From Autonomous Systems to Symbiotic System Science

Rodolfo A. Fiorini
Dept. of Electronics, Information & Bioengineering
Politecnico di Milano University
Milano, Italy
rodolfo.fiorini@polimi.it

***Abstract*—Today, disruptive technologies are appearing at an accelerating pace. Economic and societal forces, enabled by the evolution and convergence of several technologies, are driving the development of a novel generation of systems. We are at a crossroads, on the cusp of significant transformative changes that will impact society worldwide, revolutionizing global business operations and fundamentally altering how inanimate objects are perceived in a world increasingly reliant on autonomous systems. Symbiotic System Science (SSS) is a growing scientific area which is taking a leadership role in fostering consensus on how best to bring about symbiotic relationships between autonomous systems. Capitalizing on SSS insights and development, the recognition that SAS (Symbiotic Autonomous Systems) are poised to have a revolutionary impact on society over the coming years is quite straightforward. In present paper we discuss main implications of Autonomous System (AS), SAS and SSS to the incoming technological society. In order to achieve an antifragile behavior, next generation human-made system must have a new fundamental component, able to address and to face effectively the problem of multiscale ontological uncertainty management, in an instinctively sustainable way: wisdom by design!**

Keywords—Information systems; cognitive robotics; symbiotic system science; autonomous system; brain-inspired system; computational intelligence.

I. INTRODUCTION

Present planetary problems are multiscale-order deficiencies from the past, obsolete, Western, human reductionist worldview. They cannot be fixed by the usual, traditional, hierarchical approach alone, by doing what we do better or more intensely, but rather by changing the way we do [1]. Men inevitably see the universe from a human point of view, communicate in terms shaped by the exigencies of human life in a natural uncertain environment, and make rational decisions in an environment of imprecision, uncertainty and incompleteness of information.

Both complexity science and chaos theory converge on showing the unavoidability of uncertainty, whether it is embedded into feedback cycles and emergence or in the infinite precision of initial conditions. Even in mere terminology, minimizing or avoiding representation uncertainty and ambiguities is mandatory to achieve and keep high quality result and service [2]. In the past decades, we learned how traditional human-made system can be quite fragile to unexpected perturbation, because statistics by itself can fool you, unfortunately [3]. Our society is an arbitrary complex multiscale system of systems of purposive actors within continuous change. Harvard Business School professor Clayton M. Christensen coined the term disruptive technology in his 1997 book, "The Innovator's Dilemma" [4]. Building from the two fundamental, atavic Japanese concepts “kaizen” and “kaikaku,” Christensen separates new technology into two categories, “sustaining” and “disruptive.” Sustaining technology relies on incremental improvements to an already established technology. Disruptive technology lacks refinement, often has performance problems because it is new, appeals to a limited audience and may not yet have a proven practical application. Nevertheless, a disruptive technology is one that displaces an established technology and shakes up the industry or a ground-breaking product, creating a completely new industry. While we cannot predict the future, we can prepare for its potential outcome as best as we can. Knowledge and Education are our key facilitators [5].

II. TOWARDS REAL INTELLIGENT SYSTEMS

We need to reframe uncertainty-as-problem in the past into the evolutive concept of uncertainty-as-resource. The key change performance factors are knowledge and education, solving the major "information double-bind" (IDB) problem in current most advanced research laboratory and instrumentation system, just at the inner core of human knowledge extraction by experimentation in current science [6]. The solution to this problem will create the fundamental dichotomy distinguishing classic, contemporary education from a new one, based on a more reliable control of learning from uncertainty and uncertainty management; discriminating information building on sand (in the past) from information building on rock (in the future). Education has to be reconceived from the ground up: solid scientific education, in both the natural biology grounded in anticipation, and the real physics of the world, is required. This in itself is a high-order endeavor, since schools continue to indoctrinate new generations in the traditional religion of reductionist, classical physics, biology and chemistry.

Today, disruptive technologies are appearing at an accelerating pace. Blockchain, quantum computing, augmented analytics, IoT and artificial intelligence (AI) will drive disruption and new business models. These technologies offer even greater potential for enhancing productivity and quality of life and liberating human beings from physical, social and mental tasks that can be performed with equal or greater speed and quality by machines. Liberated from the monotonous, repetitive drudgery of the routine, they make it possible for us to explore and develop higher relational, emotional, intellectual and creative capacities which are uniquely human. But, if we manage the incoming Fourth Industrial Revolution with the same blindness and forms of denial with which we managed the previous industrial revolutions, the negative effects on our society will be exponential [7]. At social level, inequality and unemployment destroy opportunity freedom. Radical inequality significantly undermines opportunity freedoms and capacity freedoms, and consequently radically undermines human capital as a foundation of community prosperity [8].

