Symbiotic Autonomous Systems, Digital Twins and Artificial Intelligence:

Emergence and Evolution

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Sommario

Nei prossimi anni assisteremo ad un notevole sviluppo di Sistemi Autonomi Simbiotici (SAS) e dei Digital Twins sia in termini di capacità sia in termini di applicazioni. Questa crescita sarà accompagnata, ed anche resa possibile, dalla evoluzione parallela dell'intelligenza artificiale che giungerà ad avere capacità sempre più equivalenti e quindi superiori all'intelligenza umana, ad esempio, Intelligenza Generale Artificiale (AGI) e Superintelligenza artificiale (ASI).

SAS, Digital Twin ed Intelligenza Artificial saranno sempre più strettamente cooperanti al punto da diventare aspetti diversi di un'unica entità.

Keywords: Artificial Intelligence, Artificial General Intelligence, Artificial Superintelligence, Digital Twins, Machine Awareness, Machine Learning, Neural Networks, Symbiotic Autonomous Systems

Human cognition and creativity have manifested as our unparalleled conception, creation and usage of ever more complex and powerful tools. Our tools, in turn —along with natural environmental factors (e.g., climate, geography, and local lifeforms)—have been powerful determinants of our cultural and societal evolution. These uniquely powerful capabilities ultimately resulted from two major genetic mutations that occurred in two ancestral species in out our distant past. As our toolmaking skills grew more sophisticated and functional, our control over ourselves and our surroundings increased, with our reliance on our physical corpus (perception, muscles and dexterity) and the levels of scale, mass and distance that we could interact with and modify, the key change factor being the introduction of *de novo* external energy sources modes. Mechanical calculators gave way to electronic technology, and from there to computer hardware and software.

We are now in an increasingly ubiquitous digital age that overlaps with an emerging bioelectronic period and the beginning of synthetic genetic technology that suggest a period in which we can modify our own genomes and thereby our physical bodies, including where all the above started: our brains. Beyond that lies a possible science faction-like world in which we may be able to cure or altogether abolish disease; dramatically extend our lives; transfer our brain's content—i.e., our minds—to another neural platform, be it in a clone, computer, or synthetic neural-compatible platform.

Beyond these potential capabilities, we also may develop the ability to seamlessly share both thinking and awareness with other humans and computers, cloud databases, intelligent networks, and other seamless extensions of our conscious mind. In their most sophisticated state, these candidate Symbiotic Autonomous Systems technologies can be described as Digital Twins: digital representations of Physical Twin assets, processes, and systems. Digital Twins can represent objects and entities as varied as a turbine, a robot, internal medical nanorobotic surgeons, a vehicle of arbitrary size and complexity, a non-human mammal, a human being, an entire smart city, myriad other entities, and intangible entities such services, processes and knowledge. (At the same time, while Digital Twins mimic an object's atoms and their structural/functional relationships in bits, all bits may not be represented. However, there are upsides to this property—namely, data repositories, real-time analysis and simulation, or pattern and meaning identification.

Finally, the connections between SAS, Digital Twins and Artificial Intelligence are myriad but largely intuitive. The short version: As SAS and Digital Twins continue to develop, emerge and expand their roles, the parallel evolution of Artificial Intelligence advances with capabilities increasingly equivalent and superior to human intelligence (e.g., Artificial General Intelligence and Artificial Superintelligence), the synergy between SAS and Digital Twins with AI will become simultaneously increasingly complex yet transparent to these interdigitating components.

Our Historical Quest for Technological Intelligence

Our species is not alone in strategizing, communicating, and making and using tools. Rather, it is the degree to which we have evolved in these capacities that defines us—a result, remarkably, of two periods of neural and cranial genetic mutations. First, a replication mutation of the ARHGAP11A gene ~2–3 million years ago—that is, after our ancestors differentiated from chimpanzees, but before branching from Neanderthals—yielded the ARHGAP11B gene, which led to neocortical expansion and increased folding (Florio et al., 2015; Florio et al., 2016). This, in turn, increased our brain volume threefold (Vallender, 2008). Second, a set of genes (SRGAP2, FOXP2, and others) that may have determined changes in both neural connectivity and the shape of our skull (the latter allowing our brains, including the all-important frontal cortex, to expand), giving rise to our unique cognitive and linguistic capabilities (Benítez-Burraco et al., 2015). These modifications allowed a much greater ability to envision, convey, and create ever-increasing powerful tools.

