Image Segmentation and Various Segmentation Techniques – A Review

Binamrata Baral, Sandeep Gonnade, Toran Verma

Abstract— Image Segmentation has been an area for a long time which is providing opportunities for the intellectual communities to do research work. Image segmentation is a process of partitioning an image into meaningful regions. There exist many digital image segmentation techniques which are currently applied on different fields. These image segmentation techniques need comparative analysis for further development and modifications for continuous and consistent improvement. Hence, in this paper an overview of image segmentation and its present techniques is presented which demands a lot of research work.

Index Terms — Image, Image Segmentation, Segmentation Techniques.

I. INTRODUCTION

Images are considered as one of the most important medium of conveying information, in the field of computer vision, by understanding images the information extracted from them can be used for other tasks [9].

An **image** is a word derived from Latin word '*imago*', which is a representation of visual perception in a two-dimension or three-dimension picture that has a similar appearance to some subject.

A **digital image** is a numeric representation of a two-dimensional image. A digital image is composed of a finite number of elements, each of which has a particular location and value, are called picture elements, image elements, pels and pixels [1]. Pixels are the smallest individual element in an image, holding finite, discrete, quantized values that represent the brightness, intensity or gray level at any specific point.

There are generally two types of image- raster type and vector type. *Raster images* are images having a finite set of digital values which are represented in a fixed number of rows and columns of pixels where these pixels are stored in memory as a two-dimensional array. Digital images are usually referred as raster images. *Vector images* are images generated from mathematical geometry known as vector which have points having both magnitude and direction. The paper is organized as follows: the current section gives an overview of image and its types; the next section describes image segmentation and its processes; the third section gives a description of the different image segmentation techniques and their different respective methods used; the fourth section compares the different segmentation techniques and their methods on the basis of their advantages and disadvantages; and the last section gives a brief conclusion of the whole.

II. IMAGE SEGMENTATION

Image segmentation is the foundation of object recognition and computer vision [2]. Image segmentation is the process of subdividing a digital image into multiple regions or objects consisting of sets of pixels sharing same properties or characteristics which are assigned different labels for representing different regions or objects. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze [2]. Image segmentation is used to locate objects and boundaries in images. Segmentation is done on basis of similarity and discontinuity of the pixel values.

There are two types of segmentations – soft segmentations and hard segmentations. Segmentations that allow regions or classes to overlap are called *soft segmentations* whereas a *hard segmentation* forces a decision of whether a pixel is inside or outside the object [3].

Image segmentation is practically implemented in many applications such as medical imaging, content based image retrieval, object detection, feature recognition (such as face recognition, fingerprint recognition, iris recognition, object recognition, etc) and real-time object tracking in video.

The following computational steps have to applied for image segmentation process on the image taken as input to get the required segmented data [4], [5], [6]:-

1) **Preprocessing**: The main aim of the preprocessing step is to determine the area of focus in the image [4]. As the input image may have a certain amount of noise in the images, it is necessary to reduce or remove the noise.
2) **Image Segmentation**: In this step, the preprocessed image is segmented in its constituent sub-regions.
3) **Post Processing**: To improve the segmented image, further processing may be required which is performed in post processing step.
4) **Feature Extraction**: Feature extraction is the method in which unique features of an image are extracted. This method helps in reducing the complexity in classification problems and the classification can be made more efficient [6]. Different kind of features present in an image can be intensity-based, textural, fractal, topological, morphological, etc.
5) **Classification**: The aim of the classification step is to classify the segmented image by making use of extracted features. This step uses statistical analysis of the features and machine learning algorithms to reach a decision [4].

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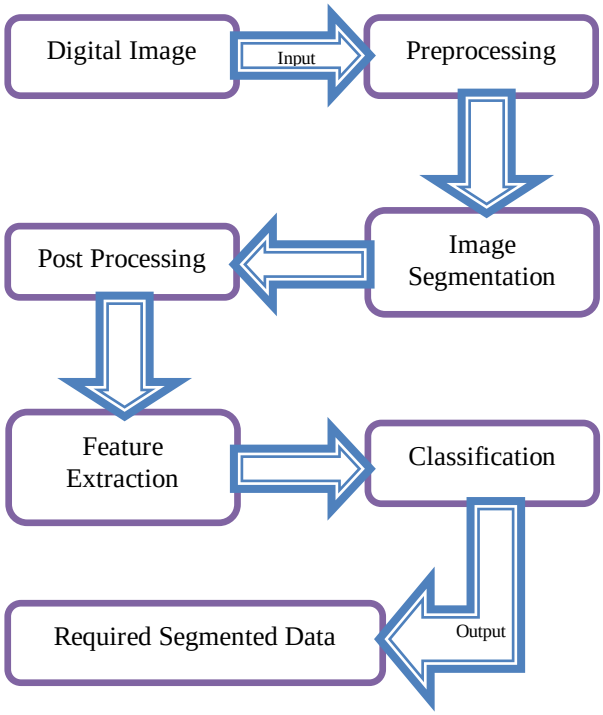

