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REVIEW ARTICLE

Various Image Segmentation Techniques: A Review

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Abstract -- The Image segmentation is referred to as one of the most important processes of image processing. Image segmentation is the technique of dividing or partitioning an image into parts, called segments. It is mostly useful for applications like image compression or object recognition, because for these types of applications, it is inefficient to process the whole image. So, image segmentation is used to segment the parts from image for further processing. There exist several image segmentation techniques, which partition the image into several parts based on certain image features like pixel intensity value, color, texture, etc. These all techniques are categorized based on the segmentation method used. In this paper the various image segmentation techniques are reviewed, discussed and finally a comparison of their advantages and disadvantages is listed.

Keywords -- Image segmentation; similarity detection; edge detection; fuzzy clustering; thresholding

I. INTRODUCTION

Digital image processing is the use of computer algorithms to perform image processing on digital images. Image segmentation is an important and challenging process of image processing. Image segmentation technique is used to partition an image into meaningful parts having similar features and properties. The main aim of segmentation is simplification i.e. representing an image into meaningful and easily analyzable way. Image segmentation is necessary first step in image analysis. The goal of image segmentation is to divide an image into several parts/segments having similar features or attributes. The basic applications of image segmentation are: Content-based image retrieval, Medical imaging, Object detection and Recognition Tasks, Automatic traffic control systems and Video surveillance, etc. The image segmentation can be classified into two basic types: Local segmentation (concerned with specific part or region of image) and Global segmentation (concerned with segmenting the whole image, consisting of large number of pixels). The image segmentation approaches can be categorized into two types based on properties of image.

A. Discontinuity detection based approach

This is the approach in which an image is segmented into regions based on discontinuity. The edge detection based segmentation falls in this category in which edges formed due to intensity discontinuity are detected and linked to form boundaries of regions [1].

B. Similarity detection based approach

This is the approach in which an image is segmented into regions based on similarity. The techniques that falls under this approach are: thresholding techniques, region growing techniques and region splitting and merging. These all divide the image into regions having similar set of pixels. The clustering techniques also use this methodology. These divide the image into set of clusters having similar features based on some predefined criteria [1] [2].

In other words, also we can say that image segmentation can be approached from three perspectives: Region approach, Edge approach and Data clustering. The region approach falls under similarity detection and edge detection and boundary detection falls under discontinuity detection. Clustering techniques are also under similarity detection.

II. CLASSIFICATION OF IMAGE SEGMENTATION TECHNIQUES

There are several existing techniques which are used for image segmentation. These all techniques have their own importance. These all techniques can be approached from two basic approaches of segmentation i.e. region based or edge based approaches. Every technique can be applied on different images to perform required segmentation. These all techniques also can be classified into three categories [3] [4]

A. Structural Segmentation Techniques

The structural techniques are those techniques of image segmentation that relies upon the information of the structure of required portion of the image i.e. the required region which is to be segmented.

B. Stochastic Segmentation Techniques

The stochastic techniques are those techniques of the image segmentation that works on the discrete pixel values of the image instead of the structural information of region.

C. Hybrid Techniques

The hybrid techniques are those techniques of the image segmentation that uses the concepts of both above techniques i.e. these uses discrete pixel and structural information together [5].

In further parts of this paper the various techniques of segmentation are discussed and compared. Mathematical description is avoided for simplicity therefore all the techniques are described theoretically. The popular techniques used for image segmentation are: thresholding method, edge detection based techniques, region based techniques, clustering based techniques, watershed based techniques, partial differential equation based and artificial neural network based techniques etc. These all techniques are different from each other with respect to the method used by these for segmentation.

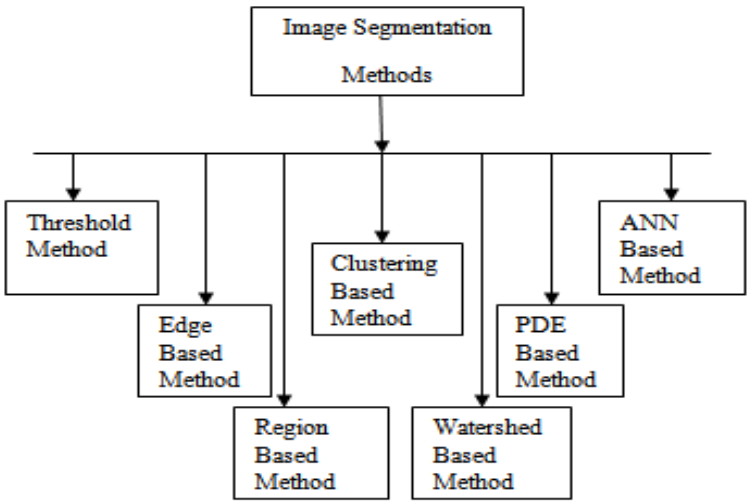

Fig. 1 Image segmentation techniques

III. IMAGE SEGMENTATION TECHNIQUES

A. Thresholding Method

Thresholding methods are the simplest methods for image segmentation. These methods divide the image pixels with respect to their intensity level. These methods are used over images having lighter objects than background. The selection of these methods can be manual or automatic i.e. can be based on prior knowledge or information of image features. There are basically three types of thresholding [16] [20]:

