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# Can Artificial Intelligence Explain Natural Intelligence?*

## A Discussion on an Actual Problem

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This paper includes a number of viewpoints regarding the extent to which existing general-purpose computers can be applied to simulate human mental processes (intelligence). It is maintained that due to fundamental structural differences between the brain and a computer, such as the non-binary firing of the neurons — the latter must be regarded as essentially a tool for increasing human mental and/or physical efficiency rather than for explaining natural intelligence. Furthermore, it is advocated that the brain is basically a pattern recognizing apparatus for which the metric characteristics of natural or symbolic patterns are not essential and consequently new mathematical techniques are probably required for modeling the non-metric regularities of the brain functions. Data are presented concerning the incapability of man in processing numerical information as well as some aspects of pattern recognition as a reduction process.

## EXPLANATION BY ANALOGY

The ultimate objective of cybernetics has recently been described as being "to construct intelligent machines and explain the mechanism of life" (Boulanger [3]), and it has been predicted that in the future such machines may even overtake human intelligence. One interpretation of these statements is that a day will probably come when advancements, particularly in synthetic techniques, will make the construction of living cells and components possible. This is, to the present author, a conceivable method by which (if realized) the mental aspects of human life, namely the underlying mechanism of intelligence — the higher functions of the brain — can be discovered and explained. On the other hand, the attribution of the psychological terms such as intelligence, learning, problem-solving to the functions of the existing computing tools — general-purpose computers — may well be considered as explanation by analogy rather than scientific explanation of the brain functions. The reason is that a pre-

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sent day computer and a brain are fundamentally different both in function (to the extent that it is known) and in structure. The whole system of analogy is built on the assumption that the neurons emit signals on an all-or-none basis, thus, making the brain into a complicated switching system similar to an adding machine – a computer – which works on the basis of binary numbers. This is, however, an oversimplification of the nature of the neuronal signals as will be clarified later in this paper. What the brain is not suitable for, is the operation of adding in general and of adding in terms of binary digits in particular. Whereas, what the brain is really apt at doing is matching of patterns, in other words, the brain is basically a pattern recognizing mechanism which is operating in the recognition of both the natural patterns – which are essential for the organism's survival – and the symbolic patterns which are used in thinking and semantic information processing. 

## THE EFFICIENCY OF TOOLS

Minsky [13] mentions a computer program that can play tournament quality chess under regular competition clock conditions with the skill of a medium amateur, and another program developed by Moses that can solve various textbook integration problems. Evans [4] has developed a program for analogical reasoning about geometric figures. A number of these problems have been taken from college-level intelligence tests. These are only a few examples of what general purpose computer programs can accomplish but they indicate that machines can do things which "require intelligence if done by men". As we know, these performances are realized by sequences of operations based upon binary numbers. As any other tool these machines, which are in no way similar to a living brain, can in the long run, improve the human physical and/or mental efficiency. Tools, however, be they manual (e.g. a bicycle), semiautomatic (e.g. a car, an aeroplane), or fully automatic (e.g. a refinery, a computer) are, as we know, all superior to man regarding their efficiency. A desk counter, for instance, – which, as far as counting is concerned, may also be called an intelligent machine – carries out arithmetical operations much faster than even the famous "lightning calculator", J. M. F. Dase, who could maximally calculate the product of two 8-digit numbers in 54 seconds (see [2]). A modern digital computer is incomparably superior to man in memory capacity and endurance, speed of recall, solving a number of algebraic equations, etc. In speaking of tools the importance of man's control over them should be regarded as a prerequisite in order for them to function. In manual and semiautomatic systems this control is exerted directly by the participation of the human operator as the decision link in the overall man-machine system and thereby the system becomes a closed one. In a fully automatic machine on the other hand, although the system is closed without man's participation, nevertheless man's control is exterted in a most stringent form, although indirectly. For example in the case of a computer, this control is realized partly by the internal (structural) program and partly by the actual program for the specific task. Thus, the computer's action is directed and decided upon by man (via his program). Even the operation of "random search" is in effect, under man's control. Therefore, to say that computers seek goals and set goals is nothing but the use of mere metaphores. How then, can such a system be used to explain the mechanism of an open self-organizing goal-directed system like the human organism?

