Study on degraded image sharpening method

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Abstract: In industrial practice, images are often collected for study. In bad weather, the images collected may be degraded to different extents. Therefore, it is necessary to study how to sharpen these degraded images. Presently, domestic and foreign scholars mostly realise sharpening of degraded images by improving and optimising the existing classic algorithms based on image enhancement techniques and image restoration techniques. Meanwhile, subjective and objective evaluation methods for image sharpening effects have also been proposed. The article presents an image enhancement algorithm with adjustable threshold and tuning parameter and verifies this algorithm through experiment by subjective and objective evaluation methods, proposing a new solution for degraded image sharpening.

1 Introduction

Image enhancement is a technology that enhances the contrast and brightness of degraded images by image enhancement algorithm and algorithm processing enables selective enhancement of interested areas of image. For human or machine, it is very necessary to analyse image and depress some useless information so as to increase the use value of images. Classic algorithms include Retinex algorithm, histogram equalisation, linear extrusion algorithm etc. At present, image enhancing techniques are more widely used than image restoration techniques.

Now, the study of available image enhancement methods covers three areas: (1) improvement based on histogram equalisation (HE) algorithm [1, 2]; (2) improvement based on Retinex algorithm [3, 4]; and (3) enhancement algorithm based on colour histogram [5, 6]. With regard to dust images, an image enhancement algorithm proposed by Zohair Al-Ameen achieves a uniformly distributed composite image histogram by decomposing RGB channels of image, restricting the threshold, introducing a tuning parameter and performing tuning processing of R, G, B channel, respectively, thus effectively solving the problem of low contrast and colour distortion of dust images.

Presently, the effectiveness of image processing algorithm is evaluated mainly by subjective vision and objective data methods. The subject evaluation method for images mainly depends on human subjective visual perception and focuses on image colour, contrast, and brightness restoration. Objective evaluation methods are classified into full reference, half reference, and no reference in light of demand [7, 8]. Of objective evaluation indices, image brightness and contrast are often measured by mean value (MV) and variance and image quality by mean-squared error (MSE) and peak signal-to-noise ratio (PSNR) [9, 10].

2 Design of image enhancement algorithm with adjustable threshold and tuning parameter

Starting from image enhancement techniques, this chapter proposes an image enhancement algorithm with adjustable threshold and tuning parameter. Based on analysis of histogram distribution of various degraded images, this algorithm improves the brightness and contrast of degraded images by adjusting threshold (τ) and tuning parameter (ζ) so as to acquire high imaging quality and subjective visual perception. This chapter introduces the designed fuzzy enhancement algorithm and gives the design flow frame diagram for this algorithm for better understanding by readers.

2.1 Linear normalisation algorithm

Linear normalisation algorithm maps the primary data of R, G, and B channels of image to 0, 1 interval at equal ratio, with the formula as follows [11]:

\[
f_R = \frac{[r - \min (r)]}{\max (r) - \min (r)} \quad (1)
\]

\[
f_G = \frac{[g - \min (g)]}{\max (g) - \min (g)} \quad (2)
\]

\[
f_B = \frac{[b - \min (b)]}{\max (b) - \min (b)} \quad (3)
\]

where \([f_R, f_G, f_B]\) represent the outputs of red, green, and blue channels, respectively; \([r, g, b]\) represent the pixel values entered R, G, B channel, respectively; \([\min, \max]\) represent the minimum and maximum pixel values entered for channels.

