A SELF-ORGANIZING MULTILAYERED NEURAL NETWORK UNDER THREE DIFFERENT CONDITIONS

by

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SYNOPSIS

A self-organized multilayered neural network has been simulated on a digital computer under each condition in three cases. Several stimulus patterns have been presented repeatedly to the cells in the first layer. The informations of them from the cells in the first layer have been communicated to the cells in the final layer integrating through in the intermediate layer. In such a case under the condition of containing lateral inhibition effect, a neural network is made almost completely except for some errors of pattern "0".

1. INTRODUCTION

The perceptron[1] proposed by Rosenblatt in 1962 as a brain model was expected its capability for information processing. However, it was revealed through the study of many works that the capability of the perception is not so large as it would be expected at the beginning.

Recently, mechanism[2] of feature extration in the visual neuvous system was revealed. Several models[3][4][5] constructing with a multilayered neural network have been proposed. In those models, the synaptic connections between neurons are not fixed and the plastic modification of the synapses has been considered. In this paper, a neural network self-organization in the multilayer network is simulated on a digital computer under each condition in three cases.

2. CONDITION FOR THE SYNAPSE MODIFICATION

As a condition for the synapse modification, it would be classified into the following three categories as shown in Fig. 1.

In Fig. 1(a), a modifiable synapse $F(X, Y)$ from cell X to cell Y is excitatory when cell X or cell Y fires. In Fig. 1(b), a modifiable synapse $F(X, Y)$ is increased some amount when cell X fires simultaneously with cell Y. In Fig. 1(c), modifiable synapse $F(X, Y)$ is changed

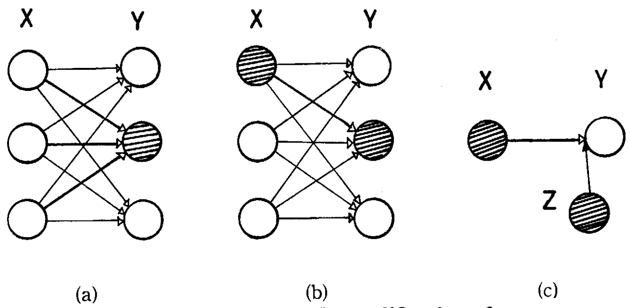


Fig. 1 Three hypotheses on the modification of synapses

when cell X fires simultaneously with cell which controls the reinforcement of its ordinary afferent synapses.

3. STRUCTURE OF MULTILAYER

In this paper, we use the cognitron as a multilayer network. The cognitron was pro posed by Fukushima.[3] It has a multilayered structure and consists of several neural layers of a similar structure cascaded one after another. As is seen from Fig. 2, one layer has excitatory $u_l(\boldsymbol{n})$ neurons and the same number of inhibitory $v_l(\boldsymbol{n})$ neurons, where $\boldsymbol{n}=(n_x, n_y)$ is two-dimensional coordinates. An excitatory neuron $u_l(\boldsymbol{n})$ receive modifiable synaptic connections $a_l(\boldsymbol{n}, \boldsymbol{\nu})$ from neurons $u_{l-1}(\boldsymbol{n}+\boldsymbol{\nu})$ in arbitrary connectable areas in preceding layer. The neuron $u_l(\boldsymbol{n})$ receive modifiable synaptic connections $b_l(\boldsymbol{n})$ from the inhibitory cell $v_{l-1}(\boldsymbol{n})$, which receives fixed excitatory synaptic connections $c_{l-1}(\boldsymbol{\nu})$ from the neighboring excitatory cells $u_{l-1}(\boldsymbol{n}+\boldsymbol{\nu})$. The output of the cell $u_l(\boldsymbol{n})$ is given by

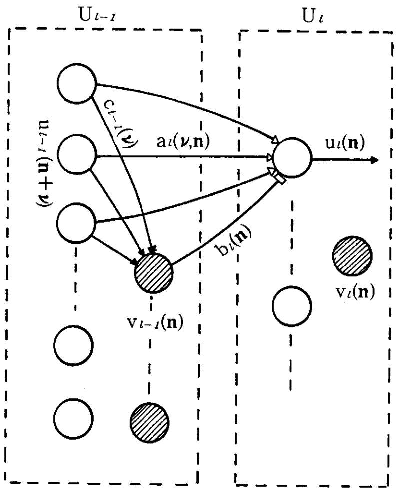


Fig. 2 The structure of the Cognitron.

$$u(\boldsymbol{n})=\phi\left[\frac{1+\sum_{\nu\in S_l}a_l(\boldsymbol{\nu}, \boldsymbol{n})u_{l-1}(\boldsymbol{n}+\boldsymbol{\nu})}{1+b_l(\boldsymbol{n})\ v_{l-1}(\boldsymbol{n})}-1\right]$$

where S_l indicates the connectable are of a cell $u_l(\boldsymbol{n})$.

