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Image Segmentation: A Comparative Study

Ajay Kumar Thakur
Bahra University
Shimla hills
Ajay_thakur_66k@yahoo.com

Madhusudan
Himachal Pradesh University
summer hills Shimla
msudan_07@outlook.com

Abstract: Image segmentation is the fundamental step to analyze images and extract data from digital images. Application of computer oriented technologies in almost every aspect of life has resulted in mass adoption of such machines. Some of the recent technologies involve applications of computer vision and image processing techniques. Image segmentation has been and still is a relevant research area due to its wide spread usage and application.Image processing is a form of signal processing. One of the typical operations on image processing is image segmentation. This paper highlights basic principles of image segmentation with different segmentation techniques.The study is useful for determining the adequate image segmentation methods under different applications keeping in mind accuracy and robustness of algorithm along with performance measures.

Keywords: Image processing, Image segmentation, segmentation methods, region approach, boundary approach, edge approach.

1. INTRODUCTION

Visual information conveyed in the form of images gives better impact than textual information. Images are the most common and convenient means of conveying or transmitting information. Images concisely convey information about position, sizes and inter-relationships between objects. Human being is good at deriving information from such images, because of our innate visual and mental abilities. Digital image play an important role, both in daily-life applications such as satellite television, magnetic resonance imaging, computed tomography as well as in areas of research and technology such as geographical information system and astronomy. Images are used in the field of computer vision for tasks such as navigation of robots, diseases identifications from MR images, identification of number plates of moving vehicle. An image is a 2D representation of a three-dimensional scene. The fields of digital image processing have grown tremendously over the past 30 years. The growth of digital image processing has been fueled by technological advances in digital imaging, computer processors and mass storage devices. Research and development is concerned primarily with the extraction of useful information from image

The term digital image processing refers to the use of computer algorithms to perform image processing on digital image. Digital image processing is the subfield of signal and systems but focus particularly on images. Main aim of field is developing a computer system that is able to perform processing on an image. In this system input is an image and the system process on that image and system process that image using efficient algorithms, and gives an image as output. The most common example is Adobe Photoshop. It is one of the widely

used applications for processing digital images [1].

Digital image processing deals with

- Image representation
- Enhancing the quality of an image,
- Restoration of the original image from its degraded version Compression of the large amount of data in the images for efficient archiving and retrieval.

Different operations that are performed on digital images for extracting information out of them include:Image acquisition,Image enhancement,Image restoration, ImageColor processing, Wavelet and multi-resolution, Image Compression, Morphological processing, Segmentation, representation and description, Recognition.

2. IMAGE SEGMENTATION

Image segmentation is the process that subdivides 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 [2]. The main objective of image segmentation is to extract various features of the image which can be merged or spilt in order to build objects of interest onwhich analysis and interpretation can be performed. Image segmentation refers to the process of partitioning an image into group of pixels which are homogeneous with respect to some criterion. Different groups must intersect with each other, and adjacent groups must be heterogeneous. Segmentation algorithms are area oriented instead of pixel-oriented. The result of segmentation is the splitting up of the image into connected areas. Thus segmentation is concerned with dividing an image into meaningful regions [3]. Actually, partitions are different objects in image which have the same texture or color. All of the pixel in a region are similar with respect to some characteristics or computed property, such as color, intensity, or texture [4]. Segmentation should stop when the objects or regions of interest in an application have been detected. Most of the segmentation algorithms are based on discontinuity and similarity which are based on basic properties of intensity values. Discontinuity approach is to partition an image based on abrupt changes in intensity, such as edges. Similarity approach is based on partitioning an image into regions that are similar according to a set of predefined criteria. Thresholding, region growing, and region splitting and merging are examples of methods in this category [5]. It is an essential process for many applications such as object recognition, target tracking, content-based image retrieval and medical image processing. Image segmentation represents the first step in image analysis and pattern recognition.

An image may be defined as a two-dimensional function, f(x, y), where x and y are spatial (plane) coordinates and the amplitude off at any pair of coordinates (x, y) is called the intensity or gray level of the image at that point. When x, y, and the intensity values of f are all finite, discrete quantities, we call the image digital image. A Digital image is basically a numerical representation of an object. A digital image is composed of finite number of element, each of which has particular location and value which are called picture elements, image elements, and pixels. A pixel represents the brightness at one point. Pixels are the smallest sample of an image [2].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. Image segmentation is the process of partitioning an image into multiple segments, so as to change the representation of an image into something that is more meaningful and easier to analyze.Segmentation technique, basically convert the complex image into the simple image as shown in the figure 1.

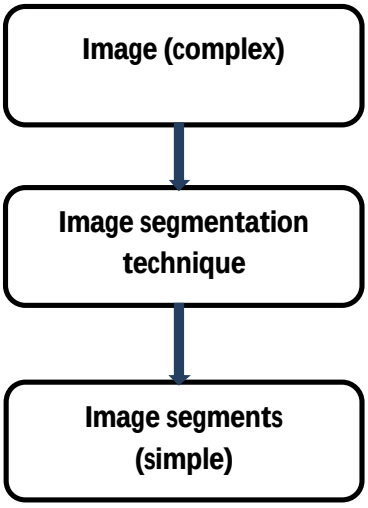

Figure 1 Segmentation technique [6]

Image segmentation can be broadly classified into two types:

- Local segmentation
- Global segmentation

Local segmentation deals with segmenting sub-images which are small windows on a whole image. The number of pixels available to local segmentation is much lower than global segmentation. Local segmentation must be frugal in its demands for pixel data.

