The Simulation of Consciousness: A Grand Challenge for Modeling and Simulation

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Keywords: consciousness, intelligence, cognitive, affective, CGF

ABSTRACT

The ultimate challenge for simulation is the representation of consciousness. While great progress has been made in simulating many aspects of intelligence in software applications such as ModSAF in and many of the so-called artificial life simulation environments the simulation of consciousness has remained unsolved. Nevertheless, the success of Deep Blue in chess, the growing capabilities of speech recognition systems, and progress in other areas of artificial intelligence, all suggest the goal is not out of reach.

Recently researchers have begun to discuss the nature of consciousness in meetings such as the biannual *Toward a Science of Consciousness* conference held at the University of Arizona. From these and other conferences, several possible approaches to solving the problem of consciousness have emerged, including quantum-based paradigms; some are being actively pursued. The classic Turing test and its variations provide one measure of success in simulating consciousness.

It is now becoming clear that the many separate aspects of intelligence modeled by AI, planning, target recognition, sensor fusion, etc., can be integrated only with a scientific understanding of consciousness, so practical payoff from simulating consciousness will be significant. In addition to aspects of intelligence normally associated with AI, consciousness research suggests consideration of affective aspects such as emotion. This line of research should lead to more effective CGF systems that provide a real training challenge as well as to truly smart machinery and weapons. We propose to simulate an emotionally informed, cognitively based representation of consciousness.

INTRODUCTION

Ray Kurzweil [2000] surmises that Moore's Law (that the effect of predictable hardware shrinkage supports a doubling of computer processing roughly each 18 months) will prevail well into the century, and more specifically, that one result is that a single machine (a $1,000 purchase) will duplicate the processing capability of a single human brain in calculations per sec within 20 years.

A decade thereafter, human duplication will cost about $1.00 per brain; and not so long hence, a $1,000 laptop (which might be organic to our garments) will rival the calculation power of all humanity. Somewhere on this path, there will be more communication among machines (or digital agents) than among humans. (Not to beacon paranoia, but what will these machines be saying about us?) Issue can be taken, of course, with the comparisons, above, but the fact is that machinery will demonstrate continued increases in capability; while the otherwise unaltered human brain will not.

This has profound implications for where augmented cognition, pharmaceutical aids, neural implants, and other technologies might take us. Might that is, provided the simulation community can develop the tools and understanding to simulate such human-machine symbioses. This article touches on ways in which the cognitive revolution and the so-called decade of the brain can be exploited, and suggests that simulation will represent the most important enabling technology of our future.

DECADE OF THE BRAIN

The 1990's were acclaimed as the nation's "decade of the brain." This moniker reflects the surge experienced in spending on central nervous system research—ranging from basic to applied levels of inquiry. The investments, made primarily by the National Institutes of Health, produced voluminous findings that are critically important to medicine, but also to exploitation for many practical applications, including computer generated forces.

The "brain decade" research benefited significantly from the cognitive paradigm, but a new concentration on

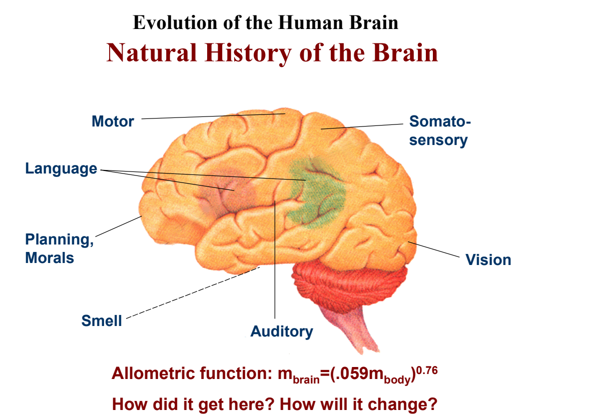

Figure 1. Brain structures involved in consciousness.

instrumentation leveraged breakthroughs in the ability to provide affordable imaging of brain activity. Functional magnetic resonance imaging (fMRI) became available to endeavors other than medical applications. For the first time, researchers were able to observe scientifically, the apparent physiological mechanisms of brain activity that were empirically suggested by cognitive research. There was much more than cognitive science, however. Perhaps one of the most important contributions that fMRI provided was the ability to examine, also, non-cognitive functioning; that is, lower level brain activity.

