Neural networks: the early days

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ABSTRACT

A short account is given of various investigations of neural network properties, beginning with the classic work of McCulloch & Pitts. Early work on neurodynamics and statistical mechanics, analogies with magnetic materials, fault tolerance via parallel distributed processing, memory, learning, and pattern recognition, is described.

1 INTRODUCTION

In this brief account of the early days in neural network research, it is not possible to be comprehensive. This article then is a somewhat subjective survey of some, but not all, of the developments in the theory of neural networks in the twent-five year period, from 1943 to 1968, when many of the ideas and concepts were formulated, which define the field of neural network research. This comprises work on connections with automata theory and computability; neurodynamics, both deterministic and statistical; analogies with magnetic materials and spin systems; reliability via parallel and parallel distributed processing; modifiable synapses and conditioning; associative memory; and supervised and unsupervised learning.

2 McCULLOCH-PITTS NETWORKS

The modern era may be said to have begun with the work of McCulloch and Pitts (1943). This is too well-known to need commenting on. Let me just make some historical remarks. McCulloch, who was by training a psychiatrist and neuroanatomist, spent some twenty years thinking about the representation of event in the nervous system. From 1941 to 1951 he worked in Chicago. Chicago at that time was one of the centers of neural of

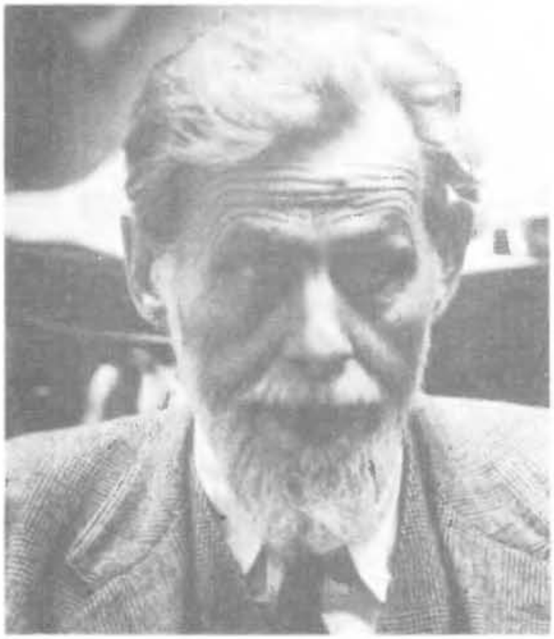

Figure1: Warren McCulloch *circa* 1962

network research, mainly through the work of the Rashevsky group in the Committee on Mathematical Biology at the University of Chicago. Rashevsky, Landahl, Rapaport and Shimbel, among others, carried out many early investigations of the dynamics of neural networks, using a mixture of calculus and algebra. In 1942 McCulloch was introduced to Walter Pitts, then a 17 year old student of Rashevsky's. Pitts was a mathematical prodigy who had joined the Committee sometime in 1941. There is an (apocryphal) story that Pitts was led to the Rashevsky group after a chance meeting with the philosopher Bertrand Russell, at that time a visitor to the University of Chicago. In any event Pitts was already working on algebraic aspects of neural networks, and it did not take him long to see the point behind McCulloch's quest for the embodiment of mind. In one of McCulloch later essays (McCulloch 1961) he describes the history of his efforts thus:

> My object, as a psychologist, was to invent a least psychic event, or "psychon", that would have the following properties: First, it was to be so simple an event that it either happened or else it did not happen. Second, it was to happen only if its bound cause had happened-shades of Duns Scotus!-that is, it was to imply its temporal antecedent. Third it was to propose this to subsequent psychons. Fourth, these were to be compounded to produce the equivalents of more complicated propositions concerning their antecedents...In 1921 it dawned on me that these events might be regarded as the all-or-nothing impulses of neurons, combined by convergence upon the next neuron to yield complexes of propositional events.

Their subsequent 1943 paper was remarkable in many respects. It is best appreciated within the *zeitgeist* of the era when it was written. As Papert has documented in his introduction to a collection of McCulloch's papers (McCulloch 1967), 1943 was a seminal year for the development of the science of the mind. Craik's monograph *The Nature of Explanation* and the paper "Behavior, Purpose and Teleology, by Rosenbleuth, Wiener and Bigelow, were also published in 1943. As Papert noted, "The common feature [of these publications] is their recognition that the laws governing the embodiment of mind should be sought among the laws governing information rather than energy or matter". The paper by McCulloch and Pitts certainly lies within this framework.

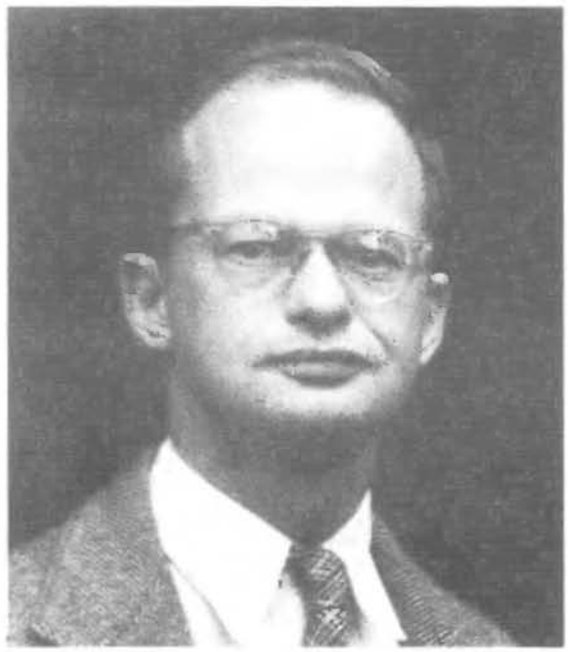

Figure 2: Walter Pitts *circa* 1952

McCulloch-Pitts networks (hence-forth referred to as MP networks), are finite state automata embodying the logic of propositions, with quantifiers, as McCulloch wished; and permit the framing of sharp hypotheses about the nature of brain mechanisms, in a form equivalent to computer programs. This was a remarkable achievement. It established once and for all, the validity of making formal models of brain mechanisms, if not their veridicality. It also established the possibility of a rigorous theory of mind, in that neural networks with feedback loops can exhibit purposive behavior, or as McCulloch and Pitts put it:

> both the formal and the final aspects of that activity which we are wont to call *mental* are rigorously deducible from present neurophysiology...[and] that in [imaginable networks]..."Mind" no longer "goes more ghostly than a ghost".

2.1 FAULT TOLERANCE

MP networks were the first designed to perform specific logical tasks; and of course logic can be mapped into arithmetic. Landahl, McCulloch and Pitts (1943), for example, noted that the arithmetical operations +, 1-, and x can be obtained in MP networks via the logical operations OR, NOT, and AND. Thus the arithmetical expression a-a.b = a.(1-b)