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A Study of Digital Image Segmentation Techniques

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Abstract: - ***In the 21st century, the internet revolution has brought about an explosion of information in the form of documents and web pages. Today, more and more focus is being given to visual representation of data. Digital Image Processing has thus emerged as one of the most researched fields in the computer domain. Image segmentation is important part in many signal processing technique and its applications. It is the process of partitioning a digital image and dividing it into meaningful structures known as segments (sets of pixels, also known as superpixels). It is often an essential step in image analysis, object representation, visualization, and many other image processing tasks. Image segmentation is a great challenge in the field of computer vision. The aim of this paper is to give an overview of image segmentation and the techniques for the same.***

Keywords: Computer vision, Computer Aided Analysis, Image Classification, Image Recognition, Image Decomposition, Image Processing, Image Segmentation

1. Introduction

The field of Computer Vision is one of the most widely researched fields in the computer world. With advancements in software engineering and technology, it has become easier to generate images and depict data in a pictorial form. Digital image processing is the application of various algorithms on the image to improve the quality of the image by removing noise & other unwanted pixels and also to obtain more information on the image. Some of the popular image processing applications include face recognition systems, cropping systems, medical imaging, etc.

Image Segmentation is one of the fundamental aspects involved in image processing. Image segmentation[1][10] is a mid-level processing technique used to analyze the image and can be defined as a processing technique used to classify or cluster[3] an image into several disjoint parts by grouping the pixels to form a region of homogeneity based on the pixel characteristics like gray level, colour, texture, intensity and other features. The main purpose of the segmentation process is to get more information in the region of interest in an image which helps in annotation of the object scene.[2][7]

Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain characteristics. The result of image segmentation is a set of segments that collectively cover the entire image[11][1], or a set of contours[14] extracted from the image. Each of the pixels in a region are similar with respect to some characteristic or computed property, such as colour, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristic(s).

If R represents an image, then the image segmentation can be defined mathematically as the division of R into sub-regions R1,R2…..Rn , such that[12]

a) Ri is a connected set, i=1,2,…..n.

b) $Ri \cap Rj = \emptyset$ for all i and j, $i \neq j$

c) Q(Ri) = True for i= 1,2,…n.

d) Q(Ri U Rj) = False for adjoint regions, Ri and Rj

Where Q(Rk) is a logical predicate

The image segmentation technique in which each pixel is assigned to the correct object segment is called as 'Perfect Segmentation'. It is only a theoretical concept and cannot be achieved, because of the following reasons:

(a) Pixels belonging to the same object are classified as belonging to different segments. As a result, a single object may be represented by two or more segments. This is called oversegmentation. [2][11][12]

(b) Pixels belonging to different objects are classified as belonging to the same object. Thus, a single segment may contain several objects. This is called as undersegmentation.[13]

2. Survey of Techniques

2.1 Threshold Method

Also known as the intensity based method, Thresholding[12] is probably the most frequently used technique to segment an image. Threshold based techniques classifies the image into two classes and works on the postulate that pixels belonging to certain range of intensity values represents one class and the rest of the pixels in the image represents the other class. It is done through that threshold values which are obtained from the histogram of those edges of the original image. The threshold values are obtained from the edge detected image. The thresholding operation is a grey value remapping operation g defined by: [12][14]

g(v) = 0, v<t
= 1, v>=t

where v represents a grey value, and t is the threshold value. Thresholding maps a grey-valued image to a binary image. After the thresholding operation, the image has been segmented into two segments, identified by the pixel values 0 and 1 respectively.

Thresholding may be classified as local or global. In case of global thresholding the threshold value chosen remains the

same for the entire image and acts as a „cutoff" value. In case of local thresholding the image is to be subdivided in to subimages and the threshold is to be chosen depending on the properties of local pixels in that subimage.
The algorithm followed for local thresholding can be stated in general as: [10][3][12]
1. Divide the image into subimage.
2. Choose a local threshold for subimage considered.
3. Compare the pixels in that subimage and segment the region.
4. Consider all subimages individually and choose corresponding threshold values.
5. Stop segmentation when all the subimages are processed.

The selection of the threshold may be done by any one of the following methods: [11]
(a) User defined selection
(b) Approximation from histogram extrema
(c) Minimum variance within segments
(d) K-Means Clustering
(e) Iterative Thresholding
Threshold method is computationally inexpensive and is well suited for real time applications. However, it neglects spatial information and is highly noise sensitive and may lead to presence of pseudo edges or missing edges.

