

A Mathematical Theory of Communication

By C. E. SHANNON

INTRODUCTION

THE recent development of various methods of modulation such as PCM and PPM which exchange bandwidth for signal-to-noise ratio has intensified the interest in a general theory of communication. A basis for such a theory is contained in the important papers of Nyquist¹ and Hartley² on this subject. In the present paper we will extend the theory to include a number of new factors, in particular the effect of noise in the channel, and the savings possible due to the statistical structure of the original message and due to the nature of the final destination of the information.

The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have *meaning*; that is they refer to or are correlated according to some system with certain physical or conceptual entities. **These semantic aspects of communication are irrelevant to the engineering problem.** The significant aspect is that the actual message is one selected from a set of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen since this is **unknown at the time of design.**

If the number of messages in the set is finite then this number or any monotonic function of this number can be regarded as a measure of the information produced when one message is chosen from the set, **all choices being equally likely.** As was pointed out by Hartley the most natural choice is the logarithmic function. Although this definition must be generalized considerably when we consider the influence of the statistics of the message and when we have a continuous range of messages, we will in all cases use an essentially logarithmic measure.

The **logarithmic measure** is more convenient for various reasons:

1. It is practically more useful. Parameters of engineering importance such as time, bandwidth, number of relays, etc., tend to vary linearly with the logarithm of the number of possibilities. For example, adding one relay to a group doubles the number of possible states of the relays. It adds 1 to the base 2 logarithm of this number. Doubling the time roughly squares the number of possible messages, or doubles the logarithm, etc.
2. It is nearer to our intuitive feeling as to the proper measure. This is closely related to (1) since we intuitively measure entities by linear comparison with common standards. One feels, for example, that two punched cards should have twice the capacity of one for information storage, and two identical channels twice the capacity of one for transmitting information.
3. It is mathematically more suitable. Many of the limiting operations are simple in terms of the logarithm but would require clumsy restatement in terms of the number of possibilities.

The choice of a logarithmic base corresponds to the choice of a unit for measuring information. If the base 2 is used the resulting units may be called **binary digits**, or more briefly *bits*, a word suggested by J. W. Tukey. A device with two stable positions, such as a relay or a flip-flop circuit, can store one bit of information. N such devices can store N bits, since the total number of possible states is 2^N and $\log_2 2^N = N$. If the base 10 is used the units may be called decimal digits. Since

$$\begin{aligned}\log_2 M &= \log_{10} M / \log_{10} 2 \\ &= 3.32 \log_{10} M,\end{aligned}$$

¹Nyquist, H., "Certain Factors Affecting Telegraph Speed," *Bell System Technical Journal*, April 1924, p. 324; "Certain Topics in Telegraph Transmission Theory," *A.I.E.E. Trans.*, v. 47, April 1928, p. 617.

²Hartley, R. V. L., "Transmission of Information," *Bell System Technical Journal*, July 1928, p. 535.

A Mathematical Theory Of Communication

Jorge Reina Schement, Brent D. Ruben



A Mathematical Theory Of Communication:

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The Mathematical Theory of Communication Claude Elwood Shannon, 1972 *A Mathematical Theory of Communication* Casey Reas, 2018 Between Communication and Information Jorge Reina Schement, Brent D. Ruben, 1993-01-01 The current popularity of such phrases as information age and information society suggests that links between information communication and behavior have become closer and more complex in a technology dominated culture Social scientists have adopted an integrated approach to these concepts opening up new theoretical perspectives on the media social psychology personal relationships group process international diplomacy and consumer behavior Between Communication and Information maps out a richly interdisciplinary approach to this development offering innovative research and advancing our understanding of integrative frameworks This fourth volume in the series reflects recently established lines of research as well as the continuing interest in basic areas of communications theory and practice In Part I contributors explore the junction between communication and information from various theoretical perspectives delving into the multilayered relationship between the two phenomena Cross disciplinary approaches in the fields of etymology and library science are presented in the second section Part III brings together case studies that examine the interaction of information and communication at individual and group levels information exchanges between doctors and patients children and computers journalists and electronic news sources are analyzed in depth The concluding segment focuses on large social contexts in which the interaction of communication and information affects the evolution of institutions and culture Between Information and Communication both extends and challenges current thinking on the mutually supporting interplay of information and human behavior It will be of interest to sociologists media analysts and communication specialists

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