Performance Evaluation of Image Segmentation Using Histogram and Graph Theory

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Abstract- Image segmentation is an elementary problem in computer vision and plays very important role in various image application domains.. Regardless of years of research in the area of general purpose image segmentation, it is still a very challenging task since it is inherently ill-posed. Out of different segmentation schemes available today, graph theory based techniques have several excellent characteristics in practical applications. Such graph theory based image segmentation techniques explicitly organize the image objects into mathematically structures, making the computation of image segmentation problem more flexible and efficient. This research work basically employs fundamental concepts of histogram and graph theory for image segmentation. The PSNR and time taken for image segmentation has been used as a comparison parameter for proposed image segmentation methods.

Index Terms- Image segmentation, graph theory methods, graph cut, histogram, differential IFT

I. INTRODUCTION

Image segmentation refers to partitioning of an image into several disjoint subsets, where each subset corresponds to a meaningful part of the image. As image segmentation is often an integral part of many large vision problems, its quality influences the performance of the whole system. Large amount of literature has been published on image segmentation over last few decades. Most commonly used approaches for image segmentation are threshold techniques, edge-based methods, region-based techniques and connectivity-preserving relaxation methods [1]. Irrespective of the choice of approach, the complexity lies in formulating prior knowledge into the segmentation process.

Threshold based image segmentation techniques take decisions depending on local pixel information and are hence more effective in situation where the intensity levels of the objects fall outside the range of levels in the background. Since the spatial information is ignored in these techniques they suffer through blurred region boundaries which create chaos. Edge-based methods are based on contour detection. Further most edge based image segmentation techniques are weak in connecting together broken contour lines which makes them prone to failure in the presence of blurring. In region-based methods the image is first partitioned into connected regions by grouping neighboring pixels of similar intensity levels. Then the adjacent regions are merged based upon some criterion such as homogeneity or

sharpness of region boundaries. A connectivity-preserving relaxation-based segmentation method begins with some initial boundary shape characterized in the form of spline curves, which is modified by applying various shrink and/or expansion operations depending upon some energy function.

Within the last few decades, graph theoretic segmentation methods have gained popularity [2-3]. These segmentation methods utilize graph cuts as their global optimization technique. In [4] a graph based approach is presented consisting of the filtering process for the removal of noise and at the same time thin edges are preserved to smooth the boundaries of the regions. Grady and Schwartz in their work [5] have presented an approach that deals with the partitioning of the image, which is mapped into graph where the isoperimetric constant is used. Tao. Z, Wenxue. H and Jinjia. W in their work [6] have explained a novel concept of texture analysis method by using Graph Spectral Theory. Ming Zhang and Reda Alhajj have presented a modified the Graph-based image segmentation method [7]. In their work they have re-defined the internal difference used to define the property of the components and the threshold function, which is the key element to determine the size of the components.

II. HISTOGRAM BASED SEGMENTATION

Histogram-based image segmentation is one of the simplest segmentation techniques. It uses the histogram which is the graphical representation of the tonal distribution in a digital image to select the gray levels for grouping pixels into regions. An image has two entities: the background and the object. The background is generally one gray level and occupies most of the image and hence has larger gray level peak in the histogram. The object or subject of the image is another gray level having smaller peak in the histogram.

Ohlander [8] proposed a thresholding technique which was based on constructing colour and hue histograms in 1975. In this technique the image is first thresholded at its most clearly separated peak. The process iterates for each segmented part of the image until no separate peaks are found in any of the histograms. Lui et al. [9] proposed the use of 2D histograms of an image for finding thresholds for segmentation rather than just using grey level information in 1D, which uses the information on point pixels as well as the local grey level average of their neighbourhood. The results showed that use of these 2D

histogram techniques gives better segmentation results with same computational demand as of 1D techniques. In [10] novel concept for multiband image segmentation has been proposed based on segmentation of subsets of bands using multi-thresholding followed by fusion of the resulting segmentation channel. Thus most histogram-based approaches rely on the estimation of the discrete density in the designated color space and do not require any kind of priori knowledge about number of clusters or their shape.

III. GRAPH THEORETIC FORMULATION

The graph theoretic segmentation problem is based on graph partitioning and optimization scheme and cane be formulated as follows [2]:

1. The set of points in an arbitrary feature space are symbolized as a weighted undirected graph

$$G = (V, E) \qquad (1)$$

2. An edge is formed between every pair of nodes providing a complete graph.

3. The weight on each edge, w(i,j) is a function of the similarity between nodes i and j.

4. Partition the set of vertices into disjoint sets V_1, V_2, ..., V_k where by some measure the similarity among the vertices in a set Vi is high and, across different sets V_i, V_j is low.

