Analysis B-scan Image by CNN and Polyfit*

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Abstract *In this paper, we have be processed ultrasound with Cell Neural Network(CNN). First we detected the edge from B-Scan images, and then we analysis the data that from the edge of image. Some interesting result has been finding. There are some regular between the number and the patient's B-scan image.*

Keywords *B-Scan image Edge detection Liver damages 10-degree polynomials fitting*

1. Introduction

In the last two decades, medical image processing technology has been developed rapidly. It can help doctor to diagnose patients' disease more accurately. Medical image processing with computer has attracted much attention recently [1]. A lot of methods for dealing with medical images have appeared [2],[3].

In Chua's articles (see [4] or [5]), many important and interesting CNNs are described. One of them is the edge detection CNN, which can detect the edge in gray-scale images. In a recent conference paper, a robustness theorem for designing edge detection CNNs is set up [6][7][8].

Detecting edges of gray-scale images may be required for a variety of purposes, such as machine vision, image analysis, and image pick-up and so on. Edge detection is one of the most important steps for image recognition since there is a direct relationship between edge and object recognition. A lot of scene information can be interpreted from the edges. In natural images, most edges are associated with abrupt changes in intensity distribution and can be approximately modelled as step edges.

Pathological changes of chronic Hepatitis patient include liver fibrosis, heterotrichosis and liver cancer, etc; however, the three states of liver disease are difficult to distinguish from B-scan image by naked eyes. Digital analysis of the B-scan images will help doctors to diagnose the stage of the damages of patients' livers.

2. Edge Detection CNN

In a Chua's exposition [1], many important and interesting CNNs are described. One of them is Edgegray CNN, which can detect the edges in gray-scale images. The template of the standard Edge gray CNN has the form。

The standard M×N CNN architecture is composed of cells $c_{i,j}$. The dynamics of each cell is given via the following equation [1]:

$$\dot{x}_{i,j} = -x_{i,j} + \sum_{k=-r}^{r} \sum_{k=-r}^{r} a_{k,l} y_{i+k,j+l} + \sum_{k=-r}^{r} \sum_{k=-r}^{r} b_{k,l} u_{i+k,j+l} + z_{i,j} \quad (1)$$

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$$\dot{y}_{i+k,j+l} = \frac{1}{2}\left(\left|x_{i+k,j+l}+1\right| - \left|x_{i+k,j+l}-1\right|\right)$$
$$(i+k, j+l) \in [1, M] \times [1, N] \tag{2}$$
$$i = 1,2,\cdots M; J = 1,2,\cdots N$$

Where $x_{i,j}, y_{i,j}, u_{i,j}, z_{i,j}$ represent state, output, input, and threshold respectively; $a_{k,l}, b_{k.l}$ are the elements of the A-template and the B-template respectively.

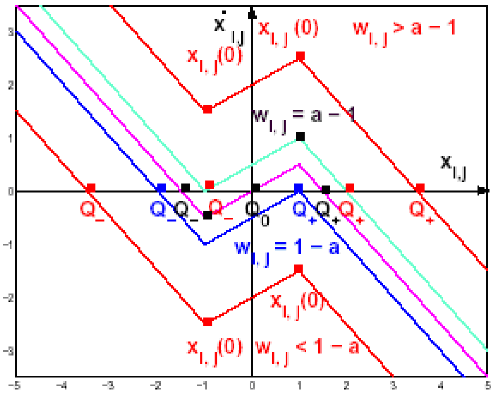


Figure 1 The dynamic routes of the CNN

The standard edge CNN's local rules and template are listed as follows:

Local Ruler

$u_{i,j} \rightarrow y_{i,j}(\infty)$

(1) white → white, independent of neighbours.

(2) black → white, if all nearest neighbours are black.

(3) black →black, if at least one nearest neighbours is white.

(4) grey →black, if the Laplacian operator $\nabla^2 U_{i,j} > z$.

(5) grey →white, if the Laplacian operator $\nabla^2 U_{i,j} < z$.

(6) grey →0, if the Laplacian operator $\nabla^2 U_{i,j} = 0$.

The standard CNN template has been generalized by the following theorem.

Theorem 1[6]: Let the positions of CNN template parameters be described by (3).Then the CNN can perform the Local Ruler of the detection of edges in gray-scale images, if the following parameter inequalities hold:

$$1.\ \left|z - 8c\right| < z \qquad 2.\ z < b - 6c$$

$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0 & a & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad B = \begin{bmatrix} -c & -c & -c \\ -c & b & -c \\ -c & -c & -c_{1,1} \end{bmatrix} \qquad z = -z \tag{3}$$

Where a > 1, $b > 1, c > 1$

$$\nabla^2 U_{i,j} \underline{\underline{\Delta}} b u_{i,j} - c \sum_{(k,l)\neq(0,0)} \sum_{(k,l)\in\{-1,0,1\}} u_{i+k,j+l}$$

Where：

$$b_{k,l}(\Delta u_{i,j}) = \begin{cases} c & if \left|\Delta u_{i,j}\right| > \mathrm{g} \\ -1 & otherwise \end{cases} \tag{4}$$

3. Segmentation of the B Scan Image

Figures 3 show the ultrasound B-scan images (UBSIs) of six people's livers. Each original UBSI is an RGB image with 720×576 pixels.

