FARMLAND PARCELS EXTRACTION BASED ON HIGH RESOLUTION REMOTE SENSING IMAGES

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ABSTRACT:

Extracting farmland parcels from high resolution remote sensing images is an important issue for land-use dynamic monitoring, precision agriculture and other fields. However, the traditional method, using GIS software and manual digital, has wasted a lot of human and material resources. In addition, the results are impacted by the human factors obviously. Therefore, an automatically extraction method which does not require too much manual intervention is needed urgently. This paper presents a remote sensing images segmentation method based on wavelet transform and watershed segmentation to get the final segmentation results. Firstly, we use the classification results to enhance the contrast of typical features in the original image. Secondly, we use wavelet transform and watershed segmentation to calculate the enhanced image, and then use improved regional merging algorithm to solve the problem of over-segmentation. Finally, we reconstruct the image by inversed wavelet transform with the edge information from Canny operator, and then label the regions to get the final segmentation results. To validate the proposed approach, experiment on Quickbird image is performed, we extract farmland parcels from the image quickly and accurately. It shows that the proposed approach is an effective farmland parcels extraction method based on high resolution remote sensing images.

1. INTRODUCTION

1.1 General Instructions

Parcels as an evaluation unit, has a very important significance in the dynamic monitoring of land use, land cover, precision agriculture, ecological planning, and other fields. Parcels is the smallest unit of land in which it has similar attributes, and it is also the basic spatial units of land assessment and classification. In different scales, parcels have different forms of performance, and its area can be more or less. The parcels have often defined the location and the border clearly, and its spectral characteristics also have a strong similarity in the remote sensing images. At present, the traditional method to extract the parcels information from high-resolution remote sensing images is to use GIS software, and getting the digital images manually. This method requires lots of experienced persons to digit the images, and obviously needs a lot of human and material resources. What's more, the results are also very subjective. Therefore, an automatically extraction method which does not require too much manual intervention is needed urgently.

Image Classification and image segmentation are two important methods to get the internal information of the images. Remote sensing images classification is aimed to divide the pixels into different categories according to some rules or algorithms, through their different spectral band brightness and spatial structure characteristics or other information. The main methods of image classification are supervised and unsupervised classification. Image Classification can distinguish the features well, but the results of classification are not in the form of parcels, the same types of regions often mixed other features, for example, large tracts of wheat containing a lot of ridge information; In addition, the classification results images have no edge information, and is impossible to label region. So it can not be used to extract the parcels automatically. However, some typical features have very obvious characteristics in the original image, such as water body, bared land and others. We can use the method of classification to identify them first, and then use the results to enhance the gray contrast of the typical features, thus contributing to the needs of the target parcels from the border closure and improving the accuracy of image segmentation. Remote sensing images segmentation is the process which will divide a whole image into a number of subsets with certain rules . Nowadays, more and more computer vision image segmentation algorithms are applied to remote sensing images segmentation research, and made a lot of improvement and innovation. These methods can be roughly divided into three groups. The first method is the threshold segmentation. Its threshold was determined according to the distribution of the image's gray values. The second method is the border segmentation. The third method is the region extraction, and the characteristics of this method is based on the different characteristics between the specific region and other background regions. Watershed transform segmentationis a kind of region extraction segmentation method. It has a strong noise suppression capability without setting a prior parameter. It can extract a region border with a single-pixel width. Although the watershed transform segmentation is a more ideal automated parcels extraction method, it is more sensitive to noise, and easily lead to over-segmentation problem. In order to suppress the image noise and reduce the over-segmentation problem, many researchers introduced the wavelet transform method. The low-frequency image decomposed by wavelet transform can suppress the image noise effectively. So it can attenuate the problem of over-segmentation well. In addition,

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Canny operator has a good effect on the image edge extraction. However, it can not meet the requirements of parcels extraction because the edges extracted by Canny are not closed. So if we can introduce the marginal information, it must be very helpful to improve the extraction results.
Based on the above considerations, this paper proposed an advanced method which can automatically extract the parcels. Firstly, we enhanced the contrast of the original image's gray value with image classification results. Secondly, the watersheds transform method was applied to the enhanced imageto segment the low-frequency image. In order to attenuate the problem of over-segmentation, an improved region merging algorithm was used in this paper. Finally, all regions were labled with the marginal information extracted by Canny.

