MOVING OBJECT DETECTION USING DELAYED-CELLULAR NEURAL NETWORK (*)

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Abstract: In this paper, we have studied moving objects in 2-D images using Delayed Cellular Neural Network (DCNN). DCNN was first introduced in 1993. It is shown that for a network whose cells are specified, complete asymptotic stability providing the delay is less than a bound which depends on only the cell parameters. Especially nowadays, only moving part of the whole image is getting more important according to the practical cases such as estimation of biomedical issues which is enlarging due to the cancer property. We have used Java language for our synthetic examples and satisfactory results were obtained.

Keywords: *Delayed Cellular Neural Networks, Moving Object Detection*

Özet: Bu makalede, 2 boyutlu görüntüler geciktirilmiş hücresel yapay sinir ağı (GHYSA) ile incelenmiştir. GHYSA ilk defa 1993 yılında tanıtılmıştır. Gecikme miktarı belirli bir değerden küçük seçilmesi halinde, asimptotik kararlılık sağlanır. Özellikle son yıllarda, görüntünün hareketli olan kısmı diğer bölgelere göre daha önemli olabilmektedir. Tıp biliminde, kanserli hücrelerin yönelimini GHYSA ile belirlemek çok önem taşımaktadır. Burada Java dilinde yazılım gerçekleştirilmiş ve yapay örnekler için iyi sonuçlar elde edilmiştir.

Anahtar kelimeler: *Geciktirilmiş Hücresel Yapay Sinir Ağ (GHYSA), Hareketli Cisim Saptama*

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INTRODUCTION

Moving object detection is among the most appealing tasks in the field of the image processing.[1] Conventional digital computation methods have same drawbacks due to their serial nature. To overcome this problem, a realatively novel class of information processing system, called Neural Networks is proposed. This new computational model is based on some aspects of neurobiology and adapted to integrated circuits. In this paper we are interested in image processing(first without considering motion and after that detection of moving objects), our attention will be focused on M x N Cellular Neural Network, having M x N cells arranged in M rows and N Columns in pixels.

Cellular Neural Network is a parallel computing paradigm defined in M x N space and characterized by locality of connections between processing elements (cells or pixels in our Cellular Neural Network is a parallel computing paradigm defined in MxN space and characterized by locality of connections between processing elements (cells or pixels, in our example) [2],[3]. In this new computational model, the key features are asynchronous parallel processing, continues time dynamics and global interaction of network elements. The main difference between Cellular Neural Network and other Neural Network paradigms is the fact that information is only exchanged between neighboring neurons.

Besides Cellular Neural Network, processing of moving images requires the introduction of delay in the signals transmitted among the cells. In this paper we show how a Cellular Neural Network with delay detects moving objects in images.

Cellular Neural Network Definition

A Cellular Neural Network is a system of cells defined on a normalized space. In this system, cell is the basic circuit unit containing linear and nonlinear circuit elements, which are linear capacitors, linear resistors, linear and nonlinear controlled sources and independent sources. The main idea is that connections are only allowed between adjacent cells. Any cell in a cellular neural network is connected to only its neighbor cells. But cells can affect each other indirectly. The propagation effects of the continuous time dynamics of the Cellular Neural Network provide this interaction between cells in space.

Theoretically, we can define a Cellular Neural Network of any dimension, but due the fact that we are interested in images, we will concentrate on the two-dimensional case. Fig 1 shows an example of Cellular Neural Network.

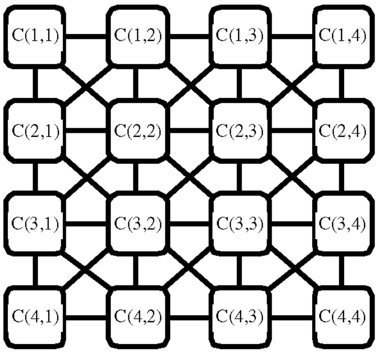
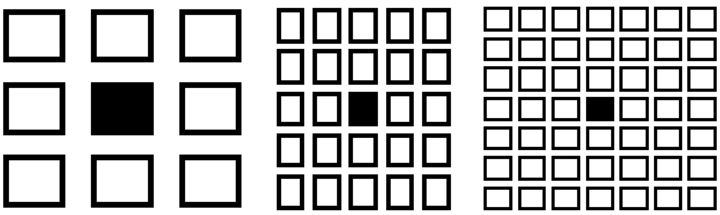


Figure 1 . A two-dimensional cellular neural network of 4 x 4 size. Squares are electrical circuit elements and represent pixels for image

The restriction of connections which are allowed to only neighboring cells requires the definition of neighborhood. Let us consider a cellular neural network with M x N cells arranged in M rows and N columns. A cell in this space is represented with (i,j) location, r-neighborhood and denoted by C(i,j) as in Figure1.
The r-neighborhood of a cell C(i,j), in a cellular neural network is defined by

$$N_r(i,j) = \{C(k,l) | \max\{|k-i|, |l-j|\} \leq r, \quad 1 \leq k \leq M; 1 \leq 1 \leq N\} \qquad (1)$$

r is a positive integer number. Following example shows r = 1, r = 2 and r = 3 neighborhood of cells, respectively.



r = 1 **r = 2** **r = 3**

Figure 2. The neighborhood of cell C(i,j) for r =1, r = 2 and r = 3, respectively

We call the r = 1 neighborhood a "3 x 3 neighborhood", the r = 2 neighborhood a "5 x 5 neighborhood" and so on. But r = 1 is the most common neighborhood using image processing. Because if the neighborhood size were as large as image itself, we might obtain a fully connected network and in this case we shall not call such a network cellular. Generally the neighborhood shall have small size.

