DEPARTMENT OF THE ARMY
UNITED STATES ARMY INTELLIGENCE AND SECURITY COMMAND
FREEDOM OF INFORMATION/PRIVACY OFFICE
FORT GEORGE G. MEADE, MARYLAND 20755-5995

August 6, 1998

Freedom of Information/
Privacy Office

Mr. John Greenewald, Jr.
[redacted]

Dear Mr. Greenewald:

References:

a. Your Freedom of Information Act (FOIA) request of May 11, 1998, for a copy of the following document: Neuron-Like Modeling and Computing Structures, FSTC-HT-0697-88.

b. Our letter of June 5, 1998, informing you the document must be obtained from another U.S. Army organization and we were unable to comply with the 20-day statutory time limit in processing your request.

Coordination has been completed with the National Ground Intelligence Center (NGIC) and the document was provided to this office for our review and direct response to you.

We have reviewed the referred document and determined that the information is partially releasable to you. The document is enclosed for your use. Fees for processing this request are waived.

Since the release of some of the information deleted from these records would result in an unwarranted invasion of the privacy rights of the individuals concerned, this information is exempt from the public disclosure provisions of the FOIA per Title 5 U.S. Code 552 (b)(6).

The withholding of the information described above is a partial denial of your request. This denial is made on behalf of Major General Robert W. Noonan, Jr., the Commanding General, U.S. Army Intelligence and Security Command, who is the Initial Denial Authority for Army intelligence investigative and security records under the FOIA. You have the right to appeal this decision to the Secretary of the Army. If you wish to file an appeal, you should forward it to this office for necessary processing so that it reaches the appellate authority no later than 60 calendar days from the date of this letter. Your appeal will then be processed to the appellate authority. After the 60 day period, the case may be considered closed; however, such closure does not preclude you from filing litigation in the courts.

For your information, this document is an unedited English language translation of a foreign language document which may be protected by international copyright for which the NGIC has no secondary dissemination rights. The translation is presented in the original language text, no attempt was made to verify the accuracy of any statement contained therein.

If you have any questions concerning this action, please contact Mrs. Sealing at (301) 677-3802. Please refer to case #1445F-98.

Sincerely,

Russell A. Nichols

Russell A. Nichols
Chief, Freedom of Information/
Privacy Office

Enclosure

DTIC FILE COPY

NOT EDITED

DEPARTMENT OF THE ARMY

US ARMY INTELLIGENCE AGENCY
FOREIGN SCIENCE AND TECHNOLOGY CENTER
220 SEVENTH STREET, NE.
CHARLOTTESVILLE, VIRGINIA 22901-5396

FSTC-HT-0697-88

DATE: 12 Jan 1989

AD-B130 820

ENGLISH TITLE: Neuron-like modeling and computing structures.

TRANSLATION OF: Elektronnoye modelirovaniye. 1986. 8, 2, 3-9.

UDC: 681.3:007.52

LANGUAGE: Russian. COUNTRY: Union of Soviet Socialist Republics.

AUTHOR (AFFILIATION): A.V. KALYAYEV and Yu.V. CHERNUKHIN.

REQUESTOR: AIFREC [redacted]

TRANSLATOR: [redacted] 5 USC 552a (b) (6)

DTIC ELECTE 22 MAR 1989 S E D

200 008 336
TRANSLATION ACC #

WARNING

The contents of this publication have been translated as presented in the original text. No attempt has been made to verify the accuracy of any statement contained herein. This translation is published with a minimum of copy editing and graphics preparation in order to expedite the dissemination of information.

Distribution authorized to US Government agencies and their contractors (Specific Authority DODD 5230.25) (1 JAN 88).

Further requests for this document shall be referred to the US Army Intelligence Agency, Foreign Science and Technology Center, 220 7th St., NE., Charlottesville, VA 22901-5396.

DESTRUCTION NOTICE - Destroy by any method that will prevent disclosure of contents or reconstruction of the document.

89 3 22 277

NEURON-LIKE MODELLING AND COMPUTING STRUCTURES

A.V. KALYAYEV, YU. V. CHERNUKHIN
ELEKTRONNOYE MODELIROVANIYE, 1986, VOL. 8, NO. 2

The development of robotics, especially adaptable, autonomous robots, increases the importance of neurophysiological and neurocybernetic research directed towards the study of the neurological mechanisms of the living brain. Linked to this is the fact that natural structures consisting of nerve cells-neurons, basically are guidance structures and, for this reason, prove interesting not only for physicians and physiologists but also for engineers involved in the design of control systems for adaptable autonomous robots in particular. Research into nerve tissue carried out by physiologists and neurocyberneticists provides rich factual material about its structure and function. However, data on fine neurophysiological experiments do not always fit into the structure of the integrated activity of an organism as a whole, and for this reason, cannot always be directly used in practical engineering. Also, there arises the need to develop special artificial neuron-like structures which could be used as a means of researching the various possibilities of neuron communication in neuron networks with different characteristics of the neurons themselves, and also as a means of creating artificial neuron systems of recognition, planning and control. Russian translations. (AW)

It must be noted that physically made neuron-like structures were first proposed by Mac Callum and Pitts in 1943. /1. These structures consisted of simple threshold elements reproducing the functions of two-digit mathematical logic. The evolution of neuron-like structures gravitated towards the broadening of functional possibilities, both of the structures as a whole and of separate neuron-like elements. There appeared functionally complete formal neurons and formal neurons with reciprocal and spontaneous fibers. Research into the theory of such neurons and neuron networks was widespread and still going on today.

