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A Comparative Study on Image Enhancement Using Image Fusion

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Abstract—Image enhancement is used for improving the visual quality of an image. In this paper two methods for image enhancement using image fusion have been described. The process of image fusion uses a source image and its histogram equalized image. The two algorithms discussed assigns weights to the source image and its histogram equalized image. First algorithm assigns weight manually whereas the second algorithm assigns them automatically. The two algorithms are compared using standard deviation and average gradient.

Keywords— Histogram Equalization, Image fusion, Gradient, Image Statistics, Edge detection.

I. INTRODUCTION

The fundamental goal of image enhancement is to process the input image in such a way that the output image is more suitable [1] for interpretation by the humans as well as by machines. There are numerous techniques available in the literature for image enhancement depending on the specific application. Contrast enhancement by histogram equalization is one such technique. A histogram equalized image enhances the hard to perceive details of the original image. Nevertheless the original image contains useful information. As a result techniques like image fusion [2] can be used to preserve the details of both the images.

In this paper two algorithms for image fusion has been described and compared. Section 2, 3, 4, 5 contains the related background information. Section 6 outlines the two algorithms, section 7 shows the simulation results. Finally, section 8 concludes this work.

II. HISTOGRAM EQUALIZATION

The histogram of an image represents the frequency of occurrence of all the gray levels in an image. If $n(k)$ is the frequency of k^{th} intensity level and n is the total number of pixels in the gray-level image then the normalized histogram is given by the equation

$$p(k) = \frac{n(k)}{n} \quad (1)$$

The conventional histogram equalization is based on cumulative frequency distribution which is given by the equation

$$c(k) = \sum_{j=0}^{k} p(j) \quad (2)$$

A disadvantage of using conventional histogram equalization (CHE) is it doesn't preserve the original brightness of the image. Various brightness preserving histogram equalization techniques have been proposed in the literature. Brightness preserving bi-histogram equalization (BBHE) [3], divides the input histogram into two subsections based on the average value of the image. Dualistic sub-image histogram equalization (DSIHE) [4] also separates the input histogram into two subsections, but the separation is based on the median. Recursive mean separate histogram equalization (RMSHE) [5] recursively divides the histogram into several subsections based on the local mean values.

III. IMAGE FUSION

The process of image fusion is used to combine two or more images. The main idea behind image fusion is that different images contain different information. For example the image of the scene which is focused to the left contains different information than the one which is focused on to the right. By fusing these two images we can retain the best features of the two images. Similarly lower resolution multispectral images can be fused with higher resolution panchromatic images to get high resolution images which can provide insightful information about the scene under consideration. This type of image fusion is most commonly used in remote sensing. Thus there can be different sources for image fusion.

Image fusion can be divided into signal level fusion, pixel level fusion, feature level fusion and decision level fusion [7]. In signal level fusion the main idea is to improve the signal to noise ratio by combining the information from different sources. In pixel level fusion the pixel set from all the source images is fused. This process is repeated for all the pixels. In feature level fusion salient features are extracted from a given set of images and then these features are fused together. Finally decision level fusion involves the extraction of information from the given set of images. The extracted information is then combined using decision rules.

For image fusion to take place the set of source images needs to be registered i.e. the images needs to be aligned spatially.

For our proposed algorithm we use pixel based fusion of source and its histogram equalized image. Conventional histogram equalization is used for the purpose of equalization.

An expression [2] to obtain a fused image *if* with two source images is given as

$$If = w * I1 + (1-w) * I2 \tag{3}$$

Where *I1* and *I2* are the two images and $0 \le w \le 1$.

