A Neuro Fuzzy Based Medical Image Edge Detection

Ahmed Mostafa, Abrar Alaa and Manar Adel

Abstract—Edge detection is one of the most important tasks in image processing. Medical image edge detection plays an important role in segmentation and object recognition of the human organs. It refers to the process of identifying and locating sharp discontinuities in medical images. In this paper, a neuro-fuzzy based approach is introduced to detect the edges for noisy medical images. This approach uses desired number of neuro-fuzzy subdetectors with a postprocessor for detecting the edges of medical images. The internal parameters of the approach are optimized by training pattern using artificial images. The performance of the approach is evaluated on different medical images and compared with popular edge detection algorithm. From the experimental results, it is clear that this approach has better performance than those of other competing edge detection algorithms for noisy medical images.

Index Terms—Neural Network , Fuzzy Logic , Edge Detection, Adaptive Neuro-Fuzzy Inference System, ANFIS, Medical edge detection;

1 Introduction

Edge detection is one of the most important tasks in the field of image processing and pattern recognition. It plays crucial role in the multimedia and computer vision, image enhancement and image compression and so forth. It is usually the first things done prior to other operations such as image segmentation, boundary detection, object recognition, classification and image registration etc. Simply, to be successful in the complicated operation of image processing, the entire attention should be invested in the field of edge detection. With the advent of new developments in the field of mathematics and artificial intelligence (AI), lots of different edge detection methods are on hand, including mathematical morphology, wavelet transformation, Roberts's method, Prewitt method, Sobel method, zero-crossing method, canny methods, LOG method and so on. The most important element decreasing the quality of the edge detection is the noise in the digital image. Digital images are almost always damaged by the Impulse noise (the common image noise, mostly noticed as white or black spots) during image acquisition or transmission. Impulse noise is experienced as a result of the environment features and conditions, quality of sensing elements, and communication channels. An important consideration while working with the image processing programs is the image noise removal which should be done first especially because of the noise-sensitiveness condition of later image processing tasks such as segmentation, feature extraction, and object recognition. Failure to do so may result in severely degraded images.

Medical image edge detection is an important work for object recognition of the human organs and it is an essential pre-processing step in medical image segmentation. There are an extremely large number of edge detection operators available, each designed to be sensitive to certain types of edges. Variables involved in the selection of an edge detection operator include edge orientation, noisy environment and edge structure. There are two main types of edge detector: one is the first derivative based edge detection operator to detect image edges by computing the image gradient values, such as Roberts, Sobel and Prewitt operator; second derivative based edge detection operator to detect edges by taking second derivative such as LOG and Canny operator. The first order derivative like Sobel, Prewitt and Laplacian of Gaussian operator, but in theory they belong to the high pass filtering, which are not fit for noisy medical image edge detection because noise and edge belong to the scope of high frequency. In real world applications, medical images contain object boundaries and object shadows and noise. Therefore, they may be difficult to distinguish the exact edge from noisy medical images. These detectors are simple to implement but they are usually inaccurate and highly sensitive to noise. The second order detects edges by taking second derivative and is very sensitive to noise too. The Gaussian edge detectors reduce the undesirable negative effects of noise by smoothing the image before performing edge detection. Hence, they exhibit much superior performance over other operators especially in noisy conditions. Neuro-Fuzzy edge detection was used widely in the last decades. In [6] authors propose an ANFIS model with 8-inputs and 1-output Neuro-Fuzzy system based in first-order-Sugano system. 2 triangular type member-ship functions are used for each input, and the output has a constant membership function. 256 rules were used with just one output. Authors use a Grid partition method on the contrary of subtractive clustering method. The Grey level image is used to detect edges, they firstly binarize the image, and then the binary image disintegrates to 3x3 windows and generates a set of the image pattern. The edge patterns in binary images were classified into 32 categories. Training the ANFIS on this category (patterns) classify the