However, already in the early sixties it became clear that the formal-logical model of a neuron was, by its own properties, far from the natural prototype and did not reflect all of its basic properties. /2. By this time there appeared more complete mathematical models of processes in nerve cells, for example, models of electrical processes on the neuron membrane. Similar models were differential controlled systems and could be attained either by programming on a general purpose computer or on computing elements of impulse or analog equipment, for example, on the basis of a resolution block of analog computers. At the same time repeated attempt to build and use program dynamic neuron models on single processor computers were not very successful. Similar results were obtained when constructing dynamic neuron models on an analog computer.

The circumstances mentioned and also the desire to build a sufficiently effective and easy to use piece of equipment for investigating the dynamics of neuron structures of the brain which reflected the latests achievements in neurophysiology led to the development of many different types of artificial neurons created on the elements of impulse equipment. However, in spite of the variety, known neuron-like elements, both formal-logic and dynamic were not widely used either in neurocybernetic research or in computer technology and control systems. The reason for this was not only because the properties of these models still differed considerably from the properties of the modelled object, but also because they were highly specialized, non-technological, unreliable and also had a series of faults during construction and use. /3. Apart from this, for analog and impulse models of neurons it was characteristic to have an uncontrolled change of parameters which made it difficult to create such a high quality in the properties of the neuron cells as a functional plasticity. The joining of the networks of the analog elements with the digital equipment made it necessary to use a transformer analog-code and code-analog which considerably complicated the receiving equipment.

Furthermore, according to modern physiological concepts, the fuctional unit of the nervous system is not a separate neuron but an aggregate of nerve cells joined together. /4. In its turn, the neuron unit is a sufficiently dynamic formation and to model it it is best to have in the neuron-like composition of networks special switching units making it possible by different methods to join the artificial neurons with the nueron entity under research. The organization of a flexible switch in analog neuron-like networks is an independent problem and there are extra difficulties in constructing and using analog neuron-like elements and structures.

For this reason let us look at the possibilities of anew range of digital neuron-like models of the dynamic type built on the basis of multi-processor computer systems (MCS) with programmed architecture /5 and especially using equipment for digital integrating structures (DIS) /6.

Digital Neuron-like Processors.

Analysis of neurophysiological data dealing with the electrical activity of neurons allows one to formulate a mathematical model of informational processes in the nerve cell in the following form:

$$\nu(t) = \sum_{j=1}^{N} \gamma_j(t)\, x_j(t); \qquad (1)$$

$$\tau(t)\frac{dP(t)}{dt} = -P(t) + \eta(t)\,\nu(t);$$

$$z(t) = \max\{0;\ k(t)\,[P(t) - \Theta(t)]\},$$

where $\eta(t)\,\nu(t)$ -- the sum potential forming as a result of the spatial summation of stimulant and inhibiting input influences; $x_j(t)$ -- the analog of frecuency of the input adhesion sequence on the j-th synaptic input of the neuron; $\gamma_j(t)$ -- the weight of the j-th synapse; N -- the number of synaptic contacts of the neuron; P(t) -- the membrane potential of the nerve cell; $\tau(t)$ -- the parameter characterizing the inert properties of the membrane; $y(t)$ _ the coefficient of spatial summation;z(t) -- the frequency of movement analog of output impulses; k(t) --the coefficient characterizing the properties of the axon monticle;$\theta(t)$ --the neuron threshold.

In connection with this it was found that since neither single processor digital nor analog computers,nor the well known multiprocessor computers,including microprocessing systems were able to effectively reproduce parallel neurophysiological processes;for reproducing system (1) it is best to use digital model equipment,but mainly digital integrating structures /6 with which one can obtain a digital neuron-like element.In the case where the latter was used,based on digital integrators functioning on a rectangular formula,the process taking place can be described in the following system of differential equations:

$$\begin{aligned} \upsilon_i \nabla t &= \sum_{j=1}^{N} \gamma_{ji} (x_{ji} \nabla t); \\ \nabla y_i &= -\alpha y_{(i-1)} \nabla t + \beta_i \nu_i \nabla t - \theta \nabla t; \\ z_i \nabla t &= \max_{i} (0;\ k y_{(i-1)} \nabla t), \end{aligned} \qquad (2)$$

where $y_i = P_i - \theta_0$, $\nabla y_i = y_i - y_{i-1}$, $\alpha = \tau^{-1}$, $\beta_i = \tau^{-1} P_i$, $\theta = \tau^{-1} \theta_0$, θ_0 -- the threshold of rest.

Theoretical and experimental research of the digital neuron-like element reproduced by the algorithm (2) shows that,in spite of the substantial methodical error which occurred when approximating the solution of the differential equation of system (1) with the solution of the appropriate differential equation of algorithm (2) the properties of such a digital neuron-like element do not differ in quality from the informational properties of the biological neuron described in the literature. This can be explained by the fact that as seen from neurophysiology,the model of spatial integration of input signals in the dendrite tree of the neuron with their summation (the first equation of system (1))does not result in a substantial methodological error. Therefore,with a temporary integration model,the simplest formula of rectangles can be used.

