Intelligent Image Enhancement System based on Similarity Pixels

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Abstract

The main goal of image enhancement is to enhance the fine details present in the images having low luminance for better image quality. In the digital image processing field, the enhancement and removing the noise from the image is a critical issue; image noise removal is the manipulation of the image data to produce a visually high-quality image. The important details and useful information on image decreasing by the noise where the noise treated as information. The filters are used to remove unwanted information. The filters’ objectives are to improve the image quality. This paper proposes an enhancement image system, which chooses the appropriate filter and value of center pixel depends on the number of similarities adjusted neighbors pixels to the center pixel. The performance of this system is evaluated by using different quality metrics, such as Mean square error (MSE), Peak Signal Noise to Ratio (PSNR), Absolute Mean Brightness Error (AMBE), Measure of Enhancement (EME), and Measure of Enhancement by Entropy (EMEE), Entropy, Second-Order Entropy (SOE), and Image Enhancement Metric (IEM). The proposed enhancement system is efficient in removing noises and enhancing the image quality. Experiments are applied to a set of images, such as Lena, butterfly, etc. with different image sizes. The results show that the enhancement quality was performed well in the proposed system with minimal unexpected artifacts as compared to the other techniques, where the results of the proposed system for MSE, PSNR, AMBE, Entropy, SOE, EME, EMEE, and IEM for baboon image with the size 255x 255 are 2.906, 8.875, 3.92, 5.154, 2.692, 3.915, 0.442 and 3.674 in sequence.

Keywords

Introduction

The image processing technique has become a common technique to make images understandable for human eyes. Digital image damage occurs through communication channels, which leads to image damage and noise in some places in the image (Arunkumar et al., 2019). Image enhancement is the preprocessing technique widely used in digital image processing (Rajitha Rani, G.R., Samson, C., 2018). The role of contrast enhancement is increasing the quality of any image (Kaur et al., 2018). The visual image quality has been improved with active research towards techniques enhancing the contrast of images in many fields, such as medical images, satellite images, radar images, digital photography and sonar images and so on. Nowadays, a trend in using mobile phones to capture pictures, but due to the limitations in hardware in mobile phones, the quality of image can vary based on its resolution, intensity, light change or a shadow effect, etc., leading to high noise levels (Supriya et al., 2017). Noise is caused by data transmission through the noisy channel, errors that occur through the measurement process, sampling, and quantization of data for digital storage (Gonzalez R. and Woods, R., 1992). The objectives of image enhancement are to remove impulsive noise, to smooth no impulsive noise, and to enhance features for a specific color. Noise filter can be viewed as replacing each image pixel value with a new value (Sarode et al., 2008). Image enhancement includes many techniques that improve the appearance of an image (Gonzalez R. and Woods, R., 1992). There are several statistical filters used for enhancement and removal of noise in images (Raju et al., 2014).

The main concept of filters is to average a pixel based on the values of another neighborhood pixel, thus, the contribution of this research work is to remove the noise from image and enhancement by choosing the best filter depending on the similarity value of a center pixel with its neighbors. This process can be applied by a variety of filtering methods (Histogram Equalization, Laplacian of Gaussian and Fuzzy filter) to obtain better images in terms of improving clarity, lighting, contrast or removing noise. The histogram equalization is used to adjust the image contrast. Laplacian filters are derivative filters, therefore, they are very sensitive to noise which used to find detect edges of images. The fuzzy filter is used to derivate a new value of the center pixel depending on the local neighborhood intensity pattern.

The organization of the paper as follows: Section 2 introduces related works. Sections 3 and 4 describe the theoretical background required in this proposed system, section 5 presents the methodology algorithms used for evaluating the performance of the system. The Experiment results and Image quality performance metrics are given in Section 6. The conclusions are presented in Section 7.
Related Works

In this paper, an enhancement image system, which chooses the appropriate filter based on the principle of comparing the center pixel with adjusted neighbor pixels that surround the center pixel is proposed for improving the quality of the image. Several types of research were introduced to provide an outline of the previous important works in an adaptive filter of image enhancement. These are can be described below:

