Image de-blurring Model based on Machine Learning

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Abstract. Due to the influence of haze in winter, outdoor images usually lose contrast and fidelity. In view of the fact that most de-fog algorithms are not effective for images with large sky areas, an improved dark channel a priori de-fog method is proposed. First of all, the sky region is segmented according to the image gradient information, and on the basis of sky segmentation, the atmospheric light value is reasonably estimated by setting the discriminant formula combined with the high brightness and smoothness of atmospheric light reference pixels. Secondly, according to the different dark channel values, the piecewise linear function is used to dynamically modify the adjustable parameters to solve the local shadow caused by excessive defog. Then, the transmittance estimated by the bright channel model and the improved dark channel prior model are fused, and the edge is optimized by guided filtering. Finally, combined with the atmospheric scattering model, the defog image is obtained by brightness compensation and contrast stretching. The experimental results show that the improved method can effectively improve the image distortion, enhance the image contrast and details, especially in maintaining the visual authenticity of the sky region.

Keywords: image defog, sky recognition, dark channel a priori, bright channel, transmittance fusion

1. Introduction

In recent years, image processing has been applied in various fields, such as navigation, aviation, transportation and other practical applications. Due to the influence of haze in winter, outdoor images usually lose contrast and fidelity, which brings difficulties to image processing. After removing the fog, the image is more visually comfortable and contains more detailed information. Therefore, the research of image defog technology has very important practical value [1].

Defog removal based on deep learning requires a lot of data for training and testing, and the algorithm has high complexity and high cost, so the research on traditional methods is still the focus of scholars. According to the above analysis, aiming at the failure of dark channel prior in the sky region, the algorithm is deeply understood and analyzed [2], and an improved dark channel prior defog method (L-DCP) is proposed. The improvement of this paper is mainly reflected in the following three aspects: 1) the sky region is segmented according to the image gradient information. 2) the piecewise linear
function is used to modify the adjustable parameters dynamically, and the haze is preserved reasonably according to the dark channel value, so as to avoid the local shadow of the image caused by excessive defog in the foreground region. 3) merge the transmittance estimated by the bright channel model and the improved DCP model [3].

2. Algorithm in this paper

2.1. Sky recognition
Considering that the sky is smooth, the texture and details of the non-sky region are rich, and the gradient features of the two parts are quite different, the foggy image can be decomposed by gradient information. This paper takes the following steps to identify the sky[4]:

1) firstly, the gradient images of R, G and B channels of the foggy image are obtained. after adding the gradient values of the same pixel position, the binary segmentation is carried out based on the threshold, and the pixels larger than the threshold are assigned to 1. The pixels less than the threshold are assigned to 0, and the candidate map of the sky region is obtained. After repeated experiments, it is found that when the threshold is 2, the junction between the sky and the foreground can be detected clearly.

2) for the candidate graph, the largest white connected region is marked as the sky by the boundary tracking algorithm.

3) Fill the processed image to remove the sky noise.

2.2. Transmittance fusion and correction
In the original dark channel a priori method, it is assumed that the dark channel value of the fog-free image normalized by atmospheric light is approximately zero [16]. However, the dark channel value of the sky is much greater than zero, which is why, after using the original dark channel a priori method, the restored color deviates from the original scene in the sky region, resulting in color distortion and halo, which looks unnatural. Therefore, this assumption does not apply to the sky area of the image. In reality, the sky area defog requires a larger transmittance value to maintain naturalness. Similar to the idea of dark channel, the basic idea of bright channel is that at least one color channel has greater intensity in such a small image area. For any image, the transmittance expression based on the bright channel model is as follows:

$$t^i(x) = \max_{\lambda \in \{R,G,B\}} \{\max_{x \in \Omega(x)} [I^\lambda(x)] \}$$

Therefore, a bright channel model is proposed to estimate the transmittance of the sky region. The experimental results show that the transmittance estimated by the bright channel model has a good effect on the sky region. However, it does not restore the prospects very well. A priori dark channel has a good defog effect for non-sky images.
\[
t^{DCP}(x) = 1 - \omega \min_{A \in \{R, G, B\}} \{\min_{x \in D(x)} \left[\frac{I^A(x)}{A}\right]\}
\]

3. Analysis and discussion

3.1. Experimental results

In order to analyze the effectiveness of the defog method, an experimental platform is built and a program is written. The hardware platform of the experiment is Lenovo notebook, Intel (R) Core (TM) i7-6500U CPU 2.50GHz Magi 16GRAM, and the test software is Matlab2014b under Windows10 environment. In addition to the hardware platform, we collect a large number of fog degraded images with sky in different scenes to verify our proposed defog method, all of which have good results.