$$\phi(x)=\begin{cases} x & x>0 \\ 0 & x\leqq 0. \end{cases}$$

Meanwhile, the output of the inhibitory cell $v_{l-1}(\boldsymbol{n})$ is given by

$$v_l(\boldsymbol{n})=\sum_{\nu\in S_l}c_{l-1}(\boldsymbol{\nu})u_{l-1}(\boldsymbol{n}+\boldsymbol{\nu}).$$

The value of the fixed synaptic connection $c_{l-1}(\boldsymbol{\nu})$ has to satisfy the following condition.

$$\sum_{\nu\in S_l}c_{l-1}(\boldsymbol{\nu})=1$$

The amounts of the synaptic reinforcement $\Delta a_l(\boldsymbol{\nu}, \boldsymbol{n})$ and $\Delta b_l(\boldsymbol{n})$ are given by
When $u_l(\boldsymbol{n})=0$

$$\Delta a_l(\boldsymbol{\nu}, \boldsymbol{n})=q_0\cdot c_{l-1}(\boldsymbol{\nu})\cdot u_{l-1}(\boldsymbol{n}+\boldsymbol{\nu})\cdot\delta_l(\boldsymbol{n})$$

$$\Delta b_l(\boldsymbol{n})=q_0\cdot v_{l-1}(\boldsymbol{n})\cdot\delta_l(\boldsymbol{n})$$

when $u_l(\boldsymbol{n})>0$

$$a_l(\boldsymbol{\nu}, \boldsymbol{n})=q_1 \cdot c_{l-1}(\boldsymbol{\nu})u_{l-1}(\boldsymbol{n}+\boldsymbol{\nu}) \cdot \delta_l(\boldsymbol{n}) \tag{1}$$

$$b_l(\boldsymbol{n})= \frac{\sum_{\nu \in S_l} a_l \theta \boldsymbol{\nu}, \boldsymbol{n}) \cdot u_{l-1}(\boldsymbol{n}+\boldsymbol{\nu}) \cdot \delta l(\boldsymbol{n})}{2v_{l-1}(\boldsymbol{n})} \tag{2}$$

where q_0 and q_1 are positive constants.

$\delta_l(\boldsymbol{n})$ is given by

$$\delta_l(\boldsymbol{n})=\begin{cases} 1 & \text{if} \quad u_l(\boldsymbol{n}) \geqq u_l(\boldsymbol{n}+\boldsymbol{\nu}) \quad \text{for every} \quad \boldsymbol{\nu} \in \Omega_l \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

where Ω_l stand for a vicinity area.

The reinforcement of the afferent synapses of cell $u_l(\boldsymbol{n})$ takes place only when none of the cells situated in the vicinity of $u_l(\boldsymbol{n})$ is firing stronger than $u_l(\boldsymbol{n})$. The algorithm as described above is the structure of a cognitron proposed by Fukushima.

In this paper, however, equation (3) is substituted the others and at the same time, equation (1) and (2) are substituted the following equation (4) and (5).

$$\Delta a_l(\boldsymbol{\nu}, \boldsymbol{n})=q_1 \cdot c_{l-1}(\boldsymbol{\nu}) \cdot u_{l-1}(\boldsymbol{n}+\boldsymbol{\nu}) \cdot F_l(\boldsymbol{n}) \tag{4}$$

$$\Delta b_l(\boldsymbol{\nu}, \boldsymbol{n})= \frac{q_1 \cdot \sum_{\nu \in S} a_l(\boldsymbol{\nu}, \boldsymbol{n}) u_{l-1}(\boldsymbol{n}+\boldsymbol{\nu})}{2v_{l-1}(\boldsymbol{n})} \,. \tag{5}$$

Now, $F_l(\boldsymbol{n})$ is considered to be a function of $u_{l-1}(\boldsymbol{n})$ and $u_l(\boldsymbol{n})$. We consider following three cases under each condition.

(i)
$$F_l(\boldsymbol{n})=\begin{cases} 1 & \text{if } u_l(\boldsymbol{n})>0 \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

(ii)
$$F_l(\boldsymbol{n})=\begin{cases} 1 & \text{if } u_l(\boldsymbol{n}) \geqq u_l(\boldsymbol{n}+\boldsymbol{\nu})>0 \text{ for} \quad \text{every } \boldsymbol{\nu} \in \Omega_l \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

(iii)
$$F_l(\boldsymbol{n})=\begin{cases} \exp\left\{1-\dfrac{\sum_{\nu \in S_l} u_l(\boldsymbol{n}+\boldsymbol{\nu})}{u_l(\boldsymbol{n})}\right\} & \text{if } u_l(\boldsymbol{n}+\boldsymbol{\nu}) \geqq u_l(\boldsymbol{n})>0 \text{ for } \boldsymbol{\nu} \in \Omega_l \\ 0 & \text{otherwise}. \end{cases} \tag{8}$$

4. COMPUTER SIMULATION

In each case described above, a neural network self-organization is simulated on a digital computer. The parameters for them are chosen in the following way as the same values in cognitron.