We chose the same eath part in the ultrasound B-scan images as that shown in Fig.2, which is on the left of the cholecyst and up of the portal vein. Expert doctors analyze this region when they diagnose sufferer according to B-scan image. So we cut this region and then processed it with edge gray detected CNN.

Clinical diagnoses for the six UBSIs are listed as follows. Figure 3(1) is obtained from a healthy hepatitis B virus (HBV) carrier. Figure 3(2) is the UBSI of a normal liver without HBV infection. The UBSI of a young (under 20 years old) chronic hepatitis B patient without liver cirrhosis is shown in Figure 3 (3) and that of an old one (over 50 years old) is given in Figure 3 (4). Figure 3 (5) and Figure 3 (6) are the UBSIs of a patient with ascites and a patient with marked liver cirrhosis, respectively.

4. Application of the Edge Detection CNN

In this section, we shall use edge detection CNN to process the part of B-scan image. The template parameters of the CNNs are given in Table 1.

Table 1 Template parameters of the CD CNN

a	b	c	z	g
4	16	2	0.4	0.4

The edge detection CNN can be used to process RGB images. An RGB image is usually represented by an M×N×3 (for the above UBSIs, M = 576, N = 720) data matrix **P** where M, N stand for the rows and the columns of the pixels in the image, and 3 represents 3 color planes ---red, green and blue, each color plane with 256 levels of intensity denoted as (R, G, B) $=\left(\tilde{P}(:,:,1), \tilde{P}(:,:,2), \tilde{P}(:,:,3),\right)$. Such an image is called an RGB 24-bit map. In order to use CNN to process RGB images, we use a transform

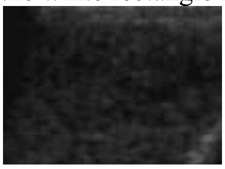
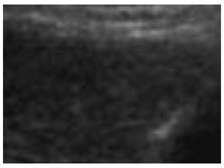
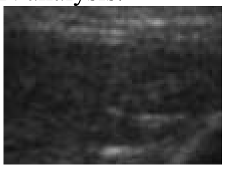
$$P \rightarrow P^{*} \tag{5}$$

To change the 256 levels of intensity of each color plane into the levels of intensity in [-1, 1]. Consequently, the lighten pixels in the original RGB image P correspond to smaller values in the transformed image P^{*} and vice versa. In the following discussions, we always assume that the levels of intensity of input RGB images P_1 and P_2 have been transformed via formula (5); the color planes of processed images have been changed into the RGB forms when the processed images are shown as color pictures.

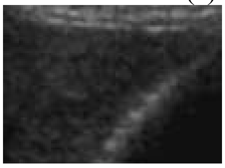
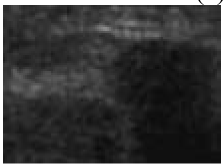
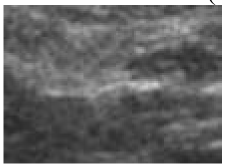
Firstly the edge detection CNN given in Table 1 is used to process the part of the UBSIs shown in Figure 3. The processing results are demonstrated in Figure 4. It is difficult to give a correct judgement for non medical researchers. However, we arrange the pixels of the three color planes P(:,:,1), P(:,:,2), P(:,:,3), of each processed image (the output "$X_{i,j}(\infty)$", not the output "$Y_{i,j}(\infty)$") in row-wise packing scheme [5]. Then wavelet transform is applied to process the images in Figure 4.

Figure 2 The selected part of the B scan image

The part in the white rectangle is chosen for EDGE CNN analysis.

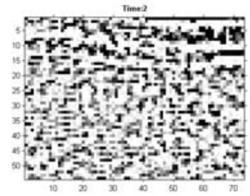
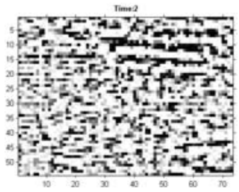
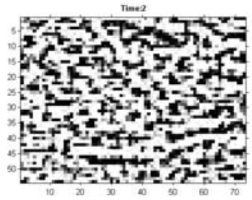
  

Patient liver NO1(a) Patient liver NO2(a) Patient liver NO3(a)

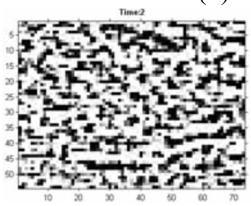
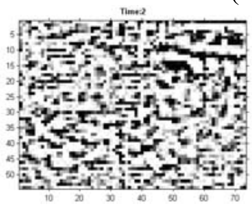
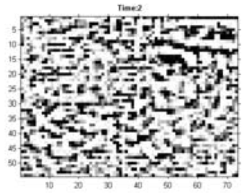
  

Patient liver NO4(a) Patient liver NO5(a) Patient liver NO6(a)

Figure 3 Segmentation of patient liver

Patient liver NO1(b) Patient liver NO2(b) Patient liver NO3(b)

Patient liver NO4(b) Patient liver NO5(b) Patient liver NO6(b)

Figure 4 The result of the B scan image processed by edge detect CNN.

