A Study of Image Segmentation and Edge Detection Techniques

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Abstract—Image segmentation is the key behind image understanding. Image segmentation is one of the most important steps leading to the analysis of processed image data. It is the prime area of research in computer vision. A number of image segmentation techniques are available ,but there is no one single technique that is suitable to all the applications .Hence researches select the techniques as per the application or combine more than one techniques as per the requirement of the application. In this paper we have discussed about some image segmentation techniques like edge based, region based and integrated techniques and explains in brief the edge based techniques and their evaluation. This paper focuses on edge based techniques and their evaluation.

Keywords-Image segmentation,Edge detection

I. INTRODUCTION

Image segmentation a solution to a number of computer vision problems is the process of dividing an image into different regions such that each region is homogeneous.

There are various applications of image segmentation like locate tumors or other pathologies, measure tissue volume, computer-guided surgery, treatment planning, study of anatomical structure, locate objects in satellite images, fingerprint recognition etc

Image segmentation methods are categorized on the basis of two properties discontinuity and similarity. Methods based on discontinuities are called as boundary based methods and methods based on similarity are called Region based methods.

This paper not only gives the overview of various segmentation techniques but also gives the details of edge detectors with their evaluation techniques

II. IMAGE SEGEMNTATION TECHNIQUES

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Segmentation is a process that divides an image into its regions or objects that have similar features or characteristics.

Mathematically complete segmentation of an image R is a finite set of regions R1…Rs, [1].

$$R = \bigcup_{i=1}^{s} Ri \qquad Ri \cap Rj = \emptyset \qquad i \neq j \qquad (1)$$

Image segmentation methods can be categorized as below

- Region Based Methods
- Edge Based Methods
- Hybrid Techniques

A. Region Based Techniques

Region based methods are based on 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.

Region-based techniques rely on common patterns in intensity values within a cluster of neighboring pixels. The cluster is referred to as the region, and the goal of the segmentation algorithm is to group the regions according to their anatomical or functional roles.

B. Clustering Technique

Given an image this methods splits them into K groups or clusters. The mean of each cluster is taken and then each point p is added to the cluster where the difference between the point and the mean is smallest. Since clustering works on hue estimates it is usually used in dividing a scene into different objects.

The performance of clustering algorithm for image segmentation is highly sensitive to features used and types of objects in the image and hence generalization of this technique is difficult.

Ali, Karmarkar and Dooley[2] presented a new shape-based image segmentation algorithm called fuzzy clustering for image segmentation using generic shape information (FCGS) which integrates generic shape information into the Gustafson-Kessel (GK) clustering framework.

Hence using the algorithm presented in[2] can be used for many different object shapes and hence one framework can be used for different applications like medical imaging, security systems and any image processing application where arbitrary shaped object segmentation is required.

But some clustering algorithms like K-means clustering doesn't guarantee continuous areas in the image, even if it does edges of these areas tend to be uneven, this is the major drawback which is overcome by split and merge technique

C. Split and Merge Technique

There are two parts to this technique first the image is split depending on some criterion and then it is merged.

The whole image is initially taken as a single region then some measure of internal similarity is computed using standard deviation. If too much variety occurs then the image is split into regions using thresholding. This is repeated until no more splits are further possible. Quadtree is a common data structure used for splitting. Then comes the merging phase, where two regions are merged if they are adjacent and similar. Similarity can be measured by comparing the mean gray level or using statistical tests. Two regions R1 and R2 are merged into R3 if ,

$$H(R1 \cup R2) = TRUE$$
$$|m1 - m2| < T$$

Where, m1 and m2 are the mean gray-level values in the regions R1 and R2, and T is some appropriate threshold [1].

Merging is repeated until no more further merging is possible. The major advantage of this technique is guaranteed connected regions. Quadtrees are widely used in Geographic information system.

Kelkar D. and Gupta, S[3] have introduced an improved Quadtree method (IQM) for split and merge .In this improved method they have used three steps first splitting the image, second initializing neighbors list and the third step is merging splitted regions. They have divided the third step into two phases, in-house and final merge and have shown that this decomposition reduces problems involved in handling lengthy neighbor list during merging phase.

