Enhancing dull images using discrete wavelet families and fuzzy

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Abstract: Enhancement of an image which is dull is used in important application like restoring an image. Especially when enhancing a gloomy image it becomes quite difficult. Hence a simpler but effective method for enhancing the image is proposed here. Here a novel method based on graphical user interface which allows the user to enhance the image based on their requirement is proposed. The algorithm used for this is the discrete wavelet transforms families which will decompose the dull image. The four approximation coefficient obtained after decomposition are further manipulated using fuzzy logic in order to enhance the image. And then inverse discrete wavelet transform is used to reconstruct the image. Experimental results show that the proposed method is robust in enhancing the quality of images.

Keywords: Image enhancement; discrete wavelet transform; fuzzy.

1. Introduction

Image enhancement finds its application in many fields. Be it computer vision or satellite imaging, there are two kinds of image enhancement technique which require high cost source. The first one is to use a high end camera to get an enhanced image and the second one uses a low end camera. Image enhancement uses algorithms like histogram equalization and transformation based methods where a gloomy image is enhanced. Most of the algorithms work only for a specific set of images. To overcome this, an algorithm which is robust as well as works for all the gloomy images is required. Here a robust algorithm is proposed for the enhancement of gloomy images which uses both discrete wavelet transform and fuzzy combination.

The algorithm used here increases the quality of the image with better peak signal noise ratio and good structural similarity index, which are considered as a quality metrics for evaluating the image. The gist of the system is to develop a graphical user interface that will allow the user to enhance the image automatically according to their requirements and to use the enhanced image for further applications.

The main motivation behind this work is necessity for an image to be enhanced to get the accurate details of the image. The contribution to the present work includes;
1. Use of discrete wavelet and fuzzy combination to enhance the image.
2. The variations of the enhanced image is done using different wavelet families like Haar and Symlets then compared with each other.
3. Applying graphical user interface to assist the user according to his/her requirements for image enhancement.

2. Literature survey

Related works have been proposed for image enhancement. A commonly used method is histogram equalisation (HE). The drawback of traditional HE is over enhancement. This is mainly because redistributing the global image and intensity contrast is not applied appropriately in a local context. Many methods have been used to resolve this issue, such as layered representation, hue and range preserving, brightness preserving, and adaptive gamma correction [1], [2], [3], [4], [6].

For gloomy images, the histograms of different areas vary, HE may need to use different constraints in different local area, that is hard to achieve. In [5], Ueda et al. propose a hue preserving color image enhancement method which is executed on a vector space of convex combination coefficients and claim that it does not generate the color gamut problem [9], [10], [11], [12].

And the notable theory that should be considered is the retinex theory that gives an effective tool for adjusting the brightness of low-light image by factorizing its values in terms of illumination and reflectance. In [8], a retinex image enhancement algorithm is proposed based on maximum and guided filters to improve the brightness of low-light images [15].

Yang et al. in [7] separated the input image into two visual pathways: structure-pathway and detail-pathway, corresponding to the M- and P-pathway in the early visual system, which code the low- and high-frequency visual information, respectively [13], [14]. In this work has been carried out with the combination of Discrete Wavelet Transform (DWT) and fuzzy logic. This combination is used to enhance gloomy images as well as non-uniformly illuminated images [16], [17].

2.1. Theoretical Background

2.1.1. Haar wavelets

In this section a brief note on Haar wavelets is discussed. Assume \( \lambda(x) = 1 \) with \( x \) ranging from 0 to 1. The scaling function is given as,

\[
\lambda(x) = \lambda(2x) + \lambda(2x - 1)
\]  

(1)

Since we have scaling function as \( \lambda(x) = \sum_{i \in \mathbb{Z}} k_i \sqrt{2^i} (2x - i) \) we can write equation 1 as,

\[
\lambda(x) = \frac{1}{\sqrt{2}} \sqrt{2^0} (2x) + \frac{1}{\sqrt{2}} \sqrt{2^0} (2x - 1)
\]  

(2)

With \( k_0 = k_1 = \frac{1}{\sqrt{2}} \) being the wavelet filter coefficients.

2.1.2 Symlet wavelets

On analysing scaling/wavelet and the discrete filters functions of Daubechies wavelets, it is found that these Daubechies functions are not symmetrical. This is because Daubechies wavelets select the minimum phase square root such that the energy concentrates near the starting point of their support. Symlets select other set of roots to have closer symmetry but with linear complex phase [18].

3. Proposed system

The working model for the proposed system is shown in Figure 1. Here the image was enhanced using the DWT and fuzzy combination. The discrete wavelet transform used are Haar and Symlet.
3.1 Pre-processing and image enhancement

The input image has to be pre-processed for enhancing the image. For pre-processing the input, RGB image is converted into HSV image. Then the planes have to be separated into H-plane, S-plane and V-plane individually. Further processing is carried out on the V plane. DWT is used to transform the V plane to get approximation coefficients, horizontal coefficients, vertical coefficients and diagonal coefficients[19][20].

