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INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

I N F O R M A L M E E T I N G

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N E U R A L N E T W O R K S

24 - 26 July 1972

(SUMMARIES)

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NOISY NEURAL NETWORKS

J.G. Taylor

Department of Mathematics, King's College, London, UK.

We build a mathematical model of neural networks which is based on recent physiological data concerning information transmission at the synaptic junction. This transmission is known to occur in nearly all synapses by means of emission of a number of quanta of a chemical transmitter on receipt of a nerve impulse at the pre-synaptic membrane. The work of Katz and his colleagues [1] has shown that there is always leakage of transmitter quanta, and that this follows a Poisson law.

Our first step is to determine the amount of transmitter substance in the synaptic cleft at any time; this follows the shot-effect, and is given explicitly in terms of the decay law for each quanta. We then put together a network composed of these noisy neurons, each of them being a binary element with fixed threshold, and obtain the equations describing the probability of firing of each neuron of the net in terms of firing probabilities at previous times. This is done initially for neurons in discrete time and then extended to the continuous time case, with a fixed absolute refractory period for each neuron.

The resulting equations [2] have the form of polynomial mappings. They are considerably simpler than the corresponding equations in the deterministic case, [3] to which they reduce when the size of the single quantum of transmitter substance is taken to zero in a suitable fashion.

We consider the general question of estimation of noise generated by transmitter leakage in a neural network and introduce a spontaneity parameter which gives a rough estimate of it. This allows us to consider where noisy behaviour may best be observed in animals, and present evidence for its occurrence in certain regions of the central nervous system in some animals, in particular in the cerebellum and cortex.

We also present a possible analogue model of noisy neural transmission, and discuss the feasibility of constructing large nets on such a principle.

Finally we discuss the role that noisy transmission may play in information processing in the nervous system, and what control there is over its interference with incoming data.

REFERENCES

1) See, for example, the monographs by B. Katz, "The Release of Neural Transmitter Substances", Liverpool Univ. Press (1969); or J. Hubbard, R. Llinas and D. Quastel, "Electrophysiological Analysis of Synaptic Transmission", and reference there.

2) J.G. Taylor, "Spontaneous Behaviour in Neural Networks", J. Theor. Biol. (to appear, 1972).

3) E.R. Caianiello, "Outline of a Theory of Thought Processes and Thinking Machines" J. Theor. Biol. 1, 204 (1961).