Research on Dehazing Algorithm of Single UAV Reconnaissance Image under Different Landforms Based on Retinex

Linhong Zhao¹ᵃ, Shun Zhang²ᵇ and Xianzhang Zuo ¹*  
¹ UAV Engineering Department of ShiJiaZhuang Campus, Army Engineering University City, Hebei Province, 050000, China  
² 13th Team, Shijiazhuang Campus of Army Engineering University City, Hebei Province, 050000, China  
ᵃemail: zlh908317474@163.com, ᵃemail: 975282141@qq.com,  
*Corresponding author’s e-mail: seller6@kedahua.cn

Abstract. Aiming at the weakness of the dark channel prior model in Retinex algorithm such as slow calculation speed, halo effect, and loss of details in the processing of UAV single image dehazing, an improved Retinex algorithm is proposed. First, convert the RGB color space to the HIS color space, separate the brightness I, assign values to the three scales of large, medium and small, use Gaussian surround to obtain the three scale brightness images and then weight, and then switch the brightness image to the RGB color space, in order to achieve the information with more details. Finally, the haze images which is distinguished in three different landforms such as city, mountainous area and forestwill be performed simulation experiments in MATLAB, and adjust the image restoration effect by changing the parameters.

1. Introduction
In modern warfare, the use of drones for battlefield reconnaissance has the advantages of real-time, accuracy, and ability to avoid casualties. However, in practical applications, due to the influence of haze, the details of reconnaissance images are often blurred, low contrast, and unclear target edges and other phenomena seriously affect the later feature extraction, target recognition and tracking. Therefore, it is necessary to clear the degraded image caused by haze.

2. Analysis and improvement of a single reconnaissance image to remove the haze algorithm
The reconnaissance images of battlefields with haze taken by drones are different from the outdoor haze-containing images collected due to the shooting angle, environment background, target characteristics and other factors. Specifically, there are the following three aspects: One is to shoot from a bird's-eye view, the transmittance of each target is roughly the same; the other is that there may be a large area of the target that is not suitable for dark primary color a priori, such as glass, vegetation, water surface, etc.; the third is that there may be a background that affects the dehazing effect. According to the above characteristics, it is necessary to find a defogging algorithm suitable for UAV reconnaissance images.
2.1 Dark primary color prior defogging algorithm

At present, scholars at home and abroad mostly use image restoration and image enhancement in the field of image defogging. Among them, the dark primary color prior algorithm proposed by He et al. is widely cited by scholars because of its clever thinking and easy-to-understand theory. He et al. through a large number of fog-free image observation statistics found that there is a color channel close to zero in a very small neighborhood in the non-sky area of the image, and call this channel a dark channel, and its expression is:

\[
\begin{align*}
J_{\text{dark}}(x) &= \min_{\Omega(x)} \Big( \min_{c \in \{R, G, B\}} J^c(y) \Big) \\
J_{\text{dark}}(x) &\rightarrow 0
\end{align*}
\]

Where \(\Omega(x)\) is a very small neighborhood of pixel \(x\), and \(c\) is the three color channels. That is, first find the minimum value of each RGB component and store it in a grayscale image with the same size as the original image, and then perform minimum filtering on this grayscale image. The filter radius is determined by the window size.

Then restore the image according to the foggy image degradation model:

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

\[
J(x) = \max(t(x), t_0) + A
\]

Where \(I(x)\) is the image containing haze, \(J(x)\) is the image to be solved, \(t(x)\) is the transmittance of light in the foggy medium, \(A\) is the intensity of atmospheric light, and \(t_0\) is a set threshold.

This algorithm has a halo effect and is not detailed enough for image edge processing, so it is not suitable for UAV reconnaissance image processing.

2.2 Single-scale parameter Retinex algorithm (SSR)

Retinex is also known as the color constancy theory, that is, the color of the object presented in the image has nothing to do with the intensity of the reflected light, only the reflection ability of the object, and is not affected by the unevenness of illumination. Its expression is:

\[
I(x, y) = R(x, y) \times L(x, y)
\]

Among them \(I(x, y)\) is the image with haze, \(R(x, y)\) is the reflection image on the object surface, and \(L(x, y)\) is the incident light intensity image.

