INFORMATICA, 1992, Vol.3, No.4, 469–473

SOME LOGIC FUNCTIONS REALIZED ON A STATIONARY NONLINEAR DENDRITE

3. Interaction of excitatory and inhibitory synapses

Algis GARLIAUSKAS, Algirdas SHIMOLIUNAS

Institute of Mathematics and Informatics
2600 Vilnius, Akademijos St.4, Lithuania

Aron GUTMAN

Kaunas Medical Academy
3000 Kaunas, Mickevičiaus St.9, Lithuania

Abstract. The binary logic functions "excitation and/or noninhibition" and "excitation and noninhibition" are realized by the model of a nonlinear stationary dendritic branch. The neuron with such dendrites is a complex logic system performing a great member of elementary logic operations.

Key words: neurocomputer, dendrite, synapse, current-voltage nonlinearity, bistability.

1. Introduction. In the previous papers (Garliauskas *et al.*, 1991, 1992) we have considered a realization of binary logical functions on a bistable dendrite branch, when two synapses of the same sign either both excitatory or inhibitory are arranged on it. Now we consider the interaction between excitatory and inhibitory synapses. Let us recall a scheme of a simulated bistable dendrite and disposition of synapses on it (Fig. 1, branch load, as in the preceding papers, is linear , $R_l = w/3$, here w is the characteristic resistance of dendrite). The parameter of a cubic polynomial of the V-shaped current-voltage characteristic of the membrane $(C - V)$ with two stable and one unstable points is equal to $b = 0.65$ (see Garliauskas *et al.* 1992)). We have illustrated on an output $C - V$ of dendrite branch that it is reasonable to consider the activity of

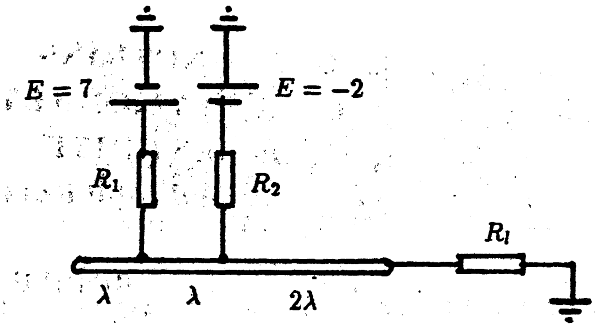

Fig. 1. The scheme of a dendrite branch with ohmic load R_l; R_1, R_2 are the resistances of synapses; E is the electromotive force of synapses.

inhibitory synapses only under great depth of the negative part of the $C-V$ membrane, such depth is guaranteed by the selected value $b = 0.65$.

2. Results. Recalling that, if we restrict with a binary logic, then the stable point of $C-V$ of branch close to the rest potential ($V \approx 0$) on the distal end of the dendrite, corresponds to the logic variable "0", while the stable point on the output $C-V$ of branch, at which the distal end of the dendrite is constantly depolarized ($V \approx H$), corresponds to the logical variable "1" (Garliauskas *et al.*, 1991, 1992).

Fig. 2 shows the realization of a logic function of nonstrict disjunction with a negation "excitation and/or noninhibition": if a stable depolarization ($V \approx H$) is the initial state, then an activation of the inhibitory synapse suspends it only in the case when the excitatory synapse is not activated.

Fig. 3 illiustrates the realization of a logic function of conjunction with a negation "excitation and noninhibition": thus, if the rest potential ("0") is the initial state, then the branch will get over to the state of stable depolarization ("1") only in the case of activation of the excitatory synapse without activating the inhibitory synapse.

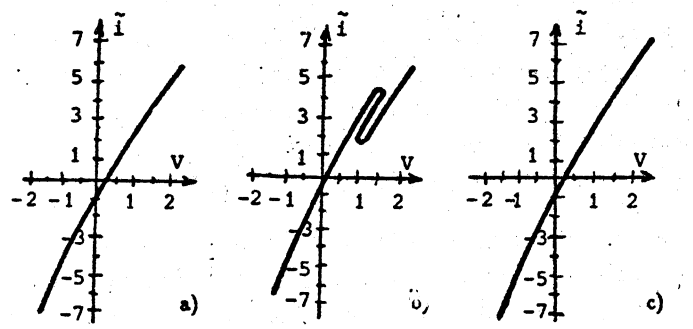

Fig. 2. The example of a logic function of nonstrict disjunction with a negation; output current-voltage characteristics of the dendritic branch are presented: the left-hand branch of the curves corresponds to the vicinity of the rest potential ($V \approx 0$, Fig. b) and the right-hand corresponds to the vicinity of stable depolarization ($V \approx H$, Fig. a and c). a) $R_1 = 5\omega$, $R_2 = \infty$; b) $R_1 = \infty$, $R_2 = 5\omega$; c) $R_1 = 5\omega$, $R_2 = 5\omega$.