In (2011), Feng et al., presented an improved protein spot detection approach in images, which is based on Laplacian of Gaussian algorithm, which can reduce the impact of noisy and background in spot detection and the morphological grayscale reconstruction algorithm can restrict and reduce the impact of noisy in spot detection (Feng et al., 2011). In (2012), Amudha et al., presented a review and analysis of the digital image restoration, where various techniques of denoising and deblurring were discussed. The perspective on the topic offered in this paper was to know various methods of digital image restoration (Amudha et al., 2012). In (2013), Hui et al., suggested using the Laplacian of Gaussian filter to detect elliptical blob structures in biomedical and natural images, where the LoG filter estimate the scales, shapes, and orientations of the detected blobs. These functions can be realized by generalizing 3-D LoG scale space blob detector to a 5-D gLoG. Manivel and Ravindran presented a review of classical and fuzzy filters for impulse noise reduction, then compared the results of filters by performance measurement metrics (Hui et al., 2013). In (2014), Shrivastava, D. & Richhariya, V proposed an adaptive fuzzy enhancement method based on the principles of fuzzy entropy and fuzzy set theory (Shrivastava, D. & Richhariya, V., 2014). In (2015), Al-Ameen, et al., proposed an image enhancement method to provide a good brightness with contrast for computed tomography images based on a contrast-limited histogram equalization method. This is done through adding a gamma correction function to avoid the errors that occur in the CLAHE approach (Al-Ameen, et al., 2015). In (2015), Kanika K. & Shaveta A., proposed the underexposed color image enhancement based on histogram technique by converting the image pixels into HSV (Hue, Saturation, Value), then decomposed the image into two parts by using the threshold and then equalized them over enhancement (Kanika K. & Shaveta A., 2015). In (2015), Pritee Singh R., Amit C., presented a review of diverse histogram equalization where the contrast enhancement is considered an important feature in the image enhancement and histogram equalization is a simple and well-known method for image contrast enhancement, this method uses the histogram of images processing (Pritee Singh R., Amit C., 2015). In (2016), Sujit et al., proposed the Fuzzy Clipped Contrast-Limited Adaptive Histogram Equalization method, which automated the clip limit selection, which was relevant to the mammogram and
enhanced the local contrast of digital mammograms (Sujit et al., 2016). In (2016), Mehdi Roopaei et. al., proposed image enhancement techniques based on histogram where attempts to provide optimal vertical and horizontal separating threshold to overcome the saturation effect of intensities (Mehdi et al., 2016). In (2016), Sheng, et al., proposed an enhancement on the images of lung nodules in chest radiographs by merging the parameterized logarithmic image processing method with Laplacian of a Gaussian filter (Sheng et al., 2016). In (2017), Liyun Zhuang and Yepeng Guan proposed an image enhancement method based on recursively separating the input histogram via the mean and variance, which effectively increases the contrast of the input image with brightness and details well preserved (Liyun Z., & Yepeng G., 2019). In (2018), Khalid Hussain et al., proposed an enhancement technique for a dark image that performs the local pixel transformation, the histogram specification technique was applied to the input image using this transformed histogram (Hussain et al., 2018). In (2019), Yuanmin Xie et al., used the principle of histogram equalization to improve the image effect, where it would increase the contrast of the image enhancing the brightness and image clarity (Yuanmin et al., 2019). In (2019), Liyun Zhuang and Yepeng Guan proposed a developed histogram function for enhancing the image contrast to make the histogram curve smoother (Liyun Z., & Yepeng G., 2019). In (2019), El-Sennary et al., proposed the extended difference of Gaussian technique for detecting edges which applied on several different images with various sizes where Laplacian operator is used for enhancement and detect the edges (Hameda et al., 2019). In (2019), they used Laplacian filter to process a biologically retina circuit architecture-based analog image. The retina construction can be thought of as a group of pixel structures, the researcher designed a pixel circuit as a sub-circuit for the retina structure where uses a current mirror and current sub-tractor circuit to perform convolution by using the masking technique (Melih Yildirim, irat Kacar, 2019). In (2019), Manisha and Dahiya presented a mirror ray transfer technique for image enhancement purposes. A two-stages model has framed for the proposed technique implementation. At the first stage, the mirror ray reflection behavior has been evaluated in a matrix form using the paraxial approximation method, which acts as a filter mask for the second stage. In the second stage, the evaluated mirror ray transfer matrix
mask is applied to a sub image of size 2*2 using sliding neighborhood operation (Manisha, Dahiya, 2019). In (2020), Raghavendra et al., presented equalization and specification of histogram techniques’ practical implementation on some images for image contrast enhancement. It was observed that these techniques worked quite well to improve picture visual quality (Raghavendra et al., 2020). Learning from the above literature research works, this paper aims at proposing a system, which operates based on the adaptive image enhancement principles. Our system has two stages, in the first stage, it selects the best filter based on the similarity value of a center pixel with its neighbors. In the second stage, the proposed method is used to calculate the value of the center pixel of the 3x3 mask depending on local neighborhood intensity pattern and fuzzy filter.