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blank elements in each 3x3window in white pixels (value: 1) and dark pixels (value: 0). In [7] authors classify image pixels into three sets of pixels contour, regular and texture using a model of Neuro-Fuzzy approach which takes the advantages of Neural Networks Learning characteristic and the fuzzy logic function. Spatial properties of the image features are the base of this approach. As every Neuro-Fuzzy system, a training set was used to create and train the classifier system. They assigned for every pixel a degree of membership for each of the three fuzzy subsets. They note that this approach would be highly attractive in the biomedical field In [8] authors uses an ANFIS(Adaptative Neuro-Fuzzy Inference System) detector and is a first-order Sugeno type Fuzzy inference system with 4-inputs and 1-output. Each input has three generalized bell type membership functions and the output has a linear membership function . for the training they use Sugano first order model which characteristic is the combination of applying a mixture of the least-squares method and the backpropagation gradient descent method. This combination is to realize a given training data set. Authors of the paper [9] use an ANFIS with 2x2 windows For edge detection. They allow four input values which are mapped to the four fuzzy inputs in the fuzzy inference system. the ANFIS system classify the output as an edge or as background. In [10] authors use Neuro-Fuzzy system in the classification of biometric Multimodal Face, Iris, and Finger Fake they detect this characteristic with an ANFIS system. Another application of ANFIS is used in [11] to classify Texture Image. They compare Classification with Artificial Neural Networks and ANFIS one. Their results prove that the ANFIS system gives better classification, and the methods could be applied to medical images or defense applications. Neuro-Fuzzy system based in TakagiSugeno fuzzy inference system was used in [12] as a classifier for image retrieval. They use Canny detector for the learning database. In This Paper we extend our search on a neuro fuzzy (NF) approach for edge detecting in noisy medical images, the neural fuzzy combine the best of two worlds with the learning and adaptability of neural network and the knowledge of the IF-THEN rules of fuzzy logic and dealing with imprecise and incomplete data. The Canny detector [5], which is a Gaussian edge detector, is one of the most popular edge detectors and it has been widely used in many applications. Although the Gaussian detectors exhibit relatively better performance, they are computationally much more complex than classical derivative based edge detectors. Furthermore, their performances quickly decrease as the density of the corrupting noise increases. As the performance of classic edge detectors degrades with noise, a novel edge detector that is capable of extracting edges from medical images corrupted by noise is highly desirable. Fuzzy logic based approach can deal with the ambiguity and uncertainty in image processing in better way as compared to the traditional approaches. When fuzzy logic is used for edge detection gives better result compare to the classical approach. The classical techniques like Sobel, Prewitt, Roberts, Canny edge detector have limitations of using fixed value of parameters or threshold. The nature of edges is not constant due to which few edges left by being detected. However, as the medical image gets complex, different local areas will need different threshold values to accurately find the real edges. In addition, the global the threshold values are determined manually through experiments in the traditional method, which leads complex in calculation when large number of different medical images needs to be dealt with. By using fuzzy techniques edges having different thickness can be also detected. Our proposed algorithm is based on the idea of bootstrap aggregation (bagging) where we combine multiple classifiers each of which trained on a subset of the training data, the final classification decision is based on a voting mechanism where we take the average of the classifiers outputs to be our final decision, this technique is used to reduce the overfitting.

The rest of this research paper is organized as follows, in Section II, we describe in details the proposed method for medical image detection. In Section III, the result of this approach has been compared with Canny and zero-crossing. Finally, conclusion followed by future work come in Section IV and V.

2 THE PROPOSED ALGORITHM

2.1 The neuro fuzzy based detection algorithm

Our edge detector is based on 2 neuro fuzzy networks operating as sub detectors for the horizontal and vertical directions respectively. Each sub detector works on a 3x3 window and evaluates the neighborhood relationships in the window according to the direction it is working on to decide if there is a horizontal or vertical edge in this window. The final output is obtained by thresholding the average of the outputs of the two sub detectors.

2.2 The sub detectors architecture

Each sub detector is a Sugeno type fuzzy inference system with 8 inputs and 1 output as show in Figure 1.

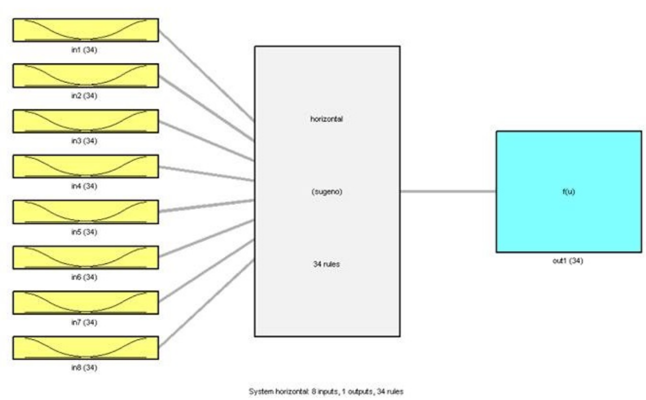

Fig. 1. The fuzzy inference system structure

Both the vertical and horizontal sub detectors have an identical internal structure which is shown in Figure 2.

