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A Survey on Image Segmentation Using Various Graph-Based Methods

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Abstract- The main goal of this paper is to survey the high quality of image segmentation with improved speed by the work that could be divided among several CPUs. In this paper to segment the image using three different graphs based segmentation algorithms. These are spanning tree-based segmentation; graph-cut based segmentation methods and shortest path methods. This paper analyses different segmentation techniques to reduce the computational complexity of the processor in the field of image segmentation. The composition of segmentation methodologies proposes for image processing is explained briefly. To determine the stability of the image parameters such as accuracy, precision, noise level, recall, complexity, pixel rate, and weighted edges are considered.

Keywords – Segmentation, Graph-based, Graph cut, Spanning tree, Distance-based.

I. INTRODUCTION

Image segmentation is a tough problem with various applications in the imaging sciences. The reviews on numerous segmentation methods can be found for image thresholding method; medical image segmentation, statistical level set segmentation, 3-D image segmentation, edge detection techniques, and so on. It needs two important tasks recognition and delineation. Recognition is the process of specifying the position of a particular object in the image, and delineation is the process of indicating the accurate spatial area and composition of the object [1]. While computer algorithms are extremely efficient in object delineation, the absence of admissible global object-related information is the main cause of their failure in object recognition. On the other hand, simple user participation in object recognition is often enough to balance this deficit and to complete the segmentation process [2]. In multidimensional image analysis, there are many methods that fail during automatic image segmentation. They need consistent user time for accurately segmenting the image.

In this context, the main goal of segmentation research is to (i) maximize precision, accuracy, and computational efficiency, (ii) minimize user interaction time, and (iii) maximize the user's control over the segmentation process. Image segmentation methods can be classified into two main categories i.e. semi-automatic, and fully automatic. Fully automated methods are much more skilled but repeatedly fail to recognize the object of interest thus resulting in faulty segmentation [3]. Thresholding, clustering methods, histogram-based and segmentation using neural network, are some methods which do not concern with any human interaction. They perform the computations and obtain the results on their own. On the other hand, semi-automatic techniques highly depend on users and it requires users interaction before the actual computation starts [4]. It gives both high efficiency and accuracy by allowing users to do object recognition and allowing computers to do the fine detailing. Thus, semi-automatic techniques are widely used in medical image analysis, digital image composition, key extraction, etc. There are numerous techniques in this category which include region growing, snakes, livewire, graph-cuts, etc., but the main focus of our paper is for the graph-based methods that extract the boundary of the object. The boundary can be curves or dots of the image.

In recent years, among the many approaches to image segmentation, graph-based methods have become a major trend. In these methods, image segmentation is modeled in terms of partitioning a graph into several sub-graphs such that each of them represents a meaningful object of interest in the image [5]. The very first step is mapping the image elements onto a graph, where the nodes may be pixels, regions, or even user-drawn markers [6]. The graph structure is formed by a set of nodes (also called vertices) and a set of edges that are connections between pairs of nodes. Basically, graph-based methods can be categorized into:

• Minimum spanning tree (also called shortest spanning tree) based methods, where the clustering or grouping of image pixels are performed on the minimal spanning tree. The connection of graph vertices satisfies the minimal sum on the defined edge weights, and the partition of a graph is achieved by removing edges to form different sub-graphs [7].

• Graph cut with cost functions. Graph cut is a natural description of image segmentation. Using different cut criteria, the global functions for partitioning the graph will be different. Usually, by optimizing these functions, we can get the desirable segmentation [8]. Normalized cut and ratio cuts are such methods.

• Graph cut on Markov random field models: the goal is to combine the high-level interactive information with the regularization of the smoothness in the graph cut function. Under the MAP-MRF framework, the optimization of the function is obtained by the classical min-cut/ max-flow algorithms or its nearly optimal variants, such as multi-label graph cut and interactive graph cut [9].

• Shortest path methods, where the object boundary is defined on a set of shortest paths between pairs of graph vertices. That is to say, the problem of finding the best boundary segment is converted into finding the minimum cost path between two vertices. In a weighted graph, the shortest path will connect the two vertices with the minimized sum of edge weights, and the path can be computed for instance with Dijkstra's algorithm. Shortest path methods require user interactions to guide the segmentation. Therefore, the process is more flexible and can provide friendly feedback.

The Graph-based approach is gaining popularity primarily due to its ability in reflecting global image properties. It explicitly organizes the image elements into mathematically sound structures and makes the formulation of the problem more flexible and the computation more efficient, which might require no discretization by virtue of purely combinatorial operators and thus incur no discretization errors. The segmentation problem is solved in a spatially discrete space by the efficient tools from graph theory.

The rest of the paper is organized as follows. Section II gives a brief discussion on three different graph-based segmentation methods to extract the features of the currently available segmentation results. Section III shows the comparative analysis with parameters of each graph-based method. Section IV concludes the paper with a summary.