Applying fuzzy logic based manipulations on the approximation coefficients of the DWT at first, the desired enhanced image is obtained. To the image then Haar based DWT and Symlet based DWT were applied. Inverse DWT (IDWT) is used to reconstruct the image after fuzzy logic based transformations is carried out on the transformed image. Table 1 shows the fuzzy rule base for image enhancement which were arrived based on trial and error method[21][22][23]. The following rules were applied; if the input is mf1 then the output is mf1. Similarly, if...then rules were applied for mf2, mf3, mf4 and mf5.

| Input | Output |
|-------|--------|
| Mf    | A | b | C | mf | a | B | c |
| mf1   | X | x | X | mf1 | -50 | 0 | 50 |
| mf2   | X | x | X | mf2 | 50 | 100 | 150 |
| mf3   | X | x | X | mf3 | 100 | 150 | 200 |
| mf4   | X | x | X | mf4 | 185 | 220 | 255 |
| mf5   | X | x | X | mf5 | 180 | 255 | 330 |

mf-membership function, a,b,c-parameters of triangular membership function, x – Variables.

4. Experimental results and discussion

Here two evaluation metrics are used. Peak signal noise ratio (PSNR) is defined as,

\[ PSNR = 10 \log_{10} \left( \frac{1}{MSE} \right) \]  

(3)
With MSE being the mean-square error and with the Structural Similarity Index (SSIM) the image is evaluated. The SSIM of the image improved is used to figure out the quality of the enhanced image. The SSIM of two images $I_{m1}$ and $I_{m2}$ is given by the luminance term, the divergence term, and the structural term using the formula,

$$SSIM(I_{m1}, I_{m2}) = [l(I_{m1}, I_{m2})]^\alpha \cdot [c(I_{m1}, I_{m2})]^\beta \cdot [s(I_{m1}, I_{m2})]^\gamma$$  \hspace{1cm} (4)

Where:

$$l(I_{m1}, I_{m2}) = \frac{2\mu_{I_{m1}}\mu_{I_{m2}}+C_1}{\mu_{I_{m1}}^2+\mu_{I_{m2}}^2+C_1}$$

$$s(I_{m1}, I_{m2}) = \frac{2\sigma_{I_{m1}}\sigma_{I_{m2}}+C_2}{\sigma_{I_{m1}}^2+\sigma_{I_{m2}}^2+C_2}$$

$$s(I_{m1}, I_{m2}) = \frac{\sigma_{I_{m1}I_{m2}}+C_3}{\sigma_{I_{m1}}\sigma_{I_{m2}}+C_3}$$

With $\mu_{I_{m1}}, \mu_{I_{m2}}, \sigma_{I_{m1}}, \sigma_{I_{m2}}$ and $\sigma_{I_{m1}I_{m2}}$ being the local means, standard deviations, and cross-covariance of the images $\alpha, \beta$ and $\gamma$ are the weights. $C_1, C_2,$ and $C_3$ are variables to stabilize the division with weak denominator. The results of SSIM of the improved image are shown in Table 2 and 3.

**Table 2.** PSNR and SSIM for the Haar based fuzzy image enhancement system

| Image | PSNR | SSIM |
|-------|------|------|
| #1    | 29.78| 0.9075|
| #2    | 32.95| 0.9686|
| #3    | 20.54| 0.8768|
| #4    | 28.15| 0.9141|

**Table 3.** PSNR and SSIM for the Symlet based fuzzy image enhancement system

| Image | PSNR | SSIM |
|-------|------|------|
| #1    | 14.64| 0.8658|
| #2    | 12.48| 0.844|
| #3    | 13.24| 0.8325|

Results of input image and enhanced image for Haar based image enhancement and Symlet based image enhancement is shown in Figure 2 and 3, respectively. The PSNR and SSIM for Haar based image enhancement is shown in Table 2 and Symlet based image enhancement is shown in Table 3, respectively.
Figure 2. Haar based fuzzy image enhancement system (a), (b), (c) and (d) are Input Images #1, #2, #3 and #4; (e), (f), (g) and (h) are enhanced output images.

Figure 3. Symlet based fuzzy image enhancement system (a), (b) and (c) are input Images #1, #2, and #3; (d), (e) and (f) are enhanced output images.

In order to automate the process a graphical user interface designed is shown in Figure 4. The variations in PSNR as shown in Figure 5 and the variations in SSIM as shown in Figure 6 indicates that the enhanced image is better in terms of efficiency.
Figure 4. A graphical user interface for image enhancement

Figure 5. Variations in PSNR for haar based image enhancement
5. Conclusions
A robust image enhancement technique is proposed. Here Discrete Wavelet Transform and fuzzy combination is used in order to enhance the image. Results show that the proposed method is optimal in terms of the efficiency of the system.

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