We carefully handcrafted the positive examples for the two small training datasets for the horizontal and vertical edges. Each dataset consists of 16 different 3x3 patterns excluding the central pixel as shown in Figure 3 and Figure 4, the exclusion of the central pixel was done to trade the accuracy for a significant improvement in the computational

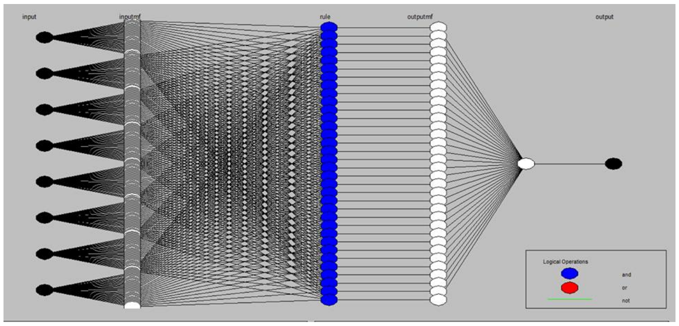

Fig. 2. ANFIS network internal structure

cost since smaller input dimensionality results in a smaller rule base. The negative training samples are obtained easily by generating smooth 3x3 windows and allowing small perturbations in them.

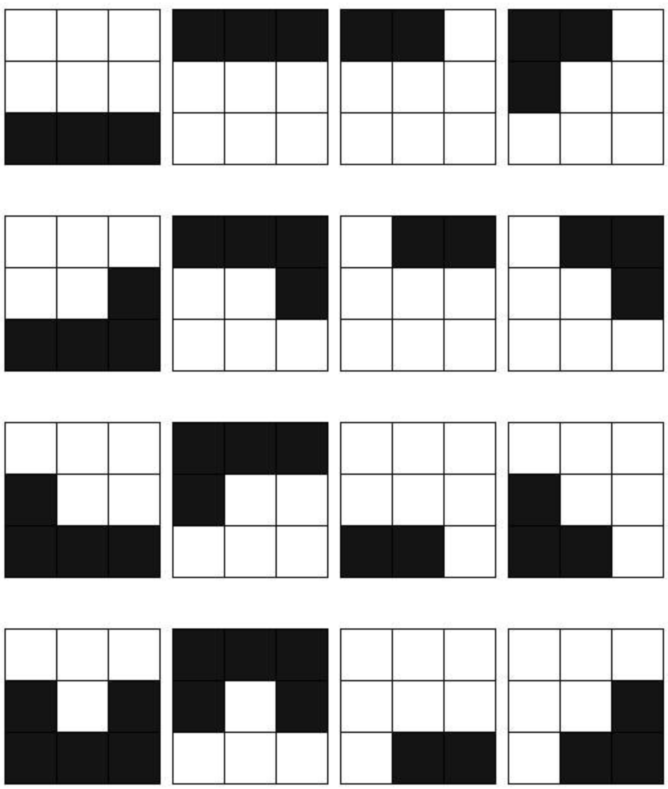

Fig. 3. Horizontal training patterns

We determined the number of input membership functions and the number of rules from the training data using subtractive clustering, which results in much less number of rules and significantly reduces the computational cost opposed to grid partitioning. Using the previously mentioned dataset the subtractive clustering algorithm found 34 clusters which results in the following rule base:

1) If (in1 is in1cluster1) and (in2 is in2cluster1) and (in8 is in8cluster1) then (out1 is out1cluster1)
2) If (in1 is in1cluster2) and (in2 is in2cluster2) and (in8 is in8cluster2) then (out1 is out1cluster2)
3) ...

