HYPERSPECTRAL IMAGE SEGMENTATION BASED ON SPATIAL-SPECTRAL CONSTRAINED REGION ACTIVE CONTOUR

Junping Zhang, Jiawei Chen, Ye Zhang and Bin Zou

Dept. of Information Engineering, Harbin Institute of Technology, Harbin 150001, China
zhangjp@hit.edu.cn, jwei1208@163.com, zhye@hit.edu.cn, zoubin@hit.edu.cn,

1. INTRODUCTION

Image segmentation is an important technique in remote sensing hyperspectral image (HSI) processing and application field. It not only can lay a foundation for subsequent object detection, positioning and recognition, but also play an assistant role on HSI data compression and transmission. Level Set which is an effective tool in dealing with image segmentation, has been developed and drawn more attention. For instance, Keaton and Brokish apply spectral and texture information to define the velocity function of level set equation and extract the road from multispectral image [1]. Ball and Bruce extend classification mask design and segment two urban and rural HSIs by using spectral similarity [2]. And some methods use the local edge information in curve evolving by velocity function restriction [3]. However, the lower spatial resolution of HSI usually leads to the vague of object margin and the existence of mixing pixels. The above methods will be less satisfied when no clear boundary of different ground covers exists.

2. METHODOLOGY

Combining the spatial and spectral constraint, a hyperspectral image segmentation method based on region active contour is proposed in this paper. The energy function in region active contour model is improved and both spatial and spectral information are employed. Spatial term of the function is restricted by global spatial information and intensity consistency in homogeneous region; while spectral term is restricted by spectrum consistency of the target. Finally the image is segmented by minimizing the energy function.

2.1. C-V model

The segmentation model (C-V model) proposed by Chan and Vese can extract the blurry contour from the image [4], which uses two-dimensional image's global information. This model adopts the closed boundary curve C to divide the image $I(x, y)$ into two parts: the interior and exterior of C, whose mean values are c_i and c_o, respectively. The energy function of the model is defined by

$$F(c_i, c_o, C) = \mu L(C) + \nu S(C) + \gamma_i \int_{inside(C)} |I(x,y) - c_i|^2 \, dxdy + \gamma_o \int_{outside(C)} |I(x,y) - c_o|^2 \, dxdy \qquad (1)$$

Where $L(C)$ is the length of closed contour C, and $S(C)$ is the area of inside C. $\mu, \nu \geq 0$, $\gamma_i, \gamma_o > 0$ are weight coefficients of the energy function.

2.2. The proposed segmentation model for hyperspectral image

In this paper, the C-V model has been modified and applied to hyperspectral image segmentation. The new model adds a spectral constraint term in energy function and it makes that interior region of the object contour has high spectral similarity. On the other hand, in order to utilize the spatial information, a band with high contrast between object and background is selected, in which a spatial constraint term is applied according to the intensity consistency of homogeneous region. Thus, the method in this paper makes full use of the spectral and spatial information in hyperspectral image. The modified energy function becomes

$$\begin{aligned} F_{HSI}(c_i, c_o, C) = \mu L(C) + \nu S(C) + \gamma_i \int_{inside(C)} |I(x,y,\lambda_i) - c_i|^2 \, dxdy \\ + \gamma_o \int_{outside(C)} |I(x,y,\lambda_i) - c_o|^2 \, dxdy + k \int_{inside(C)} \Delta\left(\beta(x,y), \beta_s\right) dxdy \end{aligned} \qquad (2)$$

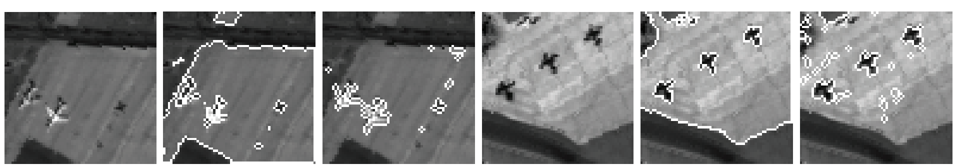
Compared with (1), the last term is augmented in (2), i.e. the spectral constrained term. Where, $\beta(x, y)$ is the vector of point (x, y), β_s is the vector of the seed point which can be either any point inside the object or the mean spectral vector of object region. $\Delta(\alpha, \beta)$ denotes the distance of vector α and β. Spectral constrained term describes the spectral similarity between the point inside the active contour and the seed point. Only if their similarity is highest, can $F_{HSI}(C)$ reach the minimum.

Another condition to minimize $F_{HSI}(C)$, the spatial restriction in energy function, is to evolve the contour to the boundary of two regions by using the gray consistency of homogeneous region. While time is taken into account, a band with high contrast between object and background is selected from hyperspectral image. The spectrums of object and background are considered as two stochastic vectors, the expectations of which are $E[\alpha(\lambda_i)]$ and $E[\beta(\lambda_i)]$, $i = 1, 2, ..., n$, and variances are both small. Specially, the contrast between object and background in ith band is the ratio of $E[\alpha(\lambda_i)]$ and $E[\beta(\lambda_i)]$. Given a threshold T, the band with high contrast is selected by using (3), and applied to the spatial items of energy function in (2).

$$\frac{\max\{E[\alpha(\lambda_i)], E[\beta(\lambda_i)]\}}{\min\{E[\alpha(\lambda_i)], E[\beta(\lambda_i)]\}} > T \tag{3}$$

3. EXPERIMENTS AND RESULTS

In order to verify the effectiveness and adaptability of the proposed method, experiments are conducted on two AVIRIS HSIs whose spatial resolutions are 3.5m and 20m, respectively. The first two experimental subsets with 3.5m' spatial resolution are shown in Fig.1(a) and Fig.(d). Let $\mu = 1000$, $\nu = 0$ and $\gamma_i = \gamma_o = k = 1$. The initial contour is a circle, the center of which is selected as the centre of the image and the radius of which is 10 pixels. The seed point can be any point of the object. The evolvement results are shown as Fig.1(b) and Fig.1(e) The segmentation results of Ball and Bruce method without classification stage, are shown in Fig.1(c) and Fig.1(f). The difference of preliminary results can be seen, such as the plane in Fig.1 (b) and Fig.1(c).



(a) (b) (c) (d) (e) (f)

Fig.1 Original images and preliminary results

(a)(d)Experimental image, (b)(e)Our method, (c)(f) Ball-Bruce's method

Chan-Vese method can extract the contour of single object, but can not extract multiple objects from complex scene. The proposed method is based on Chan-Vese model and still has the same limitation. In fact, hyperspectral image usually include not only one object, but complex multiple objects or materials. In order to check the adaptability of the proposed method, a complex AVIRIS hyperspectral image with 20 m' spatial resolution (Fig.2(a)) acquired over Indiana remote sensing test site is used in this experiment. And the analysis for the results will be continued and quantitative evaluation will be provided in the final paper.

(a) (b) (c) (d)

Fig.2 Adaptability of the methods (a)Experimental image, (b)Ground truth, (c)Our method, (d)Ball-Bruce's method without classification stage

4. CONCLUSION

A new segmentation method for hyperspectral image is proposed on the basis of active contour model in this paper, to which a spectral constraint item has been augmented. The method integrates spatial and spectral information to the model, and the usage of global information of image during segmentation reduces effectively the influences of margin vagueness and shadow nearby objects owing to the spatial resolution insufficiency. The experiments show that the new method can obtain the contour of objects in the simple scene and has better segmentation performance than some other method. At the same time, it also has good adaptability to complex scene. However, the method is slow because of the limitation of original model and non-object regions will be extracted unless the restriction of the operation scope.

5. REFERENCES

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