2.2 Improved fuzzy enhancement algorithm

Improved fuzzy enhancement algorithm is used to improve the contrast of degraded image or adjust its colour, with the formula as follows [12]:

\[
k_R = \begin{cases} 
\frac{1}{\tau_R} \times (f_R(x, y))^\gamma, & \text{if } f_R(x, y) \leq \tau_R \\
1 - \frac{1}{\tau_R} \times (1 - f_R(x, y))^\gamma, & \text{otherwise}
\end{cases} \quad (4)
\]

\[
k_G = \begin{cases} 
\frac{1}{\tau_G} \times (f_G(x, y))^\gamma, & \text{if } f_G(x, y) \leq \tau_G \\
1 - \frac{1}{\tau_G} \times (1 - f_G(x, y))^\gamma, & \text{otherwise}
\end{cases} \quad (5)
\]
where \([\tau_R, \tau_G, \tau_B]\) represent the threshold values of R, G, and B channels, respectively; \([x, y]\) represent the space coordinates of pixels; \([f_R(x, y), f_G(x, y), f_R(x, y)]\) represent the pixel values of R, G, and B channels after processing by linear normalisation algorithm, respectively; \([k_R, k_G, k_B]\) represent the channel values after processing by improved fuzzy enhancement algorithm, respectively.

2.3 Contrast enhancement algorithm

Based on the processing by linear normalisation algorithm and improved fuzzy enhancement algorithm, the image contrast can be further improved by value setting the tuning parameter, with the formula as follows:

\[
u_R = (k_R)^\zeta\]

(7)

\[
u_G = (k_G)^\zeta\]

(8)

\[
u_B = (k_B)^\zeta\]

(9)

where \([u_R, u_G, u_B]\) represent the channel values after processing by contrast enhancement algorithm, respectively. Finally, the output values of three channels are combined via cat function to form and output a coloured image.

2.4 Design of the proposed algorithm process

The image enhancement algorithm with adjustable threshold and tuning parameter and its process frame diagram are shown as Fig. 1:

(i) Enter a degraded image and read the image data;
(ii) Decompose the degraded image into red, green and blue channels;
(iii) Process the three channels by linear normalisation algorithm;
(iv) Set the threshold value and process the three channels by improved fuzzy enhancement algorithm;
(v) Set the tuning parameter value and process the three channels by contrast enhancement algorithm;
(vi) Synthesise the data of processed R, G and B channels through Cat function;
(vii) Output the processed image to end the process.

3 Experimental analysis

The experimental verification is performed on the image enhancement algorithm with adjustable threshold and tuning parameter proposed in Chapter 2 on a Core i5-4200U, 4 GB, 2.30 GHz CPU computer in a matlab2016a software environment. The chapter first analyses the histograms of degraded images of four types, namely, dust, foggy day, underexposure, and overexposure based on the mechanism of additive three primary colours (shown in Fig. 2), then performs enhancement processing on the four types of degraded images with the designed algorithm, analyses the processed degraded images by proposed appropriate subjective and objective evaluations methods and finally gives the value scope of threshold and tuning parameter.

Fig. 1 Framework of the image enhancement algorithm with adjustable threshold and tuning parameter
3.1 Dust image

The colour histogram of dust image is as shown in Fig. 3. It can be seen from the figure that the RGB channels of the dust image are scattered and the colour offset is great. It can be known from additive three primary colours mechanism that as green and red channels have higher brightness levels, their overlapping makes the overall picture tend to be yellow. Therefore, the idea for dust image processing is: making the threshold values of red and green channels >0.5 so as to depress green and yellow pixels; making the threshold value of blue channel not >0.5 so as to increase blue pixels; and setting the tuning parameter value to be <1 so as to increase brightness.

As shown in Fig. 4, the comparison with the processing effects of other three algorithms indicates that the dust image can effectively solve the problem of yellow colour inclination from subjective visual perception. It can also be known from Table 1 that the dust image processed by the algorithm proposed in the paper gets the highest mean value and lowest variance. This illustrates that images can get a maximum brightness and a minimum contrast, conforming to the anticipated processing effect.

3.2 Fog-degraded image

The colour histogram of fog-degraded image is as shown in Fig. 5. It can be seen from the distribution of RGB channels in the histogram that its RGB distribution is centralised at 0.5, 1 interval. It can be known from additive three primary colours mechanism that overlapping of three colours can result in white colour and, therefore, thin fog appears in the picture, the brightness is over-concentrated and the contrast is low. Therefore, the idea for fog-degraded image processing is: making the threshold values of three channels consistent and no smaller than 0.5 to normalise the colours of three channels; and increasing the tuning parameter value to increase the image contrast.