2.2 Region Based Method
In this technique pixels that are related to an object are grouped for segmentation[4][5]. The thresholding technique is bound with region based segmentation. The area that is detected for segmentation should be closed. Region based segmentation is also termed as "Similarity Based Segmentation". This method works on the principle of homogeneity by considering the fact that the neighboring pixels inside a region possess similar characteristics and are dissimilar to the pixels in other regions. [4][7]. The objective of region based segmentation is to produce a homogeneous region which is bigger in size and results in very few regions in the image. The regions though treated as homogeneous in nature but there is provision to note any considerable changes in the characteristic of the neighboring pixels.
The boundaries are identified for segmentation. In each and every step at least one pixel is related to the region and is taken into consideration. After identifying the change in the color and texture, the edge flow is converted into a vector. From this the edges are detected for further segmentation.
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, color, shape). [11][10] 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 fails.
Region based methods are fundamentally divided as [7][8]
1. Region growing methods which extract the image by a certain predefined criteria(usually neighbour comparison).
2. Region split and merge methods which recursively divide the image into quadrants and apply the criteria till it is found true.
This method is a highly flexible one and gives superior results as compared to other algorithms. However, its accuracy depends upon the appropriate selection of a seed pixel.

2.3 Cluster Based Method
Clustering[10] a process of organizing the groups based on its attributes. The objective of clustering techniques is to identify bunch in data. A cluster usually contains a group of similar pixels that belongs to a specific region and different from other regions. The term data clustering as synonyms like cluster analysis, automatic classification, numerical taxonomy, botrology and typological analysis[11] .Images can be grouped based on its content. In content based clustering, grouping is done depending on the inherited characteristics of the pixels like shape, texture etc. There are various clustering techniques employed, the most widely used are K-means algorithm and fuzzy C-means algorithm. The Clustering methods are usually divided as hierachical algorithms and partitional algorithms.
Generally, we can cluster in two ways: [3][4]

1. Partitioning: Here we have a large data set, and carve it up according to some notion of the association between items inside the set. We would like to decompose it into pieces that are "good" according to our model. For example, we might:
(a) Decompose an image into regions which have coherent colour and texture inside them
(b) Take a video sequence and decompose it into shots
(c) Segments of video showing about the same stuff from about the same viewpoint
(d) Decompose a video sequence into motion blobs, consisting of regions that have coherent colour, texture and motion.

2. Grouping: Here we have a set of distinct data items, and wish to collect sets of data items that "make sense" together according to our model. Image components that belong to the same object are often separated. Examples of grouping include:
(a) Collecting together tokens that, taken together, forming an interesting object
(b) Collecting together tokens that seem to be moving together

A basic clustering algorithm i.e., K-means is used for segmentation in textured images. It clusters the related pixels to segment the image. Segmentation is done through feature clustering and there it will be changed according to the color components . Segmentation is also purely depending on the characteristics of the image. Features are taken into account for segmentation. Difference in the intensity and color values are used for segmentation . For segmentation of color image they use Fuzzy Clustering technique[1][3], which iteratively generates color clusters using Fuzzy membership function in color space regarding to image space. The technique is successful in identifying the color region.

2.4 Watersheds Method
Watershed image segmentation is based on the theory of Mathematical Morphology[1][9]. Numerous techniques have been proposed to compute watersheds. The classical idea for building the watershed is using a geographical analogy, begin by piercing the regional minima of the surface. Then slowly immerse the image into a lake. The water progressively floods the basins corresponding to the various minima. To prevent the merging of two different waters originating from two different minima, we erect a dam between both lines. Once the surface is totally immersed, the set of the dams thus built is the watershed of the image. In one dimension, the location of the watershed is straightforward: it corresponds to the regional maxima of the function. In two dimensions, one can say in an informal way that the watershed is the set of crest lines of the image, emanating from the saddle points.

The method stick this initial contour to the maximum contained watershed contour. For label image G = [R, E], we assume each edge eij Є E is a directing curve with the direction the same as clockwise direction of region Ri`s contour. [9][11]

2.5 Edge Based Method

Segmentation can also be done by using edge detection techniques. [4][5]. In this technique the boundary is identified to segment. Edges are detected to identify the discontinuities in the image. Edges on the region are traced by identifying the pixel value and it is compared with the neighboring pixels[8]. For this classification they use both fixed and adaptive feature of Support Vector Machine (SVM)[1][5]. In this edge based segmentation, there is no need for the detected edges to be closed. There are various edge detectors that are used to segment the image. Few examples are Gradient, LoG, Canny, Sobel etc.

In that Canny edge detector has some step by step procedure for segmentation: [4]

1. To reduce the effect of noise, the surface of the image is smoothened by using Gaussian Convolution.
2. Sobel operator is applied to the image to detect the edge strength and edge directions.
3. The edge directions are taken into considerations for non-maximal suppression i.e., the pixels that are not related to the edges are detected and then, they are minimized.
4. Final step is removing the broken edges i.e., the threshold value of an image is calculated and then the pixel value is compared with the threshold that is obtained. If the pixel value is high than the threshold then, it is considered as an edge or else it is rejected.

