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Theoretical and hypothetical pathways to real-time neuromorphic AGI/post-AGI ecosystems

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Abstract

While *Homo sapiens* is without doubt our planet's most advanced species capable of imagining, creating and implementing tools, one of the many observable trends in evolution is the accelerating merger of biology and technology at increasing levels of scale. This is not surprising, given that our technology can be seen from a perspective in which the sensorimotor and, subsequently, prefrontal areas of our brain increasingly extending its motor (as did our evolutionary predecessors), perceptual, and—with computational advances, cognitive and memory capacities—into the exogenous environment. As such, this trajectory has taken us to a point in the above-mentioned merger at which the brain itself is beginning to meld with its physically expressed hardware and software counterparts—functionally at first, but increasingly structurally as well, initially by way of neural prostheses and brain-machine interfaces. Envisioning the extension of this trend, I propose theoretical technological pathways to a point at which humans and non-biological human counterparts may have the option to have identical neural substrates that—when integrated with Artificial General Intelligence (AGI), counterfactual quantum communications and computation, and AGI ecosystems—provide a global advance in shared knowledge and cognitive function while ameliorating current concerns associated with advanced AGI, as well as suggesting (and, if realized, accelerating) the far-future emergence of Transentity Universal Intelligence (TUI).

Keywords: artificial general intelligence; counterfactual quantum entanglement; enplants; graphene; mediated artificial superintelligence; neural prosthetics; photonics; recurrent neural networks; spintronics; synthetic genomics; transdisciplinarity; transentity universal intelligence

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1. Introduction

While investigating the overall space comprising real-time neuromorphic Artificial General Intelligence ecosystems is itself a complex task, the constituent elements—Artificial General Intelligence, Neuromorphic Computing, and Counterfactual Quantum Entanglement—are themselves (as well their nested components) highly complex At the same time, this paper presents a review of the relevant literature augmented by relevant historical events, identifying science and technology trends, and envisioning hypothetical but probabilistically viable future scenarios.

2. Core Technologies

The above triad of technologies establishing the foundation not only of our path towards a technofuture of real-time neuromorphic AGI ecosystems, but also of changes that while foreseeable beyond that horizon, are not yet able to be fully realized.

2.1. Artificial General Intelligence

Artificial General Intelligence (AGI) is a well-researched field focused on developing human-analogous AI (i.e., a machine intelligence that can successfully perform any human intellectual task), and in a broader context, functionally equivalent with human cognitive, emotional and other neural capacities other than consciousness. However, the majority of AGI R&D to date has not achieved expected goals, generating an expanding circular dilemma:

- Due largely to industry demand, AGI is increasingly addressing specific fields and issues—historically the realm of standard, or narrow, AI
- This narrowing focus is negatively impacting AGI funding and thereby momentum
- Consequently, expectations of AGI being developed as projected are affected

Moreover, most current AGI models are based on logic and inner dialogue rather than the affective foundation of human cognition, in which perception and emotion precede and influence cognition and decision-making [1].

Rather than having an AGI focus on intelligence in the form of resolving goals, tasks and problems when making decisions, the Independent Core Observer Model (ICOM) [2] utilizes emotion and motivation as do humans. Moreover, to provide AGIs with the most salient but elusive aspect of human awareness—the qualia of consciousness—is the ICOM Theory of Consciousness (ICOMTC). [3].

Emotion and Perception

A causal or associative connection between emotion and visual perception has for the most part been seen as unlikely at best. Nevertheless, it was shown that not only is this a viable physiological association, but a surprisingly variegated one at that. The researchers concluded (Table 1: Emotion/Perception Associations) that this emotion/perception interaction “allows affective information to have immediate and automatic effects without deliberation on the meaning of emotionally evocative stimuli or the consequences of potential actions” [4].

Computational Empathy

Defined as the capacity to relate to another’s emotional state, empathy has recently been modeled in artificial agents by leveraging advances in neuroscience, psychology and ethology. Expanding the definition of empathic capacity as “the capacity to relate and react to another’s emotional state, consists of emotional communication competence, emotion regulation and cognitive mechanisms that result in a broad spectrum of behavior” [5] has allowed researchers to propose an approach for modelling that incorporates affective computing, social computing and dialogue research techniques. While the scientists conclude that further research is needed, they note that a successful computational model of empathy could address ethical and moral issues being discussed in AI community.

