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Review of Image Segmentation Techniques: A Survey

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Abstract- Image segmentation is a relevant research area in Computer Vision and hundreds of segmentation algorithms have been proposed in the last 30 years. Image segmentation is a mechanism used to divide an image into multiple segments. The main goal is to make image more simple and meaningful. Most methods can be classified into three groups: the analytical, the empirical goodness and the empirical discrepancy groups. Each group has its own characteristics. After a brief description of each method in every group, some comparative discussions about different method groups are first carried out. An experimental comparison for some empirical (goodness and discrepancy) methods commonly used is then performed to provide a rank of their evaluation abilities. In addition, some special methods are also discussed. This study is helpful for an appropriate use of existing evaluation methods and for improving their performance as well as for systematically designing new evaluation methods.

Keywords- Image Analysis, Image Segmentation, Segmentation Evaluation, Analytical and Empirical Study, Image Quality Measure, Method Characterization.

I. INTRODUCTION

The purpose of image segmentation is to partition an image into meaningful regions with respect to a particular application. Image segmentation, is often an essential step in image analysis, object representation, visualization, and many other image processing tasks. The segmentation is based on measurements taken from the image and might be grey level, colour, texture, depth or motion. Segmentation divides an image into its constituent regions or objects. Segmentation of images is a difficult task in image processing. Segmentation allows in extracting the objects in images. Segmentation is unsupervised learning. Model based object extraction, e.g., template matching, is supervised learning. After a successful segmenting the image, the contours of objects can be extracted using edge detection and/or border following techniques. Shape of objects can be described. Based on shape, texture, and color objects can be identified. Image segmentation techniques are extensively used in similarity searches.

Segmentation algorithms are based on one of two basic properties of color, gray values, or texture: discontinuity and similarity. First category is to partition an image based on abrupt changes in intensity, such as edges in an image. Second category is based on partitioning an image into regions that are similar, according to predefined criteria. Histogram thresholding approach falls under this category. Usually image segmentation is an initial and vital step in a series of processes aimed at overall image understanding. Applications of image segmentation include:

- Identifying objects in a scene for object-based measurements such as size and shape
- Identifying objects in a moving scene for object-based video compression (MPEG4)
- Identifying objects which are at different distances from a sensor using depth measurements from a laser range finder enabling path planning for mobile robots.

Since a method applied to one image may not remain successful to other type of images, therefore segmentation techniques has been divided into three types, i.e. segmentation techniques based on classical method, AI techniques, and hybrid techniques. Some of the most famous image segmentation methodologies including Edge based segmentation, Fuzzy theory based segmentation, Partial Differential Equation (PDE) based segmentation, Artificial Neural Network (ANN) bases segmentation, threshold based image segmentation, and Region based image segmentation are highlighted in figure. Fig.1 contains important and famous image segmentation techniques used for the purpose of image segmentation.

II. IMAGE SEGMENTATION TECHNIQUES

Many image segmentation techniques have been developed by researchers and scientists, some of the most important and widely used image segmentation techniques are shown in Fig.1. Latest research work on image segmentation techniques highlighted in Fig.1 is discussed and evaluated below.

