ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

Analysis of Two Image Segmentation Schemes Based on Its Error Rate

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Abstract— There are various image segmentation techniques available. Each one is distinct according to the parameters and segmentation constraints. Also there are region based segmentation and boundary based segmentation. Here two such image segmentation methods: Graph cut and Maximal Similarity based Region Merging are considered and the two are analysed on the basis of error rate. Graph cut involves finding the distance between pixels and minimizing an energy function. MSRM approach finds the similarity between two regions using a similarity measure. The experiments are conducted and the results obtained are formulated. The criteria and pre segmentation procedure are different for the two methods. One is designed for the segmentation of texture images and the other for colour images. Graph cut combines both region based and boundary based methods whereas MSRM is a region based segmentation technique. The advantages and disadvantages of these methods are analysed on different aspects.

Keywords— Image segmentation, Texture, Graph cut, Colour histogram, Similarity measure, Error rate

I. INTRODUCTION

Image segmentation is a concept which is commonly heard in the area of image processing. It is also having various application areas like medical image processing, satellite image, and pattern recognition. Here we are dealing with the segmentation of objects from an image. This is a user interactive method where the user can mark his region of interest and the rest will be done by any segmentation algorithms. The question here is: what type of images is used? What are the criteria's taken for the segmentation? Which method is used for segmentation? What are the evaluation parameters? Well the answer for all these are described in detail in the following sections.

A. Segmentation Criteria's

The main problem addressed here is the extraction of a foreground objects from its complex background [1]. The method should be user interaction based because automatic segmentation does not involve the selection of the area of interest. There are several parameters which are taken into account during the segmentation. The type of image i.e.; natural images or texture image, other parameters include the colour, shape, size of the image etc… In this paper we are taking two approaches where the texture image and colour of the image are taken into account during the initial segmentation. Texture of an image can be defined as patterns in the image or in other words the information about the spatial arrangement of intensity or colour in the image [2]. In images where the foreground and background is having similar patterns, segmentation of foreground objects is difficult. For this in [1] Hailing Zhou et.al describes a texture descriptor for identifying the textures in the image. The colour of the image is another factor which is taken into account. In [2] a colour histogram is used as the descriptor to represent the object features. Both colour and texture are effective measures in pattern recognition [3] and object tracking [4].

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The next issue is the approach taken for segmentation. There are two types of approaches which are widely used for segmentation. One is the region based segmentation and the other is boundary based segmentation. Region based segmentation is similar to clustering where neighbouring pixels having similar values are grouped together [5]. This is also called region growing. Graph cut is one of the techniques that make use of the region based segmentation. Boundary based segmentation techniques are used to overcome the limitations of the region based techniques. It involves looking for explicit or implicit boundaries between regions [6]. The two main approaches of boundary based technique are the ridge detection and edge detection. Here two region based approaches are taken into account for comparison.

II. GRAPH CUT SEGMENTATION

Graph cut segmentation procedure is applied on images with textures. The classical graph cut method does not deal with colour and texture. In order to incorporate these features into the graph cut several parameters are defined. A texture descriptor is one such parameter that helps to analyse the texture feature in an image. For this range filtering technique can be applied to find the texture. To incorporate colour intensity values a structure tensor is described as in [7] which tells the local intensity variations in the area of interest. The outputs of these two parameters are considered for the segmentation process. For segmentation conventional graph cut is used. Because of some threshold parameters which have to be set during the segmentation for each image the complexity of this method increases.

A. Texture Descriptor

Texture descriptor as the name specifies the textures in the image. Texture analysis is done to find the texture boundaries and texture segmentation [8]. A range filter is used as the texture descriptor. It helps to identify the range of intensities in areas where similar or smooth textures and areas with rough textures. This is identified by considering an area or an NxN region around a pixel and finding the similarities between the intensities. An example of range filtering method is shown in the figure.

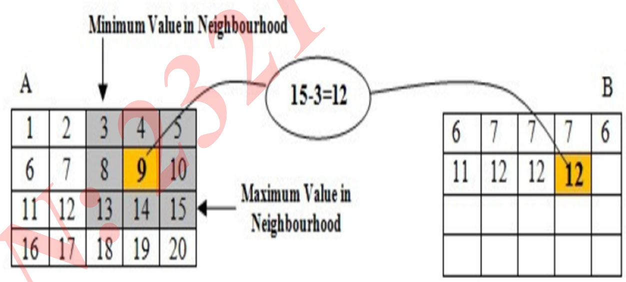

Fig 1. An example of range filter operation

Consider 3x3 neighbouring pixels around a pixel. Now the maximum and minimum value in that neighbourhood is found. These values are then subtracted and the result is replaced at the pixel position considered initially. This process is continued and the result will give a grey image showing the texture boundaries. Thus the texture descriptor output can be used to define the segmentation boundaries.