Figure 2 shows the visualization results of comparing the proposed L-DCP method with the four existing defog methods. This set of images shows that our method is the best. The second column of figure 7 is the a priori method of dark channel proposed in reference. It can be seen that the effect of removing fog in the foreground after fog is good, but there is an obvious color deviation in the sky, and the overall image is dark.

![Figure 2. Comparison of different algorithms for de-fog.](image)
3.2. Objective evaluation
In addition to subjective visual evaluation, we also analyze three quantitative evaluation indicators to evaluate our proposed algorithm. Peak signal-to-noise ratio (PSNR) and structural similarity (SSIM) represent the index of signal distortion. In theory, larger values correspond to smaller image distortion. Another index is the average gradient (AG), which reflects the image contrast, and the larger value corresponds to the higher image resolution. We choose this index to describe the details of the image. The specific calculation formula is as follows:

1) Peak signal-to-noise ratio (PSNR)

\[ PSNR = 10 \cdot \log_{10} \left( \frac{MAX^2}{MSE} \right) \]

2) Structural similarity (SSIM)

\[ SSIM = \frac{(2\mu_u\mu_v + c_1)(2\sigma_{uv} + c_2)}{(\mu_u^2 + \mu_v^2 + c_1)(\sigma_u^2 + \sigma_v^2 + c_2)} \]

3) Average gradient (AG)

\[ AG = \frac{1}{\sqrt{2mn}} \sum_{x=1}^{m} \sum_{y=1}^{n} \sqrt{(J_{ij}^x)^2 + (J_{ij}^y)^2} \]

The average values of the three indicators corresponding to the de-fog effects of each method for the images in six different situations in figure 7 are given in Table 1. The PSNR and SSIM values of our method are the highest, which proves that our method is closest to the truth. However, the average gradient AG is not the highest because our method does not over-sharpen the edges and does not show significant blocking effects and halos in the sky. The data used in this paper are all foggy degraded images with a large area of the sky, the sky is already smooth, there will not be too much detail texture, so it will pull down the overall average gradient value. Therefore, our average gradient is not very high, which is quite reasonable. And on the premise of keeping the sky region smooth, we can still get an excellent average gradient value, which indirectly proves that the texture of our proposed method can also reproduce well in the foreground region.

Table 1. Quantitative evaluation of different algorithms

| Method in Ref. | Method in Ref. | Method in Ref. | Method in Ref. | Method of this article |
|----------------|----------------|----------------|----------------|-----------------------|
| PSNR           | 11.180         | 12.167         | 11.650         | 13.934                | 14.535                |
| SSIM           | 0.506          | 0.377          | 0.441          | 0.724                 | 0.726                 |
| AG             | 0.045          | 0.060          | 0.052          | 0.033                 | 0.054                 |

4. Conclusion
Image defog plays an important role in video surveillance, target detection, navigation and tracking, daily aesthetic and other methods. In this paper, based on the atmospheric scattering model, a fog degraded image restoration method with improved dark channel prior is proposed. The main content of its research work is to set the discriminant formula and estimate the atmospheric light value according to the sky recognition. The adjustable parameters are dynamically modified to effectively reduce the local shadow in the foreground region, and according to the characteristics of the sky region, a new
model is proposed to estimate the sky transmittance. Experimental results show that the proposed algorithm can effectively restore degraded images in haze weather. Compared with the four classical algorithms, the subjective visual quality is better than other algorithms, and the restoration effect is natural, especially in maintaining the naturalness of the sky image. The peak signal-to-noise ratio, structural similarity and average gradient of quantitative indicators are significantly improved compared with the original dark channel prior algorithm.

The discriminant formula defined in this paper and the method proposed to dynamically modify the adjustable parameters can also be applied to the restoration of blurred images without sky, which is universal. Based on the method described in this paper, applied to the field of sea fog removal, sea target detection and recognition is the next research task.

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