## THE PROBLEM OF QUANTIFICATION IN BEHAVIORAL MODELS

Psychology – as the study of human behavior – is sometimes criticized for not having quantitative models for the explanation of the human mind (intelligent behavior). One of the critics is the Soviet cybernetician N. M. Amosov ([1], p. XI) who maintains that psychology and psychiatry "... are at that stage of development where, for the time being at least, they cannot offer material for modeling. The fact of the matter is that a necessary condition for the creation of any model is computation, that is quantitative regularity. Up to the present time, these sciences have almost exclusively been governed by qualitative concepts. They describe their systems by words, by simple graphs, and only very rarely by numbers (and this only in very special cases)."

These statements are only partially true, since as the literature testifies, psychology applies quantitative methods in some areas and it is also particularly abundant with statistically oriented theories. But most of these theories, not being able to resists the experimental facts, have crumbled soon after their formulation. This failure speaks in support of Minsky's view to the effect that adequate theoretical mathematical techniques for very intricate structures which show intelligent behavior, are still not available. Numerous experiments have shown that in contrast with computers, the brain is indeed a poor quantifier implying that it does not lend itself to be treated by conventional mathematical techniques. Let us clarify this point.

(1) The range of the physical intensity when the intensity is transformed into impulses in the nerve fibres shrinks considerably, that is, the frequency of impulses is roughly proportional to the logarithm of the intensity. This significant reduction of the physical information implies that the brain is not sensitive to the finer gradations of intensity which are so basic in the creation and transmission of information to the brain. Note that the impulses are discrete, implying that the transformation of the values in the two continua is not one-to-one.

(2) That the brain is not capable of quantification – i.e. measurement as used in physics – has been repeatedly shown by psychophysical scaling methods. When human subjects are instructed to compare physical magnitudes in various continua and to estimate them by assigning numbers to these magnitudes, the scales produced in this way do not meet the requirements of the interval and ratio scales that are commonly used in physical measurements (Guilford [6], Mashour [9], Mashour and Hosman [10] among others).

What the subject can do is to judge that one magnitude is "greater than", "equal to" or "less than" another one. Moreover, such numerical estimates (even if taken at their face values) are not equally accurate, the errors are smallest when two magnitudes are equal. Fig. 1 shows the plot of the relative errors against the numerical estimates of noise intensities (loudnesses) and time durations obtained from 20 subjects. This is only one example from among a great deal of similar results.

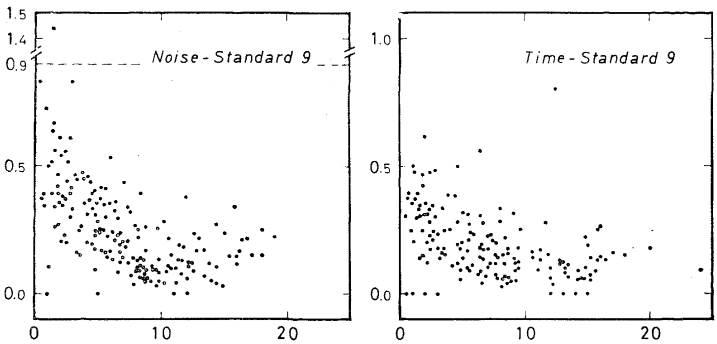


Fig. 1. The plot of the relative errors against the estimates of noise (left graph) and time (right graph) obtained from 20 subjects. The white noise (a band of 20—50.000 cps) was used as stimuli at 11 different sound pressure levels ranging from 0.22 to 1.50 microbars. The pressure level 1.28 (standard 9) served as the comparison stimulus. The time stimuli were also 11 ranging from 0.3 to 5 sec. The comparison stimulus was 3.5 sec (standard 9). The relative error was determined by the ratio of the stadard deviation to the geometric mean of the group estimates.

(3) The failure of the brain in processing metric information which is the fundament of quantification and modeling by the conventional mathematical techniques is still more evident by the rich body of results on the so called "absolute judgment" of unidimensional stimuli according to which human being are incapable of recognizing more than about 5 to 9 stimuli when these vary only along a single physical dimension. By varying wavelength, for instance, one can identify 9 colors, by varying the frequency of a sound only 6 pitches, and so on. This limited capacity has been called "the magical number seven plus or minus two" (Miller [12]) and is almost independent of the amount of practice. In contrast, identification improves remarkably if stimuli vary in two dimensions or multidimentionally (Fitts and Posner [5]). And it should be noted that multidimensionality is the essence of a pattern's organization where the absolute metric values of the single dimensions lose their significance to a considerable extent, whilst comparative (relational) judgments play a dominant role. For example,

you can identify a word irrespective of its style, letter type, size, etc. In order to do so, it is sufficient to have only a minimum of relational constancy between a few essential features (parts).

