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IMAGE SEGMENTATION TECHNIQUES: A REVIEW

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Abstract: **Image segmentation techniques play a crucial role in Digital image processing. Image segmentation is the fundamental step to analyze images and extract data from them. It is the process of partitioning a digital image in to multiple segments and regions for better understanding and further processing. Extensive research has been done in creating many different approaches and algorithms for image segmentation and several general purpose segmentation algorithms and techniques have been developed by the researchers in order to make images smooth and easy to evaluate. This paper is presented as a survey to explore the different types of segmentation methods.**

Keywords- Digital Image Processing, Image Segmentation, Segmentation Techniques.

I. INTRODUCTION

An image may be defined as a two dimensional function of spatial coordinates, f(x,y). The amplitude of f at a given pair of coordinates gives the intensity value or gray level of the image at that point. When x,y and amplitude values of f are all finite ,discrete quantities ,the image is called digital image. A digital image is composed of a finite number of elements each of which has a particular location and value .These elements are referred to as picture elements, pels or pixels. Digital image processing refers to processing of digital images by means of digital computer [1].

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 for example: navigation of robots, extracting malign tissues from body scans, detection of cancerous cells, identification of an airport, beach, building, river, forest etc. from remote sensing data, face recognition, finger print recognition etc.. Image segmentation is the first step in image analysis, with the help of which we can understand images and extract data or objects. In the segmentation process, the anatomical structure or the region of interest needs to be delineated and extracted out so that it can be viewed individually. The noise is removed from the images using some filters before segmentation. This denoising avoids false contour selection and data loss during the segmentation. The main aim of writing this paper is to provide a literature review in this area. The rest of the paper is organized as below: section II introduces the term image segmentation, section III describes the image segmentation techniques, section IV gives the comparison of segmentation techniques and section V concludes the overall study.

II. IMAGE SEGMENTATION

Image segmentation refers to partitioning of an image into its constituent regions or objects in a meaningful way. Image segmentation is a mid level process, characterized by the fact that its inputs generally are images, but its outputs are attributes extracted from those images (e.g. edges, contours and the identity of the individual objects).It is a critical step towards content analysis and image understanding.

III. IMAGE SEGMENTATION TECHNIQUES

Image segmentation has become a burning topic for researchers for many years. Many segmentation methods have been developed, but there is not even a single method which can be considered well suited for different images, all methods are not equally applicable for a particular type of image[2].Thus algorithm development for one class of images may not always be suited to other class of images. There exists no general purpose segmentation algorithm. Many segmentation methods have been proposed in the literature. The choice of a segmentation technique over another and the level of segmentation are decided by the particular type of image and characteristics of the problem being considered. Image segmentation algorithms generally are based on one of the two basic properties of intensity values: Discontinuity and similarity [1],[3].

- *Detecting Discontinuities*
  To partition an image based on abrupt changes in intensity such as edges in an image, these techniques are categorized as edge detection techniques.
- *Detecting similarities*
  To partition an image into regions that are similar according to a set of predefined criteria.Thresholding, region growing, region splitting and merging are examples of segmentation methods in this category.

