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A Study on Various Image Segmentation Techniques: Merits and Demerits

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Abstract— ***Image segmentation is the process of partitioning an image into meaningful components or structures based on color, shape, intensity etc. Image segmentation plays an important role in the field of image analysis, it can also be used for object recognition, visualization and many other image processing tasks. Image segmentation is used to classify or to cluster the image into several parts according to the features extracted from the image. The main goal of the segmentation is to make the image easier to analyze. The output of the segmentation is a set of segments that will cover the entire image. This paper presents the various image segmentation techniques, their merits and demerits.***

Keywords- Segmentation, Clustering, K-means, Watershed, FCM, Histogram, Neural network, Pixel, Region Growing

I. Introduction

In the present world images are used as a medium for conveying information. Based on image analysis more details about the image can be obtained. Image analysis plays a vital role in the fields of medical imaging, locating objects in satellite images, face recognition, machine vision and traffic control systems, etc. [1]. All the images will contain some amount of noise because of the environmental pollution and also due to the quality of the lens. Because of this reason some preprocessing techniques are employed to eliminate the noise, which leads to better segmentation results. If there is noise then the segmentation results will not be accurate one. The idea behind to write this paper is to give details about various segmentation techniques their merits and demerits and also to give an idea about in which type of image these different techniques can be applied. The paper is organized as follows section II describes about image segmentation and the various methods of image segmentation, Section III talks about the merits and demerits of various segmentation techniques and the section IV concludes the overall study.

II Image Segmentation

For image segmentation digital images are commonly used. An image can be defined as a two dimensional function f(x, y) where, x & y are the spatial co-ordinates and the amplitude of the function f at the co-ordinates x & y is called as intensity or gray level of the image at that point. A digital image is composed of a finite number of elements, each has a particular location and value and these elements are called as picture elements, image elements or pixels.

The term pixel is used to denote the elements in the digital image. There are three levels of computerized processing in the field of digital images, they are 1) low level 2) mid level 3) high level. Low level processing involves the primitive operations such as preprocessing, contract enhancement and image sharpening. The main goal of the segmentation is to partition the image into significant regions based on some features like gray values, edges and texture structures [2], [3]. The high level processing is used in the field of image recognition and image analysis. The mid level processing involves the image segmentation, which is the process of partitioning a digital image into various regions. The mid level processing is used to make the image into a suitable form for the computer to process, it can also be used for image classification, object recognition and image analysis etc. The input to the segmentation will be the digital image and the outputs will the attributes extracted from the image. Researches are still going on the field of image segmentation. There are many techniques for the purpose of image segmentation. They are:

a) Threshold Segmentation

Digital image will contain elements called pixels. The pixels belongs to the object are entirely different from those that belongs to the background. To separate the object details from the background, thresholding method is used. Thresholding is the simplest method in the image segmentation. The major goal of this method is to select a threshold value. To select the threshold value Otsu's method and K-means clustering are used. Thresholding method is mainly used for the purpose of image analysis. The output of the thresholding operation will be binary images which have two states one indicates the foreground objects and the other will indicate the background. Based on the type of information used, thresholding algorithms can be classified based on the 1) histogram shape information 2) clustering

method 3) attribute based method 4) spatial method 5) local methods 6) entropy based methods [4].

The thresholding method is reliable so it can be used to segment 3-D images with high accuracy, and the major drawback is that it is not fit for images of textured blob objects. Thresholding is the promising approach for segmenting the images having light objects with dark background [5]. Thresholding operation converts the multilevel into gray channel image. Thresholding method uses a threshold value T. If T is kept fixed the method is called as global thresholding otherwise it is called local thresholding. Thresholding method of segmentation does not deal with the spatial characteristics of the image because of the presence of noise [6].

