A Novel Approach of Fuzzy Logic Based Edge Detection for Coronary Angiogram Using Virtual Instrumentation

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ABSTRACT

Arteriosclerosis is a coronary artery disease (CAD) that is caused due to the deposition of plaque in the walls of arteries by which the arteries narrows down (stenosis) and the blood flow gets restricted. Computed Topographic angiography (CTA) has been used in clinical diagnosis and it is very difficult to visualize the blood vessels and the stenosis due to the presence of bones and tissues. This paper proposes an approach of fuzzy logic based edge detection to detect the edges of the coronary artery. The proposed method is compared with Roberts, Prewitt, Sobel and canny edge operators and the simulation results reveals that the proposed method gives better edges than the other method. The analysis of the proposed method has been evaluated on various CT angiography images qualitatively using Laboratory virtual instrument engineering workbench (Lab VIEW) software environment.

Keywords: LabVIEW, Fuzzylogic.

I. INTRODUCTION

The important rise of medical imaging during the twentieth century, mainly induced by physics breakthroughs related to nuclear magnetic resonance and X-rays has led to the development of imaging modalities devoted to visualize vascular structures. The analysis of such angiographic images is of stoking interest for several clinical applications [1]. Coronary artery disease (CAD) is the leading cause of death worldwide. It occurs when the coronary arteries that supply blood to the heart muscle become hardened and narrowed due to the build-up of plaque (fat deposits) on their inner walls, termed arteriosclerosis. As the plaque increases in size, the interior of the arteries, the lumen, gets narrower (stenosis) and less blood can flow through eventually, blood flow is reduced and the heart muscle does not receive sufficient oxygen. This can result in a myocardial infarction (heart attack) when a blood clot develops at the site of the plaque and suddenly cuts off most or all of the blood supply causing permanent damage to the heart muscle.

It is necessary to find the border of coronary artery to determine the stenosis and we go for edge detection algorithm using fuzzy logic. Edge detection is an important but difficult task in image processing and analysis. It is important because it provides basic structural properties about objects in the image. It reduces the less relevant information which reduces the amount of data to be processed and thus saves time and at the same time preserves the most important features. An edge is the boundary between two or more regions. There are many operators that are used to detect the edge of an object in the image that includes Sobel, Robert, prewitt, laplacian and canny method of operators, etc [2]-[4]. Fuzzy logic can also be used for edge detection. Fuzzy sets deal with the imprecision and vagueness embedded in human understanding systems and provides an elegant frame work for describing, analyzing, and interpreting the vague and uncertain events [5]. In this paper we propose an edge detection method based on fuzzy logic. This method is extension of the work [6], in which eight fuzzy set rules are used to detect edges on binary image. In the proposed method, Fuzzy inference system has 8 inputs, which corresponds to 8 pixels of instantaneous scanning matrix, one output that tells whether the pixel under consideration is “black”, “white” or “edge” pixel. The proposed method results for different captured images are compared to those obtained with the linear Sobel, Robert, prewitt, Laplacian and canny edge operators.

II. MEDICAL IMAGE EDGE DETECTION

Edge detection refers to the extraction of the edges in medical image. It is a process whose aim is to identify the points in an image where discontinuities or sharp changes in intensity occur. This process is crucial to understanding the content of an image and has its applications in medical image analysis and machine vision. Edge detection aims to
localize the boundaries of objects in an image and is a basis for many image analysis and machine vision applications. Conventional approaches (such as Sobel Operator, Prewitt Operator, Roberts Operator etc.) to edge detection are computationally expensive because each set of operations is conducted for each pixel [7, 8]. In conventional approaches, the computation time quickly increases with the size of the image. A statistical-based approach has the potential of overcoming the limitations of conventional methods. Furthermore, it makes the algorithm easily adaptable for any systems. Various edge detection techniques have been developed for edge detection [9-14].

