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Edge Detection Techniques for Image Segmentation – A Survey of Soft Computing Approaches

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***Abstract*—Soft Computing is an emerging field that consists of complementary elements of fuzzy logic, neural computing and evolutionary computation. Soft computing techniques have found wide applications. One of the most important applications is edge detection for image segmentation. The process of partitioning a digital image into multiple regions or sets of pixels is called image segmentation. Edge is a boundary between two homogeneous regions. Edge detection refers to the process of identifying and locating sharp discontinuities in an image. In this paper, the main aim is to survey the theory of edge detection for image segmentation using soft computing approach based on the Fuzzy logic, Genetic Algorithm and Neural Network.**

***Index Terms*—Image Segmentation, Edge Detection, Fuzzy logic, Genetic Algorithm, Neural Network.**

I. Introduction

Image Segmentation is the process of partitioning a digital image into multiple regions or sets of pixels[1][3][27]. Actually, partitions are different objects in image which have the same texture or color. The result of image segmentation is a set of regions that collectively cover the entire image, or a set of contours extracted from the image. All of the pixels in a region are similar with respect to some characteristic or computed property, such as color, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristics. Edge detection is one of the most frequently used techniques in digital image processing[27]. The boundaries of object surfaces in a scene often lead to oriented localized changes in intensity of an image, called edges. This observation combined with a commonly held belief that edge detection is the first step in image segmentation, has fueled a long search for a good edge detection algorithm to use in image processing[13]. This search has constituted a principal area of research in low level vision and has led to a steady stream of edge detection algorithms published in the image processing journals over the last two decades. Even recently, new edge detection algorithms are published each year. This paper analyses some recent soft computing approaches to detect edges for segmentation.

The first approach, Fuzzy logic includes uncertainties in logical reasoning[1]. It has been applied to image processing in many ways[19]. Segmentation aims at dividing pixels into similar region i.e. crisp sets[4]. Fuzzy segmentation in turn divides pixels into fuzzy sets i.e. each pixel may belong partly to many sets and regions of image[3][25]. The Second approach, Neural networks are computer algorithms inspired by the way information is processed in the nervous system. An important difference between neural networks and other AI techniques is their ability to learn. The network ”learns” by adjusting the interconnection (called weights) between layers. When the network is adequately trained, it is able to generalize relevant output for a set of input data. A valuable property of neural networks is that of generalization, whereby a trained neural network is able to provide a correct matching in the form of output data for a set of previously unseen input data. Learning typically occurs by example through training, where the training algorithm iteratively adjusts the connection weights [2][24]. The third approach, Genetic algorithms derive from the evolution theory. They were introduced in 1975 by John Holland and his team as a highly parallel search algorithm. Later, they have been mainly used as an optimization device. According to the evolution theory, within a population only the individuals well adapted to their environment can survive and transmit some of their characters to their descendants. GA has been used to solve various problems in digital image processing, including image segmentation [14][23].

This paper is organized as follows. Section II is for the purpose of providing some information about edge detection for Image Segmentation. Section III is focused on showing the different soft computing approaches to edge detection and also focused on comparison of various Edge Detection Methods. Section IV presents the conclusion.

II. Edge Detection for Image Segmentation

Edge detection techniques transform images to edge images benefiting from the changes of grey tones in the images. Edges are the sign of lack of continuity, and ending. As a result of this transformation, edge image is obtained without encountering any changes in physical qualities of the main image[11][25]. Objects consist of numerous parts of different color levels. In an image with different grey levels, despite an obvious change in the

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grey levels of the object, the shape of the image can be distinguished in Figure 1.

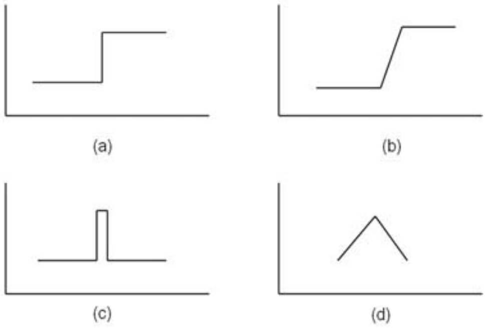

Fig. 1. Type of Edges (a) Step Edge (b) Ramp Edge (c) Line Edge (d) Roof Edge

An Edge in an image is a significant local change in the image intensity, usually associated with a discontinuity in either the image intensity or the first derivative of the image intensity. Discontinuities in the image intensity can be either Step edge, where the image intensity abruptly changes from one value on one side of the discontinuity to a different value on the opposite side, or Line Edges, where the image intensity abruptly changes value but then returns to the starting value within some short distance[3]. However, Step and Line edges are rare in real images. Because of low frequency components or the smoothing introduced by most sensing devices, sharp discontinuities rarely exist in real signals. Step edges become Ramp Edges and Line Edges become Roof edges, where intensity changes are not instantaneous but occur over a finite distance[20]. Illustrations of these edge shapes are shown in Fig.1.