Therefore, the reflected image on the surface of the object can be obtained by estimating the brightness image of the incident light \(L(x, y)\). which is:

\[
\log[R(x, y)] = \log \frac{I(x, y)}{L(x, y)}
\]

\[
\tau_i(x, y) = \log I_i(x, y) - \log[F(x, y) * I_i(x, y)]
\]

Among them, \(\tau_i(x,y)\) is the output of the \(i\)-th color channel (\(i = 1, 2, 3\)), \(I_i(x,y)\) is the image distribution, that is, the grayscale of the image at the position \((x, y)\); \(F(x,y)\) is the surround function, The brightness value of the original image is estimated by the convolution of the surround function and the haze image.

\[
\iint F(x, y)dxdy = 1
\]
\[ k = \frac{1}{\sum \sum F'(x, y)} \]

Among them, \( c \) is the scale parameter and \( k \) is the normalization factor.

The specific operation process in the simulation experiment is:
1. Read image data containing haze \( I(x, y) \);
2. Give a reasonable value to the scale factor and get \( L(x, y) \) after Gaussian blur;
3. Quantify \( \log[R(x, y)] \) into a value between 0-255 and output.

The scale parameter determines the image processing effect \([4]\). When the value of \( c \) is small, the dynamic compression capability is stronger, which can better enhance the details of the dark parts of the image, but it will cause the color distortion of the output image; the larger the \( c \), the better the color fidelity of the output image. Therefore, it needs to be improved on the basis of this algorithm.

2.3 Multi-scale parameter Retinex algorithm (MSR)

On the basis of the single-scale parameter Retinex algorithm, Rahman \([5]\) et al. proposed a multi-scale parameter Retinex algorithm, that is, by selecting three scales of large, medium, and small and then weighting, the process is as follows:

![Figure 1 Flow Chart of MSR](image)

The specific operation process in the simulation experiment is:
1. Read image data containing haze \( I(x, y) \) and decompose it into three components of RGB;
2. The double type image is converted to the logarithmic domain, and three scale factors of large, medium and small are selected for assignment, and the Gaussian function is determined and convolved with the original image to obtain a brightness image of three scales \( L(x, y) \);
3. The weighted sum of the three brightness images is then converted to the real number domain for output.

Although the multi-scale parameter Retinex algorithm can take into account the detailed information and color fidelity of the low-scale SSR algorithm, the multi-scale Retinex algorithm destroys the proportional relationship between the three color channels of the original image RGB \([6]\), and color distortion is easy to appear, so Need to be further improved.

2.4 Improved multi-scale parameter Retinex algorithm (MSRCR)

On the basis of the multi-scale Retinex algorithm, it can be changed to convert the three color channels of R, G, and B to the HIS color space for processing. The HSI model often uses three parameters \( H, S, I \) to describe the color of an object, where \( H \) is the wavelength of the color, that is, hue; \( S \) is the depth of the color, that is, saturation; \( I \) is the brightness. Hue is the attribute that emphasizes the description of pure color \([7]\); saturation gives a measure of the degree to which a pure color is diluted by white light. Brightness is a subjective description, which is unpredictable in practice. It embodies the concept of achromatic intensity and describes the color perception. The key parameters. The conversion relationship between the RGB model and the HSI model is as follows:
\[ I = \frac{1}{3}(R+G+B) \]  

(11)

\[ S = \left( \frac{3}{R+G+B} \right) \text{[min}(R,G,B)] \]  

(12)

\[ H = \frac{\theta}{2\pi - \theta} \left( \frac{G \geq B}{G < B} \right) \]  

(13)

\[ \theta = \arccos \left\{ \frac{1}{2} \left[ \frac{(R - G) + (R - B)}{(R - G) + (R - B)(G - B)} \right] \right\} \]  

(14)

Where H is tone \((0 \leq H < 360)\); S is saturation of the image; I is brightness.

Use the multi-scale Retinex algorithm for the I component:

\[ r_i(x, y) = \sum_{k=1}^{k} W_k [\log I_i(x, y) - \log (F(x, y) * I_i(x, y))] \]  

(15)

Where \(r_i(x,y)\) is the output of the i-th channel, \(I_i(x,y)\) is the value of the i-th channel of the haze-containing image, \(F(x,y)\) is the Gaussian surround function, and \(k\) is the number of Gaussian surround functions, \(W_k\) which are assigned corresponding weights. To meet the condition \(0 \leq H < 120\).

