RESEARCH ON EDGE EXTRACTION WITH LEVEL SET METHOD

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ABSTRACT:

Image edge detection or extraction is always a research hotspot in remote sensing image processing. Up to now, there are many methods have been used in this area, such as threshold segmentation, edge detection operators, region growing method and so on. But threshold segmentation cannot meet the accuracy we needed and edge detection operators are always extract all the edges in the image when sometimes we just need part of them. In this paper, we proposed using level set method to extraction edges that we want. At first, initial edge was given by Human-Computer Interaction way, and then level set method was used to evolve the initial edge to make it more accurate. Experiments were carried out in Matlab, and the results show that this method is very useful and high efficiency.

1. INTRODUCTION

Ostensibly, edge is the junction of different features in remote sensing image. It usually is the places where image brightness changes most in the local part of an image. Edge exists primarily on places between one type of objective and the other, objectives and backgrounds, region and region, and also is basis of texture feature extraction, shape feature extraction and image analysis. Edge extraction is the first step of image analysis and understanding, occupies a special position in the image processing and computer vision, and it is the one of the most important aspects of low-level processing. In the field of remote sensing image processing, edge detection has a wide range of applications, many research achievements have been made in such as road extraction, waterline extraction, cloud detection, remote sensing image segmentation.

Because of the importance of edge extraction, lots of methods have been proposed by researchers, they can be divided into a few major categories: 1. Threshold segmentation(Xie fengying, Jiang Zhiguo, 2007; Li Jiangtao, Ni Guoqiang, Huang Guanghua, 2007; R.Medina-Carnicer, F.J.Madrid-Cuevas, 2008; Ety Navon, Ofer Miller, Amir Arerbuch, 2005); 2. Method of differential operator based on gradient(Phillip A. Mlsna, Jeffrey J. Rodriguez, 2005; Lijun Ding, Ardeshir Goshtasby, 2001); 3. Region growing method(Jiangping Fan, Guihua Zeng, Mathurin Body,Mohand-Said Hacid, 2005; Ye zhou,Jhon Starkey, Lalu, 2004);4. Method of Mathematical Morphology(T.Chen, Q.H.Wu, R.Rahmani-torkaman, J.Hughes, 2002;); 5. Wavelet Methods(Dusan Heric,Damjan Zazula, 2007; Ming-Yu,Shih, Din-Chang Tseng, 2005); 6. Method of Fuzzy Mathematics(Sakari Murtovaara, Esko Juuso, Raimo Sutinen, 1996; Florence Jacquey, Frédéric Comby, Olivier Strauss, 2008；Liming Hu, H.D. Cheng, MingZhang, 2007); and 7. Method of neural networks(V.Srinivasan, P.Bhatia, S.h. Ong, 1994; M.Emin Yuksel, 2007). Sometimes, a few of these methods are combined together to perform edge extraction.

But there are some problems still exist; first. It is hard to determine thresholds, though many methods are proposed like neural networks to help to do this, there are still many mistakes in local area of an image due to the value always determined by the whole image. Second, sometimes we just want to extract a few edges like the road, waterline and so on, but many edge detectors perform on the whole image, so a lot of tasks need to do after using these edge detectors. Here we proposed a method to extract edges based on level set method, on one way, we try to provide a friendly Human-Computer Interactive environment to perform this task automatically or semi- automatically; on another way, we hope that after using this method, the follow-up processing tasks would be very easy.

2. LEVEL SET METHOD

2.1 Fundamental of level set method

Level set method was proposed by Osher and Sethian in 1988 and has been widely used in image segmentation, image smoothing, motion segmentation, moving target tracking, even in stereovision and image reparation. As a novel approach of handling the curve evolution, it implied in a manner to express the closed planar curves or three-dimensional closed surface, so as to avoid the evolution process of tracing the curve. Thus problem of curve evolution is converted to a pure searching for the numerical answers of partial differential equation.

The main idea of level set method is to embed the propagating interface as the zero level set of a higher dimensional hypersurface. By controlling the evolution of the hypersurface, we can control the evolution of the curve.