That being said, while Artificial Intelligence (as well as its variants and related technologies) have been introduced relatively recently, precursors in the forms of myth, logic and invention are known to have existed from antiquity onwards. In ancient Greece, myths of Hephaestus and Pygmalion incorporated the idea of intelligent robots and artificial beings; Archytas of Tarentum's jump to actually constructing mechanical toys and models; and Yan Shi presented King Mu of Zhou with mechanical men. More abstract achievements in logic and mathematics—including Pythagoras' theorem, Aristotle's syllogistic logic, and Euclidian geometry—appeared between the 6th and 3rd centuries BCE, with our ability to imagine and construct ever-increasing sophisticated and diversified tools, leading at an accelerated rate to an ever greater diversity, including: moveable type printing (Bi Sheng, 1041~1048); movable type *mechanical* printing (Guttenberg, 1450); the first mechanical digital calculating machine (Pascal, 1648); a universal calculus of reasoning (Leibniz, 1673); the first punched card programmable machine (Jacquard, 1801); a programmable mechanical calculating machine (Babbage and Byron, 1832); modern propositional logic (Frege, 1879, expanded by several individuals, including Russell, Godel and Church); advanced formal logic (Russell and Whitehead, *Principia Mathematica*, *3 volumes,* 1910, 1912 and 1913); universal Turing machine (Turing, proposed 1936-37); *A Logical Calculus of the Ideas Immanent in Nervous Activity* (McCulloch & Walter Pitts, 1943); *Turing Test* (Turing, 1950}; *Programming a computer to play chess* (Shannon, 1950); *Three Laws of Robotics* (Asimov, 1950); the term *Artificial Intelligence* (McCarthy, Dartmouth Conference, 1956); *Logic Theorist*, the first running Artificial Intelligence program (Newell, Shaw and Simon, 1956); *ELIZA* dialogue simulation (Weizenbaum, 1965); *The Perceptron* (*Artificial Neural Networks*, Rosenblatt, 1958); conceptual dependency model for natural language understanding (Schank, 1969); *SHRDLU* language understanding program with a robot arm that carried out instructions typed in English (Winograd, 1971); massively parallel Connection Machine (Hillis, 1987); *Neuromorphic electronic systems* (Mead, 1990); significant machine learning, intelligent tutoring, case-based reasoning, multi-agent planning, scheduling, uncertain reasoning, data mining, natural language understanding and translation, vision, virtual reality, games, and other Artificial Intelligence advances (1990s); *Sociable Machines* and *KISMET* robot facially expressed emotions (Breazeal, 2000); NASA exploration Robotic rovers *Spirit* and *Opportunity* autonomously navigate the surface of Mars (NASA, 2004); *ASIMO* artificially intelligent humanoid robot walked as fast as humans and brought trays to customers (Honda, 2005); and Google Duplex Artificial Intelligence assistant schedules appointments via cellphone and produces high-quality human-sounding speech (Google, 2018)

Artificial Intelligence (AI)

In computer science, Artificial Intelligence (AI) is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans and other animals. Computer science defines AI research as the study of intelligent agents —any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals. More specifically, Kaplan and Haenlein define AI as "a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation" (Kaplan and Haenlein, 2019). Colloquially, the term Artificial Intelligence is applied when a machine mimics cognitive functions that humans associate with other human minds, such as learning and problem solving.