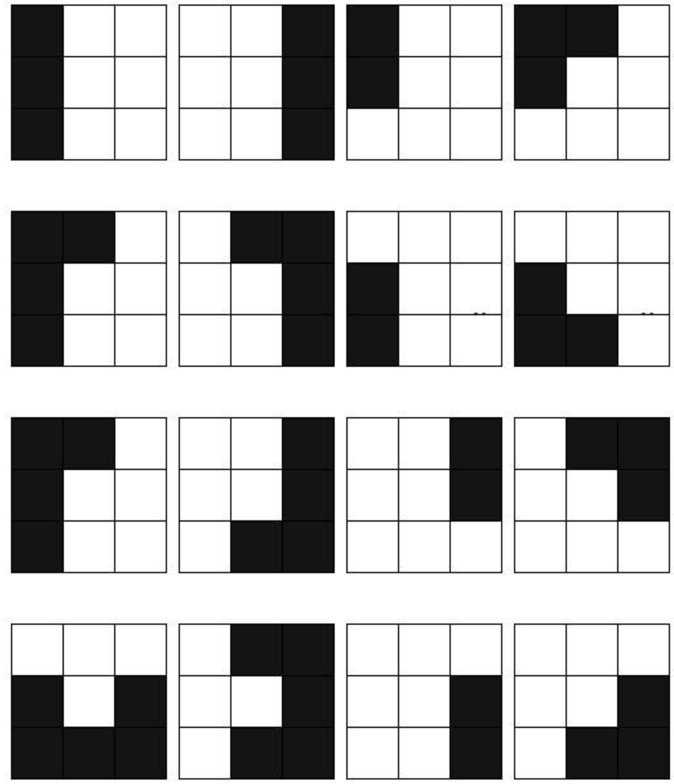

Fig. 4. Vertical training patterns

4) If (in1 is in1cluster34) and (in2 is in2cluster34) and (in8 is in8cluster34) then (out1 is out1cluster34)

Each input is represented by 34 different Gaussian membership functions which has the form

$M_{ij} = e^{\frac{-(x-c)^2}{2\sigma^2}}$

Where M_{ij} is j^{th} membership function in the i^{th} rule. The parameters of each membership function will be determined in the learning phase .

3 Results and Interpretation in the Presence of Noise

The proposed fuzzy edge detection method was simulated using MATLAB on different images, tests were performed on the images noised by Gaussian noise. The results of detections were compared with the detection of the same images by Canny and zero-crossing operators. The main feature of these detectors is revealed by the output image results. Indeed, the detection results on noisy images are clearly better than those given by the conventional Canny and zero-crossing detectors were the proposed algorithm detects much more edge pixels, and superiority of the proposed algorithm is clear. The noisy image is shown in Figure 5 (a). The edges extracted by the proposed algorithm are shown in Figure 5(b) Finally, The extracted edges by the Canny and zero-crossing methods are shown in Figure 5(c) and 5(d) .As the Figure shown, the proposed algorithm generated by the ANFIS method seem to be much smoother with less noise (no spurious edges) and has an exhaustive set of fuzzy conditions which helps to provide an efficient edge representation for images with a very high efficiency than the conventional.

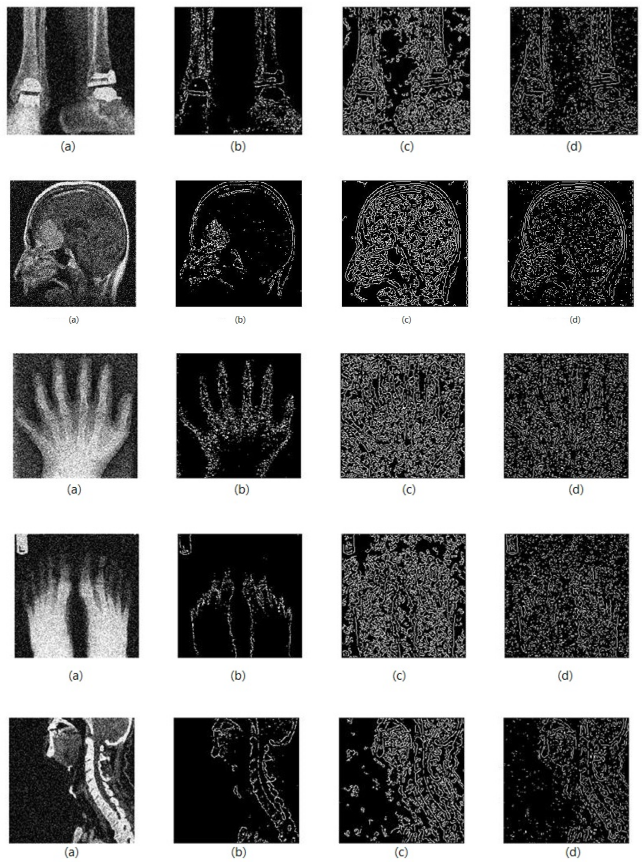

Fig. 5. Comparison of the proposed edge detector with the canny and zero-crossing edge detectors. (a) Noisy image, (b) Proposed Method, (c) Canny edge detector (d) zero-crossing edge detector.

4 Conclusion

Finally, The detector showed effectiveness are mainly for the treatment of noisy images while performing the actual detection. Besides that the proposed ANFIS technique shows an excellent performance and detects almost all the edges in all the experimental images, we cant ignore the fact that effect of noise has become to its lowest amount after the application of proposed method. In other words, the proposed method outperforms all the previously used methods.

5 Future Work

The proposed technique to find more fine edges using NF edge detector is restricted only to gray scale image. This can be further extended to color image, where edge detection task may become significantly more complex .Moreover, modification of training set so as to reduce inclusion in the output image of pixels not belonging to edges which can produce better result.

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