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Edge Detection as an Effective Technique in Image Segmentation for Image Analysis

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ABSTRACT

Digital Image processing is a technique making use of computer algorithms to perform specific operations on an image, to get an enhanced image or to extract some useful information from it. Image segmentation, which is an important phase in image processing, is the process of separation of an image into regions or categories, which correspond to different objects or parts of objects. This step is typically used to identify objects or other relevant information in digital images. There are generic methods available for image segmentation and edge based segmentation is one among them. Image segmentation needs to segment the object from the background to read the image properly and identify the content of the image carefully. In this context, edge detection is considered to be a fundamental tool for image segmentation.

Keywords :- Digital image processing, image segmentation, edge detection.

I. INTRODUCTION

The term image processing refers to processing of images using mathematical operations in order to get an enhanced image or to extract some useful information from it. It is a type of signal dispensation in which input may be image like video frame or photograph and output may be image or characteristics associated with that image. Image processing is a rapidly growing technology today, with its diverse applications in various aspects of science, engineering, management, business and day to day life activities and it is a core research area too. Image Processing is a technique useful in enhancing raw images received from cameras or sensors placed for various applications including enhancing images obtained from unmanned spacecrafts, space probes and military reconnaissance flights[1]. Image processing finds applications in areas such as Remote Sensing, Medical Imaging, Non-destructive Evaluation, Forensic Studies, Textiles, Material Science, Military, Film industry, Document processing, Graphic arts and Printing Industry.

The following sections describe different steps in image processing, specifically edge based image segmentation and image edge detection techniques in detail.

II.METHODS OF IMAGE PROCESSING

There are two types of methods used in Image Processing and they are Analog image processing and digital image processing. Analog Image Processing refers to the processing of image through electrical means. The most common example is the television image. The television signal is a voltage level which varies in amplitude to represent brightness through the image. By electrically varying the signal, the displayed image appearance is altered. The brightness and contrast controls on a TV set serve to adjust the amplitude and reference of the video signal, resulting in the brightening, darkening and alteration of the brightness range of the displayed image. In Digital Image Processing, digital computers are used to process the image. The image will be converted into digital form using a scanner or digital camera and then fed as input for processing operations by digital computer. Digital image processing includes numerous procedures such as formatting and correcting of the data, digital enhancement to facilitate better visual interpretation, or even automated classification of targets and features entirely by computer. The requirements for digital image processing is a computer system, sometimes referred to as an image analysis system, with the necessary hardware and software to process the data. There are efficient software systems, open source and proprietory, have been developed for image processing. The term digital image processing generally refers to processing of a two-dimensional picture by a digital computer and a digital image is an array of real numbers represented by a finite number of bits[2]. The main advantage of Digital Image Processing methods is its repeatability, versatility and the preservation of original data accuracy.

The main reasons for the growing interest and demand in digital image processing are due to its applications such as (i) improvement of pictorial information for human interpretation, and (ii) processing of scene data for autonomous machine perception.

Example for the first application area are the enhancement of images in medical field such as MRI image, X-ray image etc to improve the pictorial content of it, thus making it easier for human interpretation. The second application area focuses on procedures for extracting image information in a form suitable for computer processing. Examples include automatic character recognition, industrial machine vision for product assembly and inspection, military recognizance, automatic processing of fingerprints etc.

III.STEPS IN IMAGE PROCESSING

There are some common steps in image processing as listed below, though all image processing systems would not require all steps together.

i)Image Acquisition : An image is captured by a sensor such as a TV camera and then it is digitized.
ii)Image Preprocessing : The first step in preparing the picture for higher-level processing is called pre-processing and the purpose of pre-processing is two-fold: to eliminate undesirable features that will hinder further processing and to extract the desirable features that represent useful information in the image. Unwanted image attributes include noise (insignificant lines and contours) and the presence of featureless space and the important features include surface details and boundaries such as lines, edges, and vertices. Image preprocessing typically includes a processing step of transforming a source image into a new image which is fundamentally similar to the source image, but differs in certain aspects, e.g. improved contrast. In this step, computer suppresses noise and sometimes enhances some object features which are essential in understanding the image.
iii)Image segmentation: The main aim of segmentation is to reduce the information to enable easy analysis. Segmentation is also useful in Image Analysis and Image Compression[3]. In this process, an image is divided into multiple parts and this is typically used to identify objects or other relevant information in digital images. The segmentation has two objectives - i. to decompose the image into parts for further analysis. ii. to perform a change of representation. ie., The pixels of the image must be organized into higher-level units that are either more meaningful or more efficient for further analysis.
Segmentation separates an image in to its component regions or objects. Image segmentation needs to segment the object from the background to read the image properly and to identify the content of the image carefully. Because of the same reason, edge detection is a fundamental tool for image segmentation.
iv)Representation and description: Representation is transforming raw data into a form suitable for computer processing. Description, which is also called feature extraction, deals with extracting features that result in some quantitative information of interest or features which are basic for differentiating one class of objects from another.
v)Recognition & Interpretation : Recognition is the process which assigns a label to an object based on the information provided by its descriptors. Interpretation is the process of assigning meaning to an ensemble of recognized objects.
Of the different steps mentioned above, image segmentation, which has emerged as a significant phase in image based applications, is going to be dealt in detail in the following section.

