Research on an improved algorithm for image dehazing in underground coal mine

Xiaoyan Zhang, Haitao Guoa

Department of Computer Science and Technology, Xi’an University of Science and Technology, Xi’an 710600, China

papersmail@163.com

*a18208208052@stu.xust.edu.cn

Abstract. Coal mine images have low illuminance, large dust and high noise intensity, etc. It brings great obstacle to extract effective image information. This paper proposes an image haze removal algorithm for coal mine underground based on dark channel prior. First, histogram equalization method is introduced to enhance the underground image, obtain the dark channel image from the thumbnail of the image, and then restore the pixel value of the image through bilinear interpolation, for shortening the acquisition time of the dark channel image and increasing the speed of the algorithm. Results demonstrate this method greatly reduces the amount of calculation and improves the processing speed of the haze removal algorithm while ensuring the haze removal effect.

1. Introduction

Nowadays, intelligent video surveillance is widely used in coal mines[1], but uneven lighting, the mist and dust contained in the air will seriously affect the visibility of the scene, resulting in differences in contrast, resolution and color of the image. The degree of loss reduces the quality of the image and is not conducive to the subsequent processing of the image. Therefore, the application of image haze removal technology is particularly important.

In order to achieve the effect of haze removal underground, based on the traditional image haze removal researches[2]-[4], many scholars have made further researches. Wang[5] uses bicubic interpolation to improve the acquisition speed of dark primary channels, but the algorithm speed is still relatively slow.

Existing image haze removal algorithms all have different degrees of defects when applied to coal mines. Some effects are not good enough, and some are too complex and slow to process. This paper presents an improved image haze removal algorithm based on dark channel haze removal. This paper introduces the histogram equalization algorithm so that the histogram of the original image is evenly distributed in the entire gray range, which expands the dynamic range of the pixel gray value and enhances the contrast of the image; obtain the dark channel image from the image thumbnail, and use bilinear interpolation to restore the image, improve the calculation speed of the haze removal algorithm.

2. Dark channel dehazing algorithm

The image haze removal algorithm based on a priori knowledge is a better dehazing algorithm in recent years. Tan et al.[6] is the earliest researcher in this direction, followed by further research by Fattal et al.[7]. The most prominent effect is the image dehazing algorithm based on the dark channel prior theory.
proposed by He Kaiming et al.\cite{8}. This method verifies the dark channel prior conditions from multiple images. Using the prior knowledge of the minimum color channel in each local area of the image to estimate the propagation image, combined with the atmospheric scattering model to achieve image dehazing. This method can achieve good dehazing effect for most images. In order to dehaze the underground images of coal mines, the principle of dark channel prior dehazing was a basic way, and the algorithm was improved to make it suitable for the dehazing of underground images.

3. Improved algorithm

3.1 Histogram equalization

Due to the lights are used under the coal mine, the image illumination and contrast are low. When the illumination is poor, the background in the image will become dark, which will have a great impact on the later information extraction. At this time, the contrast of the image needs to be enhanced. Histogram equalization is the use of image histogram to adjust the contrast, which can effectively increase the local contrast of the image, so that the brightness of the image is evenly distributed on the histogram.

After the histogram equalization processing of the coal mine underground image, the result is shown in Fig. 1. From the two histograms before and after the histogram equalization process, it can be seen that the distribution of the histogram after the histogram equalization process is more even, the grayscale range becomes significantly larger, and the image contrast increases, the sharpness also becomes high, which effectively enhances the image.

3.2 Fast recovery of haze-free images based on bilinear interpolation

Aiming at the defect that the original dark channel dehazing algorithm has a slow dehazing speed, the obtained image is first obtained as a thumbnail and then the dark channel image is calculated, and then the pixels of the image are restored by interpolation. Three commonly used function interpolation methods are nearest neighbor interpolation, bilinear interpolation method and bicubic interpolation method\cite{9}. Among the three commonly used interpolation methods, bicubic interpolation’s effect is the best, but the speed is slow. In order to meet the characteristics of real-time, the algorithm in this paper chooses bilinear interpolation to interpolate the image based on the histogram equalization algorithm.

Bilinear interpolation is a linear interpolation extension of a binary interpolation function. Its main idea is to perform linear interpolation in two directions.
If we want to get the value of the unknown function \( f \) at point \( P = (x, y) \), suppose we know that the value of function \( f \) at \( Q_{11} = (x_1, y_1) \), \( Q_{12} = (x_1, y_2) \), \( Q_{21} = (x_2, y_1) \) and \( Q_{22} = (x_2, y_2) \) four points.