A. Steps in Edge Detection

Edge detection contain three steps namely Filtering, Enhancement and Detection. The overview of the steps in edge detection are as follows.

1) Filtering: Images are often corrupted by random variations in intensity values, called noise. Some common types of noise are salt and pepper noise, impulse noise and Gaussian noise. Salt and pepper noise contains random occurrences of both black and white intensity values. However, there is a trade-off between edge strength and noise reduction. More filtering to reduce noise results in a loss of edge strength[26].

2) Enhancement: In order to facilitate the detection of edges, it is essential to determine changes in intensity in the neighborhood of a point. Enhancement emphasizes pixels where there is a significant change in local intensity values and is usually performed by computing the gradient magnitude[14].

3) Detection: Many points in an image have a nonzero value for the gradient, and not all of these points are edges for a particular application. Therefore, some method should be used to determine which points are edge points. Frequently, thresholding provides the criterion used for detection[13].

B. Edge Detection Methods

Three most frequently used edge detection methods are used for comparison. These are (1) Roberts Edge Detection, (2) Sobel Edge Detection and (3) Prewitt edge detection[27]. The details of methods as follows,

1) The Roberts Detection: 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[27].

+1	0
0	-1

Gx

0	+1
-1	0

Gy

Fig. 2. Roberts Mask

2) The Prewitt Detection: The prewitt edge detector is an appropriate way to estimate the magnitude and orientation of an edge. Although differential gradient edge detection needs a rather time consuming calculation to estimate the orientation from the magnitudes in the x- and y-directions, the compass edge detection obtains the orientation directly from the kernel with the maximum response. The prewitt operator is limited to 8 possible orientations, however experience shows that most direct orientation estimates are not much more accurate. This gradient based edge detector is estimated in the 3x3 neighbourhood for eight directions. All the eight convolution masks are calculated. One convolution mask is then selected, namely that with the largest module[27].

-1	+1	+1
-1	-2	+1
-1	+1	+1

0°

+1	+1	+1
-1	-2	+1
-1	-1	+1

45°

Fig. 3. Prewitt Mask

3) The Sobel Detection: The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image. In theory at least, the operator consists of a pair of 3x3 convolution kernels as shown in Figure 4. One kernel is simply the other rotated by 90o.This is very similar to the Roberts Cross operator[27]. The convolution masks of the Sobel detector are given below, Figure 5. shows the comparison of the edge detections for the example image.

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-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

Fig. 4. Sobel Mask

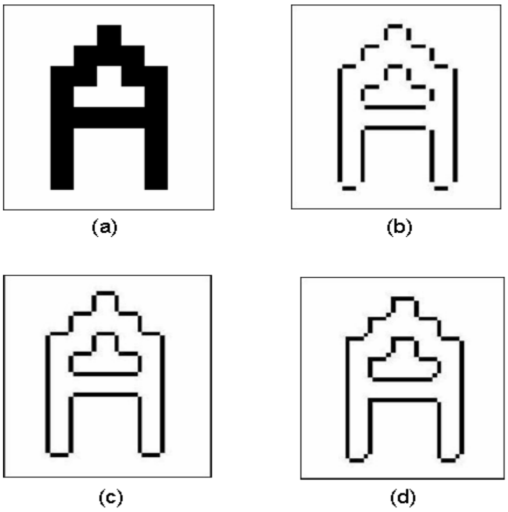

Fig. 5. The comparison of the edge detections for the example image. (a) Original Image (b) using Prewitt Edge Detection (c) using Roberts Edge Detection (d) using Sobel Edge Detection

III. SOFT COMPUTING APPROACHES

Three different soft computing approaches to edge detection for image segmentation are most frequently used. These are (1) Fuzzy based Approach[18], (2) Genetic Algorithm based approach[14] and (3) Neural Network based Approach[7]. The details of Approaches as follows,

