Active Contours with Automatic "Rectify a Deviation"*

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***Abstract*—Aiming at the shortcomings of Chan-Vese (C-V) model, using the method of literature and experimental method, based on C-V model, whose length term is changed into an automatic "rectify a deviation" term, using the adaptive parameters, an active contour model with automatic "rectify a deviation" is proposed, The experimental results show that this model can handle images with intensity inhomogeneity and strong noise, the segmentation speed is fast.**

Keywords—image segmentation; automatic; rectify a deviation; active contour ; C-V model; partial differential equation (PDE)

I. INTRODUCTION

Since Chan-Vese (C-V) model[1] has been proposed, for the study of C-V model become a hot topic. Li C M et al. proposed the RSF (Region-Scalable Fitting) model, it can handle images with intensity inhomogeneity [2]; Lin T Q et al. in C-V model, introducing a speed term, quicken the convergence rate of the model[3]. Zhang S H in C-V model to join the regularization term[4], improved the model, it can handle images with strong noise, its applicable scope expanding[5]; Yuan Y proposed an adaptive active contours without edges[6]; Feng C L et al. combined with the Split Bregman method and geometric active contour model to deal with medical images[7] ; Zhang Y C et al. to improve C-V model, used in multispectral imaging, to enhance the robustness of image segmentation[8].

Based on C-V model, the length term is changed into an automatic "rectify a deviation" term, using the adaptive parameters, got a novel automatic "rectify a deviation" active contours model. In this way, the level set function can be strong smoothed, and the distance function can be maintained, the level set function can be avoided to reinitialize, the evolution curve fitting edge of the target is satisfactory, also this model is not sensitive to noise.

II. ANALYSIS OF C-V MODEL

The energy functional for C-V model:

$$E(C,c_1,c_2)=\mu\oint_D ds$$

$$+\lambda_1\iint_{D_1}(I(x,y)-c_1)^2\,dxdy+$$

$$\lambda_2\iint_{D_2}(I(x,y)-c_2)^2\,dxdy \tag{1}$$

$$M_1(u)=H(u)\,,\quad M_2(u)=1-H(u) \tag{2}$$

$$c_i=\iint_{D_i}M_i(u)I(x,y)dxdy\Big/\iint_{D_i}M_i(u)dxdy\,,\quad i=1,2 \tag{3}$$

where, $I(x,y)$ is the image to be segmented, $C=\{u=0\}$ is the evolution curve , $D_1=\{u<0\}$ 、 $D_2=\{u>0\}$ respectively, said C's internal and external regions, $D=D_1\cup D_2$; $\mu\geq 0$, λ_1 、 $\lambda_2>0$ are the weight coefficient; u is a level set function, $H(u)$ is Heaviside function,

$$H(u)=1/2\left[1+2/\pi\arctan(u/\varepsilon)\right]$$

Using the level set method and gradient descent flow, the partial differential equation of the level set evolution can be derived:

$$\frac{\partial u}{\partial t}=\delta(u)\left[\mu div\left(\nabla u/|\nabla u|\right)\right]$$

$$+\delta(u)\left[-\lambda_1(I-c_1)^2+\lambda_2(I-c_2)^2\right] \tag{4}$$

where, $\delta(x)$ is Dirac function,

$$\delta(u)=\varepsilon\Big/\left(\pi\left(\varepsilon^2+u^2\right)\right),$$

it is first-order derivative of $H(u)$.

For level set function u , constant c_1 and c_2 are respecti -vely the average gray value inside D_1、 D_2 , they are global variables. Therefore, with c_1 and c_2 , respectively, the

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approximate the gray value of the image of intensity inhomogeneity in the evolution curve of in internal and external, will produce a large error, which leads to the C-V model can not be segmented intensity inhomogeneity images.