In fact, the speed, power and social consequences of recent technological advances in AI and Cognitive Computing pose serious challenges which need to be urgently addressed by leaders in the field. Published research by respected institutions such as McKinsey and World Economic Forum, aggravated by extravagant techno-visionary hype and public hysteria, are already raising widespread concern that continued advances in these fields will radically alter, invade and take over more and more of both the workplace and our private space, making even higher human faculties redundant or obsolete, rendering people unemployed, unemployable and unnecessary [9]. It is hard to predict the long-term effects of advanced AI and related technologies such as IoT and blockchain.

Furthermore, in January 2015, Stephen Hawking, Elon Musk, and other experts signed an open letter on AI calling for research on the societal impacts of AI, anticipating its potential risk to the violent downfall of humankind. Studies predicting a radical disruption of global job markets in the next two decades may or may not turn out to be accurate, but the impact of these studies on social attitudes and human security is already a real and present threat that is disillusioning youth, polarizing democratic societies, spurring the rise of populist leaders, fostering social alienation, crime and drug abuse.

Governments are already responding and reacting to increasing public pressure to impose regulations to protect society from unbridled application of technologies with such profound social impact. This tendency is likely to grow and spread rapidly unless its root causes are addressed. In fact, if there is any threat to humanity, it will not come from a conspiracy of superior intelligent machines that take over the planet, but rather from human beings who consciously and willfully surrender their independence and humanity to that which they have created or permit social agents to impose them. And this danger is real and ever-present.

As a matter of fact, on the contrary, current AI, Cognitive Computing, Computational Intelligence and Cognitive Robotics are helping people around the world do their jobs more easily and in shorter time. AI has helped people around the world do their jobs, including doctors who diagnose sepsis in patients and scientists who track endangered animals in the wild. In fact, recently developed AI application is accelerating research and improving lives in wildlife preservation, diagnosing sepsis, human search and rescue, cybersecurity and restoring human touch and movement. Regulating has never been easy, but the overwhelming pace of technological change and unprecedented interconnectedness of economies has made it a daunting task. One thing is quite clear, today intellectual leadership in knowledge can no longer be separated or divorced from social responsibility for its impact, be that at either environmental or societal level or both. No longer is it possible to maintain the artificial and illusory division between the development of knowledge and the policy implications of its application. This is specifically true for incoming autonomous systems (AS).

It has been recognized that advanced AI applications and AS are characterized by the power of perceptive, problem-driven, goal-driven, decision-driven, and deductive intelligence, which are able to deal with unanticipated and indeterministic events in real-time [2]. A theoretical framework for developing fully AS towards engineering applications, including brain-inspired cognitive systems, unmanned systems, self-driving vehicles, cognitive robots, and intelligent IoTs, has already been described in detail in in a different paper [10]. Here, for reader convenience, we recall their fundamental properties only.

III. Intelligent Systems

According to Wang et al. [10], in intelligence science, system sciences, and control engineering, an autonomous system (AS) is a study of fully intelligent system for implementing advanced human intelligence by machines [11-20]. AS embodies an emerging and high-level machine intelligence beyond those of imperative and adaptive systems [10]. The natural and machine intelligence underpinning ASs may be generated through data, information, and knowledge from the bottom up, even though intelligence may not be directly aggregated from data as some neural network technologies supposed in the past, because there are still multiple inductive layers from data to intelligence. The links between cybernetics and the study of the brain, intelligence and AI vary dramatically and are pertinent to the direction of our inquiry too. The sheer variety of discussions on the subject, you can find on an overwhelming number of scientific articles, is evidence that defining human intelligence remains an ever-open question. Intelligence is the paramount cognitive ability of humans that may be mimicked by computational intelligence and cognitive systems when a reliable model is available. Intelligence science studies the general form of intelligence, formal principles and properties, as well as engineering [21-23].

Identifying the levels of intelligence and their difficulty for implementation in computational intelligence is mandatory for developing resilient and antifragile AS [3]. Therefore the intelligence and system foundations of AS focus on what structural and behavioral properties constitute the intelligence power of AS and how it aggregates from its fundamental components. In [10] a Hierarchical Intelligence Model (HIM) is presented and discussed for identifying the levels of intelligence and their difficulty for implementation in computational intelligence. In HIM, the levels of intelligence are aggregated from reflexive, imperative, adaptive, autonomous, and cognitive intelligence with 16 forms of intelligent behaviors from the bottom up [10]. According to the theories of system science [12, 17, 24, 25], the relationship among the cognitive entities in the brain (data, information, knowledge and intelligence) can be formally described by a convenient, reliable model and a set of properties of system autonomy can be formally analyzed towards a wide range of AS applications in computational intelligence and system engineering. AS, underpinned by cognitive intelligence, is an advanced form of AI studied in intelligence science, system science, and computational intelligence.