First use linear interpolation in the x direction, we get:

\[
  f(x, y_1) \approx \frac{x_2 - x}{x_2 - x_1} f(Q_{11}) + \frac{x - x_1}{x_2 - x_1} f(Q_{21})
\]

\[
  f(x, y_2) \approx \frac{x_2 - x}{x_2 - x_1} f(Q_{12}) + \frac{x - x_1}{x_2 - x_1} f(Q_{22})
\]

Then use linear interpolation in the y direction, we get:

\[
  f(x, y) \approx \frac{y_2 - y}{y_2 - y_1} f(x, y_1) + \frac{y - y_1}{y_2 - y_1} f(x, y_2)
\]

\[
  = \frac{1}{(x_2 - x_1)(y_2 - y_1)} \left[ x_2 - x \right] \left[ x - x_1 \right] \frac{f(Q_{11}) f(Q_{12})}{f(Q_{21}) f(Q_{22})} \left[ y_2 - y \right] \frac{f(Q_{21}) f(Q_{22})}{f(Q_{11}) f(Q_{12})} \left[ y - y_1 \right]
\]

Take dark channel maps into equations (1) and (2), and bilinear interpolation can be used to obtain the dark channel dehazing map of the restored pixels, thereby improving the time performance of the algorithm in the entire calculation process.

4. **Experimental results**

In order to verify the algorithm proposed in this paper, two coal mine images were selected and tested using MATLAB 2016 on a computer with Windows 10 operating system configured as Intel(R) Core(TM) i5-9300HF CPU @2.40 GHz 16 GB RAM. In addition, the dehazing algorithm proposed in this paper is compared with the traditional dark channel dehazing He algorithm and bicubic interpolation algorithm. The experimental results are shown in Fig 3.
It can be seen from Fig. 3 that the algorithm provided in this paper has higher definition and better visual effect than the traditional dark channel algorithm. The two images are processed by the algorithm in this paper, which obviously removes the dust and mist in the well, eliminates the noise, and restores the original smoothness of the image. In Figures e1, e2, f1, and f2, the original dark channel dehazing algorithm and the use of bicubic interpolation dehazing algorithms result in a lower dehazing image brightness and contrast. In Figures e3 and f3, the image brightness and contrast are better.

Table 1 gives the three factors of algorithm time, image average gradient and information entropy. Among them, the two indicators of entropy and average gradient represent the clarity of the image, that is, whether the detailed information is more prominent after dehazing, and the algorithm time reflects the time performance of the dehazing algorithm. As far as information entropy and average gradient are concerned, the average gradient value of image e2 and image f2 is slightly higher than that of the algorithm in this paper, but in terms of algorithm time, this algorithm improves the other two algorithms by 25% and 65%, and the algorithm time The improvement is obvious, so it can be seen from the objective evaluation index that the method of this article is better.

Table 1 Comparison of experimental results

|                  | Time(s) | Image entropy | Average gradient |
|------------------|---------|---------------|------------------|
| e haze image     | -       | 5.36          | 1.68             |
| e1 He algorithm  | 3.01    | 4.92          | 1.91             |
| e2 bicubic interpolation | 4.30 | 5.03          | 3.96             |
| e3 this paper algorithm | **2.23** | **5.26** | **3.45**         |
| f haze image     | -       | 6.82          | 1.68             |
| f1 He algorithm  | 4.14    | 5.26          | 1.32             |
| f2 bicubic interpolation | 8.40 | 3.54          | 1.74             |
| f3 this paper algorithm | **2.88** | **3.65** | **1.50**         |

5. Conclusions
In view of the problem that the previous image dehazing algorithm is not suitable in coal mines, and the calculation is complicated and time-consuming, this paper is based on the dark channel theory proposed by He et al. and combines histogram equalization and bilinear interpolation. First the histogram is used to picture, then bilinear interpolation is used to restore image which can obtain a clearer and natural the haze-free image, and achieve a better dehazing effect of the underground image.

References
[1] WU Wenzhen. Application Research of Intelligent Video Surveillance System in Coal Mine [J].
Coal Technology, 2016, 35(04): 271-273.

[2] Zhang Bingbing, Dai Shengkui. Fast image haze-removal algorithm based on the prior dark-channel [J]. Journal of Image and Graphics, 2013, 18(02): 184-188.

[3] F. Liu and C. Yang, "A fast method for single image dehazing using dark channel prior," 2014 IEEE International Conference on Signal Processing, Communications and Computing (ICSPCC), Guilin, 2014, pp. 483-486, doi: 10.1109/ICSPCC.2014.6986240.

[4] Y. Kumar, J. Gautam, A. Gupta, B. V. Kakani and H. Chaudhary, "Single image dehazing using improved dark channel prior," 2015 2nd International Conference on Signal Processing and Integrated Networks (SPIN), Noida, 2015, pp. 564-569, doi: 10.1109/SPIN.2015.7095426.

[5] WANG Qi-ming. Study on defogging algorithm of mine high definition image[D]. Liaoning Technology University, 2018.

[6] R. T. Tan, "Visibility in bad weather from a single image," 2008 IEEE Conference on Computer Vision and Pattern Recognition, Anchorage, AK, 2008, pp. 1-8, doi: 10.1109/CVPR.2008.4587643.

[7] R. Fattal. Single image dehazing. In SIGGRAPH, pages 1–9, 2008.

[8] HE KAIMING, SUN JIAN, TANG XIAOOU. Single image haze removal using dark channel prior[C]. Proceedings of IEEE Conference on Computer Vision and Pattern Recognition. Washington, DC: IEEE Computer Society, 2009: 1956–1963.

[9] DING Xuejing. Research and comparison of Matlab interpolation algorithm for image scaling function [J]. Journal of Hubei University, 2018, 40(04): 396-400+406.