Apart from simplifying the digital neuron-like element,the use of the rectangular formula makes it possible to construct sufficiently plastic neuron-like elements,changing the functional algorithm with the change of parameters $\alpha, \beta, \theta, \gamma, k, \nabla t$. In fact,relying on an algorithm (2)of the dynamic neuron $\alpha = \nabla t = 1$; $z_i, x_{ji} \in \{0, 1\}$; $k = \beta = 1$, we find

$$z_i = \operatorname{sign}\Big[\sum_{j=1}^{N} \gamma_j x_{j(i-1)} - \theta\Big],$$

which corresponds to the algorithm of the generalized neuron. By using the inputs of this neuron,the logical diagrams of conjuncture,disjuncture and inversion,it is possible to reproduce formal neurons. Supposing $\alpha = 0$; $\nabla t = 1$; $z_i, x_{ji} \in \{0, 1\}$; $\beta = k = 1$, we have an algorithm of a summarizing neuron,

$$z_i = \operatorname{sign}\Big[\sum_{r=0}^{i-1} \sum_{j=1}^{N} \gamma_j x_{jr} - \theta\Big].$$

where $\alpha = 0;\ \beta = 0;\ \Theta = 0;\ 0 < \nabla t < 1;\ y_i > 0$ — --the pacemaker neuron $z_i \nabla t = k y_i \nabla t$.

In other words, the digital neuron-like element studied can be used as a specialized neuron-like digital processor (Fig.1) oriented for use in structures meant for models for neurophysiological or neurocybernetic work. The operational basis for such a digital neuron-like processor can consist not only of large structurally figured operations of the algorithm (2), but of operations corresponding to algorithms of different neuron-like elements. Hence, the change of operations carried out can be done not only by a gradual change of parameters α, β, Θ, γ, k, ∇t, but also by their gradual change by means of feeding into the registers of the subintegrated functions of the corresponding integrators of the digital neuron-like processor an increase of $\nabla\alpha$, $\nabla\beta$, $\nabla\Theta$, $\nabla\gamma$, ∇k both from without and from the outputs of other neuron-like processors.

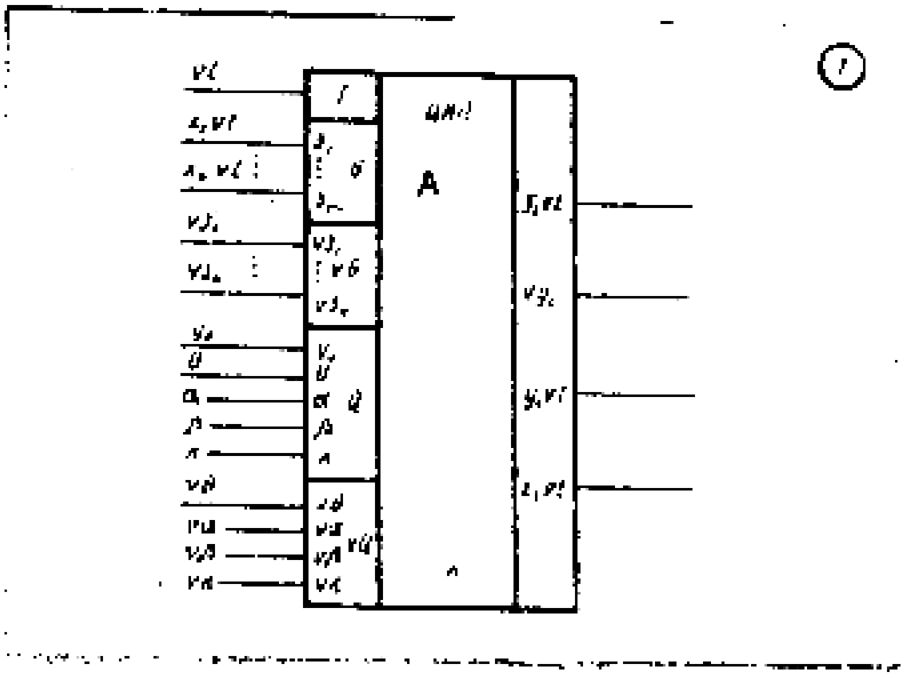


Fig 1. A = Digital Neuron-like Processor

Side by side with the basic output of increases of $z_i \nabla t$ such an element contains additional outputs $\nabla y_i \nabla t$, ∇y_i и $y_i \nabla t$. The methodical error μ_i of the stationary state of the digital neuron-like processor $(\lim \mu_i = \mu^*)$ does not depend on the size of the step ∇t when $\alpha > 0$ equals zero.

The latter circumstance and also the presence of additional outputs allows one to use digital neuron-like processors not only for qualitative imitational modelling of informational processes in the nervous system, but also to resolve formalized and informational tasks of traditional problems of computer mathematics involving neurophysiology and neurocybernetics. However, to sufficiently organize accurate computer processes it is best to use a digital neuron-like processor not only in an analog but in a quasi-analog mode when the known quantity is not the input into the digital neuron-like processos in conformity with algorithm (2) the transitional process, but its stable, stationary condition when $v_i = v^*$ const. The overall error of this stationary condition $(\varepsilon^* = \lim \varepsilon_i)$ is determined by the correlation $\varepsilon^* \leqslant 3 \times 2^{-n+1}$

5

where n --the number of significant discharges in the registers of the digital integrators of the digital neuron-like processor.

The time taken to reach this state can be evaluated by the required number of iteration cycles i_n :

$$i_n = \left] \frac{\ln \delta \, | y_0 - \alpha^{-1} \upsilon^* |^{-1}}{\ln | 1 - \alpha \nabla t |} \right[,$$

where the parentheses denote the round off to the nearest whole positive number $\delta \geqslant \varepsilon^*$ -- the allowed calculation error; ∇t -- the step chosen from ratio $0 < \nabla t < \alpha^{-1}$, determining the state of stability of processes in the digital neuron-like processor.

