A GRAPH BASED APPROACH TO SEGMENTATION OF REMOTELY SENSED IMAGES

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ABSTRACT: Graph based segmentation techniques have been popular in image segmentation. This paper proposes a two-staged technique to achieve improved image segmentation. The first stage involves definition of the graph nodes by a combination of k-means clustering and connected component labeling. The region adjacency graph is an output of this stage. This graph structure is then used to obtain the actual segmentation of the image with the help of a user defined threshold for the edge weights. The edge weights are a function of the Euclidean distance between the average multi-band mean vectors of the neighboring clusters. The value of k in k-means clustering is user controlled according to the image content – large smooth regions or several smaller regions conveying a lot of detail. This also helps to avoid over-clustering thereby keeping the number of resulting nodes to a minimum as the efficiency of the graph based stage depends on the number of nodes. A threshold is applied on the edge weights to merge adjacent regions that are similar and retain only those nodes in the graph where the edge weights linking the adjacent nodes are sufficiently high indicating that the underlying regions are significantly different. This approach has been applied to remote sensing images and compared with the standard minimum spanning tree (MST) approach. The proposed technique is found to provide better segmentation as compared to the MST based approach. Feature vectors are computed for the regions so formed based on shape, texture, spectral and contextual properties. The feature vectors are classified and compared with the results of a maximum likelihood pixel based classifier. The classification results are also compared with the results obtained following the classification of regions generated using the well-known morphological watershed transformation based region segmentation.

1. INTRODUCTION

1.1 Image Segmentation

Image segmentation in general is defined as a process of partitioning an image into homogenous groups such that each region is homogenous but the union of no two adjacent regions is homogenous. In recent years, graph based techniques have been widely explored. An image can be converted into its graph structure and various techniques in graph theory for clustering or segmenting the graph can be implemented on the image. These techniques have been proved to give good segmented images. However the actual implementation of these algorithms is complex and time / memory consuming. Application of these techniques to remote sensing imagery has shown promising results and is demonstrated using remotely sensed images (Blaschke, 2010).

The major challenge is to find suitable methods for segmentation and classification of the image to get an output that matches the human perception of various entities in the image to maximum possible extent. Graph based segmentation techniques have proved to be useful in providing good segmented outputs however with issues in efficiency of the algorithm. Feature selection and classification after segmentation is yet another challenge (Dey et al., 2010). The proposed work attempts to obtain image segmentation with the help of a graph based approach. The results of segmentation are further used for classification purposes. The description of methodology adopted in the formulation and data used in the present work are discussed in section 2. The results obtained by proposed methodology are presented in section 3. Summary and conclusion of the present work are discussed in Section 4. The last section highlights the scope for further work in this area.

2. METHDOLOGY

The flowchart of the proposed methodology is shown in Figure 1.

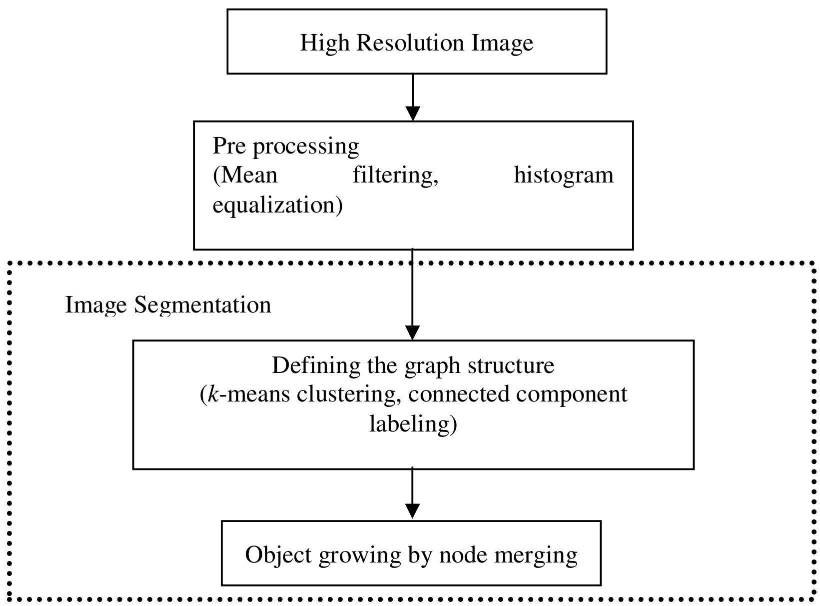


Figure 1. Flowchart of proposed methodology

2.1 Pre-processing

Analysis of remote sensing images involves various pre-processing activities to enhance the images. Two such activities are performed on the high resolution image in this work. The first step is removal of noise. A 3x3 mean filter that replaces each pixel with the mean value of the neighborhood is used for this purpose. The next step is improving the contrast of image, since segmentation results are dependent on the contrast. Hence histogram equalization is used for this purpose.

