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ASSOCIATIVE STORAGE AND RETRIEVAL OF DIGITAL INFORMATION IN NETWORKS OF ADAPTIVE "NEURONS"

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ABSTRACT

An adaptive logical element, called the ADALINE "neuron," which consists of a set of variable weights, a threshold, and adaptation machinery for automatically adjusting its weights, has been described previously.* Proofs of convergence of its learning processes and derivations of learning rates have been made. It has been demonstrated analytically and empirically that a single ADALINE can be "trained" to recognize geometric patterns, perform logical functions, and store digital information.

Machines capable of being trained to solve multistage decision problems require associative memories which permit the abstraction of previous experiences similar to current problem situations. Networks of ADALINEs can perform the associative memory function. Three types of networks are considered.

One system stores incident information in available memory registers. Classification is accomplished in the read-out process after storage by means of adaptive-neuron classifiers attached to each register. Associative retrieval is accomplished by simultaneously training the classifiers, then causing all registers to transpond to a central control if their contents fall in the desired class.

Another form of memory allows some classification of information to take place during storage, and some during retrieval. A tree-like structure, connected as a traffic control system, can be trained to route input information according to class into many storage bins, where it is recorded and possibly further classified. At each juncture in the tree, a neuron acts like an "adaptive traffic cop," controlling (gating) the choice of propagation path. After training, each class of input pattern excites a characteristic connection path or "trace" through the tree.

In a third memory system, information is stored directly in a bank of adaptive neurons and is classified as it is stored. This system is trained to produce a set of D binary output digits in response to an input set of N binary digits, and has the ability to generalize in that input stimuli that are similar to the training experiences evoke the same responses. The number of experiences required to train the neuron memory equals several times the product ND. This type of memory tends to forget previous experiences exponentially. A set of experiences, in order to be completely remembered, has to be repeated over and over again until it "sinks in," i.e., until the training process converges. The similarity to animal memory is striking.

*Widrow, B., and Hoff, M.E. Adaptive Switching Circuits, 1960 Wescon Convention Record, Part 4.