1) Global Thresholding: This is done by using any appropriate threshold value/T. This value of T will be constant for whole image. On the basis of T the output image $q(x, y)$can be obtained from original image $p(x, y)$ as:

$$q(x,y) = \begin{cases} 1, if\ p(x,y) > T \\ 0, if\ p(x,y) \leq T \end{cases} \qquad (1)$$

2) Variable Thresholding: In this type of thresholding, the value of T can vary over the image. This can further be of two types:

- *Local Threshold:* In this the value of T depends upon the neighborhood of x and y.
- *Adaptive Threshold:* The value of T is a function of x and y.

3) Multiple Thresholding: In this type of thresholding, there are multiple threshold values like T0 and T1. By using these output image can be computed as:

$$\mathrm{q}(x,y) = \begin{cases} m, if\ p(x,y) > T1 \\ n, if\ p(x,y) \leq T1 \\ o, if\ p(x,y) \leq T0 \end{cases} \qquad (2)$$

The values of thresholds can be computed with the help of the peaks of the image histograms. Simple algorithms can also be generated to compute these.

B. Edge Based Segmentation Method

The edge detection techniques are well developed techniques of image processing on their own. The edge based segmentation methods are based on the rapid change of intensity value in an image because a single intensity value does not provide good information about edges. Edge detection techniques locate the edges where either the first derivative of intensity is greater than a particular threshold or the second derivative has zero crossings. In edge based segmentation methods, first of all the edges are detected and then are connected together to form the object boundaries to segment the required regions. The basic two edge based segmentation methods are: Gray histograms and Gradient based methods. To detect the edges one of the basic edge detection techniques like sobel operator, canny operator and Robert's operator etc can be used. Result of these methods is basically a binary image. These are the structural techniques based on discontinuity detection [11].

C. Region Based Segmentation Method

The region based segmentation methods are the methods that segments the image into various regions having similar characteristics. There are two basic techniques based on this method [3] [8] [26].

1) Region growing methods: The region growing based segmentation methods are the methods that segments the image into various regions based on the growing of seeds (initial pixels). These seeds can be selected manually (based on prior knowledge) or automatically (based on particular application). Then the growing of seeds is controlled by connectivity between pixels and with the help of the prior knowledge of problem, this can be stopped. The basic algorithm (based on 8-connectivity) steps for region growing method are:

If $p(x, y)$ is the original image that is to be segmented and $s(x, y)$ is the binary image where the seeds are located. Let 'T' be any predicate which is to be tested for each (x, y) location.

- First of all, all the connected components of 's' are eroded.
- Compute a binary image P_T. Where $P_T(x, y) = 1$, if $T(x, y) = True$.
- Compute a binary image 'q', where $q(x, y) = 1$, if $P_T(x, y) = 1$ and (x, y) is 8-connected to seed in 's'.

These connected components in 'q' are segmented regions.

2) *Region splitting and merging methods:* The region splitting and merging based segmentation methods uses two basic techniques i.e. splitting and merging for segmenting an image into various regions. Splitting stands for iteratively dividing an image into regions having similar characteristics and merging contributes to combining the adjacent similar regions. Following diagram shows the division based on quad tree. The basic algorithm steps for region growing and merging are [22].

Let 'p' be the original image and 'T' be the particular predicate.

- First of all the R_1 is equal to p.
- Each region is divided into quadrants for which T (R_i) = False.
- If for every region, T (R_j) = True, then merge adjacent regions R_i and R_j such that T (R_i U R_j) = True.
- Repeat step 3 until merging is impossible.

