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SOME OBSERVATIONS ON OSCILLATIONS IN NEURAL-TYPE NETWORKS

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Abstract

This work shows the possibility of oscillations in Neural-Type Networks.

Previously, it has been shown [3], that neural networks with the topology of the Cerebellum exhibit asymptotic stability if all neurons have non-negative thresholds; thus no oscillations can be observed. Here we show that if negative thresholds are allowed then oscillations may occur for a topology similar to that of the Hippocampus.

In the following we give a brief description of the Hippocampus, present the mathematical description of a network topologically similar to it and finally present simulation results for such a network.

Physiological data have been compiled from [1], [4] and [5].

The Hippocampus, in the higher vertebrates, is located in a ventral position within the cerebral hemispheres. It has been studied for its role in memory and learning, and for the role it plays in certain seizures due to its exhibited rhythmic activity (6-waves).

The principal neuron in the Hippocampus is the Pyramidal cell and the inhibitory interneuron is the basket cell.

The axons of the Pyramidal cells send collaterals to neighboring pyramidal cells and basket cells, while the basket cells inhibit strongly 200-500 pyramidal cells in their vincinity.

Diagramatically we can describe the Hippocampal network as in Fig. 1.

Following Dimopoulos [2], a neural network similar to that of Hippocampus is described by

$$T\dot{X} + X = W\Phi[X-\theta][X-\theta] \quad (1)$$

where

$$W = \begin{bmatrix} W_{11} & -W_{12} \\ W_{21} & 0 \end{bmatrix} \quad (2)$$

X is the membrane potential vector, θ is the threshold vector given in this case as

$$\theta = [\underbrace{-\theta_1 - \theta_2, \ldots -\theta_k}_{\text{pyramidal cells}}, \underbrace{\theta_{k+1}, \ldots \theta_N}_{\text{basket cells}}]^T \quad (3)$$

W is the network connectivity matrix, where all the submatrices W_{ij} are positive and

$$\Phi[X] = \mathrm{diag}[\phi(x_a], a=1,..N] \quad (4)$$

with

$$\phi[x] = \begin{cases} 0 & \text{if } x \le 0 \\ 1 & \text{if } x > 0 \end{cases} \quad (5)$$

We simulated a network represented by Eq. (1), consisting of a total of 100 neurons (50 in each class).

The results of our simulation are given in Fig. 2.

From this figure the rhythmic activity of such a network is easily established, result that agrees with the existence of the 6-waves in the Hippocampus.

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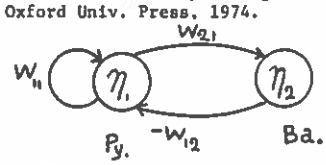

Fig. 1 Hippocampal Network
η_1 Class of Pyramidal Cells (Py),
η_2 Class of Basket cells (Ba)

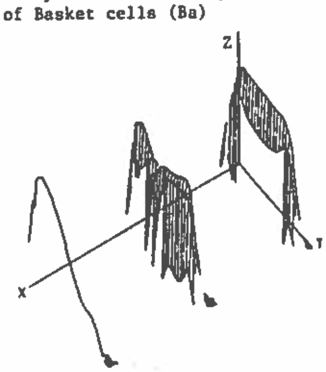

Fig. 2 Simulation results for class η_1
Z Membrane potential, X Time axis, Y neurons (in arbitrary units)