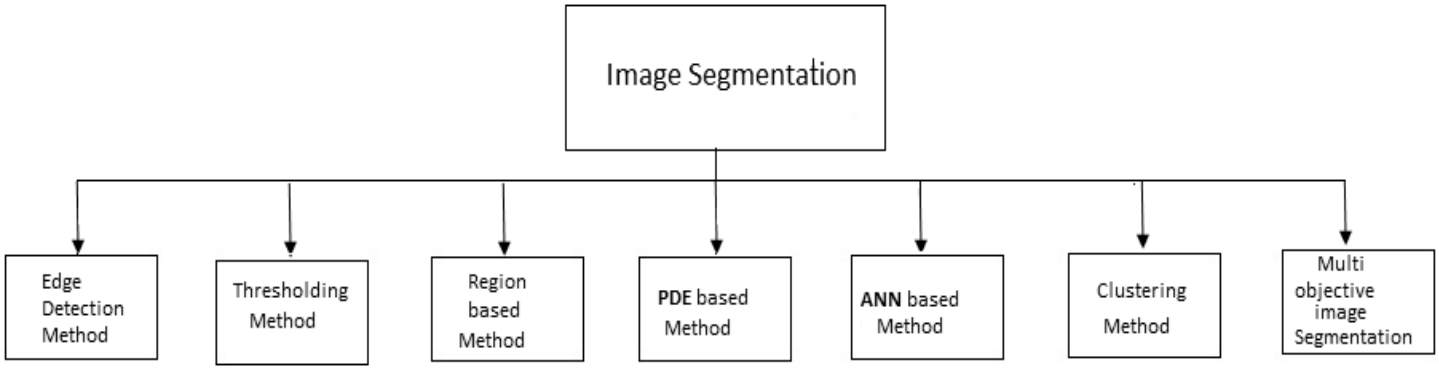

Fig.1. Image Segmentation Techniques

A. SEGMENTATION BASED ON EDGE DETECTION

Edge detection in particular has been a staple of segmentation algorithms for many years. This method is based on the principle of intensity variations among the pixels. If the image consists of two or more objects, boundaries exist and lead to formation of edges, which results in discontinuity in the pixels. Edge detection is used to divide the image on the basis of edges that have abrupt changes in intensity and brightness. These edges are extracted [1],[4] and linked to form closed object boundaries, the result is a binary image [5]. Edge detection basically involves the following steps: Smoothing the image, Edge detection and Edge localization [6],[7].

There are two main edge based segmentation methods- Gray histogram and Gradient based methods. [8]

1. *Gray histogram method:*

The result of edge detection technique depends mainly on the selection of threshold T, and it is really difficult to search for maximum and minimum gray level intensity, because gray histogram is uneven for the impact of noise, thus approximately we substitute the curves of the object and back ground with two conic Gaussian curves [8], whose intersection is the valley of the histogram. Threshold T is the gray value of intersection point of that valley.

2. *Gradient based method:*

Gradient is the first derivative of the image f(x, y).Edges can be found in gray level images by using functions approximating gradients or Laplacians of images. Gradient based method works well [8], when there is abrupt transition in intensity near edges and there is little image noise.

This method involves convolving gradient operators with the image. When there is a rapid transition between two different regions, there is a possibility of high value of gradient magnitude. Sobel operator, canny operator, Laplace operator, Laplacian of Gaussian (LOG) operators and so on are the common edge detection operators used in the Gradient based method. Out of these Canny is the most promising one.[1], but slow when compared to Sobel operator.

The edges traced by edge detection are often discontinuous. For segmenting an object from an image with high complexity however, one needs closed connected region boundaries. The desired edges are the boundaries of such objects. Segmentation approaches can also be applied to already traced edges using edge detectors for more sharp edges. Lindeberg and Li [9],[10] developed an integrated method that segments edges into straight and curved edge segments for parts –based object recognition, based on a minimum Description length (MDL) criterion that was optimized by a split and merge like method with candidate break point obtained from complimentary junction cues to obtain more likely points at which to consider partitions into different segments.

Edge detection techniques require a tradeoff between detecting accuracy and noise immunity in practice, 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 [8], some parts of the image outline may get undetected and the position of the object may be mistaken.

Thus edge detection algorithms are suitable for simple and noise free images, and will often produce missing edges or extra edges on complex and noisy images [11].

B.THRESHOLDING METHOD

It is an intensity based segmentation method. Even though it is simple, it is very powerful approach for segmenting images having light objects on dark back ground [1].Thresholding technique is based on image space regions i.e., on characteristics of image [8].Thresholding operation convert multilevel image into a binary image i.e., it is done for choosing 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 the threshold value i.e. , $f(x,y) \geq T$, else pixel belongs to back ground [12,13].Depending on the selection of thresholding value, there exists two types of thresholding methods[14],global and local thresholding. When T is fixed for the entire image, the approach is called global thresholding otherwise it is called local thresholding. Global thresholding distinguishes object and back ground pixels by comparing with threshold value chosen and use binary partition to segment the image. The pixels that pass the threshold test are considered as object pixels and are assigned the binary value "1" and other pixels are assigned the binary value "0" and treated as back ground pixels.

Local thresholding is also called adaptive thresholding, in which the threshold value varies over the image depending on the local characteristics of the subdivided regions in the image. The algorithm followed for adaptive thresholding can be stated in general as:

1. Divide the image into sub images.
2. Choose a local threshold for the sub image considered.
3.Compare the pixels in that sub image and segment the region.
4.Consider all sub images individually and choose corresponding threshold values.
5. Stop segmentation when all the sub images are processed.

