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Detail and Comparative Study on Various Segmentation Techniques

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Abstract— As day by day new computer technologies are emerging in the area of image processing, especially in the field of segmentation. Image Segmentation is a hotspot and important process of image processing. Several algorithms and techniques are developed for image segmentation. It is a technique of partitioning digital image into multiple regions called segments for further analysis. It is very useful in image comprehension and in differentiating different objects in the image. As there is no general solution to the image segmentation these algorithms are often combined for better interpretation. This paper presents a comparative study of various basic image segmentation techniques.

Keywords— Image Processing; Segmentation; Thresholding; Image Analysis; Edge Detection; Clustering.

I. INTRODUCTION

Image processing is the use of algorithms to analyse digital image. Image segmentation is one of the most difficult processes of digital image processing. In this technique digital image is partitioned in different segments depending on the similar features and properties. It is done before denoising the image. The goal of performing segmentation is for better understanding and interpretation of the digital image [4]. The extent of segmentation to which the subdivision of the image is done depends on the problem being solved. In other words, segmentation should stop when the object of interest is isolated. Image processing is a low-level operation in image engineering. It works on pixels. As operation is carried out on pixel-level a modified version of image is produced [8]. Hence it improves the visual effects of the image. Image processing follow 3 levels and each is subdivided into further different categories.

A. Reconstruction

1) Restoration
- *Radiometric*
- *Geometric*

2) Transformation
- *Contrast Stretching*
- *Noise Filtering*
- *Histogram modification*
- *Data Compression*

- *Rotation*

3) *Classification*
   - *Segmentation*
   - *Classification*
     - *Supervised*
     - *Unsupervised*

The middle-level i.e. image analysis it deals with the measurement. A new set of images are produced by Principal Component Analysis (PCA) from the given set. At the high level image understanding, image is analysed and interpreted. Image segmentation is the main step from image processing to image analysis. It makes feature measurement easier and gives better interpretability [42].

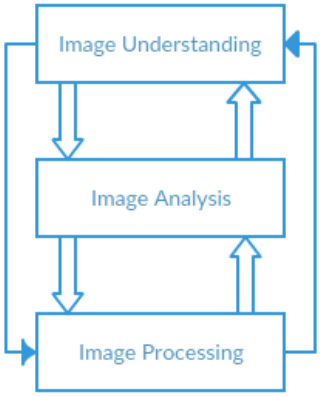

Fig. 1 Image engineering

II. CLASSIFICATION OF SEGMENTATION TECHNIQUES

Segmentation techniques are mainly classified into two main categories i.e. Layer- Based Segmentation and Block Based Segmentation Methods.

A. Layer- Based Segmentation Methods

By the use of this segmentation method object is defined more clearly on the basis of shape, appearance and depth. Hence evaluate class and instance segment.

B. Block Based Segmentation Method

Block Based Segmentation methods are based on different features present in the image. It could be colour information, information about pixels that helps in fencing off the edges or boundaries. Further, block based segmentation method are divided into two categories i.e. region based and edge or boundaries based. Fig.2

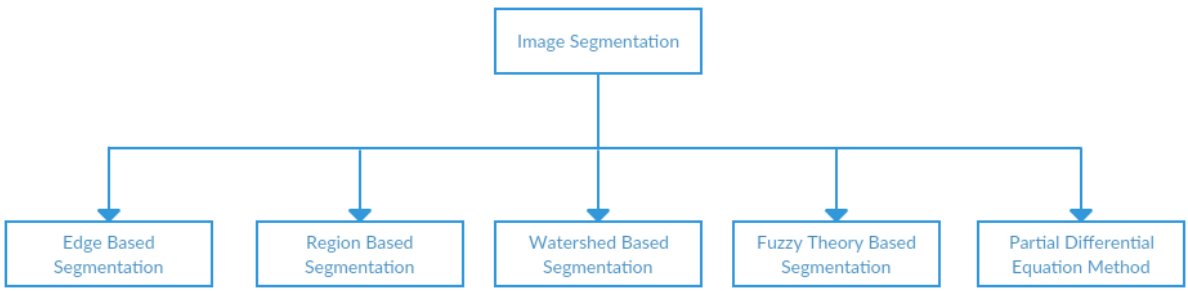

Fig. 2 Image segmentation techniques

In this paper we have discussed the popular image segmentation techniques like Thresholding Method, Edge Based Method, Region Based Method, Clustering Technique, Partial Differential Equation Based Method, Watershed method and Fuzzy Theory based Method [41]. All techniques use different approach for segmentation of a digital image.

