Research on A Quantitative Assessment Model Based on Visual Perception in Low-Altitude Remote Sensing

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Abstract—In order to evaluate the recovery effect of the visible light band in the low-altitude remote sensing, the sensitivity and significance of the visual perception of the restored image are selected and optimized by the perceptual characteristics of the human visual system. Finally, the effective detail retention ability, Structure information, multi-scale similarity and visual fidelity. A kind of image-based image fog quantification evaluation model QAMVP is proposed based on visual perception. The experimental results show that the model has a strong judgment force on the object group with obvious difference in the image quality evaluation. The accuracy rate of the sample group is 92%. In the aspect of visual perception, the MSE of the model index curve is obviously lower than the comprehensive evaluation method and the PSNR measurement method, which indicates that the model has certain advantages in the degree of visual perception and the correlation with the visual perception of the human eye. The results of the study can provide theoretical basis and practical guidance for the objective evaluation of the visible image in the low-altitude remote sensing.

Keywords—Low-altitude remote sensing; Visible band; Visual perception; Quantitative assessment; Precision agriculture

I. INTRODUCTION

Low-altitude remote sensing technology which has the advantages of low cost, high reliability and real-time acquisition that has attracted a wide spread attention in various application field. using unmanned aerial vehicles with wide-angle cameras to get multispectral remote sensing images in visible band to process remote sensing image and monitoring information of farmland rapidly has been one of the important means of precision agriculture. However, there still hasn’t been a scientific and effective evaluation method on the quality of restored image. To provide reference, basis and improvement direction for the performance test of restoration processing of low-altitude remote sensing degraded image It’s a key step in the research of the application of visible image in precision agriculture, which has important significance in the research of UAV low-altitude remote sensing.

II. DESIGN MOTIVATION

For the restoration of degraded image in visible, band so far the research has got different effect. As picture 1(b-f) showed, is He, MDCP, Retinex, Tarel, Zhu5 most popular algorithms’ effect. However, how to evaluate the effect after restoration objectively and accurately, is still an important issue in the field of image processing. Based on the literature, objective evaluation methods of image quality are full reference type, half reference type and none reference type. UAVs taking the photos in visible band in Low-altitude remote sensing can’t refers to Standard clear image, which is no reference quality evaluation category. Zhu pointed out that Image quality degradation due to Atmospheric Scattering also can’t refer to standard image, only can refer to degraded image.
reflects the ability of the restored image to eliminate noise and the "Halo" effect to influence the edge information.

The over-enhancement phenomena such as "Halo" effects of degraded image restoration processes, such as contours, depth of field, and so on, become wider and brighter. Therefore, the edge-enhanced detail intensity $I_{Halo}$ of the restored image can be obtained by summing the maximum pixel-point neighborhood of the corresponding region in the bright image of the restored image:

$$I_{Halo} = \frac{\sum_{x \in \Phi} (\sum_{y \in \Omega(x)} I_{bright}(y))}{n}$$  \hspace{1cm} (1)

Where $\Omega(x)$ is the field where the center point is $x$, $n$ is the number of pixels in the neighborhood, and $I_{bright}$ is the bright channel image. Similarly, the brightness intensity $I^i_{Halo}$ of the region corresponding to the original image is:

$$I^i_{Halo} = \frac{\sum_{x \in \Omega} (\sum_{y \in \Omega(x)} I^i_{bright}(x))}{n}$$  \hspace{1cm} (2)

The over-enhanced approximation of the restored image is the difference between the two.

The total edge detail intensity $L_{J}$ of the restored image can be solved by the Canny operator:

$$L_{J} = \sum_{j} f_{canny}(x)$$  \hspace{1cm} (3)

Finally, the image effective detail retention capability factor $L$ is reflected by the proportion of the edge of the restored image that enhances the detail intensity in the total edge detail intensity, which is:

$$L = \frac{(I_{Halo} - I^i_{Halo})}{L_{J}}$$  \hspace{1cm} (4)

In equation (4), the smaller the $L$, the stronger the effective detail retention ability of the restored image, and the better the effect of suppressing the "Halo" effect.

2) The degree of tone reduction

When the restoration effect is good, the color of the image is truly coordinated, which is consistent with the degree of color shift in the visual perception. At this time, the histogram shape of the image before and after the restoration is substantially similar, so the histogram similarity can be used to measure the degree of hue offset of the restored image.

The Pasteur distance is used in statistics to measure the separability of two discrete probability distributions. In this paper, we define the calculation of histogram similarity from histDist. The mathematical expression is:
\[ H = \sum \sqrt{p_1 \times p_2} \]  

(5)

Where \( p_1 \) and \( p_2 \) are the probability distributions of the discrete points on the histogram before and after the restoration, respectively, and \( H \) is 1 when it is completely matched, and 0 is completely absent.