Global thresholding methods are successful only when the back ground illumination is even, otherwise they fail. In local thresholding multiple thresholds are used to compensate for uneven illumination [11]. Threshold selection is typically done interactively however; it is possible to derive automatic threshold selection algorithms.

Incase of local thresholding the threshold is to be chosen depending on the properties of local pixels in that sub image. Threshold value can be modified and are categorized as Band thresholding, Multi thresholding and Semi thresholding. Either the Global thresholding or Local thresholding yield the result depending on the value of threshold chosen. Hence the choice of threshold is crucial and complicated. There are several methods employed for detection of threshold value to name a few Mean method, P-Tile thresholding, Bi model histogram, optimal thresholding, Multi spectral thresholding, Edge maximization method [6],[15]. Out of the available techniques for threshold based segmentation, threshold selection based on the histograms suggested by Nobuyuki Otsu in 1979 is the mostly used one with minor modifications [16]. Otsu method is optimal for a thresholding large object from the background.

The other approaches employed to select threshold value are histogram based methods, clustering based methods, mutual information based methods, attribute based methods and local adaptive segmentation based methods.

Merits of threshold based methods:

- Can work in real time applications [15].
- Computationally inexpensive.
- Fast and simpler to implement.

Demerits of threshold based methods:

- Highly noise sensitive.
- Neglects the spatial information of the image.
- Selection of threshold value is not trivial task and often results in over or under segmentation.
- May lead to faulty edges or missing edges.

C. REGION BASED SEGMENTATION

Compared to Edge detection method, Region based segmentation algorithms are relatively simple and more immune to noise[8],[17].Edge based methods partition an image based on abrupt changes in intensity near edges where as region based methods, partition an image into regions that are similar according to a set of predefined criteria[1],[18].

This method works on the principle of homogeneity by considering the fact that neighboring pixels inside a region possess similar characteristics and are dissimilar to the pixels in other region.

The simplest approach to segment image based on the similarity assumption is that every pixel is compared with its neighbor for similarity check (for gray level, texture,colour,shape)[19].If the result is positive then that particular pixel is "added" to the pixel and a region is "grown" like-wise the growing is stopped when the similarity test failed. Segmentation algorithms based on region mainly include following methods:

(i)Region growing:

Region growing is a procedure [5],[12] that groups pixels in whole image into sub regions or larger regions based on predefined criteria [20]. Region growing can be processed in four steps:

a. Select a group of seed pixels in original image [2]

b.Select a set of similarity criterion such as grey level intensity or color and set up a stopping rule.
c. Grow regions by appending to each seed those neighboring pixels that have predefined properties similar to seed pixels.
d. Stop region growing when no more pixels met the criterion for inclusion in that region (i.e., size, likeness between a candidate pixel and pixel grown so far, shape of the region being grown)

Region growing method is reliable output compared to other counter parts. It can be further classified as seeded region growing method (SRG) and unseeded region growing method (USRG).
The main difference between SRG and USRG is that SRG is semi automatic in nature whereas USRG is fully automatic in nature.[21]

(ii)Region split and merge method:

This method is most similar method to segment the image based on homogeneity criteria [22]. Rather than choosing seed points user can divide an image into asset of arbitrary un connected regions and then merge the regions [5][8] in an attempt to satisfy the conditions of reasonable Image Segmentation. Region splitting and merging is usually implemented with theory based on quad tree data.

Let R represent the entire image region and select a predicate Q
(i). We start with entire image if Q(R)= FALSE[1],we divide the image into quadrants, if Q is False in any quadrant that is, if $Q(R_i)$= FALSE we sub divide the quadrants into sub quadrants and so on till no further splitting is possible.
(ii). If only splitting is used, the final partition may contain adjacent regions with identical properties. This drawback can be remedied by allowing merging as well as splitting i.e., merge any adjacent regions R_j & R_k for which Q (R_j U R_k) = TRUE.
(iii). Stop when no further merging is possible.

Merits of Region based Segmentation:

- Provides flexibility to choose in between interactive and automatic techniques to segment the given image.
- This method gives superior results compared to other segmentation methods.
- If proper seed is selected it gives very accurate result than any other methods. Since it flows from inner point to outer region more likely get clear boundary for the objects.

