Global Journal of Computer Science and Technology
Volume 11 Issue 22 Version 1.0 December 2011
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

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GJCST Classification : I.4.3

IMPLEMENTATION OF IMPULSE NOISE REDUCTION METHOD TO COLOR IMAGES USING FUZZY LOGIC

Strictly as per the compliance and regulations of:

Implementation of Impulse Noise Reduction Method to Color Images using Fuzzy Logic

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Abstract - Image Processing is a technique to enhance raw images received from cameras/sensors placed on satellites, space probes and aircrafts or pictures taken in normal day-to-day life for various applications. Impulse noise reduction method is one of the critical techniques to reduce the noise in color images. In this paper the impulse noise reduction method for color images by using Fuzzy Logic is implemented. Generally Grayscale algorithm is used to filter the impulse noise in corrupted color images by separate the each color component or using a vector-based approach where each pixel is considered as a single vector. In this paper the concepts of Fuzzy logic has been used in order to distinguish between noise and image characters and filter only the corrupted pixels while preserving the color and the edge sharpness. Due to this a good noise reduction performance is achieved. The main difference between this method and other classical noise reduction methods is that the color information is taken into account to develop a better impulse noise detection a noise reduction that filters only the corrupted pixels while preserving the color and the edge sharpness. The Fuzzy based impulse noise reduction method is implemented on set of selected images and the obtained results are presented.

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I. Introduction

Processing of images which are digital in nature by a digital computer is called as digital image processing. Image Processing is a technique to enhance raw images received from cameras/sensors placed on satellites, space probes and aircrafts or pictures taken in normal day-to-day life for various applications. Various techniques have been developed in Image Processing during the last four to five decades. Most of the techniques are developed for enhancing images obtained from unmanned spacecrafts, space probes and military reconnaissance flights. Image Processing systems are becoming popular due to easy availability of powerful personnel computers, large size memory devices, graphics software etc. Image Processing is used in various applications such as remote sensing, medical imaging, film industry, military, etc.

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a) Color Models

The purpose of a color model is to facilitate the specification of colors in some standard, generally accepted way. In essence, a color model is a specification of a co-ordinate system and a subspace within that system where each color is represented by a single point.

b) Fuzzy Logic

In this paper Fuzzy logic concept has been used in order to distinguish between noise and image characters and filter only the corrupted pixels while preserving the color and the edge sharpness. Fuzzy set theory and fuzzy logic offer us powerful tools to represent and process human knowledge represented as fuzzy if-then rules. Fuzzy image processing has three main stages: 1) image fuzzification, 2) modification of membership values, and 3) image defuzzification. The fuzzification and defuzzification steps are due to the fact that we do not yet possess fuzzy hardware. Therefore, the coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make it possible to process images with fuzzy techniques. The main power of fuzzy image processing lies in the second step (modification of membership values).

II. Method

a) Implementing Filter to Remove Noise

This method consists of two phases viz., the Detection phase and De-noising phase. The result of the detection method is used to calculate the noise-free color component differences of each pixel. These differences are used by the noise reduction method so that the color component differences are preserved. We use the red-green-blue (RGB) color space as basic color space.

1) to the neighbors in the same color band and
2) to the color components of the two other color bands. if $\boldsymbol{F_i}$ denotes the input noisy image and $\boldsymbol{O_i}$ the original noise-free image at pixel position , then we can express the random-value impulse noise as

$$F_i^{col} = \begin{cases} O_i^{col} \text{ , with probability } 1-\delta \\ \zeta_i^{col} \text{ , with probability } \quad \delta \end{cases}$$

Where ζ_I^{col} is an identically distributed, independent random process with an arbitrary underlying probability density function. We consider the most used distribution: namely the uniform distribution, where the noise was added to each color component independently. The indexes *i* and *col* indicate the 2-D pixel position and the color component, respectively, i.e., col= R. col=G or col=B if the RGB-color space is used.

b) Impulse Noise Detection

1. Whether each color component value is similar to the neighbors in the same color band and
2. Whether the value differences in each color band corresponds to the value differences in the other bands. Since we are using the RGB color-space, the color of the image pixel at position *i* is denoted as the vector F_i which comprises its red (R), green (G), and blue (B) component, so $F_i = (F_i^R, F_i^G, F_i^B)$. Let us consider the use of a sliding filter window of size nxn, , with n = 2c+1 and c E N, which should be centered at the pixel under processing, denoted as F_o . For a 3 x3 window, we will denote the neighboring pixels as $F_1$to F_8 (i.e., from left to right and upper to lower corner). The color pixel under processing is always represented by $F_o = (F_0^R, F_0^G, F_0^B)$

The Detection phase consists of the following seven steps

a) Calculation of absolute differential matrix

First, we compute the absolute value differences between the central pixel F_o and each color neighbor as follows:

$$\Delta F_k^R = | F_o^R - F_k^R |, \quad \Delta F_k^G = | F_o^G - F_k^G | \text{ and } \quad \Delta F_k^B = | F_o^B - F_k^B |$$

where $k = 1,\ldots,n^2-1$ and ΔF_k^R , ΔF_k^G and ΔF_k^B denote the value difference with the color at position in the R, G, and B component, respectively.