Global segmentation is concerned with segmenting a whole image. Global segmentation deals mostly with segments consisting of a relatively large number of pixels. This makes estimated parameter values for global segments more robust.

Image segmentation can be approached from three different philosophical perspectives. They are

2.1 Region approach
- **2.1.1**Region growing
- **2.1.2**Region merging and splitting

2.2 Boundary (thresholding) approach
- **2.2.1**Global thresholding
- **2.2.2** Local thresholding

2.3 Edge approach
- **2.3.1**Gray histogram technique
- **2.3.2** Gradient based method

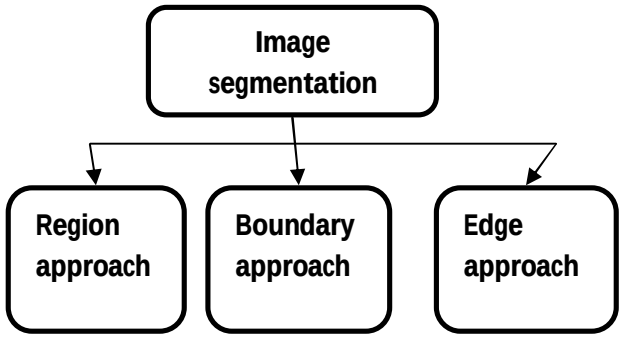

Figure 2 Image segmentation techniques [4]

2.1 Region Approach

Region in an image are a group of connected pixels with similar properties. In the region approach, each pixel is assigned to particular object or region. Boundary approach includes thresholding, clustering, region growing, region splitting and merging exploit the homogeneity of spatially dense information (e.g. intensity, color, texture properties etc.) to produce the segmented results. The goal of region base segmentation is to find regions that are correspond to objects as a person sees them.Region based segmentation is a procedure to subdivide an image into its constituent parts or objects called regions,

using image attributes such as pixel intensity, spectral values and or textural properties [5].

2.1.1 Region growing These method group pixels in an entire image into sub regions or large regions based on predefined criterion. The basic idea is to group a collection of pixel with similar properties from a region [12].

2.1.2 Region splitting and merging In this, images are subdivided into a set of arbitrary unconnected regions and merge/split the region according to the condition of the segmentation. This particular splitting technique is usually implemented with theory based on quad tree data. Quad tree is a tree in which each node has exactly four branches [12].

2.2 Edge Approach

Edge-based segmentation exploits spatial information by detecting the edge in an image. The edges are identified first, and then they are linked together to form required boundaries. Edge corresponds to discontinuities in the homogeneity criterion for segments. Edge detection is usually done with local linear gradient operators such as Prewitt, Sobel and Laplacian filters. These operators work well for images with sharp edges and low amounts of noise. Edge detection refers to algorithms which try to identify points in a digital image where there is an abrupt change in image brightness or there is a difference in intensities. There are many different ways to perform edge detection; however, two most prominent used algorithms are mentioned here:

2.2.1 GrayHistogram Technique: In this technique, segmentation depends upon separation of foreground from background by selecting a threshold value T. the difficulty arises in selecting the threshold values since gray threshold is uneven due to the presence of noise. Thus, we substitute the curves of object and the background with two conic Gaussian curves [13], whose intersection is chosen as the values of threshold T.

2.2.2 Gradient Based Method: Gradient is the first derivative for image f(x, y), when there is an abrupt change in the intensity near edge. Another noise, gradient based method[13] involves convolving gradient operators with the image High value of gradient magnitude can be points with abrupt change between intensities of the two region. These points are called edge pixels and can be linked together to form closed boundaries.

2.3 Boundary Approach (Threshold)

Boundary image segmentation techniques produce segments having pixels with similar intensities. It is a useful technique for establishing in image that contains solid resting on a contrasting background. There exist a large number of gray-level based segmentation methods using global or local image information [4].Thresholding algorithm will chose a proper threshold value T to divide image's pixels into several classes and separate object from the background. Any pixel (x, y) for which f(x, y)>=T is considered to be foreground while any pixel (x, y) which has value f(x, y) <T is considered to be background. Based on the selection of threshold value, there are two types of thresholding method that are in existence.