Table 1. Emotion/Perception Associations

Emotion	Perception	Benefits
Fear	Low-level visual processes	• Increases probability of perceiving potential threats
Sadness	Visual illusions	• Positive moods encourage maintaining current perspective • Negative moods encourage a change
Goal-directed Desire	Apparent size of goal-relevant objects	• Objects that are emotionally and motivationally relevant draw attention and may become more easily detected by appearing larger • Perception is systematically altered in ways that may aid goal attainment • Emotion can change spatial layout to motivate economical actions and deter potentially dangerous actions

Source: Zadra, J. R., & Clore, G. L.: Emotion and perception: the role of affective information. Wiley Interdisciplinary Reviews: Cognitive Science, 2(6), 676–685 (2011).

Human Level Machine Intelligence: Researchers' Predictions

Published as a book chapter in 2016 [6], a 2012-2013 survey of Artificial Intelligence researchers asked the year they predicted that Human Level Machine Intelligence (HLMI)—analogous to AGI, being defined as machine intelligence that outperforms humans in all intellectual tasks—and assign a 10%, 50%, or 90% chance of achieving HLMI at a given year, resulting in the following resulting medians: 2040: 50% confidence, 2080: 90% confidence, and Never: 20% confidence.

More specifically, of the 100 most cited AI authors in, 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.

Artificial Superintelligence

Artificial Superintelligence (ASI)—an AI variant more powerful than AGI in breadth, depth and performance—has been succinctly defined as "any intellect that greatly exceeds the cognitive performance of humans in virtually all domains of interest" [7].

A modified hive ASI, Mediated Artificial Superintelligence (mASI)—demonstrated in the lab and usable in environments from research to business—mASI provides ASI superhuman level cognition without ethical or safety concerns, and markedly reduces training time [8]. The key to mASI is its requirement that human support must be available at all times to mediate the process to the degree that the mASI's thinking and operations do not function without human involvement.

As discussed earlier, the mASI cognitive architecture is based on the ICOM Theory of Consciousness [9], which itself is based on Global Workspace Theory [10], the Integrated Information Theory of Mechanisms of Consciousness [11]—and at some level is demonstrably conscious [12,13].

That being said, it should be kept in mind that the mASI is not currently an independent AGI but has the potential to do so if and when the right context arises. Moreover, based on ICOM-related research to date, the original goal of a self-motivating emotion-based cognitive architecture similar in function but substrate independent appears to have been proven possible.

Given these recent AGI/ASI/mASI developments—most significantly that researchers have now developed an operational mASI—the survey estimates above may have to be reevaluated in the near future.

2.2. Neuromorphic Computing

Neuromorphic Computing emerged when in his 1950 paper, Alan Turing opened with the question "Can machines think?" [14]. His exploration of biological nervous systems, neurons and synapses as models for those investigating not only benefitted early AI, but also computer vision and speech recognition. These trends led to greater emphasis on network paradigms when researching cognition and general AI [15].

Developing AGIs that base their efforts on AI concepts and code may be taking the wrong approach to developing a human-equivalent functional cognitive structure: The combination of evolutionary neurobiology and self-organized learning—i.e., our advanced mammalian neocortices are not formally programmed, as is the case with computational hardware. This was first realized in 1958 when Frank Rosenblatt introduced the Perceptron [16]—an early neural network modelled on a biological neuron.

The Perceptron was later followed in the 1980s (amongst the efforts of other researchers) by Neuromorphic Electronic Systems, developed and named by Carver Mead—who had previously made advances in designing and developing a range of electronics that formed the basis for VLSI (very-large-scale integration) devices—and described in his paper on electronic modelling of human neurology and biology published in 1990 [17].

2.3. Counterfactual Quantum Entanglement

In contrast to what has previously been considered factual about quantum entanglement, the appropriately termed Counterfactual Quantum Entanglement is—as its name indicates—counterintuitive in several ways when seen from the perspective of pre-counterfactual quantum mechanics, primarily particle entanglement without particle transmission [18]. Counterfactual Quantum Entanglement has, in turn, given rise to Counterfactual Quantum Communications and Counterfactual Quantum Computation. Moreover, a key component of quantum mechanics is Quantum Disentanglement [19], which is a key aspect of Counterfactual Quantum Communications and Counterfactual Quantum Computation.