IV. IMAGE GRADIENT AND EDGE DETECTION

An image can be mathematically represented by a two dimensional function *f(x, y)*. For an image function *f(x, y)*, the gradient [1] of *f* at *(x, y)* is defined as the two dimensional column vector.

$$\nabla f = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \tag{4}$$

For our present work we are interested in the magnitude of the gradient which is calculated by using the following formula:

$$|\nabla f| = \left[\left(\frac{\partial f}{\partial x} \right)^2 + \left(\frac{\partial f}{\partial y} \right)^2 \right]^{1/2} \tag{5}$$

Here $|\nabla f|$ is the magnitude of ∇f and $\frac{\partial f}{\partial x}$ is the derivative of the two dimensional function *f(x, y)* in the x direction whereas $\frac{\partial f}{\partial y}$ is the derivative in y direction. In digital image processing $\frac{\partial f}{\partial x}$ and $\frac{\partial f}{\partial y}$ are approximated using filter masks or kernels. The most commonly used filter masks are of the order 3 × 3 and can be approximated [1] by the equations shown below:

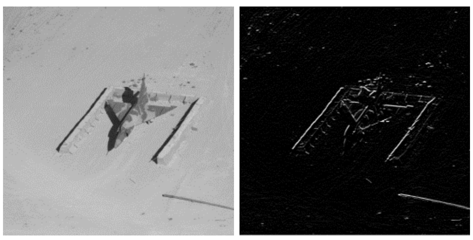
$$G_x = (z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3) \tag{6}$$

$$G_y = (z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7) \tag{7}$$

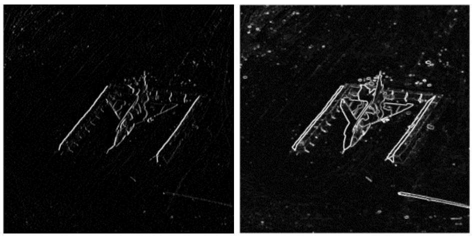
Z1	Z2	Z3
Z4	Z5	Z6
Z7	Z8	Z9

Fig. 1. Filter mask

The magnitude of the gradient gives the maximum rate of increase of *f(x, y)* per unit distance in the direction of gradient [1]. This is an important quantity for detecting edges in an image. Fig. 2 shows an airplane image and its gradient to detect the edges.



(a) (b)



(c) (d)

Fig. 2. (a) Original image (b) Image after applying x-direction Sobel mask Eq. (6) (c) Image after applying y-direction Sobel mask Eq. (7) (d) Image after calculating gradient.

V. IMAGE STATISTICS

A. Standard Deviation

Standard deviation is the deviation about mean. It represents the dynamic range of values present in an image about the mean. Greater is the standard deviation greater is the contrast of the fused image. If *m* is the mean of the image, then the standard deviation about the mean is given by:

$$STD = \sqrt{\frac{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}(I(x,y)-m)^2}{MN}} \quad (8)$$

Here, *I(x, y)* is the intensity of the pixel, M is the number of rows and N is the number of columns.

B. Average Gradient

Average gradient is used for measuring the clarity of the image. More the average gradient more is the clarity of the image. Average Gradient is given by the formula:

$$AG = \frac{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} g(x,y)}{MN} \quad (9)$$

Here, *g(x, y)* is the magnitude gradient at location *(x, y).*

VI. ALGORITHMS

A. First Algorithm

The first algorithm uses a simple approach of first finding the conventional histogram equalized image of the original image. After this weight *w* is manually selected and used in Eq. 3 to get the fused image. Here, I_1 is the original image and I_2 is the histogram equalized image.

B. Second Algorithm

Weights can also be assigned automatically [6]. For calculating the weights automatically first edge strengths in original source image and its histogram equalized image is calculated. After this a weight function is used to calculate the weight values based on the strength of edges. This calculation of weight values is carried pixel by pixel. The outline of the second algorithm for grayscale images is as follows:

- Let the input image is I_1.
- Compute the conventional histogram equalized image I_2 from I_1.
- Calculate magnitude gradient of I_1 to get the edge map S_1.
- Calculate magnitude gradient of I_2 to get the edge map S_2.
- Calculate $S = S_1 - S_2$.
- Calculate the absolute maximum value of matrix *S*.
- Normalize the matrix *S* with the absolute maximum value.

