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Design of Fuzzy Based Filter for Removal of Impulse Noise

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ABSTRACT

Background: Images and pictures are required as sources of information for analysis and interpretation in various fields such as medicine, remote sensing etc., These images are prone to impulse noise as a result of errors in the image acquisition or transmission process. Thus, the output image needs to be enhanced. **Objective:** To present a novel fuzzy logic based filtering technique to restore images corrupted by impulse noise. **Results:** Simulation results show that this filter performs well in preserving details and noise suppression. **Conclusion:** The proposed technique is simple and easy to implement.

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INTRODUCTION

The wide usage of multimedia material increases the usage of high quality of digital images in many application areas including astronomy, biology, medicine, remote sensing, material science etc. During image acquisition, the digital images are often corrupted by impulse noise due to transmission error, malfunctioning of pixel elements in camera and due to error in analog to digital conversion. Apart from this, it is also corrupted due to an imperfect medium between the original scene and the imaging system. The noise can be classified as substitutive noise and additive noise.

Removal noise from image plays an important role in image processing application, because the performance of the image processing tasks dependent upon the noise removal operation. Hence in order to remove noise from the image, variety of techniques has been introduced (Akkoul, S., 2010; Awad, A.S. and H. Man, 2008; Chen, P.Y., 2010; Matsubara, T., 2010; Ponomaryov, V., 2010). Specifically, for removal of impulse noise, median filter (Zhang, J., 2010) is proposed.

The standard median filter is a simple rank selection filter and attempts to remove impulse noise from the center pixel of the analysis window by changing the luminance value of the center pixel with the median of the luminance values of the pixels contained within the window. This approach provides a reasonable noise removal performance with the cost of introducing undesirable blurring effects into image details even at low noise densities. Since its application to impulse noise removal, the median filter has been of high research interest and a number of rank- order-based filters trying to avoid the inherent drawbacks of the standard median filter.

Weighted order statistic filters, such as the weighted median filter (Zhang, X. and Y. Xiong, 2009; Dong, Y. and S. Xu, 2007) and the center-weighted median filter, employ a mechanism for appropriately weighting pixels of the analysis window to control the transaction between the noise suppression and detail preservation. These filters yield better detail preservation performance than the median filter.

Stack filters are a class of order statistic filters consisting of some other rank order based impulse noise filters as subclasses. Rank conditioned rank selection filters are another large class of order statistic filters comprising many other rank order based impulse noise filters, including the stack filters. Different implementations of these filters were used for impulse noise suppression. Conventional order statistic filters usually distort the uncorrupted regions of the input image during restoration of the corrupted regions, introducing undesirable blurring effects into the image.

The signal-dependent rank-ordered mean filter is another median-like filter, which also utilizes the rank order information of the pixels contained within the filtering window. The filter exhibits better detail preservation and noise removal performance than the standard median filter. It is also applied for the removal of

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impulse noise from color images. There are also similar filtering methods for the detection and removal of impulse noise from color images.

But all the conventional methods have the disadvantage of introducing undesirable distortions into image during noise reduction. Hence, research is moved towards a design of non-linear filtering techniques based on soft computing method.

The filtering methods based on soft computing techniques will improve the performance of traditional filtering method. The proposed scheme is simple but efficient and works alternatively in two phases: detection of noisy pixels followed by removal of the corrupted pixels to overcome many of the shortcomings observed in the existing methods**.**

System Description:

The proposed system adapted for impulse noise reduction is shown in the figure1.

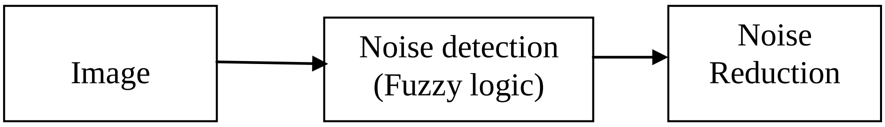

Fig. 1: Block diagram of noise reduction.

The overall block diagram of the combined filter structure is depicted in Figure 1. The noisy pixel in the image is detected using a fuzzy knowledge based and the detected noise is removed using a recursive median filter.

