A CNN-based Edge Detection Algorithm for Remote Sensing Image

Guo-bao Xu [1, 2], Gui-yan Zhao[1], Lu yin[2], Yi-xin Yin[2], Yu-li Shen[3]

1. Information School, Guangdong Ocean University, Zhanjiang 524088, China
E-mail: xuguobao@126.com

2. School of information Engineering, University of Science & Technology Beijing, Beijing 100083
E-mail: yyx_ustb@126.com

3. ZhongKai University of Agriculture and Technology, Guangzhou 510225, China
E-mail: syl8899@21cn.com

Abstract: With the development and applications of satellite remote sensing technology, the edge detection accuracy of remote sensing image is increasingly high. As the gray remote sensing image has a lot of noise, even image brightness, and vague edge, a novel edge detection algorithm based on cellular neural network (CNN) is presented. In the algorithm, image filtering, gray threshold segmentation, dilation and erosion, and edge detection using CNN are performed for remote sensing image successively. The experimental results show that, compared to the traditional edge detection algorithms of Sobel operator and Canny operator, the proposed edge detection algorithm can not only effectively eliminate the influence of the noise on edge detection, but also quickly detect the complete image edge.

Key Words: Remote Sensing Image, Edge Detection, Cellular Neural Networks, Template

1 INTRODUCTION

Recently, the remote sensing technology is gradually applied to weather, geology, disaster prediction, urban planning, etc., and experts and scholars pay more and more attention to the analysis and processing of remote sensing image [1-3]. The edge detection of remote sensing image is very important for image analysis, and is a major characteristic in image recognition. Remote sensing image has many characteristics such as: 1) small-scale and even image brightness, 2) more breakpoint and larger losses for major image edge, 3) complex figure texture and more sub-edge interference, and 4) a lot of noise. Therefore, it is difficult to obtain satisfactory results using the Sobel operator and Roberts operator, which can achieve better edge detection effect for general images, to detect the edge of remote sensing images which contain a large number of complex noise. For this reason, some experts and scholars have presented a lot of edge detection algorithms. For example, Xue Lixia [4] proposed an edge detection method of fuzzy remote sensing images based on the object-clouds. Niedermeie [1] extracted remote sensing images edge using wavelet transform methods if the image intensity is greater than a certain threshold, and proposed Block Tracing algorithm to determine the location of the Coastal Zone. Ju Cunyong [5] presented an automatic segmentation algorithm of remote sensing images based on mathematical morphology. Dellepiane [6] achieved the coastline detection and extraction with the fuzzy connection method.

In the above-mentioned algorithms, there are two flaws. First, edge detection is incomplete. Due to the presence of a large number of noise in remote sensing images, it is necessary to filter the noise in order to accurately detect the image edge. At the same time, filtering noise will inevitably weaken the edge information, consequently edge detection is incomplete. Second, some algorithms are more complex, which are difficult to achieve timely edge detection.

By taking advantage of parallel processing image capabilities of cellular neural network, and combining with good denoising capacity of mathematical morphology, a novel edge detection algorithm using cellular neural networks is proposed for remote sensing images.

The rest of this paper is organized as following. In section 2, we introduce the theory of cellular neural networks. An edge detection algorithm based on CNN is discussed in section 3. In section 4, the experimental results of edge detection are given to demonstrate the effectiveness of the proposed algorithm. The conclusions are drawn in the last section.

2 CELLULAR NEURAL NETWORKS

The cellular neural network (CNN), first introduced by Prof. Chua and Dr. Lin Yang at the University of California, is a locally connected parallel information processing system [7]. The CNN can solve real-time problems of image processing, in that it has high-speed parallel processing capability [8].

A standard CNN architecture consists of an $M \times N$ rectangular array of cells with Cartesian coordinate (i, j), $i=1,2,\ldots,M$, $j=1,2,\ldots,N$(see Fig.1).

Definition 1: Given positive integers r, k and l, when $r \geq 0$, $1 \leq k \leq n$ and $1 \leq l \leq m$, the sphere of influence, $N_r(i, j)$, of a radius r of cell $c(i, j)$ is defined as the set of all the neighborhood cells satisfying the following conditions [5]

This work is supported by Guangdong Nature Science Foundation under Grant 7010116

$$N_r(i,j)=\{c_{kl}\,\big|\max(|k-i|,|l-j|)\le r\} \qquad (1)$$

Where i and j are coordinates of the centre cell c_{ij} in the network.