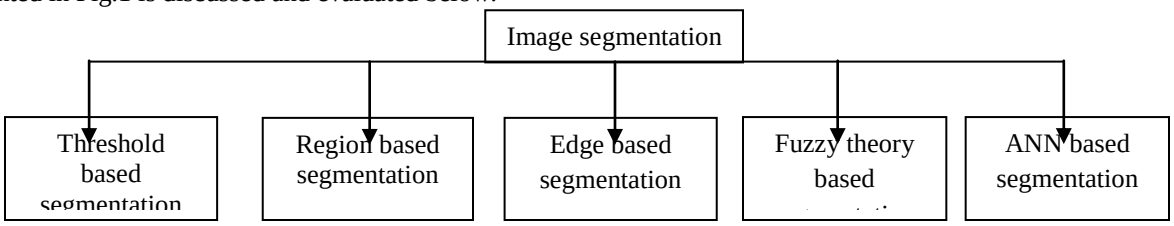

Fig.1 Various Image Segmentation Techniques

A. Threshold Based Image Segmentation

Thresholding is an old, simple and popular technique for image segmentation. Image segmentation by thresholding is a simple but powerful approach for segmenting images having light objects on dark background. Thresholding operation convert a multilevel image into a binary image i.e., it choose a proper threshold T, to divide image pixels into several regions and separate objects from background. Any pixel (x, y) is considered as a part of object if its intensity is greater than or equal to threshold value i.e., f(x, y) ≥T, else pixel belong to background. There are two types of thresholding methods. They are categorized as global and local thresholding. If T is constant then it is known as global thresholding otherwise it is local thresholding. Global thresholding methods can fail when the background illumination is uneven. In local thresholding, multiple thresholds are used to compensate for uneven illumination. There are certain disadvantages of thresholding method. Only two classes are generated, and it cannot be applied to multichannel images. Thresholding does not take into account the spatial characteristics of an image so it is sensitive to noise. This corrupts the histogram of the image, making separation more difficult.

1) Threshold Selection

Segmentation using thresholding technique is the choice of selecting threshold value T. Automatically selected threshold value for each image by the system without human intervention is called an automatic threshold scheme. In case of automatic threshold selection method, the value of T can be chosen based on histogram, clustering, variance, means etc.

2) Histogram Based Threshold Selection

The histogram based techniques is dependent on the success of the estimating the threshold value that separates the two homogonous region of the object and background of an image. Histogram based thresholding is applied to obtain all possible uniform regions in the image. Let P1 and P2 be the gray value of the peaks of the histogram.
The threshold value T is given by eq. (1)

$$T= (P1 +P2)/2 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

3) EMT Technique

The threshold image by using edge maximization technique (EMT) is used when there are more than one homogenous region in image or where there is a change on illumination between the object and its background. In this case portion of the object may be merged with the background or portions of the background may as an object. To this reason any of the automatic threshold selection techniques performance becomes much better in images with large homogenous and well separated regions. This techniques segmentation depend on the research about the maximum edge threshold in the image to start segmentation that image with help the edge detection techniques operators.

B. Region Based Segmentation

Region-based segmentation methods are based on the fact that a pixel cannot be considered a part of an object or not based solely on its gray value (as intensity-based methods do). They incorporate measures of connectivity among pixels in order to decide whether these pixels belong to the same region (or object) or not.

Mathematically, region-based segmentation methods can be described as a systematic way to partition an image *I* into *n* regions, R_1 , R_2, ……, R_n, such that the following properties hold:

1. $\bigcup_{i=1}^{n} R_i = I$.
2. R_i is a connected region, $i = 1, 2, \cdots, n$.
3. $R_i \cap R_j = \emptyset$ for all i and j, $i \neq j$.
4. $P(R_i) =$ = TRUE for $i = 1, 2, \cdots, n$.
5. $P(R_i \cup R_j) =$ = FALSE for any adjacent regions R_i and R_j.

Here P (R_i) is a logical predicate defined over the points in set R_i and Φ is the empty set.

The first property states that the segmentation will be complete, that is, each pixel in the image will be labelled as belonging to one of the *n* regions. Property 2 requires that all points within a region be 4- or 8- connected. Property 3 states that the regions cannot overlap. Property 4 states which criterion must be satisfied so that a pixel is granted membership in a certain region, for example, all pixel values must be within a certain range of intensities. Finally, property 5 ensures that two adjacent regions are different in the sense of predicate *P*.

In Region based segmentation, we have to find homogeneous regions according to a specific criterion (intensity value, texture). The aim of region detection is to provide the possibility to characterize the detected object by parameter analysis (shape, position, size...).we examine neighbouring pixels and detect whether the neighbour pixel should be added or not. Region based segmentation technique attempts to group the pixels with similar characteristics (such as approximate Gray level equality) into regions. There are two approaches in region-based methods:

1. Region Growing
2. Region Splitting and Merging

In Region Growing Method, it is based on the clustering of neighbouring pixels of a region that verify specific assumptions. The Seed region is expanded to include all homogeneous neighbors and the process is repeated. The process ends when there is no pixel to be classified. In region splitting method, Split an image into a set of regions that verifies a specific assumption. The process starts with the entire image as a seed. If the seed is inhomogeneous then it splits into predetermined number of sub-regions, typically four. The region splitting process is then repeated using each sub-region as a seed. The process ends when all sub-regions are homogeneous. In Region Merging Method, Merge any adjacent regions that are similar enough.

