THE SIMULATION OF HUMAN SYSTEMS

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Abstract: This paper deals with the qualitative differences between the simulation of physical systems and those involving human beings. The difference comes from the fact that human beings are self-aware. A typology of models is proposed: causal, teleological, and teleogenetic with physical systems falling into the first class and human beings into the third.

Simulation of Human Systems

The simulation of systems involving human beings is a conceptually different problem from simulation of physical systems such as aircraft, power systems, and so forth.

The difference stems, basically, from the fact that human beings are self-conscious whereas physical systems are not. Whereas a physical system is bound at some level by laws which remain time-invariant, (such as F=MA in classical physics), a system containing human beings can be aware of its own structure and, as a consequence of this awareness, can modify its own structure at any level.

Models of human systems must take into account this ability of such systems to modify their own structure. It must be emphasized that it is not sufficient to merely make a model's invariant structure on a high level of abstraction. For human beings and the systems of which they are a part can be conscious at an equally high level of abstraction, and can therefore modify the structure of their behavior at that level.

Types of Models

We propose that models can be classified into three groups: causal, teleological, and teleogenetic. (Figure A.) Causal models are conceptualized in terms of cause-and-effect, in the Newtonian sense. Newtonian physics is, in fact, probably the best example of a causal model. The concept of force is basic to causal models.

Typology of Models
(Figure A)

CAUSAL	FORCE	(AUTOMOBILE)
TELEOLOGICAL	INFORMATION	(CONTROL SYSTEMS)
TELEOGENETIC	MEANING	(HUMAN BEINGS)

Teleological models, on the other hand, are based on the concept of function. The functionalist theory of society is an example of a model of this kind. Teleological models involve goal-seeking; information theory and cybernetics are therefore applicable to them.

Teleogenesis refers to goal-choosing. We suggest that teleogenetic models are applicable to human systems, for the reasons given earlier. The concept around which these models are based is that of meaning. Since meaning is basically a linguistic concept, we believe that linguistic--rather than organic or mechanical--models are appropriate.

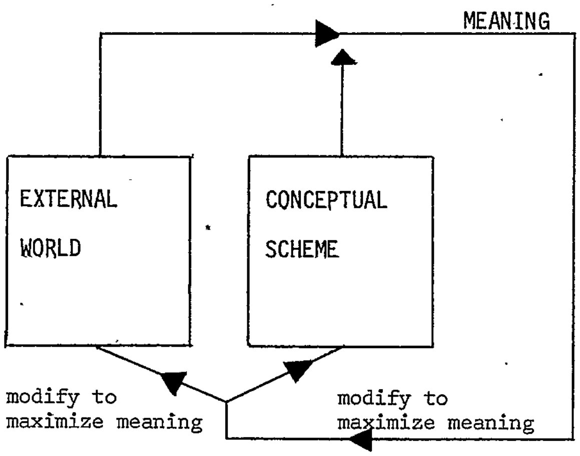
The Concept of Meaning

Our theoretical system holds that meaning is not arbitrary, but is rather the basic organizing mechanism used by the human mind and by human societies.[1]

Meaning is necessary because human beings and human societies have the capability of choosing their own goals. Meaning is the mechanism used to decide between goals.

Specifically, our model holds that human beings act to maximize meaning and furthermore that they modify their conceptual organization to maximize meaning. (Figure B.) What comes about, then, is a continuous chain. The individual acts to maximize meaning. This changes his situation. He modifies his conceptual organization to maximize meaning in his new situation. Then he again acts to maximize meaning, and so on.

Dynamic Relationship Between
Meaning and Conceptual Scheme
(Figure B)



Implementation

The danger of models which use highly abstract terms such as "meaning" is that they can remain up in the air, incapable of ever being operationalized or of ever predicting anything. We believe that the linguistic--teleogenetic--meaning model of man and society is capable of being operationalized, and would like to suggest avenues in that direction.

A society, in our model, would be represented by a matrix of associations between concepts (words, images, and so on) and other concepts. All the meanings of the individual or the society would be implicit in this matrix. We are at present leaving the concept of meaning undefined since it includes associational matrices, the Weberian concept of meaning, interpretation, and certain other concepts requiring a longer exposition than this paper permits.[2] Meaning, in other words, implies an already existing theoretical framework implicit in human behavior.[3]

It is necessary to distinguish between two elements of the concept of meaning. In one sense, meaning is a complex, multidimensional quality. A tree, for instance, "means" shade, leaves, and so on. However, meaning is in another sense a simple scalar quantity. It is possible to say that something has a "lot" or a "little" meaning. That is, there can be an order relationship of degree of meaning. For the purposes of this paper we will henceforth refer to a concept's associations as its vector meaning and to its degree of meaning as its scalar meaning. Vector meaning is explicit in the association matrix and scalar meaning is implicit.