Suppose the level set function is $\emptyset(x,y,t)$, C(p, t) is the zero level set of $\emptyset(x,y,t)$, then, we produce an Eulerian formulation for the motion of the hypersurface propagating along its normal direction with speed V, where V can be a function of various arguments, including the curvature, normal direction, etc. Let C(p, t=0) is the initial curve, $\emptyset(x,t=0)$ is usually defined by SDF (Signed distance function):

$$\emptyset(x,t=0)=\pm d(x)$$

d(x) is the distance between x and C(p, t=0), and the plus (minus) sign is chosen if the point x is outside (inside) the initial curve C (p, t=0).thus we have build the initial level set function. The equation for the evolving function $\emptyset(x,t)$ which contains the embedded motion of C (p, t) as the level set $\{\emptyset = 0\}$ is given out by equation $\frac{\partial\emptyset}{\partial t} = V(k)|\nabla\emptyset|$, V(k) is the speed function and we refer to this as a Hamilton-Jacobi "type" equation.

There are many advantages to this Eulerian Hamilton-Jacobi formulation, the most important are that it avoid the evolution of the parameters of the curve equation, makes curve topology changes(split or merge) become very natural and as evolving function $\emptyset(x,t)$ always remains a function, it can be easily carried out by using numerical approximation methods.

2.2 C-V model

In 2001, Chan and Vese proposed an simplified model based on Munford-Shah segmentation model. Suppose I(x,y) is the image, there are a few homogenous regions in an image, C_i is the edge of region R_i ,the DN value of very region is a constant, that is to every region R_i , $I(R_i)$=constant(C_i). What the C-V model to do is create an minimize energy function to find the optimal segmentation, which makes the distinction between segmented image

$$I(Ri) = \begin{cases} constant(Ci), & if\ Ri\ inside\ Ci \\ C_0, & if\ Ri\ outside\ Ci \end{cases}$$

and I(x,y) is the smallest.

We use an simple example that given by Chan and Vese in their paper to explain this idea(Tony F.Chan, Luminita A. Vese, 2001)(Fg.1). Define the evolving curve C in Ω, as the boundary of an open subset ω of Ω. inside(C) denotes the region ω , and outside(C) denotes the region $\Omega\backslash\omega$. The image u_0 is divided into two regions by curve C: u_0^i and u_0^o. The average DN value of very region is C_1 and C_2.Then consider the following "fitting" term:

$$F_1(C) + F_2(C) = \int_{inside(C)} |u_0(x,y) - c_1|^2 dxdy$$

$$+ \int_{outside(C)} |u_0(x,y) - c_2|^2 dxdy$$

In this simple case, it is obviously that C_0, the boundary of the object, is the minimize of the fitting term $\inf_C\{F_1(C) + F_2(C)\} \approx 0 \approx F_1(C_0) + F_2(C_0)$. For instance, if the curve C is outside the object, then $F_1(C) > 0$ and $F_2(C) \approx 0$. If the curve C is inside the object, then $F_1(C) \approx 0$ and $F_2(C) > 0$. If the curve c is both inside and outside the object, then $F_1(C) > 0$ and $F_2(C) > 0$.Finally, the fitting energy is minimized if C=C_0, if the curve C is on the boundary of the object.

Based on this idea, Chan and vese create the energy function $F(c_1, c_2, C)$, defined by

$$F(c_1, c_2, C) = \mu \cdot Length(C) + \nu \cdot Area(inside(C))$$

$$+\lambda_1 \cdot \int_{inside(C)} |u_0(x,y) - c_1|^2 dxdy$$

$$+\lambda_2 \cdot \int_{outside(C)} |u_0(x,y) - c_2|^2 dxdy$$

Where

$\mu \geq 0$, $\nu \geq 0$, $\lambda_1, \lambda_2 \geq 0$ are fixed parameters.

$Length(C)$ is the length of the curve C

$Area(inside(C))$ is the area of the region inside C

$Length(C)$, $Area(inside(C))$ are regularizing terms.

By solving the minimization problem $\inf_{c_1,c_2,C} F(c_1,c_2,C)$, we can get the final curve C.

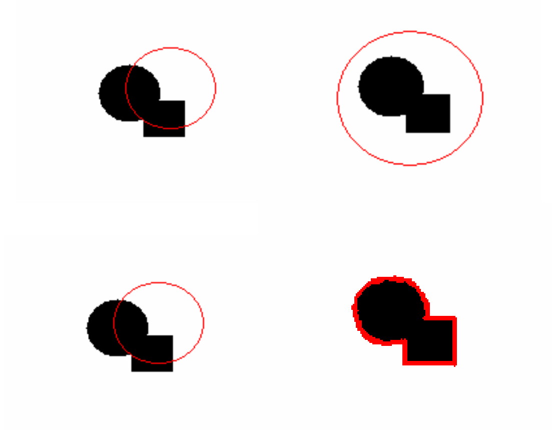

Figure 1.all possible cases in the position of the curve

3. EXPERIMENTAL PROCEDURES

The experiment procedure of this paper is directly and in a semi-automatic method. At first, the program will get initial edge by Human-Computer Interaction way. Usually, initial edge was simply given by using circular or rectangular, because it would be very easy to build signed distance function. But when we use this way to process remote sensing image, it will cost very long time to make the curve move to the real edge. Though the algorithm of building signed distance function will become a little more complicated and time costing, because the initial edge is much more accurate, the total time will be shorter.