**Image Noise and Types**

The random variation of color information or brightness in images caused by the sensor and circuitry of a scanner or digital camera is called the image noise. The noisy image can be categorized as external or internal. There are many types of noise (Onyuka et al., 2020), such as:

1. Salt and Pepper Noise: Impulse noise or shot noise or binary noise.
3. Speckle Noise: Can be modeled by random values multiplied by pixel values.
4. Periodic Noise: Image signal which is periodic rather than random disturbance.

**Image Enhancement**

Image enhancement is one of the important tasks in image processing; the purpose of it is to improve the visual appearance of an image for human or computer. More details are provided in the next subsections:

1. **Histogram Equalization**

   Histogram Equalization (HE) is used to enhance color image contrast. It is one of the easiest and least complex methods of improving color image quality. It distributes the image pixels over the dynamic range to enhance the image contrast (Pritee Singh R., Amit C., 2015). The HE operation is edited by remapping the gray levels of the image based on the probability distribution of the input gray levels. It flattens and stretches the dynamic range of the histogram of the image and results in overall contrast enhancement. HE normally changes the brightness of the input image significantly and makes some of the uniform parts of the
output image become saturated with very bright or dark intensities (Mehdi et al., 2016). The general histogram equalization formula is:

\[
h(v) = \text{round} \left( \frac{cdf(v) + cdf_{\min}}{(M+N) - cdf_{\min}} \ast (L - 1) \right)
\]

Where \( cd_{\min} \) the minimum non-zero value of distribution function, \( M \times N \) the number of pixels, \( L \) the number of grey level.

2. Laplacian of Gaussian Filter

LoG is the Laplacian and Gaussian arithmetic convolution, both edges and noise can be identified by the Laplace operator, smooth the image with a Gaussian kernel \( \sigma \).

\[
G\sigma = \frac{1}{\sqrt{2\pi \sigma^2}} \exp \left( -\frac{M^2 + N^2}{2\sigma^2} \right)
\]

where \((M, N)\) is the image space, \( f(M, N) \) is the pixel intensity. The LoG as an operator or convolution kernel defined as:

\[
LoG(M, N) = -\frac{1}{\pi \sigma^4} \left[ 1 - \frac{M^2 + N^2}{2\sigma^2} \right] \exp \left( \frac{M^2 + N^2}{2\sigma^2} \right)
\]

3. Local Neighborhood Intensity Pattern

The (LNIP) method is built on the idea that a particular pixel's neighbors contain amount of texture information that used for efficient texture representation. This method represents the variation in intensity between a specific and center pixels that represents the adjacent neighborhood then generates the sign and the magnitude pattern. Lastly, an efficient feature descriptor is generated through the concatenation of sign and magnitude patterns. This method uses a 3×3 window to determine the Local Neighborhood Intensity Pattern. \( P_c \) represents pixel center and its 8 neighbors \( P_1, P_2, P_8 \). It can be concluded that \( P_i \) among the 8 neighborhood pixels in the 3×3 has 4 adjacent pixels if \( P \in \text{odd} \), and 2 adjacent pixels if \( P \in \text{even} \). \( S_i \) refers to an adjacent pixel about \( P_i \). The mathematical definition is given by equations (4) and (5).

\[
S_i = \{I_{1+\text{mod}(i+5,7)}, I_{1+\text{mod}(i+6,9)}, I_{i+1}, I_{1+\text{mod}(i+2,8)} \} \quad \forall i = 1, 3, 5, 7
\]

\[
S_i = \{I_{i-1}, I_{\text{mod}(i+1,8)} \} \quad \forall i = 1, 3, 5, 7
\]
The $N$ bit pattern concerning $P_i$ has been gated, where $N$ is the elements number in $S_i$. The binary pattern $B_1$, $i$ calculated by equation (6), and the binary pattern $B_2$ with the same size have been calculated corresponding to the center pixel calculated by equation (7).