Now it is possible to see how meaning serves as a basis organizing mechanism. The scalar meaning of a concept is indicative of the difference it makes to the entire system. In chess, for instance, the scalar meaning of a pawn's presence in a certain square is the degree to which it affects the future chances and strategies of the players.

The scalar meaning of a concept or an event is therefore an index of the amount of time that a system should spend dealing with that concept or event. Meaning is a guide to a system's association of its intellectual resources.

It may be noted that the development of heuristic methods in artificial intelligence requires something like the concept of meaning. That is, the amount of time which is spent by the system investigating a certain branch of a tree should be proportional to the degree to which that branch influences or reflects the overall state of the system--that is, its meaning.[4]

The basic question, then, is how scalar meaning may be extracted from the matrix of associations. If it can be shown that scalar meaning may be expressed as a function of the association matrix, then meaning will have been established as a legitimate scientific concept, something which is inextricably bound up with language, rather than merely arbitrarily tagged on.

Scalar meanings are found in concepts in the association matrix on the basis of internal consistency. For example, if concept a has a high scalar meaning, and is closely associated with concept b, then concept b must also have a high scalar meaning. An association matrix with the requirement that meanings be internally consistent should result in a set of equations for scalar meanings that has a unique solution. That is, the degrees of meaning of various concepts are necessary; they follow directly from the association matrix, rather than being arbitrary.[5]

An Example

The following is an example of the manner is which scalar meaning may be extracted from the association matrix. Below is a hypothetical matrix of associations between three concepts:

Example
(Figure C_1)

$$\begin{array}{cccc} & 1 & 2 & 3 \\ 1 & - & 3 & 1 \\ 2 & 3 & - & 1 \\ 3 & 1 & 1 & - \end{array}$$

Let m_1, m_2, and m_3 represent the scalar meanings of concepts 1, 2, and 3, respectively. The internal constraint may be expressed as follows:

Internal Consistency Constraint
(Figure C_2)

$$m_i = \sum_{j=1}^{n} \left(m_j A_{ij} \Big/ \sum_{\ell=1}^{n} A_{j\ell} \right)$$

That is, the meaning of a concept is the weighted sum of its associated concepts, where the weights are equal to the proportion of the total concept's association supplied by the concept. Concept "2". for example, is weighted 3/4 in computing the meaning of concept "1"; concept "3" is weighted 1/2.

This internal consistency constraining leads to the following systems of simultaneous linear equations:

Internal Consistency Constraint--Example
(Figure D)

$m_1 = (3/4)m_2 + (1/2)m_3$

$m_2 = (3/4)m_1 + (1/2)m_3$

$m_3 = (1/4)m_1 + (1/4)m_2$

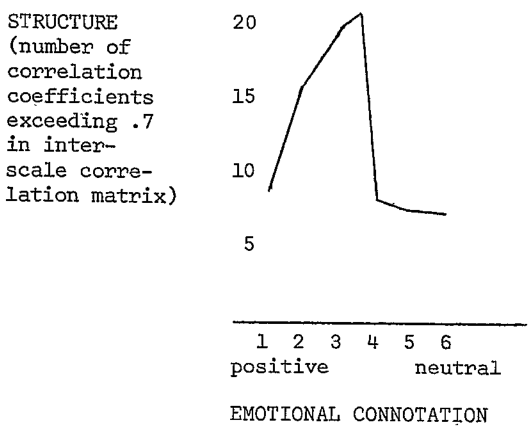
This system has the solution $m_1 = m_2 = 2m_3$. Since the units used in measuring meaning are purely relative, assigning a meaning of "1" to concept "3", we have

$$m_1 = 2$$
$$m_2 = 2$$
$$m_3 = 1.$$

Utilizing this framework on associational material, the authors found a curvilinear relationship between meaning and emotion.

We have applied this concept of meaning and emotional connotation for words of natural language. Using the Osgood Semantic Differential, which rates words on 20 scales such as good-bad, weak-strong, etc., we computed the interscale correlations for groups of words and considered the magnitude of these correlations as an index of degree of meaning. In this way we were able to determine the relationship between meaning and emotional connotation, as determined by the semantic differential. Figure E shows this relationship graphically.