To partition the graph in a meaningful way, we need to pick a suitable criterion such as optimize the output which would result in a good segmentation and finding an efficient way to achieve the optimization. Further the criterion should be easy to compute.

IV. PROPOSED SEGMENTATION METHOD

The used image segmentation algorithm starts with a initial minor segmentation, with each component containing one pixel, and repeatedly merges pairs of components based on the following merge condition:

$$\text{Diff} (C_1, C_2) \leq \text{Int}(C_1) + T(C_1) \text{ and } (2)$$
$$\text{Diff} (C_1, C_2) \leq \text{Int}(C_2) + T(C_2)$$

where $\text{Diff}(C_1, C_2)$ is the difference between components C_1 and C_2; $\text{Int}(C_1)$ and $\text{Int}(C_2)$ are the internal differences of C_1 and C_2, respectively; $T(C) = k/|C|$ is the threshold function. Parameter k controls the size of the components in the segmentation. This stop-merging condition k is considered as proposed by Ming Zhang and Reda Alhajj [7] as:

$$k < |C| \min (W(e_t) - W(e_{t-1})) \qquad (3)$$

where $E = \{e1, e2 \ldots en)$ is the set of edges in non-decreasing weight order, $W(e_i)$ 5 $W(e_i + 1)$ for $i=1,2.. . n - 1$.

Further in our work we have also employed discrete wavelet transform along with the above discussed graph theory based image segmentation algorithm. The use of DWT helps to facilitate the image segmentation process.

The first DWT was invented by the Alfred Haar. For an input list of 2n numbers, the Haar wavelet transform may simply pairs up input values, storing the difference and passing the sum. This process is repeated recursively resulting 2n-1 in differences and one final sum. Another most commonly used wavelet transform is formulated Daubechies, which is based on the use of recurrence relations to generate progressively finer discrete samplings of an implicit mother wavelet function; each resolution is twice that of the previous scale. Both Haar and

Daubechies (DB2, DB3, DB4 and DB5) wavelet transforms have been used in this work.

V. RESULTS

The above proposed algorithm which involves use of DWT along with graph theory based segmentation has been implemented using MATLAB. The designed GUI gives option to select for the wavelet to be applied during segmentation as in Figure 1. Consider the input image as in Figure 2. The outputs for different wavelets are shown in Figure 3.
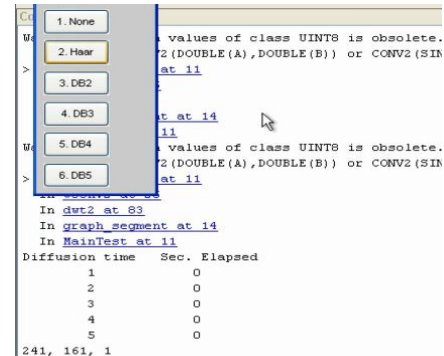

Figure 1: Designed GUI for proposed algprithm
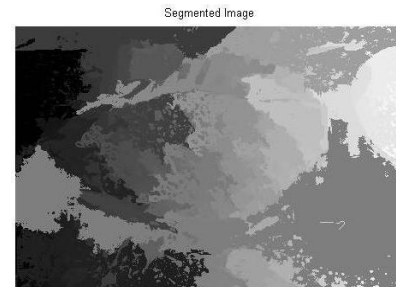

Figure 2: Input Image

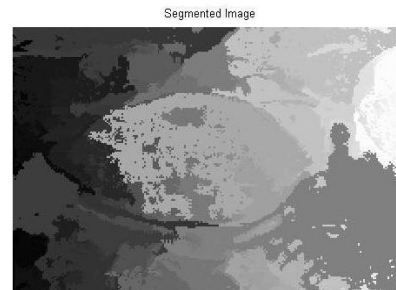Figure 3(a): Segmented Image for None

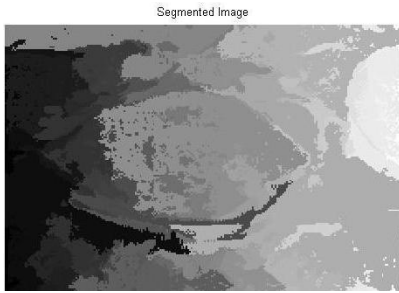Figure 3(b): Segmented Image for Haar
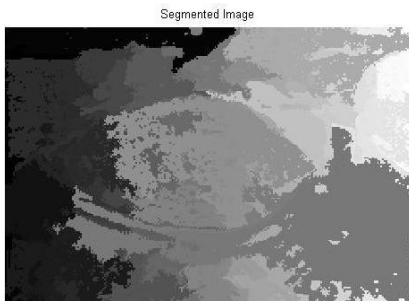
Figure 3(c): Segmented Image for DB2