2. METHOD

The main flow of the proposed segmentation approach can be described as follows: enhancing the gray value contrast of the typical features, wavelet transform and gradient image calculation, watershed segmentation, region merging, image reconstruction, post-processing and so on.

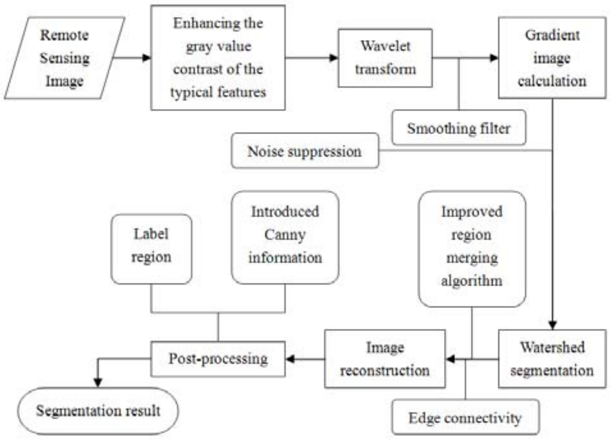

Figure 1. The flow chart of the proposed segmentation approach

2.1 Enhancing the gray contrast of typical features

The space adjacent pixels, although they belong to different features, their gray value are often similar, so using the image segmentation methods directly, is difficult to extract the edge of farmland parcels accurately. Because some typical features can be extracted easily by using conventional image classification methods, and then we can use the results to change their gray value in the original image, then enhance the gray value contrast between typical features and farmland parcels, to avoid the confusion with the edge of farmland parcels. Through this method, we can improve the accuracy of image segmentation.

2.2 Wavelet transform and gradient image calculation

Watershed segmentation has the over-segmentation problem, therefore, at first we should smoothing the image which the gray value contrast of the typical features have already enhanced. A simple low pass filtering method will be loss much image information, so we used wavelet transform method. The wavelet transform is a good mathematical tool for analyzing the multi-resolution image, it can completely represent the image, not only solve the over-segmentation problem partially, but also suppress the noises effectively. A size of level-1 scale image is only a quarter of the original image, so it can reduce the complexity of the image segmentation and computing time .
Remote sensing images often contain a lot of Gaussian and non-Gaussian noises, in the multi-resolution image, because the low-frequency image losses much of high-frequency information, so in the lower image, the edge will be very rough, in the topography, it is known as the "plateau", which many adjacent pixels have the same gray values. In order to reduce such impact on the watershed segmentation, we can first smooth the results image, and then calculate the gradient, that is smoothing equation,

$$I_{gradsmtooth}(x,y,\sigma)=\nabla\left\|I(x,y)*g_\sigma(x,y)\right\| \quad (1)$$

where $g_\sigma(x,y)$ = a Gaussian filter
σ = standard deviation
$*$ = convolution

To the image after Gaussian filtering, the paper used Sobel operator to calculate the gradient,

$$h_1=\begin{bmatrix}-1&0&1\\-2&0&2\\-1&0&1\end{bmatrix}, h_2=\begin{bmatrix}1&2&1\\0&0&0\\-1&-2&-1\end{bmatrix} \quad (2)$$

where h1 = the vertical direction factors
h2 = the horizontal direction factors

calculating through them and smoothed image, we can get the vertical and horizontal direction of gradient image I_v and I_h, so gradient image I_g can be expressed as,

$$I_g=\sqrt{I_V{}^2+I_h{}^2} \quad (3)$$

where I_v = gradient image
I_h = gradient image
I_g = gradient image

Despite the low-frequency image has been filtered some noises, but not completely, so in the gradient image, there will still exist some false edges generated by the noise. We need to suppress the noise according to Signal Noise Ratio (MSE) and standard deviation (σ).
When the T_g is setting larger than σ, the image can get a greater Signal Noise Ratio. Therefore, we make the following processing,

