Our Machines, Our Future, Our Selves

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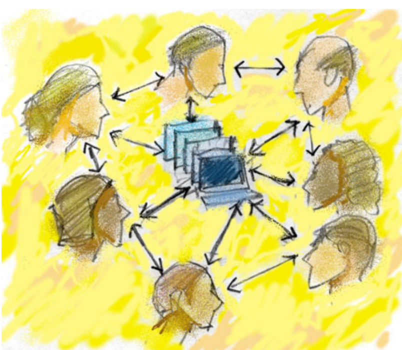
Symbiosis is "a relationship of mutual benefit or dependence", according to Bartleby's Dictionary. Are humans and computers engaged in a symbiotic relationship? Let's explore this a little. Would it be possible for Western culture as we know it to exist without information technology (IT)? No, our societies are already IT-dependent in countless ways: transportation, food production, communications, utilities, commerce, education...the list is practically endless. If all computers and software were somehow disabled tomorrow, social and economic cataclysm in the IT economies would follow.

In 1960, J. C. R. Licklider predicted that human-computer "symbiotic partnership will perform intellectual operations much more effectively than man alone can perform them." This prediction was largely true: our intellectual achievements have indeed been greatly enhanced by technology. But have we reached true symbiosis? Since computers are not a separate *species* obtaining essential relational benefits (they are yet only complex *tools*), it is not strictly correct to classify us as symbionts in the sense of biology. If artificial consciousness is ever generated, this situation might well change, but for the foreseeable future, computer technology will simply be indispensable to life as we know it. As societies and individuals, we will become ever more deeply dependent on IT, to the point that we must honestly rename ourselves *homo sapiens cyborg*. Of course, isolated cultures without functional dependence on information technology will continue to exist. Barring technological catastrophe, these will increasingly become curiosities in protected reserves rather than independently viable societies.



It is perhaps inevitable that we will continue to be transformed by our technologies. For example, the information technology revolution is making rational genetic engineering possible. We may one day augment natural selection processes and engineer our own genomes to eliminate hereditary diseases. We might even enhance the physical or intellectual capacities of our offspring. Well before those technologies mature, to be banned or adopted, I think that a new kind of personal information technology will lead the social transformation process. This new technology will be realized in systems I call *HuMachines*. A *HuMachine* is a person or group assisted by computational and sensor systems that must be able to sense human characteristics and behavior. With greater sensor power, computational resources will then be able to assist and enable human performance in novel ways. A personal assistance technology could know when we are sick, distracted, or too tired to carry out a critical team role in our workplace or at home. Based on long-term observation and automated modeling, it could notify us that we are talking too much in a meeting, or that our blood pressure rises whenever we have to use PowerPoint. With a robust voice and gesture system interface, creativity would not be inhibited or altered by the dictates of a keyboard or a software syntax. This level of assistive technology will require fundamental advances in sensor hardware and software, and will require an understanding of both neurophysiology and social processes that elude us. In the ACG, we have begun to explore the concept of enhanced personal and group performance by prototyping a *HuMachine* called Mentor/Pal©.

Following a three-month process of group study in the ACG, we developed the concept for a system to observe and coach people engaged in complex collaborative activities. We wanted a sensor system that was noninvasive so that natural behaviors would not be impeded for activities such as brainstorming, scenario development, and simulation games. The prototype was built with off the shelf components and custom software by Dr. David Warner and his *MindTel* team, based on an inexpensive networked PC platform. The system records the activities of four people as they work together. The system sensors include face video, audio, keystroke, and mouse movement. Each person is equipped with a sensor suite for recording electro-cardiogram, breathing, blood pulse volume/oxygenation, electromyelography, 3 electrode EEG signal, and galvanic skin response. Accelerometers on the head and hands record movement. The initial observations used a commercial video game for collaborative play; a game activity allowed us to track the performance of both individuals and groups quantitatively. We gradually increased the difficulty of the game and shifted team membership to mildly stress the group, and observed what took place.[1] The apparent links we saw between sensor data and human performance suggest to us that personal sensing in a team setting is an incredibly promising technology. In 2004 we will integrate simultaneous four-person 128-channel EEG recording in Prof. Akaysha Tang's laboratory at UNM, correlating brain events, physiologic dynamics, and social phenomena. We will begin a comprehensive study of collaborative behavior and develop assistive methods to improve group and individual performance. To complement this applied research, Sandia is supporting a CalTech graduate fellowship to study the neurology of learning processes under Sandia's Campus Executive program, and UNM-CalTech collaboration is planned. Our project is not in a "traditional" Sandia discipline, but we think it might reflect a new field where Sandia can truly excel and lead technology development in support of our national security mission.

What role could Sandia play in a transformational future where the line between machines and people is a little blurry? For Sandia to remain relevant, we will have to pursue development of basic research expertise in neuroscience. Please note that modern neuroscience is very different from expertise in software engineering, psychology, artificial intelligence, or systems modeling, all circa 1985. Leading neuroscientists tell us emphatically that the human brain is not a computer: its physical basis, its dynamics, and its modes of information processing are utterly dissimilar to those that take place in the static binary realms of explicit software architectures and integrated circuitry. Even with what little we know about the brain, we already are certain that "a wet computer" is possibly the worst analogy we can devise to understand the brain! People and their behaviors cannot be described or recreated by a computer program realized in binary code in a silicon substrate. Our brains and our bodies are as one, it seems. Our "gut" feelings are as essential to our higher thought processes as the power plant is to your PC. New brain imaging methods show us that emotion and "rational" cognition are not compartmentalized, but are intimately connected; to really sense and understand the brain, we must also sense and understand the body and its physiologic processes and systems. Another future Sandia initiative could be the development of sensors for human activity: small, wireless, inexpensive systems to communicate one's physical, emotional, and cognitive states to each other, and to supportive group systems. We already have expertise in sensing vanishingly small quantities of chemical agents and biotoxins in the air. Why not develop sensors to noninvasively monitor our stress and regulatory hormones like cortisol, noradrenaline, and oxytocin in real time? Development of these new tools would support basic advances in medicine and lead to novel systems for enhancing and ensuring human performance in of critical surety environments. Once we have invested in fundamental neuroscience and human sensor engineering, we will be equipped for the tremendous software engineering challenges posed by *HuMachine* systems. We will need to invent self-programming and adaptive software that does not actually get written, but will have to evolve in response to its sensor inputs...just like the human brain develops in early childhood, as populations of neurons compete, align, merge, and grow to cognitive maturity. We might even need to develop a new kind of nanotechnology-based neuromorphic circuitry to support this software.

The future of human-machine systems can be a bright one, if we develop technology that enables us to be more fully human instead of clever cyborgs. I don't think that invasive technology will have a role in my lifetime, except for medical necessity. I am not worried about anyone requiring me to get electrodes in my brain so I can keep competitive on the job. But we may have to get used to the fact that adventurous people will push the envelope and experiment with physically-embedded computers and similar invasive technology that they think enhances some aspect themselves. For certain, adversaries will use any such technology if it confers an advantage. For this reason alone (understanding the threat when it arrives), Sandia should invest in basic competencies today.

Constant and accelerating change is inevitable: our ancestors from the year 1700 would have great difficulty understanding the world we live in or the work we do. Today's everyday appliances were the subject of science fiction in 1960. Are *HuMachine* systems today's science fiction? Yes. Will Sandia be busy inventing and deploying them in 2025? Yes. So will the enemies of peace and freedom. Let's get started.

Reference:

1. SAND 2003-4225, *Enabling Technology for Human Collaboration* ■