WATER EXTRACTION FROM HIGH RESOLUTION SATELLITE IMAGE BASED ON THE FAST MATCHING LEVEL SET METHOD

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ABSTRACT:

The overarching goal of this study was to use one of the simple level set methodologies for extracting water boundaries using high resolution satellite images. In the first part of the paper, study area and the characteristics of the training data were introduced simply. The level set segmentation and the fast matching methodology would be presented in the second part of the paper. Thirdly, several images which have rivers or pond in them would be tested by the fast matching method to extract the water boundaries using a series of parameters. The result of the method would be compared with the result that made by the mathematic morphological segmentation methodology. The last part of the paper comes to the conclusions of the level set methodology for water line extraction.

1. INTRODUCTION, DATA AND STUDY AREA

1.1 Introduction

The delineation and extraction of water bodies from remote sensing image is an important task useful for various application fields such as coastline erosion monitoring, watershed definition, GIS database updating, flood prediction, and the evaluation of water resources.

With the development of the high resolution satellite images, traditional methods have great limitation for the water bodies' extraction; different techniques have been introduced for the important task.

Kaichang Di[1] used the mean shift segmentation to identify the major water body and generate the initial shoreline.

Chalabi[2] used the pixel based segmentation technique to monitoring shoreline change based on IKONOS image and aerial photographs.

In this paper, we used the level set method proposed by Osher and Sethian[3] to segmentation the images and extract the water boundaries of the small pounds or rivers.

Level set method is a simple and versatile method for computing and analyzing the motion of an interface in two or three dimensions. The numerical computation method is used for level set function as the main solution methods, but it needs to refresh the level set function values of all the points in the field of definitions, and it has a great amount of calculation, especially when the image is large.Fast matching method is a simple solution to calculate the moving process of the zero level set.

The first part gives an over view of the paper, and introduces the study area as long as the Characteristics of the training data.

The principle of the level set method and its simple solution called fast marching executed in ITK are shown in the second part.

The third part of the paper is the experiments and conclusions.

1.2 Study Area

The methodology was evaluated for the Yellow River drainage area in Jiawang District, Xuzhou, Jiangsu Province, which has a complex landform.

Figure 2: the location of Jiawang District in Xuzhou city

Jiawang District is one of the districts that belong to Xuzhou City. It is located at the northeast of Xuzhou and 35 kilometres far from the central city（see Figure 2）. The latitude of the district is between 34°17′and 34°32′, and its longitude is between117°17′and117°42′, and is 39 kilometres from east to west, 27 kilometres from north to south. Jiawang District has a total area of 690 square kilometres. It borders with the city of Pizhou at east, Tongshan County at south, the west and

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northwest, and the north neighbour is Zaozhuang city which belongs to Shandong province. The total area of the district is about 690 square kilometres.

Jiawang District is in the centre of a U shaped valley，the north of the district is classified as hilly and mountainous, the south is flat and belongs to the Yellow River Flood Plain. There are eight main rivers in the district, such as Jinghang Canal, Bulao River, Tuntou River. Jiawang District is belong to the warm temperate zone subhumid monsoon climate，and has distinctive four seasons. The mean annual temperatures is 14.2°C，frost free period is 280 days，and the mean annual rainfall is 802.4mm[4].

1.3 Characteristics of the Training Data

This study used aerial images. Aerial images usually have a relatively lower altitude to get the details of the study area. In this paper, each pixel of the training data represents 0.5meters of the ground. The images were obtained in late spring when most of the field was covered with wheat and other plants. The water bodies in the images have different grey scales because of the different cause of formations and applications, and this will be a challenge for the segmentation method.

2. MEOTHOD

2.1 Level Set method

The level set method was devised by Osher and Sethian in [3] as a simple and versatile method for computing and analyzing the motion of an interface in two or three dimensions [5].

Let's take the two dimensions as the example to discuss. The principle of the level set method is to translate the two dimensional plane closed curve C(t) to the zero level set φ(t =0), that is to embed the surface to a curved surface, and the 2 two dimensional curve would be translated to a curved surface in three dimensions.

Facing a given closed contour curve, if $\varphi(x, y)$ is the minimum distance from the point (x, y) to the contour curve, and $\varphi(x, y)$ would be called signed distance function. The sign of the function for the internal points were negative, and the external points' were positive.

The set for the signed distance function that have different values constitute the level set, and the $\varphi(x, y) = 0$ was called zero level set, which depicted the closed counter curve in the plane.

The evolution of the curve surface for level set function follows the Hamilton-Jacobi function:

$$\begin{cases} \dfrac{\partial \varphi}{\partial t} = F|\nabla \varphi| \\ \varphi(x, y, 0) = \varphi_0(x, y) \end{cases}$$
<div align="right">Function (1)</div>

F stands for the evolution speed for each point of the curve, and its direction follows the normal direction of the curve. F has a great relation to the image gradient and the curvature of curve. So that different segmentation methods comes from different F.

It is a most important task to choose the numerical computation method for the implication of level set method in the image segmentation. The key to the numerical computation method is how to solve the differential function (2) which is defined in the continual space.

$$\frac{\partial \varphi}{\partial t} - F|\nabla \varphi| = 0$$
<div align="right">Function (2)</div>

Literature [3] discussed the numerical computation methods exhaustedly.

2.2 Fast matching

The numerical computation method for level set function needs to refresh the level set function values of all the points in the field of definitions, and it has a great amount of calculation, especially when the image is large.

Narrow Band [6] and Fast marching [7, 8, 9,10] are the most used fast solution methods for level set.

