# A Method for Edge Detection in Gray Level Images, based on Cellular Neural Networks

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***Abstract*— Edge detection is an important preprocessing task in artificial vision systems. In this paper the utility of a recently reported CNN template for edge detection was verified over a set of black and white images. These images were obtained applying an threshold procedure to their corresponding associated gray level images. An optimal threshold value for preserving a large number of features from the original gray level input images was used. Combining the threshold and edge detection templates, a procedure to obtain edges on gray level images was implemented.**

**Keywords: cellular neural network, CNN template, edge detection.**

## I. INTRODUCTION

In many artificial vision systems, edge detection is an important task for the preprocessing phase. There are several methods for this task, based on convolution task [1]-[6]. Also methods based in neurofuzzy systems are reported [7],[8].

Cellular neural networks (CNN) are very useful for image processing tasks [9]-[12]. In [13] a CNN template for edge detection in black and white images is reported. In this paper, such template is combined with the threshold template to obtain edges on gray level images. The applicability of the proposed procedure is verified on several types of test images.

## II. THRESHOLD AND EDGE CNN TEMPLATES

### A. *CNN STRUCTURE*

A CNN is a rectangular array of processing cells $C_{ij}$, where $1 \leq i \leq M$, $1 \leq j \leq N$, having a space invariant interconnecting structure [9]-[12]. Real time processing and VLSI implementation are two important features of this network [11].

The dynamics of the cell $C_{ij}$ is characterized by its activation function $x_{ij}(t)$ and its output $y_{ij}(t) = 0.5 * (|x_{ij}+1| - |x_{ij}-1|)$. Another used variable is the input gray level for $C_{ij}$, denoted as $u_{ij}$. The activation $x_{ij}(t)$ is defined by the differential equation

$$\frac{dx_{ij}}{dt} = -x_{ij} + \sum_{kl \in V_r(ij)} A_{kl} y_{kl} + \sum_{kl \in V_r(ij)} B_{kl} u_{kl} + z \quad (1)$$

where

$$V_r(ij) = \{C_{kl}/max(|k-i|, |l-j|) \leq r, 1 \leq k, l \leq N\}$$

is the neighborhood of radius $r$ for the cell $C_{ij}$. A neighborhood of radius $r=1$ has associated 9 cells. The $A_{mn}$ and $B_{mn}$ values define the $3 \times 3$ feedback and control matrixes A and B [9]-[12]. So, a total of $2 \times 9 + 1 = 19$ parameters are necessary to define the dynamics of the CNN using neighborhoods of radius $r = 1$. Many applications have been implemented in the cellular neural networks [14].

The set $T = \{A, B, z\}$ is named cloning template [9]-[12]. The design of a cloning template for an image processing function is a nontrival task. There are several procedures for template design [13],[15]-[19] and template libraries for image processing tasks are available [11]-[13]. In this paper, the threshold and edge detection templates are used.

### B. *THRESHOLD TEMPLATE*

When $A_{kl} = 0$ for all the cells at $V_r(ij)$, except for $(k,l) = (i,j)$, an autonomous CNN is obtained. The activation value $x_{ij}$ does not depends of the activation values over neighbor cells. The threshold task fixs to 1 all the input pixels with gray levels larger than an threshold value $U$, and fixs to $-1$ all the input pixels with gray levels smaller than $U$. The threshold template can be obtained fixing the matrix $B$ to 0 [11],[12]. Then, the CNN dynamics for the threshold task is defined by the equation

$$\frac{dx_{ij}(t)}{dt} = -x_{ij}(t) + A_{ij} y_{ij}(t) + z \quad (2)$$

If the initial activation $x_{ij}(t)$ is contained in the interval [-1,1], then $y_{ij}(t) = x_{ij}(t)$, so the activation function is obtained from the equation

$$\frac{dx_{ij}(t)}{dt} + (1 - A_{ij}) x_{ij}(t) = z$$

of which the solution is

$$x_{ij}(t) = Ce^{(A_{ij}-1)t} + \frac{z}{1 - A_{ij}}$$

where

$$C = x_{ij}(0) - \frac{z}{1 - A_{ij}}$$

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Frequently, the case $A_{ij} = a > 1$ is supposed. The exponential term in the solution $x_{ij}(t)$ tends to $\infty$ when $C > 0$ and to $-\infty$ if $C < 0$. So, if $x_{ij}(0) > z/(1 - A_{ij})$ then $C > 0$ and $x_{ij}$ tends to $\infty$ and $y_{ij}(t)$ tends to 1. In other way, if $x_{ij}(0) < z/(1 - A_{ij})$ then $C < 0$ and $x_{ij}(t)$ tends to $-\infty$, so $y_{ij}(t)$ tends to $-1$. The above arguments indicate that

$$U = \frac{z}{1 - A_{ij}}$$

is an threshold value for the initial activation values. The cells with initial activation $x_{ij}(0) < U$ have negative output, meanwhile the others have positive output. If $A_{ij} > 1$, the U value is negative if $z > 0$, and positive on the contrary case. The above arguments indicate that the threshold template has the form

$$A = \begin{pmatrix} 0 & 0 & 0 \\ 0 & a & 0 \\ 0 & 0 & 0 \end{pmatrix} ; B = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} ; z = z_0$$

where $a > 1$ and $z_0 \in \Re$. $z_0 > 0$ sets a negative threshold $U$, meanwhile $z_0 < 0$ sets a positive threshold $U$.