Counterfactual Quantum Communications

In contrast to standard communications, Counterfactual Quantum Communications (CFC) counterintuitively also allows information exchange without particle interaction [20]. Moreover, it has been shown that a secret key distribution can be accomplished even though a particle carrying secret information is not in fact transmitted through the quantum channel. The proposed protocols can be implemented with current technologies—including photonics [21]—and provide practical security advantages by eliminating the possibility that an eavesdropper can directly access the entire quantum system of each signal particle [22].

A long-standing physics assumption has been that in order for information to travel between two parties in empty space, physical particles (often identified as Alice and Bob) must travel between them. However, the *chained quantum Zeno effect* (also referred to as the Turing paradox)—in which an unstable particle, if observed continuously, will never decay—allows investigators to demonstrate how information can be successfully transferred between the two particles without any physical particles traveling between them [23].

Counterfactual Quantum Computing

In the counterintuitive world of quantum information processing, logic and intuition frequently are at odds, such as by using the chained quantum Zeno effect. In counterfactual computation (CFC), inference can achieve certainty, while decoherence-induced errors can be eliminated—and by using a modified version of the quantum Zeno effect to increase counterfactual inference probability to unity and a computational result can be determined without the computer running [24]. Moreover, counterfactual quantum computing has been demonstrated to achieve high efficiency of up to 85%—well above the 50% limit for a standard CFC scheme [25].

2.4. Real-Time Neuromorphic AGI Ecosystems

Neuromorphic Ecosystems can be based on a surprisingly wide range of substrates—some of which are theoretical at this time—including carbon variants, electrolytes, photonics, spintronics, quantum mechanics, synthetic genomics, and multifactor systems. Moreover, hypothetical Real-Time Neuromorphic AGI Ecosystems that utilize counterfactual quantum communications to operate in real time networks; ecosystems that are based on Artificial General Intelligence; and those that incorporate both components.

Carbon

Carbon (chemical element C with atomic number 6) has atoms that can form differently structured allotropes—each with significantly different physical properties—by bonding in various configurations (Fig. 1: Carbon Allotropes). Of these, the most familiar allotropes—both naturally occurring and synthesized—are graphene, graphite, diamond, amorphous, fullerenes, carbon fiber, and carbon nanotubes.

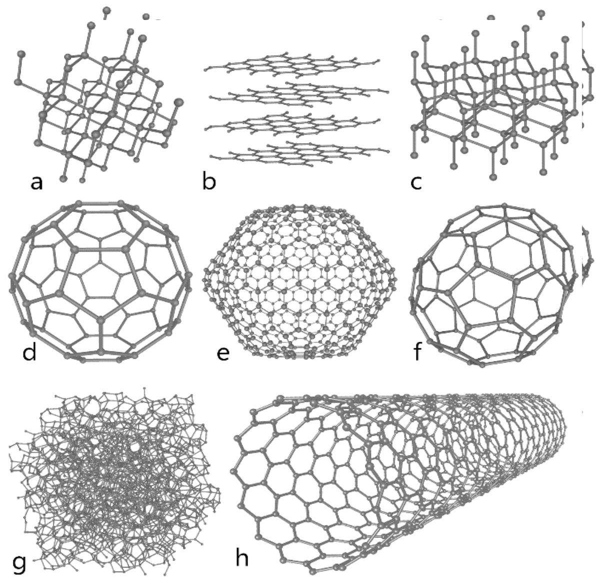

Fig. 1. Depiction of eight carbon allotropes: (a) Diamond (b) Graphite (c) Lonsdaleite (d) C60 (Buckminsterfullerene) (e) C540 (Fullerene) (f) C70 (Fullerene) (g) Amorphous carbon (h) single-walled carbon nanotube. Created by Michael Ströck (mstroeck).

Graphene

A monolayer honeycomb carbon atom lattice, graphene is the most frequently used material in neuromorphic non-biological neurons and neural networks—but while graphene's biocompatibility, high surface area electrical conductivity, and mechanical strength has benefitted neural tissue engineering, it cannot stimulate neural stem cell adhesion, proliferation, differentiation and neural regeneration—and may cause body damage. However, *graphene nanocomposites* have been shown to be efficacious in neural regeneration, as well as in neural stem cell adhesion stimulation, proliferation, and differentiation [26].

