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Modularity Based Color Image Segmentation

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Abstract: Image segmentation directly influences the successive processing and analyzing of an image. Thus segmentation becomes one of the biggest problems in image processing. Inspired by the application of community detection algorithms in large-scale social networks, we attempt to view an image from the perspective of a network and consider the image segmentation problem as a community detection problem. For a network, modularity is a crucial quantity, which is used to evaluate the performance of various community detection algorithms. A graph based method with modularity, can avoid the over segmentation problem which is present in all traditional segmentation methods. Compared with other existing segmentation algorithms, proposed algorithms start with initial segmentation techniques and lead to the computation of modularity, and try to achieve better segmentation to some extent.

Keywords: Image Segmentation, Graph based image segmentation, Modularity.

I. INTRODUCTION

Image segmentation is an important image processing step, and it is used everywhere if we want to analyze what is inside the image. It is the process of partitioning a digital image into multiple segments, set of pixels, also known as super pixels, which are homogeneous with respect to some criterion. In medical imaging, for example, image segmentation procedures can be used for diagnosis, locating tumors and other pathology's. In addition, image segmentation methods can be applied to traffic control systems, machine vision, localization of objects in satellite images and so on[6]. Different algorithms have been proposed for image segmentation such as those based on image threshold (e.g. by means of histograms of gray levels); region growing methods; edge based segmentation and graph partitioning methods. Most of these methods present some drawbacks and do not provide accurate segmentation. Among the many approaches in performing image segmentation, Graph based approach is gaining popularity primarily due to its ability in reflecting global image properties. Graph based methods[7],[9], image is regarded as an undirected weighted graph, while each pixel is treated as a node in the graph and the edge weights measure the similarity or dissimilarity between nodes, which divide a graph into two groups instead of an arbitrary numbers. Edge list, adjacency matrix, incidence matrix, adjacency list, adjacency pointer are the methods used for graph representation of an image. With the development of complex networks theory, image segmentation techniques based on graph have evolved considerably. Application of modularity [1][12] in community detection algorithms can be applied to these graph based segmentation and can reduce the computational cost to some extent thereby provide fast computation. Modularity is one measure of the structure of networks or graphs. It was designed to measure the strength of division of a network into modules (also called groups, clusters or communities). Modularity defines the similarity or dissimilarity between two groups and the optimal segmentation is achieved when the modularity of the image is maximized. Networks with high modularity have dense connections between the nodes within modules but sparse connections between nodes in different modules. Modularity is often used for detecting community structure in networks, which when maximized, leads to the appearance of communities in a given network.

There are many different techniques available to perform image segmentation. The choice of a segmentation technique over another was decided by the particular type of image and characteristics of the problem being considered. Image segmentation algorithms generally based on one of two basic properties of intensity values [3][4]: discontinuity and similarity. Based on this, segmentation techniques include Edge based Segmentation, Region based Segmentation, Threshold based Segmentation. Edge-Based Segmentation methods based on discontinuity find for abrupt changes in the intensity value. These methods are called as Edge or Boundary based methods. Edge detection is used for object detection which serves various applications like medical image processing, biometrics etc. Edge based segmentation method provide fine result for images that possessing excellent region disparity but the method is not good, when edges are unclearly defined. Region based methods are based continuity. These techniques divide the entire image into sub regions depending on some rules like all the pixels in one region must have the same gray level. Compared to edge detection method, segmentation algorithms based on region are relatively simple and more immune to noise. Threshold is one of the widely methods used for image segmentation. It is useful in discriminating foreground from the background. By selecting an adequate threshold value T, the gray level image can be converted to binary image. In threshold based image segmentation the pixels are partitioned depending on their intensity values. Image thresholding

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classifies pixels into two categories: Those to which some property measured from the image falls below a threshold, and those at which the property equals or exceeds a threshold. Different Threshold detection methods are P-tile thresholding, Optimal thresholding, Mixture modeling, Adaptive thresholding.

II. PREVIOUS WORK

Among the many approaches in performing image segmentation, Graph based approach is gaining popularity. The basic principle of most of the graph based segmentation methods is graph partitioning [7]. Each method treats an image as an undirected weighted graph, while each pixel corresponds to a node and the edge weights measure the similarity or dissimilarity between nodes, which partitioning a graph into several sub graphs such that each of sub graph represents a meaningful region or object of interest in the image. These graph based segmentation methods might be grouped [6] as (1) graph cut based methods, (2) interactive methods, (3) minimum spanning tree based methods and (4) pyramid based methods.

In Graph cut based methods [7], the graph G can be partitioned into two connected components A and B such that A ∪ B=V and A ∩ B=H by omitting the edges linking these two components. The degree of association between A and B can be inferred from the total weight of the discarded edges, which is simply called as a graph cut. By suitably and repeatedly partitioning the graph constructed from an image using the graph cut, different homogeneous regions could be obtained and also by utilizing graph cut values, which is a measure to show how much two neighbouring regions are homogeneous, regions could be united repeatedly to form image partitions. Major algorithms in this category are the minimum cut algorithm, a normalized cut algorithm, a variant of normalized cut.