IV. IMAGE SEGMENTATION

Image segmentation, one of the significant aspects of image processing, is a long standing problem in the research area of computer vision. The main aim of segmentation is to extract the ROI(Region of Interest)for image analysis. The division of an image into meaningful structures, ie., image segmentation, is often an essential step in image analysis, object representation, visualization, and many other image processing tasks. Segmentation plays an important role in image processing since separation of a large image into several parts makes further processing simpler. These several parts that are rejoined will cover the entire image. Segmentation may also depend on various features like colour or texture that are contained in the image. Before denoising an image, it is segmented to recover the original image. The main aim of segmentation is to reduce the information and hence making easy analysis possible.

There exists several image segmentation techniques, which partition the image into several parts based on certain image features like pixel intensity value, color, texture, etc and these techniques are categorized based on the segmentation method used. A great variety of segmentation methods has been proposed till now and in this article, we will concentrate on edge based segmentation methods and edge detection mechanisms. In edge based segmentation technique, detected edges in an image are assumed to represent object boundaries, and are used to identify these objects[4]. Edges characterize boundaries and are therefore a problem of fundamental importance in image processing[5]. Image edge detection filters out useless information and reduces data, while preserving the important structural properties in an image.

V.EDGE BASED DETECTION TECHNIQUES

Edge detection is a basic tool for image segmentation. Since edge detection is in the forefront of image processing for object detection, it is crucial to have a good understanding of edge detection algorithms. The edge representation of an image significantly reduces the quantity of data to be processed, yet it retains essential information about the shapes of objects in the scene. This description of an image is easy to incorporate into a large amount of object recognition algorithms used in computer vision along with other image processing applications. The major property of the edge detection technique is its ability to extract the exact edge line with good orientation. It is generally difficult to judge the performance of the edge detection techniques and the performance of edge detection techniques are often judged personally and separately, dependent to its application[6]. Edge detection methods, transforming original images into edge images, benefit from the changes of grey tones in the image. In image processing especially in computer vision, the edge detection treats the localization of important variations of a gray level image and the detection of the physical and geometrical properties of objects of the scene. It is a fundamental process which detects and outlines of an object and boundaries among objects and the background in the image and it is the most familiar approach for detecting significant discontinuities in intensity values.

Edges are local changes in the image intensity and they typically occur on the boundary between two regions. The main features can be extracted from the edges of an image and this provides major features for image analysis. These features are used by advanced computer vision algorithms. Edge detection is used for object detection which serves various applications such as medical image processing, biometrics etc. Edge detection is an active area of research as it facilitates image analysis on higher level. There are three different types of discontinuities in the grey level like point, line and edges[7]. Spatial masks can be used to detect all the three types of discontinuities in an image.

There are many edge detection techniques in the literature for image segmentation. The most commonly used discontinuity based edge detection operators are Roberts edge detection, Sobel Edge Detection, Prewitt edge detection, Kirsh edge detection, Robinson edge detection, Marr-Hildreth edge detection, LoG edge detection and Canny Edge Detection. The performance of edge detectors are to be evaluated as there is no guarantee that the edge detectors can detect all edges[8]. Some of the problems of the edge detectors are – missing valid edge points, classifying the noise points as valid edge points and smearing edges. Edge detectors often do not produce continuous edges and the detected edges may not be sharp and continuous due to the presence of noise and intensity variations. Because of this, edge linking is used to detect the presence of edges and to connect edges to their neighbours to avoid breaks. Techniques such as hysteresis thresholding and edge relaxation ensures continuity[9]. Thresholding produces uniform regions based on the threshold criterion. Edge relaxation is the process of re-evalutation of pixel classification using its context.