Demerits of Region based Segmentation:

- Formulation of stopping rule for segmentation is not a trivial task[15]
- SRG can result in scan-order dependencies and can have significant impacts on small regions.
- A good segmentation result depends on a set of "correct" choice for the seeds and can lead to erroneous segmentation results if user specifies a noisy seed.
- The seed selection process in itself requires manual interventions and is error prone.

D. SEGMENTATION METHODS BASED ON PDE(PARTIAL DIFFERENTIAL EQUATION)

Image Segmentation can also be achieved using PDE based method and solving the Partial Differential Equation by a numerical scheme. This method is mainly carried out by active contour model or snakes, which was first introduced by Kassetil in 1987[23]. Kass developed this method to find familiar objects in presence of noise and other ambiguities. Transforming a segmentation problem into a PDE frame work is the central idea of snake method. That is the evaluation of a given curve, surface or image is handled by PDEs and the solution of these PDEs is what we look forward to various methods for image segmentation are-snake, Level set and Mumford-shah model.

1. Snakes:

Active contours or snakes are computer generated curves [23],[24] that move within the image to find object boundaries under the influence of internal and external forces. The procedure is as follows:

(i) Snake is placed near the contour of Region of Interest (ROI).
(ii) During an iterative process due to various internal and external forces within the image[25] the snake is attracted towards the target. These forces control the shape and location of the snake within the image.
(iii) To measure the appropriateness of the contour of ROI, an energy function consisting of internal and external forces is constructed. The minimum value of this energy function represents the active contour's total energy. The internal forces are responsible for smoothness while the external forces guide the contours towards the contour of ROI.

Demerits of Snake method:

- It requires user interaction.
- Original snake algorithm is particularly sensitive to noise.
- The computational complexity of algorithm is high.

3. Level set model:

Many of the PDEs used in Image Processing based on moving curves and surfaces with curvature based velocities. In this area, the Level set method developed by Osher and Sethian[23] was very influential and useful. Representing the curves or surfaces as the zero level set of a higher dimensional hyper surface is the basic idea. This technique not only provides more accurate numerical

implementations but also handle topological change very easily.

Merits of Level set method:

- Its stability and irrelevancy with topology, shows a great advantage to solve the problems of corner point producing, curve breaking and combining etc.

Demerits of Level set method:

- Only objects with edges defined by gradients can be segmented.
- In practice, the Edge- stopping function is never exactly zero and so the curve eventually passes through the object boundaries.

4. Mumford-shah model:

The Mumford-shah model uses the global information of the image as a stopping criterion to segment the image [23]. . Mumford-shah takes the advantage of the entire information of the image to result in the best image segmentation.

5. C-V model:

The basic idea is to look for a particular partition of a given image into two regions [23], one representing the objects to be detected & other background. C-V model is not based on edge function to stop the evolving curve and desired boundary. There is no need to smooth the initial image even though it is noisy, the location of boundaries are very well detected. It can detect objects whose boundaries are not necessarily defined by gradient or very smooth boundaries. Starting with only one initial curve this model can automatically detect interior contours and it does not necessarily start around the objects to be detected.

E. SEGMENTATION BASED ON ARTIFICIAL NEURAL NETWORK:

Neural networks are structures made up of large numbers of elementary processors (cells) massively interconnected which performs simple functions [1][26] their design try to imitate the information processing of biological neural cells.

Neural network based segmentation is totally different from conventional segmentation algorithms. In this an image is firstly mapped into a neural network where every neuron has a pixel [4],[8], thus Image segmentation problem is converted into energy minimization problem. A neural net is an artificial representation of human brain that tries to simulate its learning strategies and can be used for decision making processes. An artificial neural network is often called a neural network or simply neural net.

In recent years, artificial neural networks have been widely used to solve the problem 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 can perform some basic computing. The learning process can be achieved through the transferring the connections among nodes and connection weights.The neural network was trained with training sample set in order to determine the connection and weights between nodes. Then the new images were segmented with trained neural networks, for example, we can extract image edges by using dynamic equations which direct the state of every neuron towards minimum energy defined by neural network.

This technique includes two important steps:

1. Feature extraction and
2. Image segmentation based on neural network.

Feature extraction is very crucial as it determines the input data of neural network [24], firstly some features are extracted from the images, such that they become suitable for segmentation and then they were the input of the neural network. All of the selected features consist of highly non-linear feature space of cluster boundary.