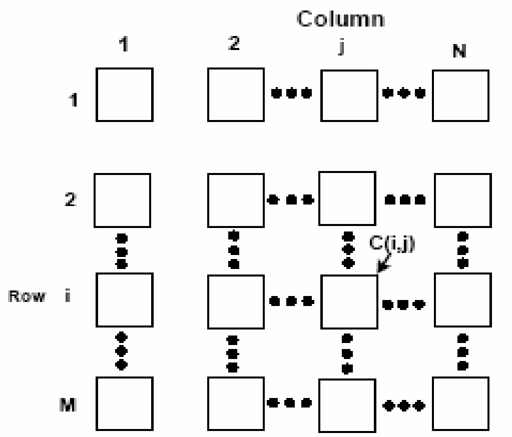


Fig.1 normal CNN diagram

From the equation (1), we can conclude that the neighborhood of cells has symmetry. That is, if $c(i,j) \in N_r(k,l)$, then at the same time $c(k,l) \in N_r(i,j)$. Generally, r is set as 1.

According to the equivalent circuit model of cells, each cell has a state, a constant external input and an output. Therefore, each cell $c(i,j)$ can be described by the following dynamic equations:

(1) Standard state equation

$$C\frac{dV_{xij}(t)}{dt}=-\frac{1}{R_x}V_{xij}(t)+\sum_{C(k,l)\in N_r(i,j)}A(i,j;k,l)V_{ykl}(t)$$
$$+\sum_{C(k,l)\in N_r(i,j)}B(i,j;k,l)V_{ukl}(t)+z \qquad (2)$$

Where $i=1,2,\cdots,M;\ j=1,2,\cdots,N$.

(2) Output equation

$$y_{ij}=f(x_{ij})=\frac{1}{2}(|V_{xij}(t)+1|-|V_{xij}(t)-1|) \qquad (3)$$

Where $i=1,2,\cdots,M;\ j=1,2,\cdots,N$.

In the equation (2), $V_{xij}(t)$, $V_{ykl}(t)$, $V_{ukl}(t)$, z are called state, output, input, threshold of cell $c(i,j)$, respectively. $A_{ij,kl}$ and $B_{ij,kl}$ are called the feedback and control templates, where $|x_{ij}(0)|\le 1, |u_{ij}|\le 1$. The equation (3) means the relationship between the state and output, which is a non-linear sub-function, as shown in Figure 2.

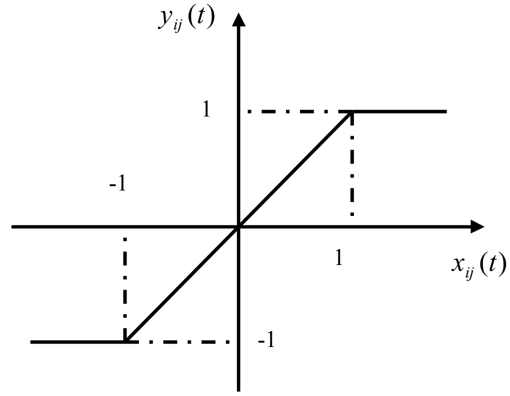


Fig.2 CNN output

The following two pretreatments are generally experienced using the CNN to process gray images.

(1) Change differential equation (2) to difference equation

$$V_{xij}(n+1)=\sum_{C(k,l)\in N_r(i,j)}A(i,j;k,l)V_{ykl}(n)+\sum_{C(k,l)\in N_r(i,j)}B(i,j;k,l)V_{ukl}(n)+z \qquad (4)$$

Where $C=R_x=1$.

(2) The adjustment of pixel scope: the input and initial state values of CNN are from -1 to +1. -1 shows that pixel gray value is white, and +1 is black. In the computer, the image gray values are expressed from 0 to 255. Where 0 is black, and 255 is white. Therefore, when the input of CNN is the image gray value, a mapping is needed to transform a gray value from the interval [0,255] to interval [-1, +1].