b) Segmentation based on Clustering

Clustering is the process of classifying the objects into different groups, samples of same group are similar to one another than the samples belonging to other groups. For the purpose of clustering 2 methods are mainly used 1) K-means clustering 2) Fuzzy clustering. The K-means is an iterative process that is used to partition the image into K clusters [7]. In the K-means algorithm initially picks up random 'K' cluster centers based on the intensity, pixel color and texture. Then assign each pixel in the input image to the cluster that minimizes the distance between the pixel and the cluster center. The cluster centers are recomputed by taking the average of all the pixels belongs to the cluster. The process of cluster center recalculation is repeated until convergence is obtained. In the K-means algorithm the quality of the solution depends on the initial set of clusters and the values of the cluster center K. The fuzzy clustering described by using the membership function. The good fuzzy clustering method is the Fuzzy C Means (FCM) algorithm because of its robust characteristics and can retain much more information than the hard segmentation methods. The efficiency of the FCM mainly depends on the initialization procedure and is very sensitive to imaging artifacts, noise and initial cluster centers [8], [9].

c) Histogram based Segmentation

This method is the simplest and the most often used technique for segmentation. In this the image histogram is used to select the gray level, for grouping the pixels. The image contains both the object and the background. The histogram will show the gray levels of the background and also the object [10], [11]. The background occupies most of the image and it is in one gray level, because its gray level has large peak in the histogram. The object of the image is another gray level and that gives smaller peaks in the histogram. The histogram based segmentation mainly depends on the histogram of the image. There are two steps in the preprocessing stage of histogram namely the histogram equalization and the histogram smoothing. Histogram equalization is to alter an image, due to this the histogram becomes flat and spreads out over the entire range of gray level. This helps to improve the contrast. The histogram smoothing is used to eliminate insignificant peaks and valleys from the histogram while retaining the basic shape of the histogram. One of the disadvantages of the histogram seeking method is that it may be difficult to identify the significant peaks and valleys in the image.

d) Compression based methods

There are many general purpose compression algorithms which don't provide satisfactory results for all kinds of applications because they are not tailored to the geometrical behavior [12]. Because of this reason segmentation based image compression method is selected for compressing the images. There are mainly two steps in the compression based segmentation, they are the segmentation and the compression of the segmented region. The image can be segmented based on the similarity. In the compression step the segmented outputs are encoded to get good compression procedure. There are two categories of image compression techniques 1) methods that preserve the original data 2) methods that keep only the approximation of the original data.

There are three techniques that preserve the original data 1) fractal image compression 2) Quad tree image compression 3) transform based coding. The fractal image compression is based on the partitioned iterated function systems (PIFS) which utilizes the self-similarity property in the image, to achieve the purpose of compression. Quad tree algorithms are simple compression techniques based upon the concepts of simple averages. The quad tree is a tree like data structure where each node either terminates on a leaf containing useful information, or branches into four sublevel quad trees [13]. Transform based techniques improve the performance by modifying or replacing the transform which are used to segment the input image. The method that keeps only the approximation of the original data, uses lossy image compression technique.

e) Segmentation based on Edge Detection

Edge detection is the most frequently used technique in the area of digital image processing [14]. Edge detection techniques helps to transform the images to edge images benefiting from the changes of gray tones in the images. Edges are the sign of lack of continuity and encoding, as a result of this, edge image is obtained without encountering any changes in the physical qualities of the main image [15]. The edge in an image is a significant local change in the image intensity, usually associated with a discontinuity either in the image intensity or in the first derivative of image intensity. Discontinuities in the image intensity can be either step/edge. In the step the intensity fastly changes from one value on one side of the discontinuity to a different value on opposite side. In the case of line edges image intensity changes fast and then returns to the starting value within some short distance. There are mainly three steps in edge detection they are 1) Filtering 2) enhancement 3) Detection. The two important edge based segmentation methods are gray histogram and gradient based method.

f) Region based Segmentation

This method is based on the idea that the neighboring pixels within a region have similar values. In this each pixel is compared with the neighboring pixels based on some similarity criteria, if it is satisfied then the pixel can be set belong to the cluster as one or more of its neighbors. The region growing segmentation algorithm is very stable with respect to noise [16]. The region based segmentation is a technique for determining the region directly. Region growing can be seeded region growing and unseeded region growing. Seeded region growing method takes a set of seeds

as input along with the seeds. The regions are iteratively grown by comparing all unallocated neighboring pixels to the regions. The difference between a pixel intensity value and the regions mean is used as a measure of similarity. The pixel with the smallest difference measured is allocated to the respective region. The segmentation results depend up on the choice of seeds. Noise in the image can cause the seeds to be poorly placed. The main advantage of this method is that it can provide good segmentation results with clear edges, and the limitation is that it may not distinguish the shading of the real images.