The drawbacks of the split and merge technique are, the results depend on the position and orientation of the image, leads to blocky final segmentation and regular division leads to over segmentation (more regions) by splitting. This drawback can be overcome by reducing number of regions by using Normalized cuts method.

D. Normalized Cuts

This technique is proposed by Jianbo Shi and Jitendra Malik is mostly used in segmentation of medical images.

This method is based on graph theory. Normalized cuts aim at splitting so that the division is optimal. Each pixel is a vertex in a graph, edges link adjacent pixels. Weights on the edge are assigned according to similarity between two corresponding pixels.

The criterion for similarity is different in different applications. Similarity can be defined the distance, color, gray level, textures and so on.

The advantage of this technique is that it removes the need to merge regions after splitting. It gives better definition around the edges Shi and Jitendra Malik [4], in their paper Normalized cuts and image segmentation shows how normalized cut is an unbiased measure of disassociation between subgroups of a graph and it has the nice property that minimizing normalized cut leads directly to maximizing the normalized association, which is an unbiased measure for total association within the subgroups.

Wenchao Cai, JueWu, Albert C. S. Chung [5] improved the performance of the normalized cut by introducing the shape information. This method can correctly segment the object, even though a part of the boundary is missing or many noisy regions accompany the object.

Thus there are various advantages of this method like it presents a new optimality criterion for partitioning a graph into clusters, different image features like intensity, color texture, contour continuity are treated in one uniform network.

But there are certain disadvantages like lot of computational complexity involved especially for full-scale images.
The performance and stability of the partitioning highly depends on the choice of the parameters.

E. Region Growing

Of the many proposed image segmentation methods, region growing has been one of the most popular methods.
This method starts with a pixel and will go on adding the pixels based on similarity, to the region. When the growth of a region stops another seed pixel which does not belong to any other region is chosen, and again the process is started. The whole process is repeated until all pixels belong to some region. The advantage of this technique is, connected regions are guaranteed.
Matei Mancas, Bernard Gosselin and Benoit Macq [6] have used in their research a method which only needs one seed inside the region of interest (ROI). They have applied it for spinal cord segmentation but have found that it also shows results for parotid glands or even tumors.
There are various applications where region growing techniques is mostly used like, to segment the parts of human body during treatment planning process e.g. segmentation of prostrate, bladder and rectum from contrast CT data.
There are certain advantages of this technique like multiple criterions can be selected at the same time, gives very good results with less noisy images.
But the various disadvantages of this technique are, if seeded region growing method is used then noise in the image can cause the seeds to be poorly placed, over segmentation may take place when the image is noisy or has intensity variations, cannot distinguish the shading of the real images, this method is power and time consuming.

F. Thresholding

This is the simplest way of segmentation. Using thresholding technique regions can be classified on the basis range values, which is applied to the intensity values of the image pixels. Thresholding is the transformation of an input image f to an output (segmented) binary image g as follows [1].

$$g(i,j) = 1 \;\; for \;\; f(i,j) \geq T$$
$$= 0 \; for \; f(i,j) < T$$

Where T is the threshold, g(i,j)=1 for image elements of objects and g(i,j)=0 for image elements of the background(or vice versa)
Thresholding is computationally inexpensive and fast, it is the oldest segmentation method and is still widely used in simple applications. Using range values or threshold values, pixels are classified using either of the thresholding techniques like global and local thresholding. Global thresholding method selects only one threshold value for the entire image. Local thresholding selects different threshold values for different regions. To segment complex images multilevel thresholding is required.