B. Structure Tensor

Structure tensors describe the local colour or intensity variations of the image [1]. They are incorporated into the graph cut in order to guide the segmentation accurately corresponding to maximal and minimal intensity variations. Structure tensor is based on a gradient function f at a point (x,y). The gradient function is calculated using Gaussian derivative filters.

$$f_x = g_{x,\sigma} * f, \quad f_y = g_{y,\sigma} * f$$

Vol. 2 Issue IV, April 2014

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

* is the convolution and gx and gy is the spatial derivative in x and y direction of the Gaussian [7]. σ is the standard deviation and is calculated as:

$$g_\sigma(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

The output of the gradient tensor is the Cartesian product of the gradient. To distribute the information over the neighbourhood spatial averaging is done using the Gaussian filters. An hour glass filter is employed as the last step for visualizing the maximal and minimal intensity variations as ellipses. The filter produces ellipses of different orientation in areas of differing intensities. The structure tensor is a complex part which increases the complexity of the method. Without the structure tensor the error rate is considerably less.

C. Graph Cut Algorithm

Graph cut algorithm takes the segmentation as a binary labelling problem where a pixel is labelled as either background or foreground. The graph cut considers every pixel in an image as a node and the distance between two nodes is represented using an edge. The labelling is formulated as a minimization problem consisting of a region term and boundary term. The graph cut segmentation combines the region based and boundary based segmentation. The minimization problem is as follows [1]:

The energy function comprises of a region term , boundary term and a trade-off factor γ which is set to 50. The region term and boundary term calculation is shown in [1]. H. Zhou et.al applies a convex active contour and local boundary editing as a post segmentation procedure to improve the efficiency of the segmentation. In [9] an active contour without edges is employed. Here the active contour is iteratively applied to the segmentation. The distance of the neighbouring points of the curve to the boundary is calculated in each of the iteration. The mean of the points and the curvature of the boundary curve give the accurate boundary and the curve is corrected accordingly. A soft brush constraint can be added into the post process where the two points are marked. The distance between these two points is calculated using Dijkstra's shortest path and the boundary is redrawn.

III. MAXIMUM SIMILARITY BASED REGION MERGING

Maximal Similarity Based Region Merging (MSRM) method involves segmentation of colour images. The main advantage of the method is that it is adaptive to image content. Also there is not threshold required like in Graph cuts. Before the segmentation the images have to be pre-processed. For this many methods are involved in which the initial segmentation is carried out using mean shift [10], watershed [11] etc. In MSRM, mean shift segmentation software-the EDISON system [12] is made use of for initial segmentation. The colour features are described using a colour histogram. This is because the colours of different regions in initial segmented result will be having similarity.

The colour histogram is computed using the RGB colour space. Each colour channel is quantized into 16 channels or levels forming a feature space of 4096 bins. Based on the colour histograms the regions are merged to extract the desired object. J. Ning et.al proposes a similarity measure [13] where the similarity between two regions are calculated using the Bhattacharya co efficient [14].

$$\rho(R,Q) = \sum_{U=1}^{4096} \sqrt{Hist_R^U . Hist_Q^U}$$

R and Q are the two regions and $Hist_R$, $Hist_Q$ are the normalized histograms of the two regions. Bhattacharya co efficient ρ is a divergence type measure and is the cosine of angle between to vectors $\left(\sqrt{Hist_R^1} \ldots\ldots \sqrt{Hist_R^{4096}}\right)^T$ and $\left(\sqrt{Hist_Q^1} \ldots\ldots \sqrt{Hist_Q^{4096}}\right)^T$.

A. Merging

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

Since this is a user interactive approach the initial step is the marking of object and the background by the user. After the user has identified the region which is the desired object the rest of the marking is done by the algorithm. One of the advantages of MSRM is that no regions are left unlabelled or unmarked. All the regions or pixels are either marked as background or object. This is possible through two merging process namely: Background merging and Object merging.

Initially when the user marks the object and the background, the regions are assigned into two marker labels, one for object and other for background. The pixels in the background marker form the basis for background merging. The unmarked labels will form the unmarked regions. The first stage of background merging is finding the similarity between the pixels in background region and unmarked region. The similarity is found using the Bhattacharya co efficient. If two pixels are found to be similar then that pixel is merged with the background region. This process continues iteratively. Thus the background region will enlarge and the unmarked region shrinks.

The next step of merging is the object merging. This works in a similar pattern as background merging. Here the pixels in object region and unmarked region are considered for the merging process. The similarity between an object pixel and unmarked pixel are found. If they are similar then the unmarked pixel will be merged with the object region. This is also an iterative process at the end of which the size of the unmarked region will be zero. Now the object can be segmented by extracting the object regions.

B. MSRM Algorithm

The overall MSRM Algorithm can be summarized as: [13] **Input**: the initial mean shift segmentation result

Output: the final segmentation map

While there is region merging in the last loop

Stage1. Merging non-marker regions in N with marker background regions in $\mathbf{M_B}$

Input: the initial segmentation result or the merging result of the second stage.