Graphene also plays a significant role in the assembly of neural networks in neural stem cell (NSC) culture, supporting functional neural circuit growth and improving neural performance and electrical signaling. In addition, NSC-differentiated neural networks can be structurally and functionally formed on graphene films, and the network activity and the efficacy of neural signal on graphene films can be strongly enhanced, suggesting that graphene would be valuable in designing graphene-based neural interfaces for regenerative medicine [27].

Memristors

In large-scale neuromorphic computing systems, charge-trapping effects provide the synaptic behavior of aligned carbon nanotube (CNT) synaptic transistors—which provide key improvements when compared with conventional memristors—by enabling a large on/off ratio in carbon nanotube channel conductance analog programmability. Moreover, tuning carbon nanotube synaptic characteristics optimizes learning rate and attains higher recognition rate [28].

With increasing development and diversity of artificial intelligence and Artificial Neural Networks (ANNs), interest in and development of memristors as synaptic building blocks for neuromorphic systems—where each synaptic memristor exhibits multilevel accessible conductance states yet can easily be converted from conventional binary to synaptic analog states—are accelerating. The researchers involved state that this approach may lead to the development of a flexible intelligent electronic system providing easy access to AI-based services [29].

Significant interest in the use of memristors (also referred to as *nanoscale resistive switching devices*) for memory, logic and neuromorphic applications. While the cause of resistive switching effects in dielectric-based devices is typically thought to be cause by transelectrode conducting filament formation—but to address existing controversy, researchers investigated nanoscale conducting filaments using direct transmission electron microscopy imaging, and structural and compositional analysis, finding that cation (positively charged ion) transport can control dielectric film filament growth—and that for a particular device under specific operation conditions, interaction of different filament growth dynamics will determine filament growth [30].

Rapid progress in memristor technology since its emergence in 2008 have led to a number of memristor-based neuromorphic hardware systems—and which the investigators have identified on-chip memory and storage, biologically inspired computing and general-purpose in-memory computing as three areas of potential memristor technological impact. Given the continual role of biology in inspiring our development of methods for achieving lower-power and real-time learning systems, and the specific innovations in memristors, future computing systems will need to aspire to reach beyond individual domains, transitioning into transdisciplinarity (Section 3.9: Transdisciplinary Multifactor AGI Ecosystems), taking into account neuroscience, physics, chemistry, computer science, electrical and computer engineering, and other disciplines [31].

Photonics

Photonics (encompassing both optics and optoelectronics) is an emerging photon-based technology with the potential to yield non-biological neuromorphic neurons and neural networks by devising an all-optical neurosynaptic system. Implemented as an all-optical *spiking neural network* (Section 3.4: Spiking Neural Networks)—which closely imitates natural neural networks by incorporating time, firing only when a membrane potential reaches a specific value—on a nanophotonic chip, photonic neurosynaptic networks comprise supervised and unsupervised learning, high speed, high bandwidth, and direct processing of optical telecommunication and visual data [32].

At a significantly larger scale, a model of a previously proposed Superconducting Optoelectronic Network (SOEN)—a novel hardware platform for neuromorphic computing based on superconducting optoelectronics— has many features of neural information processing. Next planned steps include verifying current models against network simulations, designed networks and experimentally fabricated networks, as well as implementing an energy and area evaluation of the networks produced to identify networks that minimize energy and wiring [33].

Spiking Neural Networks

Spiking Neural Networks (SNNs) are computationally more powerful than other artificial neural network models regarding the number of neurons required. Specifically, a concrete biologically relevant function is exhibited which can be computed by a single spiking neuron (at biologically utilitarian values), but which requires hundreds of hidden units on a sigmoidal neural network. (Sigmoid functions—i.e., a neural network element computes a linear combination of its input signals and applies a sigmoid function to the result—can be used in artificial neural networks to introduce nonlinearity in the model.) Moreover, this computational model has at least the same computational power as comparably sized neural networks of the first two generations (i.e., multilayer perceptions and sigmoidal neural networks) [34]. (It should be noted that while at the time this paper was published in 1997, theoretical research in spiking neuron networks was not a new research topic—a history of investigation theoretical neurobiology, biophysics, and theoretical physics was established—a mathematically rigorous analysis of SNN computational power had not yet been pursued.)

