The Digital Tumor Images System Design and its Contour Detection Using an Improved Level Set Algorithm

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Abstract—Because digital diagnostic pathology allows people to acquire, store and analyze pathological information from the images of immunohistochemical glass slides which are scanned to create digital slides, this paper introduced a system design to convert the slides to digital images. And it has become one of the most valuable and convenient advancements in technology over the past years. According to the built system, this paper acquired and analyzed the digital pictures from the slides. This analyzed method introduced OSTU segment and an improved fast level set algorithm to outline the tumor contour. Simulations results show that the image analyze algorithm is effective to segment the tumor from the other parts.

Keywords: Polarized Light, Brain Cancer Detection, Digital Pathology, Level Set

I. INTRODUCTION

Compared with the traditional pathology technology, digital pathology can provide reliability and repeatability. However, pathological using digital platform has been developed slowly and its application has been limited to the education, research and the special clinical practice. So the digital pathology needs to do a lot of preparatory work before it was widely used.

The digitalization of pathology can offer the view and analyze the data and samples from any location in the world[1-3]. The use of this method of "remotepathology" can translate the image data easily through the Internet and reduce the manual labor in the labs. Pathology digitization eliminates the traditional manual microscope or the limitations and shortcomings of pathology, for example, it can adjust the quality of image and acquire as much as possible exposure rate. This also makes the pathological splices easily to storage and retrieval. Further, analysis and process them to extract and diagnosis the related information of the image, research the tumormorphology and detect diseases, evaluate the organization's function and the metabolic stage.

Therefore, this paper proposed the edge extraction method that after the OSTU of twovalued processing, use the fast contour segment algorithm based on the level set, so that the non-normal part of the digital images acquired by brainpathology can be detected rapidly. The algorithm is improved to enhance the convergence speed by the level set algorithm on the irregular pictures and get the earlybrain tumor contour accurately, provide an effectivereferenceto the pathologist staff and doctors.

II. SYSTEM DESIGN

Because of the particularity of the pathological splices, it need translate system to convert them into digital images[4].

As shown in Fig. 1, the system first input the light source, and then through a filter, a polarizer and a phaseretarder, and the beam goes through the sample slide, the other phaseretarder and a polarizer, finally convert the sample splice into digital image by
the camera or other detector. This system can put the pathological sample slides into clear digital images.

![Diagram](Figure 1. System Design)

In the Fig. 1, the light source can be white light or laser, such as 785nm, 830nm, 1050nm. The filter contains colored filters (488nm, 546nm, 610nm, 750nm) and other angles filter; polarizer can be linear or ring; pathological section can be human tissues, lung cancer cells, brain tumor, plastics, selenium film or other substances; monitor often uses CMOS camera or a color camera.

Based on the basic system, the experiment according to the different objects, light sources, filters, polarization’s angle etc., obtain the most satisfactory pictures. This paper obtained the digital images of the pathological splices through the system.

III. THE ALGORITHM PRINCIPLE

A. The Basic Principle of the Distance Level Set Method

In 1987, Osher and Sethian proposed a method called level set which obtained the object contour and boundary by a group of evolution curves [5]. But the disadvantage is this method need re-initialization in slow speed. And in recent years it was used very broadly [6, 7]. Li [8] proposed an evolutionary method which needn’t re-initialize through adopting a internal energy function, a finite difference method and a bigger practice step size to solve the corresponding partial differential equations. That algorithm is called distance level set and improves the evolution speed.

The algorithm assuming the initial contour curve is C which is represented by the following formula

\[
\frac{\partial C(x, t)}{\partial t} = FN
\]  

where \( F \) is the speed function controlling the profile changes, \( N \) is the inside vector function with the same curvature as \( C \); the contour curve \( C \) is shown as a group of the level set function of times, and its internal data is negative and the external data is positive.

Li presented the energy function:

\[
E(\varphi) = \mu P(\varphi) + E_m(\varphi)
\]

In the first part: \( \mu \) is a common values, \( P(\varphi) \) is the internal energy, on behalf of the level set function deviates from the sign function’s distance, as shown in the formula (3):

\[
P(\varphi) = \int_{\Omega} P(\|\nabla \varphi\|) \, dx \, dy \tag{3}
\]

where \( \Omega \) is the image area, \( I(x, y) \) means images. The second part \( E_m(\varphi) \) is the outside energy function which drives the initial level set curve movetoward the goal, when reaching the target position, the value of \( E_m(\varphi) \) is zero:

\[
E_m(\varphi) = \lambda g(\varphi) \tag{4}
\]

among them, \( \lambda > 0 \) and \( \alpha \) is a constant, \( g(\varphi) \) is a function of the suspend speed function, generally, it’s inversely proportional to \( x \), and close to the edge as soon as possible, and also can monitor the weak edge. In [8], the first step is filtered by the Gaussian kernel and get \( s = \nabla G_\sigma * I \), then to obtain the

\[
g(s) = (1 + s^2)^{-1} \tag{5}
\]