Digital Neuron-like Assemblies.

When using digital neuron-like processors for organizing adaptable, self-optimizing and stable neuron-like structures difficulties arise connected with the fact that, properly speaking, neuron-like processors do not entirely possess defined properties. Like a real neuron they can only be a structure of synthesised units on their network base. Therefore, one needs methods to link the digital neuron-like processor into such an assembly which will either broaden the functional possibilities of separate processors or improve their dynamic properties. Let us examine examples of building some simple assemblies.

From analysis of neurocybernetic data, it follows that the mathematical model of one of the possible mechanisms of adaptable processes in the nerve membrane looks like the following:

$$\begin{aligned}
\upsilon(t) &= \sum_{j=1}^{N} \eta_j(t)\, x_j(t); \\
\tau_1 \frac{dP(t)}{dt} &= -P(t) + \eta_1 \upsilon(t); \qquad (3) \\
\tau_2 \frac{d\Theta(t)}{dt} &= -\Theta(t) + \Theta_0 + \eta_2 z(t) + \eta_3 P(t), \\
z(t) &= \max_t \{0;\ k[P(t) - \Theta(t)]\}.
\end{aligned}$$

To bring about the equation system (3) one needs, either to complicate the diagram of the digital neuron-like processor and build special adaptable processors[7] or to reproduce a system (3) on the combination of digital neuron-like processors linked into an assembly. In view of the fact that as a prototype for neuron-like structures, neuron networks were used, the second variation is more suitable since, according to physiologists, the functional units of the brain are not separate neurons but some of their aggregate, so called, neuron assemblies.

An adaptable neuron-like assembly based on a digital neuron-like processor can be represented in the form of a diagram shown in figure (2). A feature of this diagram is the fact that when it is built, additional outputs were used, mainly outputs of increments ∇y_i , imitating channels of subthreshold interaction of the closely packed nerve cells. Processes taking place in such an adaptable assembly are described by the following system of differential equations :

$$\upsilon_i \nabla t = \sum_{j=1}^{N} \gamma_{ji} (x_{ji} \nabla t);$$

$$\nabla P_i = -\alpha_1 P_{(i-1)} \nabla t + \beta_1 \upsilon_i \nabla t; \qquad (4)$$

$$\nabla \Theta_i = -\alpha_2 \Theta_{(i-1)} \nabla t + \alpha_2 \Theta_0 \nabla t + \beta_2 z_{(i-1)} \nabla t + \beta_3 P_{(i-1)} \nabla t;$$

$$z_i \nabla t = \max_i \{0;\ k[P_{i-1} - \Theta_{i-1}] \nabla t\}.$$

From analysis of equation (4) it follows that an adaptable assembly can function not only with different adaptable models, for example, with models having an adaptation only on the input ($\beta_2 = 0$), with an adaptation only on the output ($\beta_3 = 0$), with an adaptation both by input and output simultaneously, but also in an unadapted neuron mode ($\beta_2 = \beta_3 = 0$, $\nabla t = 1$, $\alpha_2 = 1$), in various modes of an individual digital neuron-like processor; that is, an adapted assembly actually broadens the functional possibilities of the neuron-like processor.

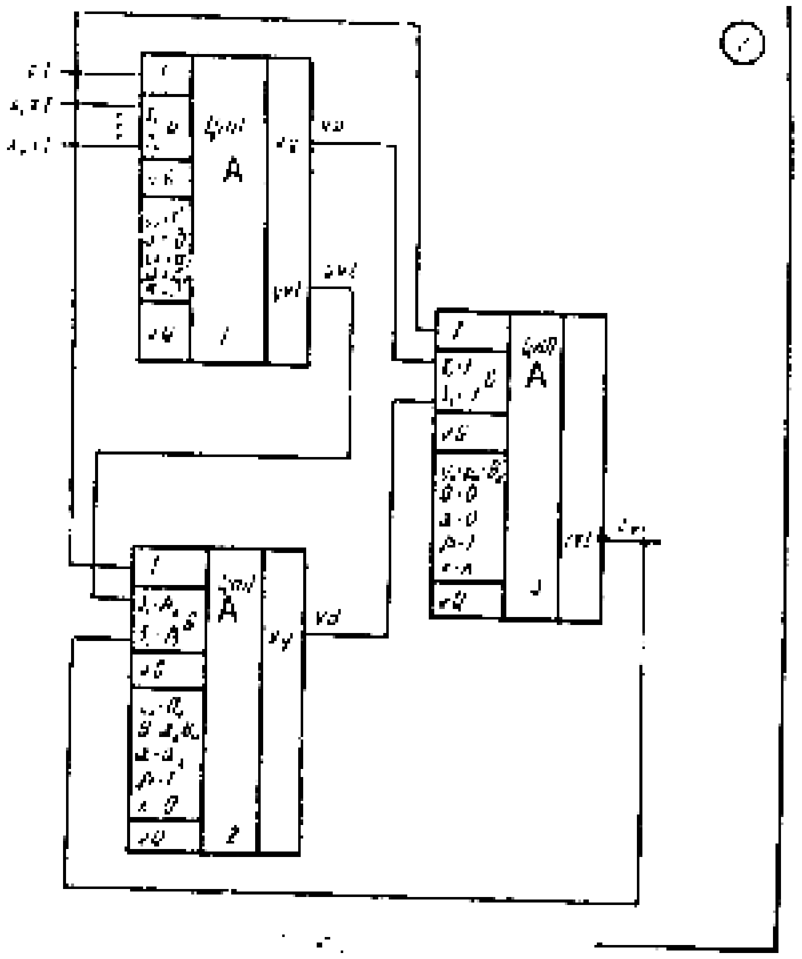


Fig 2 A = Digital Neuron-like Processor.