III. GENERAL DESCRIPTION OF FUZZY INFERENC SYSTEM
A. Fuzzy Logic

Fuzzy Logic logic was formulated in 1965 by Zadeh, many researchers have been carried out its applications in the various areas of digital image processing: such as image assessment, edge detection, image segmentation, etc [5]. Fuzzy image processing is not a unique theory. It is a collection of different fuzzy approaches to image processing. Generally speaking, edge detection with fuzzy logic is composed of expert knowledge, fuzzification, membership modification, fuzzy set theory and

![Fig.1. General structure of fuzzy system](image)

defuzzification [15] as shown in figure 1. Recognition methods based on fuzzy reasoning strategy are designed to detect edges in digital images without prior determination of threshold values or needs of training algorithm. The fuzzification comprises the process of transforming crisp values into grades of membership for linguistic terms of fuzzy sets. The membership function is used to associate a grade to each linguistic term. A fuzzy inference system (FIS) is a system that uses fuzzy set theory to map inputs (features in the case of fuzzy classification) to outputs (classes in the case of fuzzy classification). Defuzzification is the process of producing a quantifiable result in fuzzy logic, given fuzzy sets and corresponding membership degrees. It is typically needed in fuzzy control systems. These will have a number of rules that transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets.

The membership function shown in figure 2. of a fuzzy set is a generalization of the indicator function in classical sets. In fuzzy logic, it represents the degree of truth as an extension of valuation. Degrees of truth are often confused with probabilities, although they are conceptually distinct, because fuzzy truth represents membership in vaguely defined sets, not likelihood of some event or condition. Membership functions were introduced by Zadeh in the first paper on fuzzy The input image is quantized into 8-bit grayscale, so the value of imaging.

![Fig.2. Membership function](image)
IV. PROPOSED ALGORITHM

We have proposed an efficient edge detection algorithm using simple mathematical approach. This proposed method depends on masking operation. A 3x3 mask centered at pixel f(i, j) is defined as shown in figure 3. The algorithm uses two vague values, “white” and “black”, by which it classifies the ambiguous brightness values of all pixels around the surveyed central pixel. The auxiliary array A, which will form as a resulting output image with founded edge points, first fill with value “most white” and during the classification the pixels marked as “edge point” are filled with value “most black” (in our case 0). The proposed algorithm is as follows.

1. Input is a grayscale image M x N, each element (pixel) is described by the value of image function f(m,n)=f_{mn} \epsilon <0,255>, m=1,2,... M, n=1,2,...N.
2. Create the auxiliary array A (size M x N, at the end will mention the output image) and initially is setting to a constant value A(m,n) \epsilon 255 for all m=1,2,... M and n=1,2,...N.
3. Set a counter j \epsilon 2.
4. Set a counter i \epsilon 2.
5. Find values f(i,j) = f_{i,j} of all pixels in the neighborhood 3 x 3 and verify the validity of rules in Incase of validity set A(i,j) \epsilon 0.
6. Repeat for all i=2, ..., M-1 from the step 5.
7. Repeat for all j=2, ..., N-1 from the step 4.
8. Finally array A now contains the output image.

A. Fuzzy sets and rules

In this paper the image is divided into regions by using of the floating matrix 3x3 pixels. The image data are transformed from the plane of brightness values (gray levels) in the plane belonging to fuzzy sets (Fuzzification) according to fuzzy rules. In our case, we will examine the discretized image of size MxN image function f(x) then can be written for example in the form f(m, n), where m = 1, 2, ... M and n = 1, 2, ... N. We define four rules, which consider the brightness value of eight neighboring pixels around the examined pixel (i, j), as shown in Fig.3.

Figure 3. Mask 3x3 pixels in fuzzy edge detection

The fuzzy system focuses on detection of edges for coronary artery image. A set of rules are framed to detect the edge points. Fuzzy rules for the proposed method are relatively simple and allows us to get acquainted with the principle of applying fuzzy logic in image processing. Each of the fuzzy rules are created in the form of a conditional language expression of the logical implication IF X THEN Y, where X and Y are fuzzy statements, and X is a fuzzy condition and Y is a fuzzy consequence. The aim is to identify pixels that are logically edge points of the investigated image.