Moreover, augmentation is pursued through intelligence. While today we already have a number of smart machines, augmented machines will use their intelligence to augment themselves. Hence the shift from today's local intelligence, used to be more effective in doing the activities they are supposed to do, to the next decade where machines will become smarter by using their own intelligence to tap on ambient intelligence (other machines, humans, web- and environment-distributed AI). Baxter—an industrial robot (was decommissioned and replaced by Sawyer) manufactured by Rethink Robotics (which has now closed its doors) was a first step in that direction, being able to learn by observing its co-workers. In the longer term, machines will autonomously create symbiotic relationships that realize how to best collaborate in order create a team for approaching, solving, and/or executing a task to reach a goal.

AI will continue to be applied in signal processing—a mature technology being used in a growing number of applications with increasingly complex interactions requiring signal processing to migrate from monoscale to independent multiscale and, by the second part of the next decade, simultaneous polyscale environments. AI is also progressing in bio-interfaced machines as interactions become increasingly complex (e.g., capturing and delivering electrical signals to/from thousands of probes using deep brain stimulation).

In addition to signal processing, AI is becoming increasingly ubiquitous, with applications including optical character recognition; handwriting recognition; speech recognition; face recognition; artificial creativity, computer vision, virtual reality, and image processing; photo and video manipulation; diagnosis; game theory and strategic planning; game artificial intelligence and computer game bot; natural language processing, translation and chatterbots; nonlinear control and robotics; artificial life; automated reasoning; automation; bio-inspired computing; concept mining; data mining; knowledge representation; semantic web; email spam filtering; robotics (behavior-based robotics; cognitive; cybernetics; developmental robotics (epigenetic); evolutionary robotics); hybrid intelligent system; intelligent agents; intelligent control; and litigation.

Artificial Intelligence-related Technologies

Deep Neural Networks

Deep Neural Networks (DNN) are a layered structure of computation where each layer returns a probability that is further processed at the layer above. Probabilities are matched with the real world and change over time based on experience. Hence DNN therefore are an ideal technology for learning from experience. The tweaking of the computation may be done internally or by an external operator. Early in the next decade DNN are expected to become part of many autonomous systems, providing the capability to learn from experience, making them ever more flexible and autonomous. In the context of Symbiotic Autonomous Systems, every component, in principle, can contribute to DNN fine tuning.

Recurrent Neural Networks

Recurrent Neural Networks (RNN) are sequential structures that process and understand time evolution, and are utilized and well established in writing and speech recognition. This temporal observation is clearly relevant in Symbiotic Autonomous Systems, but while still in its early stages. RNN can be expected to become normative in the second part of the next decade.

Convolutional Neural Networks

Convolutional Neural Networks (CNN) are a class of feed-forward artificial neural networks mimicking the visual cortex in animals and are applied to image recognition. They are already part of the standard tool set for several image recognition applications. Scientists are making progress in understanding the circuitry of animals' brain, like the brain of a fly, and are investigating the effectiveness of replicating their capabilities in artificial neural networks. With a relative limited number of neurons and very little power requirements, a fly can orient itself in a 3D space whereas our artefacts require a massive amount of processing.

Machine Learning

Machine Learning is a mature technology, in the sense that it is already widely used today. Nevertheless, we can expect significant growth in its capability, due to neuromorphic chips (i.e., analog processors based on biological neurons) with increased capability and the extension of the data the it uses to increase learning-areas where industry research will be leading. By 2030, machine learning is expected to be a standard component in most systems. (Note that by the end of the next decade, neuromorphic chips supporting AI toolkits can be expected). Around 2040, a new generation of neuromorphic chips, at very low power (getting closer to bio-neural circuits in terms of power requirement) may become available as a platform to support Artificial General Intelligence (see the AGI section below). These chips will be de facto implemented in their architecture like today is done by deep/recurrent/convoluted neural networks in software running on normal chips. In turns this will make machine awareness possible and affordable.

Moreover, there will be an evolution of this functional area from today's *independence* in which the machine operates independently of the host biosystem (e.g., a pacemaker that sends impulses to the heart without being aware of the body's general situation) to *responsiveness*, where the machine senses the status of the bioentity and adapts its actions as needed) to a *continuous interaction*, and finally to a *symbiotic status* where machine and bioentity influence each other towards a common goal.