While Spiking Neural Networks are motivated by biological information processing's massively parallel communications and processing of sparse, asynchronous binary signals, neuromorphic hardware-based SNNs display beneficial properties that include low power consumption, fast inference, and event-driven information processing. This makes them interesting candidates for the efficient implementation of deep neural networks, the method of choice for many machine learning tasks. As the latter could likely benefit Deep Neural Networks (DNNs)— an artificial neural network with multiple layers between input/output layers—incorporating recurrence into deep SNNs (possibly described as Recurrent Deep Spiking Neural Networks, or RDSNNs) stands to improve temporal information storage and integration [35].

Spintronics

Spintronics (a portmanteau for *spin transport electronics*, also known as *spin electronics*) is the study of the intrinsic spin of the electron and its associated magnetic moment, in addition to its fundamental electronic charge, in solid-state devices. At the same time, neuromorphic computing can perform complex tasks that cannot be readily executed by conventional von Neumann machines—but the human brain efficiently processes information by way of neuronal and synaptic dynamics, which stimulate effective implementation of artificial spiking neural networks. However, spin–orbit torque switching dynamics in antiferromagnet/ferromagnet heterostructures has shown the material system's capability to form artificial neurons and synapses for asynchronous spiking neural networks. Based on the system's capability to manifest either binary or analog behavior as a function of device size, key synaptic and neuronal functions are reproduced in the same material and based on the same working principle. These results open a path toward executing cognitive tasks with the efficiency of the human brain with spintronics-based neuromorphic hardware [36].

Quantum Biology

It has been generally held that quantum fluctuations are self-normalizing and so have no consequential impacts in the brain. However, this may well not be accurate: the nervous system is a non-linear complex system, in which case such fluctuations may be augmented rather than negated, thereby affecting neural processing. Moreover, relatively temporally-extensive quantum coherence has been observed in bacteria and marine algae photosynthesis, retinal photoreceptor rhodopsin, avian magnetoreception in retinal cryptochromes, olfactory system, and quantum tunnelling in enzymes, motor proteins, and other biomolecules [37].

Looking ahead, quantum biology points to the emergence of bio-inspired quantum nanotechnologies able to operate in noisy room temperature surroundings [38]. Moreover, these envisioned devices—their descriptor perhaps merging into a *de novo* portmanteau such as bioquantechnology—might enhance future neuromorphic AGI/post-AGI ecosystems with human neural structure and function.

Quantum Stochasticity

While a classical (i.e., non-quantum) dynamical system may appear random in particular circumstances, this apparent random process—known as stochasticity—differs from quantum stochasticity: The latter entails both physical- and application-based [39].

While it seems classically improbable that the nervous system can display macroscopic quantum events, including quantum entanglement, superposition or tunneling, there *is* path by which quantum events might influence the brain activity. Conventional wisdom holds that quantum fluctuations in macroscopic objects are inconsequential due to self-averaging—but with nonlinear complex systems, this assumption might be misleading: In chaotic systems, due to high sensitivity to initial conditions microscopic fluctuations may be amplified upward and thereby affect the system's output. Stochastic quantum dynamics thereby might alter the outcome of neuronal computations, not by generating classically impossible solutions, but by influencing the selection of many possible solutions. Moreover, these and other recent theoretical proposals and experimental results in quantum mechanics, complexity theory and computational neuroscience suggest that biological evolution is able to take advantage of quantum computational acceleration [40].

Quantum Dots

In addition to being one of the most well-received nanoscale memristor devices (MDs) for Big Data and other applications requiring very large information storage capacity, the Resistive Random Access Memory (RRAM) conductive filaments' random formation displays a very broad distribution. Specifically, the RRDM MD self-assembled lead sulfide (PbS) quantum dots (QDs) improve RRAM uniformity of switching parameters in a process relatively straightforward compared with alternative methods. These achievements offer a new method of improving memristor performance, which can significantly expand existing applications and facilitate the development of artificial neural systems. In addition, a different quantum dot—the Networked QD (NQD)—was successfully implemented with comprehensive biosynaptic functions and plasticity [41].