The minimum cut for image segmentation in such a way that the smallest (k-1) cuts among all possible cuts are selected and the corresponding edges are deleted to form k-sub graph partitions. This method favours the formation of very smaller regions, which results in over-segmentation.

A large variety of interactive segmentation methods [7] have been developed during the years. In short, the main steps of an interactive graph based segmentation method are the following: (1) Get the user preferences and (2) generate an optimal solution (if not, a sub optimal solution) according to the user preferences and show it. In situations where automatic segmentation is difficult and cannot guarantee correctness or reliability, these interactive methods are best opted. The interactive graph based segmentation methods take the advantage of reliability under user's control. The interactive graph based methods demand user intervention which is not possible or desirable in many applications.

A spanning tree of a connected undirected graph is a sub graph which links all the vertices and there should be exactly a single path between any two vertices. The minimum spanning tree (MST)[7] is a spanning tree whose total weight of edges is less than or equal to the total weight of edges of every other spanning tree. By suitably removing the lowest weighted edges, different partitions that have stronger inherent affinities could be found. In the method, a tree partitioning algorithm splits up the MST built from an image into many sub-trees, which represent homogeneous regions. For noisy images, the method yields low quality results due to the incorrect configuration of the MST as an object might be contained in more than one sub-tree due to noise.

Pyramid based methods [7] involves the creation of a graph from the original image. From this base graph, a set of graphs defined in multi-level of resolution, which can be visualized as a pyramid, is built. The vertices and edges at level L+1 are formed from the reduction of vertices and edges at level L using a reduction function. A level of pyramid called as working level is chosen as the responsible level to yield segmentation. Based on the working principle to build pyramids, they can be classified into two categories: (1) regular pyramids and (2) irregular pyramids.

In regular pyramids, spatial relationships and the reduction factor, which is defined as the ratio between the number of vertices at level L and the number of vertices at level L+1, are constant and fixed, hence, the size and the layout of the structure of the pyramids are predicable. But the accuracy of this method is sensitive to the right selection of the working level. To overcome this drawback, a modified pyramid linking approach which particularly uses two scaling rules was suggested.

A few drawbacks remain in common to both these approaches. They are: elongated regions are not properly segmented, and the structure of the pyramid varies even due to small rotations, shifts and scales of the input image. In opposite to the regular ones, spatial relationships and the reduction factors are not constants in irregular pyramids; hence, the size and the layout are not predictable. However, these types of pyramid solve the problems associated with the regular pyramids such as shift variance and inability to segment elongated objects. This method yields different segmentation results depending on different outcomes of the random variable for the same input settings.

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III. PROPOSED METHOD

In perspective of a social network, an image is viewed as an undirected weighted graph, while each pixel is treated as a node and the edge weight measures the similarity or dissimilarity between nodes. Adjacency list contribute an efficient method to represent a graph where it simply store an array of vertices adjacent to a node. The weights of edges can be stored in nodes of linked lists. In the first stage, statistical measures and local homogeneity will be used for initial segmentation. Then a modularity based algorithm is used on this over segmented image for getting a fine segmentation. Modularity is a quantity used in social networks to measure the strength of division of a network into community. Modularity is often used to detect community structures in networks. Since the segmentation problem can be viewed as a graph partition problem, the incorporation of modularity may avoid the over segmentation problem.

Image Pre-processing

Image pre-processing is the preliminary step which improves the image data that suppresses unwanted distortions or enhances some image features important for further processing. In the pre-processing modules an Bilateral filter can be applied to enhance the image. Bilateral filtering is a non-linear, edge preserving and noise-reducing smoothing filter for images. The intensity value at each pixel in an image is replaced by a weighted average of intensity values from nearby pixels (This weight can be based on a Gaussian distribution). This bilateral filter is easy to understand, adapt and set up. The main advantages of bilateral filters are (1) Its formulation is simple: each pixel is replaced by an average of its neighbours, (2) It depends only on two parameters that indicate the size and contrast of the features to preserve, (3) It can be used in a noniterative manner. This makes the parameters easy to set since their effect is not cumulative over several iterations and (4) It can be computed at interactive speed even on large images thanks to efficient numerical schemes. Another algorithms used for image enhancement are CLAHE, switched bilateral filter and cellular automata. In case of CLAHE (Contrast Limited Adaptive Histogram Equalization) divides the input image into a number of equal sized blocks and then performs contrast limited histogram equalization on each block. CLAHE is an improved version of both Histogram Equalization and Adaptive Histogram Equalization by avoiding the problem of over amplification in largely homogeneous regions. The fig shows the output of bilateral filter. When analyzing we can know that bilateral filter provide better result than others.

