ISSN:0975-9646

Review: Various Image Segmentation Techniques

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Abstract—**In recent times segmentation of images is a growing and a research based field, as image segmentation is a very important part in the field of image processing and computer vision. When a set of pixels are combined together they form a digital image. Segmentation of such an image or a video is useful to extract region of interest (ROI) which further can be used for various applications such as tracking and detection of objects, medical imaging, recognition of face, eyes, etc. There are various algorithms designed to do proper segmentation of the ROI. Each one of them has its own advantages and disadvantages. This paper discusses the various segmentation techniques which are available.**

***Index Terms*— clustering, edge detection, Image segmentation, thresholding**

I. INTRODUCTION

The use of images is done in most of the fields today consisting of image processing and computer vision. Image segmentation forms an integral part of this field which can be used for various applications such as Medical imaging [1], gaming, robot navigation, detection of unknown objects, etc.

Image segmentation is the process of partitioning an image into different parts. It can be divided into two planes background and foreground or they can also be grouped together by the means of various characteristics of the pixels which thus makes it easier to analyze the data present in the image and also makes it more meaningful. The pixels hence can be categorized together based on their characteristics which include the value of pixels, their color, texture, etc. All the pixels are compared with their adjacent neighbors; those with different characteristics will look different when compared to the group. The basic aim of doing the segmentation procedure is to extract more information from the given image so that maximum information can be extracted. To improve the quality of the image and to extract maximum information filtering and denoising is done to remove noise before segmenting the ROI [2]. This helps in the proper segmentation of the region of interest and also minimizes the data loss.

The paper is divided into various subsections. Section II consists of the definition of image segmentation, Section III consists of the various techniques associated with the image segmentation and the last part Section IV consists of the conclusion.

II. IMAGE SEGMENTATION

It refers to the process of dividing the image into a number of parts or segments. The segmentation is performed on the basis of certain characterization of the set of pixels. The criterion generally followed is homogenous in nature which groups the pixels on the basis of their color, texture, similarity, boundary, etc. This helps to make a contour around the desired object and hence defines the boundary of a certain area [2].

Mathematically the above statement can be explained as the image I is divided into N number of segments. The image I consists of pixels (x,y) where the image representation can be given as f(x,y). This image is then divided into subparts such as $f_1(x_1, y_1)$, $f_2(x_2, y_2)$…., $f_n(x_n, y_n)$. The subparts are created so that maximum information can be extracted from the given image. The various practical applications of the segmentation process can range from filtering the images for better visual perception, tracking and detection of objects, medical imaging, recognition of face, eyes, etc. There are a lot of segmentation procedures the selection of a procedure depends upon the output required, type of image and its characterization.

III. IMAGE SEGMENTATION TECHNIQUES

The field of image segmentation has currently become very important and hence finding an appropriate segmentation technique is a major research area. Though thousands of segmentation techniques have been proposed so far there is still not a single technique which can be used for any kind of images. Therefore depending on the characteristics of the image a particular segmentation technique is used. There are various literatures which describe specific segmentation techniques [2], [3].

Image segmentation approach can basically be divided into two parts:

1. Based on Discontinuity:-
   The images are subdivided on the basis of abrupt changes in the intensity of the gray levels of the image. The idea of subdivision is based on identification of various edges, lines, corners or points in the image. It includes image segmentation algorithm of edge detection.
2. Based on Similarity:-
   The images are subdivided on the basis of similarity in the intensity of the gray levels of the image. The idea of subdivision is based on identification of various similar edges, lines, corners, or points in the image. It includes image segmentation algorithm such as thresholding, region merge and splitting, region growing etc.

A. Segmentation Based on Edge Detection

Edge detection refers to the boundaries where there is a sharp change in the intensity or brightness of the image [4]. Hence the obtained boundary marks the edges or the contours of the desired object. This way the object can be segmented from the image by the detection of its edges [5], [6]. The final output that is received by applying edge detection algorithm is a binary image [7].