$$B_{1,i}(k) = \text{sign}(S_i(k),I_i) \text{ where } k = 1 \text{ to } M$$

(6)

$$B_{2,i}(k) = \text{sign}(S_i(k),I_c) \text{ where } k = 1 \text{ to } M$$

(7)

The single bit ($I_i$) is calculated by comparing the two patterns $B_1, B_2$, $i$, this is down by applying XOR operation between the two patterns. The same pixels give 0 as output and the different pixels give 1. An $N$ bit pattern $D_i$ is obtained as in equation (8). The XOR of two dissimilar bits are equal to 1, where ($D_i=1$). In the two $N$ bit, the total number of positions different in range from 0 to $N$. where, $N = 4$, if $i$ is odd; $N = 2$ if $i$ is even. The threshold of the binary bit is given by equation (9). In the same way, every pattern in 8 neighboring pixels has been calculated by using $P_i$ and $S_i$, where $i=1, 2, 3, ..., 8$. The central pixel ($P_c$) is calculated by equation (9)

$$D_i = \text{XOR} \left(SB_{1,i}, B_{2,i}\right)$$

(8)

$$\text{LNIPs} \left(Ic\right) = \sum_{i=1}^{8} 2^{l-1} \times B(I_i, I_c)$$

(9)

4. Fuzzy Filter

The fuzzy idea is to take the pixel value based on its neighbors, taking into account the image structure by recognizing variations due to noise or image structure. Each pixel value is derived based on its neighbors by a fuzzy rule. The small value most likely is caused by noise, and the large value most likely is caused by an image edges. The fuzzy rules will apply to determine the neighboring pixel values (Arunkumar et al., 2019), (Jaya V. L., 2013).

Fuzzy pixel value is calculated by equation 10.

$$V(I) \left((1 / (1 + (a \times I) / \text{max}))) - \text{min} \right)$$

(10)

Where $V(I)$ = fuzzy pixel value, $I$ = pixel value, $\text{Max}$ = maximum value for 8-neighborhood of the pixel, and $\text{Min}$ = minimum value for 8-neighborhood of the pixel.

Proposed System

This paper aims to suggest a system that works on the principles of adaptive image enhancement. The proposed system passes through two stages, the first stage is choosing
the best filter depending on the similarity value of a center pixel with its neighbors, and in the second stage, and we apply the proposed method to calculate the value of the center pixel of 3x3 mask depending on local neighborhood intensity pattern and fuzzy filter. The images are used in this system have different sizes and types. The work started by using a 3x3 mask window that moves through the image pixel by pixel. If the center pixel has the same value with all the 8 adjacent neighbor pixels, then the value of the center pixel stays the same value, else if the center pixel has the same value; larger than or equal to 7 from adjacent neighbors pixels that approximately 75% then the histogram equalization method is applied, else if the value of center pixel has the same value between (4 to 6) from adjacent neighbors pixels approximately between (35% to 66%), then the Laplacian of Gaussian filter is applied. If the number of similar pixels is less than or equal to 3 with adjacent neighbors pixels. The proposed method is applied based on the intensity difference between the specific pixel and the center pixel with neighbors, then the sign and magnitude patterns are generated and connected to generate an efficient pattern descriptor, the pattern value represents the central pixel value and this central pixel value considers the input to the fuzzy filter. Example 1 describes this process (See Fig 1), the steps of the proposed system are described in Fig 2, and algorithms 1 and 2 describe the steps of the proposal system.