b) Compute the fuzzy set S1 (membership degrees) for these differences

Now, we want to check if these differences can be considered as small. Since small is a linguistic term, it can be represented as a fuzzy set. Fuzzy sets, in turn, can be represented by a membership function. In order to compute the membership degree in the fuzzy set small we have to know the desired behavior, i.e., if the difference is relatively small then we want to have a large membership degree (the membership degree should decrease slowly), but after a certain point, we want to decrease the membership degree faster for each larger difference. Therefore, we have chosen the 1-S-membership function over other possible functions. This function is defined as follows:

$$1-S(x)\begin{cases} 1, & if\ x \le \alpha_1 \\ 1-2\left(\dfrac{x-\gamma_1}{\gamma_1-\alpha_1}\right)^2, & if\ \alpha_1 < x \le \dfrac{\alpha_1+\gamma_1}{2} \\ 2\left(\dfrac{x-\alpha_1}{\gamma_1-\alpha_1}\right)^2, & if\ \dfrac{\alpha_1+\gamma_1}{2} < x \le \gamma_1 \\ 0, & if\ x > \gamma_1 \end{cases}$$

where it has been experimentally found that α_1=10 and γ_1=70 receive satisfying results in terms of noise detection. In this case, we denote *1-S* by S_1, so that $S_1(\Delta F_k^R)$, $S_1(\Delta F_k^G)$, $S_1(\Delta F_k^B)$ denote the membership degrees in the fuzzy set *small* $_1$of the computed differences with respect to the color at position *k* .

c) Calculate the degree of similarity μ^R μ^G μ^B

Now, we use the values $S_1(\Delta F_k^R)$, $S_1(\Delta F_k^G)$, $S_1(\Delta F_k^B)$ for $k = 1,\ldots,n^2-1$ to decide whether the values F_o^R, F_o^G and F_o^B are similar to its component neighbors. The number *k* of considered neighbors will be a parameter of the filter. So, we apply a fuzzy conjunction operator (fuzzy AND operation represented here by the triangular product t-norm among the first k ordered membership degrees in the fuzzy set *small* $_1$. The conjunction is calculated as follows:

$$\mu^R = \prod_{j=1}^{K} S_1\left(\Delta F_{(j)}^R\right)$$

where μ^R denotes the degree of similarity between F_0^R and K the -nearest neighbors.

d) From S1 calculate S1(RG, GB, BR) i.e differences among R, G, B components

Besides the first step of the detection method, i.e., checking if the central pixel is similar to its local neighborhood or not, we investigate whether the color components are correlated which each other or not. In other words, we determine whether the local differences in the R component neighborhood corresponds to the differences in the G and B component. we compute the absolute value of the difference between the membership degrees in the fuzzy set *small* $_1$ for the red and the green and for the red and the blue components, i.e., $| S_1(\Delta F_k^R) - S_1(\Delta F_k^G) |$ and $| S_1(\Delta F_k^R) - S_1(\Delta F_k^B) |$ where $k = 1,\ldots,n^2-1$, respectively.

e) Compute the fuzzy set S2 (membership degrees) for these differences

Now, in order to see if the computed differences are *small* we compute their fuzzy membership degrees in the fuzzy set *small* $_2$.The 1-S membership function is also used but now we used α_2=0.01 and γ_2=0.15 and , which also have been determined experimentally. In this case we denote the membership function as S_2

*f) **Calculate the joint similarity*** μ^{RG} μ^{RB} μ^{BG}

we calculate

$$\mu_k^{RG} = S_2\left(\left|S_1\left(\Delta F_k^R\right) - S_1\left(\Delta F_k^G\right)\right|\right)$$

$$\mu_k^{RB} = S_2\left(\left|S_1\left(\Delta F_k^R\right) - S_1\left(\Delta F_k^B\right)\right|\right)$$

where μ^{RG}_k and μ^{RB}_k denote the degree in which the local difference (between the center pixel and the pixel at position) in the red component is similar to the local difference in the green and blue components. The obtained degrees μ^{RG}_k and μ^{RB}_k are sorted again sorted in descending order, where $\mu^{RG}_{(J)}$ and $\mu^{RB}_{(J)}$ denote the values ranked at the k[th] position. Consequently, the *joint similarity* with respect to k neighbors is computed as

$$\mu^{RG} = \prod_{j=1}^{K} \mu^{RG}_{(j)}, \qquad \mu^{RB} = \prod_{j=1}^{K} \mu^{RB}_{(j)}$$

where μ^{RG} and μ^{GB} denote the degree in which the local differences for the red component are similar to the local differences in the green and blue components, respectively. Notice that if F_o^R is noisy and F_o^G and F_o^B are noise-free, then the local differences can hardly be similar, and, therefore, low values of μ^{RG} and μ^{GB} are expected.

g) Calculation of Noise-Free degree

$$NF_{F^R_0}, NF_{F^G}, NF_{F^B}$$

Finally, the membership degree in the fuzzy set *noise-free* for F_o^R is computed using the following fuzzy rule