(1-1) For each region $B \in \mathbf{M_B}$, form a set of its adjacent regions $\bar{S}_B = \{A_i\}_{i=1,2,\ldots,r}$

(1-2) For each A_i and $A_i \notin \mathbf{M_B}$, form its set of adjacent regions $\bar{S}_{A_i} = \{S_j^{A_i}\}_{j=1,2,\ldots,k}$. There is $B \in \bar{S}_{A_i}$

(1-3) Calculate $(A_i, S_j^{A_i})$. If $(A_i, B) = \max_{j=1,2,\ldots,k} \rho(A_i, S_j^{A_i})$, then $B = B \cup A_i$. Otherwise B and A_i will not merge.

(1-4) Update $\mathbf{M_B}$ and **N** accordingly.

(1-5) If the regions in $\mathbf{M_B}$ will not find new merging regions, the first stage ends. Otherwise go back to (1-1).

Stage 2. Merging non marker regions in **N** adaptively

Input: the merging result of the first stage.

(2-1) For each region $P \in \mathbf{N}$, form a set of its adjacent regions $\bar{S}_P = \{H_i\}_{i=1,2,\ldots,p}$

(2-2) For each H_i that $H_i \notin \mathbf{M_B}$ and $H_i \notin \mathbf{M_O}$, form its set of adjacent regions $\bar{S}_{H_i} = \{S_j^{H_i}\}_{j=1,2,\ldots,k}$. There is $P \in \bar{S}_{H_i}$.

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

(2-3) Calculate $\rho(H_i, S_j^{H_i})$. If $\rho(P, H_i) = \max_{j=1,2,\dots k} \rho(H_i, S_j^{H_i})$, then $P = P \cup H_i$. Otherwise P and H_i will not merge.

(2-4) Update **N**.

(2-5) If the regions in **N** will not find new merging region, the second stage stops. Otherwise go back to (2-1).

End

IV. EXPERIMENTAL RESULTS

The Graph cut Segmentation and MSRM segmentation was performed on the Berkeley Segmentation dataset [15]. The BSD dataset is rich in images. It has around 500 images having texture rich images and also colour images suitable for both the segmentation schemes. The ground truth segmentation results are also available. The MATLAB R2008b was used for the implementation of the segmentation. The software is embedded with various in built toolboxes which are used in the segmentation. After the segmentation implementation is over both the algorithms were tested using the images in the dataset.

On completion of the testing it is found that according to the variations in the trade off factor set in the Graph cut algorithm the segmentation results vary. Similarly by the number of input markers on the image given by the user the segmentation results vary in MSRM approach. The more number of input markers will yield the accuracy of the segmentation. However in images having shadows, low contrast boundaries the segmentation boundary is jaggy in the case of MSRM and it is corrected in Graph cut method enhanced with the boundary editing.

For quantitative analysis of the segmentation algorithms error rate was taken as the parameter for finding the efficiency of the algorithms. Error rate can be defined as the ration of number of wrongly marked pixels to the total number of unmarked pixels. MSRM approach guarantees the fact that none of the pixels are left unmarked, but on quantitative analysis it is found that some pixels are still unmarked. This can vary according to the number of input markers.

The following table shows the error rate obtained for the Graph cut and MSRM approach.

$$\text{Error rate} = \frac{\text{Number of wrongly marked pixels}}{\text{Total number of unmarked pixels}}$$

The number of wrongly marked pixels can be found by taking the difference between the segmented result and the ground truth. For this the ground truth segmentation results are available in the BSD dataset.

TABLE I

ERROR RATES OBTAINED FOR THE TWO SEGMENTATION TECHNIQUES

SEGMENTATION APPROACH	ERROR RATE
Graph cut	4.15
MSRM	2.78

The table shows the error rate of both the methods. The experiment was done on six different images and the error rate of individual images was found which is tabularized below. From the values of the error rate it is clear that the MSRM based image segmentation scheme produces less error on segmentation. But the constraints taken on the different approaches are different and so both the methods can be applied on various applications as required.

TABLE II

ERROR RATES OBTAINED FOR GRAPH CUT

IMAGES	ERROR RATE
Bear	2.3
Boat	5.1
Cheetah	3.2
Panther	4.8
Plane	4.3
Tiger	5.2

TABLE III

ERROR RATES OBTAINED FOR MSRM

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

IMAGES	ERROR RATE
Bird	3.3
Flower	3
Fruit	2.2
Girl	1.8
Starfish	2.5
Tiger	3.9

V. Conclusions

The two segmentation schemes are having advantages as well as disadvantages. Both are giving a reasonable error rate. But comparing the error rate of the two MSRM approach is having considerably less error rate than Graph cut. Also complexity of the MSRM is less than that of Graph cut. Due to the complexities in the components used in the graph cut the implementation becomes difficult. The approaches can be chosen suitably according to the application. These methods are mainly used in pattern recognition and object extraction applications. Future work may include the application of boundary editing method into MSRM to increase the accuracy during segmentation of images having shadows and low contrast boundaries.

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