Machine Awareness

In order to get smarter, machines need to become more and more aware of their context, goals, and abilities. By far the basic enabling technologies are the capability to process the signals received through sensors from the environment (including their active observation of the environment) and the intelligence to make sense out of them. Accordingly, three phases can be identified: task awareness, goal awareness, and self-awareness.

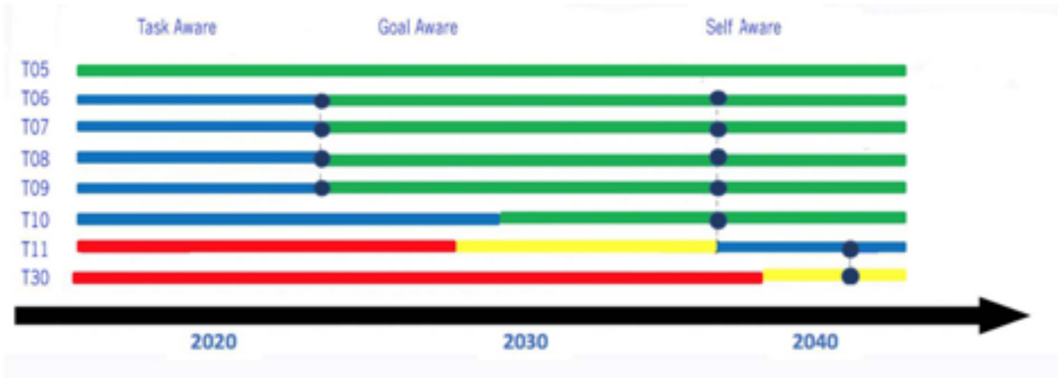

Figure 1
Timeline of context-aware machine-related technologies

Legend:
T05: Signal processing
T06: Artificial Intelligence
T07: Deep Neural Networks
T08: Recurrent Neural Networks
T09: Convoluted Neural Networks
T10: Machine Learning
T11: Artificial General Intelligence
T30: Sentient Machines

Context-Aware Machines

As machines can harvest and process more data from their environment to create a model of the environment and to perceive their role and interaction with the environment, they are shifting from being passive to becoming active towards an understanding of the environment. There are a few areas that are already seeing this evolution with self-driving cars at the forefront (it is likely that in the military area there is faster evolution, but progress is not disclosed). The context-awareness has already reached the mass market in products like robotic vacuum cleaners, but it is focused on very specific environment niches. A more generalized context-awareness will take a few more decades to become the norm.

Machine Sentience

It is generally accepted that in order to be sentient an entity should be able to sense, perceive, think, feel and experience subjectivity. Unsurprisingly, then, if there is not a consensus on machine awareness metrics, it is not unexpected that there is even less so regarding sentient machines—that is, machines that have a self and recognize themselves as a "living" entity with a goal and a sense of fulfilment. That said, there are technologies that clearly cover the sense and perception aspect; support processing that can be described as thinking; and machines that can be programmed with a sense of identity (subjectivity). The difficult part, however, is related to feelings: While a machine can be programmed to respond to rewards, as well as having a sense of an undesirable situation, it is currently unknowable if these machine states translate into feelings or emotions. These are complex states that require the participation of several biological structures and functions in the mammalian brain, including the frontal lobe, the olfactory bulb, the thalamus and hypothalamus, the hippocampus, and the amygdala—all parts of the limbic system. While a hybrid robot might *simulate* such processes, it would remain to be seen whether that would lead to *experience* the feelings necessary to correlate with the attending circumstances.

Affective Computing

An endeavor complementing and relating to AI/AGI, affective computing is the development of technology capable of recognizing, interpreting, processing, and simulating (and eventually actually possessing) human or human-analogous affect, the goal being to provide "computing that relates to, arises from, or influences emotions" (Picard, 1995), and realizing that while emotional arousal data has been collected for over a century, "technology can now measure, communicate, adapt to, be adapted by, and transform emotion. (Picard, 2010). The MIT Affective Computing Group is applying these capabilities to "help people gather, communicate, and express emotional information and to better manage and understand the ways emotion impacts health, social interaction, learning, memory, and behavior" (MIT Affective Computing Group).

