# ANALOGUE TO DIGITAL: A SUBSET OF THE INFINITE

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A NEW PERSPECTIVE BY K. STRANG

**Analogue to digital: A Subset of the Infinitei**

It is clear to me that the digital world is an impoverished copy of the real world. An avatar, robot or mannequin can by definition possess only a subset of the infinite qualities of a human being.

Here is a passage from the book by John R. Pierce *An Introduction to Information Theory: Symbols, Signals and Noise* [Dover Publications, 1961 p65-67] on how to distinguish good encoding from bad encoding but also highlighting the difficulties in coding continuous rather than discrete phenomena.

"It is the study of this problem . . . which has provided through information theory new ideas important to all encoding, whether cryptographic or genetic. These new ideas include a measure of amount of information, called *entropy*, and a unit of measurement, called the *bit*.

I would like to believe that at this point the reader is clamoring to know the meaning of "amount of information" as measured in bits, and if so I hope that this enthusiasm will carry him over a considerable amount of intervening material about the encoding of messages.

It seems to me that one can't understand and appreciate the solution to a problem unless he has some idea of what the problem is. You can't explain music meaningfully to a man who has never heard any. A story about your neighbor may be full of insight, but it would be wasted on a Hottentot. I think it is only by considering in some detail how a message can be encoded for transmission that we can come to appreciate the need for and the meaning of a measure of amount of information.

It is easiest to gain some understanding of the important problems of coding by considering simple and concrete examples. Of course, in doing this we want to learn something of broad value, and here we may foresee a difficulty. Some important messages consist of sequences of discrete characters, such as the successive letters of English text or the successive digits of the output of an electronic computer. We have seen, however, that other messages seem inherently different.

Speech and music are variations with time of the pressure of air at the ear. This pressure we can accurately represent in telephony by the voltage of a signal traveling along a wire or by some other quantity. Such a variation of a signal with time is illustrated in a of Figure IV-1. Here we assume the signal to be a voltage whichvaries with time, as shown by the wavy line.

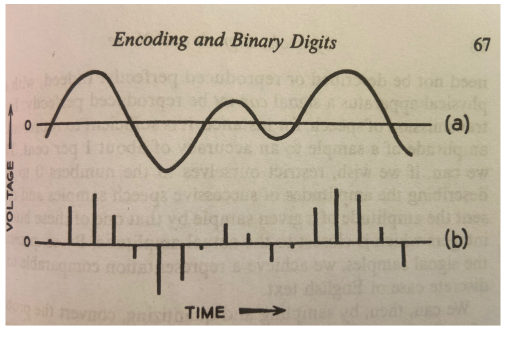
Information theory would be of limited value if it were not applicable to such *continuous* signals or messages as well as discrete messages, such as English text.

In dealing with continuous signals, information theory invokes a mathematical theorem called the sampling theoremwhich we will use but not prove. This theorem states that a continuous signal can be represented completely by and reconstructed
perfectly from a set of measurements or samples of its amplitude which are made at equally spaced times. The interval between such samples must be equal to or less than one-half of the period of the highest frequency present in the signal. A set of such measurements or samples of the amplitude of the signal *a*, Figure IV-1, is represented by a sequence of vertical lines of various heights in *b* of Figure IV-1.

We should particularly note that for such samples of the signal represent a signal perfectly they must be taken frequently enough. For a voice signal including frequencies from 0 to 4,000 cycles per second we must use 8,000 samples per second. For a televsion signal including frequencies from 0 to 4 million cycles per second we must use 8 million samples per second. In general, if the frequency range of the signalis *f* cycles per second we must at least use *2f* samples in order to describe it perfectly.

Thus, the sampling theorem enables us to represent a smoothly signal by a sequence of samples which have different amplitudes one from another. This sequence of samples is, however, inherently different from a sequence of letters or digits. There are only ten digits and there are only twenty-six letters, but a sample can have any of an infinite number of amplitudes. The amplitude of a sample can lie anywhere in a *continuous* range of values, while a character or a digit has only a limited number of *discrete* values."

Fig. IV-I




No matter how powerful, no computer has the energy to compete with the inbuilt infinity in nature. 