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# Progressive Image Transmission by Sigma-Delta Cellular Neural Network having Coupled Cells

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## 1. Introduction

Progressive image transmission technology is widely used in fields such as remote sensing and medicine. Progressive image transmission converts an input image into a sequence of images. During reconstruction, the image sequences are averaged pixel by pixel to progressively recover the intensity of pixel. Progressive image transmission can be classified into two types [1]: hierarchical coding using multiple resolution or discrete wavelet transform (DWT) [2] and bit-plane decomposition (BPM). On the other hand, we proposed progressive image transmission method by sigma-delta cellular neural network (SD-CNN) [3]. This framework utilizes a simple artificial vision system based on the human visual information transfer mechanism. SD-CNN represents the luminance value of each pixel as a pulse density modulated bit stream. [3] enabled lossless or near-lossless progessive image transmission for various test images. In this paper, in order to further improve the transmission efficiency of this method, we introduce coupled cells which enable complex dynamics.

## 2. Proposed Method

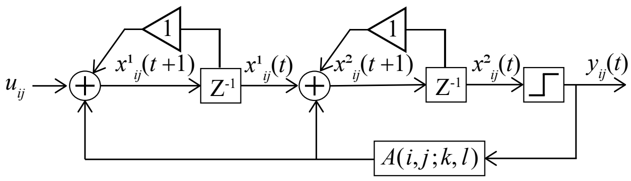


Figure 1: The block diagram of the SD-CNN having coupled cells

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In the proposed method, we design the SD-CNN having coupled cells. The block diagram of a coupled cell of the SD-CNN is illustrated in Fig. 1 The state equations of a coupled cell at the coordinates $(i, j)$ is given by

$$x^1_{ij}(t+1) = x^1_{ij}(t) + \sum_{C(k,l)\in N_r(i,j)} A(i,j;k,l)y_{kl}(t) + u_{ij}, \quad (1)$$

$$x^2_{ij}(t+1) = x^2_{ij}(t) + \sum_{C(k,l)\in N_r(i,j)} A(i,j;k,l)y_{kl}(t) + x^1_{ij}(t+1), \quad (2)$$

$$y_{ij}(t) = f\left(x^2_{ij}(t)\right) = \begin{cases} 1 & x^2_{ij}(t) \geqq 0, \\ -1 & \text{otherwise}, \end{cases} \quad (3)$$

where $x^1_{ij}(t)$,$x^2_{ij}(t)$, $y_{ij}(t)$, $u_{ij}$, $f(\cdot)$ and $A(i,j;k,l)$ are the first layer internal state, the second layer internal state, the output(the second layer), the input of a cell(the first layer), the nonlinear output function and the A-template, respectively. The $r$-neighborhood $N_r(i,j)$ is defined by $N_r(i,j) = \{C(k,l)|\max\{|k-i|,|l-j|\} \leq r\}$. The A-templates is defined by

$$A(i,j;k,l) = -\frac{1}{2\pi\sigma^2}\exp\left(-\frac{(k-i)^2+(l-j)^2}{2\sigma^2}\right), \quad (4)$$

where $\sigma$ follows $2\pi\sigma^2 = 1$.

Next, the binary image sequence obtained by Eq.(3) are weighted and added. Finally, the reconstructed image is obtained by applying a Gaussian filter to the weighted sum of the binary image sequence.

## 3. Experimental Results

To evaluate the effectiveness of the proposed method, we perform image coding and decoding experiments on two standard grayscale images. We compare the proposed method with [3] and the first-order SDM in terms of PSNR for average MSE. The two standard grayscale images used in this experiment are shown in the Fig. 2. The progressive image transmission performance for each iteration is summarized in Table. 1.

Figure 2: Test images

Table 1: PSNR for average MSE of each method[dB]

| method | Iteration | | | | |
|---|---|---|---|---|---|
| | 8 | 46 | 53 | 75 | 228 |
| proposed | 38.70 | $\infty$ | 97.55 | $\infty$ | $\infty$ |
| [3] | 41.81 | 52.62 | 54.43 | 56.87 | $\infty$ |
| SDM | 22.45 | 38.06 | 39.14 | 42.28 | 50.71 |

As shown in Table. 1, [3] recovers two images losslessly in 228 iterations. On the other hand, the proposed method once recovers two images losslessly in 46 iterations, however the performance went up and down from there, and always maintains the images reproducted losslessly after 75 iterations. Comparing the number of iterations to obtain images reproducted losslessly, the proposed method achieves a 67% performance improvement over [3]. For the SDM, the proposed method requires only 8 iterations to obtain the results of 53 iterations of SDM.

## 4. Conclusion

In this paper, a progressive image transmission method by the SD-CNN having coupled cells has been proposed. The experimental results show that the proposed method is able to achieve the images reproducted losslessly in a small number of iterations, however its performance is subject to fluctuations.


## Ackowledgments

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