III. IMAGE SEGMENTATION TECHNIQUES

C. Edge Based Segmentation Method

Edge detection techniques convert image to edge image by using the change of grey tone. Edges in the image are significance of discontinuity in the image. It shows rapid change in intensity value and form boundary between two regions. Edges are detected where either the first derivative of intensity is greater than a particular threshold or second derivative has zero crossings. Few popular types of edges are as follows.

1) Step Edge

Image intensity changes abruptly from one value to a different value which shows the discontinuity.

2) Ramp Edge

In real life it is very rare that a digital image has sharp edge. In reality ramp edges are the actual form of step edge.

3) Line Edge

In such edges intensity changes abruptly then returns to the initial value within short distance.

4) Roof Edge

The reality of line edges are roof edge.

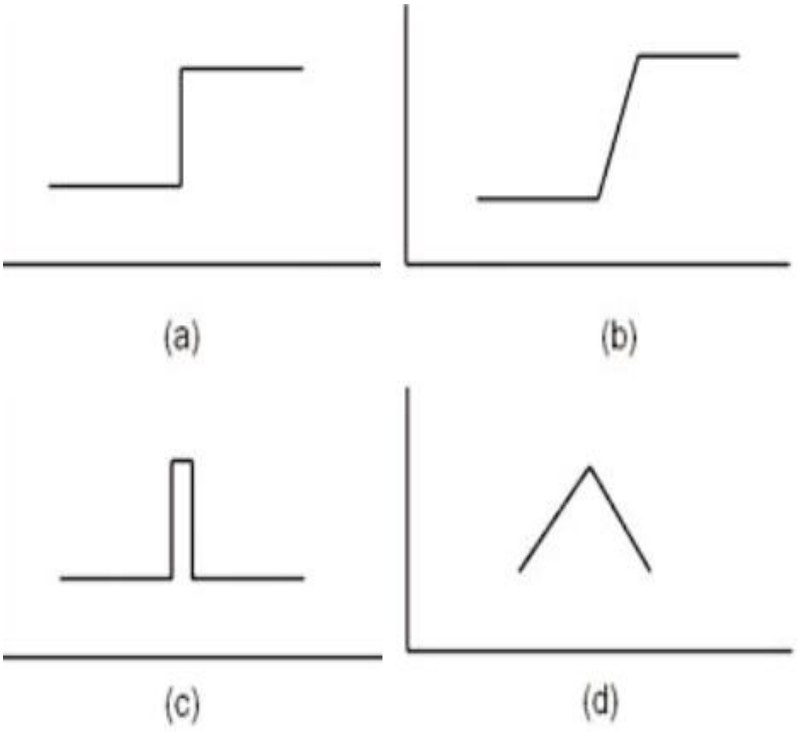

Fig. 3 types of edges (a) Step edge (b) Ramp edge (c) Line edge (d) Roof edge

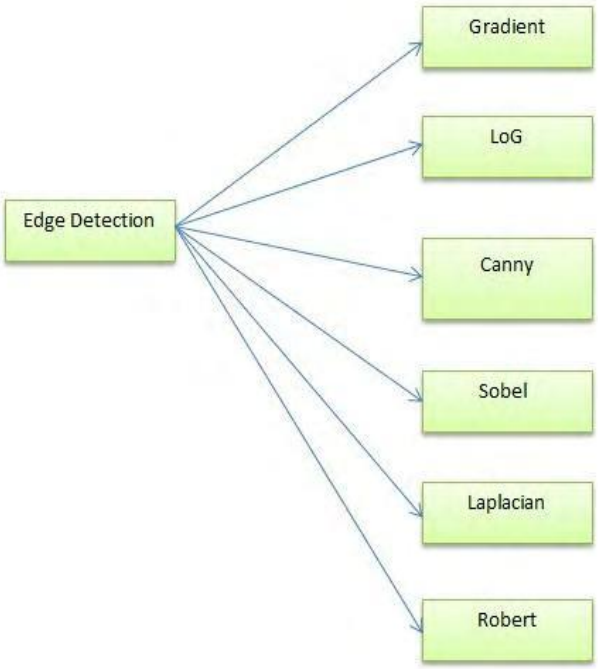

Fig. 4 Types of edge detection

There are various techniques shown in Fig.4 used for edge detection. Edges are detected on the basis of discontinuity in the intensity present in the digital image. Region are traced and compared with the neighbouring pixel value, by using both fixed and adaptive feature of Support Vector Machine (SVM).

There are some steps followed in canny Detector shown in Fig.5 described below.