### C. EDGE DETECTION TEMPLATE

Some edge templates have been reported [11]-[13]. In this paper the template reported in [13], given by

$$A = \begin{pmatrix} -0.29 & 0.06 & -1.10 \\ 0.06 & 9.72 & -1.38 \\ -1.10 & -1.38 & -0.46 \end{pmatrix} ;$$

$$B = \begin{pmatrix} 0.41 & -1.57 & 0.48 \\ -1.57 & 6.84 & -1.07 \\ 0.48 & -1.07 & -0.15 \end{pmatrix} ; z = -4.98$$

is used to detect black and white image edges. The matrixes used in this template are symmetric, so the convergence is guaranteed [11].

## III. PROPOSED PROCEDURE FOR EDGE DETECTION

When the threshold and edge templates are combined, a procedure to detect edges in gray level images is obtained. The proposed procedure is the following:

***a)****Transform linearly the input gray level image I such that their gray levels are contained in the interval* $[-1, 1]$.

***b)****Determine the optimal threshold value* $U$ *for the input gray level image* $I$*. This value is such that the largest number of features is retained when the threshold procedure is applied. The default value may be fixed as* $U = 0$.

***c)****Apply the threshold template to the input gray level image* $I$ *for obtaining the binary output* $I_c$.

***d)****Apply the edge extraction procedure to the image* $I_c$*, obtaining the output edge image* $O$.

The threshold value determines directly the quality of the resultant output edge image, because the edge detection is done on the processed image $I_c$. A larger number of preserved original features produces a better edge image.

## IV. EXPERIMENTAL RESULTS

In this section some results are shown. The dimensions of the test images 1a)-4a) and the used threshold parameters are shown in table I. In all the cases, a temporal step having a value 0.2 was used. The threshold values were fixed empirically, searching the preservation of the largest number of features.

The image 1b) was obtained applying the threshold task to the Lena image shown in Fig 1a). The final image, obtained applying the algorithm, is shown in Fig 1c). A detailed inspection of Fig. 1c) reveals that the edge template detects the white pixels sourranding the black areas.

*TABLE I. DIMENSION AND THRESHOLD VALUES USED FOR FIGS. 1-4*

| Fig. | Dimension | threshold value |
|---|---|---|
| 1 | 512 × 512 | 0.5 |
| 2 | 512 × 512 | -.58 |
| 3 | 256 × 256 | .057 |
| 4 | 512 × 512 | .117 |

The results corresponding to Figs. 2a), 3a) and 4a) are interpreted in a similar way. Fig. 2a) contains a blonde women with very shine pixels. Fig. 2c) shows that an acceptable output is obtained. Fig. 3 shows the importance of using an optimal value for the threshold value. When the threshold task is applied to Fig 3a), some details are lost in the resulting figure 3b), and it is reflected in the output edge image 3c).

Fig 4a) is very complex because there are areas with a large number of details and fractal structure. The sea water has very abrupt shine variations. The algorithm detects these fractal zones generating sets of points as is shown in the output image 4c).



MATLAB code is avaliable in matlab1.com

In all the above cases, the large boundaries of the features are detected by the algorithm, but it is observed that a deficient election of the threshold value produces the loss of some features.

## V. CONCLUSIONS

In this paper a procedure for edge detection at gray level images has been described. The structure for the threshold template has been reviewed. The correct performance of a recently reported edge detection template has been verified using some black and white images produced with the threshold operation. The threshold and edge detection templates were combined into a procedure to obtain edge detection of gray level images. The proposed procedure is fast and simple, and the experimental results are acceptable for a broad class of images, whenever a convenient threshold value is finded. Future reseach includes the automatic setting of the optimal threshold value as function of the input gray level image.

## V. ACKNOWLEDGEMENTS

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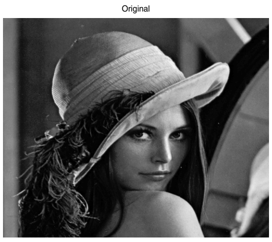


Fig. 1a). Lena


Fig. 1b). Lena after threshold process

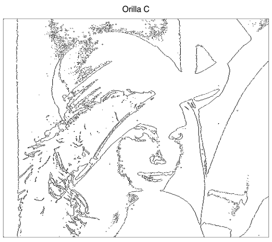


Fig. 1c). Edge detection for Lena.

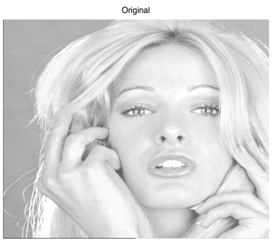


Fig. 2a). Blonde woman.

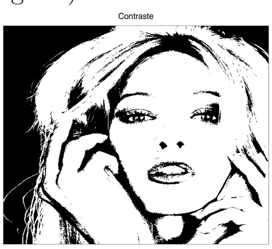


Fig. 2b). Blonde woman after threshold process.

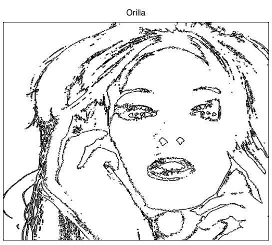


Fig. 2c). Edges for blonde woman.


Fig. 3a). Peppers


Fig. 3b). Peppers after threshold operation

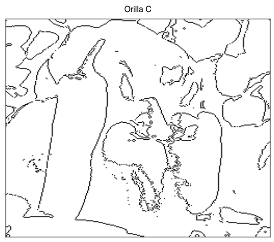


Fig. 3c). Edges for peppers

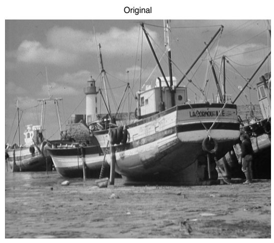


Fig. 4a). Boats


Fig. 4b). Boats after threshold operation

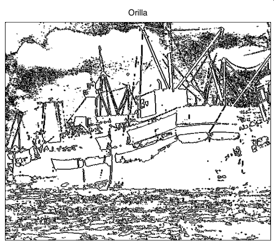


Fig. 4c). Edges for boats