5. Introduction of Polynomial Fitting

Given data (x_i, y_i) (i=0,1,…, m), we shall find a polynomial p(x) such that the error's square sum is the least, i.e. $\sum_{i=0}^{m}[p(x_i)-y_i]^2 = \min$

Suppose that Φ is the set of polynomials of degree $n(n \le m)$. Let $p_n(x)=\sum_{k=0}^{n}a_k x^k \in \Phi$ and

$$I=\sum_{i=0}^{m}\left[p(x_i)-y_i\right]^2=\sum_{i=0}^{m}\left(\sum_{k=0}^{n}a_k x_i^k-y_i\right)^2=\min \tag{6}$$

It is obvious that

$$I=\sum_{i=0}^{m}\left(\sum_{k=0}^{n}a_k x_i^k-y_i\right)^2$$

is a function of $a_0, a_1, \cdots, a_n$, . So the problem is to find the extreme value of $I=I(a_0, a_1, \cdots, a_n)$. By the necessary condition of extreme points, we have:

$$\frac{\partial I}{\partial a_j}=2\sum_{i=0}^{m}\left(\sum_{k=0}^{n}a_k x_i^k-y_i\right)x_i^j=0 \qquad j=0,1,\cdots n \tag{7}$$

i.e.

$$\sum_{k=0}^{n}\left(\sum_{i=0}^{m}x_i^{j+k}\right)a_k=\sum_{i=0}^{m}x_i^j y_i \qquad j=0,1,\cdots n \tag{8}$$

In matrix form, (8) becomes

$$\begin{bmatrix} m+1 & \sum_{i=0}^{m}x_i & \cdots & \sum_{i=0}^{m}x_i^n \\ \sum_{i=0}^{m}x_i & \sum_{i=0}^{m}x_i^2 & \cdots & \sum_{i=0}^{m}x_i^{n+1} \\ \vdots & \vdots & & \vdots \\ \sum_{i=0}^{m}x_i^n & \sum_{i=0}^{m}x_i^{n+1} & \cdots & \sum_{i=0}^{m}x_i^{2n} \end{bmatrix}\begin{bmatrix} a_0 \\ a_1 \\ \vdots \\ a_n \end{bmatrix}=\begin{bmatrix} \sum_{i=0}^{m}y_i \\ \sum_{i=0}^{m}x_i y_i \\ \vdots \\ \sum_{i=0}^{m}x_i^n y_i \end{bmatrix} \tag{9}$$

It is easy to show that the coefficient matrix of (9) is positive definite, therefore (9) has a unique solution. Solving (9), we obtain a_k (k=0, 1,…, n), and thus the polynomial

$$p_n(x)=\sum_{k=0}^{n}a_k x^k \tag{10}$$

It is easy to show that (10) satisfies, i.e. (10) is the fitting polynomial.

Figure 3 and Figure 4 are 6 livers' original B-scan images and resulting images processed by CNN, respectively. Each original B-scan image is an RGB image with 720×576 pixels. In this paper we deal with these B-scan images by EDCNN. Then by polynomial fitting (10-degree), we find that the coefficients of the polynomials are related to the damage of the patients' livers.

6. Concluding Remarks

We have detected 6 B-scan images by CNN. Then using polynomial fitting, we obtain the following data as shown in Table 2. Data of normal liver is No. 1 in Table 2, From 2 to 5 are B-Hepatitis in Table 2.

From the Tables 2, it is easy to see that the value of a1 is closely related to the condition of the liver. Most values of a1 are smaller than 7, and few are smaller than 12.

Therefore, According statistic regular[9], we can conclude that if a1 is larger than 7, the liver is normal; and if a1 is smaller than 7, the liver is CHB. We can use this way to diagnose the CHB.

Table 2 Data of edge B-scan analysis by CNN

	a10 e-47	a9 e-41	a8 e-35	a7 e-29	a6 e-24	a5 e-19	a4 e-13	a3 e-09	a2 e-04	a1 e-00	a0 e+5
1	-2.1535	4.9041	-4.7809	2.6041	-8.6754	18.181	-2.3715	18.313	-7.4913	12.252	1.8006
2	1.1509	-2.2140	1.7396	-0.7036	1.4633	-1.0387	-0.1564	3.6640	-2.5314	5.3752	2.0242
3	-0.3927	0.9139	-0.9437	0.5649	-2.1400	5.2406	-0.8123	7.4907	-3.6249	6.5730	1.9970
4	-0.8249	1.7516	-1.6135	0.8469	-2.7937	5.9910	-0.8262	6.8948	-3.0492	5.1082	2.0678
5	1.3496	-2.4470	1.7724	-0.6260	0.9187	0.6274	-0.4292	6.0397	-3.5273	6.9943	1.9646
6	0.5490	-0.8967	0.5185	-0.7841	-0.4708	2.6723	-0.5914	6.5870	-3.5138	6.6962	1.9830

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