Self-Oscillations in Recurrent Neural Structures

Yuriy Romanyshyn, Svitlana Petrytska

Abstract – **In this paper the conditions of the self-oscillations in one and two neurons with feedback are considered.**

Keywords – **Self-oscillation, neuron, Hodgkin-Huxley neuron model.**

I. INTRODUCTION

Recurrent neural networks are one of the most important classes of artificial neural networks. Their importance lies in possibilities of their use as associative memory systems, patterns and signals recognition, classification of objects and in their use in modeling of bioneural structures, most of which are feedback systems that are adequately represented by recurrent neural networks [1]. One of the important tasks of study of neural structures is the analysis of self-oscillations and synchronization processes in such structures [2]. Self-oscillating processes will be discussed in this report.

II. MODELS OF NEURON WHICH ARE USED IN THE ANALYSIS OF SELF-OSCILLATIONS

Self-oscillations in recurrent neural structures were investigated using different models of neurons in particular models based on equations with delay [3], Hodgkin-Huxley model, the energy frequency selective model of neuron.

For models based on equations with delay the network-ring with three neurons was considered in [3]. After running one of the neurons of network and generating spikes by this neuron of the ring it turns in refractory state. Under the action of spike of the first neuron, second neuron also generates spike and turns in refractory state, then the same happens with the third neuron. In such a way oscillations in this model takes place.

Model of Hodgkin-Huxley of neuron is represented by the system of four nonlinear differential equations of first order:

$$\frac{dy_1}{dt} - f_1(y_1, y_2, y_3, y_4) = x_1(t)\,; \frac{dy_2}{dt} - f_2(y_1, y_2) = x_2(t)\,;$$
$$\frac{dy_3}{dt} - f_3(y_1, y_3) = x_3(t)\,; \quad \frac{dy_4}{dt} - f_4(y_1, y_4) = x_4(t)\,. \quad (1)$$

Frequency selective neuron model includes band-pass filter approximated transfer coefficient of which is determined by the expression:

$$\tilde{K}(j\omega) = \frac{j\omega\tau_0 A}{(j\omega\tau_0 + D_1)(j\omega\tau_0 + D_2)}\,, \quad (2)$$

where ω - circular frequency; τ_0, D_1, D_2, A - filter parameters.

Yuriy Romanyshyn - Lviv Polytechnic National University, S. Bandery Str., 12, Lviv, 79013, UKRAINE;
University of Warmia and Mazury in Olsztyn, Oczapowskiego Str. 2, Olsztyn, 10-719, POLAND
E-mail: romol@mail.lviv.ua
Svitlana Petrytska - Lviv Polytechnic National University, S. Bandery Str., 12, Lviv, 79013, UKRAINE

III. THE CONDITIONS OF THE SELF-OSCILLATIONS ON A SINGLE NEURON WITH FEEDBACK

To get self-oscillations in neural network we need to make the positive feedback in it. The appearance of self-oscillations can be illustrated by the example of one neuron N_1 with feedback which shown in Fig. 1. Modeling of appearance the oscillations was performed for Hodgkin-Huxley neuron, starting of self-oscillations was performed by the rectangular current impulse with the duration of 10 msec and with value of current density of 10 μ A/cm^2.

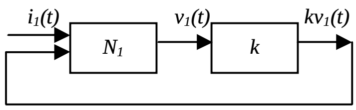

Fig. 1. The structure of self-oscillating systems on a single neuron

Unit k is the coefficient of connection, which performs the function of conversion the voltage to current. Neuron N_1 has two activating inputs, on the first of which an external start signal $i_1(t)$ is supplied, the second activating input provides positive feedback.

Self-oscillations on a neuron arise only in a certain range of values of the connection coefficient k = 0.31 $\div$ 0.56, with the same duration and value of the input starting impulse. Mode of self-oscillations of one neuron with k = 0.4 is shown in Fig. 2.

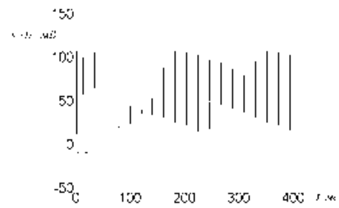

Fig. 2. The self-oscillations of one neuron with feedback

IV. CONCLUSIONS

In this work the conditions of appearance of self-oscillations on a single Hodgkin-Huxley neuron are examined, a range of values of the coefficient of feedback at which oscillations are arising is determined and it is shown that with an increase of coefficient of feedback frequency of self-oscillations is decreased.

REFERENCES

[1] Y.M. Romanyshyn "Mathematical and software of functioning of recurrent neural networks". – 2008. (in Ukrainian).
[2] A. Pikovsky, M. Rosenblum, J. Kurths "Synchronization. A universal concept in nonlinear sciences" – 2003. 496 p. (in Russian).
[3] N.S. Lagutina "The model of impulse neuron. Oscillations in the simple network of three neurons". - 7 p. (in Russian).