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INHOMOGENEOUS CELLULAR NEURAL NETWORKS:
POSSIBILITY OF FUNCTIONAL DEVICE DESIGN.

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Abstract.

A possibility of designing functional devices for various applications in terms of unified technology on the basis of CNNs is discussed on examples of an associative memory device, complex oscillations generator, devices for chaotic memory scanning and pattern recognition.

1. INTRODUCTION.

One of the advantages of analog (CNN)cellular neural networks [1] is a possibility of their realization as chips.

But CNNs with relatively small number of elements may also be promising. Even if all the elements are coupled with each other, the total number of connections is not excessive here.

Then an interesting possibility to design chips of integral functional devices for various applications in terms of unified technology on the basis of CNNs with inhomogeneous couplings, appears.

For example, a possibility to use neural networks as A/D converter and circuits for solving linear programming problems were discussed in [2].

This approach can also be used for designing various classifiers [3].

We will discuss in this report an application of this approach to the design of devices for chaotic memory scanning and pattern recognition.

2. ASSOCIATIVE MEMORY, CHAOTIC SCANNING AND PACEMAKER.

Two devices are necessary to organize chaotic memory scanning: a memory [4] itself and some external generator or pacemaker to push the system from one memorized pattern to another.

2.1. Associative memory on the basis of an inhomogeneous CNN.

To store images into a neural network, we have to find an algorithm of forming the matrix of couplings or templates, providing correspondence between equilibrium states of a CNN circuit and memorized patterns.

ADALINE algorithm [5] was chosen as a learning rule (an algorithm of coupling matrix forming). This algorithm was chosen for the next reasons: it is simple in realization and its matrix of couplings is not symmetric.

In general, the matrix of couplings is not local. But demands on the locality of the matrix of couplings can be lowered for the case of a little number of cells and images. This case of a little number of cells and patterns is important not only as an example, but for classifier design also.

2.2. Generator of complex oscillations with amplitude modulation.

The dynamics of a non-autonomous harmonically driven CNN composed of two cells was studied in details in [6]. A chaotic attractor was found in this non-autonomous system.

Such complex dynamics can obviously be obtained in an autonomous system, replacing an external harmonic signal by the signal from a generator composed of two cells. The dynamics of the four cell-CNN is described by:

$$\begin{aligned}d\mathbf{Y}/dt + \mathbf{Y} &= \mathbf{T} * \mathbf{F}(\mathbf{Y}), \\ \mathbf{Y} &= \{ y(1), y(2), y(3), y(4) \} \\ \mathbf{F}(\mathbf{Y}) &= \{ f(y(1)), f(y(2)), f(y(3)), f(y(3)) \}, \\ f(x) &= (|x + 1| - |x - 1|) / 2\end{aligned}\tag{1}$$

To design a pacemaker that could be used to control memory scanning a neural generator in which a large amplitude chaotic oscillations are interchanged by oscillations with a small amplitude near zero value, should be constructed.

We modify then the system (1) to a neural network of Fig. 1. Two

additional controlling cells 5 and 6 are introduced here. The dynamics of the cells 5 and 6 are described by equations

$$\begin{aligned} \alpha(t) \frac{dx}{dt} + x &= f(u), \\ \alpha(t) &= \alpha_0 + \alpha_1 \cdot \sin(2\pi t/T) \end{aligned} \quad (2)$$

where u is an output signal from the cells 1 or 3 for the cells 5 or 6 respectively, T is a period of controlling signal for parameter $\alpha(t)$.

With an increase of the parameter $\alpha(t)$ chaotic oscillations disappear in the system.

We can obtain the needed control signal (Fig.2) for the memory device with the help of high-pass filter composed of neural cells.

Applying the signal from the pacemaker to the associative memory device we obtain the device for chaotic scanning of memory. Fig. 3 shows the regime of memory scanning for CNN composed of nine cells with three stored patterns V_1 , V_2 and V_3 .

It should be noted that chaotic memory scanning may also be organized in some other way [7].