A. Fuzzy based Approach

There are different possibilities for development of fuzzy logic based edge detections[18][25]. One method is to define a membership function indicating the degree of edginess in each neighbourhood[25]. This approach can only be regarded as a true fuzzy approach if fuzzy concepts are additionally used to modify the membership values [6]. The membership function is determined heuristically. It is fast but the performance is limited[3][13].

$$\mu_{Edge}\big(g(x,y)\big) = 1 - \frac{1}{1 + \frac{\sum_N \| g(x,y) - g(i,j) \|}{\Delta}}$$

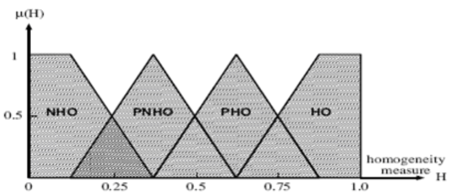

Fig. 6. The fuzzy sets used for homogeneity inference.

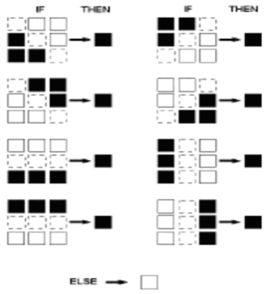

Fig. 7. Neighborhood of a central pixel

Using appropriate fuzzy if-then rules, one can develop general or specific edge detections in pre-defined neighborhoods[11]. Figure 7. shows the fuzzy rules for edge detection and neighborhood of a central pixel of the image. Homogeneity is a measure to test the similarity of two regions under consideration during the segmentation procedure[5][9]. Figure 6. shows the membership function for homogeneity inference.

B. Genetic Algorithm Approach

Basically, a genetic algorithm consists of three major operations: selection, crossover, and mutation. The selection evaluates each individual and keeps only the fittest ones in the population[23]. In addition to those fittest individuals, some less fit ones could be selected according to a small probability[14]. The others are removed from the current population. The crossover recombines two individuals to have new ones which might be better. The mutation operator induces changes in a small number of chromosomes units. Its purpose is to maintain the population diversified enough during the optimization process[3].

Image segmentation aims at partitioning an image into homogeneous regions. A great number of segmentation methods are available in the literature to segment images according to various criteria such as for example grey level, colour, or texture. This task is hard and very important, since the output of an image segmentation algorithm can be fed as input to higher-level processing tasks, such as model-based object recognition systems. Recently, researchers have investigated the application of genetic algorithms into the image segmentation problem[15]. Perhaps the most extensive and detailed work on GAs within image segmentation is that of Bhanu and Lee. Many general pattern recognition applications of this particular paradigm can also be found in . One reason (among others) for using this kind of approach is mainly related with the GA ability to deal with large, complex search spaces in situations where only minimum knowledge is available about the objective function[14].

For instance, this led Bhanu et al. to adopt a GA to determine the parameter set that optimise the output of an existing segmentation algorithm under various conditions of image acquisition and is namely Phoenix segmentation algorithm[3]. Another situation wherein GAs may be useful tools is illustrated by the work of Yoshimura and Oe[22]. For example, Bhandarkar et al. defined a multi-term cost function, which is minimized using a GA-evolved edge configuration. The idea was to solve

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medical image problems, namely edge-detection. In their approach to image segmentation, edge detection is cast as the problem of minimising an objective cost function over the space of all possible edge configurations and a population of edge images is evolved using specialised operators. Fuzzy GA fitness functions were also considered by Chun and Yang, mapping a regionbased segmentation onto the binary string representing an individual, and evolving a population of possible segmentations[3]. Other GA approaches for image segmentation include manually-traced contours by Cagnoni et al., methods by Andrey, artificial ant colonies by Ramos, Koza's genetic programming paradigm, Poli's GP work, etc.,.

C. Neural Network Approach

Neural networks are formed by several elements that are connected by links with variable weights[8][21]. Artificial neural networks (ANN) are widely applied for pattern recognition[27]. Their processing potential and nonlinear characteristics are used for clustering[12][16]. Self organization of Kohonen Feature Map (SOFM) network is a powerful tool for clustering[24]. Ji and Park proposed an algorithm for watershed segmentation based on SOM[10]. This method finds the watershed segmentation of luminance component of color image[2] [27]. The method can be explained as follows. It consists of two independent neural networks one each for saturation and intensity planes[7][17]. The neural network consists of three layers namely input layer, hidden layer, and output layer as depicted in the following Figure 8.