It is therefore reasonable to conclude and emphasize that the raw material or elements used in higher through processes in the brain – or intelligence – are essentially nonmetric patterns which might be called qualities. These are either complicated patterns of objects in the environment or simplified abstract patterns, that is, symbols and words. Consequently the mathematics which might be developed in the future should be of such a nature as to be appropriate to treat qualities.

The non-metric characteristics of the brain functions are also apparent in the orientation of the organism in the environment. The organism does not measure (on an interval or ratio level) the distance and direction relative to a goal, because it can always correct its errors by feedback information. Some of the problems related to the human pattern recognition will be dealt with in the following section.

## PATTERN RECOGNITION AS A REDUCTION PROCESS

Pattern recognition may be considered to be a process in which the reduction of information is essential. This is especially the case regarding natural patterns, namely, those patterns which arise from the environmental sources, objects and events. This problem can best be illustrated in connection with the visual system. At the retinal level, the incident light acts on about $2 \times 10^8$ rods and $6.5 \times 10^6$ cones. Thus, the number of patterns which can be produced by these receptors will be even larger than astronomically large. In order to get an idea about how large this figure might be we can only mention that a matrix consisting only of $100 \times 100$ elements can create $10^{3000}$ patterns. The first reduction of information, however, occurs through the convergence of the receptors on almost $10^6$ optic nerve fibres. The rate of information arriving at these fibres has on the basis of the all-or-none firing activity of the ganglion cells been estimated to be approximately $3.4 \times 10^6$/sec (Jacobson [8]).

This amount should correspond to what is seen of the visual field rather than to the recongition of specific patterns of objects. (Seeing the visual field is an instantaneous process – a parallel processing – while pattern recognition is a sequential process.) In pattern recognition the mechanism of attention (priority processing, amplification) is usually involved. Moreover, the more specific (the more detailed) a pattern the more learning that is required to recognize a pattern as a specific one. There is in principle no difference between learning to recognize a word or an object. Only very elementary patterns such as simple geometric figues may be excepted.

The sequential character of pattern recognition was verified by an experiment in which very simple pictures of familiar objects, words, letters, and geometric figures (such as those in Fig. 2) were presented simultaneously in a homogeneous dim background under various time periods (Mashour [11]). Fig. 3 shows the typical increase in the number of patterns both recognized and seen as functions of presentation time (left graph) which supports the assumption of sequential processing in pattern recognition. Note that the number of patterns either recognized or seen never reaches the total number of patterns presented. 

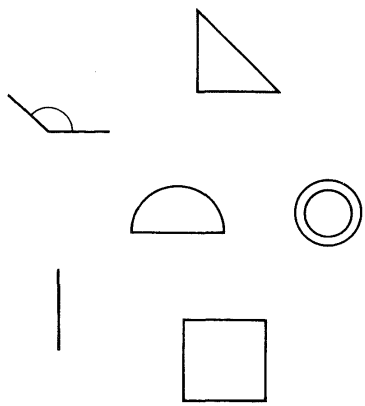

**Fig. 2.** A sample of simple geometric figures projected simultaneously on a screen under various presentation times ranging from 0.125 to 5 sec.

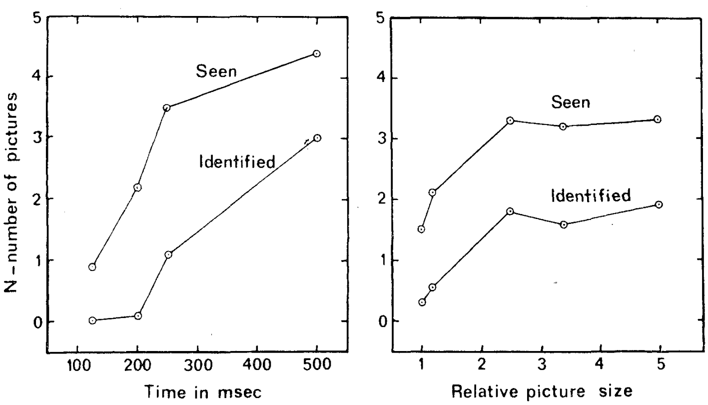


**Fig. 3.** The number of patterns seen and recognized by 20 subjects as a function of presentation time (left graph) and pattern size (right graph). Each point represents the group average.