G. Edge Based Techniques

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 the problem of fundamental importance in image analysis. Edge detection techniques are generally used for finding discontinuities in gray level images. Edge detection is the most common approach for detecting meaningful discontinuities in the gray level. Image segmentation methods for detecting discontinuities are boundary based methods
Edge detection can be done using either of the following methods
Edges are local changes in the image intensity. Edges typically occur on the boundary between two regions. Important features can be extracted from the edges of an image (e.g., corners, lines, curves).Edge detection is an important feature for image analysis. These features are used by higher-level computer vision algorithms (e.g., recognition). Edge detection is used for object detection which serves various applications like medical image processing, biometrics etc. Edge detection is an active area of research as it facilitates higher level image analysis. There are three different types of discontinuities in the grey level like point, line and edges. Spatial masks can be used to detect all the three types of discontinuities in an image.
The various reasons that cause intensity changes are

- **Geometric events**
  - object boundary (discontinuity in depth and/or surface color and texture)
  - surface boundary (discontinuity in surface orientation and/or surface color and texture)
- **Non-Geometric events**
  - Specularity (direct reflection of light, such as a mirror)
  - shadows (from other objects or from the same object)
  - inter-reflections

2.1. Ideal edges in an image are

- Step edge: the image intensity abruptly changes from one value to one side of the discontinuity to a different value on the opposite side.
- Ramp edge: a step edge where the intensity change is not instantaneous but occur over a finite distance.

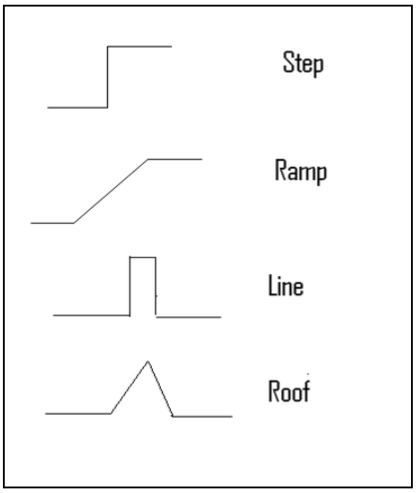

Fig.1 Various ideal edges in an image

- Line edge: the image intensity abruptly changes value but then returns to the starting value within some short distance (generated usually by lines).
- Roof edge: a ridge edge where the intensity change is not instantaneous but occur over a finite distance (generated usually by the intersection of surfaces).

In typical images, edges are characterized as object boundaries and are therefore useful for segmentation, registration and identification of object in the scene.
An edge is a vector variable with two components magnitude and orientation, where

- Edge magnitude – gives the amount of the difference between pixels in the neighborhood (the strength of the edge).
- Edge orientation gives the direction of the greatest change, which presumably is the direction across the edge

Edge detection, segments the object while filtering the noise while preserving the structural properties of the image. Edge detection becomes difficult in case of noisy images as noise is also a high frequency content
According to John canny the following three criterions should be well taken care of while edge detection [6]

1. High probability of marking the real edge point and low probability of marking non edge points
2. The points marked as edge points should be as close as possible to the center of the true edge
3. There should be only one response to a single edge i.e. double line for edges should not be detected

III. Edge Detection

All the edge detection operators are grouped under two groups as

- 1st order Derivative
  - Prewitt operator
  - Sobel operator
  - Canny operator
  - Test operator
- 2nd Order Derivative:
  - Laplacian operator
  - Zero-crossings.

IV. Edge Detection evalutaion

Before you begin to format your paper, first write and save the content as a separate text file. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

Various people have demonstrated various ways of evaluation of edge detectors. While some of them follow the visual method of edge detection, where the edge map is shown to some people and various people rate the edge map on the basis of number of edges being detected. Most of them have also used the Receiver operating characteristic (ROC) curves for evaluating the performance of edge detectors [7-8].