Merits of neural network based Segmentation:

- Highly parallel ability and fast computing capability [8] which makes its suitable for real time applications.
- Improve the segmentation results when the data deviates from the normal situation [24].
- This technique is robust which makes it insensitive to noise.
- Reduced requirement of expert intervention during the image segmentation process.

Demerits of neural network based Segmentation:

- Some kind of segmentation information should be known beforehand [8].
- Initialization may effect the result.
- Training time is long.
- Over training should be avoided.

F.SEGMENTATION BASED ON CLUSTERING:

Clustering is an un supervised learning task, where one needs to identify a finite set of categories known as

clusters to classify pixels [27].Clustering use no training stages rather train themselves using available data.

clustering mainly used when classes are known in advance similarity criteria is defined between pixels [5], and then similar pixels are grouped together to form clusters. The grouping of pixels into clusters is based on the principle of maximizing the intra class similarity and maximizing the inter class similarity. The quality of clustering result depends on both the similarity measure used by the method and its implementation. The degree of Clustering result depends on both the similarity measure used by the method and its operational procedure.

Clustering methods are classified as hard clustering, Fuzzy clustering, k-means clustering etc.

a) Hard clustering:

Hard clustering assumes that pixel of an image belongs to one and only one cluster and also that there exists sharp boundaries between each cluster [5][25]. Well known hard clustering, algorithm is k-mean algorithm, it assigns n pixels into k number of clusters with k<n.

The pixel assignment to a particular cluster is done on the basis of some characteristics like gray level intensity, distance between pixels [12]

b) Fuzzy clustering:

In real time applications one of the most difficult task in Image processing is to assign a particular pixel into a cluster when there is no clear boundaries between different objects in the image[5]. In such cases fuzzy clustering is used. It assigns image pixel to a cluster on the basis of similarity criteria. Similarity criterion can be distance connectivity, intensity etc.

The uncertainty in image extraction and subsequent segmentation from noise effected scene can be effectively handled by Fuzzy logic. Apply Fuzzy operators, properties, mathematics and inference rules; provide a way to handle the un certainty inherent in a variety of problems due to ambiguity rather than randomness. Most commonly used Fuzzy clustering algorithms are Possibilistic c-means (PCM) and Fuzzy c-means algorithm(FCM), GK(Gustafson-Kessel), GMD (Gaussian mixture Decomposition), FCV (Fuzzy c varieties), AFC, FCS,FCSS,FCQS,FCRS algorithms etc.

Merits of Fuzzy based Segmentation:

- It is easy to understand because it uses Fuzzy set.
- Fuzzy membership function can be used to locate the degree of some properties or linguistic phrase, and Fuzzy IF-THEN rules can be used to perform approximate inherence.

Demerits of Fuzzy based Segmentation:

- For noisy images it does not take into account special information which makes it sensitive to noise.
- The determination of Fuzzy membership is not a trivial job.
- Intensive computation is involved in Fuzzy approaches.

G. MULTI OBJECTIVE IMAGE SEGMENTATION

Earlier image segmentation problem has been treated as mono objective. Mono objective images consider only one objective because a single segmentation image. Such type of segmented images are of good quality but may not allow a higher level process(as image segmentation considered as low level process& pattern recognition, object tracking& scene analysis as high level process) to extract all information included within the image. So different segmentation results are calculated. Image segmentation is a multi objective optimization problem [28]. The consideration of multiple criteria (objectives) start from the understanding of image pattern to its selected segmentation process involved i.e, feature selection/extraction, similarity and dissimilarity method and finally the validity assessment of its output. Multiple representations have to be considered as there are multiple source of information for a segmentation problem.

For instance in segmenting in a medical image based on CT scan multiple features like intensity, shape and spatial relation should be considered. Similarly criteria for inter pattern similarity that is grouping can be multiple, spatial coherence vs feature homogeneity, connectedness vs compactness,
diversity vs accuracy. For image segmentation multiple methods can be used for getting appropriate output, and there may be a tendency for multiple optimization and decision making processes where multiple validity assessment should be used. There are two general approaches for multi objective optimization problem.

a) Conventional weighted formula approach (WFA):

In this approach the multi objective problem is transformed into a problem with single objective [29] numerical weights are assigned to each objective and then the values of weighted criteria are combined into a single value either by adding or by multiplying weighted criteria.

b) Pareto approach (PTA):

In this approach instead of transforming a multi objective problem into a single objective function [29] and then solving it by using a single objective search method, one uses a multi objective algorithm to solve the problem. The formulation start with simultaneous optimization of several objectives, a reasonable solution is to investigate a set of solutions each of which satisfies the objectives at an acceptable level without being dominated by other solutions, these solutions are called non dominated solutions and the region of these solutions is called Pareto front.