In order to improve the dynamic characteristic of a digital neuron-like processor and decrease the adaptable reaction time, it is best to link them into self-optimizing dynamic assemblies. These assemblies consist of a minimum of two digital neuron-like processors, one of which is the main one and the other the auxiliary. Both DNPs function so that the results of the work of the auxiliary processor are used for optimizing the processes in the main DNP. The processes taking place in the self-optimizing dynamic assembly are described by the following differential equation:

$$y_i = y_{i-1} - \nabla t_i (a y_{(i-1)} - v^*);$$
$$\nabla t_i = \nabla t_{i-1} - \tau (a \nabla t_{(i-1)} - 1), \qquad (5)$$

where τ -- the step of the differing diagram of the auxiliary DNP.

From equations (5), it is seen that the iterative processes in the main and auxiliary processors are directed towards each other. Hence, the auxiliary DNP determines the non-stationary iterative parameter $\{\nabla t_i\}$ of the main DNP, so that $\lim_{i\to\infty} \nabla t_i = a^{-1}$. This leads to a decrease in the length of the transient process in the main processor. So, expressing number i_a of the iterative cycles necessary to attain the the stationary condition in the main DNP, the self-optimizing assembly, through a number of iterative cycles i_n required to attain the same condition in an individual DNP, we obtain $i_a =]2^{-1}(\sqrt{1+8i_n} - 1)[$. It is obvious that with $i_n \gg 1$ $i_a \approx]\sqrt{2i_n}[$.

One can obtain an even shorter length of transient processes in the DNP if one builds an assembly with dual optimization, that is, assemblies whose auxiliary DNP optimizes the functioning not only of the main processor, but, in turn, its own $\nabla t_i = \nabla t_{i-1} - (a\nabla t_{i-1} - 1)\nabla t_{i-1}$. Then

$$i_a = \left]\frac{\ln\frac{i_n}{2} + 1}{\ln 2}\right[.$$

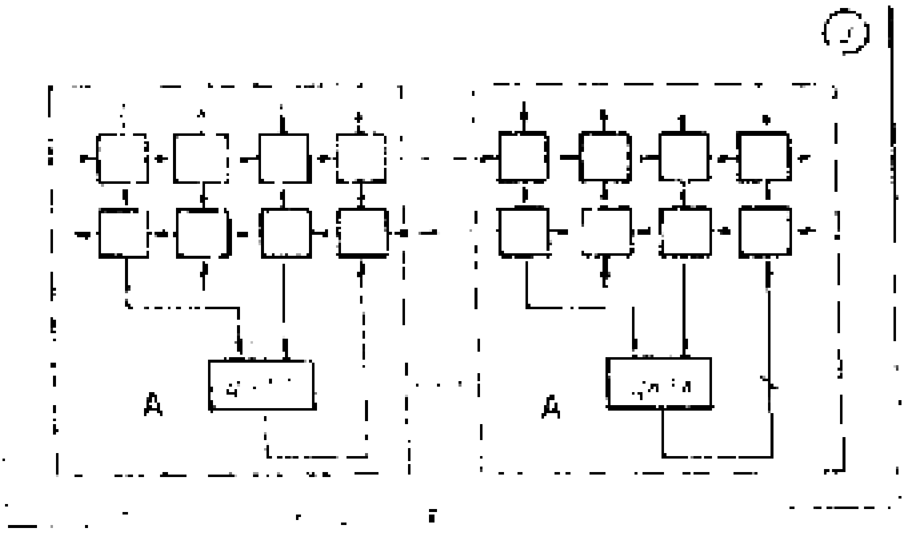
Other neuron-like assemblies can be built on the base of a DNP, for example, a matrix neuron-like assembly, assemblies reproducing the sensitization mechanism (relief of synaptic transmission); assemblies which classify specimens and computing assemblies. They all differ from each other by both use of modes in which the DNPs function and in the differentinterprocessing links. Therefore, when building simulating neuron-like structures the need arises to devise DNPs capable of functional reconstruction and also to create effective means for switching them.

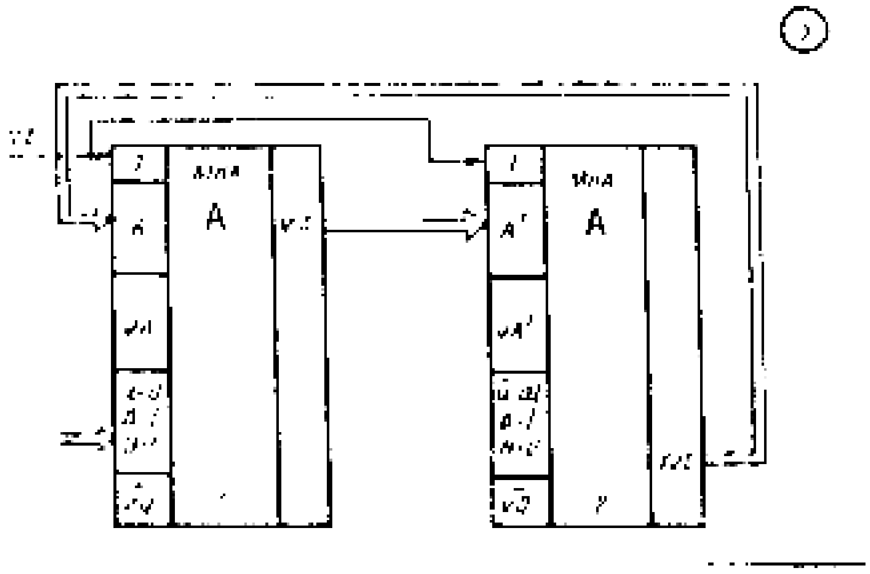
Switching Elements of Digital Neuron-like Structures.

