The future cometh: Science, technology and humanity at Singularity Summit 2011 (Part II)

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(PhysOrg.com) -- In its essence, technology can be seen as our perpetually evolving attempt to extend our sensorimotor cortex into physical reality: From the earliest spears and boomerangs augmenting our arms, horses and carts our legs, and fire our environment, we're now investigating and manipulating the fabric of that reality – including the very components of life itself. Moreover, this progression has not been linear, but instead follows an iterative curve of inflection points demarcating disruptive changes in dominant societal paradigms. Suggested by mathematician Vernor Vinge in his acclaimed science fiction novel *True Names* (1981) and introduced explicitly in his essay The Coming Technological Singularity (1993), the term was popularized by inventor and futurist Ray Kurzweil in The Singularity is Near (2005). The two even had a Singularity Chat in 2002.

While the Singularity is not to be confused with the astronomical description of an infinitesimal object of infinite density, it can be seen as a technological event horizon at which present models of the future may break down in the not-too-distant future when the accelerating rate of scientific discovery and technological innovation approaches a real-time asymptote. Beyond lies a future (be it utopian or dystopian) in which a key question emerges: Evolving at dramatically slower biological time scales, must *Homo sapiens* become Homo syntheticus in order to retain our position as the self-acclaimed crown of creation – or will that title be usurped by sentient Artificial Intelligence? The Singularity and all of its

implications were recently addressed at Singularity Summit 2011 in New York City.

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In an ambitious talk (and accompanied by his engaging dry wit), neuroscientist Christof Koch – Professor of Biology and Engineering at the California Institute of Technology in Pasadena and the Chief Scientific Officer of the Allen Institute for Brain Science in Seattle – discussed *The* Neurobiology *and Mathematics of* Consciousness – a thorny problem at the forefront of cognitive neuroscience. The challenge is derived from the quixotic nature of consciousness as an instance of qualia: introspectively accessible, phenomenal aspects of our mental lives we experience as real, but which nonetheless elude definition and neurobiological localization.

For Koch, whose research has focused on the physical basis of consciousness for well over a decade, consciousness is a fundamental property of networked entities that may well be explained by psychiatrist Giulio Tononi's integrated information theory (IIT) – an approach hypothesizing that consciousness is measure in that it corresponds to the capacity of a system to integrate information. Koch also sees IIT as a blueprint for building sentient machines.

Koch rejects a number of popular concepts of consciousness, including the views that consciousness emerges from the brain or is inherent in complexity. "It is not the nature of the stuff that the brain is made out of that matters for mind, it is rather the organization of that stuff—the way the parts of the system are hooked up, their causal interactions," he writes in his latest book, Consciousness – Confessions of a Romantic Reductionist, scheduled to be published by MIT Press in early 2012. "A fancier way of stating this is consciousness is substrate-independent."

Speaking of substrate independence, it should be noted that some of the Singularity's most noteworthy thinkers, researchers and futurists did not present at Singularity Summit 2011. Among them is Randal Koene, neuroscientist, neuroengineer leading the effort in advancing substrate-independent minds (ASIM) – that is, advancing the field of substrate-independent mind (SIM) research, which is focused on transferring mind functions from the biological substrate to another substrate on which those functions can be replicated. (The process of moving our mind from our biological brain to a SIM is referred to as mind uploading, while *whole brain emulation* is a specific SIM implementation.)

In fact, Koene – Co-Founder of carboncopies, Founder of MindUploading, Director of Neural Engineering Corporation, and Director of Analysis at Halcyon Molecular – is a member of the Oxford working group that convened in 2007 to create a first roadmap toward whole brain emulation, a topic he addressed at Singularity Summit 2009. He also discussed Artificial General Intelligence and Neuroscience at AGI 2011.

Randal Koene at Singularity Summit 2009 -- The Time is Now: As a Species and as Individuals we Need Whole Brain Emulation

For Koene, substrate independence is about successful long-term evolution rather than the actual technological mind uploading process of achieving that independence. "If you look forward billions of years toward the end perspective," Koene told *PhysOrg*, "what will take up the majority of intelligent spacetime? Since there's always going to be the competitive natural selection of universal Darwinism, the entities that survive are those that are the most able to understand, adapt to and address new challenges in their surroundings. If you're dependent on a particular substrate, you can't be that flexible." To Koene, then, ultimate adaptability is substrate independence as pattern rather than genetic propagation – a concept he explicated in Pattern Survival versus Gene

Survival.