As a matter of fact, according to previous analysis [10], there had rarely any fully AS been developed in the past 50 years in AI and system engineering, because the theoretical foundations of autonomous intelligence and systems were not mature to do so [11, 12, 19, 24, 26, 27, 28, 29]. Many AI systems are still bounded by the intelligent bottleneck of adaptive systems where machine intelligence is constrained by the lower-level reflexive, imperative, and deterministic adaptive intelligent abilities based on the statistic or probabilistic approach only [18, 20]. It would be expected that AI will be matured once an AS may independently discover a law in sciences or autonomously comprehend the semantics of a humor in natural languages.

Most AI systems currently act as a complement to humans instead of replacing them, much like symbiotic organism and system in nature. Traditional theories and technologies perceive AS as human-system interactions where humans are "in-the-loop" or "on-the-loop. In the coming decades we are bound to see progress in both the "computerization" of the world and in its digitalization. Since the dawn of the internet, a digital revolution has transformed life for millions of people. Digital files have replaced paper, email has replaced letters, and cell phones provide access to many services that facilitate daily life. We are flowing through this digital revolution, and there is now a growing deployment of technologies to arrive to a worldwide network of interconnected objects that are uniquely addressable via standard communication protocols. These two trends will strengthen one another and will overlap creating the age of real "intelligent" systems. A classification of "intelligent" systems may be determined by the forms of input (Event) and output (Behavior) under system internal uncertainty management algorithms [30], as shown in Table I.

TABLE I A CLASSIFICATION OF ADAPTIVE, AUTONOMOUS, AND SYMBIOTIC SYSTEM BEHAVIOR

		Behavior (O)		
		Constant	**Variable**	**Unexpected (Creative)**
Event (I)	**Constant**	Reflexive	Adaptive	Evolutive
	Variable	Imperative	Autonomous (Reflective)	Symbiotic Autonomous
	Unexpected	Fragile	Symbiotic Fragile	Human-Centered Symbiotic

One possible AS evolution is Symbiotic Autonomous System (SAS). The adjective "symbiotic" derives from the noun "Symbiosis." Symbiosis is any type of a close and long-term biological interaction between two different biological organisms, be it mutualistic, commensalistic, or parasitic. The organisms, each termed a symbiont, may be of the same or of different species. In 1879, Heinrich Anton de Bary defined it as "the living together of unlike organisms". The term was subject to a century-long debate about whether it should specifically denote mutualism, as in lichens; biologists have now abandoned that restriction [31]. Emerging SAS focus on enhancing the relationship between human beings and machines rather than on designing machines to operate as autonomous agents only. Therefore, for us an SAS is a bio-and-social-inspired system characterized by heterogeneously synergized, adaptive structures and behaviors (see Section AS, SAS and SSS).

Current situation is under a strong evolutive push to pass through SAS under Symbiotic Systems Science (SSS) [32] first, to arrive to Human-Centered Symbiotic System (HCSS) under Human-Centered Symbiotic Systems Science (HCSSS) eventually. HCSS and HCSSS are presented and discussed in a different paper [33],[34].

IV. SUPER-SMART SOCIETY

Our societies are arbitrary complex multiscale system of systems of purposive actors within continuous change. Society is, without any doubt, a complex system and the idea to use the knowledge from the analysis of physical complex systems in the analysis of societal problems is tempting. Indeed, the notions of, nonlinearity, interactions, impredicativity, self-organization, stability and chaos, unpredictability, sensitivity to initial conditions, bifurcation, etc., are phenomena which also characterize social systems.

In their Technology Basic Plan (2016–2020), the Japanese introduced a new concept, namely "Society 5.0," as a way by which to guide and mobilize action in science, technology, and innovation to achieve a prosperous, sustainable, and inclusive future that is, within the context of ever-growing digitalization and connectivity, empowered by the advancement of AI [35]. With its potential to equip and better shape our society with new services, businesses, social structures, values, and welfare, AI is perceived by Japanese as a fabulous enabler, but its benefits to society will deeply depend on the way it will be implemented and used in real socioeconomic systems.

"The essence of Society 5.0 is that it will become possible to elicit quickly the most suitable solution that meets the needs of each individual. We will become able to solve challenges that have defied resolution until now," according to Prime Minister Shinzo Abe, at the International Conference on The Future of Asia, last June 2017 (The Future of Asia, 2017). Furthermore, he is ready to extend cooperation for China's ambitious "Belt and Road Initiative," sending another signal that Tokyo wants to mend fences with Beijing ahead of any possible, future bilateral summit [36].

The Japanese endeavor called Society 5.0 aims to empower all actors in the society, placing a special emphasis on enabling each individual to actively participate and live safely, comfortably and securely. Taking the first stride to realize a new vision for its society and economy, Japan’s contribution to policy-making, research and development could one day be applied to solve the world's biggest challenges, hopefully.

Taking into account all the previous discussed components, many nations, and Japan on first line, are planning to create "super-smart society," capable of providing customized solutions through the adoption of new technologies like AI, robotics, Big Data, and drones, as well as through policy and regulatory reform.