Fig. 1: Computational steps for Image Segmentation

III. IMAGE SEGMENTATION TECHNIQUES

Several general-purpose algorithms and techniques have been developed for image segmentation. These techniques must typically be combined with a domain's specific knowledge in order to effectively solve the domain's segmentation problems. There exists many different types of segmentation techniques in literature but there is no particular method which can be applied on different types of images which would generate same result. Algorithm development for one class of images may not always be applied to other class of images [2]. Hence, there are many challenging issues like development of a unified approach to image segmentation which can be applied to all type of images, even the selection of an appropriate technique for a specific type of image is a difficult problem [2], [8], [9].

A. Thresholding

This is the simplest method used for image segmentation. In this method, a certain value is taken for measurement known as threshold. If the value of the pixel in an image is greater than or equal to the threshold value, then it is an object pixel or otherwise it is a background pixel [1]. Thresholding technique can be applied in three ways: local thresholding, global thresholding and adaptive or dynamic thresholding. *Local thresholding* technique is the one in which the threshold parameters is consider over small region. Intensity distribution of object and background pixel are sufficiently distinct, then it is possible to use a *global* (single) *thresholding* on the entire image. If threshold value depends on the spatial co-ordinates (a, b) themselves then thresholding is referred as *dynamic or adaptive thresholding* [1], [12].Thresholding methods can be categorized into the following six groups based on the information the different Thresholding algorithm manipulates [16]:

1) **Histogram shape-based methods**: In this method, the analysis of smoothed histogram is done on the basis of peaks, valleys and curvatures.
2) **Clustering-based methods**: In this method, the gray-level samples are clustered in two parts i.e. background object and foreground object, or alternately are modeled as a mixture of two Gaussians.
3) **Entropy-based methods**: In this method, the entropy of the foreground and background regions is used.
4) **Object Attribute-based methods**: In this method, the measure of similarity is searched between the gray-level or intensity and the binary images provided.
5) **Spatial methods**: In this method, the higher-order probability distribution and/or correlation between pixels are used.
6) **Local methods**: In this method, the procedures that adapt the threshold value on each pixel to the local image characteristics are used.

B. Edge Based Segmentation

Edge detection is one of the fundamental methods for image segmentation and analysis. Edges are the boundaries between regions in an image, which helps with segmentation and object detection and recognition [8]. Edge pixel is a term in image processing and computer vision, which refers to those pixels at which there is an abrupt change or discontinuity in image brightness or intensity. Edge detection methods require a balance between detecting accuracy and noise immunity in practice. Thus, edge detection algorithms are suitable for images that are simple and noise-free as well often produce missing edges or extra edges on complex and noisy images [9].There are many ways to perform edge detection, however, the majority of different methods may be grouped into two categories:

1) **Gray Histogram Technique:** In this technique, segmentation is done on the basis of a threshold value. The threshold values used can be global threshold i.e. single valued threshold being applied on the whole image, multiple threshold i.e. arbitrary number of threshold is applied on the whole image and variable threshold i.e. different values of threshold is applied on different properties of the image. This method is very efficient as compared to other segmentation methods. Firstly depending upon the color or intensity a histogram is calculated from the entire pixel in the image, and then edges are located on the basis of contours and valleys in image are located [11], [12].
2) **Gradient Based Method:** Gradient can be defined as change in magnitude in the image while traversing from one end to another. This method involves convolving gradient operators with the image. If the gradient magnitude is high, then there is a possibility of rapid transition from one region to another. Then these are pixels which form edges and linking of these edges is done to form closed boundaries to result regions. Common edge detection operators used in gradient based method are Sobel, Prewitt, Roberts, or Canny method [1]. Canny method results are good compared to others, but take more time [25].

