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SUBJECT: Comparisons Between the Brain and Automatic Computer Machines

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Reprint of remarks of R. H. Lazinski on comparisons drawn between the brain and automatic computing machinery in Review of Input and Output Equipment Used in Computing Systems, Joint AIEE - IRE - ACM Computer Conference, December 10 - 12, 1952. AIEE Publication S-53, pp 140-1.

NOTE

This brief article is reproduced because in my opinion, it contains information of importance to the long range planning of computer and communication research. This article was not indexed in the Engineering Index and hence would not be found directly from checking abstracts.

The Information Research Group under Mr. N. Rochester in Poughkeepsie is pursuing basic research on the possible interrelationship between electronic computers and biological nerve systems.

An experiment in modifying the channelized education which Mr. Lazinski holds responsible for the seeming diversity of the neurophysiological and information-handling fields is being conducted at California State Polytechnic College, San Luis Obispo, California. Dr. J. T. Culbertson is using the concepts and terminology of nerve networks in an undergraduate course on the mathematics of digital computers.

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Raymond H. Lazinski: My thesis is that engineers and logicians of the computing machinery and information handling equipment fields have not availed themselves of the abundance of pertinent information gathered by members of the field of biological sciences. Biophysicists, biochemists, and neurophysiologists have investigated the components and circuitry of the most highly developed information handling equipment as we know it, the mammalian nervous system. These components have been described in great detail in numerous publications in the field of neurophysiological histology.

The comparisons drawn between the brain and automatic computing machinery by A. M. Uttley,[1] W. Grey Walter,[2] and E. C. Berkeley,[3] are an endeavor to show the similarity of two types of mechanisms which have in common the fact that their outputs result from the manipulation of information either stored or obtained directly from input equipment.

A more quantitative approach is necessary if the members of the computing machinery field are to take full advantage of the knowledge gained by biological researchers. In order to understand and extrapolate on the workings of a nervous system, a working knowledge of its basic unit, the neuron, is essential. Only after the reader has acquired a knowledge of the characteristics of the individual neuron can he appreciate the integrative nature of a neural network.[4] As this is not intended to be a text on neurophysiology for the engineer or a repetition of information so ably presented in many texts, a minimum of physiological terminology will be used. Instead, this brief paper will be a description, in simple terms, of the neuron and its interactions with other neurons.

The neuron, which is a single cell, is composed of three major parts: the soma, the dendrites, and the axone. The soma is the cell body of the neuron. The dendrites, which serve to transmit impulses to the soma, are small hair-like processes which emerge from the cell body and branch out in all directions. The axone serves to carry the impulse from the soma to a junction of dendrites and axones of other neurons. The axone may range in size from 1/[illegible] to 1/[illegible] inch in diameter and it may be several feet in length. The hair-like branches of the axonal endings are arranged in intermeshing proximity with the dendrites of other neurons (as illustrated by Kuntz[5]). This junction between the axonal endings and dendrites is called a synapse. The impulse which travels along the neuron is described by Adrian[6] as an all or none type of impulse. The polarization potentials maintained between the inside and the outside of the axone (owing to the interchange of potassium and sodium ions through the axonal membrane by means of a biological 'sodium pump,' as shown by Hodgkin and Huxley)[7] deteriorate when sufficient stimulus is applied to the dendrites of the neuron. This depolarization will travel from the soma along the axone towards a synapse. The velocity of this electrochemical impulse ranges from one meter per second in thin axones to 160 meters per second in thick axones. Gasser and Erlanger[8] show that the velocity is proportional to the square root of the axonal diameter. Immediately after a neuron has been stimulated and caused to 'fire' it enters an absolutely refractory phase, that is, a second impulse can not be initiated, regardless of the intensity of the stimulus. A relatively refractory phase immediately follows the absolute refractory one, that is, a period during which a large stimulus is needed to initiate an impulse. This phase exists until the neuron is repolarized. It is now apparent that stimuli from more than one neuron at a synapse may be necessary to cause another neuron to initiate an impulse. To be effective the incoming impulses need not arrive at a synapse simultaneously, but they must arrive within the period of latent addition.[9] Not all impulses from adjacent neurons are facilitating; they may in fact be inhibitory.[10] It is now clear that the firing of a neuron depends upon its polarization (a function of metabolism), its refractoriness, the relation of its dendrites to the axones of other neurons;[11] the relative time of arrival of stimulating impulses; axonal transmission delays; synaptic delays, and so forth. For more detailed information on the operation of the components of neural networks, the interested reader may consult an article entitled "The Nerve Impulse" by B. Katz.[12] If not satiated he can then consult a chapter on neurophysiological histology in almost any modern anatomy or physiology text.

It was shown by Lorente de Nó[13] that a chain of neurons forming a closed loop can be made to trigger each other indefinitely around a closed circuit. Due to the presence of the inhibitory and facilitory[14] neurons at many of the synapses within the closed loop, the path and velocity of the impulses can be altered. Because of the temporal and spatial summation at a synapse, solitary as well as cyclical impulses can be readily routed. Saunder and Young[15] imply that this is the basis for learning. MacKay and McCulloch[16] suggested that the nervous system uses a pulse interval modulation system to transmit its information. The characteristics of neurons and synapses have been used by McCulloch and Pitts to develop a "logical calculus"[17] of neural nets. Shimbel and Rapoport[18] consider a probabilistic approach to neural networks in differentiation to what they call McCulloch's and Pitts' deterministic approach. Landahl and Runge[19] have applied a matrix algebra to neural networks. The extension of the McCulloch and Pitts logical calculus manifests itself in an explanation of the operation of some sensory organs. They have used these concepts to explain the operation of auditory and visual sensation, and recognition of form.[20] Culbertson[21] has described the optic nerve conduction and form recognition in these terms. This type of information input mechanism is certainly of greater value than a photoelectric word reader, such as the 5 by 7 matrix reader, which reads only print of a certain type with a specific orientation and size.

Channelized education has been responsible for the seeming diversity of the neurophysiological and information handling fields. It is for this reason that the aforementioned principles have not been used to advantage in the field of information handling. Unfortunately the lack of personnel trained in both fields has served as an obstacle to the interchange of pertinent information. It is the belief of the writer that implementing of the study of neural networks, with a view toward their information handling abilities, will result in an advantageous change of emphasis in the automatic computing machinery field. Obviously the system under discussion is ripe for investigation for after all it does work.

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