After getting the initial curve, the program will build signed distance function and evolve the curve automatically.

We provide two ways to stop the evolving of the curve. The first way is that the program judges if the curve has moved to the right place and determines to continue or stop by itself. The second way is to stop the curve by human sending commands, this way is more effective because we use our experience to determine if the curve has moved to the right place.

4. RESULTS

Many experiments are carried out using several images oriented to different objectives. The results show that this method is very useful when extracting edges between objectives and the background. Following are four of them to show how this method works.

Images with initial curve are on the upper side and the results are on the underside. The first experiment (Figure 2) is to extract the edge of a lake. From the image we can see that the edge is very clear and the water is distinct from the land, if we use threshold segmentation, the rivers will influence the result. we will do some extra work to remove edges we do not need. By using level set method, we can see from the result that it successfully extracts out the edge without facing those problems. Figure 3 shows the second experiment, this experiment is to extract waterline of tidal flat, Because of the influence of the tidal, the shape of the waterline is very complicated, and this make the curve evolves a longer time than the first experiment. When this method extracts the waterline, we also can see some spots and they also exist in Figure 4 and Figure 5. The reasons of producing these is partly because the C-V model which we used. But it is not a big problem, we can just track the line we want and do not care about them. In Figure 4, we assume a situation that there are several homogenous areas in an image, but we only want to extract one of them, the image was cut from an image of a city, there are several green areas in this in image, then we want to extract one of them and we can see that this method works very effectively. The fourth experiment is to extract out waterline of Jiuduansha Shoal in Changjiang Estuary (Figure 5), Jiuduansha Shoal located in the Turbidity Maximum zone in Changjiang Estuary, and high suspended sediment concentration greatly enhances the reflection of the water body in this area. So in some area, the DN value from water to mudflat changes gradually which makes it hard to determine the exact location of the waterline, but the idea of minimize energy of C-V model can solve this problem in an reasonable way. From this experiment, we can see another advantage of this method which is that when the curve evolves, it will split when it meets several targets.

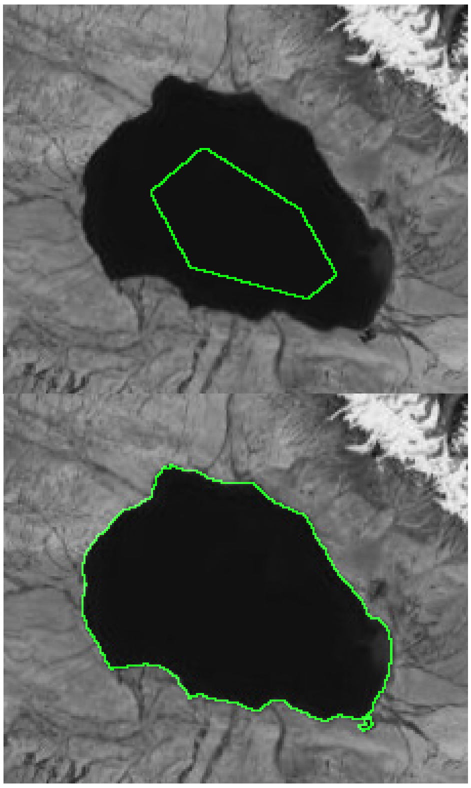

Figure 2. Extract lake edge. Upper: image with initial curve. Underside: result curve