2.3.1 Global Thresholding: Global thresholding method is used when there the intensity distribution between the object of foreground and background are very distinct. When the difference between foreground and background objects are very distinct, a single values of the threshold can be used to differentiate both objects apart. Thus, in this type of thresholding, the value of threshold T depends solely on the property of the pixel and the gray level value of the image. Some of common used global thresholding methods are Otsu method, entropy based thresholding, etc. [12]

2.3.2 Local Thresholding: this method divides an image into several sub regions and then chooses various thresholds $T_s$for each sub region respectively. Thus, thresholding, 2-D entropy-based thresholdinghistogram transformation thresholdingetc. [13]

3. METHODS OF IMAGE SEGMENTATION

There are much knowledge based approaches to segment an image and can be listed as:

- Intensity based methods
- Graph based methods
- Discontinuity based methods
- Clustering methods
- Pixon based methods
- Hybrid methods

3.1 Intensity based methods

One of the simplest approaches to segment an image is based on the intensity levels and is called as threshold based approach. 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.

3.2 Discontinuity based methods

These methods are based on the principle of intensity variations among the pixels. If the image consists two or more objects boundaries exists and hence can be applied to segment the image. The boundaries of the objects lead to formation of edges. There are four different edge types that may be present in the image (a) step-edge (b) ramp edge (c) ridge edge and (d) ramp edge.

3.3 Clustering based methods

Clustering 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. 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.

3.4 Graph based methods

Graph based methods for image segmentation has several good features in practical applications. It explicitly organizes the image elements into mathematically sound structures, and makes the formulation of the problem more flexible and the computation more efficient.

3.5 Pixon based methods

The pixon method is a nonlinear image reconstruction method that has decision levels as pixons instead of pixels. This method increases linear spatial resolution by few factor and sensitivity by the order of magnitude. Another advantage of pixon based method is computational fastness compared to other methods. The pixon based method has three steps:

- Achieve a pseudo image with same resolution as the observed image.
- Filter using anisotropic diffusion filter to achieve pixon.
- Use hierarchical clustering algorithm to extract pixons [7].

3.6 Hybrid methods

Hybrid methods combine one or more of the basic segmentation methods. These algorithms inherit the good quality of several approaches and gives better performance compared to its parent approach. The combination of threshold based and clustering methods [8] are used in medical image segmentations along with the region-edge based approaches [9], region–deformable models, region-edge-based with

morphological watershed [10]. Hybrid methods rely on morphological operations performed on images. The widely used techniques are watershed segmentation, variable-order surface fitting and active contour methods. The watershed algorithm uses concept from edge detection and mathematical morphology to partition image into homogenous regions [11].

4. APPLICATION OF IMAGE SEGMENTATION

4.1 Facial recognition system is a computer application capable of identifying or verifying a person from a digital image or a video frame from a video source. One of the ways to do this is by comparing selected facial features from the image and a facial data base. It is typically used in security systems and can be compared to other biometrics such as fingerprint or eye iris recognition systems. Recently, it has also become popular as a commercial identification and marketing tool.

4.2 Video surveillance Closed-circuit television (CCTV), also known as video surveillance, is the use of video cameras to transmit a signal to a specific place, on a limited set of monitors. It differs from broadcast television in that the signal is not openly transmitted, though it may employ point to point (P2P), point to multipoint, or mesh wireless links. Though almost all video cameras fit this definition, the term is most often applied to those used for surveillance in areas that may need monitoring such as banks, casinos, airports, military installations, and convenience stores.

4.3 Machine vision Machine vision (MV) is the technology and methods used to provide imaging-based automatic inspection and analysis for such applications as automatic inspection, process control, and robot guidance in industry. The scope of MV is broad. MV is related to, though distinct from, computer vision.

4.4 Fingerprint recognition Fingerprint recognition or fingerprint authentication refers to the automated method of verifying a match between two human fingerprints. Fingerprints are one of many forms of biometrics used to identify individuals and verify their identity.

4.5 Iris recognition Iris recognition is an automated method of biometric identification that uses mathematical pattern-recognition techniques on video images of one or both of the irises of an individual's eyes, whose complex random patterns are unique, stable, and can be seen from some distance.

4.6 Medical imaging Medical imaging is the technique and process of creating visual representations of the interior of a body for clinical analysis and medical intervention, as well as visual representation of the function of some organs or tissues (physiology). Medical imaging seeks to reveal internal structures hidden by the skin and bones, as well as to diagnose and treat disease. Medical imaging also establishes a database of normal anatomy and physiology to make it possible to identify abnormalities. Although imaging of removed organs and tissues can be performed for medical reasons, such procedures are usually considered part of pathology instead of medical imaging.

4.7 Pedestrian detection Pedestrian detection is an essential and significant task in any intelligent video surveillance system, as it provides the

fundamental information for semantic understanding of the video footages. It has an obvious extension to automotive applications due to the potential for improving safety systems.

5. CONCLUSION & FUTURE SCOPE

In this paper, we have classified and investigated major image segmentation methods with different areas that involve application of image segmentation. Image segmentation algorithms have promising future ahead since they are the basis of image processing and computer vision and have become the focus of contemporary research.Though several techniques have been devised for segmentation of digital images but it is found that there is no perfect method for segmentation since the result of image segmentation depends on many factors, i.e., pixel color, texture intensity, image content and problem domain. Methods with similar attributes can be combined to enhance the results of segmentation and achieve higher accuracy.It is not possible to consider a single method for all types of images nor can all methods perform well for a particular type of image. Further there are chances of analyzing different methods in groups for deducing useful results.

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