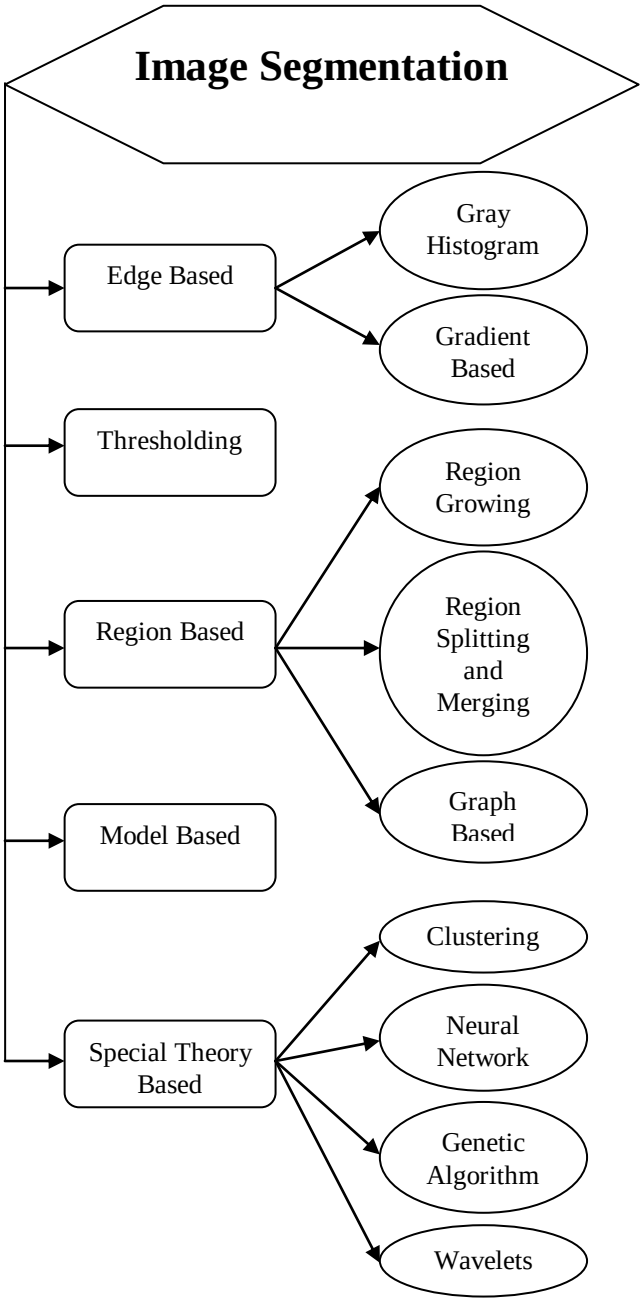

Fig. 2: Classification of Image Segmentation Methods [2], [7], [10]

C. Region Based Segmentation

Region based segmentation is another image segmentation method in which the image is divided into its constituent sub-divisions which has similar properties known as regions [17]. This segmentation can be categorized into various techniques:

1) Region **Growing:** It is an approach of image segmentation in which pixel groups or sub-regions are grouped into larger regions based on predefined criteria of growth [1]. One seed pixel and threshold value is selected in this process and check is conducted for every pixel for the given threshold value. If threshold is greater than pixel value then put into one region otherwise put into another region. A small numbers of seed points are needed to represent the property of region we require. This process will be continued until all the pixels are resulting into the region.
2) **Region splitting and merging:** It is an approach of image segmentation in which an image is subdivided into a set of arbitrary disjoint regions and then these disjoint regions are merged to satisfy the condition of segmentation [1]. A top-down approach used for splitting or dividing an image which results to a quad tree where an image is successively subdivided into smaller quadrant.
3) **Graph Based Technique:** It is based on pair wise region comparison. In Graph based approach for segmentation, there is a graph G having vertices V and edges E such that G=(V,E) where each edge is connecting two vertices and have a weight $w(v_i,v_j)$ which is a measure of dissimilarity between two neighboring elements v_i and v_j [13].

D. Special Theory Based Segmentation

Many different fields have contributed in development of better image segmentation such as clustering based technique, neural network-based technique, genetic algorithm-based technique, wavelet-based technique, and so on [12].

1) **Genetic Algorithm Based Segmentation:** A genetic algorithm is a heuristic search method that imitates the process of natural selection and evolution for optimization of search problems. Genetic algorithm is a part of evolutionary algorithms (EA), which uses techniques like selection, crossover, mutation and inheritance. Solutions are represented by a population of individual chromosomes, each made of genes having their own property [18]. Crossover is done to combine two chromosomes to generate a new individual. Mutation is applied on a small set of individuals to alter their chromosomes which may generate optimal individuals thus, resulting optimal result. The genetic algorithms used for image segmentation can be classified into two major classes [19]:
   i. Parameter selection based image segmentation
   ii. Pixel-level labeling based image segmentation
2) **Neural Network Based Segmentation:** An artificial neural network is an imitation of a real nervous system. Neural networks are systems of interconnected "neurons" which communicate with each other and compute values from inputs by forward feeding or back propagate information through the network. Each neuron represents a pixel. The mostly used neural networks are Kohonen and Hopfield ANNs [20]. Neural network based segmentation approach has three basic characteristics [2]:
   i. High parallel computing and fast computing capability.
   ii. Unrestricted nonlinear and high interaction among processing units i.e. neurons.
   iii. Satisfactory robustness making it insensitive to noise.