The fact that a DNP is built on the base of computing blocks of digital integrating structures allows the use of switching register structures for switching them /8, which is very effective not only for multi-use computers and digital systems, but also for neuron-like structures.

As is known from physiology, links between neurons are made by means of nerve fibers, axons. The nerve impulse extends along the axon unevenly from one Ranvier node to the other. These nodes are amplifiers and, as a result, the nerve impulse extends along the axon withouy interruption. This means of transmitting information along the axon is similar to the transmission of information in a moving register. Therefore, the register principle of switching more adequately reproduces the process of information transmission in an actual nerve fiber. One should also note the flexibility and reliability of register switching, the ease with which it can be used technically, based on modern technology, and the simplicity of practical use.

As is known /8 ,the separate switching register of a cell is an element having two inputs and two outputs which can be built in switching register structures and consists of many such cells,a large variety of branching and interwoven communication links. On this principle,the DNP,linked with switching register structure cells can be built,having quite plastic digital neuron-like model structures. One of the possible ways of creating such structures is by having the inputs and outputs of the neuron-like processor linked to the inputs and outputs on the switching register structure unit,consisting of several sets of switching register cells. As a result,several standard blocks are produced(on Fig.3 shown by a shaded line)consisting of DNP and switching register structure units. By connecting the inputs and the outputs on the corresponding lateral switching cells of these blocks one can obtain a neuron-like assembly with a flexible reconstructed form,shown in diagram form in Fig.3. By linking these assemblies we obtain a digital neuron-like simulation structure shown in Fig. 4. The structure can be used for reproducing flexible,lightly reformed self-adjusting and self-optimizing nerve proesses whichare required when simulating the model of unresearched section of the brain.





Figures 3 and 4. A = Digital Neuron-like Processor

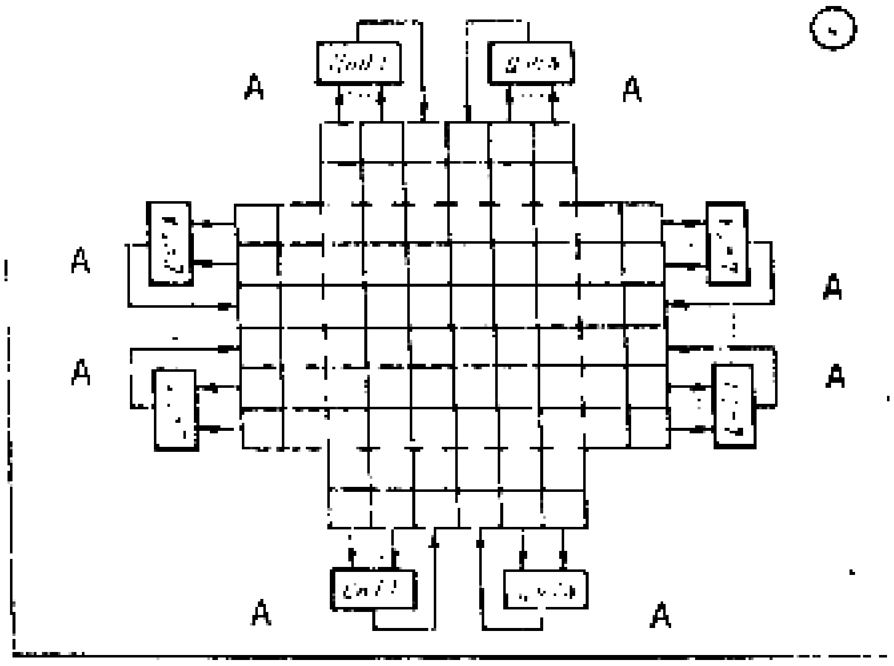


Fig. 5. A= Matrix Neuron-like Assembly.

It must be noted,however,that when resolving simulation problems,in general, one must reproduce not only non-formalized processes in the unresearched section of the nerve fiber,but also organize a concerted functioning of the researched and already studied nerve processes which have been described in mathematical terms. One must also reproduce joint functioning of researched sections of the brain and the organs controlled by them and carry out biologically controlled experiments to substitute some part of the nerve fiber by its physical model,functioning in an artificial or natural environment. In these cases,the simulation model must interact with additional computer equipment,reproducing the already formalized processes by resolving such traditional problems as computer mathematics,algebraic systems, differential equations, linear programming, integral equations, etc. These problems must be solved on a real time scale with a constant calculation of the large number of parameters of biological or biotechnical systems interacting in the external environment. Such a situation, for example, is characteristic of simple models of the brain-perceptors, where the learning neuron-like network must function in conjunction with the supplementary computer equipment resulting in formalized methods of learning. Using in this fashion single processor digital computers or other well known types of computer equipment either slows down the work of simulating neuron-like models or lead to problems in coordinating the various types of equipment. Therefore, in order to simplify the experimental installation, eliminate the need to coordinate the various types of computer equipment and models and make ideal working conditions on a real time scale, for example, when organizing biological controlled experiments or when producing perceptors with parallel learning, one must ensure the neuron-like structures consisting of digital neuron-like processors and assemblies can be used to resolve both non-formalized problems and formalized problems of neurophysiology and neurocybernetics. In other words, the need arises to d vise methods for building neuron-like computer structures based on DNPs.

