Fuzzy edge detection using wavelet and adaptive median filter for corrupted image by salt and pepper noise

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ABSTRACT:
The goal of edge detection in image processing is to determine the frontiers of all represented objects, based on automatic processing of color or gray level information contained in each pixel. This procedure has many applications in image processing, computer vision and biological and robotic vision [1], [2], and [3].
Edge detection is an important preprocessing step in image analysis. Successful results of image analysis extremely depend on edge detection [1]. This paper presents a new approach for edge detection in situations where the image is corrupted by noise. Traditional edge detections are sensitive to noise. The structure of our proposed edge detector, to make the process robust against noise, is a combination of wavelet transform, fuzzy inference system and adaptive median filter. The proposed method is tested under noisy conditions on several images and also compared with conventional edge detectors such as Sobel and *Prewitt Roberts Cross and* Canny .
Experimental results reveal that the proposed method exhibits better performance and may efficiently be used for the detection of edges in images corrupted by noise.

KEYWORDS: edge detection, wavelet, image processing, fuzzy inference system, salt and pepper noise.

1. INTRODUCTION

THE edges are place of abrupt changes in the intensity of image and are most essential feature of an image. They contain a richness of internal information of image [4],[5]. Edge always inhabits in two neighboring areas having different gray level and it mostly exists between objects or objects and background [6],[7]. Edge detection is one of the most important tasks in pattern recognition and image processing [8]. It plays an important role in the multimedia and computer vision, Image Understanding, Image enhancement and image compression, etc [9]. It is usually the first operation that is performed before tasks such as boundary detection, segmentation, classification, registration, understanding and recognition in image processing scope [10],[13].Thus, success in such operations extremely depends on edge detection. In recent years several methods have been developed for edge detection, These methods include mathematical morphology, wavelet transformation, Roberts, Prewitt, Sobel, Zero-crossing, Canny, Laplacian of Gaussian (LOG) etc [8],[11]. The most important factor in decreasing the quality of edge detection is the noise in images. One of the important noises is Salt-and-Pepper. This is described by random distribution of white or black spots. This noise is often happens during image acquisition and/or transmission due to environment condition, quality of sensing elements and communication channels [12]. In most image processing applications, it is of crucial importance to remove the noise from the image because the performances of image processing tasks (such as segmentation, feature extraction, recognition, etc.) are severely degraded by noise [6].

This paper presents a novel method for edge detection while images are corrupted by salt and pepper noise. The proposed method is very simple and includes a fuzzy inference system, an adaptive median filter and wavelet transform. The essential advantage of the proposed method over other operators is that it offers higher edge detection performance under noisy conditions. Experiments show that the proposed operator may be used for efficient edge detector when an image is corrupted by Salt and- Pepper noise and high accuracy is needed.

The rest of this paper is organized as follows. Section II explains the proposed method and its building blocks. Section III discusses the experimental results of the proposed method and classical methods such as Sobel, Prewitt and Canny. Section IV, which is the final section, presents the conclusions and further research.

2. PROPOSED METHOD

Fig. 1 shows the structure of the proposed method. It is a Fuzzy Inference System (FIS) . proposed FIS used to edge detection. *DH* and *DV* are generated from wavelet transform to estimate 1st derivative of I in horizontal and vertical directions. *HP* & *M* are masks of a high pass and low pass filters.med is median filter used to estimate absolute intensity in salt & pepper noisy condition.

A nonlinear image filtering technique is developed here which is based on **fuzzy inference systems (FIS)**. During input image processing, four kinds of linear filters are applied to it:

1- Wavelet transform used to estimate its derivative in horizontal and vertical directions (*DH h* and *DV h* filters).
2- A high-pass filter.
3- Adaptive median filter used to estimate absolute intensity in salt & pepper noisy condition.

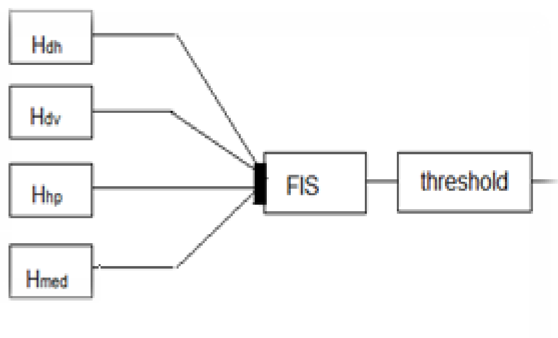

Fig. 1. structure of the proposed method

Here the gray level associate to pixel (i,j) in the output image *E* depends not only on the pixel (i,j) in each pre-processed image but also on some neighbor pixels Besides, each image *DH* and *DV* that results from applying wavelet transform is passed to the FIS system, and not only the image composition $D = \mathrm{sqrt}(DH^2 + DV^2)$.

The purpose of proposed fuzzy system is to determine if pixel (i,j) evaluated is or is not present in one of the edges of the image, given the information explicit in the input filtered images.

2.1. Implementation of the FIS System

During input image pre-processing step, three linear filters were employed. We use wavelet transform to compute *DH* and *DV*.

