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APPLICATION OF COARSE TO FINE LEVEL SET SEGMENTATION IN SATELLITE IMAGES

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ABSTRACT

Segmentation of vegetated areas is inevitable in precision agriculture and has high importance in urban area with social and environmental aspects. This paper addresses the segmentation of fused high resolution multispectral satellite images into distinct regions such as vegetation, buildings and barren land. Even though the IHS based fusion of satellite imagery improves the visual interpretation, it results in color distortion which can be nullified using vegetation indexes(VI).The vegetated area can be depicted using high resolution normalized vegetation index and to detect the distribution of vegetated area, soil classes, buildings and barren land. For that the coarse-to-fine level set method is used. Undecimated wavelet transform is adopted to separate focused areas from the background. Homogeneity metric is used to measure the variation inside and outside the contours. The weight distribution ratio is proposed to adaptively tune the relative weight of the features. Based on the homogeneity metric and the weight distribution ratio, a novel energy functional is developed to solve the contour extraction problem and a coarse-to-fine scheme is applied to progressively extract contours in finer scale which also reduces the computational burden.

Keywords: *Contour Extraction, Homogeneity Metric, Level Set Methods, Intensity-Hue-Saturation (IHS) Transform, Vegetation Enhancement*

1. INTRODUCTION

Segmentation of fused remotely sensed images provides exact delineation of different landscape patches. The accurate segmentation of vegetation helps in precision agriculture, finding rare species of plants in forest area, unauthorized plantation in interior forest and mapping of urban green for effective management and protection. Images from satellites with enhancement using the advanced technologies of remote sensing provide detailed and accurate information about land use for management and planning. Remote sensing data and its software processing represents powerful tool for creation of thematic maps.

Simultaneously obtained remote low resolution multispectral (MS) images and high resolution panchromatic (PAN) images from earth observation satellites has to be fused to get a high resolution image[1][2]. High resolution multispectral images are efficient for classifying both homogeneous and heterogeneous objects. A large variety of vegetated images are available from satellites and we need efficient methods to extract the vegetation. For obtaining the high resolution image the most commonly used fusion technique is intensity hue saturation (IHS) which make use of three bands of multispectral image but when the fourth band NIR is included GIHS [1] is used. But neither IHS nor GIHS produce an image without distortion, so an enhancement step is to be included. A method of weighted average is described [13] which restrain spectral degeneration. As the focus is on vegetated area, an enhancement technique using vegetation index is used [4]. In this paper high resolution vegetation index is used and the resultant enhanced vegetated images are used for segmentation [1]. The coarse to fine segmentation method include a number of steps which results in the exact contours [5].

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The relevance of this paper is to have a three dimensional segmentation whose image is obtained by applying a fusion algorithm which safeguards the spatial properties of PAN and spectral properties of MS image. The fusion is done with GIHS method with some spectral adjustment [1]. After enhancing, Intensity difference is calculated using haar filter and passed to the homogeneity metrics [5]. The homogeneity metric measures the variations of images inside and outside contours. Based on the homogeneity metrics discriminative ability is also calculated. Weight distribution ratio is calculated to tune the relative weight of the images. The result of homogeneity metrics and the weight distribution ratio leads to novel energy function. The purpose of novel energy function is to solve contour extraction problem. Finally coarse to fine level set is implemented by Euler Lagrange equation to reduce the computation cost.

This paper is organized as follows. Section 2 is divided into three which discusses the related works. Section 3 presents the architecture and model. Section 4 is about the problem definition. Section 5 presents the implementation of the proposed algorithm and the performance analysis. Section 6 contains the conclusion.

2. RELATED WORKS

2.1. FUSION AND SEGMENTATION

Various fusion methods based on PCA, Brovey, wavelet and IHS exist for obtaining a high multispectral image resolution image .As we consider vegetated area, the fusion should be free from color distortion and the latest IHS techniques proposed by M. Mezouar, N. Taleb [1] helps in achieving the same. And for segmentation [10] tells about a hierarchical method of segmentation and [11] of a region based method. This paper proposes a new approach which makes use of Euler Lagrange equations [5].

