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SOCIO-ENGINEERING PROBLEMS. NO 19-A

"COMMUNICATION THEORY IN SCIENCE AND RELIGION"

A Part of (A Proposal for a Book on)

"FRONTIER PROBLEMS OF ENGINEERING SOCIOLOGY"

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Abstract

These notes on "Communication Theory in Science and Religion" were originally prepared for a seminar. It is now proposed that these notes be edited for use in Chapter 10 (?): Distribution of Negentropy in Political Organization of the book proposed in S.E.P. No. 65 (12/18/61). This note does not contain anything essentially new. The object is to bring certain ideas to the educated layman, so that the public can better understand the content and uses of modern science. The topics included here are:

(a) Information Theory

(b) The Second Law of Thermodynamics

(c) The Life Process

(d) Conditions of Maximum Negentropy

(e) Consistency of Principle of Political and Religious Freedom with Maximizing Information or Negentropy, and

(f) Questions Brought Up Concerning Use of Information Theory.

Introductory Notes

This issue of Socio-Engineering Problems is one piece of a plan to help promote the "humane use of science" and to properly distinguish between "pure science" with its "freedom" and "technology" with its "social restrictions." It is my hope that this series will be of value in dealing with the issues discussed by Paul Goodman in "The Human Uses of Science", Commentary 30:461-72, Dec. 1960. I also hope that when these issues are pieced together to form a book, that this material will be useful in developing the "criticism of computer applications" started by Mortimer Taube in his book: Computers and Common Sense - The Myth of Thinking Machines, N.Y.: Columbia University Press (1961).

Part of the material in this note is derived from Shannon and Weaver, The Mathematical Theory of Communication Urbana: University of Illinois (1949) and some parts may be derived from discussions with Professor Stuart Dodd, University of Washington. Therefore these sources will have to be carefully checked for proper acknowledgement before publication.

Frederick B. Wood

"Communication Theory in Science and Religion"

(a) Information Theory

Consider the categories in Table I. Can you group into two classes containing related categories? The first three are obviously related by their common property of being physically measureable quantities. Numbers 5 and 6 cannot be weighed or measured with a yardstick. There is something about beauty and melody which is not reduced to measureable units; these categories involve emotional feelings which are complex while they are more elementary in human development. Does entropy belong in Class I or II? Entropy is a measure of the ratio of disorder to order, a measure of something sililar to beauty and melody, so it belongs in Class II. Yet at the same time, entropy in thermodynamics (the relationship between heat and energy) is a measureable quantity defined by equations. Thus the concept of entropy becomes a link between the scientifically measureable and the emotionally beautiful.

The mathematical theory of information establishes a measure of the amount of information in a message. The theoretical information carrying capacity of a telephone or telegraph channel is predicted by information theory. The reduction in capacity due to physical noise is treated by information theory. A sample communication system is illustrated in Fig. 1.

CATEGORY	CLASS I	CLASS II
1) Distance	X	
2) Mass	X	
3) Electric Force	X	
4) Entropy	?	?
5) Beauty		X
6) Melody		X

Table I. Classification of Categories

(b) Second Law of Thermodynamics*

The amount of information in a telegraph transmission problem is equivalent to the concept of entropy in Thermodynamics. The basic laws of thermodynamics are:

1st Law: Conservation of Energy

2nd Law: Heat will not of itself flow from one body to another body at a higher temperature.

The second law can be restated in the form that in any heat flow process the total entropy always increases or remains the same, i.e. in the long run entropy increases. This corresponds to a gradual degradation of energy toward a uniform temperature.

* Ref: Brillouin p.115; Collier's Enc. 9-600d

(c) Life Process

Biological systems preserve or increase order, decreasing entropy.* The life process represents local reversals if the degradation processes predicted by the second law of thermodynamics. The units of information are related to both the life process and to negative-entropy (or "negentropy") in thermodynamics.

* E. Schroedinger What is Life?