Neuron-like Computing Structures.

When building neuron-like computers structures we shall assume that accuracy of calculation can be achieved on the base of DNPs when they are used, not in an analog but in a quasi analog mode. /9. For this reason, one should install on a neuron-like computer structure either final equation systems or problems, the solution of which is based on preliminary algebraics. In turn, from the final equations one must transfer to systems for determining differential equations, the stable solution of which is assured in coincides with the solution of the initial problem. After transfering, the neuron-like computer structure is atuned to determine stable solution of the differential equation system in the form

$$\frac{dY}{dt} = -BY + H, \qquad (6)$$

where B -- the expanded matrix of constant coefficients of the initial problem; H-- the expanded vector of the right section; Y -- the vector of unknowns.

In order to provide stability to the computing process in the method for building determinant differential equations it is best to use the gradient method, in accordance with which BY¬p grad J (Y)+H, where J(Y)-- the quadratic functional chosen for specific type of problem. For example, for linear algebraic equation systems with an arbitrary, including non-quadratic or quadratic coefficients having a special matrix A, AY=F, it is best to use the functional

$$J(Y, \alpha) = \frac{1}{2}(\|AY - F\|^2 + \alpha\|Y\|^2), \qquad (7)$$

where α – the regularization parameter. In this case, the matrix B in equation (6) takes on the form

$$B = A^T A + \alpha E. \qquad (8)$$

If problems of linear programming are being resolved

$$CY \to \max; \quad AY = F; \quad Y \geq 0,$$

where C -- the linear form vector; A -- the condition matrix; F -- the limitations vector, or you may use the functional $J(Y, \Lambda) = CY - (AY - F)\Lambda - v/2\, YY;\ Y \geq 0;\ \Lambda \geq 0$, where Λ -- the Langgrange multiplication vector; v -- the given positive number. Here matrix B in equation (6) takes the form, different from (8):

$$B = \begin{bmatrix} Ev & A^T \\ -A & 0 \end{bmatrix}.$$

When resolving the systems of ordinary differential equations with the linked limiting conditions

$$\frac{dY}{dX} + AY = F; \quad \sum_{j=0}^{N-1} \Gamma_j Y(X_j) = L,$$

where Y -- is the vector of unknowns; A -- the square matrix of coefficients; F -- the right section vector; Γ_j -- the given matrices; L -- the given vector, they must be transformed beforehand to the form

$$(D + \bar{A})\bar{Y} = \bar{F}, \quad G\bar{Y} = \bar{L},$$

where D -- the difference operator; G -- the matrix obtained from matrices Γ_j; $\bar{A}, \bar{F}, \bar{Y}, \bar{L}$ -- the expanded matrix A and the corresponding vectors F, Y, L, and then go over to the final equation system $M\bar{Y} = \Phi$, где $M = D + \bar{A} + G$; $\Phi = \bar{F} + \bar{L}$. Obviously, after such a transition as J (Y) one can use the functional (7).

In this way, when setting up the problems shown on the neuron-like computer structure, processes in the structure will be described by a difference vector equation, in form coinciding with the equation describing the processes in the matrix neuron-like assembly:

$$\nabla Y_t = -BY_t \nabla t + H \nabla t. \qquad (9)$$

However, a neuron-like computer structure in general consists not of one but of several neuron-like assemblies, linked so that the NCS is stable for any matrix A. In diagram 5 an NCS is shown for resolving the LAU system with an arbitrary coefficient matrix. This NCS consists of two neuron-like assemblies and has a two layer neuron-like structure which is stable, if step ∇t satisfies the inequality $0 < \nabla t < 2(\|A\|^2 + \alpha)^{-1}$. The overall error ε^* of the unknown stable stationary solution of equation (9) can be judged by the correlation $\|\varepsilon^*\| \leq 2^{-n}[Y + 2\|B\| + \|B^{-1}\|(N\|Y\| + 1)]$, where N -- the size of the vector Y; n -- the number of significant discharges in the registers of the DNP.

The time for obtaining the solution on the NCS can be judged by the number of required iteration cycles

$$i_H \leq \frac{\ln \delta \|Y_0 - B^{-1}H\|^{-1}}{\ln \max\limits_{1 \leq k \leq N} |1 - \gamma_k \nabla t|},$$

where γ_k -- the proper values of matrix B. To increase the speed of the NCS one can use a method for building self-optimizing assemblies. The algorithm of the self-optimizing NCS has the form

$$Y_i = Y_{i-1} + D_i(-BY_{i-1} + H); \qquad (10)$$

$$D_{ki} = D_{k(i-1)} + Vt(-BD_{k(i-1)} + I_k), \qquad (11)$$

where $k = 1, 2, \ldots, N$; $I_k = [0, \ldots, 1, \ldots 0]^T$. The self-optimizing NCS consists of basic neuron-like assemblies giving the vector equation (10) and of the aggregate of auxiliary matrix assemblies reproducing equation (11) The speed of the self-optimizing structures increases significantly. For example, for the NCS with dual self-optimizing functioning according to the algorithm