For each pixel located at position *(x, y)* repeat the following steps:

- Calculate *w = (1 / (1 + 10^ (-S(x, y))))*. This function is used for weighting each pixel based on the strength of edges of I_1 and I_2. If $S_1(x, y) > S_2(x, y)$, then $I_1(x, y)$ is given the higher weightage and $I_2(x, y)$ the lower weightage. But if $S_2(x, y) > S_1(x, y)$, then $I_2(x, y)$ is given the higher weightage and so on.
- Use the value of *w* in equation (3) to find the fused image *If(x, y).*

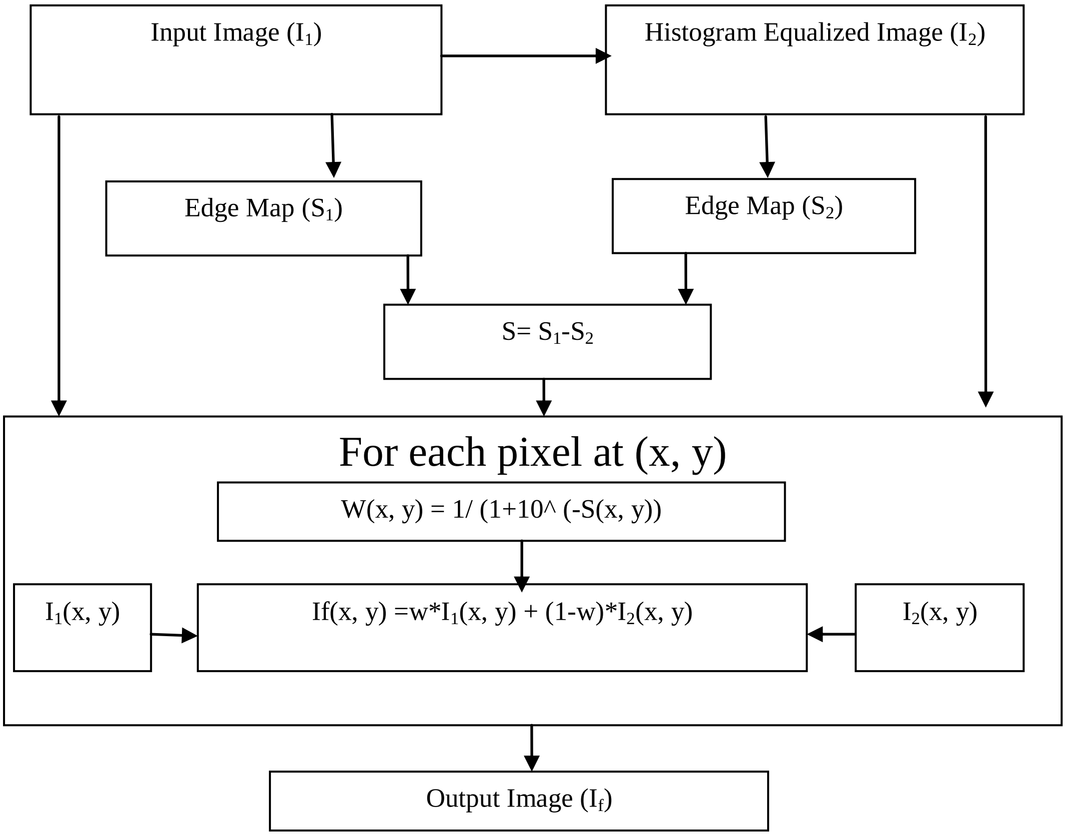
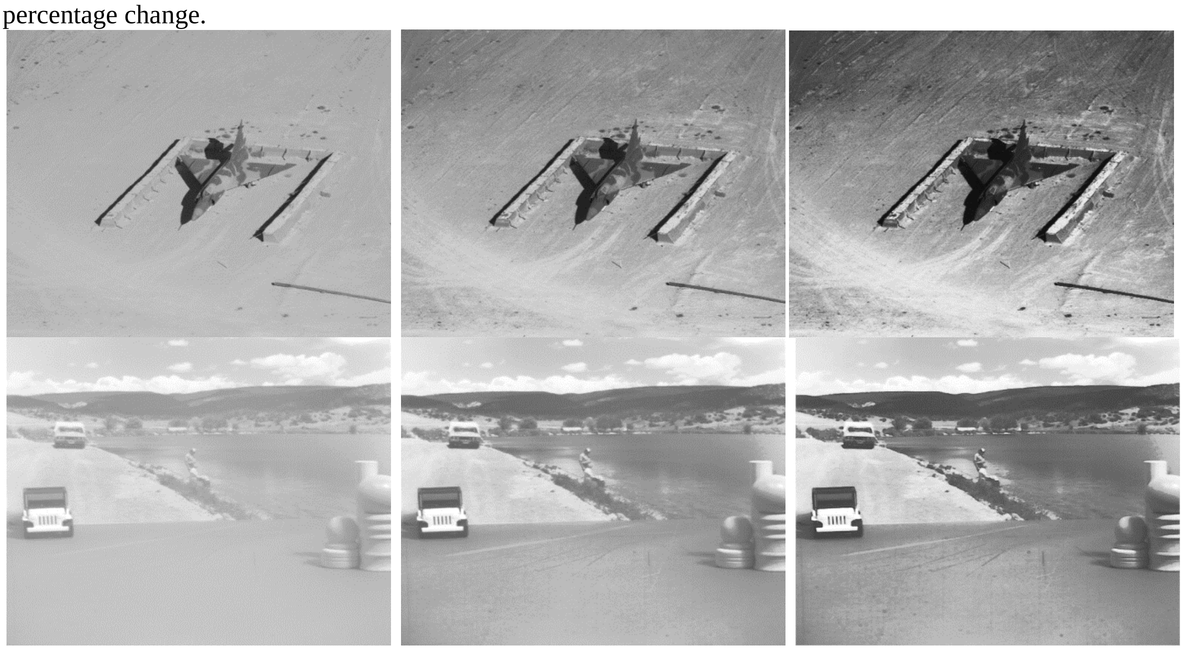


