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Importance of Mean Shift in Remote Sensing Segmentation

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Abstract: *The segmentation of an image can be considered as a preprocessing step for many of the algorithms such as object detection and identification. Many algorithms exist in the field of remote sensing for segmentation, in every case the desirable output of segmentation is a well defined region or features of object which can be distinguished from another. The desirable features include well based edges, gradients, textures etc. For a real world image the desirable features are difficult to identify. With the advancement of the high resolution imagery, the features which defined the object are too finely defined. It also contains noises which are due to fine edges, gradient variations and non-uniform textures. Segmentation algorithms are plenty in image processing which can be broadly categorized as edge based, color based and textured based. Edge based techniques fails due to the noise content. Textures are not uniform in real world images leading to problems of segmentation. Color based techniques need homogeneous regions which can distinguish objects, which will be difficult with the gradient variation. Defined in this paper is the importance of non-parametric clustering technique called Mean Shift, which in its inherent nature is able to cluster regions according to the desirable properties. The paper is a study on Mean-shift and its probable use in clustering of remote sensing imagery. Rather than a theoretical paper, the paper is arranged as an application based survey which can show the possible use and importance of mean shift in remote sensing.*

Keywords: *Mean shift, Remote sensing, Segmentation*

I. Introduction

Segmentation is an image processing technique which is nearly an unavoidable preprocessing step. There are many techniques used for segmentation in the field of IP, which can be adapted to remote sensing applications. Adapting the algorithm to remote sensing is same as using the techniques for real world datasets. For a remote sensing system the desirable output of segmentation are well defined regions or features of object which can be distinguished from another. These features are affected by the homogeneity of regions. Homogeneity can be recognized as same color or same texture for a region. The remote sensing images of a natural region such as forest have regions of greenery more. This helps in the segmentation of those regions which may be a good part of the image. If it is an urban image the number of regions will be more with lots of small homogenous regions.

In real world remote sensing imagery, the homogeneity may not be evident as expected. There will often be small gradient and textural variation. The images also may contain large number of regions, which may not be known prior to execution. These interfere in the segmentation steps and further processing using those regions. Some of the earlier version of segmentation included edge based, contour based, model based, template based and also region based segmentation.

Schiewe [1] has stated the usage of edge based segmentation as having the problem of giving large number of edges, due to trees in natural images and blocks in urban areas. The edges were needed then to group and form meaningful geometry. The algorithms are not viable, due to the reason that edge grouping to segment a region with specific geometry is of non-polynomial complexity. Using region based segmentation techniques such as K-Means segmentation techniques [2] has the inherent disadvantage of knowing the number of regions prior to segmentation, which is not known in real world cases. Contour based techniques such as Active contour models [3], sometimes used in remote sensing also has the problem of knowing the approximate location of the region and also the noises will hinder its performance. A template based approach [4] is not scale invariant and using multiple scales is not suited in real time detection. Color based segmentation is also not suited for the problem due to the fact that the object may have gradient variation and color ranges.

Schiewe [1] has also given an overview of the use of segmentation technique in remote sensing. He has stated some of the method with example and also given some of the applications in which segmentation can be used.

This paper is organized such that the next section describes about the challenges in segmentation, followed by the solution to the challenges which is identified as the technique known as mean shift segmentation. A case study is also presented as proof.

II. Challenges Of Segmenting A Remote Sensing Image

Segmenting a real world image is always been a difficult task. Many algorithms are implemented in ideal image which are developed based on situations. Segmentation of remote sensing images requires identifying solution to the following challenges

- Cluttered background
- Gradient variations causing multiple small regions
- No specific texture or color for oil depot
- Overlapping shadows
- Number of regions unknown
- Noise level is high in real images

III. Mean Shift Based Segmentation

Mean shift is a non parametric clustering technique which is not affected by the small variation of points. It is a powerful unsupervised data analysis technique which does not require prior knowledge of the number of clusters, and does not constrain the shape of the clusters. Comaniciu et al. [5] and Boukir et al. [6] have done studies on Mean shift and have put forward the advantages of using Mean Shift as a segmentation process in the remote sensing images.

The advantages of the mean shift are:

- Smoothens regions or clusters
- Considers cluster size, avoids small clusters below threshold
- Cluster number is not a parameter.
- In segmentation it is color and texture independent
  Mean shift is an iterative method. The segmentation algorithm can be broadly classified into 3 stages.

- Mean shift filtering stage
- Pixel and region clustering stage
- Pruning stage

The filtering stage smoothen the image and tries to rectify noises, gradient variations and textural variations. After filtering the clustering is done so as to cluster together homogenous regions according to their color proximity. Finally a pruning method is implemented to avoid small regions which may be occurring due to noises.

In the filtering stage for each data point, mean shift defines a window around it and computes the mean of data point. Then it shifts the center of window to the mean and repeats the algorithm till it converges. A kernel function $K(x_i - x)$ is defined. This function determines the weight of nearby points for re-estimation of the mean. Typically Gaussian kernel on the distance to the current estimate is used, $K(x_i - x) = e^{-c\|x_i - x\|^2}$. The weighted mean of the density in the window determined by K is:

$$m(x) = \frac{\sum_{x_i \in N(x)} K(x_i - x) x_i}{\sum_{x_i \in N(x)} K(x_i - x)} \qquad (1)$$

where $N(x)$ is the neighborhood of x, a set of points for which $K(x) \neq 0$. The mean-shift algorithm now sets $x \leftarrow m(x)$, and repeats the estimation until $m(x)$ converges.