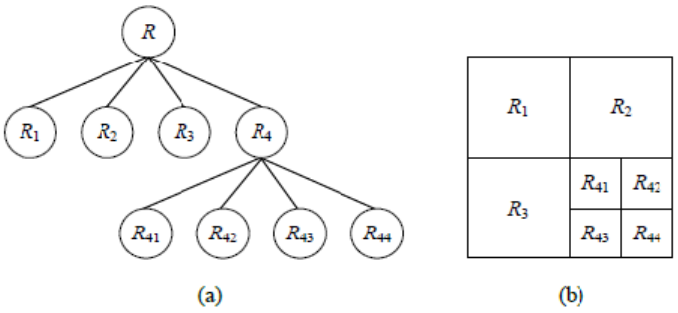

Fig. 2 Division of regions based on quad tree[27]

D. Clustering Based Segmentation Method

The clustering based techniques are the techniques, which segment the image into clusters having pixels with similar characteristics. Data clustering is the method that divides the data elements into clusters such that elements in same cluster are more similar to each other than others. There are two basic categories of clustering methods: Hierarchical method and Partition based method. The hierarchical methods are based on the concept of trees. In this the root of the tree represents the whole database and the internal nodes represent the clusters. On the other side the partition based methods use optimization methods iteratively to minimize an objective function. In between these two methods there are various algorithms to find clusters. There are basic two types of clustering [13] [24].

1) *Hard Clustering:* Hard clustering is a simple clustering technique that divides the image into set of clusters such that one pixel can only belong to only one cluster. In other words it can be said that each pixel can belong to exactly one cluster. These methods use membership functions having values either 1 or 0 i.e. one either certain pixel can belong to particular cluster or not. An example of a hard clustering based technique is one k-means clustering based technique known as HCM. In this technique, first of all the centers are computed then each pixel is assigned to nearest center. It emphasizes on maximizing the intra cluster similarity and also minimizing the inter cluster equality.

2) *Soft clustering:* The soft clustering is more natural type of clustering because in real life exact division is not possible due to the presence of noise. Thus soft clustering techniques are most useful for image segmentation in which division is not strict. The example of such type of technique is fuzzy c-means clustering. In this technique pixels are partitioned into clusters based on partial membership i.e. one pixel can belong to more than one clusters and this degree of belonging is described by membership values. This technique is more flexible than other techniques [13].

E. Watershed Based Methods

The watershed based methods uses the concept of topological interpretation. In this the intensity represents the basins having hole in its minima from where the water spills. When water reaches the border of basin the adjacent basins are merged together. To maintain separation between basins dams are required and are the borders of region of segmentation. These dams are

constructed using dilation. The watershed methods consider the gradient of image as topographic surface. The pixels having more gradient are represented as boundaries which are continuous [15].

F. Partial Differential Equation Based Segmentation Method

The partial differential equation based methods are the fast methods of segmentation. These are appropriate for time critical applications. There are basic two PDE methods: non-linear isotropic diffusion filter (used to enhance the edges) and convex non-quadratic variation restoration (used to remove noise). The results of the PDE method is blurred edges and boundaries that can be shifted by using close operators. The fourth order PDE method is used to reduce the noise from image and the second order PDE method is used to better detect the edges and boundaries [13].

G. Artificial Neural Network Based Segmentation Method

The artificial neural network based segmentation methods simulate the learning strategies of human brain for the purpose of decision making. Now days this method is mostly used for the segmentation of medical images. It is used to separate the required image from background. A neural network is made of large number of connected nodes and each connection has a particular weight. This method is independent of PDE. In this the problem is converted to issues which are solved using neural network. This method has basic two steps: extracting features and segmentation by neural network [8].

IV. COMPARISON

Table I shows a comparison between various segmentation techniques by specifying a brief description of every method each with its advantages and disadvantages[27].

TABLE I
COMPARISON OF VARIOUS SEGMENTATION TECHNIQUES

Segmentation technique	Description	Advantages	Disadvantages
Thresholding Method	based on the histogram peaks of the image to find particular threshold values	no need of previous information, simplest method	highly dependent on peaks, spatial details are not considered
Edge Based Method	based on discontinuity detection	good for images having better contrast between objects	not suitable for wrong detected or too many edges
Region Based Method	based on partitioning image into homogeneous regions	more immune to noise, useful when it is easy to define similarity criteria	expensive method in terms of time and memory
Clustering Method	based on division into homogeneous clusters	fuzzy uses partial membership therefore more useful for real problems	determining membership function is not easy
Watershed Method	based on topological interpretation	results are more stable, detected boundaries are continuous	complex calculation of gradients
PDE Based Method	based on the working of differential equations	fastest method, best for time critical applications	more computational complexity
ANN Based Method	based on the simulation of learning process for decision making	no need to write complex programs	more wastage of time in training

V. CONCLUSION

In this review of image segmentation techniques, various image segmentation techniques are detailed described and compared. These all techniques are suitable for many medical image applications. These techniques can be used for object recognition and detection. In medical images these can be used to detect cancer and in satellite images these can be used to detect roads and bridges. Thus it is clear that various methods are suitable for various types of image applications. But from the study it is clear that no single method is sufficient for every image type and no all methods are suitable for a particular image type. Due to the need of image segmentation in many applications, it has a challenging future.

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