The number of the layer are four, U_0, U_1, U_2, U_3 from the front. Each layer has $12 \times 12 = 144$ excitatory cells $u_l(\boldsymbol{n})$ and the same number of inhibitory cells $v_l(\boldsymbol{n})$. The connectable areas S_l is $5 \times 5 = 25$ cells. The vicinity area Ω_l is 13 cells in area where have a rhombic shape whose height and width are both 5. The conductance $c_l(\boldsymbol{\nu})$ of the synaptic connection from an axon terminal $u_{l-1}(\boldsymbol{n}+\boldsymbol{\nu})$ to a cell $v_l(\boldsymbol{n})$ is a function of only $\boldsymbol{\nu}$. The initial conductances of all the modifiable synapses $a_l(\boldsymbol{n}, \boldsymbol{\nu})$ and $b_l(\boldsymbol{n})$ are chosen to be 0.05. The amount of reinforcement q_0 and q_1 are chosen to be 16.0.

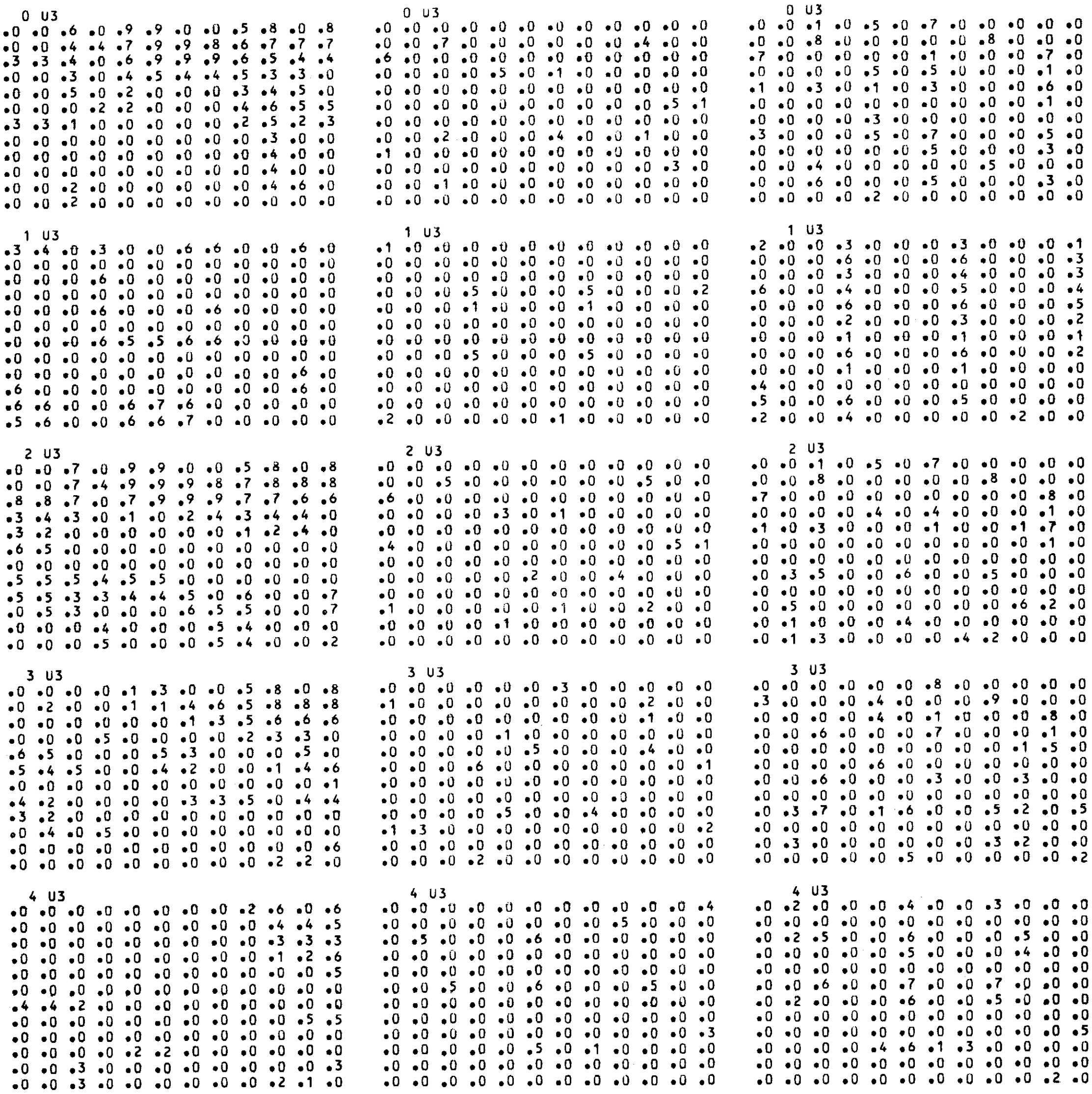
Five stimulus patterns "0", "1", "2", "3", "4" have been presented repeatedly to layer U_0 in a cyclic manner. Each pattern is constructed with value 1.0. a cell $u_0(\boldsymbol{n})$ in the layer U_0 is given this pattern repeatedly. In Fig. 3, it shows. The cells in each layer respond to each of the stimulus patterns in the 10th cycle of presentation. The responses of the cells in each layer are shown in Fig. 4. When only stimulated pattern "2" has been presented, the response for each case as described above is shown in Fig. 5.