Finally, complete the color conversion from HIS to RGB. The specific formula is as follows:

When \(0 \leq H < 120\):

\[ B = I (1 - S) \]  

(16)

\[ R = I [1 + \frac{S \cos H}{\cos(60 - H)}] \]  

(17)

\[ G = 3I - (R + B) \]  

(18)

When \(120 \leq H < 240\):

\[ R = I (1 - S) \]  

(19)

\[ G = I [1 + \frac{S \cos H}{\cos(60 - H)}] \]  

(20)

\[ B = 3I - (R + G) \]  

(21)

When \(240 \leq H < 360\):

\[ G = I (1 - S) \]  

(22)

\[ B = I [1 + \frac{S \cos H}{\cos(60 - H)}] \]  

(23)

\[ R = 3I - (G + B) \]  

(24)

Among them, only the I component is enhanced, and H and s are not processed.
3. Simulation results and analysis

In the "USGS National Map Urban Area Imagery" UAV aerial image database, select the smog-containing images taken by drones under three different terrains and landforms: cities, mountains, and forest areas for simulation. The experimental environment is Matlab R2017b, in windows 10 under the system. The same UAV reconnaissance image is processed by the dark primary color prior algorithm, the single-scale parameter Retinex algorithm, and the improved multi-scale parameter Retinex algorithm, and the effect of image restoration is compared by modifying the scale parameter, and the simulation experiment results as follows:

In terms of operating speed, the proposed algorithm only enhances the luminance component I, while the original algorithm needs to process the three channels of RGB at the same time, which greatly reduces the calculation amount of Gaussian convolution, thereby reducing the running time of image processing. From the processing effect, the improved algorithm can effectively restore the details of the image when the three scale parameters are selected as [15, 80, 250]. In the restoration process of the three different geomorphic images, only the urban area contains The haze image has achieved a good restoration effect, but because the image restoration effect of the mountain and woodland environment is poor, and the image of the mountain area has color distortion, the purpose of highlighting the important target details and sharpening the edge is not achieved.

Analyzing the reason for this experimental result is that the distribution of the grayscale histogram of the haze image in the forest and mountain areas is more concentrated in the lower brightness position. Therefore, try to reduce the gap between the three scale parameters and maintain the color restoration The constant α remains unchanged, and the following experimental results are obtained:
It can be seen that the image restoration effect has not changed much after changing the parameters. Although there is a certain improvement in color distortion, the edge information of important targets is still not clear enough. Analyzing the reasons why changing the parameters has little effect on the improvement of image restoration, the improved Retinex algorithm can improve the global contrast of the image by selecting the blur kernel parameters, but for scenes with too many image scenes and uneven illumination light distribution, there is still the phenomenon of blurred contours of some targets. Therefore, for different types of terrain and landforms, it is necessary to select different types of defogging algorithms for image restoration processing according to the distribution law of the scene gray map.

4. Conclusions
This article briefly discusses and analyzes how to clear a single UAV reconnaissance image of three different topography and landforms in a haze environment. First, the dark primary color prior image defogging algorithm is introduced, then the Retinex theory and the single-scale parameter, multi-scale parameter Retinex algorithm are introduced, and finally the improved Retinex algorithm is given. The algorithm in this article separates the brightness $I$ from the conversion between the RGB color space and the HIS color space of the foggy image for separate processing, thereby increasing the calculation speed, improving the defect of insufficient brightness and making the image color richer. The detailed information of the image is clearer. However, through simulation experiments, the reconnaissance images in different terrain and landform environments are brought into. From the results of image restoration processing, it can be seen that urban landforms change smoothly due to the light intensity and the scene is relatively single. The algorithm in this paper can effectively improve the contrast of the image and make it important. The target details are more clarified, providing data information that is more convenient for machine recognition for the next target recognition and tracking. However, the combat terrain of the land battlefield is complex and changeable. The algorithm in this paper cannot achieve the expected effect in the reconnaissance image scenes of woodland, mountainous areas, etc., and the uneven distribution of illumination light. Therefore, in other terrain and landform environments, it is necessary to find a more suitable image dehazing algorithm.

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