A super-smart society is characterized as follows: a society where the various needs of society are finely differentiated and met by providing the necessary products and services in the required amounts to the people who need them when they need them, and in which all the people can receive high-quality services and live a comfortable, vigorous life that makes allowances for their various differences such as age, sex, region, or language [35].

Science does not exists to enlighten people's minds only. Science can be seen not only as representational but as a mode of performative engagement with the world [24]. It mainly exists to show the educated way from quanta to qualia and to grow human knowledge exponentially. That way starts from social predicative competence to arrive to computational competence, and to discover that, by the right AI perspective, they are not so different after all [37]. To maximize the benefits from AI technologies, in addition to appropriate knowledge of the AI technologies themselves, users need digital goods and services literacy and knowledge of data privacy. However, all people cannot acquire or maintain this knowledge and literacy, and it might be a causal factor in the so-called "AI divide." For instance, "rideshare," backed by AI optimization technologies, could offer a new means of transport at a low cost comparative to taxis; therefore, it is supportive of socially disadvantaged people. However, access to these services require a minimum familiarity with digital devices, so those without literacy may be excluded from the benefit of rideshare services. Potential discrimination based on the output of personal profiling by AI technologies must be prevented.

Nevertheless, what is currently called AI it is not actually "intelligence" (yet), just trained pattern recognition engines (a technology that has been around for more than 20 years), a sophisticated tool for a very specific subset of human cognitive abilities rather than a thinking machine. We are not being out-thought, we just have found a way to use the “Idiot Savant” powers…Under the guidance of programmers, different types of AI application have even produced original songs, paintings and digital artwork; some bust out their own dance moves, and others recite rhymes like Kanye. Sophisticated AI systems use a process called deep learning to solve computational tasks quickly, using networks of layered algorithms that communicate with each other to solve more and more complex problems, or like GANs (Generative Adversarial Network) which thrive on "random noise" [38]. But to accomplish these feats, any artificial neural network (ANN) still relies on a human programmer setting the tasks and selecting the data for it to learn from. Cognitive robots and AI are part of a long-term plan, and the biggest fear for human being should be that they may not be developed fast enough to make us immortal and save humanity from extinction by virtue of global thermonuclear war, a catastrophic geological event, or an astronomical hazard.

Education for children is especially urgent because it takes time, and the development of AI technologies is so rapid. It is important to consider what abilities should be still learned by humans for proper brain development even though the activities enabled by said abilities can be performed instead by AI technologies. However, like many other tools and technologies, AI technologies’ utilization cannot be socially enforced. It may be necessary to take into consideration the need to ensure the freedom to use AI technologies, based on an individual's faith, and avoiding social conflict between users and non-users of AI technologies. Recent acceleration of the advancement of AI technologies makes it difficult for institutional and social adaptation to keep pace, which leads the Japanese government to address the question of transition management.

V. AS, SAS AND SSS

We are witnessing an increasing availability of AS that operate in nondeterministic (uncertain) environments and offer some form of programmability [2]. All these ASs are currently being revolutionized by advancements in sensing (vision, language understanding) and actuation components (automated mobile manipulators, automated storage and retrieval systems). However, such ASs are held back by the fact that their logic is still based on hard-wired rules either designed or possibly obtained through a learning process. On the other hand, we can envision systems that are able to program themselves, automatically tailoring their behavior so as to achieve desired goals, maintaining themselves within safe boundaries in a changing environment, and following regulations and conventions that evolve over time. In this way, AS can act in an informed and intelligent way in their environment, by changing the way they behave as a consequence of the information they acquire from the external world and exchange with the humans operating therein [39].

Taking into consideration all the previous issues, SSS is the fast growing scientific area which is taking a leadership role in fostering consensus on how best to bring about symbiotic relationships between AS and SAS [32] to develop super-smart society. SAS is an intelligent and cognitive system embodied by computational intelligence in order to facilitate collective intelligence among human-machine interactions in a hybrid society.

Current paradigms of SAS are such as natural intelligence systems, social computing systems, man-machine systems, cognitive robots, bioinformatics systems, brain-inspired systems, self-driving vehicles, unmanned systems, intelligent IoT, cyber-physical-social systems, cognitive systems, etc. Cognitive systems are based on Cognitive Informatics (CI), and Cognitive Computing (CC) is a cutting-edge paradigm of intelligent computing methodologies and systems based on CI, which implements computational intelligence by autonomous inferences and perceptions mimicking the mechanisms of the brain. CI and CC not only synergize theories of many modern information science areas, but also reveal exciting applications in cognitive computers, cognitive communications, computational intelligence, cognitive robots, cognitive systems, and the AI, IT, and software industries, according to the cognitive foundations of information [40].