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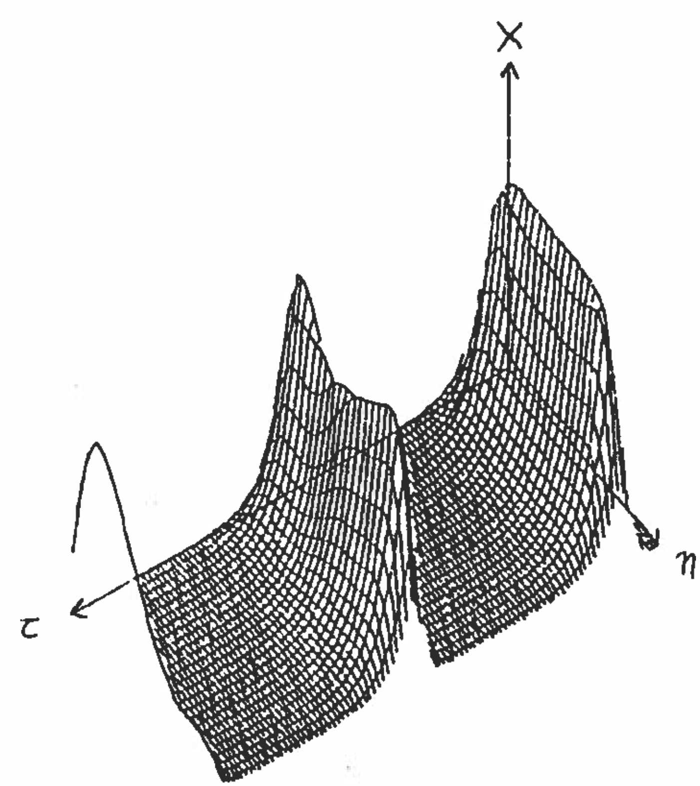


X : Membrane Potential
τ : Time
η : Neurons

Figure 3. Membrane potential of neurons in class η_2 versus time

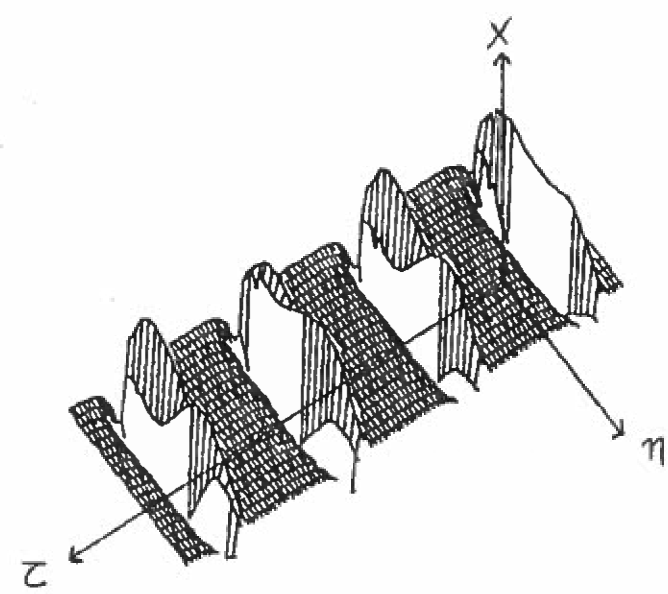
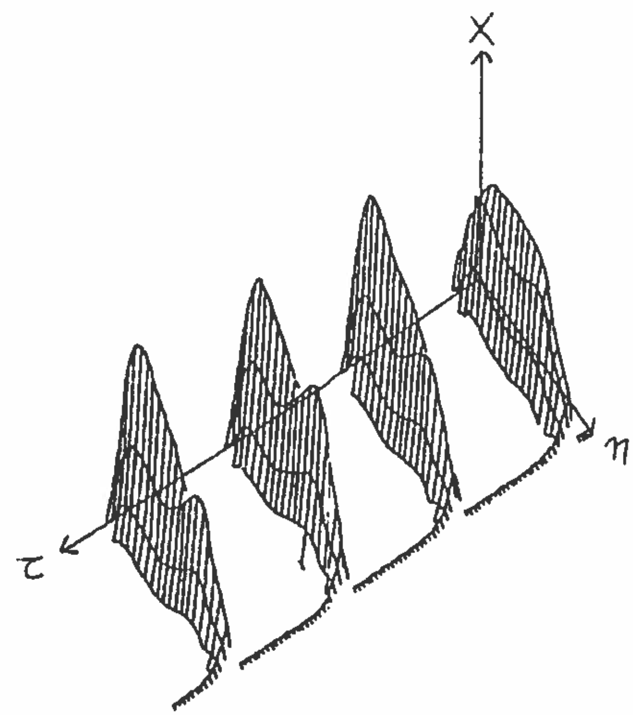


Figure 4. Membrane potential of neurons in class η_1 vs. time



X: Membrane Potential
τ: Time
η: Neurons

Figure 5. Membrane Potential of neurons in class η_2 vs. time