Using discrete wavelet transform with haar basis function:

The Harr transform

- Basic functions are the oldest and simplest known orthnormal wavelet
- Separable and symmetric and can be expressed in matrix form T=HFH

where F is an N * N image matrix, H is an N X N Haar transformation:

matrix, and T is the resulting N * N transform

$$h_k(z) = h_{pq}(z) = \frac{1}{\sqrt{N}} \begin{cases} 2^{p/2} & (q-1)/2^p \le z < (q-0.5)/2^p \\ -2^{p/2} & (q-0.5)/2^p \le z < q/2^p \\ 0 & \text{otherwise}, z \in [0,1]. \end{cases} \quad (1)$$

The Harr basic functions are :

z€[0 1],k=0,1,2,…,N,N=2^n , k=2^p+q-1,0≤p≤n-1

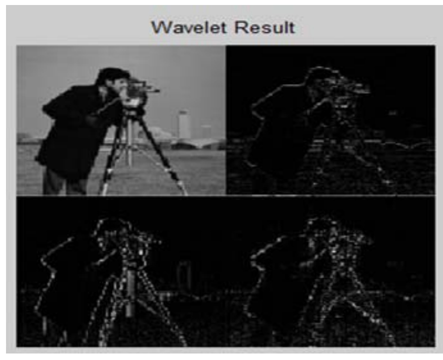

Fig. 2. using wavelet to estimate DH (top right) and DV (bottom left)

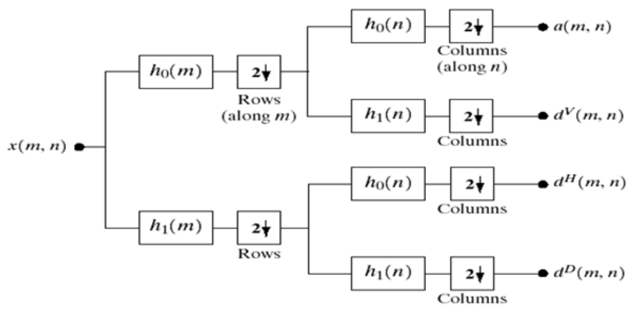

Fig. 3. for pixel in position (m,n)

Using a 3*3 mask to estimate the high pass filter:

$$h_{HP} = \begin{bmatrix} -1/16 & -1/8 & -1/16 \\ -1/8 & 3/4 & -1/8 \\ -1/16 & -1/8 & -1/16 \end{bmatrix}$$

2.2. Using Window Area to Estimate Median Filter

Adaptive median filter can handle salt-and-pepper noise with preserving the details [9]. This filter works in a rectangular window area **Sxy**. Depending on certain conditions, adaptive median filter changes the size of **Sxy** during filtering operation. Consider the following notations:

zmin = Minimum intensity value in Sxy
zmax = Maximum intensity value in Sxy
zmed = Median of intensity values in Sxy
zxy = intensity value at coordinates (x,y)
Smax= Maximum allowed size of Sxy

The adaptive median filter algorithm works in two stages, denoted stage A and B, as follows:

Stage A: A1= zmed – zmin
A2= zmed – zmax
If A1 > 0 and A2 < 0, go to stage B
Else increase window size
If window size <= Smax repeat stage A
Else return zxy
Stage B: B1= zxy – zmin
B2= zxy – zmax
If B1 > 0 and B2 < 0, return zxy
Else return zmedian

2.3. Fuzzy Sets and Fuzzy Membership Functions

The system implementation was carried out considering that the input image and the output image obtained after *defuzzification* are both 8-bit quantized; this way, their gray levels are always between 0 and 255. These values define the working interval of the output variable and the input variable *M* the other input variables are not guaranteed to be less than 255 so we use sigmoid member ship function for them. Besides, three fuzzy sets were created to represent each variable's intensities; these sets were associated to the linguistic variables "low", "medium" and "high".

The Gaussian membership function is adopted for the fuzzy sets ("low , medium and high") associated with input M and the output. The mean value for the Gaussian membership function is taken as 0, 127.5 and 255.

2.4. Fuzzy Logical Operations and Defuzzification Method Definitions

The functions adopted to implement the "and" and "or" operations were the minimum and maximum functions, respectively. The Mamdani method was chosen as the defuzzification procedure, which means that the fuzzy sets obtained by applying each inference rule to the input data were joined through the add function; the output of the system was then computed as the centroid of the resulting membership function[52].

2.5. Inference rules

The fuzzy inference rules were defined in such a way that the FIS system output ("Edges") is high only for those pixels belonging to edges in the input image.

The first three rules were defined to represent the general notion that in pixels belonging to an edge there is a high variation of gray level in the vertical or horizontal direction:

1- (DH low) AND (DV low)AND(MED low) →("Edges" low).
2- (DH medium) AND (DV medium) AND(MED medium) → ("Edges" high).
3- (DH high) OR (DV high)) AND(MED high)→ ("Edges" high).

To guarantee that edges in regions of relatively low contrast can be detected, the two following rules were established to favour medium variations of the gray level in a specific direction in regions of *low frequency* of the input image (HP "low"):

4- (DH medium) AND (HP low) AND(MED medium) → (" Edges" high).
5- (DV medium) AND (HP low) AND(MED medium) → (" Edges" high).