The development of the new field of SSS will allow to consolidate and advance technological and managemental expertise with emphasis even on Ethical, Legal, and Societal (ELS) implications, and with the objective to promote fundamental human-centric economic and social growth [4]. The promise of SSS is to reveal a convenient path to arrive to HCSSS and HCSS, to fully utilize the capabilities of cognitive computing as a support for more effective application of our higher human faculties.

In different papers we will present and discuss HCSSS and HCSS to bring about symbiotic relationships between SAS with either Person-Centered System (PCS) [7] or Social-Centered System (SCS) resources [8], supported by the *CICT* OUM framework [41],[42]. To minimize or overcome major system limitations and to arrive much closer to reliable and resilient HCSS, we need to extend our traditional system model representation understanding first, taking into consideration quantum field theory (QFT) main interactions conveniently, even at macroscale level [30].

The final goal of HCSSS is to formulate theoretical and practical knowledge required to maximize security, human welfare and individual wellbeing of all humanity in a manner consistent with universal human rights, cultural diversity and civilizational values and what it will mean to live in harmony with Nature. The goal is not to discover immutable, universal, natural laws based on any existing precedent, model or theory, but to identify the laws and first principles of social system suitable for promoting global human welfare and wellbeing. Capitalizing on SSS insights and development, the recognition that SAS are poised to have a revolutionary impact on society over the coming years is quite straightforward [32]. SAS is an intelligent and cognitive system embodied by computational intelligence in order to facilitate collective intelligence among human-machine interactions in a hybrid society. Currently, communities and global organizations are conducting ongoing efforts in the area of autonomous and intelligent systems which are converging towards SAS, supported by the SSS concept.

The theoretical foundations of SAS are underpinned by the emergence of abstract sciences, based on cognitive transdisciplinarity and cognitive transdisciplinary education, as counterpart of classical concrete sciences, based on traditional focused education [18],[40],[43]. The latter includes physics, chemistry, biology, neuroscience, neurology, physiology, brain science, biomedical engineering, bioengineering, engineering sciences, management, etc. The former encompasses data, information, knowledge, intelligence sciences, as well as sociology, mathematics, system science, etc. In the coming decades we are bound to see progress in both the “computerization” of the world and in its digitalization. These two trends will strengthen one another and will overlap creating the age of SAS.

VI. Social Responsibility

Since "with great power comes great responsibility", introducing advanced forms of self-programming calls for the ability to make the behavior automatically synthesized by AS and SAS system comprehensible to human supervisors, who are thus able to control and guide it. Crucially, empowering AS and SAS with self-programming ability carries significant risks and therefore we must be able to balance power with safety. For this reason we need to realize AS and SAS under the "white-box" concept, that is, whose behavior is at any moment fully queryable, analyzable and comprehensible in human terms, and guarded by human oversight. Ultimately it is the fact that the resulting behavior is analyzable in terms comprehensible to humans that will make white-box self-programming AS and SAS trustworthy.

To do so we need to lay the theoretical foundations and developing practical methodologies of a science and engineering of "white-box self-programming." In fact, although interest is evident, currently self-programming abilities are missing or very limited in actual systems operating in nondeterministic, uncertain, and unpredictable environments. By exploiting advances in AI, and specifically in Knowledge Representation, Planning and Synthesis, Agent Technologies, Automated Reasoning, Reinforcement Learning and forms of Deep Learning, it will be possible to equip AS and SAS with advanced self-programming abilities in the future. The significance of this enterprise can be understood in general, but more specifically within three strategic areas of pivotal importance in the current socio-economic context, namely: Smart Manufacturing, IoT and Business Process Management [39].

But eventually, there will come a day where robots will perform most tasks and the role of humans in the production cycle will be marginal. It is very hard to envision the dynamics of a robot-driven economy. But how will humans sustain their lives when robots take all their jobs? Governments should impose an income tax on robots that replace humans, Bill Gates suggested in 2017. The Microsoft founder proposed that the robot tax could finance jobs to which humans are particularly well suited. The basic idea in taxation is you can tax capital or you can tax labor, and a robot is a capital good. The Microsoft founder proposes that the robot tax could finance jobs to which humans are particularly well suited. This can include taking care of elderly people or working with kids in schools, for which needs are unmet. The 2019 World Development Report, prepared by Simeon Djankov and Federica Saliola of the World Bank, opposed a robot tax arguing that it would result in reduced productivity and increased tax avoidance by large corporations and their shareholders [44].

Other experts are endorsing the notion of a Universal Basic Income (UBI), or handing out unconditional money to all citizens. The concept has been around for centuries, but it is gaining traction as full automation starts to loom on the horizon. There are many political, economic and ethical hurdles to the full implementation of the UBI, There are many political, economic and ethical hurdles to the full implementation of the UBI, but pilot programs are underway. Private firms as well as Governments are testing the concept in small scale [45].