Table 1:
Comparison of Different Image Segmentation Techniques

METHOD	TECHNIQUE	ADVANTAGE	DISADVANTAGE
Thresholding	• Histogram shape-based methods • Clustering-based methods • Entropy-based methods • Object Attribute-based methods • Spatial methods • Local methods	• Fast and simple to implement.	• No guarantees of object coherency.
Edge Detection	Gray Histogram Technique	• Very efficient as compared to other segmentation methods.	• Found difficult to use when significant edges and valleys in the images were to be identified.
	Gradient Based Method	• When there is abrupt change in intensity near edge and there is little image noise, gradient based method works well.	• If the level of detecting accuracy is too high, noise may bring in fake edges making the outline of images unreasonable and if the degree of noise immunity is too excessive, some parts of the image outline may get undetected and the position of objects may be mistaken.
Region Based Segmentation	Region Growing	• Provide accurate separation with respect to properties of pixel. • Gives good segmented result with clear edges.	• Very sensitive to noise. • Prior Knowledge is required.
	Region Splitting and Merging	• Connected regions guaranteed. • Some (limited) possibility to incorporate geometric knowledge.	• It is difficult to find point of splitting. • It does not provide the unique solution.
	Graph Based Technique	• It addresses segmentation in a global optimization framework and guarantees a globally optimal solution for wide class of energy functions [14]. • Both the regional and the boundary properties can be used.	• Graph cut has problems with segmenting thin elongated objects due to the "shrinking bias" [15].
Special Theory Based Segmentation	Genetic Algorithm	• Good for solving problems with multiple solutions. • Easy to understand as they don't require mathematical knowledge.	• The stop criterion is not clear. • Have a tendency to converge towards local optima.
	Neural Network	• Fast and parallel computing is provided.	• Prior information should be known. • Training of neural network is required which may take very long.
	Clustering	• Easy to implement. • Relations between clusters are simple and easy to understand.	• Sensitive to the selection of the initial random centroids. • Number of clusters selected in image is user dependent.

	Wavelets	• Provides image inpainting. • Nice multi-resolution properties and decoupling characteristics.	• Shift sensitivity. • Poor directionality. • Absence of phase information [24].
Model Based Segmentation	-	• Non invasive technique to explore the structure.	• Knowing the exact shape of the objects contained in the image is necessary.

3) **Clustering Based Segmentation:** Clustering is a process of grouping of pixels into various classes without any prior information such that pixels belonging to the same class should be similar to each other. This technique can be classified into two types: Hierarchical clustering and Partition clustering [10]. In the *hierarchical clustering*, the distance between each pattern is calculated. In the *partition clustering*, centroid of cluster is calculated. Several clustering based image segmentation algorithm exists such as Fuzzy c means clustering algorithm and K-Means clustering algorithm [2].
4) **Wavelet Based Segmentation:** This technique uses wavelet transform for features extraction associated with individual image pixels [21]. Wavelet transform has been used as a good image representation and analysis tool mainly due to its multi-resolution analysis, data reparability, compaction and sparsity features in addition to statistical properties [22]. Wavelets provide the inpainting feature for images. Inpainting is the art of modifying an image in a form such that it is not easily detectable by an ordinary observer [23].

E. Model Based Segmentation

Model Based Segmentation is useful when there is a need to segment object which have a repetitive structure or form of geometry i.e. the shape of the object to be segmented is known beforehand [26]. Hence, is widely used in medical imaging.

IV. COMPARISON OF IMAGE SEGMENTATION TECHNIQUES

A comparison is very essential to figure out the benefits and deficiency of any technique. Hence, a comparison has been done of the different segmentation techniques that are currently used in different fields on the basis of the literature reviewed in the Table 1.

V. CONCLUSION

This paper presents discussion on image segmentation and its different techniques that are used in various fields such as biomedical field, computer vision and image processing. The review is aimed at providing an overview of current image segmentation techniques; therefore, analysis and comprehensive assessment of these image segmentation techniques are done. Based on this, we now come to the conclusion that image segmentation has a promising future and a lot of research work is required for developing a common and consistent segmentation technique which can be applied universally.

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