is naturally expected to be extended to the individual level, but here we have to observe both the benefic consequences of ICT, including the inspiration of our thinking by the ways it advances, but also the less desired consequences, including the above mentioned and **our increasing dependence of what ICT products, services mean for every person or community**.

Considering this preliminary analysis and the presented premises, **a further continuation is to be done, in order to obtain more valuable and detailed information about the consequences of the new ICT probabilistic computing paradigm, through all IS/KBS development and even for people's way of thinking**.

3. Conclusions

In the actual context of ICT exponential pace of development and its amazing advances, the paper approached the premises of the ICT probabilistic computing paradigm in a critical point of ICT evolution, where it is largely agreed that Moore Law is going to an end and the future solutions for ICT progress are intensely searched, in order to keep the IS/KBS progress pace. Also, our analysis considered the main consequences, for humankind, from this new ICT step with unprecedented challenges, including the economical, social, human behaviour and Earth environment ones. ICT, beyond being the main motor of IS/KBS, is an inspiration model of progress for almost all human activity domains, in many ways, revealing the complex and complicate mutual relations between human creation potential and the ICT advances.

The paper analysis and literature quotations confirmed, by relevant examples, our earlier estimations, that living things or biological systems (especially human brain) will be among the main inspirations/solutions for ICT revolutionary advances, including but not restricting to AI/ML.

As main examples, the new technologies inspired by human brain model are analyzed, as this approach is manifest and very much exploited in the ICT development, but for surpassing the performances limits of advanced computing and AI, this is quite the most promising direction, including Pohoiki Springs, a data center which is Intel's largest neuromorphic computing system that integrates 768 Loihi neuromorphic chips-inspired from the human brain, but being up to 1,000 times faster and 10,000 times more efficiently than conventional processors.

Among the advances toward unprecedented ICT performances, we also approached the ways that software could bring a decisive contribution to the ICT probabilistic computing paradigm. As a conclusion, the solution for such challenges comes naturally from the same human brain reference way of operation, pointing that our algorithms could mimic what human brain makes having fewer data and computing power. Such complex and relevant dependencies underneath the ICT context led to probabilistic computing and could compensate the uncertainties from rough data. From here, a prominent conclusion is revealed, as it is obvious that the combination of these concepts could further inspire many human processes of thinking/decision – our title main idea.

Further, the paper also approached quantum computing, which is one of the most promising technology for ICT future, by pointing its relation with 'probabilistic computing', confirmed by gradually achievements like *probabilistic bits (p-bits)*. It is confirmed that the actual state-of-art of quantum computing is still in the phase of basics and one of the major difficulties of quantum computing development comes from the specific very low temperatures, as Intel started with the silicon existing base, which revealed higher temperatures of operation.

Such examples led to another important conclusion, as the flexibility of approaching diverse techniques/technologies solutions is an inherent feature of the probabilistic computing paradigm that drives this ICT development struggle, due to the logical approach of all events and their chances, in order to select and maximize the expected benefits.

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