Looking over the year that has passed, it is a nice question whether human stupidity or artificial intelligence has done more to shape events. Perhaps it is the convergence of the two that human beings really need to fear. This is the main reason we have the social responsibility and the need to invest in collective intelligence, the quality of laws, and regulatory approaches for governments to address disruptive technologies and individual limitation.

We need to start embracing one unique authority: the absolute knowledge of our own being. It is the only thing that all people have in common, the source of the peace and fulfillment which all people long for. It is the only full shared knowledge there is that could serve as a foundation for world peace. We have yet to see how the accelerating evolution of AI will unfold, but what is for sure is that fundamental changes lie ahead. Nevertheless, according to expert estimates, we are still decades away from general artificial intelligence and full automation.

Societal implications of intelligence, knowledge, big data sciences and related technologies can range from the emerging hybrid societies of humans and intelligence machines to advances in paradigms regarding cognitive robots, cognitive big data systems, brain-inspired systems, etc. As the gap between human and machine shrinks, it becomes increasingly important to develop computer systems that incorporate and enhance existing situation awareness. A key outcome of this transformation will be a notable shift in the interaction of previously independent systems, including humans, and an increased awareness and responsiveness to autonomous systems that will lead to the development of symbiotic relationships that have significant implications for human society as a whole.

The ever accelerating pace of technological development in fields related to cognition and AI have momentous implications for the future of global society and human wellbeing. It raises fundamental transdisciplinary questions about the relationship between human beings and the technologies they develop, the process and direction of social evolution, and the social responsibilities of science. The quest to discover the deep relationship between humanity and the technologies it develops is one of the greatest challenges of the 21st century.

Clashing visions of the future project images of unparalleled technological marvels beset by unanticipated and uncontrollable consequences for society and human wellbeing. Some view technology as the answer to all our problems, while others view it as the source of unprecedented threats to democracy, social stability, employment, human identity, culture and ecological security. The readers are invited to explore topics such as the similarities and differences between human and machine consciousness and learning, the impact of AI on employment and human security, emerging forms of global social organization, the nature of creativity and wisdom, the integration of objective and subjective dimensions of knowledge, and the need for radical changes in education.

It is important to examine the economic, educational, social, legal, political, cultural, epistemological and psychological implications of rapid advances in AI and machine learning.

Social implications, laws and regulations govern the everyday life of businesses and citizens, and are important tools of public policy. Regulating has never been easy, but the overwhelming pace of technological change and unprecedented interconnectedness of economies has made it a daunting task. International organizations, which promote policies that will improve the economic and social wellbeing of people around the world, are already looking at the challenges for regulating disruptive technologies (i.e. the sharing economy, artificial intelligence, online platforms, biotechnology, etc.) as well as emerging (regulatory) approaches for governments to address them, while fostering innovation and making use of the benefits of these new technologies to enhance the life of citizens and business.

VII. CONCLUSION

Science does not exists to enlighten people's minds only. It mainly exists to show the educated way from quanta to qualia starting from computational competence and intelligence in high end, symbiotic application.

The objective of SSS is to formulate theoretical and practical knowledge required to maximize economic security, human welfare and individual wellbeing of all humanity in a manner consistent with universal human rights, cultural diversity and civilizational values and what it will mean to live in harmony with Nature. Economic security ensures minimum material needs. Human welfare encompasses a wider range of material and social needs related to safety, health, education, social security and cybersecurity.

The goal is not to discover immutable, universal, natural laws of economy based on any existing precedent, model or theory, but to identify the laws and first principles of a social system suitable for promoting global human welfare and wellbeing. The promise of SSS is to reveal a convenient roadmap to arrive to HCSSS (Human-centered Symbiotic System Science), to fully utilize the capabilities of cognitive computing as a support for more effective application of our higher human faculties.

Consciously or unconsciously, the construction of any image of the real world relies on personal beliefs based on personal predicative and numeric competence. In this paper, we have brought to light SSS fundamental components, according to our personal experience, and formulated the proposal for a new understanding of them, at an effective scientific and operative level.

Therefore, in order to achieve an antifragile behavior, next generation human-made system must have a new fundamental component, able to address and to face effectively the problem of multiscale ontological uncertainty management, in an instinctively sustainable way: wisdom by design! The interested reader eager to dig deeper into SSS, HCSSS and HCSS is referred to [30],[33],[34].

ACKNOWLEDGMENT

Author acknowledges the continuous support from the CICT CORE Group of Politecnico di Milano University, Milano, Italy, for extensive computational simulation resources and enlightening talks. Furthermore, author acknowledges the continuous and vital exchange of ideas with his numerous IEEE and WAAS fellows.

References

[1] R. A. Fiorini, "Would the big government approach increasingly fail to lead to good decision? A solution proposal," *Kybernetes*, vol. 46, no. 10, pp. 1735–1752, 2017. Available at: http://www.emeraldinsight.com/doi/full/10.1108/K-01-2017-0013

[2] R. A. Fiorini, "Embracing the unknown in post-Bertalanffy systemics complexity modeling," in *Proceedings of the Seventh National Conference on Systems Science*, G. Minati, E. Pessa and M. Abram, Eds., Springer, 2019 (in press).