\( \delta(x) \) and \( H(x) \) are the one-dimensional Dirac function and Heaviside function, the same as in many literatures:

\[
\delta_\varepsilon(x) = \begin{cases} 
\frac{1}{\pi\varepsilon} [1 + \cos \left(\frac{nx}{\varepsilon}\right)], & |x| \leq \varepsilon \\
0, & |x| \geq \varepsilon
\end{cases} \tag{6}
\]

\[H_\varepsilon(x) = \begin{cases} 
\frac{1}{2} \left( 1 + \frac{1}{\pi} \sin \frac{\pi x}{\varepsilon} \right), & |x| \leq \varepsilon \\
1, & |x| > \varepsilon \\
0, & |x| < -\varepsilon
\end{cases} \tag{7}
\]

Which \( \delta_\varepsilon(x) \) is the difference of \( H_\varepsilon(x) \), i.e. \( H_\varepsilon'(x) = \delta_\varepsilon(x) \); parameter \( \varepsilon = 1.5 \).

B. The Proposed Algorithm

In this paper, after obtained the digital image from the designed system as Fig 1, it needsto identify the lesion part to provide reference to the doctors. According to the obtained image characteristics:

1. The image mainly displays in gray feature, so using gray scale processing method.
2. There is a lot of noise in the image which most part is caused by the formalin; meanwhile, there are also other cells. If directly using the level set algorithm, it would get the wrong edge and the contour may be sunken deeply.
3. The original algorithm is not fast enough.

So this paper adopts two-step improved algorithm based on [8], as shown in Fig 2.
First, use OSTU algorithm to remove unnecessary noise. Then, set the distance level set’s parameters; considering the speed of the algorithm, this paper uses the initial curve outside of the object; Dirac function takes another formula different with formula (6) and (7).

(1) The initial contour curve is set in the target’s outside and evolves inside direction. Because of the tumor cells’ show deep gray, and the noise gray scale is shallow, the algorithm computes the center of the image to reduce the detection area and enhance the evolutions speed.

(2) After careful analysis of the original algorithm, the effect of the weight coefficients is very large, because it will change the amplitude of $g(x)$. After many times experiments, let $\alpha = 4$.

According to the [9,10], because the formula (6) is only acting on the local and easy to make the curve evolution missed into a local minimum, but lost the contours of objects and can’t get the boundary of deep sunken region and multi objects, this paper using the regularized DIRAC function instead of formula (6)

$$\delta_c(x) = \frac{1}{\pi x^2} \lim_{x \to 0} \delta(x)$$

After the abovementioned treatment, the iterations number may reduce much and it still get the satisfied contour.

IV. THE EXPERIMENTAL RESULTS

The experimental object is get from the second part of this paper. And the digital images acquired from brain tumor in the slides which are from a hospital. Because the images are similar, here show the sample and its results.
Fig. 3 (a) is the digital image from the tumor slides acquired by the built system. Fig. 3(b) is the result after OSTU segment. Fig. 3 (c) is the result of the Li’s algorithm; (d) is the result of the proposed algorithm.

In the view of the Fig. 3, (a) is the image get through the built system; (b) is the image after OSTU segment method. It shows that delete the noise clearly; (c) is the result of the Li’s algorithm with the original image. And its result lost many useful tumor points and can’t obtain the correct edge. Also, it can’t be used after the OSTU method because the edge is disappeared. it cost 510 time’s iterative. And Fig. 3(d) is the result of the proposed algorithm which can delete the most noise and get the accurate contour. Meanwhile, it cost only 80 times iterative. So the proposed algorithm is proved to be effective to the tumor images.

V. CONCLUSION

In this paper, through the establishment of the system, the pathological slides are converted to digital images, which is the research trend of the discipline of pathology. And in the early tumor treatment and medical research, it has the vital significance.

The proposed algorithm in this paper gets good results: 1) this algorithm is faster, and also can extract the good contour; 2) it can solve the problem that the contour stop at the aim position, not deep in depression boundary; 3) avoid the interference of much noise points.

ACKNOWLEDGMENT

The Project Supported by Zhejiang Provincial Natural Science Foundation of China (LY12F01009); Research on Application of technology for public welfare of Zhejiang Province (2014C31056).

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