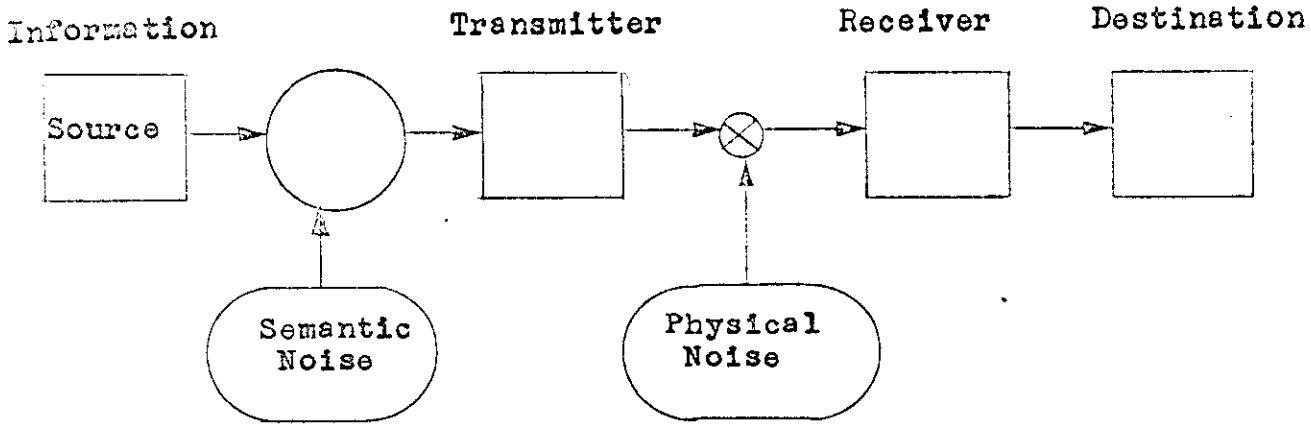
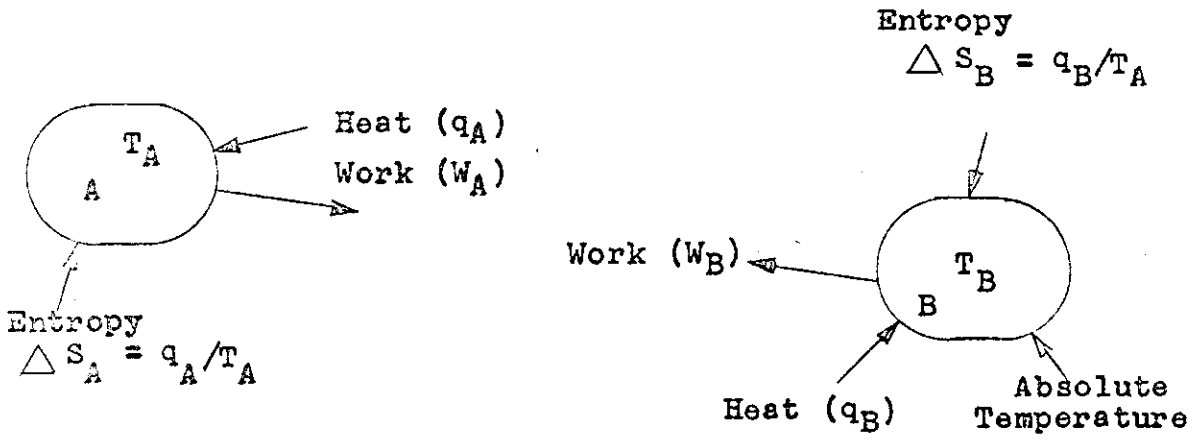


Fig. 1 Communication System



1st Law: $W_A - q_A + W_B - q_B = 0$

2nd Law: $\triangle S_A + \triangle S_B \geq 0$

If $T_A > T_B$, heat flow from A to B, no work

$$W_A = W_B = 0,\ q_A = -q_B\ ;\ q_B > 0$$

Then: $\triangle S_A + \triangle S_B = q_B\,(1/T_B - 1/T_A) > 0$

Fig.2 Thermodynamics

(d) Conditions for Maximizing Negative Entropy

Physically entropy can be stated as:

$S = k \ln P$, where

k is the Boltzman constant of 1.38×10^{-16} erg/oc

ln means "logarithm of", and

P = The number of elementary states of a system

In information theory the negentropy of a message of n symbols, each symbol having a probability P_n, is:

$$H = -(P_1 \ln P_1 + P_2 \ln P_2 + \ldots\ldots + P_n \ln P_n)$$

The condition for maximizing H for a fixed n, is that $P_1 = P_2 = \ldots\ldots = P_n$, i.e. equal probability for each of the n symbols.

(e) Consistency of Principle of Political and Religious Freedom with Maximizing Information or Negentropy

If we take the formula for information or negentropy and substitute n philosophical systems (or political systems) in place of the n symbols of a message, then the probabilities of occurrence of the respective philosophies among the population of a country.

If one philosophy is required by all on instruction or order of a dictator and this philosophy is number "k",

$$H = -(0 \ln p_1 + 0 \ln p_2 + \ldots. 1 \ln 1 + \ldots. + 0 \ln 0)$$

$$H = 0$$

Thus the requirement that people adhere to an official philosophy is equivalent to a zero contribution to the negative entropy or the "life process".

For example, if the probabilities of four different philosophies are as indicated in column one to four, the negentropy is as indicated in column five.

P_1	P_2	P_3	P_4	H_5^* $= -\sum p_i \log p_i$
0	0	0	1	$0 + 0 + 0 + 0 = 0$
0	0	$\frac{1}{4}$	3/4	$0 + 0 + \frac{2}{4} + .416(\frac{3}{4}) = 0.81$
0	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	$0 + \frac{2}{4} + \frac{2}{4} + \frac{1}{2} = 1.5$
$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{2}{4} + \frac{2}{4} + \frac{2}{4} + \frac{2}{4} = \frac{8}{4} = 2.0$

(f) Questions Brought Up Concerning Use of Information Theory.

Can the concepts be described in terms of the ratio of "disorder" and "order", so that unfamiliar terms such as "negentropy" do not have to be used?

How can the confusion over whether disorder is good or bad be resolved?

Can good things be made better through the use of information theory?

Is there not both "good" and "bad" information?

* Calculation of H_1^*:

$-1 \log_2 1 = -1 \cdot 0 = 0$

$-\frac{1}{4}\log_2(\frac{1}{4}) - \frac{3}{4}\log_2(\frac{3}{4}) = -\frac{1}{4}(-2) - \frac{3}{4}(-.416) = 0.5 + 0.31 = 0.81$

$-2(\frac{1}{4})(\log\frac{1}{4}) - (\frac{1}{2})\log_2(\frac{1}{2}) = -2(\frac{1}{4})(-2) - (\frac{1}{2})(1) = 0.5 + 0.5 + 0.5 = 1.5$

$-4(\frac{1}{4})(\log\frac{1}{4}) = -4(\frac{1}{4})(-2) = 0.5 + 0.5 + 0.5 + 0.5 = 2.0$