Structure As A Function
Of Emotional Connotation
(Figure E)



As pointed out before, this is by no means a complete solution to the problem of extracting scalar meanings from association matrixes. In addition to the fact that it does not deal adequately with the influence of context, this procedure implicitly assumes that the association between concepts is something external to the association matrix. In fact, if association is interpreted in its most complete sense, it should also reflect the degree to which concepts have the same pattern of association with other concepts in the association matrix itself. That is, the internal-consistency requirement needs to be carried one level higher.

Computer Implementation

A great deal has been written about computer simulation of human beings. It has been inferred, for instance, that computers can simulate human beings because the manner in which they function electrically is similar to the manner in which human minds function.[6]

The important question is not "what is the electrical nature of the computer?" At the lowest, machine-language level, the computer is a completely general device, not analogous to any particular system. It is only when operating under the control of a compiler and using a high-level language that a computer becomes analogous to a system. A computer using GPSS, for example, is analogous to a queueing system. A system such as FORTRAN presents a causal world-view; a linear programming system presents a teleological world-view.

The question, then, is what form of high-level language is appropriate for the simulation of behavioral systems. It is true, of course, that all general high-level languages are equivalent logically and that, for example, anything that can be done in GPSS can be done in FORTRAN. But this is not necessarily any more meaningful than saying that all forms of matter are made out of atoms and are therefore in a sense equivalent . You still find it difficult to use a chair for a table. A good high-level language will have facilities for doing things which are completely impractical in other languages, even though they are logically possible. A language, furthermore is, as pointed out before, a world-view.[7] It leads the modeller by the nose into a certain way of looking at things. For example, an experimenter who is modelling a social system in COBOL is not likely to define concepts in terms of recursion. One who is writing in LISP might.

The present high-level languages are not really appropriate for the modelling of systems containing human beings. As has been stressed in this paper, human systems can modify their structure at any level. Although computer programs, at the machine language level, have the same property, it is unfortunately largely lost in most high-level languages. The user of FORTRAN, for example, conceptualizes in terms of a fixed program performing operations on variable data. This is, at least to some degree, a consequence of the fact that compilation is done at one time and that the compiler is not even in the system at the time of program execution. That is, there are three different and uncommunicating languages in use: the compiler language, machine language, and data structure. This absence of communication is destructive of the self-consciousness which we stressed earlier as the component of human systems.

List-processing languages are a step in the right direction; they permit data structure to evolve dynamically, rather than being determined beforehand. Furthermore, the capability for recursive definition in such languages as LISP permits processes, to some degree, to evolve dynamically.

However, a new form of high-level language is required for real progress in the simulation of human systems. Such a language must be capable of dynamic self-modification to the degree that a programmer will not be able to predict the state of the program at the end of the run from its state at the beginning, just as today he cannot predict the state of the data at one time from its state at another (without, of course, actually executing the program.)

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[1] Max Weber, The Theory of Social and Economic Organization. Trans. A. M. Henderson and Talcott Parsons, (New York: Free Press of Glencoe, 1964), pp. 118-120. Also from a somewhat different approach see G. H. Mead, Mind Self and Society, (Chicago: University of Chicago Press, 1934), pp. 5-13, 362-367.

[2] Ibid. Even Durkheim, in his later writings, appears to have been moving in this direction. See G. P. Stone and H. Farberman, On the Edge of Reapproachment: Was Durkheim Moving toward the Perspective of Symbolic Interaction, Sociological Quarterly 8, 1967, pp. 149-164.

[3] Peter F. Winch, The Idea of a Social Science, (London: Routledge & Kegal Paul Ltd., 1958), pp. 45-57.

[4] After this article was completed Saul Amarel's article in the proceedings of the 1962 Conference on Self Organizing Systems was called to our attention. This article seems to be relevant to the present point.

[5] Bowman Clark in discussing the Carnap-Goodman controversy about quality classes shows that meaningful relations may be analyzed in terms of set theory along the lines of Whitehead's theory of extensive abstraction. See Bowman Clark, Goodman on Quality Classes in the 'Aufbau' Southern Journal of Philosophy 1, 1963, pp. 15-19.

[6] W. R. Ashby, Design for a Brain, (New York: John Wiley and Co., 1952).

[7] It is obvious that the conception of Benjamin Whorf--(The Whorf-Sapir Hypothesis)--William I. Thomas' (Definition of the Situation) and Freud's ideas of symbol processes play a major role in our thinking which cannot be presented in so brief a paper.