We call cellular neural network as a dynamical system operating in continuous or discrete time. A general form of the equations may be stated as follows:

State equation:

$$C \frac{dV_{xijt}(t)}{dt} = -\frac{1}{R_x} V_{xijt}(t)$$

$$+ \sum_{C(k,l) \in Nr(i,j)} A(i,j;k,l) V_{ykl}(t)$$

$$+ \sum_{C(k,l) \in Nr(i,j)} B(i,j;k,l) V_{ukl}(t) + I,$$

$$1 \leq k \leq M; 1 \leq 1 \leq N \qquad (2)$$

Output equation:

$$V_{yijt}(t) = \frac{1}{2} \left(|V_{xij}(t)+1| - |V_{xij}(t) - 1| \right)$$

$$1 \leq k \leq M; 1 \leq 1 \leq N \qquad (3)$$

Input equation:

$$V_{uij} = E_{ij}, \qquad 1 \leq k \leq M; 1 \leq 1 \leq N \qquad (4)$$

A cellular neural network is completely characterized by set of equations as above, associated with the cells in the circuit. The state equation of a cellular neural network, composed by M x N cells after having ordered the cells in some way (e.g. by rows or columns) can be rewritten in continuous time as follows:

$$\frac{dx(t)}{dt} = - x(t) + Ay(t) + Bu + I \qquad (5)$$

The equation (5) then can be rewritten in discrete form as,

$$x(n+l) = - x(n) + Ay(n) + Bu + I \qquad (6)$$

In Equation(6), x(n+1),y,u,I denote respectively cell state, output, input and bias. X is a local instantaneous feedback function, A and B are arrays of parameters.

Delay Cellular Neural Network Definition:

Cellular neural networks with delay τ was first introduced in 1993 [4], [5]. By assuming that the input of each cell is constant, they are described by state equations of the form:

$$C \frac{dV_{xijt}(t)}{dt} = -\frac{1}{R_x} V_{xijt}(t)$$

$$+ \sum_{C(k,l) \in N_r(i,j)} A(i,j;k,l) V_{ykl}(t)$$

$$+ \sum_{C(k,l) \in N_r(i,j)} A^T(i,j;k,l) V_{ykl}(t - \tau) \qquad (7)$$

$$+ \sum_{C(k,l) \in N,(i,j)} B(i,j;k,l) V_{ukl}(t) + I,$$

by output equations:

$$V_{yijt}(t) = \frac{1}{2}\left(|V_{xij}(t)+1| - |V_{xij}(t) - 1|\right) \quad (8)$$

and input equation:

$$V_{uij} = E_{ij}, = const \quad (9)$$

$N,(i,j)$ represents the neighborhood of order r of the cell $C(i,j)$. For delay cellular neural network, the space-invariance property is expressed by

$A(i,j;k,l) = A(i - k, j - l)$

$B(i,j;k,l) = A(i - k, j - l)$ (10)

$A^T(i,j;k,l) = A^T(i - k, j - l)$ (11)

State equation (7), by ordering the cells and assuming $R_x = C = 1$, then can be rewritten in a more compact form:

$$\frac{dx(t)}{dt} = -x(t) + A_0 y(t) + A_1 y(t-\tau) + Bu + I \quad (12)$$

The Equation (12) can be rewritten in discrete form as,

$$x(n+1) = - x(n) + A_0 y(n) + A_1 y(n-\tau) + Bu + I \quad (13)$$

As we see in the state Equation (13) of delay cellular neural network, delay parameter τ adds an extra $A_1 y(n-\tau)$ (in discrete form) operand to the ordinary cellular neural networks state equation. A_0 and A_1 can be easily calculated from the cloning templates and delay cloning template. $y(n-\tau)$ can also be calculated easily by using output equation with previous state of delay cellular neural network. In our Java application, we managed this using following:program.

```
...
c = getBU_Plus_I(getConvSum(pu,B), z); // B*U + I
for (int i = 0; i <= 10; i++) {
    n=i+1;
    x = AY_Plus_TY_Plus_C(getConvSum(y,A), getConvSum(y_d,T),c);
     if (i >= to)  y_d = new_Y(xx[MOD(i-to,to)]);
     setXX (x,xx, MOD(i,to));
     y = new_Y(x);}
```

The program output is shown in Figure 3.

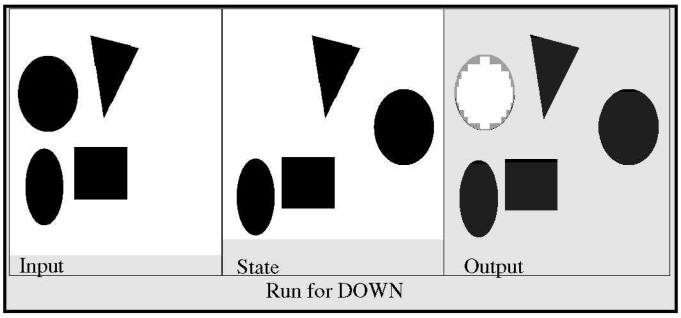


Figure 3. Delay CNN output of a synthetic example.

In the output pane we see the circle which is a moving object was detected by drawing the edge of itself after some iteration.

Conclusion:

In this paper, we try to explain a cellular neural network with delay for a synthetic example. If the signals exchanged among cells are delayed, the network is called delay cellular neural network, then state and response can exhibit oscillations. In our example, we show how we can use delay cellular neural network by modifying ordinary cellular neural network and model delay cellular neural network with a Java programming language.

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