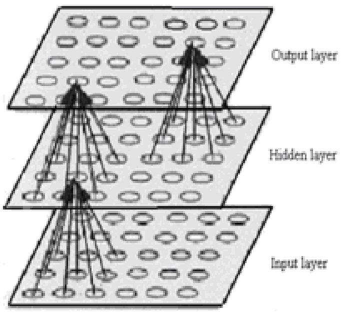

Fig. 8. Neural network approach for Image Segmentation Process

The input to a neuron in the input layer is normalized between [0-1]. The output value of each neuron is between [0-1]. Each layer is having a fixed number of neurons equal to the size (I x J) of the image[16]. All neurons are having primary connection weight as 1[20]. Each neuron in one layer is connected to respective neuron in the previous layer with its d order neighborhood as shown in the following Figure 9.

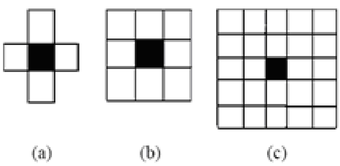

Fig. 9. Neighborhoods of a pixel (a) First order neighborhood (b) Second order neighborhood (c) Sequence of neighborhood.

In edge detection process, Initialize the synaptic weights of the network, $V_j(0)$ to small, different, random numbers at iteration k=0. draw a sample y from the input set. Find the best matching (winning) neuron r(y) at iteration k, using the minimum distance Euclidean criterion[24]

$$r(y) = \min \| y - V_j \|, j = 1,2,...,L$$

Update the synaptic weight vectors using the update formula

$$V_{r(y)}^{k+1} = V_{r(y)}^{k} + \eta^k (y - V_{r(y)}^{k}),$$
$$V_j^{k+1} = V_j^k + (\eta^k)^2 (y - V_j^k)$$
$$\forall_j \exists \Omega_{r(y)}(k)$$

where $\Omega_{r(y)}(k)$ is the neighborhood pixel of r(y). Increment k by 1, go to input set, and continue until the synaptic weights reach their steady-state values.

Fig. 10. Original Image

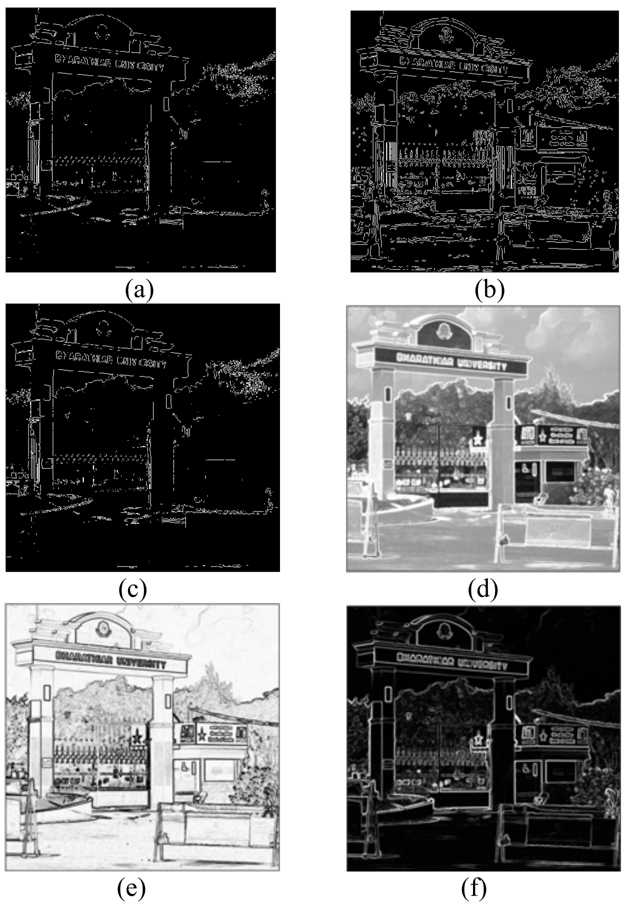

Fig. 11. Using Edge Detection Methods. (a) using Prewitt Method (b) usingRoberts Method (c) using Sobel Method (d) using Fuzzy Method (e) using Genetic algorithm Method (f) using Neural Network Method

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D. Comparison of Edge Detection Methods

Figure 10 and 11. shows the comparison of the six edge detection methods for the image of Bharathiar University. Since different edge detections work better under different conditions.

IV. CONCLUSION

This paper mainly focuses on the study of soft computing approach to edge detection for image segmentation. The soft computing approaches namely, fuzzy based approach, Genetic algorithm based approach and Neural network based approach is applied on a real life example image of nature scene and the results show the efficiency of image segmentation.

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