3) Structural information

The measure of the degree of change in scene structure is a good approximation of image perceived distortion. A large increase in the restoration of image structure information means over-enhancement and the introduction of noise, while a significant reduction represents the loss of detail information. Therefore, the structural information of the reconstructed image can be scientifically measured, and the realism and distortion of the restored image can be effectively evaluated.

An image \( I(x) \) can be expressed as a product of a reflection image \( R(x) \) and an illumination image \( L(x) \), which is:

\[ I(x) = R(x) \cdot L(x) \]  

(6)

The structure of the object in the scene is independent of the illuminance, so the texture information is extracted only for the reflected image \( R \). The derivation of the reflection image \( R(x) \) is achieved by separating the illumination image by Gaussian kernel \( Gc(x) \):

\[ R(x) = Gc(x) \ast I(x) \]  

(7)

The similarity function is defined as \( S \), and the reflection images \( R1 \) and \( R2 \) of the restored image are compared with the structural information, obtain:

\[ S(R_1, R_2) = \frac{\sigma_{12}}{\sigma_1 \sigma_2} \]  

(8)

among them,

\[ \sigma_{12} = \frac{1}{M+1} \sum_{i=1}^{M} (R_{1,i} - \mu_1)(R_{2,i} - \mu_2) \]  

(9)

\( M \) is the number of pixels; \( \mu_1 \) and \( \sigma_1 \) are the mean and standard deviation of \( R1 \), respectively; \( \mu_2 \) and \( \sigma_2 \) are the mean and standard deviation of \( R2 \) respectively.

4) Multi-scale structure similarity

Multi-scale Structural SIMilarity (MSSIM) is based on structural similar image quality evaluation factors, based on the HVS highly adaptable to natural vision systems. Compared with the single-scale structure similarity is only applicable to the specific situation, the multi-scale structure similarity has higher adaptability. The mathematical expression of MSSIM is:

\[ \text{MSSIM}(x, y) = \left( \frac{1}{M} \sum_{i=1}^{M} \frac{S_{HistDist}MSSIM(x, y)}{(1 - VIF(x, y))^\gamma} \right) \]  

(10)

In the above equation, the indices \( \alpha, \beta, \gamma \) and \( \theta \) are used to adjust the relative importance of the different components of the formula.

5) Image visual fidelity

Visual Information Fidelity (VIF) reflects the perception that the image is the remake of the human eye by the HVS, similar to the process of extracting the valid information for the degraded image.

The traditional VIF carries out the fidelity calculation with the distortion less pattern as the reference pattern. In this paper, the original degraded image is used as the reference image, and the image information before and after the restoration is compared with the knowledge of the information theory. The results of the image fidelity evaluation are obtained. According to the above theory, VIF can be defined as:

\[ \text{VIF}(x, y) = \sum_{j=1}^{s} \sum_{i=1}^{M} \frac{I(c_{i,j}, f_{i,j})}{\sum_{j=1}^{s} \sum_{i=1}^{M} I(c_{i,j}, e_{i,j})} \]  

(11)

\[ I_{c f}(i, j) = i_{f}(x, y) - i_{e}(x, y) \]

\[ I_{c e}(i, j) = i_{e}(x, y) \]

Where \( s \) is the number of scales of the image, \( M_j \) represents the number of image blocks on the scale \( j \), and \( I(c_{i,j}, f_{i,j}) \) and \( I(c_{i,j}, e_{i,j}) \) are represented as mutual information. In general, the information obtained by the human eye is less than the original image, so the value range of VIF \( (x, y) \) is \([0, 1]\), the larger the value of VIF \( (x, y) \), the more the visual fidelity high.

B. The construction of the model

The above five visual sensory sensitive transcendental factors, from the aspects of the perception mechanism of HVS, and the characterization of degraded images of low-level remote sensing visible-band, the global weights and Measures of Image Quality Evaluation are carried out. Further, by normalization and multivariate fitting analysis, we can come to the mathematical expression of QAMVP model as follows:

\[ Q = \frac{(S)^\alpha \cdot (\text{HistDist})^\beta \cdot (\text{MSSIM})^\gamma}{(L)^\theta \cdot (1 - \text{VIF})^\phi} \]  

(12)

In the above formula, \( Q \) is a comprehensive quantitative evaluation parameter, the larger the value of \( Q \), the better the processing effect of the restored image. The five weight adjustment parameters, \( \alpha, \beta, \gamma, \theta \) and \( \phi \) are the degree of sensitivity of the factors. According to the degree of
IV. TEST RESULTS ANALYSIS

In order to verify the stability of the QAMVP model, the specific experimental method is as follows:

A. Test image sample library build

Through the network search, UAV sampling, etc. to establish low-altitude remote sensing visible light band degradation image sample library, a total of 600 images. Then, randomly extract 200 pictures to build the test image sample library.