With the advent of fMRI, brain and behavior science have begun to support investigations of the entire central nervous system. This affordable ability re-energized the focus on so-called "lower brain function" such as emotional activity. Emotion, often used together by behavioral scientists with the term, motivation has of course long been the target of investigators and theorists. We contend that it is our 1990s-informed, clearer understanding, and visual imaging of human emotion that supports a disciplined foray into affective based CGFs (ACGF) and other consciousness simulation applications in the near future.

In addition, many professional-level conferences have sprung up to support research in consciousness. The biannual *Toward a Science of Consciousness* conference held at Tucson by the University of Arizona is the preeminent meeting in the field. The Sante Fe Institute is another center where non-linear dynamics and complexity theory are brought to bear on problems related to consciousness.

Consciousness until recently has been a taboo subject in science. Talk of consciousness would bring to mind images of gypsy women peering into crystal balls. But a combination of advances in neuroscience such as MRI and PET scans and new approaches to computation such as neural networks have made scientific consideration of consciousness reasonable. In the past decade great detail about the functional nature of brain structures has been determined (Figure 1)

The entry of such eminent scientists as Francis Crick (of DNA fame, 1993) into the field of consciousness studies has led to the establishment of major conferences devoted to consciousness studies. The spirit and content of one of these conferences will be discussed below as part of this paper.

RELATION TO SIMULATION

The following quotation from A Network Orange by R. Crandall and M. Levich concisely captures the benefits to be obtained from a theory of cosnciousness that enables true simulation and modeling of rather than mere emulation of conscious behavior:

- Rather than …assuming that machinery is slightly smart and needs to be made truly smart, AI research should incorporate a theory of machine consciousness.
- It is better to conjecture … than to relegate machine consciousness to the limbo of hard problems.
- Machine intelligence is the ability to produce a manifestly relevant output stream.
- Machine consciousness will be a state of legitimate and effective anticipation with respect to chaotic and entropic input streams.

The military applications of truly intelligent or conscious machines are fairly evident. Intelligent science fiction weapons such as the Terminator leap to mind. However, even before consciousness is completely understood to the point of engineering truly intelligent machines, the insights gained in researching consciousness will pay big benefits.

For example it can be argued that one of the main roles of consciousness is in fusing the multitude of sense data that the organism receives. Dr. David Nagel of the Naval Research Lab who gave a post paper at Tucson III [Nagel, 1998] described how he thought of himself as an advance scout looking for emerging technologies for NRL. Sensor fusion is a difficult problem for military systems. Combining data from FLIR, visual, radar and other sensors is proving surprisingly hard. It is, however, a task that the lowliest animal performs with ease so research into consciousness can be expected to suggest new approaches and solutions.

Within the simulation community, the same problems are faced as with operational systems so that consciousness studies will be significant for simulation. As simulation becomes a more integral part of the acquisition process, the ability to fuse simulated data from a variety of sources will be crucial to achieving maximum fidelity.

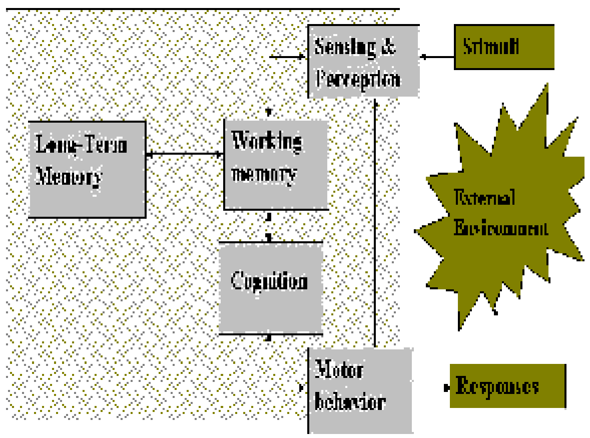

Figure 2. Modified stage model [Pew and Mavor, 1998].