$$Y_i = Y_{i-1} + D_i(-BY_{i-1} + H);$$
$$D_{ki} = D_{k(i-1)} + D_{i-1}(-BD_{k(i-1)} + I_k); \qquad (12)$$
$$k = 1, 2, \ldots, N; \qquad I_k = [0, \ldots, 1, \ldots 0]^T,$$

the speed can be judged from the correlation

$$2(2^i - 1) \leq \frac{\ln \delta \|Y_0 - B^{-1}H\|^{-1}}{\ln \max_{0<k\leq N} |1 - d_0\gamma_k|},$$

where Ed_0 --- the initial values for matrix D_i, $0 < d_0 < 2(\|A\|^2 + \alpha)^{-1}$. Compared with the speed of the NCS without self-optimization i_H, the speed of the NCS using the systems of equations (12) is m time greater $m = i_H\left[\ln\left(\frac{i_H}{2} + 1\right)\right]^{-1}\ln 2$.

In this way, the suggested neuron-like modelling and computing structures definitely possess wide functional possibilities and can be used as instruments in neurophysiological and neurocybernetic research into the study of neuron mechanisms of the living brain.

BIBLIOGRAPHY.

1. Mac Culloch U.,and Pitts V. A Logical Calculation of Ideas Concerning Nervous Activity.// Automatic Machines. M. Published in the foreign literature , 1956 -- pp.362-384.

2. Kostyuk P. G. The Neuron // Encyclopedia of Cybernetics.--1974-- Vol. 2 pp. 74 -75.

3. Decowska Z.,Decowski M.,Cawronski R. Realizacja cufrowego modelu nuroni. Pz. Inst. cebern. stosow.-1973 N 21 - pp. 15-21.

4. Kogan A. B. On the Principles of Neuron Organization of Working Mechanisms for Functional System Control // Principle of Systematic Organization of Functions. Moscow; Nauka,1973.--pp. 125-130.

5. Kalyayev A. V. Multiprocessing Systems with Programmed Architecture.-- Moscow Radio and Communications, 1984-- .240.pages.

6. Kalyayev A. V. The Theory of Digital Integrated Machines and Structures.-- Moscow.: Soviet Radio,1970. -- 472 pages.

7. Kalyayev A. V., Chernukhin Yu. V., Galyev G. A. Adaptable Digital Neuron-like Elements.-- Izvestiye. Northern Caucasus Scientific Center of High Schools. Technology and Science Series.--1980--No. 2 --pp.13-18.

8. Kalyayev A. V. Uniform Switching Register Structures.--Moscow.: Soviet Radio,1977.--334 pages.

9. Pukhov G. E. Selected Questions on the Theory of Mathematical Machines.-- Kiev : Published in AN. USSR,1964.--264 pages.

DEPARTMENT OF THE ARMY
UNITED STATES ARMY INTELLIGENCE AND SECURITY COMMAND
FREEDOM OF INFORMATION/PRIVACY OFFICE
FORT GEORGE G. MEADE, MARYLAND 20755-5995

June 5, 1998

Freedom of Information/
Privacy Office

Mr. John Greenewald, Jr.
[redacted]

Dear Mr. Greenewald:

This responds to your Freedom of Information (FOIA) requests of May 11, 1998, for a copy of the following document: AD Number: B130820; TITLE: Neuron-Like Modeling and Computing Structures; Authors: Kalyayev, A.V. and Chernukhin, YU. V.; Report Dated: 12 January 1989; Pagination: 13; Report Number: FSTC-HT-0697-88. Your request was received in this office May 20, 1998.

Since the information you seek concerning the document you requested must be obtained from another agency, we are unable to comply with the statutory 20-day time limit in processing your request. Therefore, you may consider this delay an administrative denial of your request and you have a right to appeal this denial, or you may agree to wait for a substantive reply upon completion of our coordination. Your agreement to waive the statutory time limit does not prejudice your right to appeal any releasability decision after it is made.

The Commanding General, U.S. Army Intelligence and Security Command, is tthe Initial Denial Authority in this matter, under the FOIA. You may appeal this decision to the Department of the Army, Office of the General Counsel. If you wish to file an appeal, you should forward it so that it reaches this office for necessary processing no later than 60 days from the date of this letter (excepting Saturdays, Sundays and legal public holidays). The mailing address is:

FREEDOM OF INFORMATION AND
PRIVACY OFFICE
ATTN IAMG C FOI/PO
4552 PIKE ROAD
FORT MEADE MD

If you have any questions concerning this action, contact Ms. Kelley at (301) 677-4908. Please refer to the following case number #1445F-98.

Sincerely,

Russell A. Nichols
Chief, Freedom of Information/
Privacy Office

DEPARTMENT OF THE ARMY
NATIONAL GROUND INTELLIGENCE CENTER
220 SEVENTH STREET, NE.
CHARLOTTESVILLE, VIRGINIA 22902-5396

REPLY TO
ATTENTION OF:

May 19, 1998

Mr. John Greenwald, Jr.
[redacted]

Dear Mr. Greenwald:

Your letter, dated May 11, 1998, was received on May 19, 1998, requesting FSTC-HT-0697-88, Neuron-Like Modeling and Computing Structures.

We have forwarded your request to the following address for appropriate action and direct reply to you. In the interim, if you wish, you may contact them at:

Freedom Of Information
And Privacy Office
Central Security Facility
4552 Pike Road
Fort Meade, MD 20755-5995

Sincerely,

for Ginger D. Stage
STEVEN D. OWEN
MAJ, AG
Adjutant