III. THE PROPOSED MODEL

For the first term in C-V model (1), using the "rectify a deviation" term to replace [9]:

$$\mu\iint_D 1/2\left(|\nabla u|-1\right)^2 dxdy \tag{5}$$

For C-V model (1), the second, three, replace with

$$+\iint_{D_1} 1/2\,(I(x,y)-c_1)^2\,dxdy$$

$$+\iint_{D_2} 1/2\,(I(x,y)-c_2)^2\,dxdy$$

So, a new energy functional is proposed in this paper:

$$E(u)=\mu\iint_D 1/2\left(|\nabla u|-1\right)^2 dxdy+$$

$$+\iint_{D_1} 1/2\,(I(x,y)-c_1)^2\,dxdy$$

$$+\iint_{D_2} 1/2\,(I(x,y)-c_2)^2\,dxdy \tag{6}$$

where, μ is $mean\left(\max(I)\right)./\,mean(I)$, $I(x,y)$ is the image to be segmented, $D=D_1\cup D_2$, u is a level set function, c_1、c_2 by (3) calculation.

Using variational level set method, introducing the Heaviside function in (6), it is modified to be an energy functional of embedding function $H(u)$, namely

$$E(u)=\mu\iint_D 1/2\left(|\nabla u|-1\right)^2 dxdy+$$

$$+\iint_{D_1} 1/2\,(I(x,y)-c_1)^2\,H(u)\,dxdy$$

$$+\iint_{D_2} 1/2\,(I(x,y)-c_2)^2\left(1-H(u)\right)dxdy \tag{7}$$

By the gradient descent flow, to derive the control partial differential equation of level set evolution:

$$\frac{\partial u}{\partial t}=\mu\left(\Delta u-div\left(\nabla u/|\nabla u|\right)\right)$$

$$+\delta(u)(c_1-c_2)(I-(c_1+c_2)/2)$$

Then, make $\delta(u)=1$, we can get

$$\frac{\partial u}{\partial t}=\mu\left(\Delta u-div\left(\nabla u/|\nabla u|\right)\right)$$

$$+(c_1-c_2)(I-(c_1+c_2)/2) \tag{8}$$

By the C-V model, for each of the level set function u, c_1 and c_2 is global variables. The distance function term, named "rectify a deviation" term in (8), keep $|\nabla u|=1$, to impose strong smooth level set function, it has no need to reinitialize the level set function, and whose coefficient is adaptive parameter; the second term in (8) as binary fitting, make the evolution curve fitting edge of the target, the model fully realize the adaptive.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The numerical implementation uses a simple central difference method. All the experiments are conducted in Matab8.1.

A. *The real images segmentation*

Fig.1(a) shows a cell image with complex background, the size of which is 138×143, 60 iterations; (b) shows a medical organ image, the size of which is 227×339, 30 iterations; (c) shows An airplane image, the size of which is 340×234, 15 iterations; (d) shows a pepper image, the size of which is 372×276, 210 iterations; (e) shows image of a tree, the size of which is 420×340, 150 iterations; (f) shows a potato image, the size of which is 233×233, 20 iterations. By using our model, the results of image segmentation are satisfactory.

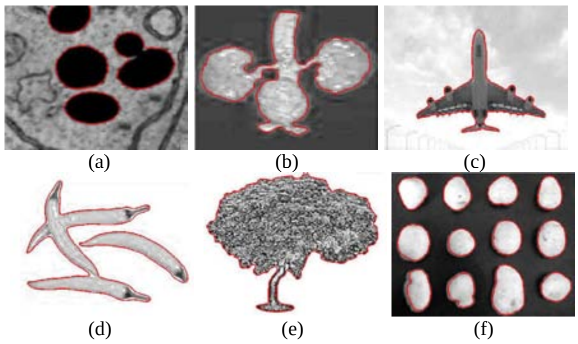

Fig.1. Segmentation results of real images. (a) Cell image 60 iterations; (b) Medical organ image 30 iterations; (c) Airplane image 15 iterations; (d) pepper image 210 iterations; (e) tree image 150 iterations; (f) potato image 20 iterations.

