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Sparse Coding for Gray-Scale Image Using Cellular Neural Networks

Taisuke NISHIO Yoshifumi NISHIO
(Tokushima University)

1. Introduction

Cellular neural networks (CNNs) 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. Unlike the conventional neural networks, the CNN has local connectivity property. Since the structure of the CNN resembles the structure of animals' retina, the CNN can be used for various image processing applications.

In this paper, we propose an image coding method using CNNs. The most important feature of this coding is sparsity.

2. CNN Model

A simple CNN model is described as follows.

State Equation:

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

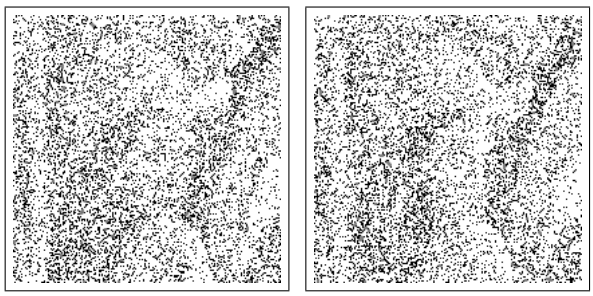
Output Equation:

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

v_x, v_y and v_u represent a state, an output and an input of cell, respectively. $\boldsymbol{A}$ is the feedback template and $\boldsymbol{B}$ is the control template, these and bias I are collectively called cloning template.

3. Encoding

We developed the method to create sparse codes using simple CNN operations.



(1) encoded image. (2) encoded image.

Figure 1: Sparse coding.

4. Decoding

The developed cloning template for decoding and the simulation results are shown. Inputting all codes to CNNs continuously, the original gray-scale image can be decoded.

$$\begin{aligned}\mathbf{A_1} &= \begin{bmatrix}0&0&0\\0&0&0\\0&0&0\end{bmatrix} \\ \mathbf{B_1} &= \begin{bmatrix}0&0&0\\0&1&0\\0&0&0\end{bmatrix} \\ \mathbf{C_1} &= \begin{bmatrix}0&0&0\\0&0&0\\0&0&0\end{bmatrix} \\ \boldsymbol{I_1} &= \mathbf{0} \end{aligned}$$

$$\begin{aligned}\mathbf{A_2} &= \begin{bmatrix}0&0&0\\0&-1&0\\0&0&0\end{bmatrix} \\ \mathbf{B_2} &= \begin{bmatrix}0&0&0\\0&2&0\\0&0&0\end{bmatrix} \\ \mathbf{C_2} &= \begin{bmatrix}0&0&0\\0&1&0\\0&0&0\end{bmatrix} \\ \boldsymbol{I_2} &= \mathbf{-0.987} \end{aligned} \quad (3)$$

(1) original image. (2) decoded image.

Figure 2: Image decoding

This result show that the original image can be successfully restored.

5 Conclusions

In this study, we proposed a sparse image coding method using cellular neural networks. By computer simulations, we confirmed that this algorithm could restore the original image.