The clustering stage is divided into two. The first one known as pixel based clustering cluster together spatially closer pixels into homogenous regions according to their color proximity. The second clustering is a segment based clustering which clusters together spatially closer regions formed from the first cluster into homogenous regions according to color proximity.

The pruning stage is developed so as to remove small regions which are of less importance for further processing. The smaller regions are mostly said as the regions formed by noisy parts. The smaller regions are then merged to larger regions and the final output of segmentation is provided.

IV. Applications Of Mean Shift In Remote Sensing

Described here are some of the papers which has applied mean shift in remote sensing images.

4.1. Forest mapping

Boukir et al. [6] have used a fast mean shift algorithm called path assigned mean shift, which is said to be 5 times faster than original mean shift. The method uses mean shift segmentation first to segment the image then as a second refinement used k-means algorithm to converge to a refined solution. The drawback of k-means is to have the prior knowledge of k. This is rectified by using the modes obtained from mean shift as cluster count in k-means. This algorithm is then used to segment images of forest sites. The main four classes of the image were defined as: soil, water hole, trees and shadows. The combination algorithm of mean shift with k-means was able to successfully segment out regions into the four classes. The drawback of mean shift is the high computation leading to more time to segment. In order to avoid this drawback the mean shift parameters (mainly spatial radius) are relaxed so that the computation is fast.

4.2. Segmentation of land covers

One of the most widely accepted application in remote sensing is the segmentation of land covers. Mean shift has been proven to have good results in this segmentation process.

Moacir and Ponti [7] have proposed a method of segmentation for low cost remote sensing systems. They applied vegetation indices used in remote sensing image processing along with mean shift in order to detect green coverage, gaps and degraded areas. The dataset used was of land images which are acquired from a low resolution 10 megapixel CCD sensor fitted on a helium gas balloon. The paper first applies mean shift as preprocessing to segmentation of the image, this removes texture and small irregularities by find the local maxima of regions and smoothing it out. The vegetation indices are applied to transform RGB to gray level image, increasing the green vegetation indices.

Torsten and Ostermann [8], proposed a method of combining mean shift with pixel wise classification. The image is processed with a pixel wise classification and mean shift in parallel. The results of the two are combined with a weighted majority voting scheme which allowed removing misclassifications of segmentation which may occur individually. The author used this method on regions having both green regions and urban regions. The approach aligns class labels to image edges to cope with the smoothing, which typically originates from classification of image content with varying scales. The smoothed classification results and noise was shown to be significantly reduced by this approach.

Xie et al. [9] have proposed a combination of spatial and spectral features to be used in segmentation of images. They proposed this algorithm taking into consideration that a single feature, either spatial or spectral may cause under segmentation of the regions. They applied a Gabor filter approach to finding the spatial and orientation features of images. The spectral image is chosen as the corresponding Lab color space of the RGB image. The combined feature is then passed to the mean shift clustering algorithm. The output of the mean shift is the segmented image. The algorithm was tested with synthetic texture image from a quick bird sensor.

4.3. Object segmentation

Tao et al. [10] used mean shift segmentation as a pre processing to object detection. The segmented regions are represented like a graph and the topological and geometric relations are assigned to each node. SST-minmax method is then used to merge the regions. The final segmented regions were found to successfully segment objects. The author verified this method by detecting a ship in the sea from an infrared image.

He et al. [11] had derived an algorithm based on mean shift and conditional random field (CRF) in order for extracting building objects from polarimetric SAR images. The algorithm is implemented by first applying the mean shift to extract homogenous regions. These regions are fed into a CRF classifier which classifies the regions into building structures or other regions. 3 classes of regions were expected in the paper mainly, they are the building structures, shadows and other regions such as background. The classifier was trained with a sample data set and is used for the classification.

V. Case Study on Segmentation of Remote Sensing Images

The mean shift procedure is applied on a remote sensing image containing oil storage tanks (Fig. 1(a)) which has minor noises, gradient variations and texture variations. The input image is taken from a GeoEye-1 satellite sensor which can have a resolution of 0.5m. It can be seen in the resulting image (Fig. 1(b)) that factors such as gradient variations, texture variations and noises are avoided in the mean shift so as to output

homogenous regions representing objects. The segmented image can be distinguished by the color which can also be said as the mode of the mean shift regions. The algorithm was tested with the EDISON software which is considered to be one of the fastest mean shift procedure. The algorithm completed execution in 3 seconds in an Intel i3 processor with 3 GB memory. Whereas a test using level-set algorithm executed in MATLAB was experienced to be slower than the mean shift on the same image. This can be taken as a valid experiment which can state that for a real time remote sensing system mean shift is an excellent choice of segmentation algorithm.

(a) (b)

Fig. 1: (a) Original GeoEye-1 image (b) segmented image with mean shift

VI. Conclusion

In the paper described are the challenges faced in the segmentation of remote sensing image. It was identified that some common segmentation techniques in IP fails due the difficulty posed by the challenges. By defining the process of mean shift it was shown that the technique has more desirable features for using in remote sensing systems than that of other techniques and it is possible to use in segmentation of the regions more accurately and faster than some modern algorithms. A number of applications were listed in the paper which proves the effectiveness of mean shift in the field of remote sensing image processing. The paper has also proposed a simple case study by comparing the segmentation of images with mean shift and a modern contour based segmentation technique known as level set. It was experimentally shown that mean shift was able to give good segmentation on remote sensing image with near to real time processing speed.

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