It can be seen by subjective comparison in Fig. 6 that all the four algorithms have the role of fog removal for fog-degraded images, with that of Retinex algorithm and the algorithm proposed here most evident. However, it can be known from the data in Table 2 that the fog-degraded image processed with the algorithm proposed here has a higher mean value and variance value compared with the original image and the images processed by the other three algorithms. This illustrates that images can get a higher brightness and a contrast, conforming to the anticipated processing effect.
3.3 Underexposed image

The colour histogram of underexposed image is as shown in Fig. 7. It can be known from the image information indicated by the histogram that underexposed images are characterised by low brightness and low contrast. Therefore, the idea for processing of such images should be: reducing the threshold values of three channels to make the pixels of RGB channels more distributed on areas with high brightness level; making $\zeta$ value smaller than 1 to reduce contrasts and increase brightness.

![Original image](image1.png)

![Underexposed image](image2.png)

![HE algorithm](image3.png)

![Retinex algorithm](image4.png)

![Zohair algorithm](image5.png)

![Proposed algorithm](image6.png)

**Fig. 6** Processing effect of the proposed algorithm $(\tau_R = 0.7, \tau_G = 0.7, \tau_B = 0.7, \zeta = 1.2)$ and other algorithms

| Algorithm          | Mean value | Variance   |
|--------------------|------------|------------|
| original image     | 153        | $1.19 \times 10^3$ |
| HE algorithm       | 127        | $5.56 \times 10^3$ |
| retinex algorithm  | 153        | $2.75 \times 10^3$ |
| zohair algorithm   | 158        | $3.51 \times 10^3$ |
| proposed algorithm | 161        | $5.81 \times 10^3$ |

**Table 2** Objective evaluations methods of Fig. 6

3.4 Overexposed image

The colour histogram of overexposed image is as shown in Fig. 9. The overexposed images are characterised by high brightness and low contrast. Therefore, the idea for processing of such images is: increasing the threshold values of three channels to depress pixel distribution over the bright area of image; increasing $\zeta$ value to enhance the contrast of image.

![Overexposed image](image7.png)

![HE algorithm](image8.png)

![Retinex algorithm](image9.png)

![Zohair algorithm](image10.png)

![Proposed algorithm](image11.png)

**Fig. 7** Colour histogram of underexposed image

**Fig. 8** Processing effect of the proposed algorithm $(\tau_R = 0.6, \tau_G = 0.6, \tau_B = 0.6, \zeta = 0.9)$ and other algorithms

| Algorithm          | MV     | Variance | MSE   | PSNR  |
|--------------------|--------|----------|-------|-------|
| original image     | 152    | $3.4 \times 10^3$ | —     | —     |
| HE algorithm       | 127    | $5.05 \times 10^3$ | 171.37 | 25.79 |
| retinex algorithm  | 142    | $5.67 \times 10^3$ | 145.97 | 26.48 |
| zohair algorithm   | 138    | $5.33 \times 10^3$ | 114.30 | 27.55 |
| proposed algorithm | 153    | $4.69 \times 10^3$ | 66.23  | 29.92 |

**Table 3** Objective evaluations methods of Fig. 8
3.5 Value scopes for threshold and tuning parameter

The analysis and subjective and objective evaluations in the foregoing four paragraphs provide ideas for using the algorithm proposed here to process the four types of degraded images and the value setting scopes for thresholds of three channels and tuning parameters are shown below in Table 5.

4 Conclusion

The paper introduces an image enhancement algorithm with adjustable threshold and tuning parameter. Processing ideas based on the analysis of four types of degraded images are used to adjust threshold and tuning parameter values so as to realise image enhancement. The result indicates this algorithm is feasible. In the future efforts, we will consider designing a GUI interface that will make the threshold and turning parameter values adjustable by sliding block, the user view image processing in real time and the operation more convenient.

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