Fig. 3. Flowchart for grayscale images

VII. SIMULATION RESULTS

In this section, we apply the algorithms described above on a set of images. The analysis of the simulation is based on subjective and objective analysis. In subjective analysis human ingenuity is used to verify the results. The subjective analysis by humans is not reliable and hence one has to depend on objective analysis in order to arrive at meaningful conclusions. Objective methods used for the measurement of image fusion performance are statistical in nature. Here we used the standard deviation and average gradient for comparing the performance of the two algorithms. For the first algorithm we manually select the value of *w* as 0.7 [2]. The simulation results are shown in Fig. 4 and Tables 1, 2. All the simulation has been carried out using double data type in MATLAB. This is not a problem since we are interested in the percentage change.



(a) (b) (c)

Fig.4. (a) Original images (b) Result of using first algorithm (c) Result of using second algorithm

Image	Manual	Automatic	% Change w.r.t manual
Airplane	0.1363	0.1867	36.9773
Road	0.1450	0.1925	32.7586
Bridge	0.2369	0.2546	7.4715
Crowd	0.2197	0.2349	6.9185

Table 1: Comparison between manual and automatic algorithms using Standard Deviation

Image	Manual	Automatic	% Change w.r.t manual
Airplane	0.1990	0.2862	43.8191
Road	0.1344	0.1788	33.0357
Bridge	0.4551	0.5062	11.2283
Crowd	0.3272	0.3706	13.2641

Table 2: Comparison between manual and automatic algorithms using Average Gradient

VIII. CONCLUSION

Comparing the simulation results in Fig. 4 and Tables 1, 2 one can easily find out that the second algorithm not only automates the selection of assigning the weights but also enhances the original image in terms of standard deviation and average gradient as compared to the first algorithm. It means the second algorithm increases the contrast and the clarity (sharpness) of the original image.

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