In addition, simulation faces unique challenges not faced by the operational community. Training simulations must simulate human beings, the ultimate conscious animal, in the form of computer generated forces (CGFs). The Army's motto is "We train as we fight"; to meet this goal the simulated enemies must be just as savvy and wily as real human opponents. Anything short of full human consciousness will be found wanting for training purposes. While Deep Blue did defeat Gary Kasparov in the narrow domain of chess, Kasparov's next move should of course to challenge Deep Blue to a game of poker, sending IBM back to a very expernsive drawing board. This illustrates that humans are always constantly changing context and creating new challenges for their opponents. Nothing short of simulation of consciousness will serve to train as rigorously as a real fight.

AFEECTIVE CGF - AN EXAMPLE

As an example of how insights into the brain and consciousness can have significant impact on simulation, this section discusses some work at the University of Central Florida [Franceschini, McBride, and Sheldon, 2001] that applies the theory of affect, the conscious subjective aspect of an emotion, to computer-generated forces (CGF). This research demonstrates how the convergence of advances in psychology, computing, and simulation enables new techniques for understanding human behavior. In particular, CGFs provide a useful testbed within which to develop human behavior representation theories, because CGFs have the following characteristics.

- CGFs have clear and focused goals, viz., improve training/analysis/acquisition applications of simulation.
- CGFs are sophisticated systems that include detailed representations of the natural environment and physical entities.
- CGFs are sufficiently simplified (as compared to the real world) so that controlled testing of human behavior representations is possible.

Taken together, these characteristics imply that successful CGFs may not need to represent all aspects of human behavior. However, CGFs can and should include aspects of human behavior that improve the results of the focused CGF applications. Furthermore, because CGFs contain reasonable models of the environment, they provide non-trivial yet simplified platforms upon which to conduct investigations into sophisticated human behavior representations.

Important advances in CGF models have been made, but CGF technology still has far to go. This section considers one important extension to CGFs: the capability of representing human affect, especially with respect to the impact this has on the decision making process.

The theories on affect have been exploited in an effort to improve human performance for various tasks (i.e., vigilance, decision-making, problem-solving) and interaction with machine-systems (i.e., training simulators, vehicles, navigational systems). Essentially, these endeavors have focused on either the physiological or the cognitive processes underlying affect, to develop an explanatory model of the influence affect has on task performance or machine interaction. Additionally, the models that have resulted from these efforts are not sensitive to individual differences in affective responding, and hence, the effects of emotion are generalized. There is evidence that affective response is influenced by several variables (i.e., current affective state, physiology, cognition, behavior, environment, personality) such that there are between and within individual differences in affective responding to a given situation or event.

THE FUTURE

To date the nature of consciousness has remained elusive. Only recently have scientists begun to discuss the nature of consciousness. From the time of Descartes to the early 1990's, science had regarded consciousness as the domain of philosophers and mystics, but this is rapidly changing and will lead to developments that cannot be ignored by the simulation community.

It is now becoming clear that the many separate aspects of intelligence modeled by AI, planning, target recognition, sensor fusion, etc, can only be integrated with a scientific understanding of consciousness. In addition to aspects of intelligence normally associated with AI, consciousness research suggests consideration of affective aspects such as emotion. This line of research may need to more effective smart bombs that "want" to hit their target and will do whatever it takes to reach that goal.

Within the simulation world consciousness research should result in methods for building more robust and capable CGFs for this century. Sensor fusion techniques should also enhance design simulation making simulation more widely applicable in the design process. Quantum computation, in part motivated by consciousness research, is poised to revolutionize the art of computing and thereby of simulation.

Thus there should be a synergy of simulation with consciousness research that will yield very valuable fruit during this century.

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