To avoid including in the output image, pixels belonging to regions of the input where theed mean gray level is lower, the following two rules were established. These regions are proportionally more affected by noise, supposed it is uniformly distributed over the whole image. The goal here is to design a system which makes it easier to include edges in low contrast regions, but which does not favour false edges by effect of noise.

6- (DV medium) AND (MED low) →("Edges" low).
7- (DH medium) AND (MED low) → ("Edges" low).

To avoid forming double edges in the output image that tend to appear due to shadows in the natural images and to guarantee that output result haven't got any breaked edges and some isolated point the following four rules were developed. We define a new variable that contain both DH & DV by adding them together: DT=DH+DV;

8- (dt(i-1,j-1) high) AND (dt(i,j) high) AND (dt(i+1,j+1) high) → (“Edges” high).
9- (dt(i-1,j) high) AND (dt(i,j) high) AND (dt(i+1,j) high) → (“Edges” high).
10- (dt(i-1,j+1) high) AND (dt(i,j) high) AND(dt(i+1,j-1) high) → (“Edges” high).
11- (dt(i,j-1) high) AND (dt(i,j) high) AND (dt(i,j+1) high) → (“Edges” high).

3. SIMULATION RESULTS

The proposed method presented in the previous section is simulated by computer programs. The performance of the method is tested under noisy condition (Salt & Pepper noise) on two test images including *lena* and *peppers*.

The images are corrupted by Salt & Pepper noise with 20%, 30%, 40% and 50% noise density before processing.

Several experiments are performed to compare our proposed scheme with Sobel and *Prewitt Roberts Cross and* Canny. that discussed in [13]. Fig. 5 shows the results for images corrupted by 30% noise density. It can be seen that the performance of the proposed method is much higher than other three schemes (Sobel, Canny and method in [13]).

comparison of images in fig. 5 obviously indicated that the proposed method detects most of the edges better than [13]. The essential purpose of our method is to increase performance of edge detection in highly noisy condition that it almost is obtained. The test images demonstrated that when images corrupted with high degree of salt and pepper noise Sobel, Canny and the method discussed in [13] no have appropriate performance, while in this condition the proposed method detected the most of edges whit high precision.

4. CONCLUSION

A novel edge detection method for digital images corrupted by Salt & Pepper noise was proposed.
1- It has a simple structure, thus this extremely simplified implementation.
2- The Fuzzy Inference System (FIS) is performed without difficulty by using artificial images that can be generated in computer.
3- It can detect edge in image that corrupted by high degree of Salt-and-Pepper noise.
4- The proposed method could be had good performance for images without noise too.

The simulation result shows that this scheme outperforms conventional edge detectors under noisy conditions.

However, the computational barrier of this scheme is higher than Sobel and Canny edge detectors.

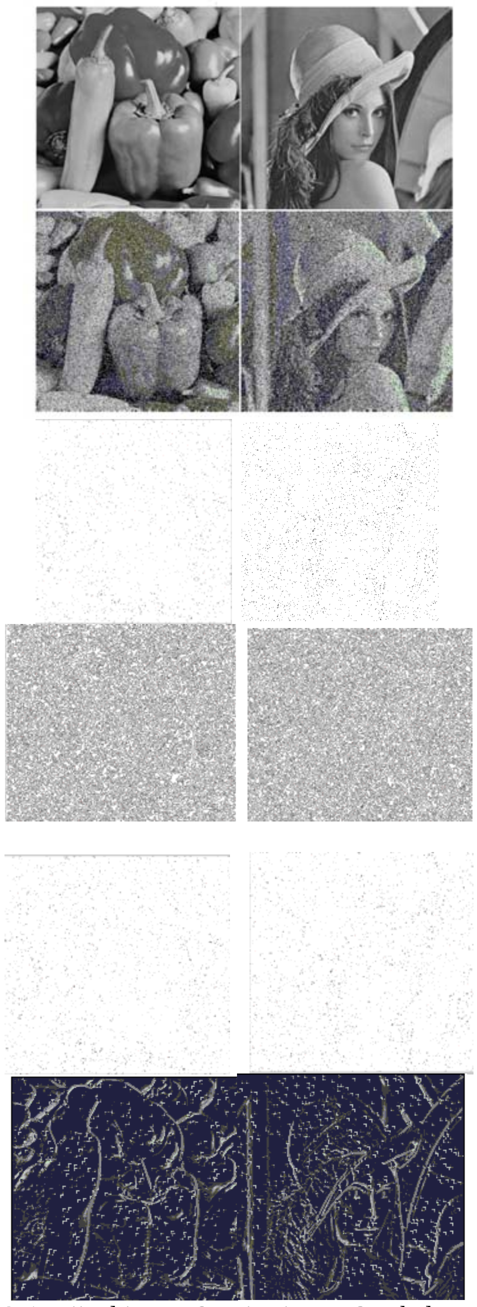

Fig. 4. 1-orjinal image 2-noisy image 3-sobel operator 4-canny operator 5-perwitt operator 6-proposed method

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