The difference between the number of patterns presented and the number of patterns seen indicates that the visual system is subject to a kind of partial blindness which runs counter to the view that all information is present in the short-term memory. The rate of pattern recognition determined at this experiment was about 5–8 patterns/sec depending mainly on the pattern type (and size) which clearly confirms the substantial reduction of information flow from the periphery (receptors) to the central mechanism. Hunt [7] has, on some other context, provided an interesting discussion concerning the reduction process in human information processing.

The technique of pattern recognition by intelligent machines has advanced possibly farther than any other branch of artificial intelligence so that some types of pattern recognizers such as character recognizers are at the present time in common use. A review of the attempts made for the construction of pattern recognizing machines is to be found in [14]. One may wonder how, while our knowledge of natural pattern recognition is almost entirely blocked already at the retinal level, one is able to construct devices that might recognize patterns in the same way that living beings do. To differentiate letters by some technical mechanism does not necessarily imply that the mechanism explains human letter recognition, just as a thermometer which discriminates degrees of temperature offers no explanation of the underlying mechanism of human sensitivity to and discrimination of temperature.

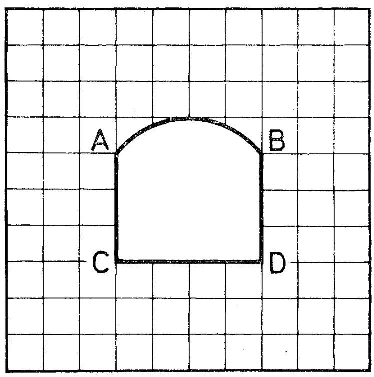


**Fig. 4.** A simple closed curve (*ABCD*) used for recognition by computers.

An interesting version of artificial recognition technique which belongs to the artificial intelligence domain is one which was designed by Evans [4] as part of his program for the solution of a class of geometric analogy intelligence test questions. In his program a simple closed curve (SCC) as for example the pattern show in Fig. 4 is described by coordinates $(x, y)$ of the points $(A, B, C, D)$ the straightness of the lines ($AC$, $CD$, $DB$) being taken as 0 and the degree of curvature of curve $AB$ as 1 in this case. Thus the programmed description of the pattern (Fig. 4) is written as

$$(SCC((0{\cdot}3,\ 03)\ 0{\cdot}0\ (0{\cdot}7,\ 0{\cdot}3)\ 0{\cdot}0\ (0{\cdot}7,\ 0{\cdot}6)$$

$$1{\cdot}0\ (0{\cdot}3,\ 0{\cdot}6)\ 0{\cdot}0\ (0{\cdot}3,\ 03)))$$

Using such programs, the computer can process the digital information fed into it and thereby discriminate each individual pattern; then, by following an advanced program it can make correct analogies between geometric figures. As can be understood from the descriptive program, artificial intelligence works with numbers as features of a pattern rather than the features themselves. In the case of natural intelligence on the other hand, all information about the relevant features and their mutual relations should be fed into, say, the human computer so that a pattern similar to the original natural one can be reconstructed (recognized). Evans' program ultimately results in a series of binary digits instead of a pattern. Even so, a full numerical representation of the pattern in Fig. 4 in terms of $(x, y)$ instead of only 4 points, would require a much longer program and thereby the waste of the computer's memory as a consequence.

## THE PROBLEM OF ALL-OR-NONE FIRING

Now, let us disregard all the structural and functional differences which exist between a computer and the brain and confine ourselves to an examination of the main assumed similarity between them which is thought to justify the simulation of the brain functions by general-purpose computers; namely, the neurons'action in an all-or-none manner. It is a well-established fact that a neuron (a ganglion cell, for instance) either fires or does not fire which, in this respect alone, it may be considered similar to the computers binary units. But, when it fires it sends not one but a series of impulses to the next cell or cells. The frequency of impulses produced by a firing depends on the intensity of the stimulus which affects the corresponding receptor(s). This means, therefore, that in contrast to a neutral single impulse (firing) in a computer which magnetizes a magnetic core in one of 2 different ways (i.e. 0 or 1), a neuronal firing conveys, in addition, specific information about the intensity of the stimulus. On this basis, the correct description of the all-or-none firing of a cell would be that either a cell does not fire or it fires in one of many ways (i.e. 0 or $n$, $n$ being a variable whose value depends on the frequency of impulses produced by a firing), and consequently the binary number character of the cell function and with it the similarity (which has almost been taken for granted) between the computer and the brain will, most probably, lose its validity. Therefore, it is hard to believe that artificial intelligence of the *present* structure might explain natural intelligence.

 However, this important field of research — the techniques of artificial intelligence — will certainly bring about still greater achievements in increasing human mental efficiency.

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