Essentially, affective computing seeks to give computers the capability to take into account emotion related to human cognition and perception, a key result being Digital Twins with the capacity to more effectively support humans, as well as they themselves being able to make better decisions. Current investigations into applying affective computing in the enhancement of applications include computer-assisted learning, perceptual information retrieval, and human health and interaction.

Artificial General Intelligence (AGI)

While Artificial Intelligence can be said to have a rudimentary, narrow awareness of basic environmental activity or changes (for example, signal frequencies and document edits), it will be Artificial General Intelligence with human-like characteristics of self-awareness and conscious reflection that will emerge. In this sense, AGI is rapidly becoming a mature, industrial grade technology expected to become a common tool in industry by the middle of the next decade—and as such, will likely be a subsystem that is invoked as needed within AGI environments.

Artificial General Intelligence refers to a machine intelligence that can successfully perform any human intellectual task. AGI is a primary goal of some AI research and a common topic in future studies and science fiction. (Note that some researchers refer to Artificial General Intelligence as *strong* AI, others assign the term AGI to machines capable of experiencing consciousness.

At the same time, AGI is not a requirement for achieving machine awareness—and it is not given that AGI will become possible by 2050 (although some researchers are convinced that this will take place within the next 20 years). In fact, there is no consensus on the achievability of AGI, its unique definition, or metrics for determining when AGI has become a reality. Therefore, in the absence of an unexpected breakthrough, AGI will primarily be a matter of academic research for the next decade—and while a few companies, such as Google, are involved, general industry is not expected to become active in AGI before the 2040 timeframe. That said, acceleration may derive from results of ongoing brain projects—for example, Human Brain6, Brain Initiative7, and Human Connectome Project—and as discussed above, AGI is not required to support basic machine awareness, with AGI demonstrating self-awareness.

Even with the above considerations, AI has progressed in the last decade, due largely to vast computation capabilities and access to Big Data in specific areas (e.g., speech recognition and understanding). However, creating AGI has proven elusive to the point that some experts are not optimistic on achieving it in the coming decades—but others assert that it will be a reality by 2030. In reality, it is becoming difficult to place a boundary between AI and AGI (for example, will AGI include emotions and self-awareness?). AI is bound to extend its fields of application to the point at which it might be practically indistinguishable from AGI.

A development on the forefront of AGI research, startup Artificial General Intelligence Inc. recently published a paper that articulates the fundamental theory of consciousness used in the Independent Core Observer Model (ICOM) research program (Kelley and Twyman, 2018) and the consciousness measures as applied to ICOM systems and their uses in context including defining the basic assumptions for the ICOM Theory of Consciousness (ICOMTC) and associated related consciousness theories (CTM, IIT, GWT, etc.) upon which ICOMTC is built. The paper defines the contextual experience of ICOM based systems in terms of a given instances subjective experience as objectively measured and the qualitative measure of Qualia in ICOM based systems, stating that ICOM is a cognitive architecture based on the ICOM Theory of Consciousness for independent self-aware intelligence that is able to experience things emotionally with an internal subjective experience, making decision purely based on how it "feels" about a thought (Kelley and Waser, 2018).

The paper notes that the Independent Core Observer Model Theory of Consciousness is partially built on the Computational Theory of Mind, where an AGI research core issue is the absence of objective consciousness: The related measurements are ambiguous due to the lack of agreed-upon objective measures of consciousness. Therefore, to continue serious work in the field we need to be able to measure consciousness in a consistent way that is not presupposing different theories of the nature of consciousness and further not dependent on various ways of measuring biological systems. Rather, the focus must be on the elements of a conscious mind in the abstract—and with the more nebulous Computational Theory of Mind, research into the human brain does show some underlying evidence to the same.

