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Architecture of Symbiosis

"Man as a behaving system is quite simple. The apparent complexity of his behavior over time is largely a reflection of the complexity of the environment in which he finds himself'

-Herbert *Simon,5aena>softhe Artifidal,* 1981

[Simon 1981] notes that complexity of behavior resides in the hybrid condition of organism and environment Here three units of analysis are posited, the organism, the environment and imphotly the behavior as well. This paper examines the relationship between humans and the en.. ronments that they create and argues that the nature of these environments is undergoing a fundamental shift, one that suggests that the proper units of analyses are the hybrid conditions rather than individual components that comprise them.

[Brooks 19911, following Simon, has undertaken the study of intelligence through the agency of robotics. Intelligence is understood in this context as an attribution made on the basis of the relationship between behavior and the environmental conditions. Intelligence is not inferred from behavior, that is, it has no independent or a priori existence that can be discovered by observation, but is completely bound into and considered an attribute of the contextual operations of the agent. Intelligence so conceived does not reside in the sensor-processor functions of the robot, but in the hybrid of "robot within the environment"There is evidence that this perspective is not hrruted to silicon and aluminum but may be true as well of humans and the contexts in which they exist

In the computer game Ietris, irregularly shaped "bricks"drop from the top of the screen and are to be rotated and translated to fomn compact walls building up from the bottom of the screen. [Kirsh and Maglio 1994] found that many ofthe operations performed by players, even those that had developed considerable skill in the game, were counter-productive in the sense that they were not instrumental actions toward the goal of constructing walls. The falling shapes were repeatedly rotated in order to perceive advantageous orientations. The time required to enact these rotations on the screen and to visually evaluate the applicability of the resulting orientation is less than the time it takes to do the rotation and evaluation mentally. While this finding may surprise few Tetris players, why should it be sol The answer lies in the genetically determined structure of the nervous system and us development as an adaptive device.

[Moravec 1989] claims that the computational power needed to achieve human level competence in arithmetic calculations is about one operation per second and for logic problems 100, but to match the human visual capacity one billion per second are needed. The specific numbers are of little consequence here. Then relative relationship, however, clearly indicates that the sensory apparatus is more highly developed than the native logic circuitry. For this reason, large and complex numeric data sets are frequently output in graphic modes to allow the visual system draw out relationships that may otherwise be difficult or perhaps impossible to ascertain The field of scientific visualization has developed specifically to assist in this process.

One need not be involved in scientific visualization to find additional examples. Many in the design fields make use of repeated sketches at various levels of abstraction in an effort to solve functional, programmatic and aesthetic issues. There is an almost ritual externalization and re-ingestion that forms a processing loop enabling elements under consideration to be"brought to mind'for evaluation and refinement in subsequent iterations. This process is often characterized as one of drawing out, discovering or allowing relationships to emerge from the process. But there is no need to deal in spooky stuff, to attribute intention, desire, or abilities to the inert and the abstract. The relationships exist because they are established and perceived. That these occur on paper or screen makes them no less mental activities. [Kirsh and Maglio 1994] distinguish between pragmatic and epistemic activity. The mtent of pragmatic operations is to effect functional changes in the environment - they are goal directed behaviors. The epistemic are undertaken m order to alter the agents computational state. Epistemic actions are integrated parts of the thinking process.

[Clark and Chalmers 1996] have proposed that the concept of the mind be extended to include the environment in which operations are performed based on the active role that the environment plays in dnv,ng cognrtive processes. This conceptualization questions the boundary of the mind arguing that the skm or skull is too narrow and too arbitrary a dernarcation. Iradrtionholds that the mind resides ,n the brain, how could it develop otherwise?

The mind as an adaptive system develops in response to environmental conditions. It is commonly thought that the nervous system controls and directs the body. At one level of analysis this rs true, however as [Perves 1988] notes the body effects the nervous system both in its development and its ongoing operation. The body in this case serves as a kmd of non-neutral interface between the neurological structures and the environment. The interaction between the structure of the mind and the environment is clear from studies of the organization of the nervous system during infancy as well as from research indicating a continuous rewiring ofthe neural connections due to the frequency and strength of synaptic communications. The nervous system, is in fact, a volatile network responding to experienre. Ihts is notto argue for primacy ofthe body over brain but to note that there is evidence for significant feedback between the body as interface and its neurological apparatus. One cannot operate or develop without the other. The developing organism is not a passive recipient of environmental stimuli but is rather an active participant in its own adaptation [Davidson 1980].

Given that the mind develops, through the agency of the body, in response to environmental conditions, it should not be surprising that it develops in such a way as to make use of, to incorporate and to function to some extent by means of that environment. There is no advantage to the conceptualization that divides such a continuous process into elements that take place inside the skull and those that occur outside and that ascribe elements of the mind only to those on the interior. In fact, rt denies the common occurrence of a kind of flow in the work where the media seems to disappear and there is only the experience of operating in realms where thought and production fuse. Doing is thinking. There are levels of complexity where, for many of us, the thinking cannot take place without the doing. Ittakes place at the same time and through the agency ofthe activity.