Fig. 1 Example 1 of describing the process
Algorithm 1: Proposed Image Enhancement Filter
Input: Original image with Noise
Output: Enhanced image
Begin
Step 1: Get the image with noise
Step 2: Do Until not EOF (image file).
Step 3: Separate the color component to three color bands (R, G, and B).
Step 4: Apply the convolution mask (3 X 3) then sort the image pixels.
Step 5: Find Min=Minimum, Max=Maximum, and Med= Median values.
Step 6: for all pixels in the matrix.
Step 7: Calculate count similar = similar pixel.
If count similar = similar pixel in matrix then pixel = pixel value
Else
If count similar ≥7, then use the histogram equalization equation (1).
Else
If count similar ≥4 and count similar ≤ 6, then use the Laplacian of Gaussian Equation (3).
Else
If count similar ≤ 3 then call algorithm 2
End If
Step 8: End for
End

Fig. 2 Block diagram of the proposed system
Algorithm 2: Fuzzy with Local Neighborhood Intensity Pattern

Input: Center pixel, |Neighbors pixel

Output: Enhanced Center Pixel

Begin

Step1: Calculate the intensity difference for the 8 neighbors ($P_1=1$, $P_2=2$, $P_8=8$) of a center pixel by using equations (4, 5)

Step2: For $k=1$ to $N$ (number of elements in $S_i$)

Step3: for $i = 1$ to 8

Calculate $B_{1,i}$ for ($P_i$) using equation (6).

Calculate $B_{2,i}$ for the center pixel ($P_i$) that represents the same neighbors of $S_i$ by using equation (7).

Get a $D_i$ by Calculating bitwise XOR on $B_{1,i}$ and $B_{2,i}$ using equation (8).

Find the (LINP) pixel corresponding to central Pixel using equation (9).

Step4: End for

Apply the fuzzy filter for LINP pixel to find the enhanced pixel by using the equation (10).

Step5: End for

End

Results

In this section, the effectiveness of the proposed system is proved using a set of images with different sizes and different file formats; Fig. 3 lists some of these results.

![Fig. 3 Results of Proposed System for both Gray Scale and Color Images](image)

The tested results are discussed and compared through various tables and images where the proposed system was compared with fuzzy enhancement filter described in Figures (4, 5, 6, 7, 8, and 9) that show the results of the comparison between the proposed system and the enhancement filter.
Fig. 4 Comparing results with existence filters (a) the original color images, (b) apply the fuzzy filter on the noisy image, (c) the result of proposed algorithm

Fig. 5 Comparing results with existence filters (a) the original color images, (b) applying the fuzzy filter on the noisy image, (c) show the result of proposed algorithm

Fig. 6 Comparing results with existence filters (a) the original color images, (b) apply the fuzzy filter on the noisy image, (c) the result of proposed algorithm

Fig. 7 Comparing results with existence filters (a) the original color images, (b) apply the fuzzy filter on the noisy image, (c) the result of proposed algorithm
Fig. 8. comparing results with existence filters (a) the original color images, (b) apply the fuzzy filter on the noisy image, (c) the result of proposed algorithm

Fig. 9 Comparing results with existence filters (a) the original color images, (b) applying the fuzzy filter on the noisy image, (c) the result of proposed algorithm

Referring to (Gupta and Porwal, 2016), performance evaluation is conducted in this paper. Thus, a comparison of the proposed enhancement filter with fuzzy enhancement filter is carried out. Comparative analysis has shown that the proposed enhancement filter is in a much better way and thus it is used for the same purpose. Many parameters are used for this comparative analysis namely Entropy (EN), (MSE), (PSNR), (AMBE), Measure of Enhancement (EME), and Measure of Enhancement by Entropy (EMEE), Second-Order Entropy (SOE) and Image Enhancement Metric (IEM). The details about basic Measures of Image Enhancement are below:

i. Entropy: Entropy is the randomness measure of image texture.

$$\text{Entropy} = - \sum_{k=0}^{G-1} P(m) \log_2(P(m))$$    \hspace{1cm} (11)

Where $P$ is the histogram of the image segment.

ii. Mean Square Error: (MSE) is an expected value of squared errors. It can be calculated by the equation:
\[ \text{MSE} = \sum_{M,N} \frac{(x-y)^2}{M*N} \quad (12) \]

\( M \) and \( N \) represent the number of rows and columns in the input images \( x \) and \( y \).

iii. Peak Signal-to-Noise Ratio: Peak Signal-to-Noise Ratio (PSNR) is used to calculate the ratio between the max signal power and the noise that affects an image. PSNR is usually calculated as:

\[ \text{PSNR} = -10 \log_{10} \frac{R^2}{\text{MSE}} \quad (13) \]