2.2 Image Segmentation

Segmentation is one of the crucial steps in object based image analysis as it results in the formation of objects in the image. In this work, an improved approach to graph based segmentation has been employed. As is evident from the literature surveyed on this topic, one of the major challenges in graph based segmentation techniques is to improve the efficiency of the algorithm by reducing the number of graph nodes involved in the initial stages. Grouping of pixels to form the initial nodes of the graph rather than considering each pixel as a node is a possible solution to this problem.

2.2.1 Defining graph

In order to efficiently form region graphs for large images, spectrally similar pixels are first grouped by simple K-Means clustering algorithm and each group of spatially adjacent pixels (regions) that is assigned to a cluster is treated as nodes of the region adjacency graph. Obviously there will be several regions assigned to a single spectral cluster but physically disjoint in the image. Each region has several other regions adjacent to it, resulting in a region adjacency graph (RAG). This approach to region adjacency graph formation is more efficient than the top-down region merging approaches starting with each pixel as a separate region. Figure 2 illustrates the steps involved in defining of the graph.

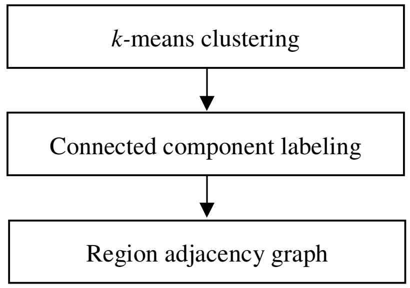


Figure 2. Steps involved in defining image graph

a) *k*-means clustering

Using K-means clustering, the pixels in the input image are grouped based on spectral similarity in the feature space. The result of K-means algorithm on an image results in several regions made up of pixels having similar spectral features. Obviously each spectral cluster will have several regions possibly distributed throughout the image. Depending on the value of K, the number of spatial groupings of pixels that result from this step (connected components) will vary. Larger the value of K, more will be the connected components. Since splitting a large region is difficult compared to merging adjacent regions, the value of K is so chosen that there is a little over-segmentation but no under-segmentation. The clustered image is connected-component labeled and then converted to a region adjacency graph in the subsequent steps (Zhang and Alhajj, 2006).

b) Region adjacency graph (RAG)

A region adjacency matrix represents which nodes of a graph are adjacent to which other nodes. The connected components are the nodes of the graph and only those nodes that share a boundary are considered as neighbors. Based on this condition, the neighbors of each node are identified. The region adjacency graph indicates the neighbors of each node in the graph. It also includes the edge weight of the edge between two neighboring nodes. The value of edge weights are the Euclidean distance between the feature vectors of the nodes. The feature vector of a node is defined by the average gray level value of the pixel in each band. Mathematically, for a node *i* with n neighbors, the edge weight w_{ij} of an edge with its neighbor *j* can be defined as

$$wij = \sqrt{(B_{1i} - B_{1j})^2 + (B_{2i} - B_{2j})^2 + .. + (B_{ni} - B_{nj})^2} \tag{1}$$

where B_{xy} is the value of the y^{th} node in band x. After the region adjacency graph has been obtained, the graph structure is now defined in terms of graph nodes and edges between neighboring nodes that are associated with edge weights. The nodes in this graph are initial versions of the objects in the image. The next step takes this graph structure as the input and performs the refinement of these objects with the help of an approach similar to region growing techniques (Shi and Malik, 2000).