Narrow band was first put forward by D.Chop, exact solution was executed by Adalsteinsson and Sethian. The principle of narrow band is that the ideal value is in the narrow ribbon region near the zero level set.

Fast matching method comes from the special condition of function (2), which is the speed F is always maintain the same sign, positive or negative, and at this circumstance function (2) is called static function. The fast marching method was first put out by Sethian.

2.3 The Fast Matching Executed in ITK

ITK represents for the American National Library of Medicine Insight Segmentation and Registration Toolkit.

ITK is an open-source, cross-platform system that provides developers with an extensive suite of software tools for image analysis[11].

There are 6 kinds of level set methods supported by ITK : Fast marching , Shape detection, Geodesic active contour, Threshold level set, Canny edge level set, Laplacian level set ,etc.

In this paper, we segmented the images using the fast matching method that is included in ITK.

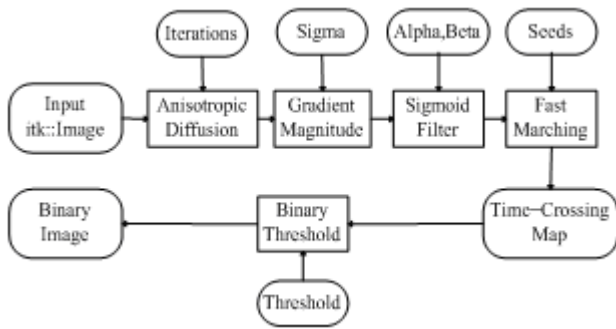Figure1 [12] shows the typical pipeline of the usage for performing segmentation with fast marching.

Figure 1.Collaboration diagram of the Fast Marching Image Filter applied to a segmentation task

Firstly, the input image is smoothed using curvature anisotropic diffusion image filter.

Secondly, the magnitude of gradient for the smoothed image gradient would be computed, and the gradient image would be passed to the sigmoid filter

The image coming from the usage of sigmoid filter is the image potential, which would have a great affect on the speed term of the differential equation.

Finally, image result from the Fast Marching Image Filter would be passed to the Binary Threshold Image Filter so that a binary mask representing the segmented object would be produced.

2.4 Parameters Needed In the Segmentation

There are 6 Parameters in the Fast Marching method in ITK.

(1) seed
User is asked to provide a seed point from which the contour will expand.

(2) σ
σ is used in Gaussian filter to control the range of influence of the image edges.

(3) α and β
Two parameters are required in the Sigmoid Image Filter to define the linear transformation to be applied to the sigmoid argument; we call them α and β.The two parameters are used to intensify the differences between regions of low and high values in the speed image.

From the gradient magnitude image, let's call K_1 the minimum value along the contour of the anatomical structure to be segmented. Then, let's call K_2 an average value of the gradient magnitude in the middle of the structure.

α and β follows the following functions;
$\alpha = (K_1+K_2)/2$ Function (3)
$\beta = (K_2-K_1)/6$ Function (4)

(4) Stopping Value

Stopping Value is desirable to stop the process once a certain time has been reached

(5) Threshold

The application of a threshold in the output image is then equivalent to taking a snapshot of the contour at a particular time during its evolution.

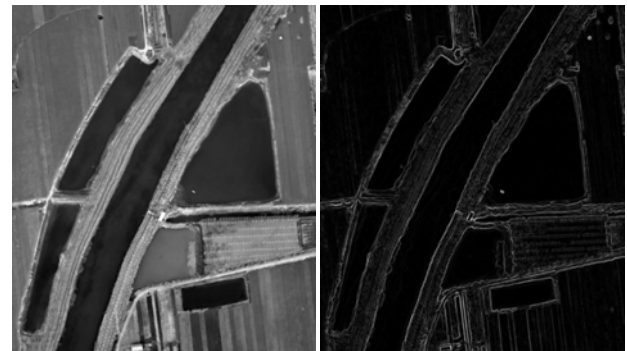In principle, the stopping value should be a little bit higher than the threshold value.

3. EXPERIMENTS AND CONCLUSIONS

3.1 Experiment results

In this paper we experiment the fast marching method using the aerial images taken from Jiawang District.Table 1 shows the parameter values using in the paper for the image segmentation.

input image	seed	σ	α	β	thres-hold	stopping value	output image
(a)	(529, 360)	1.0	-1	2	245	500	(d)

Table 1.Parameters used for segmenting images using the Fast Marching method

(a)   (b)

(c)   (d)

Graph1. Input Image and Output Image
(a) Input Image (b) Output Image
(c) Filter Image (d) Smoothed Image

The workflow of the proposed extraction approach is demonstrated in section 2.3. The selected test data is aerial imagery with 721×825 pixels. The resolution of the imagery is 0.5 meters.

Graph 1 show the results using the fast matching level set method with the parameters shown in table 1. Image (a) is the input image which has main water bodies in it.

σ is selected as 1.0 to use in Gaussian filter to control the range of influence of the image edges. Image (b) shows the Gaussian filter.

α and β are set as -1 and 2 respectively in the Sigmoid Image Filter to define the linear transformation to be applied to the sigmoid argument. Image (c) shows the result of the Sigmoid Image Filter.

The stopping value and the threshold are set as 500 and 245, and the seed in the experiment is set at (529,360). Image (d) shows the final result of the experiment.

3.2 Conclusions

In this paper, we introduce a simple solution of the level set solution method to separate the high resolution imagery and extract the water body in it.

There are six parameters that should be given by the users. From graph1 we can see that the six parameters are suitable for this imagery; while if another image is used, the parameters should be experimented to test whether they would come to the ideal result. The next work of the method is to select the parameters automated compare to different images.

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