In order to make an investigation that the information of only the pattern "2" in the layer U_0 is communicated till the cells in the layer U_3 without erasing, an experiment by means of reverse reproduction is made. That is, the actual values in the layer U_3, obtained above, have been presented to the layer U_3. The cells in the layer U_2 response to the stimulus pattern values using the same values $a_2(\boldsymbol{\nu}, \boldsymbol{n})$ and $b_2(\boldsymbol{n})$ obtained above. Figure 6 shows results of reverse reproduction from the information of pattern "2" in layer U_3. In case of (i), when only pattern "2", the reverse reproduction is made completely from the information of whole parts in the layer U_3. For five stimulation patterns, however, a complete reproduction of the original pattern is impossible even from all the u_3-cells as is seen in Fig. 7.

In case of (ii), the reverse reproduction is made almost completely except erasing one part of cells. When five stimulus patterns, it is made considerably as is seen in Fig. 7. In case of (iii), the reverse reproduction of only the pattern "2" is made almost completely. When five stimulus patterns, also, it is made almost completely as is seen in Fig. 7.

```
      0  U0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0 1.0 1.0 1.0  .0  .0  .0  .0  .0
  .0  .0  .0 1.0  .0  .0  .0 1.0  .0  .0  .0  .0
  .0  .0 1.0  .0  .0  .0  .0  .0 1.0  .0  .0  .0
  .0  .0 1.0  .0  .0  .0  .0  .0 1.0  .0  .0  .0
  .0  .0 1.0  .0  .0  .0  .0  .0 1.0  .0  .0  .0
  .0  .0 1.0  .0  .0  .0  .0  .0 1.0  .0  .0  .0
  .0  .0 1.0  .0  .0  .0  .0  .0 1.0  .0  .0  .0
  .0  .0  .0 1.0  .0  .0  .0 1.0  .0  .0  .0  .0
  .0  .0  .0  .0 1.0 1.0 1.0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
      1  U0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
      2  U0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0 1.0 1.0 1.0  .0  .0  .0  .0  .0
  .0  .0  .0 1.0  .0  .0  .0 1.0  .0  .0  .0  .0
  .0  .0 1.0  .0  .0  .0  .0  .0 1.0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0 1.0  .0  .0  .0
  .0  .0  .0  .0  .0  .0 1.0 1.0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0  .0
  .0  .0  .0 1.0  .0  .0  .0  .0  .0  .0  .0  .0
  .0  .0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
      3  U0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
  .0  .0  .0 1.0 1.0 1.0 1.0  .0  .0  .0  .0  .0
  .0  .0 1.0  .0  .0  .0  .0 1.0  .0  .0  .0  .0
  .0  .0 1.0  .0  .0  .0  .0  .0 1.0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0 1.0 1.0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0 1.0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0  .0 1.0  .0  .0
  .0 1.0  .0  .0  .0  .0  .0  .0  .0 1.0  .0  .0
  .0  .0 1.0  .0  .0  .0  .0  .0 1.0  .0  .0  .0
  .0  .0  .0 1.0 1.0 1.0 1.0 1.0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
      4  U0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0 1.0 1.0  .0  .0  .0  .0
  .0  .0  .0  .0  .0 1.0  .0 1.0  .0  .0  .0  .0
  .0  .0  .0  .0 1.0  .0  .0 1.0  .0  .0  .0  .0
  .0  .0  .0 1.0  .0  .0  .0 1.0  .0  .0  .0  .0
  .0  .0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  .0  .0
  .0  .0  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0 1.0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0
```

Fig. 3 Five stimulus patterns "0", "1", "2", "3", "4".



(i) (ii) (iii)

Fig. 4 The responses of the cells in each layer for five patterns.