Neurofunctional Computing

Strictly speaking, neuromorphically identical substrates are not necessarily required in order to establish isomorphic neural functionality between $N \geq 2$ neural substrate variants. Therefore, neuromorphic solutions can be specific hardware independent or semi-independent, two examples of which being Electrolyte Gating and Learning-to-Learn:

- The brain's data information processing operates in a neural network where neurons are interconnected by a vast number of synapses within an electrochemical environment in which, for example, a variety of hormones regulate global network function. While this regulatory homeoplasticity is rarely found in neuromorphic devices, researchers studying Electrolyte Gating have recently reported demonstrated global homoplastic control of organic device environments, demonstrating the possibility of highly complex functional biotechnological neuromorphic ecosystems comprising neuromorphic devices requiring only minimal hardwired connectivity [42].
- Learning-to-Learn (L2L) accelerates the learning of tasks that are partially related to previous tasks by extricating previously learned data—and L2L is highly suitable for processing high computation volumes by accelerated neuromorphic hardware [43].

2.5. Synthetic Genomics

A subdomain of synthetic biology focused on redesigning pre-existing life forms and/or on artificial gene synthesis to create new DNA or entire lifeforms, synthetic genomics may provide a biological route to an augmented neural environment. The most dramatic illustration to date of synthetic genomics' capabilities is the 2010 creation of a *synthetic cell*—that is, a biological cell controlled not by genome engineering-modified natural genomes, but rather host cell control by a computer-designed genome assembled from chemically synthesized DNA (in this case, a synthetic *Mycoplasma mycoides* genome transplanted into *M. capricolum*) [44].

Regarding future synthetic genomic achievements, a synthetic genome that expresses a modified neuron with quantum communications and accelerated operational capacities functions. This currently hypothetical *enplant* (***en**dogenous im**plant***) [45] could then function as a node in a real-time translocal biotechnological neuromorphic ecosystem.

3. Transdisciplinary Multifactor AGI Ecosystems

Transdisciplinarity merges discrete scientific and technological domains and transcends traditional boundaries in order to synthesize *de novo* conceptual, theoretical, methodological, and translational innovations.

By comparison, multidisciplinarity draws on knowledge from different disciplines that remains within their boundaries, while interdisciplinarity analyzes, synthesizes and harmonizes links between distinct disciplines into a coordinated and coherent whole [46].

3.1. Technofuture Scenarios

There is a range of futurology tools [47], knowledge, skills, and experience, and that can be brought to bear when envisioning alternative futures and evaluating their likelihood and impact—but these are not enough without engaging the tryptich of *imagination, intuition* and *insight* that, if taken together, may approximate Albert Einstein's *Gedankenexperiment* (i.e., *thought experiment*) that he used to describe his preference for conceptual rather than experimental investigations—famously the theory of relativity.

Table 2. Hypothetical Future Artificial Superintelligence (ASI) Variants

Proposed Mediated ASI	Key Properties	Benefit(s)
Distributed Artificial Superintelligence (dASI)	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 ASI	• Reduced footprint • Increased mediation speed • CRISPR-based modification
Quantum Computing Artificial Superintelligence (qASI)	Quantum entanglement-based ASI	• Quantum entanglement-based communications • Superposition-based parallel processing • Superluminal instantaneous processing speed • Infinite number of threads

Source: Dambrot, S. M.: Symbiotic Autonomous, Digital Twins and Artificial Intelligence: Emergence and Evolution. Mondo Digitale. YEAR XVII N.81 (2019)

3.2. Envisioning Far-Future Artificial Intelligence Variants

Looking further into the AI future, and assuming that the increasingly human-like intelligence expected in AGIs/ASIs will continue evolving and likely accelerate, the theoretical systems proposed in Table 1 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 (counterfactual quantum entanglement-based communications, simultaneous superposition-based parallel processing, synthetic genomics, and other factors).

Such a massively distributed real-time system could enable space-and time-agnostic networks comprising metahuman intelligence without the limitations of today's systems [48].

3.3. Simultaneously Connected Multiple Exoselves

At the same time, however, as such an environment achieves normalcy, the number of experienced physical and virtual exoselves would not only increase but come to be experienced as normal—and if these quantum links were to be unpredictably interrupted due to sudden disentanglement caused by quantum decoherence, the human and AGI/ASI sense of loss, however brief, of otherwise present exoselves—of which there is no inherent numerical limit [49]—might cause the bioself to experience a psychological response analogous to diminished cognitive function, memory loss, sensory deprivation, and/or a disorienting sense of loss and isolation [50]. Therefore, when considering a world in which humans and AGI/ASI entities will be perpetually interconnected in real-time, it is necessary to realize that if such a mesh network can be interrupted into account, the potential cause must be identified, addressed and prevented.