II. Graph-based Segmentation Methods

A. Spanning Tree

M P Dewi et al., [10] proposed the application of a minimum spanning tree on the graph in the segmentation process of the digital image. This method is able to separate an object from the background and the image will change to be the binary images. In this case, the object that is the focus is set in white, while the background is black or otherwise. The first process is to form the image into a graph form that is represented in the form of an adjacency matrix, the process of finding the minimum range of trees, and forming the result of image segmentation. The minimum range search process uses a modified algorithm of the Prim algorithm, where the algorithm produces some minimum range trees.

Janakiraman et al., [11] proposed the novel spanning tree-based graph-theoretic approach. The image to be segmented is subjected to background elimination and then represented as an undirected weighted graph G. Each pixel is considered as one vertex of the graph and the edges are drawn based on the 8-connectivity of the pixels. The weights are assigned to the edges by using the absolute intensity difference between the adjacent pixels. The segmentation is achieved by effectively generating the Minimal Spanning Tree (MST) and thereby adding the non-spanning tree edges of the graph with selected threshold weights to form cycles satisfying the certain criterion.

Jianpu Lin et al.,[12] proposed an improved Minimum Spanning Tree algorithm and a modified Canny edge detector to segment images that contain a considerable amount of noises. Initially, modified Canny operator to pre-process an image, and record the obtained object boundary information; then, the improved Minimum Spanning Tree algorithm is applied to associate the above information with boundary points in order to separate edges into two classes in the image, namely the inner and boundary regions. In particular, the Minimum Spanning Tree algorithm is improved by using Fractional differential and combining the functions of the intra-regional and inter-regional differences with a function for edge weights.

Ping Wang et al..,[13] proposed a Minimum Span Tree (MST) based image segmentation method for UAV images in the coastal areas. An edge weight-based optimal criterion (merging predicate) is defined, which based on statistical learning theory (SLT). And we used a scale control parameter to control the segmentation scale. Experiments based on the high-resolution UAV images in coastal areas show that the proposed merging predicate can keep the integrity of the objects and prevent results from over-segmentation. The segmentation results prove its efficiency in segmenting the rich texture images with a good boundary of objects.

Geetha et al.,[14] proposed an algorithm that uses Minimum Spanning Tree (MST) for the segmentation of point cloud. As a preprocessing step, first-level clustering is done which gives a group of cluttered objects. Each of these cluttered groups is subjected to a more finite level of segmentation using MST based on distance and normal. In our method, we build a weighted planar graph of each of the clustered cloud and construct the MST of the corresponding graph. By taking advantage of normal, we can separate the surface from the object.

B. GRAPH-CUT

Muhammad Rizwan et al., [15] deal with segmentation of the grayscale, color, and texture images using graph cuts. Based on the nature of the image, a fuzzy rule-based system is designed to find the weight that should be given to a specific image feature during graph development. The graph obtained from the fuzzy rule-based weighted average of different image features is further used in the normalized graph cuts framework. The Berkeley segmentation database is used to test our algorithm and the segmentation results are evaluated through probabilistic rand index, global consistency error, sensitivity, positive predictive value, and Dice similarity coefficient, and provides effective results for most types of images.

YanhuiGuo et al., [16] presented an efficient image segmentation algorithm using a neutrosophic graph cut (NGC). An image is offered in a neutrosophic set, and an indeterminacy filter is constructed using the indeterminacy value of the input image, which is defined by combining the spatial information and intensity information. The indeterminacy filter reduces the indeterminacy of the spatial and intensity information. The results showed that the presented method can segment the images properly and effectively, on both clean images and noisy images, because the indeterminacy information in the image has been handled well in the proposed approach.

Mamathaet al.,[17] proposed Multiple interactive segmentation based graph cut method with three steps Initially, nodes representing pixels of image area connected to their k-nearest neighbors to cover foreground image. Within the second step, the energy function of the graph is employed to improve the segmentation on the object borders to hide the background information set. Third step extracting user interacted object from the image set. This technique is evaluated for segmenting the MRI images to find brain tissues and other brain elements and as well as mammogram images. Finally, as a result, the graph-cut based multiple interactive methods show higher performance than previous methods.

Hardik K Pate et al., [18] reported that Normalized cut (Ncut) is based on a graph-cut technique to solve image Segmentation problems. Rather than just focusing on local features and their consistencies, Ncut considers the global impression of an image. As a result, it is found that Ncut algorithm accurately segments the given image into meaningful parts. The time complexity of the algorithm is higher due to the calculation of Eigenvector and Eigen-values.

Song Wang, et al., [19] proposed a new cost function, cut ratio, for segmenting images using graph-based methods. This new cost function allows the image perimeter to be segmented, guarantees that the segments produced by partitioning are connected, and does not introduce a size, shape, smoothness, or boundary length bias. The latter allows it to produce segmentations where boundaries are aligned with image edges. Furthermore, the cut-ratio cost function allows efficient iterated region-based segmentation as well as pixel-based segmentation.

The author presented an implemented algorithm for finding a minimum ratio cut, prove its correctness, discussed its application to image segmentation.