[3] N. N. Taleb and R. Douady, *A Mathematical Formulation of Fragility.* Peer-Reviewed Monographs, Des Cartes, 2015.

[4] C. M. Christensen, *The Innovator's Dilemma.* Harward Business School Press, Boston, MA, USA, 1997.

[5] R. A. Fiorini, "Transdisciplinary Education for Deep Learning, Creativity and Innovation," in *Proceedings 2nd International Conference on Future Education,* WAAS, Ed., pp. 94-107, WAAS Press, 2018. Available at: http://worldacademy.org/files/rome2017/papers/RCP-S6-6.2.Transdisciplinary-Education-RF.pdf

[6] R. A. Fiorini, "A Cybernetics Update for Competitive Deep Learning System," Proceedings 2nd International Electronic Conference on Entropy and Its Applications, 15-30 November, 2015. Online: MDPI. Available at: http://sciforum.net/conference/ecea-2/paper/3277.

[7] A. Zucconi, "The Need for Person-Centered Education," *Cadmus*, vol. 3, no. 1, pp. 1–26, 2016.

[8] W.P. Nagan, "The Concept, Basis and Implications of Human-Centered Development," *Cadmus*, vol. 3, no. 1, pp. 27–35, 2016.

[9] M. Ford, *Rise of the robots: technology and the threat of a jobless future.* Basic Books, New York, 2015.

[10] Y. Wang, K. N. Plataniotis , S. Kwong, H. Leung, S. Yanushkevich, F. Karray, M. Hou, N. Howard, R. A. Fiorini, P. Soda, E. Tunstel, and S. Patel, "On Autonomous Systems: From Reflexive, Imperative, and Adaptive Intelligence to Autonomous and cognitive Intelligence," IEEE SMC 2019, October 7-10, Bari, Italy, (submitted).

[11] J. Albus, " Outline for a Theory of Intelligence," *IEEE Transactions on Systems, Man and Cybernetics,* vol. 21, no. 3, 473 - 509, 1991.

[12] W.R. Ashby, "Requisite Variety and Implications for Control of Complex Systems," *Cybernetica*, vol. 1, no. 2, pp. 83-99, 1958.

[13] M. I. Jordan, "Computational Intelligence," in Wilson, R.A. and C.K. Frank, eds., *The MIT Encyclopedia of the Cognitive Sciences,* MIT Press, i73-i80, 1999.

[14] Y. Bengio, G. LeCun, and G. E. Hinton, "Deep Learning," *Nature*, vol. 521, no. 7553, pp. 436-444, 2015.

[15] A. Mohammadi, and K.N. Plataniotis, "Event-Based Estimation with Information-Based Triggering and Adaptive Update," *IEEE Transactions on Signal Processing*, vol. 65, no. 18, pp. 4924-4939, 2017.

[16] Mnih, Volodymyr, et al., "Human-level Control through Deep Reinforcement Learning," *Nature*, vol. 518, pp. 529–533, 2015.

[17] Y. Wang, Sam Kwong, Henry Leung, Jianhua Lu, Michael H. Smith, Ljiljana Trajkovic, Edward Tunstel, Konstantinos N. Plataniotis, Gary Yen, and Witold Kinsner, Brain- Inspired Systems: A Transdisciplinary Exploration on Cognitive Cybernetics, Humanity, and Systems Science towards AI, *IEEE System, Man and Cybernetics Magazine*, vol. 5, no. 3, 2019, (in press).

[18] Y. Wang, Keynote: The Emergence of Abstract Sciences and Brain-inspired Symbiotic Systems, IEEE FDC *Workshop on Symbiotic Autonomous Systems* in SMC'18, Japan, pp. 3, 2018.

[19] Y. Wang, "Cognitive Robots: A Reference Model towards Intelligent Authentication", *IEEE Robotics and Automation*, vol. 17, no. 4, pp. 54-62, 2010.

[20] D. P. Watson, and D.H. Scheidt, "Autonomous Systems," *Johns Hopkings Appl. Tech. Digest*, vol. 26, no. 4, pp. 268-376, 2005.

[21] Y. Wang, and T.H. Falk, "From Information to Intelligence Revolution: A Perspective of Canadian Research on Brain and Its Applications," Invited panel talk at the *Workshop on Global Brain Initiatives* (GBI'18) in *IEEE SMC'18*, Miyazaki, Japan, Oct., pp. G.3-4, 2018.

[22] Y. Wang, W. Kinsner, and D. Zhang, "Contemporary Cybernetics and its Faces of Cognitive Informatics and Computational Intelligence," *IEEE Trans. on System, Man, and Cybernetics* (Part B), 39(4), pp.1-11, 2009.