ID+IO ULI JU•'OI UL/NNZ•KUZ1J

U0

.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	I0	I0	I0	.0	.0	.0	.0	.0
.0	.0	.0	I0	.0	.0	.0	I0	.0	.0	.0	.0
.0	.0	I0	.0	.0	.0	.0	.0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	I0	I0	.0	.0	.0	.0
.0	.0	.0	.0	.0	I0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	I0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	I0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	I0	I0	I0	I0	I0	I0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

U1

.0	.6	.7	.8	.8	.7	.8	.8	.7	.6	.0	.0
.6	.7	.8	.8	.0	.0	.0	.8	.8	.7	.6	.0
.6	.8	.8	.0	.7	.0	.7	.0	.8	.8	.7	.0
.6	.8	.0	.8	.8	.8	.7	.7	.7	.8	.7	.0
.6	.8	.0	.8	.7	.7	.7	.0	.0	.8	.7	.0
.6	.6	.7	.8	.8	.0	.7	.0	.8	.8	.7	.0
.0	.0	.7	.0	.0	.0	.0	.0	.8	.7	.0	.0
.6	.8	.8	.7	.6	.7	.7	.8	.8	.8	.6	.0
.6	.8	.7	.0	.6	.6	.7	.0	.0	.0	.6	.0
.6	.8	.0	.0	.7	.7	.7	.0	.0	.8	.6	.0
.6	.8	.8	.7	.7	.7	.7	.0	.8	.8	.6	.0
.6	.7	.8	.8	.8	.8	.8	.8	.8	.7	.6	.0

U2

.6	.6	.5	.6	.6	.6	.6	.0	.5	.6	.6	.6
.6	.5	.4	.5	.5	.6	.5	.5	.4	.5	.6	.7
.5	.4	.4	.4	.5	.5	.5	.4	.4	.4	.5	.6
.5	.4	.4	.4	.4	.4	.5	.5	.4	.4	.5	.6
.0	.5	.4	.4	.4	.0	.5	.5	.5	.0	.5	.6
.6	.5	.4	.4	.5	.5	.5	.5	.5	.5	.6	.7
.6	.5	.4	.4	.5	.5	.5	.5	.4	.0	.6	.6
.6	.0	.4	.4	.5	.5	.5	.5	.5	.5	.6	.6
.5	.0	.4	.4	.4	.0	.5	.5	.5	.5	.6	.6
.5	.4	.4	.4	.4	.4	.5	.5	.5	.5	.6	.6
.5	.0	.4	.4	.4	.0	.5	.5	.5	.0	.0	.6
.6	.0	.5	.5	.5	.6	.6	.6	.6	.0	.6	.7

U3

.7	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6
.6	.6	.6	.5	.5	.5	.6	.6	.6	.5	.5	.6
.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.5	.6
.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.5	.6
.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.5	.6
.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.5	.6
.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.5	.6
.6	.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.6
.7	.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.0
.7	.6	.6	.6	.6	.5	.5	.5	.5	.5	.5	.6
.7	.6	.6	.0	.6	.6	.6	.0	.6	.6	.6	.0
.7	.7	.7	.6	.7	.6	.6	.6	.6	.6	.6	.0

(i)

U0

.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	I0	I0	I0	.0	.0	.0	.0	.0
.0	.0	.0	I0	.0	.0	.0	I0	.0	.0	.0	.0
.0	.0	I0	.0	.0	.0	.0	.0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	I0	I0	.0	.0	.0	.0
.0	.0	.0	.0	.0	I0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	I0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	I0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	I0	I0	I0	I0	I0	I0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

U1

.0	.0	.0	.0	.0	.0	.0	.0	.7	.0	.0	.0
.0	.7	.0	.0	.0	.0	.0	.0	.0	.7	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.7	.0
.6	.0	.0	.0	.1	.1	.7	.1	.0	.0	.7	.0
.6	.0	.0	.0	.1	.0	.0	.0	.0	.0	.7	.0
.0	.0	.0	.1	.0	.0	.0	.0	.0	.0	.7	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.1	.1	.1	.1	.2	.7	.2	.1	.1	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.6	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.1	.1	.8	.1	.8	.1	.1	.0	.0	.0

U2

.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.5
.6	.0	.0	.0	.0	.0	.6	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.1	.0	.0	.0
.0	.0	.6	.0	.0	.0	.0	.0	.1	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.1	.0	.0	.0
.0	.0	.0	.0	.1	.1	.1	.0	.7	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.1	.1	.7	.0	.1	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.3

U3

.0	.0	.0	.0	.0	.0	.0	.0	.2	.0	.0	.0
.0	.0	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.3	.0	.0	.0	.0	.0	.4	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.2	.0	.0	.0	.0	.0	.0	.0	.3	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.5	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.3	.0	.0	.0	.0	.0

(ii)