Fuzzy Logic Design:

Fuzzy logic control (FLC) (Zadeh, L.A., 1971) has gained much interest in the application of system control for the past few decades. It has a real time basis as a human type operator, which makes decision on its own basis. The controller can incorporate easily the dynamic changes of the system due to the operating point shifting; hence it can tackle efficiently nonlinearity of any system. Zadeh has developed the concept of fuzzy logic.

A FIS can utilize human expertise by storing its essential components in knowledge base, and perform fuzzy reasoning to infer the overall output value. However, there is no systematic way to transform experiences of knowledge of human experts to the knowledge base of a FIS. For building a FIS, the fuzzy sets, fuzzy operators and the Knowledge base has to be specified. The main feature of FLC is that it is governed by symbolic rules (generally if-then rules) and qualitative fuzzy variables and values. It deals with linguistic variables. Fuzzy logic approximates the relation between variables regardless of their analytical dependence. The fuzzy controller is composed of the following four elements:

1) A rule-base (a set of if-then rules), which contains a fuzzy logic quantification of the expert’s linguistic description of how to achieve good control.
2) An inference mechanism (also called a fuzzy inference engine), which emulates the expert’s decision making in interpreting and applying knowledge about how best to Control the plant.
3) A fuzzification interface, which converts controller inputs into information that the inference mechanism can easily use to activate and apply rules.
4) A defuzzification interface, which converts the conclusions of the inference mechanism in to actual inputs for the process.

Noise Detection Using Fuzzy Technique:

There are two cases of noise distributions for impulse noise: fixed valued impulse noise and random-valued impulse noise. For fixed-valued impulse noise which is also known as the “salt-and-pepper”.

The intensity of an impulse noise impaired pixel is usually much larger (or smaller) than that in the surrounding pixels. When a small window is centered at an impulse-impaired pixel, the effect of the impulse noise is observed after an average filter is applied. With this concept, each pixel in the image the intensity difference between the center pixel and the neighboring pixels in a sliding window of 3x3 shown in Figure 2 is calculated. By considering the intensity difference method, fuzzy knowledge base is used to detect whether a given pixel is noise or not. A fuzzy set detect the noise using the trapezoidal membership function for input and the output of fuzzy system detects the non-noise and noisy pixels.

P1	**P2**	**P3**
P4	**P0**	**P5**
P6	**P7**	**P8**

Fig. 2: Processing window to Compute Intensity Different.

Fuzzy reasoning resorts to a set of rules in order to detect noise pulses are depicted as follows
If (D_1 is L) and (D_2 is L) and (D_3 is L) and (D_4 is L) Then (O is L)
If (D_1 is L) and (D2is L) and (D_3 is L) and (D_4 is H)Then (O is H)
If (D_1 is L) and ($D_2$is L) and ($D_3$is H) and (D_4 is L) Then (O is H)
If (D_1 is L) and (D_2 is L) and (D_3 is H) and D_4 is H)Then (O is H)
If (D_1 is L) and (D_2 is H) and (D_3 is L) and D_4 is L) Then (O is H)
If (D_1 is L) and (D_2 is H) and (D_3 is L) and (D_4 is H)Then (O is H)
If (D_1 is L) and (D_2 is H) and (D_3 is H) and (D_4 is L) Then (O is H)
If (D_1 is L) and (D_2 is H) and (D_3 is H) and (D_4 is H)Then (O is H)
If(D_1 is H) and (D_2 is L) and (D_3 is L) and (D_4 is L) Then (O is H)
If(D_1 is H) and (D_2 is L) and (D_3 is L) and (D_4 is H)Then (O is H)
If(D_1 is H) and (D_2 is L) and (D_3 is H) and (D_4 is L) Then (O is H)
If(D_1 is H) and (D_2 is L) and (D_3 is H) and (D_4 is H)Then (O is H)
If(D_1 is H) and (D_2 is H) and (D_3 is L) and (D_4 is L) Then (O is H)
If(D_1 is H) and (D_2 is H) and (D_3 is L) and (D_4 is H)Then (O is H)
If(D_1 is H) and (D_2 is H) and (D_3 is H) and (D_4 is L) Then (O is H)
If(D_1 is H) and (D2 is H) and (D_3 is H) and (D_4 is H)Then (O is H)

The fuzzy sets output are fed to the defuzzifier blocks. The defuzzifier defuzzifies the input fuzzy set and converts it into a single scalar value. If the output of the greater than the threshold of 0.6 is classified as noisy while that with probability less than the threshold is not.