Kevin Bowyer have used the edge map and the ground truth of the images where the statistical measure gives the true positive, true negative, misdetected and false alarm [8]

The primary concern in any Segmentation system is its ability to correctly verify a claimed edge or efficiently segment the image by determining the correct edges in the given image database. In order to assess a given system's ability to perform these tasks, a variety of evaluation methodologies have arisen. Performance evaluation of edge detectors have always been a biggest point of concern.
Some of the key measurements in evaluation the efficiency of edge detectors include
Some of the key measurements in Verification include:

- The False Acceptance Rate (FAR) and
- The False Rejection Rate (FRR)

The FAR, also known as a False Match Rate, describes the number of times the edges are inaccurately positively matched.

$$\text{False Acceptance Rate (FAR)} = \frac{\text{Incidences of False Acceptance}}{\text{Total Number of Sample}} \times 100 \qquad (1)$$

The FRR, also known as a False Non-Match Rate, derives the number of times an edge which should be identified positively is instead rejected.

$$\text{False Rejection Rate (FRR)} = \frac{\text{Incidences of False Rejections}}{\text{Total Number of Sample}} \times 100 \qquad (2)$$

The combination of the FAR and FRR can help determine which edge detector is more useful for a particular type of image. The performance of an edge detection system may also be summarized using the measures based on Receiver Operating Characteristic (ROC) such as the Receiver Operating Characteristic Area (ROCA).

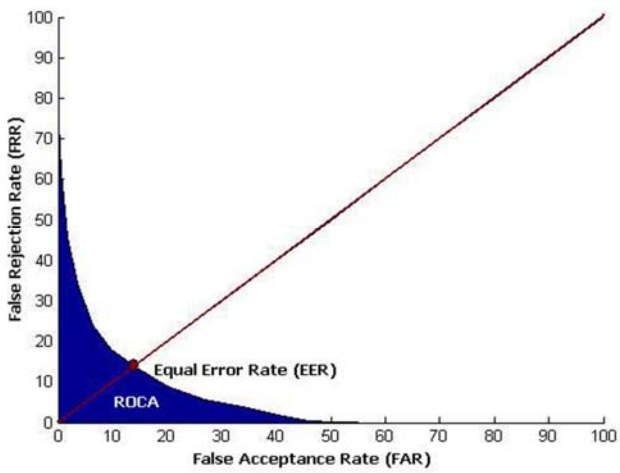

Fig: 2 Receiver Operating Characteristic

The lower the ROCA, the better the performance of edge detection system.
In case of comparison of the various edge detectors the edge map is compared with the ground truth to determine the percentage of edges correctly detected (i.e., the best match). The best match edge detector can be determined by examining the FAR and FRR ratios in comparison with each other. And the edge detector with the lowest ROCA and highest RR is considered to be the best.
The identification rate (Recognition rate) indicates the proportion (percentage) of the edges correctly identified (detected) by the edge detection system.

$$\text{Rcognition Rate (RR)} = \frac{\text{Incidences of True Identificaton}}{\text{Total Number of Sample}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

V. ALGORITHM

The algorithm together for edge detection and evaluation works as below [9]

- Apply the Edge detectors on the images.
- Compare the Edge Map : the output of the previous step with the Ground truth of the image
  - Exact match pixels are counted as True positives(TP) or true identification
  - The ground truth edge pixels which do not have any declared edge pixels within a distance of chosen threshold t are misdetected pixels
  - The edge map pixels which do not have any ground truth pixels within the threshold t are false alarm pixels
- After the exact match pixels are found the remaining misdetected and False alarm pixels can be found by finding the distance between the edge map and ground truth pixels
- Then by applying the Hungarian algorithm the pixels in the Edge map are matched with the ground truth and this give the TP, misdetected (MD) and False alarms(FA).
- After TP,MD and FA are found the recognition rate(RR) and ROCA can be calculated by using the formulae given above to compare the results of edge detectors

Table 1 Comparative result of the edge Detectors

Images	Edge Detectors			
	Prewitt		Sobel	
	RR	ROCA	RR	ROCA
image1	91.82	5.98	91.86	5.11
image2	86.77	57.69	86.89	55.7

VI. CONCLUSION

This paper describes the various image segmentation techniques and discusses in detail the edge detection techniques and their evaluation. It gives an algorithm which is a combination of detection and evaluation of the edge detectors. The results show that the recognition rate depends on the type of the image and their ground truths.

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