2.2. IHS FUSION AND ENHANCEMENT

IHS fusion is most commonly used fusion technique and it uses an RGB image consisting of distant bands and transforms them into the IHS space, and the intensity component is replaced by PAN and is transformed back to original RGB space. The IHS fusion for each pixel is discussed in paper [2] [3].

R', G' and B' are the corresponding values to RGB in the fused images.

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} R+\delta \\ G+\delta \\ B+\delta \end{bmatrix} \quad (1)$$

From the above equation a much more efficient method Fast IHS (FIHS) is computed. Even though FIHS fusion provides the full details of PAN, introduces certain distortion due to the difference in PAN and Intensity (I). Two algorithms exists which reduces the difference (δ) by generating an I component close to PAN. In this the Near Infra Red (NIR) component is added and the first method is termed as Generalized IHS(GIHS) whose intensity value is calculated by

$$I=(R+G+B+NIR)/4 \quad (2)$$

and the second method is spectral adjustment IHS which include a weighting coefficient which is related to the spectral characteristics of the sensors[14]. The intensity calculation for SAIHS is termed as

$$I=(R+aG+bB+NIR)/3 \quad (3)$$

where 0.75 and 0.25 corresponds to a and b, respectively, are found to be suitable for fusion.

Next step is the enhancement of the vegetated area, but before enhancement the vegetated area has to be detected and is performed with high resolution normalized index [1] [4].

$$HRNDVI = 2\,\frac{NIR-R}{NIR+R-B+4PAN-G} \quad (4)$$

and If HRNDVI is greater than 0 .15 the green bands are enhanced using

$$\begin{bmatrix} G' \\ B' \end{bmatrix} = \begin{bmatrix} G+\beta\delta_4 \\ B'-\beta\delta_4 \end{bmatrix} \quad (5)$$

β is set to 0.25 which gives a natural look in the vegetated areas.

The fused bands are computed using

$$\begin{bmatrix} R \\ G \\ B \\ NIR \end{bmatrix} = \begin{bmatrix} R+\alpha\delta_4 \\ G+\alpha\delta_4 \\ B+\alpha\delta_4 \\ NIR+\alpha\delta_4 \end{bmatrix} \quad (6)$$

Where $\alpha = 0.6$

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2.3. AREA EXTRACTION AND NOVEL ENERGY FUNCTIONAL MODEL

Here we extract the object from background by using undecimated wavelet transform (UWT) [12]..The undecimated wavelet transform is selected because it is shift invariant and produces sub bands of same size as the input image.

There are three types of undecimated wavelet transform (Discrete cosine transform).

i) Hough Transform

ii) Haar filter banks

iii) Daubechies

The haar filter banks are used to calculate the intensity difference between object and the background [5], [6].

Homogeneity metric is used to measure the variation of the images inside and outside contours. So this homogeneity is calculated based on the intensity difference using haar filter. The homogeneity metric of d^i in region Ω_k(k=0,1,2)is defined by

$$E(d^i,\Omega_k) = \int (d^i(x,y)-d_k^i)^2 dxdy \qquad (7)$$

The discriminative ability of d^i can be measured by

$$\eta(d^i,c)=\frac{E_{i,0}+\varepsilon_0}{E_{i,1}+E_{i,2}+\varepsilon_0} \qquad (8)$$

Where d^i_k is the mean value of d^i over region Ω_k. Weight distribution ratio is used to tune the relative weight of the features. And this weight distribution ratio is calculated based on discriminative ability component.

$$\xi(d^i,c)=\frac{\eta(d^i,c)}{\sum_{j=1}^{4}\eta(d^j,c)} \qquad (9)$$

2.4. COARSE TO FINE LEVEL SET SCHEME

The purpose of this scheme is to reduce the resolution level at a time. It consists of three sub modules.