[23] R. A. Wilson, and C.K. Frank, eds., *The MIT Encyclopedia of the Cognitive Sciences.* MIT Press, MA, 2001.

[24] G. J. Klir, *Facets of Systems Science.* Plenum, NY, 1992.

[25] Y. Wang, "In Search of Denotational Mathematics: Novel Mathematical Means for Contemporary Intelligence, Brain, and Knowledge Sciences," *Journal of Advanced Mathematics and Applications,* vol. 1, no. 1, pp. 4-25, 2012.

[26] E. A. Bender, *Mathematical Methods in Artificial Intelligence.* IEEE CS Press, Los Alamitos, CA, 2000.

[27] J. McCarthy, M. L. Minsky, N. Rochester, and C. E. Shannon, "Proposal for the 1956 Dartmouth Summer Research Project on Artificial Intelligence," Dartmouth College, Hanover, NH, USA, 1955.

[28] T. O'Connor, and D. Robb, eds., *Philosophy of Mind: Contemporary Readings.* Routledge, London, UK, 2003.

[29] Y. Wang, "On Cognitive Informatics," *Brain and Mind: A Transdisciplinary Journal of Neuroscience and Neurophilosophy,* vol. 4, no. 2, pp. 151-167, 2003.

[30] R. A. Fiorini, "Quantum Uncertainty Management in Human-Centered Symbiotic System Science (HCSSS)," IEEE SMC 2019, October 7-10, 2019, Bari, Italy, (submitted).

[31] Wikipedia, "Symbiosis," March, 2019. Available at: https://en.wikipedia.org/wiki/Symbiosis

[32] IEEE, "Symbiotic Autonomous Systems, White Paper II," October 2018, IEEE Press. Available at: https://symbiotic-autonomous-systems.ieee.org/white-paper/white-paper-ii

[33] R. A. Fiorini, "Human-Centered Symbiotic System Science (HCSSS)," IEEE ICCI*CC 2019, July 23-25, 2019, Politecnico di Milano University, Milano, Italy, (submitted).

[34] R. A. Fiorini, "Industry 4.0 and Human-Centered Symbiotic System Science (HCSSS)," IEEE SMC 2019, October 7-10, 2019, Bari, Italy, (submitted).

[35] JTBP, "JAPAN'S 5TH SCIENCE AND TECHNOLOGY BASICPLAN (2016-2020)," 2015. Available at: https://www8.cao.go.jp/cstp/english/basic/5thbasicplan_outline.pdf

[36] T. Suruga, "NAR," 2017. Available at: https://asia.nikkei.com/Politics/Abe-offers-olive-branch-on-China-s-Belt-and-Road

[37] R. A. Fiorini, "From Computing with Numbers to Computing with Words," in *Proceedings IEEE 16th nternational Conference on Cgnitive Informatics and Cognitive Computing,* N. Howard, Y. Wang, A. Hussain, F. Hamdy, B. Widrow and L.A. Zadeh, eds., pp. 84-91, 2017.

[38] I. Goodfellow, J. Pouget-Abadie, M. Mirza, B. Xu, D. Warde-Farley, S. Ozair, A. Courville, and Y. Bengio, "Generative Adversarial Networks," in *Proceedings of the International Conference on Neural Information Processing Systems, NIPS 2014*, pp. 2672–2680, 2014.

[39] G. De Giacomo, "Queryable Self-Deliberating Dynamic Systems," Workshop AI forIndustrial Automation, March 18, 2019, Centro Congressi Auditorium della Tecnica, Universita' degli Studi di Bologna, Bologna, Italy.

[40] Y. Wang, "On the Mathematical Theories and Cognitive Foundations of Information," *International Journal of Cognitive Informatics and Natural Intelligence*, vol. 9, no. 3, pp. 41-63, 2015.

[41] R. A. Fiorini and G. Laguteta, "Discrete tomography data footprint reduction by information conservation," *Fundamenta Informaticae*, vol. 125, no. 3-4, pp. 261–272, 2013.

[42] R. A. Fiorini, "New CICT Framework for Deep Learning and Deep Thinking Application," International Journal of Software Science and Computational Intelligence, vol. 8, no. 2, pp. 1–21, 2016.

[43] Y. Wang, "From bioengineering and cognitive engineering to brain inspired systems," *Journal of Bioengineering & Biomedical Sciences*, vol. 7, pp. 4 (Suppl), 2017. DOI: 10.4172/2155-9538-C1-016.

[44] S. Djankov, and F. Saliola, "The Changing Nature of Work," A World Bank Group Flagship Report, WBG, 2019.

[45] F. Giugliano, "Italy Starts Handing Out Free Money," Bloomberg, January 27, 2019. Available at: https://www.bloomberg.com/opinion/articles/2019-01-28/italy-s-populists-hand-out-some-free-money