2.2.2 Object growing

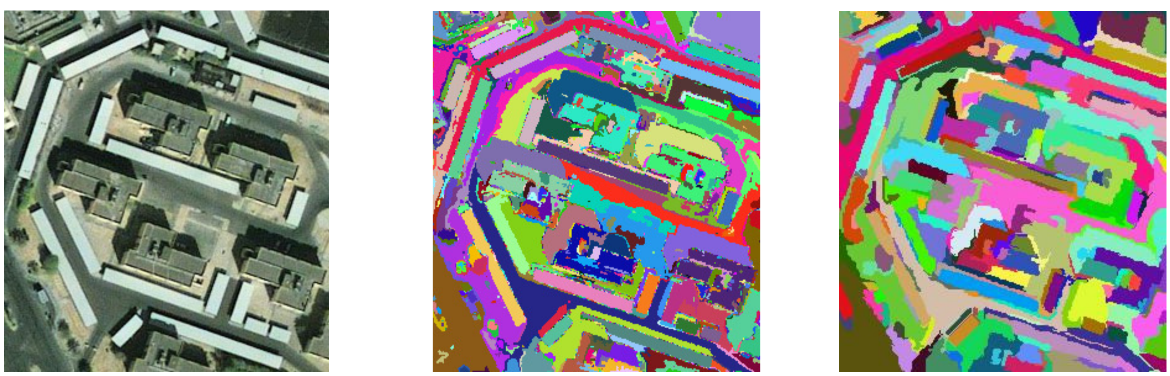
The main intention of the previous step was to obtain an over segmented image. Since the image is over segmented, objects in the image that match the human perception of entities in the image are now in broken segments. Hence the graph obtained from the previous step consists of neighboring nodes that may be a part of the same object. The reason for the use of the RAG in the last step is because of the same consideration that neighboring nodes together form an object and there is no need to look into the edges between all pairs of nodes. A region growing like approach is adopted to merge neighboring nodes based on certain threshold values and refine the objects in the image. The merging criterion is defined by a predicate M based on the similarity of the neighboring nodes. For neighboring nodes *i* and *j* with the corresponding edge weight of w_{ij}, the similarity predicate is defined as follows.

$$M\ (i,j) = \text{TRUE, if } wij < T\text{, FALSE Otherwise} \tag{2}$$

In equation (2), *T* is the threshold value that determines the similarity between adjacent nodes. Different values of T will provide segmentations at different levels. Lower values of *T* may result in over segmented images while high values of T will result under segmentation. The predicate M being true indicates that the nodes are similar and are to be merged. When M is false, no merging is to take place as the nodes are not similar. The refinement of the objects yields a segmented output with segments that can be related to the objects in the image.

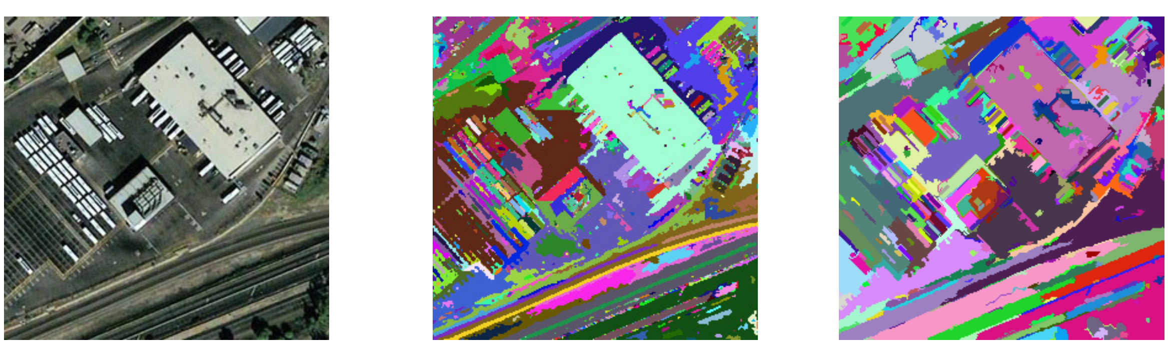
3. RESULTS

The segmentation results obtained from the proposed approach are compared with the standard MST based approach (Felzenszwalb, 2004). Since segmentation results are subjective in nature, visual assessment of both results is performed for analysis. Figure 3(a) is a Quickbird image of Riyadh. Figures 3(b) and 3(c) are the segmentation results using the proposed approach (T = 40) and the MST based approach respectively. It can be observed that the proposed algorithm results in an image that has been segmented at a higher resolution. Smaller regions that have not been detected by the MST based approach have been detected by the proposed algorithm. The effect of over-segmentation is negligible in the results of the proposed approach. Similar observations can be made in Figures 4 and 5. Figure 4(a) and 5(a) are Quickbird windows of downtown urban and urban fringe areas. The segments in these outputs can be used as objects for object based classification purposes. Figure 6(a) gives the output of an unsupervised classification performed on the objects of Figure 3(b). The feature vector consists of shape and intensity features. The shape features used are the area, perimeter and compactness (area/square of perimeter) of the objects. Figure 6(b) is the classified output obtained using a pixel based maximum likelihood classifier.



