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A NEW SATELLITE IMAGE SEGMENTATION ENHANCEMENT TECHNIQUE FOR WEAK IMAGE BOUNDARIES

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ABSTRACT: *Level Set Method (LSM) and Snakes Method (SM) are two different procedures used in image processing to determine objects location and boundaries. In this research, a new algorithm for image processing of the weak gradient features was developed to improve the overall image boundary detection system. This algorithm was based on the active contour model in conjunction with LSM to enhance images detection. The algorithm presented a new technique to incorporate the advantages of both LSM and SM. In proposed algorithm, different bands of satellite image for a specific region were extracted from the satellite scene. Then, the obtained image was improved by linear combination. After that, the initial image segmentation of satellite bands produced by LSM was transformed and used as an input for the SM and began its evolvement to interested object boundary. The results showed that the algorithm can deal with low contrast images and features, and demonstrates the segmentation accuracy under weak image boundaries which responsible for lacking accuracy in image detecting techniques. Thus, proper segmentation and boundary detecting for the satellite images were achieved. The ability of the system to improve low contrast images and low gradient features increased with no over and under segmentation.*
KEYWORDS: *Remote Sensing, Image Segmentation, Boundary Detection, Feature Extraction*

INTRODUCTION

Image Feature Extraction is a useful method for Image Segmentation Technique in Digital Image Processing. In this method, binary image is analyzed for desirable feature. Because of too much information and high value of Signal-to-Noise Ratio in satellite images, the automatic feature extraction is not possible and this process is done manually [8]. There are different methods for Image Segmentation. In these methods, optimized results are visually determined by the user. The user should enter the important information for Segmentation Algorithm. This information includes number of classes or initial seeds of segment(s) of input data.

Geometric deformable models, such as active contours (or Snake Method: SM) and Level Set Method (LSM), are used extensively in image processing applications including region-based and edge-based extraction of features [3,4]. Some of the applications of these methods are land features detection in satellite imagery and detection of the object limits in medical image analysis. Both of these methods use energy minimization to find image features regions or edges, but have their own advantages and limitations. The initial segmentation by Topological Alignments is firstly transformed into the input of the snake model and begins its evolvement to the interested object boundary [1]. In a research, a precise mathematical relationships between the algorithms is presented for an extensive family of active contour and surface models, encompassing spatially varying coefficients, both tension and rigidity, and both conservative and non-conservative external forces [13] . According to [9], roads were extracted using high resolution satellite images based on LSM and mean shift methods. The main idea in that research was segmenting image into two classes – Roads and non-roads - by remaining the roads classes from an unsupervised classification and a nearest neighborhood grouping operation applied to the result of classification. Finally, LSM extracted the roads from result image. Hinz automatically extracted objects for change detection and GIS update depends on user clicks. However, proposed method in this research also needed user clicks in the SM stage. The final object was extracted by fewer clicks because of low amount of unassociated features remains in the image [5].

In this research, a new algorithm was developed for image processing of weak gradient features to eliminate the defects of both former algorithms. The proposed method uses these algorithms on the image respectively. The feature image obtained by LSM method considered as the input of SM and boundaries of determined regions was extracted by LSM.

SNAKE METHOD (SM)

Snake Method (SM) is a parametric curve defined in the image domain by the equation (1) and is one of image segmentation algorithms [6].

$$v(s)=(x(s),y(s)) , \quad s\in[0,1] \tag{1}$$

Snakes are initial contours defined in the image domain that can move under the influence of the vector field created by local grey-level gradient of the desired feature in image, and can lead the curve *to the boundaries of image. In this method, final extracted boundary will be continuous, because curve deformation is done with initial continuous contour. When we want to have no discontinuity in extracted boundary of a feature, we have to use the SM. Because of definition of Energy functions in this method, a continuous curve was fitted to the surface of the features at the sections of boundary that have discontinuity, and finally a continuous function in the boundary was fitted to discontinuous function that can be the initial boundary. Equation (2) shows the energy function in SM [14].*

$$E_{Snake} = W_1 \int_0^1 E_{Internal}(v(s))ds + W_2 \int_0^1 E_{Image}(v(s))ds \tag{2}$$

where $E_{internal}$ represent the internal curve deformation energy and can be written as equation (3).

$$E_{Internal} = \frac{1}{2}\int_0^1 (\alpha(s)|v'(s)|^2 + \beta(s)|v''(s)|^2)ds \tag{3}$$

where α(s), β(s) specify the elasticity and stiffness of the snake.
E_{image}, also in more cases known as $E_{external}$, represents the force developed by the change in gradient of grey-level in the image and can be derived from equation (4) as below.

$$E_{Image} = -|\nabla I(x,y)|^2 \tag{4}$$

where I(x, y) is the intensity of image grey-level.
The GVF (Gradient Vector Flow) field in both direction x and y - which represented by u and v – must satisfy the equation (5) (Euler Equation) to create the external force.

$$\begin{aligned} u_t &= u + \mu\nabla^2 u - (u - f_x)(f_x^2 + f_y^2) \\ v_t &= v + \mu\nabla^2 v - (v - f_y)(f_x^2 + f_y^2) \end{aligned} \tag{5}$$

where f_x and f_y are gradients in x and y directions respectively.