3 EDGE DETECTION ALGORITHM BASED ON CNN FOR REMOTE SENSING IMAGE

The CNN's size is same as the scale of images to be processed. If the images to be processed include $M\times N$ pixels, the $M\times N$ neuronal cells are required for CNN. Each pixel is a nice match for each cell. The state of each neuron is changed in accordance with equation (2) iteration until the entire network is converged [9]. And image processing is completed.

From the state equation (2), we can see that CNN dynamic mechanism includes input control and output feedback. The effect of the input control depends on template B, and the effect of the output feedback depends on template A. Hence, using CNN to process image, the key is how to find a suitable template.

As the gray remote sensing images have the features of much noise, even image brightness, and vague edge, a series of image preprocessing is experienced for remote sensing images before edge detection.

The proposed algorithm uses the templates of convexity, threshold, erosion and dilation, and edge detection to realize the following operations of image filtering, gray image binarization, padding of cavity and edge detection, respectively.

1）Image filtering

As remote sensing image contains a lot of noise, filtering noise is a fundamental step for edge detection, which directly determines the performance of edge detection. In this paper, the noise of remote sensing image is removed using the CNN's convexity resume template. Convexity resume templates are as follows:

$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad B = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad Z = 0 \qquad (5)$$

2) Gray image binarization

Generally, the gray value of objective and background is similar in image processing. Therefore, we can use the threshold segmentation to turn the gray-scale remote sensing images into binary images in order to better detect the image edge. The CNN template of gray threshold segmentation has the form of

$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad B = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad Z = z^* \qquad (6)$$

The value of threshold z^* affects directly the performance of segmentation [10].

3) Dilation and erosion

Inevitably, there is some unnecessary isolation points and cavity produced during generation of the binary images with the gray threshold. We can use dilation and erosion operations to remove isolation points better, and to fill cavity, which prepares for the next edge detection.

4) Edge detection

Edge detection operation is carried for remote sensing images after above convex filter, threshold segmentation, and operations of dilation and erosion.

The templates of edge detection are:

$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad B = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix} \quad Z = -1 \qquad (7)$$

Through above several operations, the edges of remote sensing images are better detected finally.

4 EXPERIMENTAL RESULTS AND DISCUSSION

The experiments of edge detection were carried for different scenes of remote sensing images to demonstrate the effectiveness of the proposed algorithm. As the laboratory equipment is limited, experimental platform is Aladdin V1.3 visual mouse platform, a cellular neural network simulation system, by analogic computers Ltd.

The proposed algorithm is compared with the traditional methods to better illustrate the effectiveness of the algorithm. We use canny operator and sobel operator to detect the edges of three different remote sensing images on matlab6.5, respectively. The experimental results are shown in Fig.3, Fig.4 and Fig.5.

