Improvement of the Algorithm Based on Dark Channel Prior Defogging

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Improvement of the Algorithm Based on Dark Channel Prior Defogging

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Abstract. The dark channel prior defogging algorithm is a method for rough estimation of transmittance. The dark channel prior method is not obvious enough for the sky. The paper uses a rough estimation model based on the relationship between depth of field and transmittance. A dehazing method that makes the transmittance more refined is proposed on a priori basis. The atmospheric light value is calculated from the atmospheric scattering model, and the image is converted from the RGB color space to the HSV color space and the S (saturation) component is extracted as a supplement to the transmittance. The final transmittance is obtained by the method of transmittance fusion, and a clear image is restored according to the atmospheric scattering model. The experimental results show that the method can effectively eliminate the fog, and the restored image better preserves the image details.

Keywords: Defogging, Atmospheric light value, Transmittance fusion, Image restoration.

1. Introduction
Two major algorithms based on image enhancement and restoration-based defogging[1] . The shortcoming of the image enhancement algorithm is that it does not consider the factors that affect the image degradation. It only achieves the defogging by improving the quality of the image. This method does not defog through the essence, so the effect is lacking. In the study of the latter method, Tan[2] et al. used a method of maximal local contrast, which achieved good results in denser fog regions, but the transmittance obtained by this method was not derived from the model. Tarel [3] et al. proposed a method of fast defogging, but it is easy to lose edge information after two median filtering. In 2015, Zhu[4] et al. proposed a new defogging algorithm, the color attenuation prior algorithm, which can effectively remove smog but involves machine learning. Most scholars perform algorithmic rendering and algorithm improvement. He[5] et al. proposed a dark channel prior method that removes fog but is computationally time consuming and dark overall due to the use of software mapping. In order to obtain better defogging effect, this paper proposes a simple and effective method, first estimating the atmospheric light value; estimating the transmittance according to the depth of field model, then using the image fusion method to obtain the final transmittance, and finally recovering according to the atmospheric scattering model. image.
2. Physical model
McCartney [6]-[7] proposed an atmospheric scattering model that is widely used in computer vision and image processing. Narasimhan and Nayar[8]-[11] further derived the mathematical expression of the model, which can be described as:

\[ I(x) = J(x)t(x) + A[1 - t(x)] \]  

(1)

In the formula, \( x \) represents the coordinates of the pixel, \( I \) represents the image with fog; \( J \) is the fog-free image restored by the algorithm; \( t(x) \) is the transmittance to indicate the ability of the light to penetrate the atmospheric medium; \( A \) represents the intensity of the atmospheric light.

\[ t(x) = e^{-\beta d(x)} \]  

(2)

\( \beta \) is the atmospheric scattering coefficient, \( d \) is the depth of field, and \( J \) is known in (1), which can be obtained by sensors. \( J \) is required by us. \( t(x) \) and \( A \) are unknown, so defogging requires \( t(x) \) and \( A \) value.

3. Method of this paper

3.1. Estimated Atmospheric Light Value
For the calculation of atmospheric light value, this paper adopts a more robust atmospheric light value estimation method based on quad-tree subdivision method [12], which is realized as follows: select an original image as input and divide the image into four. A rectangle that defines the value of C as the average pixel value in each rectangular area minus the standard deviation of these pixels. Then in the region with the largest C value, divide the region into four smaller rectangular regions again, repeating the previous process until the region we selected is less than the specified threshold. The red area shown in the figure below is the area we selected. The area we select is the area closer to white, which is the brightest area in a picture. As the atmospheric light value, its visual expression is shown in Fig.1.

**Figure 1.** Atmospheric light value map

3.2. Transmittance calculation
He et al. proposed a dark channel prior defogging algorithm. The core idea of this method is that for images in outdoor scenes, at least one color channel has a pixel value that tends to zero, as defined below:

\[ J_{\text{dark}}(x) = \min_{y \in \mathbb{R}} \left( \min_{c \in \{r, g, b\}} \left( J^c(y) \right) \right) \rightarrow 0 \]  

(3)
Where: \( J^c \) represents each component of the color image; \( \Omega(x) \) represents the window centered on pixel \( x \); \( y \) is the pixel coordinate in a small square region \( \Omega(x) \) centered at \( x \), which is brought into (1) because \( J_{\text{dark}}(x) \) tends to zero. The formula for obtaining the transmittance coefficient in the formula:

\[
t_1(x) = 1 - \min_{y \in \Omega(x)} \left( \frac{I^c(x)}{A^c} \right)
\]

According to this formula, the range of transmittance is \([0, 1]\). In reality, even in sunny weather, there are some impurity molecules in the atmosphere. When we look at the distance, we can see the fog, and if the fog is completely removed, the image will be unreal. In order to be more realistic, we need to add a coefficient \( \omega \) to keep a certain sense of mist. (4) was rewritten as:

\[
t_1(x) = 1 - \omega \min_{y \in \Omega(x)} \left( \frac{I^c(x)}{A^c} \right)
\]

\( \omega \) is 0.95 based on experience.