The limitation of feature extraction from satellite image by using SM is that the input image for this method must be binary and region of interests in pre-processing must be well segmented to prevent creation of energy valleys at the desirable feature boundaries [2,7]. If aggregation of irrelevant grey-level of features in the image has a high value, the resulted external energy will be significant and cause the deviation of points of initial contour. Therefore, the results will not proper. Because of high details in satellite images, a pre-processing on the input image was necessary to eliminate the irrelevant features in this algorithm. Before SM processing on the image, LSM was used for image segmentation. The principal of LSM was changes in grey-level gradient on boundaries, and there was no need to Threshold definition.

LEVEL SET METHOD (LSM)

Because of using Local Grey-level gradients, there was no need to initial parameters definition in LSM, and image segmentation was done automatically [11]. One of the limitations in this method was over segmentation, because this method was defined on the concept of Local Gradients. Over segmentation included of abundant segments with the shape of points and small lines everywhere in the resulted image by the LSM. For example, we could identify a region as a segment visually, but this method divided it to the smaller segments. Therefore, merging technique was used beside the LSM for Segmentation to identify the boundaries of segments properly. The defects of LSM were surmounted by the using of SM simultaneously.

At the beginning, defined initial curve split the image into two segments (inside of the curve segment and outside of the curve segment). This curve created an energy field in the image and caused every curve gathered to its center of gravity. The grey-level features that positioned crossover with the points on this curve, was shifted to create a hole inside the regions of features. These functions and convolution of Dirac delta or Heaviside Functions (equations (6) and (7)) were done on the image points in the initial curve simultaneously [12].

$$\delta_\alpha(\phi) = \begin{cases} 0 & , \quad |\phi| > \alpha \\ \frac{1}{2\alpha}(1 + \cos(\frac{\pi\phi}{\alpha})) & , \quad |\phi| < \alpha \end{cases} \tag{6}$$

where; δ is the Dirac Delta function, $\propto$ is the interval around the boundary and ϕ is the initial curve in image domain.

$$H_\alpha(\phi) = \begin{cases} 1 & , \quad \phi > \alpha \\ 0 & , \quad \phi < -\alpha \\ \frac{1}{2}(1 + \frac{\phi}{\alpha} + \frac{1}{\pi}\sin(\frac{\pi\phi}{\alpha})) & , \quad |\phi| < \alpha \end{cases} \tag{7}$$

where H is the Heaviside function. Formulation of LSM to reach the zero-level set is defined as equation (8).

$$C=\{(x,y)|\phi(x,y)=0\} \qquad (8)$$

Thus, the Chan-Vese energy functional is calculated by equation (9).

$$C(\phi,a_1,a_2)=C_1(\phi,a_1,a_2)+C_2(\phi,a_1,a_2)=\int_{inside(\phi)} H_\alpha(\phi)(I(x,y)-a_1)^2dxdy+\int_{outside(\phi)}(1-H_\alpha(\phi))(I(x,y)-a_2)^2dxdy \qquad (9)$$

where I(x, y) represents the Intensity of grey-level input image and Constants a_1 and a_2 represents the mean Intensities of the interior and exterior of the segmented objects. In order to find the minimum value of $C(\phi, a_1, a_2)$, we had to find its derivatives and set them to zero. By taking Euler-Lagrange equation and update C1, C2 and ϕ recursively, they can be written as equation 10.

$$\begin{cases} C_1(\phi)=\dfrac{\int_{inside(\phi)} H_\alpha(\phi)I(x,y)dxdy}{\int_{inside(\phi)} H_\alpha(\phi)dxdy} \\ C_2(\phi)=\dfrac{\int_{inside(\phi)} (1-H_\alpha(\phi))I(x,y)dxdy}{\int_{inside(\phi)} (1-H_\alpha(\phi))dxdy} \end{cases} \qquad (10)$$

where C1 and C2 minimize the Chan-Vese energy functional C (Equation (9)) utilizing (Equation (11))

$$\frac{\partial\phi}{\partial t}=\delta_\alpha(\phi)(v\,\mathrm{div}(\frac{\nabla\phi}{|\nabla\phi|})-(I(x,y)-C_1(\phi))^2-(I(x,y)-C_2(\phi))^2) \qquad (11)$$

where v represents the area inside ϕ. The input image was divided into two regions by using Eq. (11) - inside and outside of the feature - and finally the binary image was resulted.