Recursive Median Filtering Algorithm:

Recursive median filtering of an arbitrary level signal is equivalent to decomposing the signal into binary signals, filtering each binary signal with a binary recursive median filter, and then reversing the decomposition.

In this work, to process the corrupted image pixel, recursive median filter is applied. The two dimensional median filter is realized by passing a window over each point of the image signal, ranking the values in the window, and replacing each point with the output of the recursive median filter on that particular point before shifting the window to the next position.

This process can also be described by the following pseudo-C code. Here, we assume that the total number of signal points is L and at both ends of the signal, N points are appended to allow the filter to reach the edges of the signal.

```
for (n = l;n 5 L;n++){V,(n) = b,(n);}
do { success = 0;
for (n = 1; n 5 L; n++){
m = median ( (V, (n - N) , . . . , b, (n) , . . . , V, (n + N) )
if (m == V,(n)) success++
K(n) = m; >}
while (success # L); }
```

This operation has the properties of smoothing the signal and at the same time the outputs of each pass to resemble the original (noisy) signal. Thus, in this way, features such as thin lines and sharp edges can be better preserved.

Simulation Results:

The filter performances are usually compared in terms of Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Mean Absolute Error (MAE). Larger values of PSNR and small values of MSE indicate less noise power in an image. PSNR and MSE are used to test the effectiveness of the proposed algorithm.

Mean Square Error (MSE):

MSE is given by

$$MSE= \frac{1}{ME}\sum_{X=1}^{M}\sum_{Y=1}^{N}[f(x,y)-f'(x,y)]2$$

Where f(x, y) - M×N initial image
f'(x, y) –Noised image

Peak Signal to Noise Ratio (PSNR):

PSNR is defined as

$$PSNR= 10 \log_{\mathbf{10}} \frac{[255^2]}{MSE} \text{ dB.}$$

If PSNR value is high or MSE value is low THEN image quality is better. The proposed method has been applied on test image shown in Figure 3. Table 1 shows the quantitative comparison of the proposed method and the existing methods with respect to images corrupted with fixed-valued impulse noise.

Fig. 3: Original image.

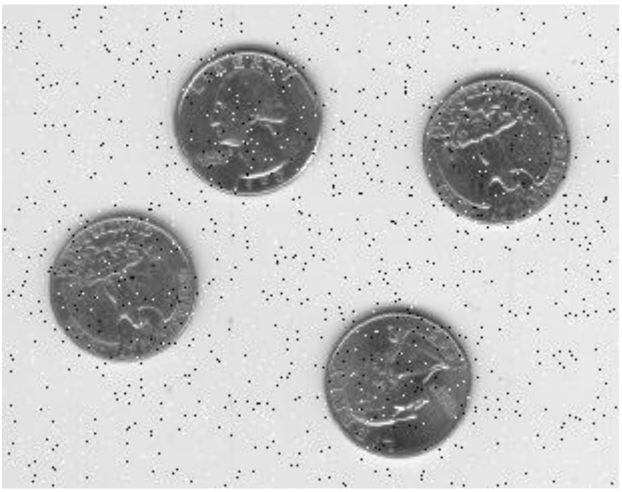

Fig. 4: Noisy image with Salt & Pepper noise.

Fig. 5: Image with Noise Removed by proposed Filter.

Table 2: Comparison of the MSE'S of restored images between different image filtering techniques.

Filter Name	MSE
Mean filter(3×3)	382
Median filter(3×3)	245
Proposed fuzzy filtering technique	111

Conclusion:

A novel fuzzy logic based impulse noise detection and filtering technique is presented. Extensive simulation have been conducted on a variety of filters and their performance is compared with the proposed method The efficiency in detection of corrupted pixel and suppression of the detected impulse noise from digital images without distorting the useful information within the image of the proposed technique is better when compared to the existing methods. Thus, the proposed technique is simple and easy to implement.

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