g) Split and Merge methods

Region growing by merging is a procedure that groups pixels or regions into larger regions. The simplest approach is the pixel aggregation, which starts with a set of seeded pixels. From these, pixel regions grow by appending each seed point to the neighboring pixels that have similar properties in the sense of the predicate P which defines the process. Region growing by splitting is just opposite to the merging. If a region does not satisfy the homogeneity criteria then it is subdivided into four regions. This procedure continues until all the regions satisfy the homogeneity criteria. The main drawback of this method is that adjacent regions may have identical properties, thus it does not give a global solution rather than give local solution. Splitting technique has convenient representation in the form of a quad-tree, where the root of the tree corresponds to the entire image, each node corresponds to a subdivision and leaves of the final tree define the set of regions contained in the image. If only splitting were used, the final partition would be likely to contain adjacent regions with identical properties [17]. This drawback may be solved by using merging, as well as splitting. The quad tree partition starts from the root of the tree that represents the whole image. If it is found non-uniform then it is divided into four squares. If four squares are homogeneous they can be merged as several connected components. The node in the tree is a segmented node, this process is repeated until no further splits or merges are possible.

h) Graph Partitioning methods

Graph partitioning methods can be used for image segmentation. Graph partitioning is the process of grouping all the nodes in a graph into two or more partitions. Graph cut techniques are used for partitioning the graph. The minimum cut method gives only the imbalanced partitions [18]. For the purpose of overcoming the imbalanced partitioning normalized graph cut method is used and it is very expensive also. In the graph partitioning methods the image is modeled as a weighted, undirected graph. Pixels or group of pixels associated with the nodes and edge weights define the similarity between the neighboring pixels. The graph is then partitioned according to a criterion designed to model good clusters. Various techniques employed for graph partitioning are normalized cuts, random walker, minimum cut, isoperimetric partitioning, minimum spanning tree based segmentation, and the segmentation based object categorization.

i) Semi-automatic Segmentation

Semi-automatic segmentation can segment object of interest from its background, based on a single user selected seed. It is possible to obtain reliable and robust segmentation with the low user interaction by assuming that the object to be segmented is of compact shape. In many applications purely automatic segmentation is used. Purely automatic segmentation is ambiguous in the presence of multiple objects and in the absence of strong edges. These problems can be avoided by using semi-automatic segmentation methods which depends on the user guidance. The user outlines the region of interest with the mouse clicks and algorithms are applied so that best fits the edges of the image. Techniques like SIOX, Livewire are used for this kind of segmentation [19]. In an alternative kind of semi automatic segmentation, the algorithms return a spatial taxon selected by the user.

j) Neural Network segmentation

A neural net is an artificial representation of human brain that tries to simulate the learning strategies that can be used for decision making process. An artificial neural network [20] is also called as a neural network or neural net. For recent years, artificial neural networks have been widely used solve problems in the field of medical image segmentation. Neural network that simulate life, especially the human brain's learning procedures, constitutes a large number of parallel nodes. Each node performs some basic computing process. The learning process can be achieved by transferring the connections among nodes and connection weights. Its main advantage is that it doesn't dependent on the probability density distribution function. Neural network reduces the requirements of expert intervention during the image segmentation process. This problem is prevalent in many age segmentation methods. Firstly, the image segmentation problem is converted into energy minimization. Then the issues are solved based on neural network. The neural network was trained with training sample set in order to determine the connection and weights between the nodes. Then the new images were segmented with trained neural network. There are two major steps in the Neural network segmentation method 1) feature extraction 2) segmentation based on neural network.

k) Segmentation based on Partial Differential Equations

Partial differential equation (PDE) based method and solving the PDE equation by a numerical scheme, is used for segmenting the images. Curve propagation [21] is the technique in this category, with various applications to object extraction, object tracking, stereo reconstruction, etc. The different partial differential equation based methods include parametric methods, level set methods, fast marching methods. Parametric methods are based on parameterizing the contour according to some sampling strategy and then evolve each element according to image and internal terms. Such techniques are fast and efficient, the original purely parametric is generally criticized for its limitations regarding the choice of sampling strategy, the internal geometric properties of the curve, topology addressing problems in higher dimensions etc.