Where \( R \) is the maximum pixel value. PSNR is measured in decibels (dB).

iv. Absolute Mean Brightness Error: Absolute Mean Brightness Error is used to calculate the mean of gray levels between the original and enhanced images. The AMBE is calculated by equation (14):

\[ \text{AMBE} = |E[Z] - E[R]| \quad (14) \]

Where \([Z]\) and \([E[R]\) the original, enhanced images. \( m, n \) a size of image. The original and enhanced image is given as:

\[ E[R] = \frac{1}{m \times n} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} (A(x,y)) \quad (15) \]

\[ E[Z] = \frac{1}{m \times n} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} (B(x,y)) \quad (16) \]

v. Complex Measurement of Image Enhancement: These measures depend on contrast measures, image background, texture, and noise. They are described as follows:

a) The measure of Enhancement (EME): The measure of Enhancement (EME) is appropriate for uniform background, small targets, and segments without randomness. The EME is defined as:

\[ EME_{rc} = \frac{1}{S \times t} \sum_{k=1}^{S} \sum_{l=1}^{t} \left[ 20 \ln \left( \frac{l_{max, k,l}}{l_{min, k,l}} \right) \right] \quad (17) \]

b) The measure of Enhancement by Entropy (EMEE): The measure of Enhancement by Entropy (EMEE) represents the absolute value in an image based on image contrast, the EMEE is defined as:
c) Second-Order Entropy (SOE): is the image enhancement based on first-order entropy that less sensitive to noise. The drawback of this metric is to ignore the correlation among pixels. The second-order enhancement metric is more sensitive to noise. In SOE, the co-occurrence matrix is used for spatial correlation. Let $a, b$ represent an image size, $G$ gray level, then the correlation of the image is given as:

$$C_{mn} \sum_{m=0}^{b-1} \sum_{n=0}^{a-1} \varphi (lk)$$

(19)

Where $c_{mn}$ is the correlation element.

$$A(l, k) = i, A(l, k + 1) = n$$
$$\varphi(l, k) = 1 \text{ if and/or } A(l, k) = i, A(l, k) = i, A(l + 1, k) = n$$
$$\varphi(l, k) = 0 \text{ otherwise}$$

(20)

(21)

The co-occurrence probability $p_{nm}$ is computed as:

$$p_{nm} = \frac{c_{nm}}{\sum_{k=0}^{b-1} \sum_{l=0}^{l-1} c_{nm}}$$

(22)

and the SOE is computed as:

$$SOE = - \sum_{i} \sum_{j} p_{i,j} \log_2 p_{i,j}$$

(23)

IEM represents the ratio of the sum of absolute differences for all 8-neighbors pixels in original and enhanced images and is calculated by:

$$IEM_{8n} = \frac{\sum_{k_1=1}^{k_1} \sum_{l_1=1}^{k_2} \sum_{n_1=1}^{8} \sum_{n_2=1}^{8} |I_{e,c}^{l,m} - I_{e,n}^{l,m}|}{\sum_{m=1}^{k_1} \sum_{l=1}^{k_2} \sum_{n=1}^{8} I_{e,c}^{l,m} - I_{e,n}^{l,m}}$$

(24)

Where the image is divided into $k_1, k_2$ blocks of size 3 x 3 and $I_{e,c}^{l,m}, I_{e,n}^{l,m}$ is a center pixel intensity in $(l, m)$ block of original and enhanced images. $I_{n}^{l,m}$, $n=1, 2, 8$ represent the 8 neighbors of the center pixel. Figure 10 shows the images that were used for the evaluation metrics on the proposed method. The results of applying the performance evaluation metrics on the proposed system are shown in Table 1.
The results of comparison between the proposed system and Fuzzy Filter of the MSE, PSNR, and the entropy metrics are shown in Tables 2, 3, and 4 and Figures 11, 12, 13.

