The Design of Intelligent Environments

Soft Architecture

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WALKING TO WORK this morning I remembered the white-gloved policeman who is now replaced by computer-timed, radio-controlled traffic lights. All lights used to be of equal duration, regardless of the hour or the traffic load. They were "stupid" in the days before actual flow was fed back to change stop light duration. Flow projections and intelligent guessing are necessary features of our newer computer-controlled traffic systems: necessary for the speed and density of flow now common, for example, in subways.

Nevertheless, this intelligence of the subway system and a multitude of other similar computer-controlled systems is still like the automated control of a well run insect colony whose program for behavior leads them to compute approximately the same course of action repetitively, with little creative effort on their part to evolve a purposeful behavior. When should this regulation which provides survival be called intelligence? I wonder if a man from the 17th Century looking at our present world would say that we had an intelligent environment. Would he be able to say that our environment was able to control itself more intelligently than his?

The concept of an intelligent environment softened by a gentle control which stands in place of steel bones and stone muscles is refreshing. A dam that senses impending flood and uses intelligence to prepare itself would not need be so ponderous. To date we have not endowed our environment with this creative flexibility; the intelligence we have commonly achieved is uncreative, stupid and in large measure hostile to human well-being. We have allowed hard shell machines to multiply and control us. Man is a captive of his increasingly automated mechanical environment. This process we have accepted ever since the early days of the industrial revolution, not imagining any other possibility. We have accepted the proposition that in order to use the power which machines deliver *economically,* we must restrict ourselves to the limited human behaviors that the machines can accept as meaningful control. One must steer by turning the steering wheel in the prescribed way regardless of one's body size, fatigue or personal style. Human behavior is mass produced by the power delivering tools man has learned to depend upon.

As we have created more and more power we have felt the iron gloves, which at first protected our hands from work, gradually thicken to protect us from touching the world around us. The teenagers search for a way back to "contact." But we cannot go forward by destroying the past. When man adapted for survival against a natural environment over which he had little control, he evolved; now men must evolve against the pollution of environment produced by our own progress.

What is the solution? Evolution now must include evolving environments which evolve man, so that he in turn can evolve more propitious environments in an ever quickening cycle. To stabilize the capacity we need to characterize this evolutionary dialogue. This characterization is increasingly being seen as the unsolved problem of our time. It is familiar to designers and architects in the student's question: "How do you design a house which will grow to meet the changes in the family that the house itself will produce?"

No man as yet knows the solution, but we can seek at least to clarify the question; a question well defined provides the beginning of its answer.

A DECADE AGO Rosenbleuth, Weiner and Bigelow wrote their historic paper, "Behavior, Purpose and Teleology." This ushered in cybernetic thinking. Their conception considered a thing and its environment in terms of their mutual relation. It defined behavior of the inanimate and animate within one frame of reference. The categories of behavior defined in that paper are a valuable start for developing a common notation for the design of intelligent environments.

Rosenbleuth, Weiner and Bigelow separated *active* behavior from passive behavior — behavior in which the object behaving is not a source of energy — as an object thrown. They subdivided active behavior into *purposeful* and *non-purposeful.* The latter is not directed to a goal, whereas the former is. If we decide, for example, to take a glass of water and carry it to our mouth we do not command certain muscles to contract to a certain degree and in a certain sequence; we merely trip the purpose and the reaction follows automatically. Although a gun may be used for a definite purpose, the attainment of a goal is not intrinsic to its performance. Some machines, on the other hand, are intrinsically purposeful. A torpedo with a target-seeking mechanism is an example.

In that historic paper the term "feedback" was first defined, and purposeful behavior was then separated into *feedback* or teleological and *nonfeedback* or nonteleological behavior. The word teleological was originally used to describe an innate or final divine purpose in all living things. The feedback control concept now allows us to define purpose without divinity: it is that goal from which deviation is corrected by feedback. The evolution of error correction procedures is used to define purpose; this brings us close to Darwin's concept of an evolutionary tree — a tree expanded in time by errors which escape correction and alter the feedbacks, but pruned by the death of those patterns which cannot survive when recontexted by the evolving environment. Survival and purpose intermingle.

Feedback, or purposeful behavior, is in turn subdivided. It can be *predictive* or *non-predictive.* "The amoeba merely follows the source to which it reacts. There is no evidence that it extrapolates the path of a moving source. . . . A cat starting to pursue a running mouse does not run directly toward the region where the mouse is at a given time, but moves toward an extrapolated future position." Predictive behavior may be subdivided into different orders. "Throwing a stone at a moving target requires a certain order of prediction. The paths of the target and the stone should be foreseen. Prediction will be more effective and flexible if the behaving object can respond to changes in more than one . . . coordinate. The sensory receptors of an organ or the corresponding elements of a machine may limit the predictive behavior."

When the Rosenbleuth, Weiner, Bigelow paper was written, the existing automatic environments did not have the capacity to predict and extrapolate with sufficient complexity to be sensitive and responsive to self-organizing and evolutionary purposes. Given this capacity of our present machines, we can add to the list of behaviors defined in the paper. The category of the predictive machines can be further divided into *complex* and *simple.* An aggregation of simple machines grows only into a *complicated* machine decomposable into simple elements. The complex machine is more than an aggregate of its parts and their relations. It cannot be decomposed without destroying its capacity to maintain its organization. The complex machine can be further categorized as *self-organizing* (convergent) or *non-self-organizing.* In the latter kind of machine there may be sudden breakdowns, but in the former reliability is maintained by continuous breaking down and rebuilding. The system maintains its convergence by simplifying itself in terms of an internal purpose as defined by a complex net of intertwined feedbacks. If the self-organizing machine can maintain its purpose by responding to what was noise so as to evolve a new purpose, it can be called *evolutionary.* If it cannot, even though it is self-organizing, it is *non-evolutionary.*

GIVEN THIS HIERARCHY of behaviors of an object in relation to its environment, we can now redefine environment. Rosenbleuth *et al* defined it in these words: "Given any object relatively abstracted from its surrounding for study, the behavioristic approach consists in the examination of the output of the object and of the relations of this output to the input." When we speak of intelligent environments we traditionally define man as the object and the environment as the surrounding.

But we could also consider the surrounding as the object and man as the environment, or at least make them both object and environment to each other. Think of the effect of an infant's mattress or of his crib on the child. The balance of the mattress will affect the movement of the child — it will control him. It will teach him by subduing some movements and reinforcing others. The assemblage of rooms, walls and spaces in a home actively control the actions possible within it. An employee is trained by his work space and tools, a driver by his automobile. This concept of man as a passive unintelligent abstraction who does not create or evolve is a common simplification used by those concerned with environmental design. It is merely the reverse of considering the man as active and the environment as capable of only passive behavior. But much simplification is unwarranted. Imagine a time-lapse movie taken of a city and its inhabitants over the years. It would show an interaction involving purposeful, feedback, predictive,