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Template Learning of CNN Using Neural Networks

Masashi NAKAGAWA Takashi INOUE Yoshifumi NISHIO
(Tokushima University)

1. Introduction

Cellular Neural Networks (CNN) were introduced by Chua and Yang in 1988. The idea of the CNN was inspired from the architecture of the cellular automata and the neural networks. There is a parameter called a template in CNN. If the template changes, an output changes. Although the template is very important in CNN, it is difficult to find out a suitable template for a given task. Then, it is the purpose of this study to make a suitable template by learning of neural networks (NN) with an input image and an ideal image (teacher image).

2. CNN and NN

The basic circuit unit of CNN is called a cell. It contains linear and nonlinear circuit elements. The CNN is an array of cells. Each cell is connected to neighboring cells. The state and the output equations of the cell are shown as follows.

State equation:

$$\frac{dv_{xij}(t)}{dt} = -v_{xij}(t) + \sum_{k=i-r}^{i+r}\sum_{k=j-r}^{j+r} A_{(i,j;k,l)}v_{ykl}(t) + \sum_{k=i-r}^{i+r}\sum_{k=j-r}^{j+r} B_{(i,j;k,l)}v_{ukl}(t) + I \qquad (1)$$

Output equation:

$$v_{yij}(t) = \frac{1}{2}(|v_{xij}+1| - |v_{xij}-1|) \qquad (2)$$

where v_x, v_y and v_u represent a state, an output and an input of cell, respectively. In (1), A is the feedback template and B is the control template, these and bias I are collectively called template.

Neural network is a mathematical model which imitates human brain function. The NN in this study is a hierarchical type which consists of three layers of an input layer, a hidden layer, and an output layer. The elements called weight are between the layers, and these are greatly concerned with a result. The back propagation algorithm can decide suitable weight values for a given task by using some input signals and their ideal output signals (teacher signals).

3. Template learning

In this study, we use the back propagation algorithm of NN to obtain a suitable template of CNN for a given task. As the first step, the simplest task which reverses black and white of one-dimensional binary input images is considered.

The simulations are carried out according to the following procedure.

Step 1. One example of one-dimensional binary image (input image) and its reversed image (teacher image) are prepared.

Step 2. The input image is processed by CNN using a template decided at random.

Step 3. The back propagation algorithm is applied to obtain more suitable CNN template using the difference between the obtained output image and the teacher image.

Step 4. The back propagation is repeated until the error between the output and the teacher becomes small enough.

4. Learing result

An input image and its reversed image (teacher image) are shown in Figs. 1 and 2, respectively. The black pixels correspond to the value +1 and the white pixels correspond to the value −1.

Figure 1: Input image

Figure 2: Teacher image

The learning curve is shown in Fig. 3. The horizontal axis shows the number of learning and the vertical axis shows the error. The result shows that the error between the output image and the teacher image is approaching zero.

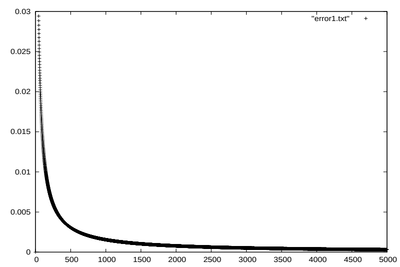

Figure 3: Learning curve

An example of the obtained templates after the learning is given as follows.

$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0.449175 & 0.569888 & 0.779094 \\ 0 & 0 & 0 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & 0 & 0 \\ -1.477137 & -1.810602 & -2.096231 \\ 0 & 0 & 0 \end{bmatrix}$$

$$I = 1.603537 \qquad (3)$$

5. Conclusions

In this study, a template learning method of CNN has been proposed. Computer simulations confirmed the efficiency of the proposed method.

In the future, CNN templates for more complicated tasks should be obtained by the proposed method.