2.6 Model Based Method

Markov Random Field (MRF) based segmentation is known as Model based segmentation [6]. An inbuilt region smoothness constraint is presented in MRF which is used for color segmentation [3]. Components of the color pixel tuples are considered as independent random variables for further processing. MRF is combined with edge detection for identifying the edges accurately. MRF has spatial region smoothness constraint and there are correlations among the color components. Expectation-Maximization (EM) algorithm values the parameter is based on unsupervised operation. Multiresolution based segmented technique named as "Narrow Band". It is faster than the traditional approach. The initial segmentation is performed at coarse resolution and then at finer resolution. The process moves on in an iterative fashion. The resolution based segmentation is done only to the part of the image. So, it is fast. The segmentation may also be done by using Gaussian Markov Random Field (GMRF) where the spatial dependencies between pixels are considered for the process [7] Gaussian Markov Model (GMM) based segmentation is used for region growing.[1] The extension of Gaussian Markov Model(GMM) that detects the
region as well as edge cues within the GMM framework. The feature space is also detected by using this technique.

2.7 Pattern Recognition Method

Pattern Recognition Techniques[2] is a non-linear modelling tools and we can be used to model the inputs and outputs relationships. Weights in the classifier[2][3] are selected through optimizing energy functional defined by the features of structures and are updated through processing each sample in the training set.

The extracted information from the training set provides important cues of the structures such as intensity, position and shape, which can be valuable complementary information for the segmentation of test images. Active appearance models (AAM) are statistical models of the shape of structures. [11].Training samples are used to extract the mean shape, mean appearance and define ranges of shape parameters. Restrictions on shape parameters guarantee the similarity between the segmentation result and the training samples. The segmentation procedure is to find the better positions of the shape points according to the appearance information. Algorithms based on classifiers have been widely applied to segment organs in medical images like cardiac and brain images. If properly modelled, supervised classification algorithms can greatly enhance the segmentation accuracy. However, supervised classification algorithms are sensitive to the initial conditions. To guarantee the correctness of the results, the training set must contain enough samples and the samples should be representative and segmented accurately.

2.8 Active Contour Model

Active contour models (snakes[15]) goal is to apply segmentation process to an image by doing deformation to the initial contour towards the boundary of the object of interest. We do that by deforming an initial contour to minimizing the energy function which defined on contours . There are two components in this energy: the potential energy, which is small when the contour is aligned to edges of the image, and the internal deformation energy, which is small when the contour is smooth. Both components are contour integrals with respect to a parameter of the contour.

An Active contour can be parametrically represented by [11]

$v(s) = (x(s), y(s))$

The total image energy can be represented as a combination of three weighted energy functions and can be written as[11]:

$E_{img} = w_{line}E_{line}+w_{edge}E_{edge}+w_{term}E_{term}$

Active contour models (Snakes) can be represented by two models: region based models and edge-based models. The characteristics of the image determine the model we should choose. The main advantage of snakes models is the ability of snakes to give a linear description of the object shape during the time of convergence without adding extra processing. But what scientifically limits the use of snakes is the need of the method to have strong image gradients to be able to drive the contour.

2.9 Inversion Method

The principle of the inversion[10][12][13] is to continuously update the muscle activity to produce a face movement following a given face . When the inversion had been carried out for all frames, the inverted activity was used to generate an animation. A conventional nonlinear optimizer minimizing a cost function was selected to implement the inversion.

3. Comparitive Study

SR NO	METHOD	ADVANTAGES	DISADVANTAGES
1	Threshold	• Computationall	• Highly sensitive to

		y inexpensive • Suited for real time applications	noise • Neglects spatial information and may lead to pseudo edges
2	Region-Based	• Easy for implementation • Method is highly flexible	• Accuracy is variable and depends upon selection of seed pixel.
3	Clustering	• Makes use of basic algorithms • Can be carried out in parallel	• Has high time and space complexity
4	Watershed	• Based on concepts of basic morphology • Helps to improve capture range.	• Problem of over-segmentation is possible.
5	Edge Based	• Power efficient algorithm	• Output may be distorted based on deformations in transitions
6	Model Based	• Can be used for colour segmentation • Faster than traditional approach	• It needs some similarity between pixels
7	Pattern Recognition	• Models relationship between input and output	• Complicated to implement • Restrictions on shape and size
8	Active Contours	• Preserves global line shape • Makes use of existing contour model	• Requires strong image gradients • Less accuracy with weak image boundaries.
9	Inversion	• Animation is of good quality • Uses non linear optimizer	• Differet EMG may produce same output.

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4. Conclusions

Image segmentation is one of the important and most widely researched fields in the domain of Image Procesing and Computer Vision. It can be carried out by various techniques. A few of the methods have been studied and contrasted.
The appropriate method can be chosen depending upon nature of application, cost constraints, available computational tools, etc.
Image segmetation has tremendous application in various fields such as medical imaging, face recognition systems, biometrics, etc.

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