There are many ways to perform edge detection; here two of the techniques are described:

1. Gray Histogram Technique:-

This technique is based on a threshold value T. It is defined for the division of the image into foreground and background. The complexity of the method lies in the proper selection of the threshold as the range of gray histogram is not uniform due to the presence of noise. Hence two conic Gaussian curves [8] are selected, each curve representing the foreground and the background. The intersection point of the curves defines the threshold T value.

2. Gradient Based Method:-

Gradient refers to a generalized version of a derivative for image f (x,y), whenever there is an abrupt change in the intensity of the image near its edges. This is a method which convolves gradient operators with the image [8]. The gradient magnitudes with high value are generally those regions which represent abrupt changes between two regions. They are referred as edge pixels and they form closed boundaries by linking the pixels together.

There are many edge detection operators that can be used in gradient based methods such as sobel operator, canny operator, Laplace operator, Laplacian of Gaussian (LOG) operator & many others. The canny operator gives best results among the following but it is complex and takes more time when compared with the sobel operator [4]. Generally the method of edge detection requires a balance between the proper detection of the edges and the level of noise present. The edge detection process depends highly on the proper level of accuracy too. If the accuracy level is very high the detected edges might be fake or extra as detected by the noise adding unreasonable outlines in the image, if the level of accuracy is lower than usual then many of the important edges might be missed or won't get detected leaving out important objects. Hence, the edge detection algorithm is generally used for simple and noise free images [9].

B. Segmentation based on Thresholding

The segmentation of images by using thresholding is a very powerful technique used to segment foreground or an object from a specific background [4]. This technique depends on the characteristics of an image [8]. The foreground is lighter than the background for proper detection or vice versa. The separation of the objects from the background is generally done by selecting a value T which is known as the thresholding value according to the thresholding algorithm. If we consider a pixel (x,y) whose value is greater than or equal to the threshold value i.e. $f(x,y) \geq T$ then the object is considered to be a foreground and if $f(x,y) \leq T$ then it is considered as background.

Depending on the thresholding value there are two techniques described:

1. Global (single) Thresholding:

When the histogram of the image intensity is plotted it shows two peaks referring to the foreground and the background. It consists of setting a fixed threshold value T, all the pixels that are below T refers to the background and those above the fixed value are considered to be the foreground. Mathematically it can be given as

$$g(x,y) = \begin{cases} 1 \text{ if } f(x,y) > T \\ 0 \text{ if } f(x,y) \leq T \end{cases}$$

Where g(x,y) is the output after thresholding. The method fails when the background illumination is not proper or even, in that case local thresholding is preferred. The examples of global thresholding are Otsu thresholding, entropy based thresholding, etc [10].

2. Local Thresholding:

In the cases where global thresholding doesn't work, the image is divided into sub images and then they are thresholded individually. Here the threshold for each pixel depends on the location of the pixel within an image. So in this case multiple thresholds are selected to compensate for the uneven illumination. Hence various T's are selected for each of the sub images [11]. Commonly used local thresholding techniques are simple statistical thresholding, 2-D entropy-based thresholding histogram transformation thresholding etc.

C. Region Based Thresholding Methods

When comparing thresholding and region based segmentation methods, the latter are more immune to noise and is relatively simpler as this method is based on regions. It partitions the image into homogeneous areas of the connected pixels based on the similarity criteria. The pixels are grouped on the basis of certain characteristics such as intensity, color, texture, etc [10]. Region based segmentation can be classified as:

1. Region Growing:

It is also classified as pixel based segmentation method as it involves an initial seed pixel. It is based on the examination of the neighboring pixels with the seed points and determining whether or not it should be added to the region. This method uses the fact that the neighboring pixels have relatively similar gray values.

It is processed in the following steps:

(i) Initially an arbitrary seed pixel is chosen and it is compared with its corresponding neighboring pixels.
(ii) Then the size of the region further grows starting from the seed pixel as the similar neighboring pixels are added. Hence the size of the region increases.
(iii) When growth of one region is completed then another seed pixel is chosen which does not belong to any region and start again.
(iv) The whole process is continued until all the pixels belong to certain region.

Region growing method gives better segmentation results than thresholding.