VI.CLASSIFICATION OF EDGE DETECTION OPERATORS

The classification of the edge detection operators are as follows: Classical or Gradient based edge detectors (first derivative), Zero crossing (second derivative), Laplacian of Gaussian (LoG) and Gaussian edge detectors.

i)Classical Edge detectors

Classical edge detectors include classical operators such as Sobel, Prewitt, Krisch, Robert's and and these operators use first directional derivative operation. Detection of edges and their orientation is the main advantage of these types of edge detectors. Main disadvantage of these types of edge detectors is that they are sensitive to noise and are inaccurate. The Roberts Cross operator performs a simple, quick to compute, 2-D spatial gradient measurement on an image. It thus highlights regions of high spatial frequency which often correspond to edges. In its most common usage, the input to the operator is a grayscale image, as is the output. Pixel values at each point in the output represent the estimated absolute magnitude of the spatial gradient of the input image at that point[10]. The Sobel edge detection technique is similar to that of the Roberts Cross algorithm. Despite the design of Sobel and Robert are common, the main difference is the kernels that each uses to obtain the image is different. The sobel kernels are more suitable to detect edges along the horizontal and vertical axis whereas the Roberts's able to detect edges run along the vertical axis of 45 degrees and 135 degrees.

ii)Zero Crossing

The zero crossing detector looks for places in the Laplacian of an image where the value of the Laplacian passes through zero i.e. points where the Laplacian changes sign. Such points often occur at edges in images. It is best to think of the zero crossing detector as some sort of feature detector rather than as a specific edge detector. Zero crossings always lie on closed contours, and so the output from the zero crossing detector is usually a binary image with single pixel thickness lines showing the positions of the zero crossing points[11]. It is having fixed characteristics in all directions and sensitive to noise. Haralick[12] proposed the use of zero-crossing of the second directional derivative of the image intensity function.

iii)Laplacian of Gaussian (LoG)

It was invented by Marr and Hildreth (1980)[13]. The Gaussian filtering is combined with Laplacian to break down the image where the intensity varies to detect the edges effectively. LOG (Laplacian of Gaussian) operator find the optimal filter of edge detection by ratio of the signal to noise of image. Firstly, a Gaussian function is used to low-pass smoothingly filter image; then high-pass filter the Laplacian operator, according to the second derivative of zero to detect the edges.

iv)Gaussian Edge Detectors

Since it reduces the noise by smoothing the image, it gives better results in noisy environment. One widely used Gaussian edge detector operators is Canny. The Canny edge detection is known as the optimal edge detector. The Canny edge detector uses a multi-stage algorithm to detect a wide range of edges in images and it was developed by John Canny[14] in 1986. The Canny algorithm contains a number of adjustable parameters such as the size of guassian filter and thresholds, which can affect the computation time and effectiveness of algorithm.

The problem with this type of traditional edge detection approach is that a low threshold produces false edges, but a high threshold misses important edges. So, it requires that the image is to be smoothed with a Gaussian mask, which cuts down significantly on the noise within the image. Then the image is run through the Sobel algorithm, and as discussed before, this process is hardly affected by noise. Lastly, the pixel values are chosen based on the angle of the magnitude of that pixel and its neighboring pixels. Unlike Roberts Cross and much like Sobel, the canny operation is not very susceptible to noise. If the Canny detector worked properly, it would be superior to both Sobel and Roberts Cross, the only drawback is that it takes longer to compute.

VII.DIFFERENT APPROACHES IN EDGE DETECTION

i)Fuzzy based approach

Since fuzzy logic is a powerful tool to manage the uncertainty efficiently, it can be used in edge detection to help in making a decision regarding whether to consider a certain pixel as an edge pixel or not.

In the Fuzzy reasoning system, the rules are framed for edge localization and the rules are based on the following simple reasons. If a pixel (i, j) possesses larger edge uncertainty, this point should be preserved. Inversely, if it possesses smaller edge uncertainty, this point is regarded as a non-edge point. The gradient and standard deviation computed at each pixel and are used as fuzzy system input. The fuzzy system includes member functions and fuzzy rules which decide about pixel classification as edge or non-edge [15].

ii)Wavelet approach

Wavelet is useful mathematical tool for signal analysis that has gained remarkable achievements in digital signal processing as well as image compression. It provide mechanism to visualize the non-stationary signal by taking time and frequency information simultaneously. Very first wavelet analysis comes for existence in late 1980’s. For image edge detection, wavelet transform provides facility to select the size of the image details that will be detected. Wavelets transform separates the lower frequencies and higher frequencies easily, which is prime important for edge detection. The wavelet scale sets the size of detected edges. For discrete wavelet transform, many signals are passed through wavelet filter for choice of the scale. For 2-D image, wavelet analysis is carried out in terms of horizontal and vertical function and edges are detected separately[16].

iii)Genetic Algorithm Approach

One of the most recent interesting AI areas in the image feature extraction regards the *Evolutionary Algorithms* (EAs). Commonly, these kinds of algorithms use a heuristic approach to find approximate solutions to optimization and search problems. The EAs are inspired by Darwin’s theory about biological evolution.