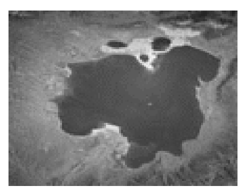
a. gray image with noise

b. canny operator

c. sobel operator

d. CNN algorithm

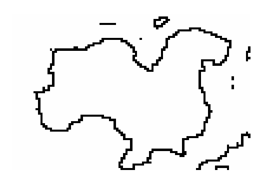
Fig.3 plane edge detection



a. remote sensing image

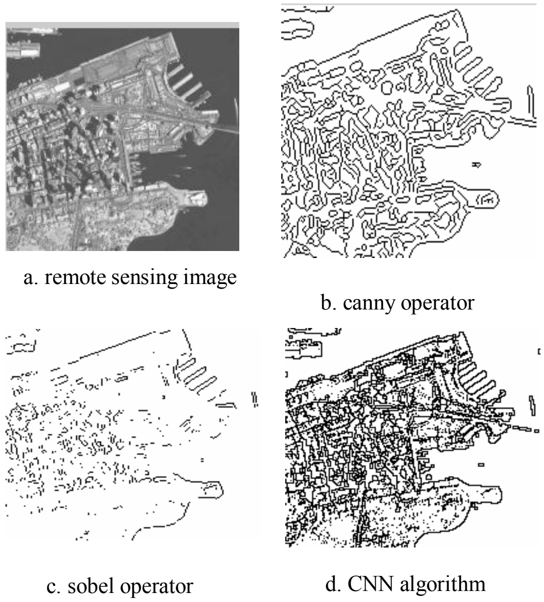
b. canny operator

c. sobel operator



d. CNN algorithm

Fig.4 lake edge detection



a. remote sensing image

b. canny operator

c. sobel operator

d. CNN algorithm

Fig.5 harbor edge detection

From Fig.3 to Fig.5, we can see that Fig.b is the detection edges with the traditional canny operator. The major problem is over-detection with the canny operator, and some edge of background information is also extracted (Fig.4.b). Fig.c is the detection edges with sobel operator. Although the algorithm does not exist over-detection, the extraction edge is poor continuity and integrity, and there are still some edges not to be detected. (Fig.5.c). Fig.d is the detection edges with the CNN algorithm. The experimental results show that the integrity and continuity of extraction edge are relatively well.

The results of edge detection illustrate that the proposed algorithm can better eliminate noise, overcome even brightness and the vague edge, and detect the edges of remote sensing images quickly and completely.

In addition, compared with the traditional methods, the prominent advantage of CNN algorithm is the parallel image processing capability, and the speed of image processing has nothing to do with image size, but only hardware speed of CNN-UM. Therefore, it has great potential in real-time image processing.

5 CONCLUSIONS

As the remote sensing image has many characteristics such as much noise, even brightness and vague edge, the general algorithms of edge detection (such as Canny operator and Sobel operator) are difficult to achieve the edge detection of remote sensing image. Therefore, an edge detection algorithm is presented using cellular neural network for remote sensing image. The experimental results show that: compared with the classic algorithms of edge detection, the proposed algorithm has strong robustness. It not only effectively overcomes the noise impact on edge detection, but also detects the complete edge of the remote sensing image quickly and completely. This algorithm may help pave the way to the recognition and analysis of the remote sensing image.

REFERENCES

[1]. A Niedermeie, E Romancessen, S Lehner, Detection of coastlines in SAR images using wavelet methods, IEEE Transactions on Geoscience and Remote Sensing, vol.38, 2270-2281, 2000.

[2]. O Germain, P Refregier, Edge location in SAR images performance of the likelihood ratio filter and accuracy improvement with an active contour approach, IEEE Transactions on image processing, vol.10, 72-78, 2001.

[3]. Li Bo, Jiao Runhai, Li Yuancheng, Fast adaptive wavelet for remote sensing image compression, Journal of Computer Science and Technology, vol.22, 770-778, 2007.

[4]. Xue Lixia, Wang Linlin, Li Yongshu, A New Edge Detection Method of Remote Sensing Image, Computer Science, vol.34, .235-237, 2007.

[5]. Ju Cunyong, Cai Tijiu, Feng Zhongke, Automatic segmentation of high-resolution remote sensing image based on mathematical morphology, Journal of Beijing Forestry University, vol.27, 84-87, 2005.

[6]. S Dellepiane, R De Laurentiis, F Giordano, Coastline extraction from SAR images and a method for the evaluation of the coastline precision, Pattern Recognition Letters, vol.25, 1461-1470, 2004.

[7]. Chua L O, Yang L, Cellular neural network: theory and applications, IEEE Trans on Circuit and System, CAS, Vol.35, No.10, 1257-1290, 1988.

[8]. Kananen A, Paasio A, Laiho M, CNN applications from the hardware point of view: Video sequence segmentation, International Journal of Circuit Theory and Applications, Vol.30, 117-137, 2002.

[9]. Zhang Hongyue, Qian Fang, Guo Hongtao, Edge detection of binary images and gray-scale images using cellular neural networks, Journal of Image and Graphics, Vol.6(A), No.10, .974-978, 2001

[10]. Xu Guobao, Yin Yixin, Yin Lu, Hao Yanshuang, Wang Zhenyu, Visual Information Processing Using Cellular Neural Networks for Mobile Robot, Proceedings of 2007 IEEE International Conference on Grey Systems and Intelligent Services, Nov.2007, 1046-1050