$$\text{IF } T_g\le 0.5\sigma\text{, THEN } T_g=0 \quad (4)$$

where T_g = the value of gradient image
σ = standard deviation

2.3 Watershed segmentation

2.3.1 watershed segmentation

The watershed segmentation is a well known image segmentation approach, which is based on the following morphological principles. If we regard a grayscale image as a topographic relief, the gray value at a given location represents the elevation at that point. If this relief is to be flooded, starting at surface global minima, the water would fill up lower elevation points first, and then the water level would increase. At locations where water coming from different minima would meet, a 'dam' is built. Finally, when the whole surface is flooded, each minimum becomes completely surrounded by 'dams' (i.e. the watersheds). These watersheds delimit the segmented regions, which are the minima catchment basins. If this process is applied to a gradient image, where to each pixel corresponds the local gradient modulus, then the watersheds correspond to the gradient image crest lines. In this case, the catchment basins correspond to the segmented image objects. Unfortunately, images are inherently noisy, and contain gray level fluctuations that generate spurious gradients. Such gradients generate spurious watersheds, which are the main cause of over-segmentation, a known limitation of the watershed segmentation approach [24-25]. Therefore, we need to merge these regions.

2.3.2 Improved regional merging algorithm

The traditional merging methods are based on the adjacent image, each merger will need to update the order of the relevant links in the queue, this approach will consume a lot of times in the sorting, searching, updating and removing links, the efficiency is not high, also needs a great amount of computation. In order to improve the efficiency of the regional merging algorithm [26], the paper proposes a new method, which using mathematical morphology algorithm to find the adjacent regions, and using the regional merging cost function to set the threshold, then completing the regional merging.
Assuming the watershed segmentation image for I0, and was divided into N regions.,

$$R_i(S_i, G_1), i = 1, 2, \cdots N \qquad (5)$$

where S_i = the size of the region i
G_i= average gray value of the region i

To the adjacent regions p and q, merging cost function can be defined like this,

$$MergeCost = \frac{\|S_p\| \times \|S_q\|}{\|S_p\| \times \|S_q\|} \times |G_p - G_q|^2 \qquad (6)$$

where S_p = the size of the region p
S_q = the size of the region q
G_p = average gray value of the region p
G_q = average gray value of the region q

The steps of the regional merging algorithm:
Firstly, find the spatial distribution of the gray value of G_1 in the image I0, and then record them to a blank image I1 (I1 is the same size with I0), and change these pixels gray value to 1; Secondly use the mathematical morphology (Dilate) algorithm to expand the image I1 by the structure of 5 × 5, and then record these pixels to another blank image I2 (I2 is the same size with I0); Thirdly, get the image I3 by I1 subtracts from I2, so I3 recorded the location of the edge information and the adjacent pixels information of G_1, as shown in Figure 3; Because the watershed segmentation image I0's edge pixels value is 0, so if I3 multiplied by I0, the results array can recode all the adjacent pixels gray value of G_1; Fourthly, use the regional merging cost function, and calculate the distance between these adjacent pixels and G_1, if the value is less than the defined threshold value (based on the prior knowledge of the image, users defined), merge two, otherwise not merge. After the merger we can get a new region, the gray value of the new region is the average of two original regions; At last, merge the regions which gray value is $G_{2....N}$, the process is not end until all the regions are not meet the merging conditions.

2.3.3 Edge connectivity

We found that after the merging process, although the gray value of the adjacent regions which can merged into a new region have been changed, the edge pixels between this two regions still exists, and they have not really connected, so this requires us to remove the redundant edge information.
The steps of the edge connectivity:
Firstly, judging the pixel value whether is equal to 0, if the value is equal to 0, we know that the pixel is the edge of the region; Secondly, judging it's adjacent pixels value whether is equal to 0, if not, then judging it's adjacent pixels value are whether the same, if same, it shows that this edge pixel is redundant, we should amend this pixel vale equal to it's adjacent pixel; The process is not end until all the pixels are not meet the amending conditions.
Through the improved regional merging algorithm, we can suppress the over-segmentation problem well.

2.4 Image reconstruction and post-processing

After watershed segmentation and regional merging, we use inverse wavelet transform to reconstruct the image.