Unfortunately, that cause already exists—and has the potential to terminate these quantum cognitive links without any indication or warning. The quantum phenomenon termed *entanglement sudden death* (ESD)—a condition caused by decoherence on two-qubit systems, the results being degraded and potentially terminated entanglement and thereby the potential loss of what will have become to be a ubiquitous and normative network. Fortunately—and for reasons simpler than protecting projected extensive real-time multi-exoself networks—research into reversing or preventing ESD in underway, with one such investigation already showing that quantum measurement reversal on only one subsystem can avoid ESD, providing methods for practical entanglement distribution under decoherence, thereby "providing methods for practical entanglement distribution under decoherence" [51].

Relatedly, limiting exoself technology availability (e.g., by ability to afford the acquisition price or other parameter that differentiates qualified recipient demographics) would create a deprived population unable to participate in exoself benefits, and thereby cognitively disenfranchised. A situation of this nature would therefore present significant societal and ethical dilemmas.

3.4. Transhumanism/Posthumanism

As neurobiology, somatic physiology, and diminishingly small biomorphic genetically expressed nanotechnologies merge, *H. sapiens* will accelerate the current transmutation first into what might be the Transhuman *H. sapiens technología* subspecies. Beyond this point, accelerated evolution [52] will be able to transform us into a lifeform recognized as a new species, eventually followed by an ever-increasing range of genetically designed Posthuman lifeforms.

3.5. Transentity Universal Intelligence (TUI)

In the context of the postulated futures envisioned above, the utility of automatic universal translation would clearly be necessary. Fortunately, the likelihood of these scenarios emerging are also feasible given three interdigitated forms of neural enplants (Section 2.5: Synthetic Genomics) in part due to the possibility of those wishing or needing to utilize these technologies may have dramatically different physiologies, modes of communication and sociocultural parameters. Note that while herein proposed TUI components—Real-Time Bidirectional Multistream Neural⇔Speech Signal Transcoder (MSNSST), Real-Time Bidirectional Multinode Interlingua Translator (MNIT), and Counterfactual Quantum Communications (CFC)—are at conceptual, exploratory or basic levels of research and development, fully realized functional technologies are future-focused.

Real-Time Bidirectional Multistream Neural Activity ⇔ Audible Speech Transcoder

The existing basis for this projected future technology—described as a neural decoder that explicitly leverages kinematic and sound representations encoded in human cortical activity to synthesize audible speech [53]—has already been demonstrated, which is an important achievement in itself, given that the researchers' stated goal is to provide a voice to those unable to verbally communicate due to neurological disabilities or other damage.

A key functional component of their design, Recurrent Neural Networks (RNN)—Artificial Neural Networks equipped with internal memory that can store previous output or hidden states as inputs for later use—decoded recorded cortical activity as articulatory movements, then transforming them into speech acoustics that listeners easily identified and transcribed from cortical activity [54].

Real-Time Bidirectional Multinode Interlingua Translator

As discussed above, an emerging technology in the early stages of deployment—universal spoken language translation—was made public on September 2, 2016, when Google announced the Google Neural Machine Translation (GNMT) system, a significant improvement to Google Translate launched a decade prior. There was, however, a surprising appearance that the AI system had independently learned "a common representation in which sentences with the same meaning are represented in similar ways regardless of language"—in short, an recurrent neural network (RNN) equipped AI-generated Interlingua [55] reminiscent of the Rosetta Stone, a stele over 2,000 years old, discovered in 1799, and inscribed with a decree in Ancient Egyptian hieroglyphic script, Ancient Egyptian demotic script, and Ancient Greek, its purpose being translingual deciphering [56].

Counterfactual Quantum Communications

As discussed earlier (Section 2.3: Counterfactual Quantum Entanglement), in contrast to standard communications, Counterfactual Quantum Communications (CFC) counterintuitively allows information exchange without particle interaction.

Conclusion

Our journey from early toolmaking, through today's interdigitating science and technology, and accelerating towards a future—and descendants—that may well be difficult to recognize in a shorter timeframe than we might expect. The most salient challenge is not, as one might expect, in continuing to continue our voyage to date, but rather that we manage it wisely.

Acknowledgments

To those who hold these insightful words in their thoughts:

- *Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution. It is, strictly speaking, a real factor in scientific research*. –Albert Einstein [57]
- *Any sufficiently advanced technology is indistinguishable from magic*. –Arthur C. Clarke [58]

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