In the near term, Koene points out, the focus is on the whole brain emulation approach to creating substrate-independent minds because "it's the one approach that is so conservative, we can work on it today. It's the process of emulating processes as they operate in the brain right now rather than creating something more abstract. In this case you don't want to do the latter because we don't have a clear understanding of how the brain works on a cognitive level: We wouldn't know what to capture where – that is, what's important to keep in order to create a substrate-independent version of yourself that retains what you personally consider essential about you." Since Koene sees the mind as emerging from the brain, his approach to whole brain emulation therefore looks to neuroanatomy and neurophysiology as the determinants of how and what we think.

Alexander Wissner-Gross offered his own implementation-centric view of mind uploading, telling PhysOrg that this will be accomplished using a non-invasive technique – i.e., not a Hans Moravec-type procedure, which appears rather barbaric despite its technological sophistication:

A robot surgeon is equipped with a manipulator which subdivides into ever-finer branches that terminate in billions of nanometer-scale sensitive probes equipped with electrochemical sensors that translate single-neuron activity into a functional simulation. Once so virtually replicated, a neuron is removed, with the process continuing until the brain has been, in a sense, consumed.

"I'm not sure how long it will take," adds Wissner-Gross, "but, again, I'm optimistic. A non-invasive mind uploading technology might look something like fMRI capture of brain states with a veneer of machine learning." Wissner-Gross also waxes enthusiastic about *optogenetics*, a groundbreaking photonics-based technique developed by Ed Boyden in

the Synthetic Neurobiology Group at MIT for reading from, and writing to, single neurons.

Other recent research is also suggestive: Neuroanatomy and neurophysiology are inherently three-dimensional domains. Neuronal cell body projections – axons and dendrites – can interconnect large numbers of neurons distributed over large cortical distances. Since the brain processes sensory, somatic, conceptual, and other classes of information in this 3D structural space, the need to (1) image neural structures and (2) stimulate and record neural signals are essential to understanding the relationship between brain structure and function. While 3D imaging and 3D photostimulation using scanning or parallel excitation methods have been used, they have not previously been combined into an optical system that can successfully decouple the corresponding optical planes when using a single lens – a shortcoming that has limited investigators to small neural areas. Recently, however, scientists at Université Paris Descartes have combined digital single photon holographic stimulation with remote-focusing-based epifluorescent functional imaging to overcome these limitations.

Working at the intersection of physics and biology, Francesca Anselmi and Cathie Ventalon in the Emiliani Wavefront-Engineering Microscopy Group led by Dr. Valentina Emiliani, along with Aurélien Bègue and David Ogden, have demonstrated simultaneous high-resolution single-neuron 3D neural imaging and photostimulation by integrating digital single photon holographic stimulation with scanless remote-focusing-based epifluorescent functional imaging.

Asked about the role of quantum processes in consciousness – specifically, as extrapolated from Coherently wired light-harvesting in photosynthetic marine algae at ambient temperature, research conducted at University of Toronto by Elisabetta Collini and others – Wissner-Gross adds that while this and related channelrhodopsin research

disproves the argument that quantum events don't occur at room temperature, he cautions that it still is the case that capturing quantum states may not be necessary for mind uploading.

Not necessarily so for Eliezer Yudkowsky, an AI theorist focused on ensuring that the Singularity gives rise to what he terms a friendly AI (as witnessed by his talk, *Open Problems in Friendly Artificial Intelligence*). Speaking with *PhysOrg*, Yudkowsky succinctly proclaimed, "It's all quarks."

Intimately related to human-like AI is an ability to recognize, understand and act upon complex visual images, motion and sensory flow fields. Stealth startup Vicarious Systems co-founders Scott Brown and Dileep George – the latter previously CTO of Numenta (which pioneered the neocortical-like technology Hierarchical Temporal Memory, or HTM, a theory first described by Numenta co-founder Jeff Hawkins in On Intelligence) and before that Research Fellow at the Redwood Neuroscience Institute – gave a seductively sparse talk. *From Planes to Brains: Building AI the Wright Way* described their neurobiological approach to artificial vision software that at first will understand the contents of images and videos the way humans do, eventually expanding to all sensory systems by building what might be called a *sensory mode-agnostic* model – that is, by capturing neocortical invariants common across vision, hearing, olfaction, taste and touch – that mirrors human learning and thought. While the Vicarious system wasn't demonstrated, details will be revealed…soon.

Given the historical difficulties of instantiating human-like visual performance and comprehension in AI systems, it will be disruptive indeed if that revelation occurs far in advance of the Singularity it portends.

More information: Part 1: The future cometh: Science, technology

and humanity at Singularity Summit 2011 (Part I)