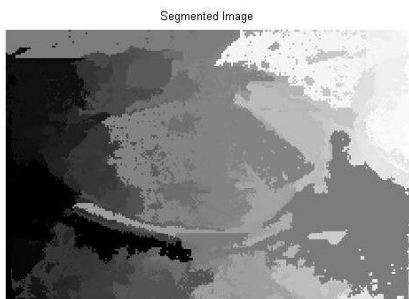Figure 3(d): Segmented Image for DB3

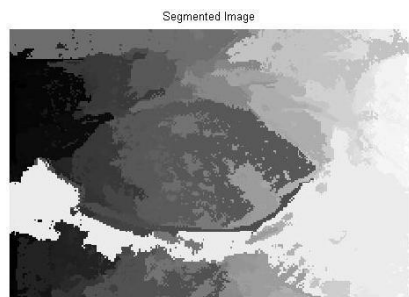Figure 3(e): Segmented Image for DB4
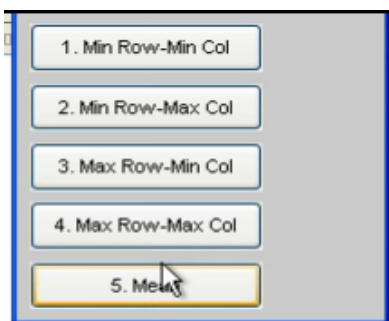

Figure 3(e): Segmented Image for DB5

Figure 4: Designed GUI for Histogram based segmentation

Figure 5(a): Segmented Image for Min-row Min-column

Figure 5(b): Segmented Image for Min-row Max-column

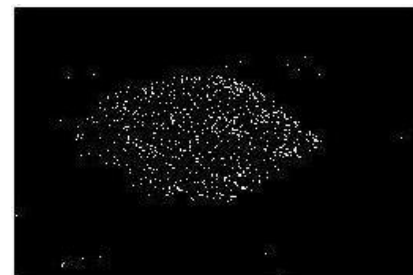Figure 5(c): Segmented Image for Max-row Min-column

Figure 5(d): Segmented Image for Max-row Max-column

Figure 5(e): Segmented Image for Mean

Figure 4 shows the designed GUI for histogram based segmentation, which gives the option of segmenting the input image with Min or Max of column and/or rows and mean of column and rows. Figure 5 shows the output results for input

image in Figure 2 for different options for Histogram based image segmentation.

The above results are summarized in table I and II below using PSNR (peak signal-to-noise ratio) and segmentation time required. The PSNR here is used as the quality metrics along with time taken for image segmentation as comparison parameter. It can be seen from table I that for histogram based segmentation with Max-row and Max-column gives the best PSNR and segmentation time. From table II for graph theory based image segmentation, the best PSNR is obtained for no DWT applied, but the time required for segmentation is large as compared to one with DWT. However the use of Haar wavelet has good values of PSNR and segmentation time.

TABLE I
HISTOGRAM BASED IMAGE SEGMENTATION RESULTS

	Histogram Based Image Segmentation	
	PSNR	**Time Required (s)**
Min-row Min-column	7.61	0.07
Min-row Max-column	8.29	0.10
Max-row Min-column	7.52	0.06
Max-row Max-column	33.62	0.07
Mean	4.85	0.14

TABLE III
GRAPH THEORY BASED IMAGE SEGMENTATION RESULTS

Wavelet Used	Graph Theory Image Segmentation	
	PSNR	**Time Required (s)**
None	12.97	3.58
Haar	12.94	0.55
DB2	12.91	0.54
DB3	12.86	0.57
DB4	12.83	0.56
DB5	12.92	0.59

VI. CONCLUSIONS

In this project work histogram based and graph theory based image segmentation has been evaluated. The proposed algorithms have been implemented using MATLAB. From the results it can be seen that histogram based segmentation technique requires small segmentation time in comparison to graph theory based segmentation techniques but suffers from lower PSNR values. Further the use of Haar and DB2 wavelet for

graph based segmentation has good PSNR and low segmentation time.

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