U0

.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	I0	I0	I0	.0	.0	.0	.0	.0
.0	.0	.0	I0	.0	.0	.0	I0	.0	.0	.0	.0
.0	.0	I0	.0	.0	.0	.0	.0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	I0	I0	.0	.0	.0	.0
.0	.0	.0	.0	.0	I0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	I0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	I0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	I0	I0	I0	I0	I0	I0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

U1

.0	.0	.2	.7	.7	.0	.6	.8	.5	.0	.0	.0
.0	.6	.8	.0	.0	.0	.0	.0	.3	.7	.0	.0
.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.5	.0
.3	.0	.0	.0	.6	.7	.7	.1	.0	.0	.6	.0
.2	.0	.0	.0	.1	.0	.0	.0	.0	.0	.6	.0
.0	.0	.4	.7	.0	.0	.0	.0	.8	.5	.6	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.2	.7	.7	.2	.6	.7	.7	.3	.1	.0	.0
.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.8	.0	.0	.0	.0	.0	.0	.0	.0	.6	.0
.0	.7	.0	.0	.0	.0	.0	.0	.0	.0	.3	.0
.0	.1	.1	.6	.8	.3	.6	.5	.1	.0	.0	.0

U2

.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.7	.0
.0	.0	.0	.0	.1	.4	.7	.0	.0	.0	.5	.0
.0	.0	.1	.1	.7	.0	.1	.0	.6	.0	.0	.0
.0	.0	.6	.1	.0	.0	.0	.0	.7	.0	.0	.7
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.6	.1	.1	.5	.7	.6	.4	.1	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.1	.7	.0	.0	.0	.0	.0	.0	.5	.6	.6	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.5	.5	.6	.7	.4	.3	.3	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.3

U3

.0	.0	.1	.0	.5	.0	.0	.0	.2	.0	.0	.0
.0	.0	.5	.0	.0	.0	.6	.0	.6	.0	.0	.0
.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.5	.0
.0	.0	.0	.1	.4	.5	.7	.1	.0	.0	.6	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.5	.0	.1	.6	.0	.0	.0	.0	.2	.5	.5	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.1	.4	.2	.5	.6	.1	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.2	.5	.0	.0	.0	.0	.0	.0	.0	.4	.4	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.2	.1	.3	.5	.1	.0	.0	.0	.0	.0

(iii)

Fig. 5 The responses of the cells for only pattern "2".
I0, I1, and I2 mean 1.0, 1.1 and 1.2 respectively.

10:47' OCT' 31,'81 DC/NNI2.RD215

U3

.7	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6
.6	.6	.6	.5	.5	.5	.6	.6	.6	.5	.5	.6
.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.5	.6
.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.5	.6
.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.5	.6
.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.5	.6
.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.5	.6
.6	.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.6
.7	.6	.6	.5	.5	.5	.5	.5	.5	.5	.5	.0
.7	.6	.6	.6	.6	.5	.5	.5	.5	.5	.5	.6
.7	.6	.6	.0	.6	.6	.6	.0	.6	.6	.6	.0
.7	.7	.7	.6	.7	.6	.6	.6	.6	.6	.6	.0

U3

I0	I0	10	I1	I2	I2	I2	.0	10	I0	I0	.7
I0	.9	.8	.9	I1	I1	I1	.9	.8	.9	I0	I0
I0	.8	.8	.9	.9	I0	.9	.8	.7	.7	I0	I0
I0	.9	.9	.9	.9	.8	.9	.9	.9	.8	I0	I1
.0	.9	.9	.9	.8	.0	I0	I0	.9	.0	I0	I1
I1	.9	.9	.9	I0	I1	I1	I0	.9	.9	I0	I1
I1	.9	.8	.8	I0	I1	I1	.9	.8	.0	I1	.9
I1	.0	.9	.9	I1	I1	I1	I0	.9	.9	I0	.9
I0	.0	.9	I0	.9	.0	.9	.9	I0	.9	I0	.8
I0	.8	.9	.9	.8	.7	.9	I0	I0	.9	I0	.9
I0	.0	.9	.9	.8	.0	.9	I0	.9	.0	.0	.8
I1	.0	I1	I1	I1	I1	I2	I1	I1	.0	I0	.8

U1

.0	.4	.8	I1	I0	I0	I0	I1	.8	.4	.0	.0
.4	.9	I2	I1	.0	.0	.0	I1	I2	.8	.4	.0
.4	I2	I2	.0	I0	.0	I0	.0	I1	I2	.8	.0
.4	I2	.0	I1	I1	I0	I0	I0	I0	I2	.8	.0
.5	I3	.0	I1	.9	I0	I0	.0	.0	I2	.8	.0
.5	.4	.8	I0	I1	.0	I0	.0	I1	I2	.8	.0
.0	.0	.7	.0	.0	.0	.0	.0	I1	.7	.0	.0
.4	I1	I3	I1	.9	.9	I0	I1	I1	I1	.4	.0
.4	I2	I2	.0	.8	.9	I0	.0	.0	.0	.5	.0
.4	I2	.0	.0	.9	I0	I0	.0	.0	I3	.5	.0
.4	I2	I2	I1	I0	I0	I0	.0	I2	I2	.5	.0
.4	.8	.9	I0	I0	I0	I0	I0	.9	.8	.5	.0