B. Evaluation of the sample map library building

The HE and DCP algorithm were used to reconstruct the test image sample database, and 200 restoration results were obtained. The construction of the sample library was evaluated. Herein, the reason for selecting the HE method is that although the method improves the contrast of the image to a certain extent in the restoration process, the recovery result is likely to be enhanced, the visual perception is not coordinated, and the comprehensive restoration effect is poor. The choice of DCP algorithm is because the algorithm is currently recognized as one of the best methods for recovering visual effects. Therefore, the statistical results of the two algorithms on the restoration of large-volume image processing should be obvious.

C. Comparison of evaluation methods

The QAMVP model, the comprehensive evaluation method in, and the PSNR measurement method were used for comparative analysis. By evaluating the probability of the highest value of the DCP algorithm in the scatter plot of each evaluation method, it can reflect the evaluation performance stability of each evaluation method. The detailed experimental data scatter plot is shown in Figure 3 to Figure 5.

In the figure, the abscissa indicates the evaluation sample group number; the ordinate indicates the evaluation index value, the same figure is large, indicating that the recovery effect is better. Figure 3 is the QAMVP model to evaluate the sample map library of the evaluation index value of the scatter plot, which DCP recovery results of the high value of 184 indicators, accounting for 92% of all the figure, can be seen as The QAMVP model has an accuracy rate of 92%. Figure 4 is a comprehensive evaluation method to evaluate the sample map library of the evaluation index value of the scatter plot, which DCP recovery results of the index value of the high group of 136, accounting for 78% of all the graph, the accuracy of this test is 78%. Similarly, Figure 5 is the PSNR measurement method to evaluate the sample map library of the evaluation index value of the scatter plot, which DCP recovery results of high indicators of 44 groups, accounting for 22% of all graphs, that is, the test The accuracy rate is 22%.

It can be seen that the QAMVP model has a strong judgment on the objective group with obvious difference in the sample evaluation effect of the sample pool, and it can be deduced effectively. It is excellent in the evaluation experiment of 200 groups The stability of the. Through the data comparison and analysis, the comprehensive evaluation method can also get the correct evaluation result to a certain extent, but the accuracy rate is lower than the QAMVP model. PSNR measurement method evaluation accuracy is poor, the reason should be sensitive to PSNR HE method of a certain indicator of the upgrade. From the other side, it is pointed out that the objective evaluation method based on single factor is easy to fall into the trap of one-sided analysis in the evaluation process, and it is necessary to ignore the characteristics of the integrated information.
V. CONCLUSION AND PROSPECT

Low-altitude UAV remote sensing technology is one of the important means of fine agriculture, and it is of practical significance to carry out objective quantitative evaluation of the restoration of visible light band images in low-altitude remote sensing. Currently, in connection with the situation that the comprehensive quality evaluation of the reconstructed image is Emphasis on subjective evaluation, lacking of a scientific and objective quantitative evaluation system. Based on the perception of HVS, this article came up with an image quality evaluation model based on visual perception. The conclusion is as follows:

(1) The five low-altitude remote sensing degraded images visual perception sensitive a priori factors, which proposed by the QAMVP model, simulating the visual perception of the human eye, the subjective image performance evaluation, into a comprehensive factor to solve the mathematical problems, and it compensate for the single defect of the index in the traditional objective evaluation method. From the Visual perception perspective, a comprehensive evaluation analysis of the reconstructed image was made.

(2) Compared with the comprehensive evaluation method and PSNR measurement method, QAMVP model has its certain advantages in terms of evaluating performance stability, and obvious advantages in the aspect of visual perception as well as meeting performance.

(3) In this paper, the evaluation rate of 200 groups of evaluation samples is 92%, the value of MSE in two graphs of visual perception and meeting performance, are 0.075332 and 0.118076832 respectively, which shows that bases on visual perception, the model can evaluate the image of low-level remote sensing visible-band recovery effectively.

In the field of precision agriculture, application Technology of Low-level remote sensing visible light band image, will play an important role in the next period of time. With the involvement of large data acquisition and deep learning areas, the development of image quality evaluation methods, which based on visual perception, will also get rapider and rapider.

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