Journal of Applied Communications

Volume 52 | Issue 1 Article 4

Information Theory Adapted to Wide Range of Scientific Activity

William L. Carpenter

Recommended Citation
Carpenter, William L. (1969) "Information Theory Adapted to Wide Range of Scientific Activity," *Journal of Applied Communications*: Vol. 52: Iss. 1. https://doi.org/10.4148/1051-0834.2118

Information Theory Adapted to Wide Range of Scientific Activity

Abstract

Claude Shannon, Bell Telephone Co. engineer and mathematician, set in motion a chain of events in a wide variety of scientific disciplines when he revealed his theoretical communications framework at the end of World War II.

Information Theory Adapted to Wide Range of Scientific Activity

WILLIAM L. CARPENTER

CLAUDE SHANNON, Bell Telephone Co. engineer and mathematician, set in motion a chain of events in a wide variety of scientific disciplines when he revealed his theoretical communications framework at the end of World War II. But like most scientific breakthroughs, Shannon's achievement was not a one-man effort; he added his own thoughts and insights to the ideas of a number of individuals who had studied the same problem before him.

Theory Development

In 1894 Boltzmann, in some of his work on statistical physics, observed that entropy was related to missing information, inasmuch as it was related to the number of alternatives which remained possible to a physical system after all the macroscopically observable information concerning it had been recorded. *(7)*

In 1924 Nyquist and Kupfmuller stated the law that, in order to transmit telegraph signals at a given rate, a definite bandwidth is needed. In 1928 Hartley expounded on this law and showed that transmitting a given quantity of information required a definite product (bandwidth $\times$ time). He defined information as the successive selection of signs or words from a given list, and stated that the "quantity of information is most reasonably defined as the logarithm, that is, $H = N \log S$." *(3)*

During the World War II period, Shannon and Wiener were independently giving considerable thought to the information-communication process. Wiener, particularly interested in biological application of the process, is credited with much of the basic philosophy and theory of communication. *(8)* Shannon,

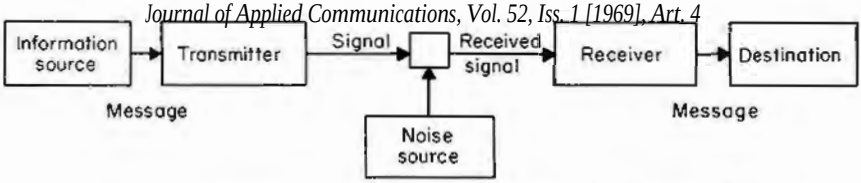

FIG. 1. A communication model (Shannon and Weaver, 1949).

working in the Bell Telephone Laboratories, was more concerned with the application of theory to engineering communication.

Shannon's communication model, which has stimulated much research in communication and other areas, can be diagrammed as shown in Figure 1.

Areas of Development

The development of information theory created interest in a number of diverse directions, as illustrated by Figure 2, which presents the author's schematic diagram designed to categorize this activity.

Based primarily on R. A. Fisher's application of the term "information" to statistical data (*The Design of Experiments*, Oliver & Boyd, Ltd., 1935) there was some effort to apply the information theory, particularly the statistical concepts, to a wide variety of scientific disciplines.

A number of communications researchers have attempted to adopt the original Shannon concept to the practical side of human communications. *(1, 4, 6, 9)* Their models have become the basis for the development of a discipline of human communications and guides for research and application to both intrapersonal and interpersonal communication (communications theory and practice, Figure 2). Agricultural editors make extensive use of these models in their teaching and everyday editorial activities.

A third area has been the application of information theory, or an adaptation of it sometimes called psychological information theory, to psychology. Here the psychologist applies information-theory measures to phenomena within the purview of psychology and uses information-theory language to formulate laws or hypotheses with testable implications about behavior. The measures may be applied to any situation in which one is willing to identify the stimulus and response classes and make some statements about their probability distribution. Situations involving percep-

https://newprairiepress.org/jac/vol52/iss1/4
DOI: 10.4148/1051-0834.2118

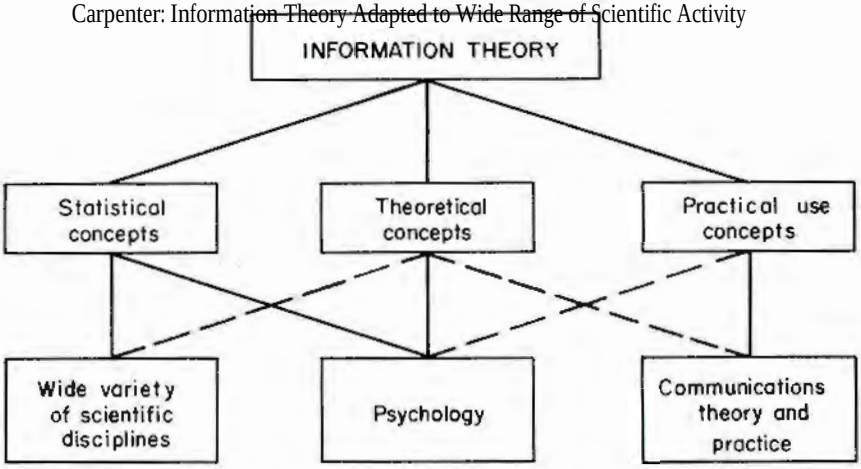

FIG. 2. A schematic representation of information theory and its application. The second (middle) level represents the conceptual areas of the theory and the third (lower) level gives the scientific disciplines making most use of the three concepts. Solid lines represent primary use, broken lines secondary use.

tion, for example, may be considered in terms of the transmission of information.