U0

.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	I0	I0	I0	.0	.0	.0	.0	.0
.0	.0	.0	I0	.0	.0	.0	I0	.0	.0	.0	.0
.0	.0	I0	.0	.0	.0	.0	.0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	I0	I0	.0	.0	.0	.0
.0	.0	.0	.0	.0	I0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	I0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	I0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	I0	I0	I0	I0	I0	I0	I0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

(i)

U3

.0	.0	.0	.0	.0	.0	.0	.0	.2	.0	.0	.0
.0	.0	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.3	.0	.0	.0	.0	.0	.4	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.2	.0	.0	.0	.0	.0	.0	.0	.3	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.5	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.3	.0	.0	.0	.0	.0

U3

.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.4	.0	.0	.0	.0	.0	.4	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.8	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.6	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

U1

.0	.0	.0	.0	.0	.0	.0	.0	.3	.0	.0	.0
.0	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.3	.0	.0	.0	.0	.0	.9	.0	.0	.0	.5	.0
.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.5	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.5	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.9	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.6	.0	.6	.0	.0	.0	.0	.0

U0

.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.6	.6	.7	.0	.0	.0	.0	.0
.0	.0	.0	.6	.0	.0	.0	.9	.0	.0	.0	.0
.0	.0	.7	.0	.0	.0	.0	.0	.8	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.8	.0	.0	.0
.0	.0	.0	.0	.0	.0	.8	.8	.0	.0	.0	.0
.0	.0	.0	.0	.0	.9	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.6	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.5	.5	.8	.8	.8	.7	.7	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

(ii)

U3

.0	.0	.1	.0	.5	.0	.0	.0	.2	.0	.0	.0
.0	.0	.5	.0	.0	.0	.6	.0	.6	.0	.0	.0
.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.5	.0
.0	.0	.0	.1	.4	.5	.7	.1	.0	.0	.6	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.5	.0	.1	.6	.0	.0	.0	.0	.2	.5	.5	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.1	.4	.2	.5	.6	.1	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.2	.5	.0	.0	.0	.0	.0	.0	.0	.4	.4	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.2	.1	.3	.5	.1	.0	.0	.0	.0	.0

U3

.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.4	.0
.0	.0	.0	.0	.0	.4	I1	.0	.0	.0	.1	.0
.0	.0	.0	.0	I0	.0	.0	.0	.9	.0	.0	.0
.0	.0	.8	.0	.0	.0	.0	.0	I1	.0	.0	I0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.6	.0	.0	.8	I2	.7	.2	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.9	.0	.0	.0	.0	.0	.0	.3	.5	.6	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.4	.4	.7	.9	.3	.1	.2	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