IV COMPARISION OF DIFFERENT IMAGE SEGMENTATION TECHNIQUES

Segmentation Technique	Method of Description	Advantages	Disadvantages
Edge Detection Technique	• Edge based segmentation is used to divide image on the basis of their edges. • Based on the detection of discontinuities generally tries to trace points with more or less abrupt changes in gray level	Edge detection technique is the way in which human perceives objects and works well for images having good contrast between regions	• Does not work well with images in which the edges are ill-defined or there are too many edges. • It is not an easy task to produce closed curve or Boundary. • Less immune to noise than other Techniques.
Thresholding Technique	• Thresholding technique is based on image space regions. • Requires that the histogram of an image has a number of peaks each corresponds to a region.	• It does not need prior information of the image. • Computationally inexpensive. • Fast and simpler to implement • Can work in real time applications.	• Neglects the Spatial information of the image. • Highly noise sensitive • Selection of threshold value is crucial and often results in over and under segmentation. • May lead to pseudo edges or missing edges • It cannot be applied to multi channel images.
Region Based Technique	• This method is based on continuity principal. • Group pixels into homogeneous regions including growing region, splitting region, merging region or their combination	• Relatively simple and more immune to noise than edge based methods. • Work best when the region homogenuineity criteria is easy to define.	• Are by nature sequential and quiet expensive both in computational time and memory • Region growing has inherent dependence on the selection of the seed region and the order in which pixels and regions are examined. • The resulting segments by region splitting appear too square due to the splitting scheme.
Artificial Neural Network(ANN) based Technique	• Includes two important steps feature extraction and image segmentation based on neural networks.	• Highly parallel ability and fast computing capability which makes its suitable for real time applications. • Improve the segmentation results when the data deviates from the normal situation. • This technique is robust which makes it insensitive to noise. • Reduced requirement of expert intervention during the image segmentation process.	• Some kind of segmentation information should be known beforehand. • Initialization may effect the result. • Training time is long • Over training should be avoided.
Fuzzy Technique	• The uncertainty in image extraction and subsequent segmentation from noise effected scene can be effectively handled by Fuzzy logic. • Apply Fuzzy operators, properties, mathematics and inference rules; provide a way to handle the un certainty inherent in a variety of problems due to ambiguity rather than randomness.	• Fuzzy membership function can be used to locate the degree of some properties or linguistic phrase, and Fuzzy IF-THEN rules can be used to perform approximate inherence.	• For noisy images it does not take into account special information which makes it sensitive to noise. • The determination of Fuzzy membership is not a trivial job. • Intensive computation is involved in Fuzzy approaches.
Partial Differential Equation(PDE) based Technique	• This is mainly carried out by active contour model or snakes, level set. • Transforming a segmentation problem into a Partial Differential Equation frame work is the central idea in snakes model. • The basic idea in Level set method is to represent the curves or surfaces as the zero level set of a higher dimensional hyper surface.	• Level set method's stability and irrelevancy with topology, shows a great advantage to solve the problems of corner point producing, curve breaking and combining etc.	• In traditional snake method user interaction is required to determine the curve around the detected object and this method is Sensitive to noise • Computational complexity of snakes algorithm is high. • Using Level set method only objects with edges defined by gradients can be segmented and • The edge stopping function is never exactly zero at the edges and so the curve eventually passes through object boundaries.

V. CONCLUSIONS

In this paper an overview of various segmentation techniques applied for Digital Image Processing is briefly explained. This study also reflects the research on various research methodologies applied for Image segmentation and various research issues in the field of study. This study aims to provide a simple guide to the researchers for those who are carrying out their research study in the Image Segmentation. Inspite of several decades of research till now, there is no universally accepted method for Image segmentation, for Image segmentation depends on many factors, such as: homogeneity of images, spatial characteristics of image continuity, texture, image content and problem domain. Thus there is no single method which can be considered good for all types of images, or all methods are equally good for a particular type of image, therefore image segmentation is still a very crucial area of research for Image Processing field.

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