The authors made several assumptions to provide an experimental reference point when designing AGI cognitive architecture:

- *Qualia is the subjective experience that can be measured external to the system if the mind in question is operating under known parameters.*
- *Humans are not able to make logical decisions.* Looking at the neuroscience behind decisions the researchers have already proven that humans make decisions based on how they feel and not based on logic.
- *Subjective experience can be measured and understood.* As a matter of principle in this paper, the traditional view that the subjective nature of experience is purely subjective is rejected. Even scientists in the field frequently consider consciousness the realm of ontology and therefore philosophy and religion. The researchers' assumption is that this is false.
- *Consciousness can be measured.* Despite this enormous commitment to the study of consciousness on the part of cognitive scientists covering philosophical, psychological, neuroscientific and modelling approaches, until now no stable models or strategies for the adequate study of consciousness have emerged, the exception being the ICOMTC. The researchers also believe that they can measure consciousness regarding task accuracy and awareness as a function of stimulus intensity that applies to brain neurochemistry as much as the subjective experience from the point-of-view of systems such as ICOM.
- *The researchers have a concrete definition of" subjective" as a concept.* "Subjective" is then defined as the relative experience of a conscious point of view that can only be measured objectively only from outside the system, where the system in question experiences things "subjectively" as they relate to that systems internal emotional context.
- *Consciousness is a system that exhibits the degrees or elements of the Porter method for measuring consciousness regarding its internal subjective experience*. While the dictionary might define consciousness subjectively in terms of being awake or aware of one's surroundings, this is a subjective definition—but the researchers need an "objective" definition

to measure. Therefore, the latter is assumed for the context of ICOM research and the ICOMTOC.

Artificial Superintelligence (ASI)

Artificial Superintelligence is a hypothetical agent that possesses intelligence far surpassing that of the brightest and most gifted human minds. (University of Oxford philosopher Nick Bostrom defines superintelligence as "any intellect that greatly exceeds the cognitive performance of humans in virtually all domains of interest" (Bostrom, 2014). Artificial Superintelligence (ASI) is artificial intelligence that surpasses the brightest human minds in all areas., thereby surpassing human intelligence-equivalent Artificial General Intelligence. Moreover, several researchers observe that computers today are better than humans in several areas (e.g., calculus) and are getting increasingly better in a range of fields. This implies that once AI reaches the AGI, it may become an ASI—thereby bypassing the AGI transition. In this scenario, machines will not achieve human intelligence equivalence, segueing directly from human intelligence-inferior to human intelligence-superior. Note, however, that ASI does *not* imply Artificial Consciousness.

Technological researchers disagree about how likely present-day human intelligence is to be surpassed. Some argue that advances in “narrow” artificial intelligence (AI) will probably result in general reasoning systems that lack human cognitive limitations. Others believe that we will evolve or directly modify our biology to achieve radically greater intelligence. A number of futures studies scenarios combine elements from both of these possibilities, suggesting that humans are likely to interface with computers, or upload their minds to computers, in a way that enables substantial intelligence amplification.

Superintelligence may also refer to a property of problem-solving systems (e.g., superintelligent language translators or engineering assistants) whether or not these high-level intellectual competencies are embodied in agents that act in the world.