B. *The noise images segmentation*

Fig.2 shows two noise images, the size of them respectively 136×136、208×202. By using our model, the boundaries of them are detected successfully. C-V model can not segment two images(When no noise, our model and C-V model can segment the images.). The experimental results show that the proposed model is better than C-V model not sensitive to noise. Because the distance function term, named "rectify a deviation" term in (8), keep $|\nabla u| = 1$, the level set function can be strong smoothed.

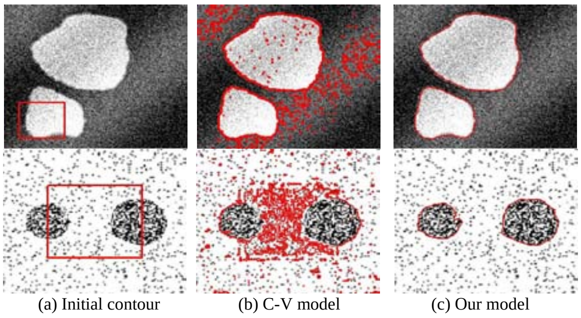

Fig.2. Segmentation results of noise images

C. Segmentation speed comparison

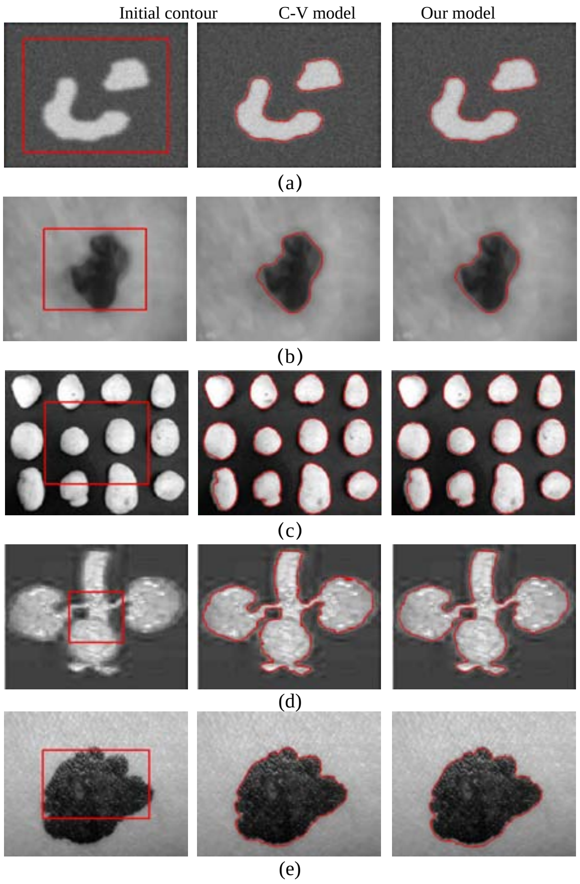

Fig.3. The comparison of the segmentation speed for two methods. (a) Synthetic image; (b)Medical image; (c) Potato image; (d) Medical organ image; (e) Medical image.

Fig.3 (a) shows a synthetic image, the size of which is 84×84; (b) shows medical image, the size of which is 252×185; (c) shows potato image, the size of which is 233×233; (d) shows a medical organ image, the size of which is 227×339; (e) shows a medical image, the size of which is 241×193.

TABLE I. THE COMPARISON OF ITERATIONS AND COMPUTATIONAL TIME FOR TWO METHODS

Images(size)	C-V model		Our model	
	Iteration number	*Computational time(s)*	*Iteration number*	*Computational time(s)*
(a)(84×84)	20	5.9748	2	0.3423
(b)(252×185)	160	8.1277	30	2.5272
(c)(233×233)	160	12.1873	20	2.0904
(d)(227×339)	1000	70.3097	30	4.7424
(e)(241×193)	12800	353.7947	40	3.4320

V. CONCLUSIONS

The new model based on C-V model, the length term of C-V model is changed into the distance function term, named a "rectify a deviation" term, using adaptive parameters, so that the curve evolution can be adaptive to the global information, and can avoid the level set function to reinitialize, can make the evolution curve fitting edge of the target accurately, the segmentation speed is fast, it is not sensitive to noise. However, the weak boundary images can not be segmented as blood vessels.

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