C. SHORTEST PATH

Ter-Feng Wu et al., [20] proposed modified Dijkstra's algorithm was used to turn vertices of convex-shaped obstacles into network nodes, to determine the shortest path by a cost function, and to find an obstacle avoidance path connecting between the start and endpoints. The main purpose is to identify and avoid obstacles using images to plan out the shortest and smoothest obstacle-avoiding path. Through the boundary sequence permutation method and Rosenfeld– Johnston's turning point detection algorithm, all the turning point coordinates of the object were measured. The results showed that the proposed method in path planning not only is feasible but can also obtain good results.

Sophia et al.,[21] proposed the shortest path algorithm for optimal boundary extraction based on representing edge segments in the form of the graph. Here, an intuitionistic triangular fuzzy number is assigned to each arc instead of a fuzzy number. Euclidean distance is computed for all the paths with the edge of minimum distance are the shortest path for membership and non- membership values. This algorithm provided a better output for different types of graphs and networks.

Doadet al.,[22] presented the Dijkstra Shortest Path Algorithm for automated segmentation of the vasculature in retinal images. The method produces segmentations by classifying each image pixel as a vessel or non-vessel, based on the pixel's feature vector. The given method preserves vessel thickness, requires no manual intervention, and follows vessel branching naturally and efficiently. To test this method by using a retinal video indirect ophthalmoscopy (VIO) image database from pediatric patients and compared the segmentation achieved by this method.

Li XU et al., [23] proposed a boundary-aware superpixel segmentation method, which could quickly and exactly extract superpixel with a non-iteration framework. The basic idea is to construct a minimum spanning tree

(MST) based on structure edge to measure the local similarity among pixels, and then label each pixel as the index with shortest path seeds. Experimental results on the segmentation benchmark demonstrate the proposed method obtains the best performance compared with seven state-of-the-art methods. Especially for the low-density situation, this method can obtain the boundary-aware over-segmentation region.

ChandanpreetKauret et al., [24] introduced an effective hierarchical agglomerative clustering algorithm based on modularity intensification with initial pre-processing. The final segmented image is produced when the increase in modularity ceases and thus the algorithm stops combining the neighboring regions. The histogram of states of image gradient feature is used altogether with the color feature to produce an adaptive similarity matrix which retains the reiterative patterns in homogeneous region. The proposed algorithm is tested on the publicly available Berkeley Segmentation Data Set and compared with other popular segmentation algorithms. Compared to the previous existing segmentation algorithm, the proposed algorithm commence with initial denoising and segmentation techniques and gives the computation of modularity index which leads to better segmentation and improved accuracy.

III. COMPARATIVE ANALYSIS

TABLE1 COMPARISON OF SPANNING TREE METHODS

Author	Method	Accuracy	Pixel Rate	Edge Weights
M P Dewi et al.,	Minimum Spanning Tree with Prim algorithm	Moderate	Very low	High
Janakiraman et al.,	Novel spanning tree based-graph theoretic approach.	Low	Moderate	Moderate
Jianpu Lin et al.,	Improved Minimum Spanning Tree algorithm and a modified Canny edge detector	Low	Moderate	High
Ping Wang et al..,	Minimum Span Tree (MST)	High	Low	High
Geetha et al.,	Minimum Spanning Tree (MST) with clustering	Moderate	Very low	Very high

TABLE 2COMPARISON OF GRAPH CUT METHODS

Author	Method	Noise level	Complexity	Accuracy
Muhammad Rizwan et al.,	Fuzzy rule-based system	Very high	Low	Moderate
YanhuiGuo et al.,	Neutrosophic graph cut (NGC).	Moderate	High	Moderate
Mamatha et al.,	Multiple interactive segmentation based graph-cut method	Very low	Moderate	Very high
Hardik K Pate et al.,	Normalized cut (Ncut)	Moderate	Very low	Moderate
Song Wang, et al.,	Cost function based graph cut	Very low	Low	Very high

TABLE3 COMPARISON OF SHORTEST PATH ALGORITHMS

Author	**Method**	**Recall**	**Precision**	**Accuracy**
Ter-Feng Wu et al.,	Modified Dijkstra's algorithm	Moderate	Very low	Low
Sophia et al.,	Shortest path algorithm for optimal boundary extraction	Low	Very high	Very high
Doad et al.,	Dijkstra Shortest Path Algorithm for automated segmentation	Low	Moderate	Moderate
Li XU et al.,	Boundary-aware super pixel segmentation method	Moderate	Very low	Very high
ChandanpreetKaur et al.,	Effective hierarchical agglomerative clustering algorithm	Very low	moderate	High

IV.CONCLUSION

In this paper, we have briefly described the existed segmentation methods and the advantages of the graph-based method in the introduction section. We also present the graph-based concept in detail which will be helpful for the researchers. Due to a lot of graph-based segmentation methods, we have classified these methods into three categories. They are spanning tree-based segmentation; graph-cut based segmentation methods, and shortest path methods. After this classification, the researcher can put weight to different aspects as their requirement. However, it is not necessary for the three kinds of graph-cut methods to be executed independently. Most of the time, they can be combined as to speed up the segmentation of large images.

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