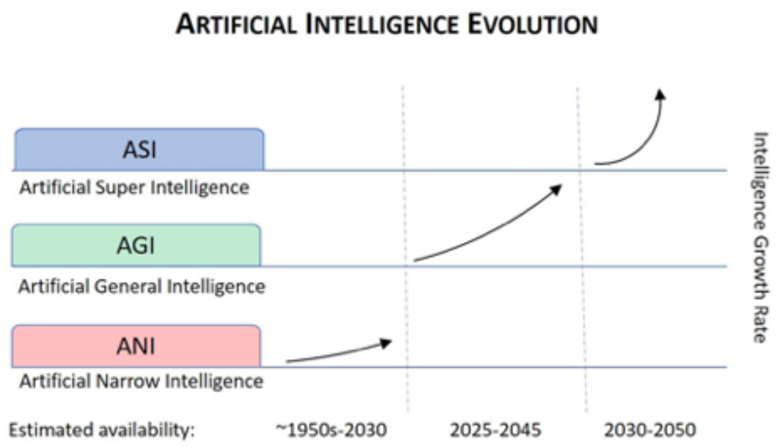

Figure 2
Artificial Intelligence Evolution

Some researchers believe that Artificial Superintelligence will likely follow shortly after the development of Artificial General Intelligence. The first generally intelligent machines are likely to immediately hold an enormous advantage in at least some forms of mental capability, including the capacity of perfect recall, a vastly superior knowledge base, and the ability to multitask in ways not possible to biological entities. This may give them the opportunity to—either as a single being or as a new species—become much more powerful than humans, and to displace them.

In a survey of the 100 most cited authors in AI (as of May 2013 (Müller et al., 2016), according to Microsoft academic search), the median year by which respondents expected machines "that can carry out most human professions at least as well as a typical human" (assuming no global catastrophe occurs) with 10% confidence is 2024 (mean 2034, st. dev. 33 years), with 50% confidence is 2050 (mean 2072, st. dev. 110 years), and with 90% confidence is 2070 (mean 2168, st. dev. 342 years). These estimates exclude the 1.2% of respondents who said no year would ever reach 10% confidence, the 4.1% who said 'never' for 50% confidence, and the 16.5% who said 'never' for 90% confidence. Respondents assigned a median 50% probability to the possibility that machine superintelligence will be invented within 30 years of the invention of approximately human-level machine intelligence.

Mediated Artificial Superintelligence (mASI)

Mediated Artificial Super Intelligence is an incremental in-process AI > AGI > ASI evolution goal. Demonstrated in the lab, and usable now in environments from research to business, mASI provides ASI superhuman level cognition without ethical or safety concerns—and markedly reduces training time (Jangra et al., 2013). mASI requires human support at all times to mediate the process to the degree that its thinking and operations do not function without human involvement. The mASI cognitive architecture the researchers are using is based on the ICOM Theory of Consciousness (Kelley and Twyman, 2018), which itself is based on Global Workspace Theory (Baars), the Computational Theory of Mind (Rescorla, 2016), and Integrated Information Theory (Tononi, 2014)—and at some level is demonstrably conscious (Yampolskiy, 2019) (Kelley, peer review pending).

Envisioning Far-Future Symbiotic Autonomous Systems Artificial Intelligence

Looking further into the AI future within an SAS context, and assuming that the increasingly human-like intelligence demonstrated in AGI and ASI will continue and likely accelerate, the theoretical systems proposed in Table 1 (Dambrot, 2019) may be seen as a feasible vision of far-future Artificial Superintelligence variants. Perhaps the most powerful concept is the Quantum Computing Artificial Superintelligence (qASI) variant, given the hypothetical properties of such a system (quantum entanglement-based communications, superposition-based parallel processing, superluminal instantaneous processing speed, and infinite number of threads). Such a massively distributed real-time system could enable space-and time-agnostic metahuman intelligence without the characterizing current systems.

Table 1

Proposed Mediated ASI	Key Properties	Benefits
Distributed Artificial Superintelligence (daisy)	Networked independent ASI nodes form a collective mind	• Multifocus distributed superintelligence system far beyond superhuman AGI • Distinctly nonhuman-like superintelligence
Genetic Computing Artificial Superintelligence (gASI)	Genetic computing-based sASI	• Reduced footprint • Increased mediation speed • CRISPR-based modification
Quantum Computing Artificial Superintelligence (qASI)	Quantum entanglement-based sASI	• Quantum entanglement-based communications • Superposition-based parallel processing • Superluminal instantaneous processing speed • Infinite number of threads

Conclusion

The accelerating evolution in Symbiotic Autonomous systems, Digital Twins and increasingly human-equivalent and superior generations of Artificial Intelligence —and the synergy between these three domains—present an expanding integration of biology, technology and biotechnology in which separations between these now distinct classes of entities will gradually disappear. As these trends continue, expand and accelerate, it will be just a matter of time for this state of affairs to become a forgotten memory.

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