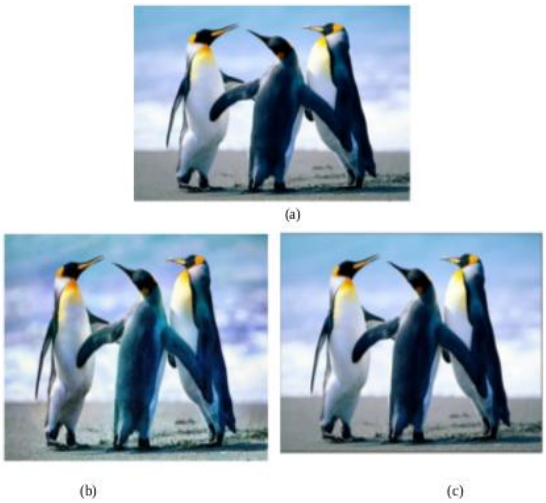

Fig. 1. figure (a): Original image, (b): output of CLAHE algorithm, (c) :output of Bilateral filter

Initial segmentation

In the first stage an initial segmentation is performed by region growing algorithm. Region Growing is an approach to image segmentation in which neighbouring pixels are examined and added to a region class if no edges are detected. This process is iterated for each boundary pixel in the region. The first step in region growing is to select a set of seed points. Seed point selection is based on some user criterion (for example, pixels in a certain gray scale range, pixels evenly spaced on a grid, etc.).

The initial region begins as the exact location of these seeds. This approach to segmentation examines neighbouring pixels of initial seed points and determines whether the pixel neighbours should be added to the region if they are similar to the seed. Canberra distance can be used to measure the similarity between pixels. The Advantages of region growing are (1) Region growing methods can correctly separate the regions that have the same properties we define (2) Region growing methods can provide the original images which have clear edges with good segmentation results (3) The concept is simple. We only need a small number of seed points to represent the property we want, then grow the region (4) We can determine the seed points and the criteria we want to make.

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Modularity based image segmentation

Modularity based image segmentation module provide the final segmentation. Modularity is one measure of the structure of networks or graphs. It was designed to measure the strength of division of a network into modules (also called groups, clusters or communities). Networks with high modularity have dense connections between the nodes within modules but sparse connections between nodes in different modules.

Modularity was first defined by Newman for the analysis of weighted networks. For a weighted network G with the weighted adjacency matrix A, the modularity Q is defined by

$Q = 1/2m\Sigma i;j[Ai;j - kikj/2m]\delta(ci; cj)$
where Ai;j is the weight between nodes i and j ,

$m = 1/2\Sigma$ i;j Ai;j is the total weights of the network, $ki = \Sigma j$ Ai;j is the weighted degree of the node i, ci is the community label to which node i belongs, and $\delta(ci; cj)$ is 1 if nodes I and j are in the same community, otherwise it is 0. Intuitively, modularity means to evaluate the difference between the actual probability of the connectivity of two nodes in the same community and the estimated probability under the assumption that the two nodes are connected randomly. The modularity increase caused by merging community j into community i can be computed by

$\Delta Qi;j = 1/2m[kj;in - \Sigma totkj/m]$

Where Pin is the total weights of the edges inside community i , tot is the total weights of the edges incident to nodes in community i , kj ,in is the sum of the weights from community j to community i.

Algorithm 1 Modularity-Based Image Segmentation

Input : Initial segments

Output : The set of image segments R.

1. While Pixel labels still change do
2. Reconstruct the neighbourhood for each region in R.
3. While modularity increase still exists by merging any two adjacent regions do
4. For each region Ri € R do
5. Compute modularity and delta modularity increase by using equation (3) and (4), caused by merging region Ri with its adjacent region Rj,
6. Find the neighbouring region Rj , which gives the largest delta modularity increase among all of the neighbouring regions of Rj
7. Merge regions Ri and Rj if they satisfy the homogeneity criterion by setting the labels of pixels in these two regions to be of the same label
8. end for
9. end while
10. Update the region labels to get a new set of regions R =R1;……;Rm , where m is current number of regions;
11. end while

IV. CONCLUSION

Image segmentation is an important image processing step. Accurate and efficient image segmentation is fundamental for the analysis of ground truth in various images. Recently, there has been increasing interest in using graph based methods as a powerful tool for segmenting images. This review has discussed some of the major graph based methods and highlighted their strengths as well as limitations. Some difficulties of these methods have brought down their use in practical applications.

The primary reason is the higher computational complexity. In this proposed project, a new and efficient segmentation method has been proposed. This method is based on the graph representation of an image and the application of modularity, which is used in social networks. It avoids over segmentation and gives perfectly segmented output without any user interaction.

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