U1

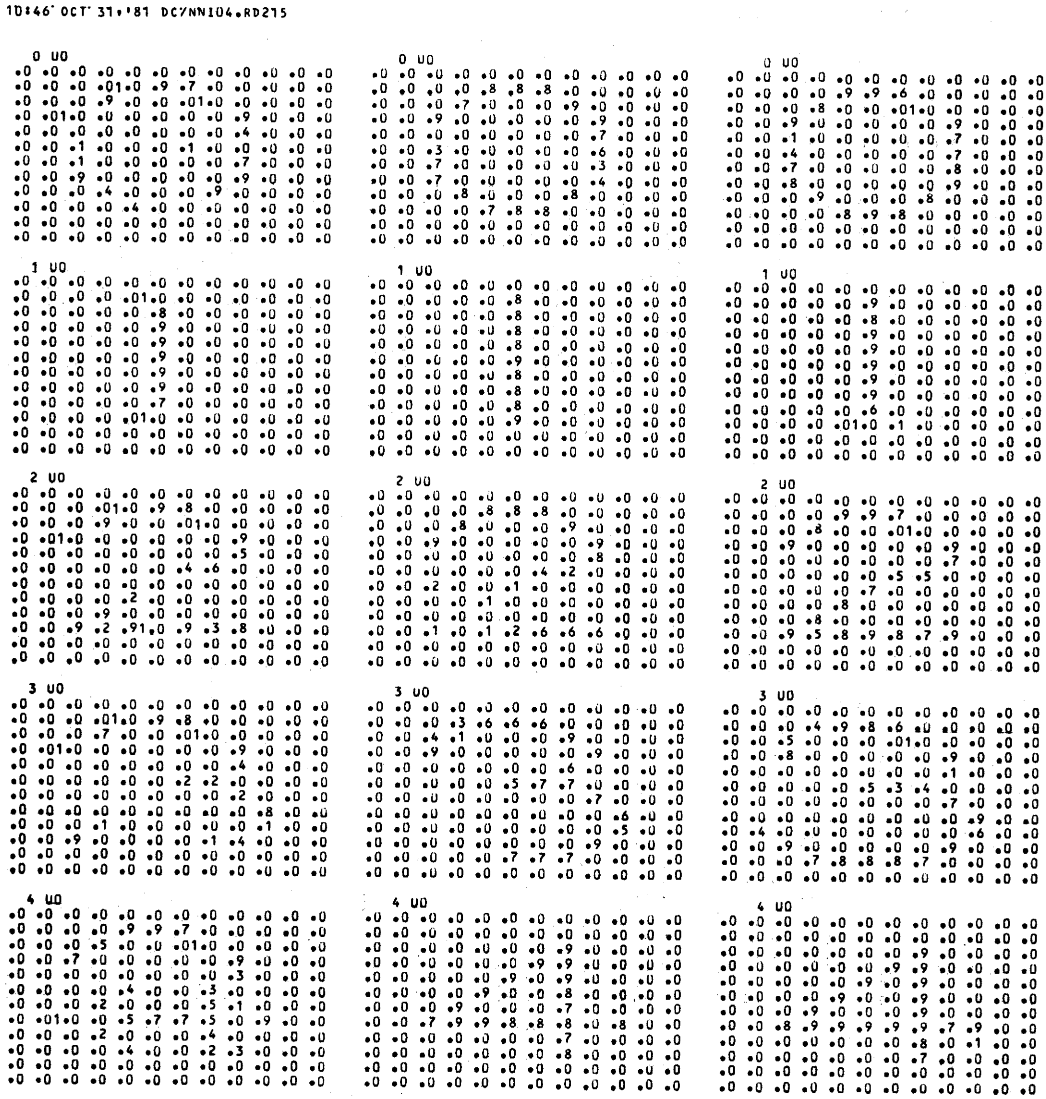
.0	.0	.0	.6	.5	.0	.5	I2	.4	.0	.0	.0
.0	.8	I0	.0	.0	.0	.0	.0	.2	I2	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.5	.0
.0	.0	.0	.0	.8	I2	I4	.0	.0	.0	.8	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.9	.0
.0	.0	.2	I2	.0	.0	.0	.0	I1	.7	I0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	I2	I3	.0	I0	I3	.9	.3	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.9	.0	.0	.0	.0	.0	.0	.0	.0	.4	.0
.0	.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.4	.9	.2	.7	.2	.0	.0	.0	.0

U0

.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.9	.9	.9	.0	.0	.0	.0	.0
.0	.0	.0	.9	.0	.0	.0	I0	.0	.0	.0	.0
.0	.0	.9	.0	.0	.0	.0	.0	.9	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.9	.0	.0	.0
.0	.0	.0	.0	.0	.0	.9	I0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.9	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.9	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.9	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.9	.9	.9	.9	.9	.8	.8	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

(iii)

Fig. 6 reverse reprodaction of the pattern "2".
I0, I1, and I2 mean 1.0, 1.1, and 1.2 respectively.



(i) (ii) (iii)

Fig. 7 reverse reproduction of five stimulus patterns.

5. CONCLUSION

Under each condition in three cases, a self-organized multilayered neural network has been performed for only one pattern "2" and five stimulate patterns "0", "1", "2", "3", "4". As is seen these results, when only pattern "2", in the case of (i), neural network has been made completely. It results that in case of (i), all the synaptic connections between presynaptic cells $u_{l-1}(\boldsymbol{n})$ and postsynaptic cells $u_l(\boldsymbol{n})$ are made completely without erasing when $u_{l-1}(\boldsymbol{n})$ and $u_l(\boldsymbol{n})$ fired. In the five stimulated patterns, however, it has not been made almost except the pattern "1". It would result that the inhibitory synapses became too strong in each layer, because all the synaptic connections receive a lot of stimulations from the five stimulate patterns repeatedly.

In case of (ii), the neural network has been constructed considerably, but the reversely reproduced patterns contain some errors for four stimulated patterns except the pattern "2". It would be supposed that the cells of the layer U_3 could receive a few information through the cynapices from each preceding layer.

In case of (iii), the neural network has been constructed satisfactorily for each stimulate pattern on comparing with two the other cases. In this case, however, there are a number of firing cells in the layer U_3 than in case of (ii).

In three cases, (i), (ii) and (iii), a self-organized multilayered neural network has been performed. It results that in case of (iii), it performed better. It is expected that the neural network would acquire more ability, if the information from the cells in each layer is integrated more effectively in the case of (iii).

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