FEATURE EXTRACTION

Flow chart of extracting feature boundaries is shown in figure 1. Since there were no access to satellite stereo images with high quality to feature extraction; therefore, we used Single Multi Spectral Quick-Bird Imagery (© Quick-Bird Image Copyright 2011) with Basic Imagery and Standard Imagery types (Figure 2). The purpose of basic Imagery in this sensor was images with the lowest amount of processing (geometrically raw) and another purpose was Standard Imagery with radiometric and geometric correction and delivered in map projection.

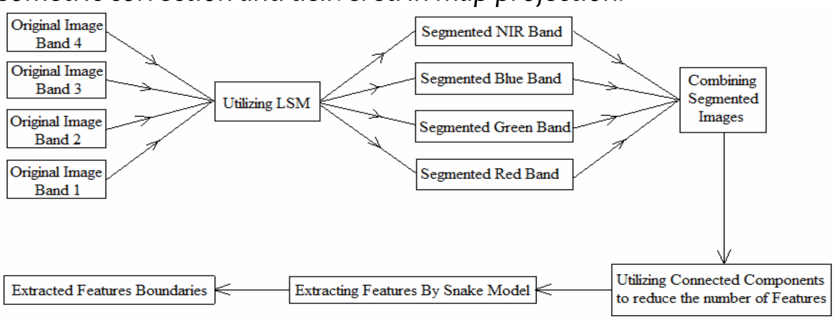


Figure 1. Flow chart of extracting feature boundaries using active contour model in combination with region-based LSM result, reduced by connected components method

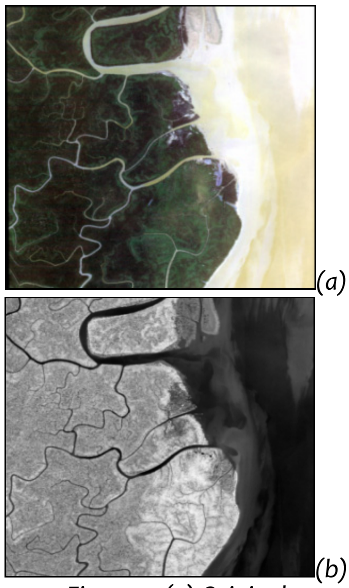


Figure 2. (a) Original multispectral satellite image. (b) Original Panchromatic satellite image

LSM REGION EXTRACTION

The sensor imagery contained three visible spectral bands and a Near Infrared band and a panchromatic band. There were four different spectral bands in each scene (Figure 3). The Panchromatic image with high spatial resolution was available; but using this image resulted abundant segments, because of containing of high details. Therefore, after doing the LSM without threshold, obtained result would be an image with a large number of segments. The obtained segments were not due to the desirable feature and we had to eliminate the extra segments in the image (Figure 4(b)).

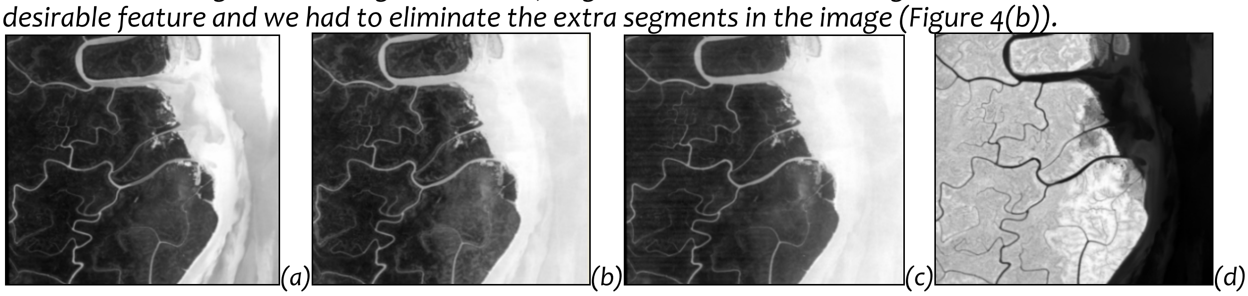
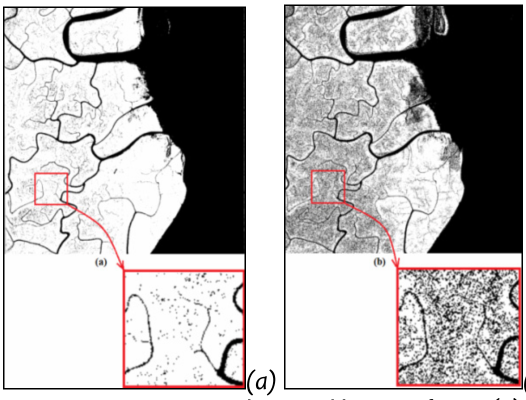