3. PATTERN RECOGNITION.

By pattern recognition we mean the following. Let an external signal is applied to a neural system, in which chaotic scanning of memory is organized. If the external signal corresponds to one of the patterns, stored in the neural network (memory device), the system must stabilize itself in the state, associated with that pattern. Otherwise, it should continue chaotic memory scanning.

For the organization of pattern recognition we introduce a local feedback between the memory and pacemaker. This feedback turns on and destroys the complex oscillations of the pacemaker only if a given equilibrium state of the memory device corresponds to the pattern being recognized. The feedback can be described by the relation

$$\alpha(\|\mathbf{Y} - \mathbf{Z}\|) = k / (\|\mathbf{Y} - \mathbf{Z}\| + \varepsilon), \quad (3)$$

where k and ε are some fixed parameters and $\varepsilon \ll 1$; vector \mathbf{Z} stands for an external signal or external pattern; vector \mathbf{Y} describes an internal state of associative memory; $\|\cdot\|$ is a vector norm. $\alpha(\|\mathbf{Y} - \mathbf{Z}\|)$ is added to $\alpha(t)$ (section 2.2).

We organize pattern recognition only on one component of \mathbf{z} .

$$\alpha(\|\mathbf{y} - \mathbf{z}\|) = k/(|y(2)-z(2)| + \epsilon), \quad (4)$$

where $y(2)$ is the second component of \mathbf{y} , $z(2)$ is the second component of \mathbf{z} .

Fig. 4 shows the trajectory of the state variable $y(2)$ for a pattern recognition regime.

4. CONCLUSION.

So we discussed the possibility of applying CNNs and their combinations to the design of various functional devices. This approach was discussed on the examples of associative memory, complex oscillation generator, chaotic memory scanning and pattern recognition. The advantage of this approach is in the use of universal CNN chips for different purposes.

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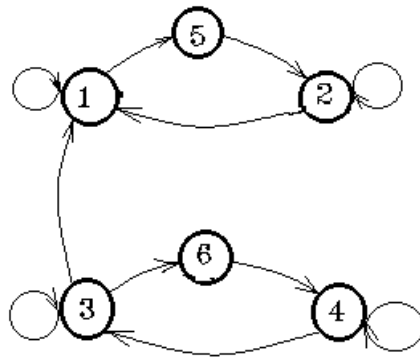


Fig. 1 The four-cell CNN with two control cells 5 and 6. Couplings between cells are $T_{11} = T_{22} = 2.0$, $T_{33} = T_{44} = 1.2$, $T_{15} = T_{36} = 1$, $T_{52} = -T_{21} = 1.2$, $T_{64} = -T_{43} = 2.1$, $T_{31} = 3.5$.

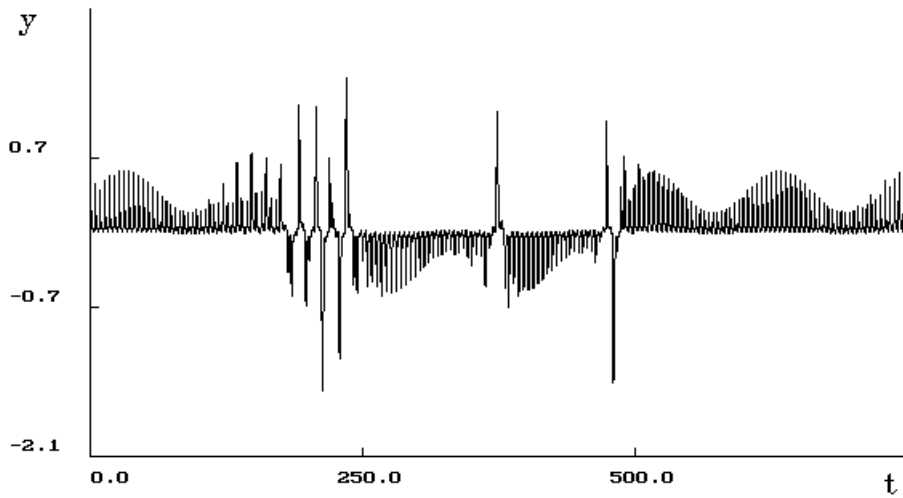


Fig. 2. Control signal for the "memory" device.