3.3. Rough Estimation Model Based on the Relationship Between Depth of Field and Transmittance

For He's dark channel algorithm, the algorithm does not deal well with the sky part. This paper proposes another algorithm, namely image depth of field model to estimate transmittance fusion method, RGB to HSV color space conversion relationship [13], can be obtained. The expression for the S (saturation) component is as follows:

\[
S(x) = \begin{cases} 
0, & \text{if } \max_{c \in \{r,g,b\}} I^c(x) = 0; \\
\frac{\max_{c \in \{r,g,b\}} I^c(x) - \min_{c \in \{r,g,b\}} I^c(x)}{\max_{c \in \{r,g,b\}} I^c(x), \text{other}} & \text{otherwise}
\end{cases}
\]

The color decay prior has proved that the image with a small depth of field has a higher saturation. We extracted the S component as a rich complement to \( t_1(x) \). We take the extracted S component as the supplemental transmittance \( t_2(x) \).

3.4. Transmittance fusion

Image fusion based on wavelet transform [14], using wavelet image fusion technology, can reflect the image transmittance while having the original image details. In this paper, two different transmittances are fused to refine the transmittance. First, the two-dimensional image is decomposed. The three high-frequency and one low-frequency information are features of wavelet decomposition. The high-frequency includes information such as details and noise, and the image contour is reflected in the low frequency.

After being decomposed by the N layer, there will be 3N+1 frequency bands, and in these 3N+1 frequency bands, there are 3N high frequencies and one low frequency band.

The weighted average method is used for the high frequency part:

\[
hF = \alpha \cdot hF_1 + (1 - \alpha) \cdot hF_2
\]

\( hF \) is the high frequency coefficient after fusion, \( hF_1 \), \( hF_2 \) is the high frequency subband coefficient.

Use the averaging method for the low frequency part:
\[ IF = \frac{1}{2} (IF_1 + IF_2) \]  

In the formula, \( IF \) is the low frequency coefficient after fusion, and \( IF_1 \) and \( IF_2 \) are the low frequency subband coefficients.

The different transmittances \( t_1(x) \) and \( t_2(x) \) are input, and the low-frequency sub-band coefficients and the high-frequency sub-band coefficients are obtained respectively through the wavelet N-layer decomposition, and then the fusion high-low frequency coefficients are obtained by the formulas (7) and (6), and finally obtained by wavelet reconstruction. Transmittance \( t(x) \). The \( t_i(x) \) is obtained by domain partitioning, so there is a serious block effect, which needs to be filtered. In this paper, we use He et al filtering algorithm to filter \( t_t \) as the coarse transmittance.

3.5. Original image restoration

According to the two equations (6) and (7), the transmittance is obtained. Combined with the atmospheric light value \( A \), a fog-free image can be obtained. The formula is as follows:

\[ f(x) = \frac{I(x) - A}{t(x)} + A \]  

4. Analysis and comparison of experimental results

4.1. Subjective comparison analysis

In order to verify the effectiveness of the proposed algorithm, this paper selects the test maps that need to deal with the sky area and do not need to deal with the sky area for comparison. Different algorithms are used to compare multiple algorithms. The algorithm includes He algorithm and Tarel algorithm.

It can be seen from the following two sets of graphs that the dark channel algorithm of the literature [15] has better dehazing effect, the color and details are more natural and clear, but the effect of dealing with the sky area is not as good as this paper, and the overall color is dark, the literature [3] The overall result of defogging is rather vague and the image details are not obvious. The algorithm in this paper is better than the dark channel algorithm in the literature [15]. The overall dehazing effect is better than the dark channel algorithm in [15] and the dehazing algorithm in [3].

Figure 2. Top left: Original image Upper right: Literature Bottom left: Literature Bottom right: this paper
4.2. Analysis of objective comparison results

In this paper, the entropy of the image is used as the evaluation index as shown in Table 1. The entropy describes the amount of information contained in the image. The entropy values of the algorithm are relatively higher than those in the literature [3] and [15].

| Image       | Entropy       |
|-------------|---------------|
|             | Input map     | Literature [15] | Literature [3] | This article |
| Image 2     | 7.2889        | 7.2910          | 7.0915          | 7.5253       |
| Image 3     | 7.6423        | 7.2667          | 7.5910          | 7.6506       |

5. Conclusion

Based on the method of quadruple tree subdivision to estimate the atmospheric light value, a more accurate atmospheric light value can be selected in any foggy map. Compared with He et al., a pixel of 0.1% of the brightness in front of the image is used as the atmospheric light value. Has reliability. In this paper, the image depth of field model is proposed to estimate the transmittance fusion method. The image fusion method is used to fuse the transmittance and then defog. According to the results of image restoration experiments, the effective feasibility of the algorithm is proved, which is obviously improved compared with the classic dehazing algorithm. Ultimately, the algorithm can more effectively remove the effects of smog.

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