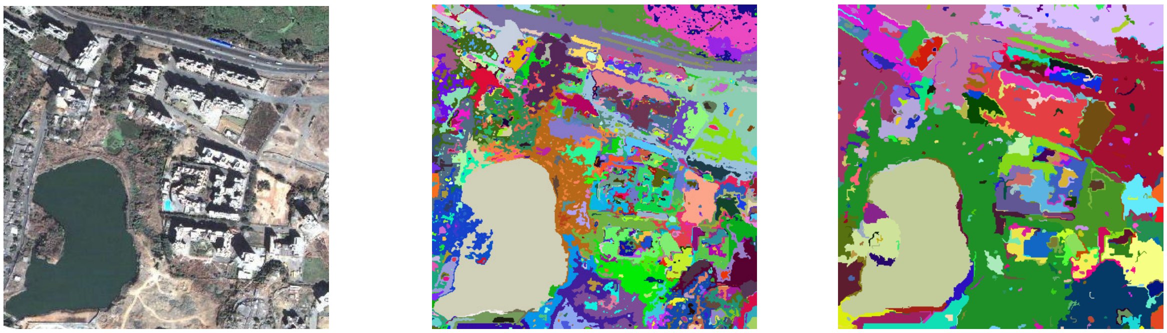
(a) (b) (c)

Figure 3 (a) Original Image (b) Output of proposed approach (T=40) (c) Output of MST based approach (sigma = 0.5, *k*=300, min_size = 10)



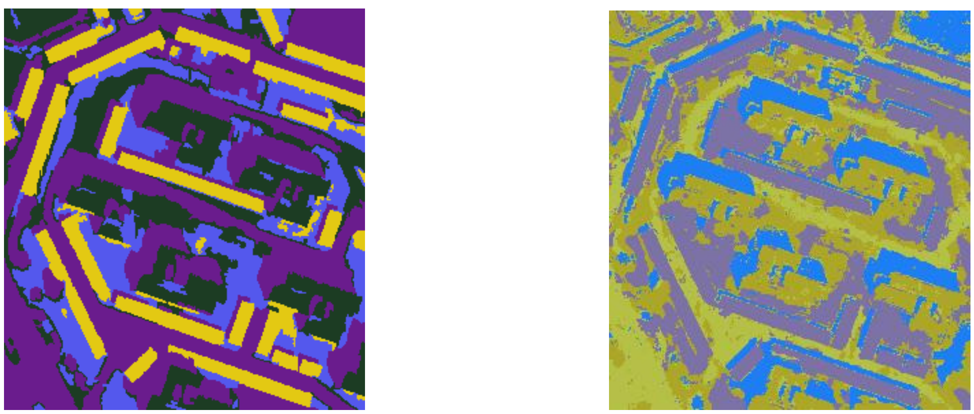
(a) (b) (c)

Figure 4 (a) Original Image (b) Output of proposed approach (*T*=20) (c) Output of MST based approach (sigma = 0.5, *k*=150, min_size = 10)



(a) (b) (c)

Figure 5 (a) Original Image (b) Output of proposed approach (*T*=20) (c) Output of MST based approach (sigma = 0.5, *k*=200, min_size = 10)



(a) (b)

Figure 6 (a) Classified output using object features from Figure 3(b) and (b) Classified output using pixel based maximum likelihood classifier

It is observed from the classified images in Figure 6, the object based approach performs better compared to the traditional pixel based approach. Since the accuracy of the segmentation process is crucial in all object based approaches, the improved classification accuracy can be attributed to better segmentation results and the use of object based features like shape features.

4. SUMMARY AND CONCLUSION

The work described in this paper is carried out in four major steps: pre-processing, segmentation, feature selection and image classification. Pre-processing involves removal of noise and other image enhancement activities to make the image ready for processing. Segmentation is carried out by first defining the graph and then refining the objects. Definition of the graph involves clustering of pixels followed by labeling the connected components which are then considered as the graph nodes/ initial versions of the objects. Object refinement involves merging neighboring nodes to grow the object into entities that closely match user perception of the same. Once the objects are obtained, suitable features are extracted and an attempt is made to obtain a suitable feature vector for the given area. The image is then classified.

Graph based segmentation approaches were identified to be promising techniques to achieve quality object based segmentation. One of the major objectives of this work was to achieve image segmentation with the help of a graph based approach by improving upon the existing methods. The segmentation algorithm proposed in this work has been proven to improve the efficiency as well as provide better quality segmentation by making suitable changes. The final classification results also prove that object based image analysis approach involving object based segmentation and classification provides better results than the traditional pixel based techniques.

5. SCOPE FOR FUTURE WORK

The graph based segmentation technique proposed in this work takes inspiration from a minimum spanning tree based approach for segmentation. Many other algorithms make use of the graph based approach such as normalized cuts, minimum cuts and all. The proposed algorithm involves definition of a graph followed by the object refinement stage. The refinement stage could be modified with the help of the above mentioned algorithms and the corresponding results can be studied to conclude upon the quality of these algorithms. Also the refinement stage involves application of a user defined threshold. The quality of the results can be improved by giving a more proper definition to the threshold rather than keeping it completely subjective. Various options for feature selection and classification can be explored for better classified results.

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