Figure 3. (a) to (d) Original satellite images in Red, Green, Blue, NIR bands



(a) (b)

Figure 4. Features detected by LSM from, (a) Multispectral image , (b) Panchromatic image.

We can see over segmentation in panchromatic image.

USING CONNECTED COMPONENTS TO REDUCE REGIONS

In this research, connected components and remaining of features with the minimum length were used to eliminate small components in the image [10]. Since one of the objectives in this study was accessing enhanced image in the region, therefore with compounding of four NIR and visible spectral bands, an image would be obtained. It should be mentioned that if only a band is used for segmentation, under segmentation will be occurred and feature will not be detected. As a result, with using of these four bands, an image with the maximum number of useful features may be created (Fig. 4(a)). In this research, The LSM algorithm was used for each band individually and finally, linear compounding of these four results was calculated. In this case, maximum number of features and their details in four visible and infrared bands were extracted from the image without creation of over segmentation. After that, the extra features were eliminated by using connected components. The resulted image had only desirable feature and a small number of other features. Then, the boundaries were extracted using SM.

Snake Method

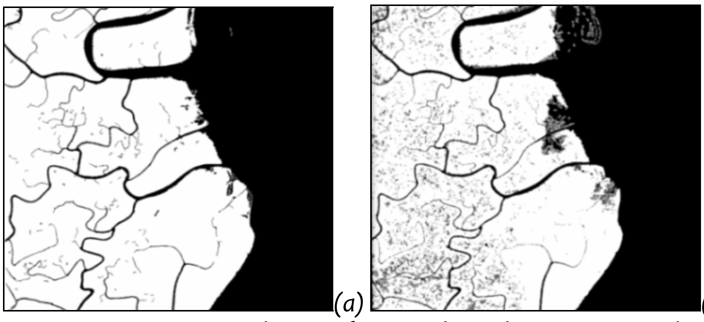
The boundaries of the image including desirable features were extracted with the SM. A contour was considered around the image and began to contract and approached to the features boundaries. At last, with achieving this curve to the local image constant gradient with take into account elasticity and stiffness of the snake, finally stopped there. Therefore, we could extract the desirable feature boundary.

NUMERICAL SOLUTION

LSM Region extraction was done for four bands of input image and four binary images were resulted. Then, the average of these images was calculates by equation (12). The desirable feature details of obtained image increased and other details were decreased (Figure 4(a)).

$$Segment = \frac{seg1 + seg2 + seg3 + seg4}{4} \qquad (12)$$

In equation (12), seg1 to seg4 stand for segmented images of NIR, Red, Green and Blue bands. The image features were limited by definition of minimum length of each connected component. The results presented in this paper were based on feature extraction, such as coastline, forest boundary and river. The features were linear and their length is much more than their width. In connected components definition, the minimum length of feature was defined for estimating it as a component. Length of 20 pixels was considered for connected component to estimate it as a part of linear feature of river or coastline or forest boundary (Figure 5). After Contrast improvement, if the segments remain ruptured, the SM can eliminate these ruptures without making sharp changes in the general form of the features (Figure 6).



(a) (b)

Figure 5. Decreased image features by utilizing connected components. (a) Multispectral image, (b) Panchromatic image.

Figure 6. Extracted rivers boundary by snake method

CONCLUSIONS

Satellite scenes of Quick-Bird Sensor that exist in every region contain four spectral domains in visible and NIR domains. Since every topological features show different spectral responses for spectrums, it is possible to use maximum information of every feature by using these four domains information simultaneously. Beside these four spectral domains, Panchromatic Image with high local segmentation was presented by sensor, but the details were significant and the boundaries might be changed. The proposed algorithm was compared with traditional SM and LSM separately. The results showed that combining both of these methods in conjunction with connected components, can demonstrate the accuracy of under and over *segmentation of linear objects in the satellite images. Also the features with low possibility of extraction by an image were detected properly. This algorithm can deal with low contrast features in the images.*

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