2.4.1. Coarse Scale Extraction

The purpose is to minimize the energy function, which is the summation of weighted homogeneity metric of four components in a region. The four components are haar filter, homogeneity metrics, and discriminative ability component and weight distribution ratio

$$F_N(c)=\mu\int|\nabla H_\phi|dxdy+\sum \xi_{i,c}\int(d^i-\bar{d}^i_1)^2 H_\phi\, dxdy + \sum_{i=1}^{4}\xi_{i,c}\int_{\Omega 0}\left(d^i-\overline{d^i_2}\right)^2(1-H_\phi)\,dxdy \qquad (10)$$

2.4.2. Fine scale Contour Extraction

Contour position constraint is used to reduce the contour evolution space to a small region it is obtained by the following equation

$$R_\alpha(x,y)=\exp\left(-\frac{d(x,y,\gamma_\alpha)-1}{2}\right) \qquad (11)$$

2.4.2. Euler Lagrange Numeric Solution

In order to minimize the uniform level set functional, we deduce the associated Euler Lagrange [5] [7] [8] equation for ϕ by introducing the artificial variable t to ϕ .The Equation

$$\frac{\partial\phi}{\partial t}=\delta(\phi)R_\alpha\left[\mu\,div\left(\frac{\nabla\phi}{|\nabla\phi|}\right)-\sum_{i=1}^{4}\left(\xi_{i,c}\left(d^i-\overline{d^i_1}\right)^2-\xi_{i,c}\left(d^i-\overline{d^i_2}\right)^2\right)\right] \qquad (12)$$

Fine scale can be implemented by Euler-Lagrange equation.

It solves the contour extraction problem.

3. ARCHITECTURE AND MODELING

Many a time's data gathered from remote sensing satellites provides excellent possibilities for mapping, monitoring, measuring, and managing various earth surface features. This helps in areas where only limited fieldwork is possible. The architecture and modeling of the proposed algorithm is shown below.

The step by step process of fusion and the segmentation is shown in figure 2. It begins with the panchromatic image, multispectral image of the same location. The IHS fused image, the vegetation enhanced image and the segmentation using coarse to fine level set is shown in figure2.

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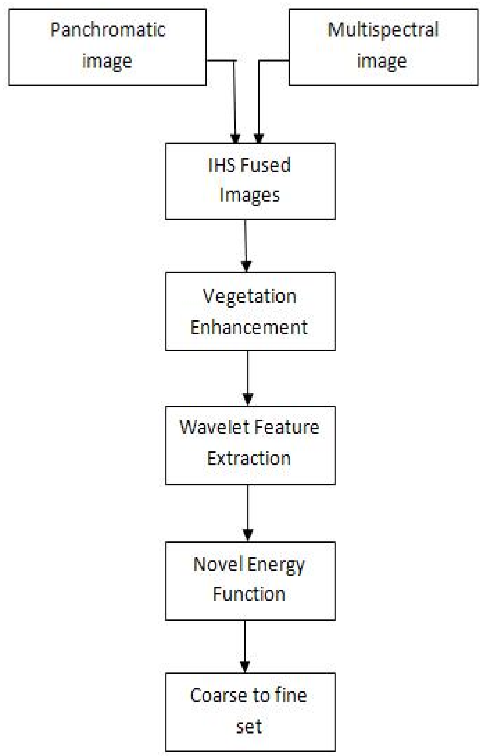

Fig.1 Block diagram for Fusion and Segmentation

Figure 1 shows the flow of the algorithm for fusing images and segmentation into distinct regions.

4. ALGORITHM

Given satellite imagery the target is to fuse the image, enhance the vegetation and segment using Euler Lagrange.

Step 1: Input panchromatic and multispectral image.

Step 2: Perform IHS fusion where the I value is calculated using (3) and δ value is difference of PAN and I.

Step 3: Calculate the HRNDVI index.

Step 4: Enhance the Vegetation.

Algorithm for fusion and enhancement

Step 1: Input the Enhanced image.

Step 2: Eliminate noise from the image.

Step 3: Distinguish image from background using haar filter

Step 4: Calculate homogeneity metric and weight distribution ratio.

Step 5: Based on this novel energy functional calculated.

Step 6: Segment the image into distinct regions like residential area, vegetation and barren land.