Fig. 5 Procedures of canny Edge Detector

- The surface of the digital image is smoothened to reduce the effect of noise. This is done by using Gaussian Convolution.
- To measure edge strength and direction, sobel operator is used.
- Pixels are not taken in account which is not related to the edge and minimized. For non maximal suppression, the edge directions are taken into consideration.
- In last step, threshold value of an image is calculated and pixel value is compared. If the pixel value is higher than the threshold value then, it is considered as an edge else discarded.

D. Region Based Method

The entire image is divided into various regions having similar properties, also known as "Similarity Based Segmentation".

1) Clustering: K- means

Dividing the image into k graphs by adding point p, to the cluster where the difference is smallest between the points and the mean sharp boundaries between clusters produced by hard clustering. Fuzzy clustering is shape-based segmentation algorithm.

2) Split and Merge

At first the whole image is considered as a single region, repeatedly split until no more split is possible. Two regions are merged together if they are similar and adjacent. Merging is repeatedly done until no more merge is required.

3) Normalized Cuts

It aims at optimal splitting by reducing number of regions based on graph theory. Each pixel is considered as a vertex and edges link the adjacent pixels. On the basis of similarity, colour, distance, grey level between two corresponding pixels [42].

4) Region Growing

It is one of the most popular techniques. Combine the similar pixels based on properties and repeat until all pixels belong to the same region.

5) Thresholding

Algorithms come under Threshold Based Segmentation Technique divide the pixel with respect to their intensity level. There are basically three types of thresholding:

- *Global Thresholding*

An appropriate value for T is set and this value will be constant for whole image. On the basis of T output image q(x, y) can be obtained from the original image p(x, y).

$$q(x,y) = \begin{cases} 1, & p(x,y) > T \\ 0, & p(x,y) < T \end{cases}$$

- Variable Thresholding

In this type of thresholding, the value of the T can vary over the image and further grouped into two categories:

a) Local Threshold: In this the value of T depends upon neighbourhood of x and y.
b) Adaptive Threshold: The value of is a function of x and y.

- *Multiple Thresholding*

In this method there are multiple threshold values like T0 and T1 by these images can be computed as

$$q(x,y) = \begin{cases} m \ if \ p(x,y) > T1 \\ m \ if \ p(x,y) \leq T1 \\ m \ if \ p(x,y) \leq T0 \end{cases}$$

E. Watershed Based Method

Topological interpretation is used in this method. In this method intensity shows the basin having hole in its minima from where the water spills. Two adjacent basins are merged when water reaches the border of the basin. Dams are required to maintain the separation, which are made of dilation. Gradient of image is considered as topographic surface in this method [17]. Those pixels which have more gradient depicts the edges

F. Fuzzy Theory Based Method

Fuzzy sets are made by dividing pixels. Single pixel may belong to many sets and regions, as shown in Fig.5. Fuzzy rules for neighbourhood and edge detection for central pixel is clearly shown in the following diagram.

G. Partial Differential Equation Based Segmentation Method

As partial differential equation methods are one of the fastest methods for segmentation used in time critical application. Two basic methods partial differential equation are as follows:

1) Non-Linear Isotropic Diffusion filter(used for improve the edge)
2) Convex Non-Quadratic Variation restoration(used in noise removal)

Hazy and blur edges are produced by applying partial Differential Equation Method, and can be shifted by the use of close operator. For enhanced edge and boundary 2nd Order Partial Differential Equation Method is used and 4th Order Partial Differential Equation Method is used for noise removal [41].

IV. COMPARISON

Table I shows the difference between different image segmentation techniques with their advantages and disadvantages.

TABLE I
DIFFERENCE BETWEEN SEGMENTATION TECHNIQUES

S. No.	Segmentation Technique	Overview	Advantages	Disadvantages
01.	Edge Based Segmentation	Discontinuity present in the image is the significance of edge.	Images having contrast gives better result	Not good for multiple edge
02	Region Based Segmentation	Divide image into multiple partitions	Great for defining similarity of the region	Time and memory consuming
03	Watershed Segmentation	Depends on topological interpretation	Edges are continuous	Calculation is more complex
04	Fuzzy Based Segmentation	Fuzzy sets are made by dividing pixels on the basis of their properties.	Easy to implement and converge very well	Determination of set is tough and noise sensitive
05	Partial Differential Equation Method	Based on evaluation of partial differential equation	Fastest method and great for time critical applications	Computational complexity is high

V. CONCLUSIONS

In this paper, a detail and comparative study is carried out on various image segmentation techniques. From the study it is found that no single method is good enough for all kinds of images. As segmentation result depends on various factors like pixel, colour, intensity, image texture, content, similarity etc. Also an image can be segmented by using different segmentation techniques. As segmentation techniques are required in many real life applications, it has challenging future.

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