Genetic algorithms (GA) are random search algorithms based on the theory of biological evolution and these algorithms require an initial population of individuals, which are representatives of possible solutions of the problem being solved. The population evolves by transformations applied to its individuals while a fitness function is used to determine the strength of the elements in the population. The elements of the population are known as chromosomes and are represented by strings of bits. The fitness function is usually computed with basis on the values of those bits. An iteration of the algorithm is basically equivalent to a generation in the evolutionary process[17].

Mainly, a genetic algorithm consists of three most important operations. They are Selection, Crossover and Mutation. In Selection, ie., fitness-proportional selection, the chromosome with minimum fitness value and another randomly chosen chromosome are selected from the parent pool to process crossover and mutation. In Crossover, two individuals are recombined to have new ones which might be better. In Mutation, random changes are introduced in the population in order to steer the algorithm from local minimums that could prevent the discovery of the global solutions to the problem.

The GA is started with a set of abstract candidate solutions population and these solutions are represented by chromosomes. The Solutions from one population are taken and used to form a new population. This last process is motivated by the hope that the new population will be better than the previous one. In each generation, the fitness of each candidate solution is evaluated, and multiple candidate solutions are stochastically selected from the current solutions based on their fitness, and then modified (performing genetic operation like recombining, mutating etc) to form a new population of candidate solutions. The new population is then used in the next iteration of the algorithm.

iv)Neural network

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. Neural network diversifies from other techniques by means of its learning capacity. Digital images are segmented by using neural networks in two step process. First step is pixel classification that depends on the value of the pixel which is part of a segment or not. Second step is edge detection that is the detection of all pixels on the borders between different homogeneous areas which is part of the edge or not. Several neural networks are available in the literature for edge detection. The potential base function for digital image processing can be created using differential operators[18].

v)Morphology based approach

Being based on Set theory of mathematics, it slowly grows up a new theory and innovative method for digital image processing and recognition. The morphological edge detection algorithm is developed from the basic morphological operations. Morphological operators are directly deal with the shape information with the help of a structuring element. The most basic operations are dilation and erosion which may be defined by using union and intersection. Dilation increases the object and erosion shrinks the object. Using the basic operators dilation and erosion, two more operators known as Opening and Closing are defined. Opening retains only those parts of the objects that can be fitted in the structuring element and Closing fills up small holes and gulfs. Thus they both can extract fine shape features that are narrower than the structuring element[19].

VIII.COMPARISON OF EDGE DETECTION METHODS

It is a very challenging problem to evaluate edge detection results produced by various edge detectors with different parameters. Extensive research has been done in creating many different approaches and algorithms for image segmentation, but it is still difficult to assess whether one algorithm produces more accurate result than the existing algorithms. Image quality measures (IQMs) are figures of merit used for the evaluation of imaging systems or of coding /processing techniques. Various image quality metrics are in existence. One example of edge based quality measures is Pratt edge measure. The Pratt's Figure of Merit evaluates edge location accuracy by the displacement of detected edge points from an ideal edge. It is defined by $R = (1/I_n)\sum_{i=1}^{IA} 1/1+\alpha d^2$ where $I_n = Max(I_i, I_A)$, I_i=No: of ideal edge points, I_A=No: of actual edge points, d=displacement of actual edge points from ideal edge and α=scaling constant.

IX.CONCLUSION

The goal of segmentation is to simplify or to change the representation of an image into something that is more meaningful and easier to analyze and because of the same reason the efficiency of edge detection used in segmentation is also significant. Segmentation process is often a very complex task and segmentation of region of interest in real world images is the one major hurdle for effective implementation of image processing applications. The success of image processing applications is a crucial factor in determining the success of image segmentation. Edge detection is a fundamental tool for image segmentation and it plays a significant role. The user has to choose the suitable edge detection method based on the application.

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