IC/72/83

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

INFORMAL MEETING ON NEURAL NETWORKS

24 - 26 July 1972

(SUMMARIES)

INTERNATIONAL ATOMIC ENERGY AGENCY

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

1972 MIRAMARE-TRIESTE

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RANDOM LOGIC NETS: STABILITY AND ADAPTATION

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I. Introduction

This paper reviews some of our recent work on the behaviour of randomly interconnected memory elements. Two specific types of "intelligence" are discussed: the first is related to the fact that a random network tends to be stable even when the memory elements perform functions chosen at random. The second aspect considers the behaviour of a network after it has been exposed to a non-random environment and the functions of the elements are made to change as a result.

It has long been suggested by Caianiello (and indeed by too many others to mention) that "thought" may be related to the cyclic behaviour of a network of neurons. Indeed, Caianiello has been able to solve network matrix equations which predict the reverberation period of such cyclic behaviour. Caianiello's neural elements are analytic and of the "linear separator" kind, making the setting up of matrix equations possible.

It is now also common empirical knowledge that networks of less analytic logic elements behave in a stable cyclic way (few and short cycles) particularly if the number of inputs to each element is low. Such systems have been used by S. Kauffman as analogues of gene interaction in a biological cell. He has used the property of stability to explain the "intelligently" reproducible differentiation and replication time of biological cells.

It seems significant that stability is not heavily dependent on the function of the elements and that, if found to be inherent, causes an inherently intelligent behaviour in random networks. Sec.II of this paper discusses the reasons for and nature of such stability. In our descriptions, a concept similar to Kauffman's "forcing structures" is used, the main advance being, however, that our technique incorporates a theory of physical ring structures of logic elements in a probabilistic sense.

This largely solves the problems where "forcing structures" only hint at a solution.

Sec.III reports the results of some experiments in which the function of the elements is allowed to vary as a result of exposures to an environment.

II. Adaptation

Only the most sketchy analysis of the results of single exposures has been given in this paper. This shows, however, that exposures create stabilities in the state structure which "draw in" states Hamming distance similar to the exposure itself. Even though not explicitly stated here, this Hamming distance effect is characteristic of all stable nets, even before any adaptation takes place.

Clearly, only one way of exposing the network to the environment has been considered here. Others (such as studied by Tollyfield) are being investigated. In these, the elements have certain inputs reserved solely for incoming information whereas other inputs are continuously connected to the feedback connections. These nets show a greater tendency to use the naturally arising cycles of the net (i.e. as in their original random structures) without there being a great deal of disruption of the state structure as a result of exposures.

This and a great deal of experimental evidence taken from less trivial exposures (viz. where the net is exposed to many examples of patterns in a similarity class, and where an "aging" process is introduced) leads us to the conclusion that the net attempts to adapt its stable state structure so as to create regions for events "seen" in its environment and to associate unseen inputs with these regions.

III. Stability

A natural tendency for stability in adapting and untrained nets, as previously seen empirically, has been analysed here and related to the net elements. This has shown that elements with low numbers of inputs (but > 1) can be expected to be more stable than those with high values of this quantity. However, from a point of view of adaptation, it is seen that the greater the number of inputs per element the greater will be the discrimination of the net. That is, the net is better able to separate events that may be Hamming distance similar but require different reactions.

However, I conclude that it is the stability of the network which enables it to interact "intelligently" with its environment. However, one can have over-stable nets which would tend to over-generalize and under-stable nets which would require very long training exposures. Thus one cannot relate the degree of stability to the "quantity" of intelligence whatever that may be. A good match is clearly what one is looking for, but a great deal of work remains to be done in order to understand what one means by a "good match".

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