The described method analyzes the brightness values of all pixels in the 8-neighborhood (by mask 3x3) of the image centre pixel (i, j), and if conditions are met, the centre pixel is considered as the edge pixel and it is marked. Every pixel is processed with fuzzy rules, and if one of the rule is satisfied then the pixel is considered as an edge point, else it is discarded. It is applied on all the pixels of the images and the edge points are collected and all the edge points are taken as the edges of the image. The rules are shown in the table 1.
V. RESULT AND DISCUSSION

The algorithm developed has been simulated using Lab VIEW. The simulation is performed by applying the proposed algorithm on CTA images of coronary artery. The dataset used for the evaluation consist of sequences of 512x512 images and has a gray value resolution of 8bit and the grey values varied from 0-255, i.e. 256 gray level. The proposed method has been validated both on synthetic data and real time DSA and has been applied to test DSA drawn from clinical practice. For the purpose of analysis we have considered three different patient images. The block diagram for fuzzy logic edge detection using Lab VIEW environment is shown in figure 4. The proposed method is compared with other linear operators such as Sobel, Robert, prewitt, laplacian and canny edge detecting operators on the same set of images and are shown in figure 5. In figure 5 (a) depicts the original original Angiographic Image, (b) Edge detection using Laplacian operator, (c) Edge detection using Prewitt operator, (d) Edge detection using Sobel operator,(e) Edge detection using Robert operator (f),Edge detection using canny edge operator, (g) proposed method (fuzzy ) Edge detection for image 1, (h) proposed method (fuzzy ) Edge detection for image 2, (i) proposed method (fuzzy ) Edge detection for image 3.. From the analysis it is found that the proposed method gives sharp and clear edges than that obtained by other linear operator

**Table 1.** The rules of fuzzy set

<table>
<thead>
<tr>
<th>Rule Number</th>
<th>Edges</th>
<th>Rule</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td><img src="image1" alt="Rule1 Edges" /></td>
<td>IF ( f(i-1,j-1) &amp; f(i-1,j) &amp; f(i-1,j+1) ) are whites &amp; IF ( f(i,j-1) &amp; f(i,j) &amp; f(i,j+1) ) are whites &amp; IF ( f(i-1,j-1) &amp; f(i-1,j) &amp; f(i+1,j+1) ) are blacks THEN ( f(i,j) ) is “edge”</td>
</tr>
<tr>
<td>2</td>
<td><img src="image2" alt="Rule2 Edges" /></td>
<td>IF ( f(i-1,j-1) &amp; f(i-1,j) &amp; f(i-1,j+1) ) are blacks &amp; IF ( f(i,j-1) &amp; f(i,j) &amp; f(i,j+1) ) are whites &amp; IF ( f(i-1,j-1) &amp; f(i-1,j) &amp; f(i+1,j+1) ) are whites THEN ( f(i,j) ) is “edge”</td>
</tr>
<tr>
<td>3</td>
<td><img src="image3" alt="Rule3 Edges" /></td>
<td>IF ( f(i-1,j-1) &amp; f(i-1,j) &amp; f(i+1,j-1) ) are blacks &amp; IF ( f(i-1,j) &amp; f(i,j) &amp; f(i+1,j) ) are whites &amp; IF ( f(i-1,j-1) &amp; f(i+1,j-1) &amp; f(i+1,j+1) ) are whites THEN ( f(i,j) ) is “edge”</td>
</tr>
<tr>
<td>4</td>
<td><img src="image4" alt="Rule4 Edges" /></td>
<td>IF ( f(i-1,j-1) &amp; f(i-1,j) &amp; f(i+1,j-1) ) are whites &amp; IF ( f(i-1,j) &amp; f(i,j) &amp; f(i+1,j) ) are whites &amp; IF ( f(i-1,j-1) &amp; f(i+1,j-1) &amp; f(i+1,j+1) ) are blacks THEN ( f(i,j) ) is “edge”</td>
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Fig.4. Block diagram of edge detection using fuzzy Logic
a. Original images

b. Edge detection using Laplacian operator

c. Edge detection using Prewitt operator

d. Edge detection using Sobel operator

e. Edge detection using Robert operator

f. Edge detection using Canny edge detector
VI. CONCLUSION

An approach of fuzzy logic for detection of edges in medical grayscale images is presented in this paper. The proposed method is compared with traditional edge detectors. The designed fuzzy rules are an attractive solution to improve the quality of edges as much as possible. The implemented FIS system presents greater robustness to contrast and lighting variations, besides avoiding obtaining double edges. On the basis of visual perception and edge counts of edge maps of various grayscale images it is proved that our algorithm is able to detect highest edge pixels. Also it gives smooth and thin edges without distorting the shape of images.

REFERENCE

[7]. Pratt, William K. “ Digital Image Processing”.