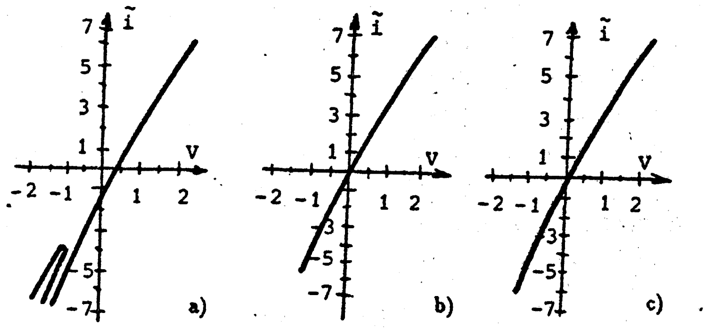

Fig. 3. The example of a logic function of conjunction with a negation; output current-voltage characteristics of the dendritic branch are presented: the left-hand branch of the curves corresponds to the vicinity of the rest potencial ($V \approx 0$, Fig. b and c) and the right-hand corresponds to the vicinity of stable depolarization ($V \approx H$, Fig. a). a) $R_1 = 10\omega$, $R_2 = \infty$; b) $R_1 = \infty$, $R_2 = 1\omega$; c) $R_1 = 10\omega$, $R_2 = 1\omega$.

The presented results of numerical simulation are obtained under a more distal disposition of the excitatory synapse (the inhibitory synapse is closer to the load); their mutual replacement does not change the situation in principle. Neither brings any essential change the replacement of the slow potassium inhibitory synapse ($E = -2$) by a quiker one of chloride nature ($E = -1$).

3. Discussion. This report illiustrates two more combinations of synaptic interaction in which a dump inhibition (Garliauskas *et al.* 1992) became apparent: inhibition is unnoticeable in the body of cell, nevertherless it can be felt functionally as a result of a discontinuation or prevention of the stable depolarization. In this respect one may also speak of a dump excitation the result of which is not seen if there is a competitive inhibition.

Thus, we have completed the simulation of a realization of six from of eight nontrivial binary logical functions of two variables on a separate dendrite branch. The remaining two strict disjunctions require to introduce overexcitation in a dendrite branch. The, so called Ca^{+}, – dependent potassium current may serve as a physiological basis of overexcitation. Up till recent time there was no evidence of the presence of these canals in dendrites. Recently it has been shown by testing the action of extracellular electrical field on motoneurons of the turtle that the stable depolarization appearing in the distal dendrite is established easier if one blocks up the mentioned canals (Haensgaard, Kichn). Thus, a possibility of realizing a complete set of binary logical functions on a bistable dendrite is arised.

REFERENCES

Garliauskas, A., A.Gutman and A.Shimoliunas (1991). Some logic functions realized on a stationary nonlinear dendrite. 1. Excitatory synapses. *Informatica*, **2**(3), 403–413.

Garliauskas, A., A.Gutman and A.Shimoliunas (1992). Some logic functions realized on a stationary nonlinear dendrite. 2. Inhibitory synapses. *Informatica*, **3**(3), 385–392.

Haensgaard, J., and O.Kichn *J. Physiol.*, (in press).

Received June 1992

A. Garliauskas received the Degree of Technical Sciences from the Computer Center, the Department of the USSR Academy of Sciences, Novosibirsk, USSR, in 1977. He is a head of the Department of Complex System, Institute of Mathematics and Informatics, Lithuanian Republic. His research interest includes optimization problems of complex systems and development of neural network software and hardware for neurocomputer technology.

A. Gutman graduated the Faculty of Physics of Vilnius University in 1958, received the Degrees of Candidate of Physics and Mathematics from Leningrad University in 1962 and of Doctor of Biology from Kaunas Medical Institute in 1974. He is a research professor at the Laboratory of Neuron Physiology in this Institute. He is interested in biophysical aspects of neuroscience and electrophysiology.

A. Shimoliunas received the Degree of Candidate of Physical and Mathematical Sciences from the Institute of Biological Sciences, Pushchino, Acad. Sci. USSR, in 1986. He is a researcher at the Department of Complex Systems, Institute of Mathematics and Informatics, Lithuanian Republic. His research interests include nets of nonlinear neurone.