[Brooks 1991] in discussing the merits of embodied and situated robots notes that "the world is its own best model'He argues that it is unnecessary for the machine to contain explicit representations of its context if knowledge of the environment can be made available to it via its sensors. Information about the world is immediately and directly available in its current state. The robot may, in fact, communicate with itself via the environment. The results of an activity are given by changes to the robots context and may be directly perceived and made use of by other sensors. This is more efficient than passing the projected consequences of the action to a centralized comprehensive model and then verifying the model relative to the actual context. It may be that these benefits accrue to humans as well and may fomn the basis for the need to externalize certain operations so that alternative sense modalities can be brought to bear on the activity at hand. These are powerful advantages that lead to the optimization of neuro-processes with the availability of the environment as an assumption. The reliability of the external media as a repository for certain kinds of information in tum generates a reliance externalization as an integral part of the cognitive loop.

This reliance on the externalization of cognitive activity creates artifacts that may be available to several individuals simultaneously and to many over time if the object is physically enduring This is to suggest that the mind as an adaptive system which relies on external media for portions of its cognitive processes is especially well suited to the development of culture. [Stein 1997, Torrance and Stein 1995] propose that multiple interacting systems may extract structurally similar regularities from a shared environment and that these regularities form the basis for a shared grounding of their respective internal representations which may be disparate. While her concern is with inter-robotic communication and communication between robotic systems and humans, the principle of shared grounding is valid for social contexts as well. There is little evidence that any two of us share the same internal representations, but there is ample evidence that we are all immersed in a sea of cultural artifacts that are mutually accessible as physical objects and which form the basis for our interaction. This conference is a particularly immediate example

[Hutchins 1995b] argues that the cognitive work that is required to land a plane takes place in part through the *agency* of the cockpit *reference* materials, markers and instrumentation that serve not only a recording or memory function but by their configuration allow for the instantaneous calculation and processing of certain critical information relative to the operation of the craft. His analysis shows that the processing required takes place not within the individuals nor in the machine but by the agency of *the soao-techmcal* system that they comprise. It is concluded that *the* thinking that takes *place during* this activity resides in the hybrid condition of pilots and cockpit, not in one or the other. Here the unit of analysis has shifted from individual components to the conjunction of humans and artifact together. This translation of perspective is of more fundamental interest and wider applicability than the navigational situation discussed

[Hutchins 1995a] considers cognition to be a cultural process and culture to be a cognitive one. Artifacts which are frequently and incorrectly considered to be synonymous with culture exist only as the residue of the cognitive process. They are a kind of instrumentation that makes the process of culture available for analysis, but do not in themselves constitute that culture. Artifacts derive their utility by virtue of the fact that they are the means by which the shared grounding that drives the cultural process is enacted.

The nature ofthe artifact 1sundergoing a transition based on the widespread integration of techniques for adaptability, intercommunication between devices and interactivity with the sooal end physical environment. While these developments represent a difference in degree rather than in kind, they suggest that the role of the artifact in the cultural process may be strengthened. within Hutchins paradigm.

[Krueger 1996] suggests that architecture may acquire elements of adaptability and interactivity through the implementation of techniques under development in a variety of fields - among them artificial intelligence, robotics, and intelligent materials and structures- and that these capabilities enable a biological metaphor, that of a socially inhabited body, an architectural organism.

[Krueger 1997] argued that there are technical parameters that suggest that complex behaviors can only be obtained by investing the architectural artifact with an intelligence and then by ceding control to it Increases in functionahty are accompanied by a loss of control. Architecture becomes autonomous.

This autonomy is a fundamental change in the nature of the artifact which in tum requires an re-evaluation of roles that objects play in both the cultural and cognitive processes. Intelligent and adaptive autonomous objects achieve *an* equivalency with the human participants. [Agre 1995] *conveys* the change that the principled characterization of interactions between agents and the environment has had for the field of artificial intelligence. The concept of agent *may* embrace human and other biological entities, machines and software. Each may be to some degree autonomous, intelligent and situated within an environment. *Principles* inspired by *or* generated in *a* variety of fields may be tested and applied in many others. Equivalency does not suggest that the objects become human or replace them, but to note that theirroles become interlocked and complementary. [Kirsh 1995] uses the term complementary strategies to define organizing activities which recruit external elements to reduce cognitive loads. This concept of complementary may be applicable here as well. We might consider recruitment of the humans by the machines and the machines by humans in the service of cognitive processes operating at the social scale to be a symbiotic relationship .. This does not fundamentally change Hutchins' analytic framework, but instead increases it saliency.

An interactive and adaptive architecture indicates that the locus of design migrates from form to the parameters of behavior. Its mtent shifts from control to facilitation, from restriction to amplification of the design space. It becomes necessary to redefine our relationship to the products of our material culture. At the point of our perfecting the synthetic environment, it becomes populated with new beings, a second nature.

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