Table 1 The results of evaluation metrics on the proposed system

<table>
<thead>
<tr>
<th>Images</th>
<th>MSE</th>
<th>PSNR</th>
<th>EMBE</th>
<th>Entropy</th>
<th>SOE</th>
<th>EME</th>
<th>EMEE</th>
<th>IEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>2.532</td>
<td>7.932</td>
<td>6.72</td>
<td>4.823</td>
<td>2.853</td>
<td>5.021</td>
<td>0.311</td>
<td>3.620</td>
</tr>
<tr>
<td>(b)</td>
<td>1.316</td>
<td>8.274</td>
<td>6.18</td>
<td>3.735</td>
<td>2.726</td>
<td>4.960</td>
<td>0.382</td>
<td>3.733</td>
</tr>
<tr>
<td>(c)</td>
<td>3.385</td>
<td>9.081</td>
<td>4.92</td>
<td>2.981</td>
<td>3.427</td>
<td>3.497</td>
<td>0.253</td>
<td>4.825</td>
</tr>
<tr>
<td>(d)</td>
<td>2.906</td>
<td>8.875</td>
<td>3.92</td>
<td>5.154</td>
<td>2.692</td>
<td>3.915</td>
<td>0.442</td>
<td>3.674</td>
</tr>
<tr>
<td>(e)</td>
<td>1.22</td>
<td>6.768</td>
<td>5.56</td>
<td>5.778</td>
<td>3.083</td>
<td>4.455</td>
<td>0.529</td>
<td>4.862</td>
</tr>
<tr>
<td>(f)</td>
<td>1.842</td>
<td>6.831</td>
<td>5.73</td>
<td>2.612</td>
<td>3.117</td>
<td>3.925</td>
<td>0.324</td>
<td>4.411</td>
</tr>
</tbody>
</table>

Table 2 The Comparison of the MSE values with fuzzy enhancement filter

<table>
<thead>
<tr>
<th>Images</th>
<th>size</th>
<th>Fuzzy Filter</th>
<th>Proposed Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>225 x 225</td>
<td>3.412</td>
<td>2.532</td>
</tr>
<tr>
<td>(b)</td>
<td>255 x 255</td>
<td>2.217</td>
<td>1.316</td>
</tr>
<tr>
<td>(c)</td>
<td>240 x 240</td>
<td>4.280</td>
<td>3.385</td>
</tr>
<tr>
<td>(d)</td>
<td>255 x 255</td>
<td>3.577</td>
<td>2.906</td>
</tr>
<tr>
<td>(e)</td>
<td>169 x 260</td>
<td>2.081</td>
<td>1.22</td>
</tr>
<tr>
<td>(f)</td>
<td>255 x 165</td>
<td>2.605</td>
<td>1.842</td>
</tr>
</tbody>
</table>

Table 3 The Comparison of PSNR values with fuzzy enhancement filter

<table>
<thead>
<tr>
<th>Images</th>
<th>Fuzzy Filter</th>
<th>Proposed Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>5.615</td>
<td>7.932</td>
</tr>
<tr>
<td>(b)</td>
<td>4.175</td>
<td>8.274</td>
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<td>9.081</td>
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<td>(d)</td>
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<td>8.875</td>
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<td>(e)</td>
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<td>6.768</td>
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<td>(f)</td>
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<td>6.831</td>
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Table 4 The Comparison of Entropy values with fuzzy enhancement filter

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<th>Proposed Filter</th>
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<td>(a)</td>
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<td>(f)</td>
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<td>2.612</td>
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Fig. 11 The Comparison of MSE values with fuzzy enhancement filter

Fig. 12 The Comparison of PSNR values with fuzzy enhancement filter

Fig. 13 The Comparison of Entropy values with fuzzy enhancement filter
Conclusions

In this paper, an effective image enhancement system was presented. The system passed through two stages, for denoising and enhancing the images, the first stage was choosing the best filter depending on the similarity value of a center pixel with its neighbors, and in the second stage, we applied the proposed method to calculate the value of the center pixel of 3x3 mask depending on local neighborhood intensity pattern and fuzzy filter. The evaluation of the enhancement method was done by using several quality metrics, such as MSE, PSNR, AMBE, EME, EMEE, Entropy, SOE, and IEM. The results showed that the proposed system yields more efficient MSE, PSNR, AMBE, EME, EMEE, E, SOE, and IEM in comparison with other enhancement filters. The results of this system can be applied in wide practical applications, such as satellite images and medical images. In the future, the proposed enhancement system can be applied to video processing and we will study the results of other possible measures.

Conflict of Interest

The authors assert that no conflict of interest exists.

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References