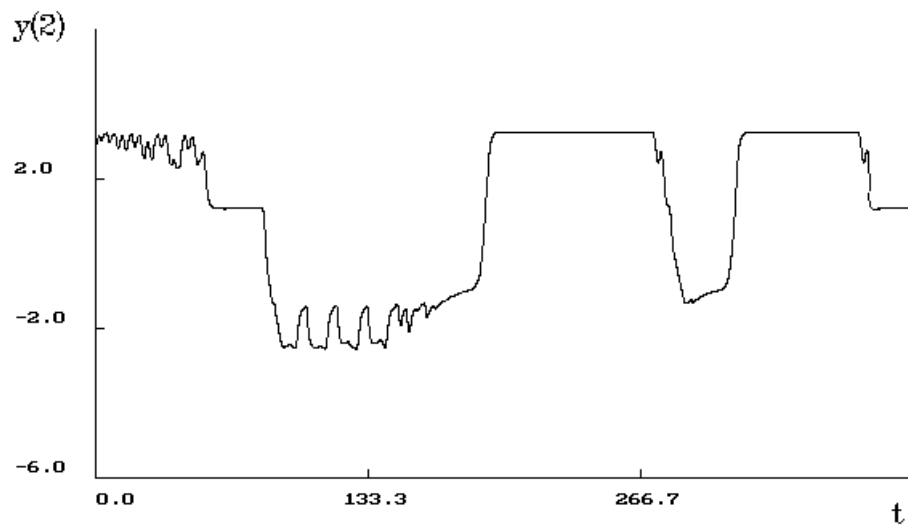


Fig. 3. Chaotic memory scanning. Memory device falls onto memorized pattern V1 for $0 < t < 45$, $200 < t < 270$, $310 < t < 360$; onto V2 for $90 < t < 190$, $280 < t < 300$; onto V3 for $45 < t < 90$, $360 < t < 400$.

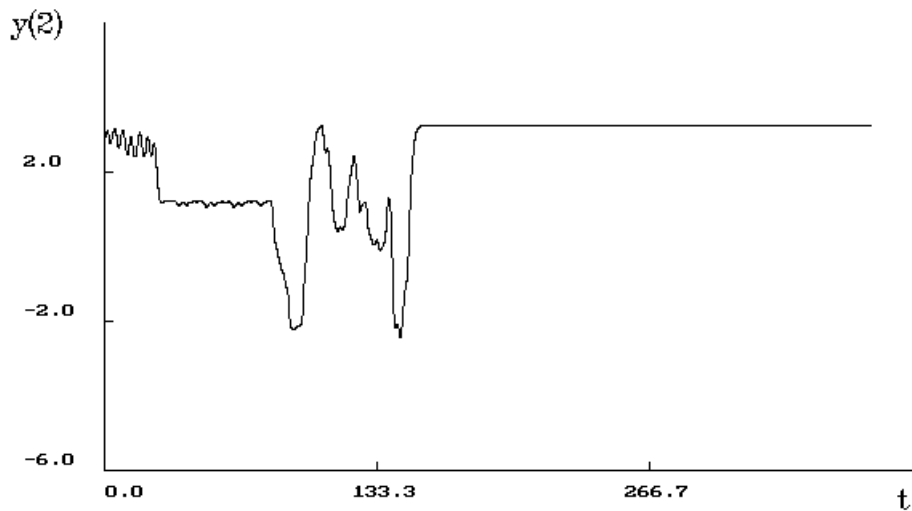


Fig.4. Pattern recognition: $k = 0.02$, $e = 0.002$. Z is an arbitrary external pattern for $0 < t < 140$ and $Z = V1$ for $t > 140$.