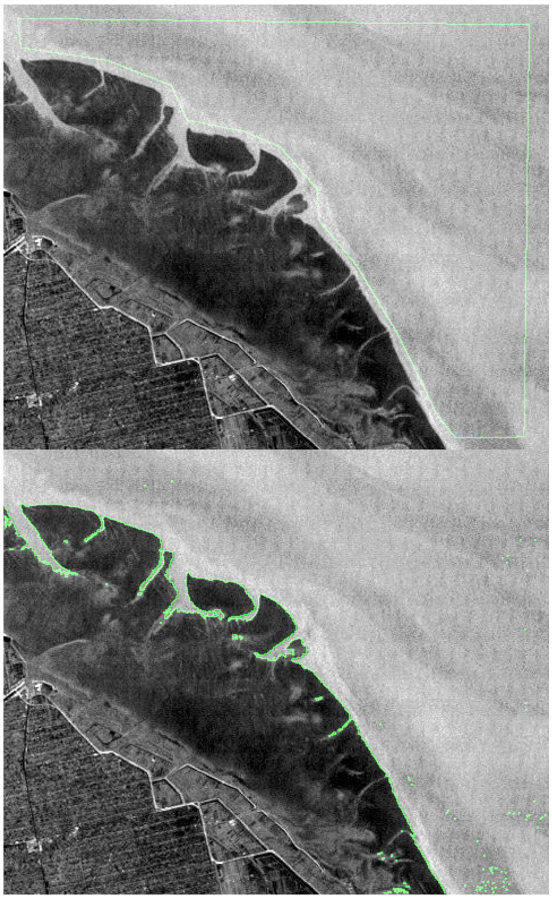

Figure 3. Extract waterline. Upper: image with initial curve. Underside: result curve

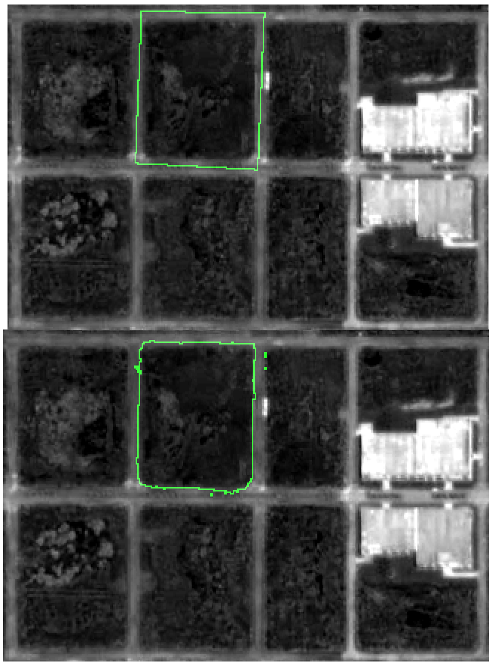

Figure 4. Extract edge of a block. Upper: image with initial curve. Underside: result curve

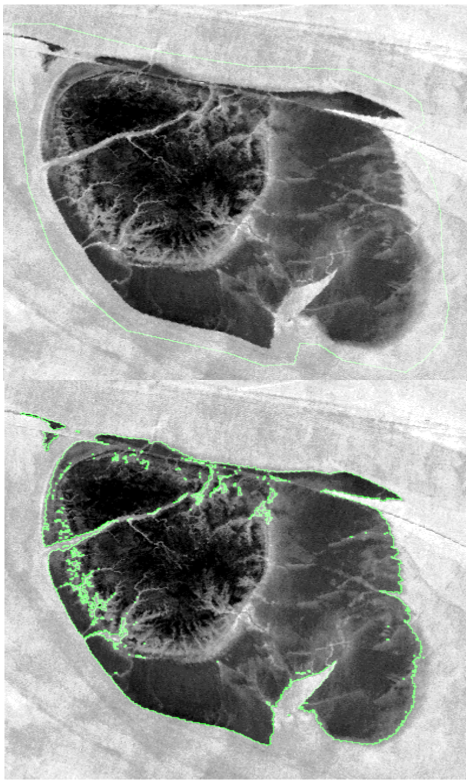

Figure 5. Extract edge of Jiuduansha Shoal in Changjiang Estuary. Upper: image with initial curve. Underside: result curve

5. CONCLUSIONS

Up to now, there are few papers about processing remote sensing image using level set method. But there are several advantages of extract edge using level set method. First, this method is very flexible, we can just extract the edge that we want and we can have some controls when the curve moves. Second, when we use edge detectors, sometimes we will meet a lot of problems of how to track the edges, while using level set method, the curve is continuous which make it easy to be tracking. At the end, we did not need to compute how accurate of the edge would be, but from the image, we can find that the result is very good.

The disadvantage of this method is also obviously, because the algorithm of this method is much more complicated that other methods, it will cost a very long time if running on a low assembled PC which would limit its application of processing remote sensing image to a certain degree.

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