The level set method was initially proposed to track moving interfaces. It can be used efficiently to report the problem of surface propagation. The main idea is to represent the evolving contour using a signed function, where its zero level corresponds to the actual contour. Then,

according to the motion equation of the contour, one can easily derive a similar flow for the implicit surface that when applied to the zero-level will reflect the propagation of the contour. The level set method encodes numerous advantages. It is implicit, parameter free, provides a direct way to estimate the geometric properties of the evolving structure, can change the topology and is intrinsic. The fast marching method has been used in image segmentation and this model has been improved in an approach called the generalized fast marching method.

l) Watershed Transformation

A grey-level image can be seen as a topographic relief, where the grey level of a pixel is interpreted as its altitude in the relief. A drop of water falling on a topographic relief flows along a path to finally reach a local minimum [22]. The watershed of a relief corresponds to the limits of the adjacent catchment basins of the drops of water. In image processing, different types of watershed lines may be computed. In graphs, watershed lines may be defined on the nodes, on the edges, or hybrid lines on both nodes and edges. Watersheds may also be defined in the continuous domain. There are also many different algorithms to compute watersheds. Watershed algorithm is used in image processing primarily for the purpose of segmentation. Different approaches may be employed to use the watershed principle for image segmentation.

The two major algorithms used are the Mayer's flooding algorithm and the optimal forest algorithms. Mayer's flooding algorithms works well for the gray scale image [23]. During the successive flooding of the grey value relief, watersheds with adjacent catchment basins are constructed. This flooding process is performed on the gradient image, i.e. the basins should emerge along the edges. Normally this will lead to an over-segmentation of the image, especially for noisy image material. Either the image must be pre-processed or the regions must be merged on the basis of a similarity criterion afterwards. Optimal spanning forest algorithms establish the consistency of the watersheds, they can be equivalently defined by their catchment basins or by the dividing lines separating these catchment basins [24].

Table 1 Merits and Demerits of different image segmentation techniques

Sl.No.	Segmentation Technique	Merits	Demerits
1	Segmentation based on thresholding	Reliable, used to segment 3-D images with high accuracy.	Spatial characteristics of images are not considered.
2	Segmentation based on clustering	K-means is faster when k is small and hence form tighter cluster.	It is very difficult to predict the number of initial cluster centers K, FCM needs more computation time.
3	Histogram based methods	Needs less computational time.	Difficult to identify significant peaks and valleys in the image.
4	Compression based methods	Transform based compression is preferred in real time because it's easy implementation.	Computational complexity
5	Segmentation based on edge detection	Used as a base for another segmentation for sharp segmentation.	Edges traced by edge segmentation are often discontinuous.
6	Region based segmentation methods	Algorithm is very stable with respect to noise.	It may not distinguish the shading of the real images.
7	Split and merge methods	Split and merging methods helps to avoid the over segmentation.	Adjacent regions may have identical properties, thus it does not give a global solution rather than local solution.
8	Graph partitioning methods	Easy to implement.	Minimum cut method gives only the imbalanced partitions.
9	Semi-automatic segmentation	Segment an object of interest from its background based on a single user selected seed.	Not accurate and efficient.
10	Neural network segmentation	Neural network also reduces the requirements of expert intervention.	Training is necessary for the neural networks.
11	Segmentation based on partial differential equations	Fast and efficient.	Difficulty in handling topological changes, failures to detecting the interior boundary.
12	Watershed transformation	Gives connected components, priori information can be implemented using markers.	Often needs preprocessing to work well, Fragmentation or over-segmentation can be a problem.

IV Conclusion

This paper briefly explains the various techniques used for segmenting digital images. The various techniques discussed in this paper will be helpful for object recognition, image analysis and pattern recognition etc. Image segmentation can be performed on any type of images by employing any of these techniques discussed here. In the last section of the paper merits and demerits different image segmentation techniques are also mentioned.

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