C. Edge Based Image Segmentation

One of the most important applications is edge detection for image segmentation. Edge-based Segmentation represents a large group of methods based on information about edges in the image. Edge-based segmentations rely on edges found in an image by edge detecting operators—these edges mark image locations of discontinuities in gray level, color, texture, etc. Image resulting from edge detection cannot be used as a segmentation result. Supplementary processing steps must follow to combine edges into edge chains that correspond better with borders in the image. The most common problems of edge-based segmentation are an edge presence in locations where there is no border, and no edge presence where a real border exists (false alarms and missed detections).

The process of partitioning a digital image into multiple regions or sets of pixels is called image segmentation. Edge is a boundary between two homogeneous regions. Edge detection refers to the process of identifying and locating sharp discontinuities in an image. Edge detection is one of the most frequently used techniques in digital image processing. The boundaries of object surfaces in a scene often lead to oriented localized changes in intensity of an image, called edges. Edge detection techniques transform images to edge images benefiting from the changes of grey tones in the images. Edges are the sign of lack of continuity, and ending. As a result of this transformation, edge image is obtained without encountering any changes in physical qualities of the main image.

An Edge in an image is a significant local change in the image intensity, usually associated with a discontinuity in either the image intensity or the first derivative of the image intensity. Discontinuities in the image intensity can be either Step edge, where the image intensity abruptly changes from one value on one side of the discontinuity to a different value on the opposite side, or Line Edges, where the image intensity abruptly changes value but then returns to the starting value within some short distance.

D. Fuzzy Based Image Segmentation

Fuzzy set theory is used to analyze images, and provide accurate information from any image. Fuzzy Rule Based Image Segmentation techniques are able to integrate expert knowledge and are less computationally expensive compared with fuzzy clustering. There are several methods for segmenting gray-level images based on discontinuity and similarity. First approach uses the discontinuities between gray level regions to detect isolated points, edges and contours. Second approach includes clustering, thresholding, region growing, region splitting and merging. Fuzzy c-means (FCM) is a method of clustering which allows one piece of data to belong to two or more clusters. This method is frequently used in pattern recognition. It is based on minimization of an objective function.

Fuzzy *c*-means (FCM) algorithm is the most popular method used in image segmentation because it has robust characteristics for ambiguity and can retain much more information than hard segmentation methods. Although the conventional FCM algorithm works well on most noise-free images, it has a serious limitation: it does not incorporate any information about spatial context, which cause it to be sensitive to noise and imaging artifacts.

E. ANN Based Image Segmentation

Most segmentation methods are based only on color information of pixels in the image. Humans use much more knowledge than this when doing image segmentation, but implementing this knowledge would cost considerable computation

time and would require a huge domain-knowledge database, which is currently not available. In addition to traditional segmentation methods, there are trainable segmentation methods which can model some of this knowledge.

Neural Network segmentation relies on processing small areas of an image using an ANN or a set of neural networks. After such processing the decision-making mechanism marks the areas of an image accordingly to the category recognized by the neural network.

Pulse-coupled neural network are neural models proposed by modeling a cat's visual cortex and developed for high-performance biometric image processing. In 1989, Eckhorn introduced a neural model to emulate the mechanism of a cat's visual cortex. The Eckhorn model provided a simple and effective tool for studying the visual cortex of small mammals, and was soon recognized as having significant application potential in image processing. In 1994, the Eckhorn model was adapted to be an image processing algorithm by Johnson, who termed this algorithm Pulse-Coupled Neural Network.

Some of the mostly used neural networks for image segmentation are Hopfield, BPNN, FFNN, MLFF, MLP, SOM, and PCNN. Segmentation of image using neural network is perform in two steps, i.e., pixel classification and edge detection. In this section several new approaches of ANN used for image segmentation is discussed from last five years.

III. CONCLUSION

In this paper, Image segmentation has a promising future as the universal segmentation algorithm and has become the focus of contemporary research. The Five important segmentation techniques are discussed. There are different types of techniques available for segmentation process. But the paper focused on top five techniques used for segmentation. The paper shows the detailed explanation about how the segmentation is done by using each technique separately. Thus there is no single method which can be considered good for all type of images but all methods are equally good for particular type of images. Due to all above factors, Image Segmentation faces a challenging problem in image processing and computer vision.

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