Algorithm for coarse-to-fine-segmentation

5. IMPLEMENTATION AND PERFORMANCE ANALYSIS

The two algorithms one for fusion and another for segmentation is implemented using MATLAB 7 and JAVA 6 respectively. The performance analysis of fusion is shown in table 1. And the vegetated area is accurately segmented where the vegetation enhancement plays a vital role. Removal of noise and low resolution image generation are done by haar wavelet transform. The advantage of haar filters is referred [6]. The segmentation of vegetation is done by passing the green intensity pixel value as the input to the Euler Lagrange numeric solution and ten iterations are done for obtaining the segmentation. Euler Lagrange is mainly for segmenting 2D objects. As the buildings in the image appear as 2D it can be directly applied to Euler Lagrange and results in 3D objects. The difference of the original image and the combination of vegetated area and building will give the barren land. The number of iterations is eight for both buildings and barren land. In objective analysis, the method in [7] is adopted to evaluate the accuracy of extracted contours. The success score is the number of pixels contained in regions both inside ground-truth and extracted contours divided by the regions inside the ground-truth or the extracted contours .And the success score is near to 1 for all the segments. This proves the efficiency of segmentation

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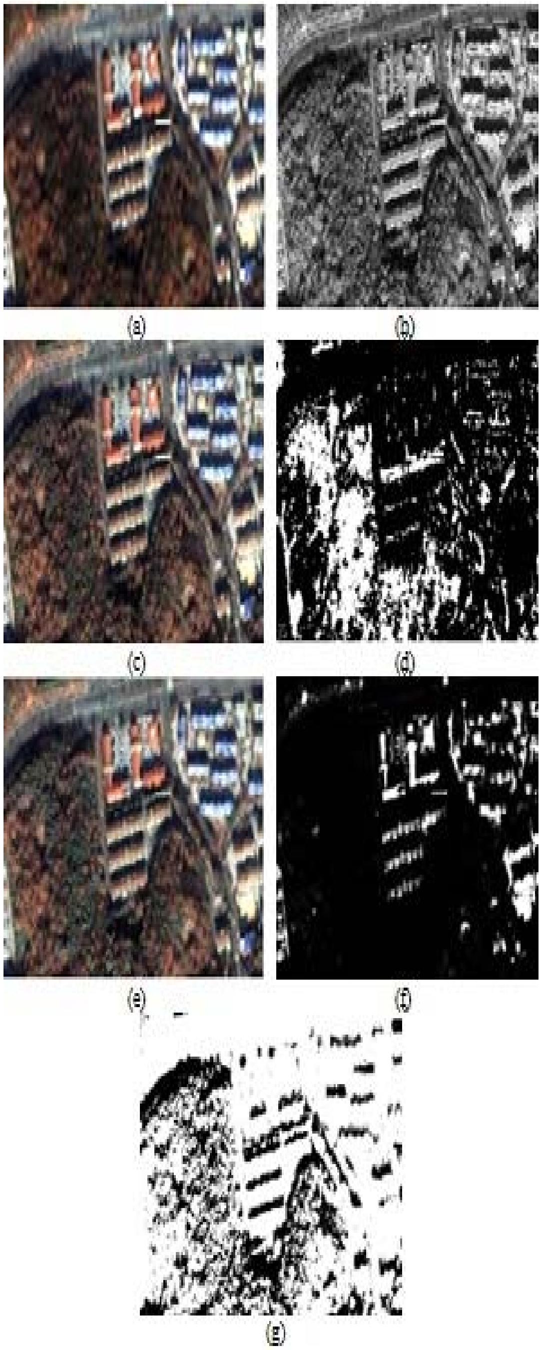

Fig.2 (a) Multispectral Image (b) Panchromatic Image (c) SAIHS Fused Image (d) Vegetation Detection (e) Vegetation enhanced Image (f) Building (g) Vegetation Area

Parameters	IHS Fusion
Mean Input	81.954531
Mean Output	89.672349
Relative Bias	0.094172
Relative Variance	0.011154
Standard Deviation	0.012126
Correlation	0.915645
SAM	15.061873
UIQI	0.994825
ERGAS	7.6835

Table 1. Performance Measures

6. CONCLUSION

This paper presents a new approach for segmenting the satellite images. The capability of this method is appreciable as it is computationally efficient and provided good results in terms of objective and subjective evaluations. As the areas are so accurately segmented the paper can be extended for counting the number of trees in a plantation [9], for segmenting different types of herbs and can be used for urban development and precision agriculture.

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