2.4.1 Introduced Canny information

From the edge model and noise model, Canny (1986) put forward the optimal filter of edge detection, and achieved good results, it is an ideal edge detection algorithm. As Canny result is not closed, it is not suitable for extraction enclosed area, but we can introduced the Canny result into reconstructed image, improve the accuracy of image segmentation.
The steps of introducing the Canny information:
Assuming the Canny image for C0, first of all, with 1 subtracts from C0, we can get the image C1 which edge gray value is 0 and other pixels gray value is 1, then C1 multiplied by a large number N (defined by users according to the gray value of the reconstructed image); Secondly, get the image C2 by C1 add the reconstruction image; Finally, amending the pixels value in the C2 which can be seen as the edge pixels to 0, and other pixels value in C2 subtracts by N, to restore the reconstructed image's original gray value.

2.4.2 Labeling regions

In order to facilitate the distinction between the various regions, we labeled the reconstructed image (label region), and received the ultimate remote sensing images segmentation results.

3. APPLICATIONS

We select Qucikbird which is a high-resolution and multi-spectral remote sensing images data as test image, the imaging time is on May 2, 2006, the spatial resolution is 2.4 meters, it covers the Tongzhou District of Beijing, the size is 512*512 (Units: Pixel). From it, we can see the following types of features clearly: water, farmland, bare land and construction sites(buildings). The paper wants to extract the farmland parcels, which is in red. If we extract the parcels by traditional methods, it would be necessary to spend a lot of time, if we use the method proposed by this paper, we can get the results easier. Our method can be achieved by ENVI software and interactive data visualization programming language IDL.

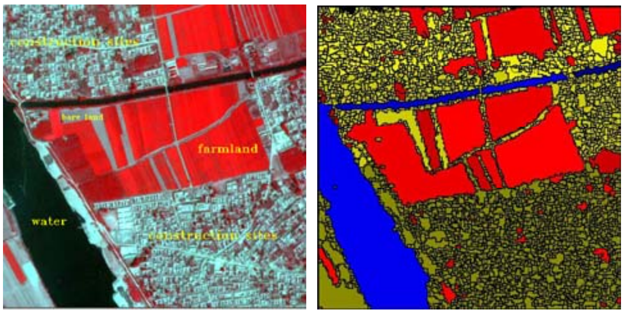

Figure 2. The result of image segmentation

Contrasting experimental results with the original image, we can see that the large area of farmland parcels can extract fast by the proposed method in the paper, but for the smaller parcels, the results of the extraction are also necessary to improve, the main reason is that the gray value contrast of the smaller parcels and the other surrounding parcels are not strong, so it is difficult to extract them from the others. Because the gray value contrast of water and other features is strong, so it is easy to extract. But the construction sites because of its uneven internal conditions, the extraction results are poor. What's more, in the regional merging, the quality of the threshold is very important to the segmentation result.

Obviously, compared to the traditional method, this method has great advantages: (1) Remote sensing images segmentation method based on wavelet transform and watershed is an automatic extraction method, which can save a lot of human and material resources, does not require too much manual intervention, and extracts large area of farmland parcels accurately. (2) Using the image classification results to change the gray value of the typical features in the original image, and then enhance the contrast between typical features and farmland parcels, through this method, we improve the accuracy of image segmentation. (3) Changing the original image into a low-resolution image by wavelet transform, can suppress the noise effectively, and improve the speed of the watershed algorithm, because after wavelet transform, the size of image is only a quarter of the original image. (4) Proposed a simple and effective regional merging algorithm, which reduces the amount of computation, and ensures that little image information is lost.

4. CONCLUSIONS

This paper presents a remote sensing images segmentation method based on wavelet transform and watershed segmentation to get the final segmentation results by the steps of enhancing the gray value contrast of the typical features, wavelet transform, gradient image calculation, watershed segmentation, image reconstruction, post-processing and so on. The experimental results show that it can extract the farmland parcels quickly and accurately.

However, the method proposed in this paper also has some aspects where improvement is needed: (1) Using this method to extract the large area parcels which internal information is homogeneous (such as farmland parcels), we can get the results quickly and accurately, but for those smaller or internal information is uneven parcels, there is still existing some defects; (2) In the regional merging, the threshold is setting manually, it will affect the results of the image segmentation a lot, so to find the threshold automatically is the focus of the study in the future.

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