2. Region Split and Merge:

Initially a threshold is required as an input. The merging and splitting of the various regions depends on this threshold value, it is done on the basis of the difference in the minimum and maximum intensities of each region. If the difference between the regions is within the threshold then those regions are merged into one single region. If the difference exceeds the threshold the region is split into half. This mechanism is based on a quadtree structure, which means that the merging and splitting of regions goes from 4 to 1 or 1 to 4 respectively [10]. It includes two steps:

(i) Split the region into four branches.

(ii) Merge the region when no further splitting is possible.

Stop when no further merging is possible.

D. Theory Based Segmentation

This is the type of segmentation technique which includes various algorithms that includes derivatives from different fields. They include genetic algorithms, wavelet based algorithms, fuzzy based algorithms, and neural network based algorithms, clustering based algorithms and many others [10].

1. Clustering Techniques:

Clustering follows the concept of unsupervised learning, in which identification is done between pixels and then they are grouped together to form clusters. Therefore a cluster is a collection of pixels which are similar between them and are dissimilar to the pixels belonging to the different clusters. The clusters are formed on the basis of a certain criteria such as color, texture, size, etc. The quality of the results of the clustering methods is dependent on the similarity measure and its implementation. The methods are classified as hard clustering, k-means clustering, fuzzy clustering, etc [12].

(a) Hard Clustering:

Every pixel in an image belongs to just one cluster and there are sharp boundaries between different clusters. The most famous and well known clustering algorithm is k-means algorithm [12]. This algorithm aligns the pixels n into different clusters k, where $k < n$. The various pixels in an image are classified into k number of clusters on the basis of some image characteristics such as grey level intensity of pixels and distance of pixel intensities. The algorithm is based on randomly choosing a centroid initially.

The various steps involved in the k-means algorithm are as follows:

(i)The number of clusters is randomly chosen.

(ii)Amongst the k pixels certain random pixels are chosen as centroids.

(iii)A centroid is found out by calculating a mean of a certain region. The centroids should be placed far away from each other.

(iv)Now every nearby pixel is compared to every centroid and then it is assigned to the closest centroid. The initial pixel assignment corresponds to the initial stage.

(v)The next stage is to recalculate the mean of each cluster and to recalculate the position of each centroid.

(vi) The above two steps are repeated until the centroids stop moving.

(b) Fuzzy Clustering:

There are many algorithms applied to segment images, which are based on features like color, texture, and location and their combinations, which limits their generalization capability. Recently, object shape has been integrated into fuzzy clustering algorithms. It is the most distinguished feature of an object. Fuzzy clustering techniques have been proposed for image segmentation to extract regular geometric contours/regions, so they are not used for segmenting arbitrary-shaped objects. It is the most well known algorithm as it preserves the maximum information. The various types of fuzzy clustering algorithms are Possibilistic c-means (PCM) and Fuzzy c means (FCM), etc [13].

2. Artificial Neural Network-based segmentation

The structure and operation of this algorithm resembles that of a mammal brain. Here every pixel represents a neuron. The neural network consists of a training set to determine the connection and weights between different nodes. The images are then segmented on the basis of the trained neural network set [8], [14].

There are two basic steps involved in neural network segmentation:-

(i) The extraction of features: It determines the input of the neural network. It extracts certain features from images that help in the next step of segmentation.

(ii) Image segmentation: This is the most important step which involves the segmentation of specific regions from the images based on its features.

The various characteristics of this algorithm are as follows:-

(i) It is most suitable for real time applications as the computing is very fast and it has highly parallel computing ability.

(ii) The segmentation results are very good even though when the data is deviated from a normal situation.

(iii) It is immune to noise because of the robustness of the algorithm.

IV. CONCLUSION

In this paper various image segmentation techniques are discussed, it is a very important topic in the field of image processing and computer vision. All these algorithms have a promising future as they have become the focus of contemporary research. Though the research in this area is being done since decades still there is no one segmentation technique that can be applied to every kind of image or which is universally accepted. There are various factors that affect the image segmentation process such as: homogeneity of images, spatial characteristics of the image continuity, texture, image content. Due to all the above factors this segmentation problem still remains a major concern in the image processing and computer vision fields.

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