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# Cellular Neural Networks with Delay Output for Edge Detection

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## 1. Introduction

In this study, we apply Cellular Neural Networks (CNN) with delay output (D-CNN) to image processing (edge detection). The D-CNN does not depend on only the current information, however it processes an image after having considered the past information. In a general way, the D-CNN is applied motion image processing. On the other hand, we applied it to image processing (edge detection). We investigate how the D-CNN influenced image processing. As a result, we can obtain effective results in the image processing using the D-CNN.

## 2. D-CNN

The state and the output equation of the cell are shown as follows. The state equation contains feedback template with time delay. The conventional CNN performs image processing only depending on current information. Though the D-CNN performs image processing depending on not only current but past information.

*State equation* :

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

*Output equation* :

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

Figure 1 shows block diagram of the D-CNN. In the state equation, $A$ is the feedback template, $B$ is the control template, $T$ is the bias and $D$ is delay type feedback template. $D$ template can substitute the value with various characteristics. From the above reason, it can expect various image processing.

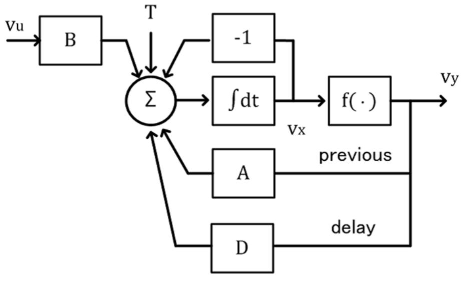


Figure 1: Block diagram of the D-CNN.

## 3. Simulation Result

Figure 2 shows simulation results of edge detection. $D$ template has a characteristic of binary image representing the concentric black and white rings.

*Using template* :

$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \; B = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix},$$

$$D = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 3.5 & -1 \\ 0 & -1 & 0 \end{bmatrix}, \; T = -1. \quad (3)$$

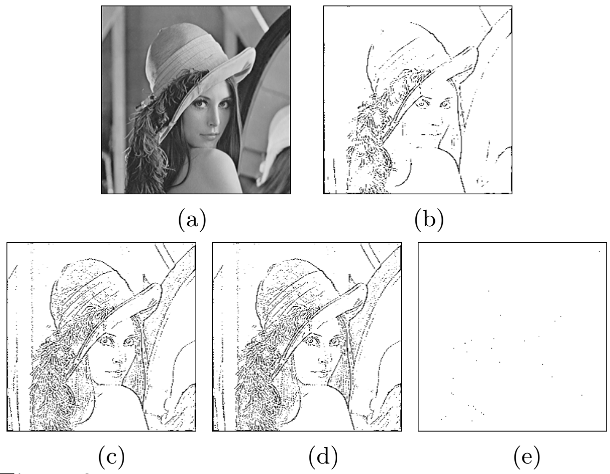


Figure 2: Simulation results. (a) Input image. (b) Simulation result of the conventional CNN. (c) Simulation result of the D-CNN ( $\tau$ = 5). (d) Simulation result of the D-CNN ( $\tau$ = 10). (e) Simulation result of the logical difference in the D-CNN.

Figure 2($a$) shows an input image. In the characteristic of an input image, the boundary of the pillar and background are indistinct. Figure 2($b$) shows the result of the conventional CNN. The conventional CNN can not detect indistinct parts. Figures 2($c$) and ($d$) show results of the D-CNN. In the D-CNN, the boundary of the pillar and background can detect indistinct parts. Moreover we investigate how processing changed when we change delay time. Figure 2($e$) shows logic difference from $\tau$ = 10 to 5. By the Fig. 2($e$), even if delay time change, it detects little differences are visually. The D-CNN can detect indistinct parts of input image in edge detection.

## 4. Conclusions

In this study, we applied the D-CNN to image processing (edge detection). The D-CNN adds a past output value by feedback template. From simulation results, the D-CNN can detect indistinct parts of image. The D-CNN has an effective influence on image processing.