Fuzzy Rule 1: Defining the membership degrees NF F_o^R for the red component F_o^R in the fuzzy set *noise-free*

$$\text{IF } \mu^R \textit{ is large } \text{AND } \mu^{RG} \textit{ large } \text{AND } \mu^G \textit{ is large}$$

OR

$$\mu^R \textit{ is large } \text{AND } \mu^{RB} \textit{ large } \text{AND } \mu^B \textit{ is large}$$

THEN

$$\textit{the noise} - \textit{free degree } F_0^R \textit{ is large}$$

A color component is considered as noise-free if

1) it is similar to some of its neighbor values (μ^R) and
2) the local differences with respect to some of its neighbors are similar to the local differences in some of the other color components (μ^{RG} and μ^{GB}).

In fuzzy logic, triangular norms and co-norms are used to represent conjunctions and disjunctions respectively. Since we use the product triangular norm to represent the fuzzy AND (conjunction) operator and the probabilistic sum co-norm to represent the fuzzy OR (disjunction) operator the noise-free degree of F_o^R which we denote as $NF_{F^R_0}$ is computed as follows

$$NF_{F_0^R} = \mu^R \mu^{RG} \mu^G + \mu^R \mu^{RB} \mu^B - \mu^R \mu^{RG} \mu^G \mu^R \mu^{RB} \mu^B$$

Analogously to the calculation of noise-free degree for the red component described above, we obtain the noise-free degrees of F_o^G and F_o^B denoted as $NF_{F^G_0}$ and $NF_{F^B_0}$ as follows

$$NF_{F_0^G} = \mu^G \mu^{RG} \mu^R + \mu^G \mu^{GB} \mu^B - \mu^G \mu^{RG} \mu^R \mu^G \mu^{GB} \mu^B$$

$$NF_{F_0^B} = \mu^B \mu^{RB} \mu^R + \mu^B \mu^{GB} \mu^G - \mu^B \mu^{RB} \mu^R \mu^B \mu^{GB} \mu^G$$

In fuzzy logic, involutive negators are commonly used to represent negations. We use the standard negator $N_s(x)= 1- x$, with x E [0,1]. By using this negation, we can also derive the membership degree in the fuzzy set *noise* for each color component, i.e., $NF_o^R = 1-NF_{F^R_0}$, where denotes the membership degree in the fuzzy set *noise.*

Algorithm for Impulse Noise Generator

Step1: Read the pixels from image ,we take some temporary variable initialize to zero.

Step2: For Red

- **Step 2.1:** check the condition if temporary variable equal to zero assign color code 0x00ff0000.
- **Step 2.2:** check the condition if temporary variable equal to one assign color code 0xff00ffff.
- **Step 2.3:** repeat Step 2.1 and Step 2.2 until red pixels are encountered.

Step3: For Green

- Step 3.1: check the condition if temporary variable equal to zero assign color code 0x0000ff00
- Step 3.2: check the condition if temporary variable equal to one assign color code 0xffff00ff
- Step 3.3: repeat Step 3.1 and Step 3.2 until green pixels are encountered .

Step4: For Blue

- **Step 4.1:** check the condition if temporary variable equal to zero assign color code 0x000000ff
- **Step 4.2:** check the condition if temporary variable equal to one assign color code 0xffffff00
- **Step 4.3:** repeat Step 4.1 and Step 4.2 until blue pixels are encountered.

III. Results Analysis

Different images as inputs are taken and apply this algorithm on these images and obtained the PSNR values .All these values are tabulated in table:1.

	
Original Mushroom image	Image corrupted with 5% random-value impulse noise. PSNR = 15
	
output of the filter with a 3x3 window and K = 2; PSNR = 28	the output of the proposed two-step filter PSNR = 30

Figure 1 : Noise Detection For Random-Value Impulse Noise

	
Original Mushroom image	Image corrupted with 5% fixed-value impulse noise. PSNR =22
	
output of the filter with a 3x3 window and K = 2; PSNR = 38	output of the proposed two-step filter. PSNR = 35

Figure 2 : Denoising - 5 % Fixed-Value Impulse Noise

PSNR VALUES OF A COLOR IMAGE			
RIN %	Filter	FIN %	Filter
1	36.089537	1	30.2734961
2	33.6586222	2	28.1291336
3	32.1085337	3	26.5705585
4	30.6483222	4	25.5990663
5	30.136797	5	24.6834733
6	28.0413943	6	23.9445168
7	27.5204845	7	23.1597035
8	26.4836001	8	22.9446623
9	25.7170883	9	22.6951294
10	25.2244423	10	22.1748394

Table 1 : PSNR Valued of lena image corrupted with (RIN & FIN both ranging from 1 to 10)

IV. Conclusion

In this paper, a new fuzzy filter for impulse noise reduction in color images is presented. The main difference between the proposed method (denoted as INR) and other classical noise reduction method is that the color information is taken into account in a more appropriate way .This method also illustrates that color images should be treated differently than grayscale images in order to increase the visual performance.

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