The methodology of information theory has created particular interest by psychologists in the absolute judgment method of measuring stimulus response. Absolute judgment may be characterized as a type of judgment in which an observer is required to identify by a name, number, or value each member of a set of individually presented stimuli.

The objective is to determine how much information the observer obtains about a particular stimulus. In such a situation the human organism is regarded as a communication system. *(2)*

Difference in Approach

Perhaps the most distinguishing feature between the theoretical and the practical approach to information theory usage (as defined in the model presented in Figure 2) is that in the practical application there is concern for meaning (semantics) and the degree to which the received meaning affects conduct in the desired way, while in the theoretical application there is no such concern. Only the amount of information is measured, with no specification as to content, truthfulness, exclusiveness, history, or purpose of information. *(5)*

Model Defined

The unifying or commonality feature that has enabled researchers to put the theory to wide use in both theoretical and practical situations is the model itself (Figure 1). It is best to think of this model as a step-by-step process, consisting of essentially five parts:

1. An **information source** produces a message or sequence of messages to be communicated to the receiving terminal.
2. A **transmitter** operates on the message in some way to produce a signal suitable for transmission over the channel.
3. The **channel** is the medium used to transmit the signal from transmitter to receiver.
4. The **receiver** performs the inverse operation of that done by the transmitter, reconstructing the message from the signal.
5. The **destination** is the person (or thing) for whom the message is intended.

If a communication system were operating perfectly, the received message would correspond perfectly to the original message. However, the system is not likely to be perfect. Shannon introduced the term "noise" to cover the many elements that may affect the message transmission. Noise may be regarded as any irrelevant signal arising within the system itself which may interfere with the message being transmitted in ways which mask the signal or confuse the message. The efficiency of a communication system may also be impaired by coding and decoding mistakes, and a system is limited with respect to the kind and amount of information which it can transmit.

Information Measurement

Information within the information-theory context is usually defined in terms of the reduction of uncertainty. The amount of information contained is related to the probability of predicting its occurrence. Mathematically stated, the amount of information contained in any given segment is equal to the logarithm to the base 2 of the number of alternatives which can occur in a given context.

In its simplest form, the formula is: $I = \log_2 n$ when the probability of occurrence of all stimuli in the set is equal; n is the number of alternatives or probabilities, and $\log_2$ is the logarithm

https://newprairiepress.org/jac/vol52/iss1/4
DOI: 10.4148/1051-0834.2118

of n to the base 2. The unit most often used in the measurement of information and uncertainty is the "bit," a contraction of binary digit. To illustrate, if a given set of stimuli contains eight equally likely alternatives, the amount of information or stimulus uncertainty contained in the set is 3 bits (log of 8 to the base 2 = 3).

Shannon, seeking to explain the phenomena of telephone transmission systems, undoubtedly has been surprised at the wide range of usage, and the contribution to human communication and other sciences resulting from his rather simple formula.

References

(1) Berlo, David K. 1960. *The Process of Communication.* Holt, Rinehart and Winston, New York, N.Y. pp. 23-39.

(2) Carpenter, William L. 1968. *The Relationship Between Age and Information Processing Capacity of Adults.* Rept. No. 7, Dept. of Agr. Information, N.C. State Univ.

(3) Cherry, Colin. 1957. *On Human Communication.* John Wiley and Sons, Inc., New York, N.Y. pp. 42-43.

(4) Gerbner, George. 1956. *Toward A General Model of Communication.* Audio-Visual Communications Review, Vol. 35, No. 4. pp. 171-199.

(5) Miller, George A. 1953. *What is Information Measurement?* The American Psychologist, Vol. 8. pp. 3-11.

(6) Schramm, Wilbur. 1954. *The Process and Effects of Mass Communication.* Univ. of Ill. Press, Urbana, Ill. pp. 3-26.

(7) Shannon, Claude E. and Warren Weaver. 1949. *The Mathematical Theory of Communication.* Univ. of Ill. Press, Urbana, Ill.

(8) Wiener, Norbert. 1948. *Cybernetics.* The M.I.T. Press and John Wiley and Sons, Inc., New York, N.Y.

(9) Westley, Bruce and Malcolm S. McLean, Jr. 1955. *A Conceptual Model for Communications Research.* Audio-Visual Communications Review, Vol. 34, No. 3. pp. 3-12.