Retraction

Retracted: Adaptive Enhancement Algorithm of High-Resolution Satellite Image Based on Feature Fusion

Journal of Mathematics

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope

(2) Discrepancies in the description of the research reported

(3) Discrepancies between the availability of data and the research described

(4) Inappropriate citations

(5) Incoherent, meaningless and/or irrelevant content included in the article

(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] R. Wang and W. Xiao, "Adaptive Enhancement Algorithm of High-Resolution Satellite Image Based on Feature Fusion," *Journal of Mathematics*, vol. 2022, Article ID 1029247, 9 pages, 2022.

Hindawi

Research Article

Adaptive Enhancement Algorithm of High-Resolution Satellite Image Based on Feature Fusion

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Since the traditional adaptive enhancement algorithm of high-resolution satellite images has the problems of poor enhancement effect and long enhancement time, an adaptive enhancement algorithm of high-resolution satellite images based on feature fusion is proposed. The noise removal and quality enhancement areas of high-resolution satellite images are determined by collecting a priori information. On this basis, the histogram is used to equalize the high-resolution satellite images, and the local texture features of the images are extracted in combination with the local variance theory. According to the extracted features, the illumination components are estimated by Gaussian low-pass filtering. The illumination components are fused to complete the adaptive enhancement of high-resolution satellite images. Simulation results show that the proposed algorithm has a better adaptive enhancement effect, higher image definition, and shorter enhancement time.

1. Introduction

With the continuous progress of computer electronic technology, human beings have higher and higher requirements for computer applications. In particular, the rapid development of the Internet and multimedia technology is ubiquitous in our lives, which makes the way we obtain information constantly changing. The acquisition of this information must be based on the accurate analysis and processing of the digital image, which is called digital image processing technology. So far, many technologies of digital image processing have been increasingly developed and matured, and their applications have achieved great success in military, industrial research, medicine, and other fields [1].

Satellite remote sensing is a very important part of remote sensing. It takes man-made satellites as a platform. In 1999, the Earth Eye company of the United States successfully launched a satellite named "IKONOS" with a multispectral image resolution of 4 m and a panchromatic image resolution of 1 m, which is called "one of the most important developments in the history of the space age." In 2008, it successfully launched a satellite with a panchromatic image resolution of 0.41 m and a multispectral image resolution of 1.65 m, which is called the "real GeoEye-1;" In 2013, China launched the gaogao-1 satellite. After years of gradual development, satellite remote sensing technology has made great progress. Now, it has entered the era of all-weather information acquisition and observation. In the global earth observation system, the mutual cooperation among large, medium, and small satellites and the mutual compensation between high, medium, and low resolution have been formed. A large number of remote sensing data provided have been widely used in many fields such as the military [2].

According to the statistics provided by the international satellite cloud climate program, it is found that the amount of clouds in the sky accounts for more than 50% over the earth's surface. Therefore, the existence of clouds cannot be avoided in a large number of remote sensing images. In addition, the use of high-resolution satellites plays an important role in the interpretation of small ground objects,

and the image resources are very valuable. Therefore, we need to improve the utilization of available information in the image as much as possible and reduce the waste of data. When the satellite sensor receives the signal, it will inevitably be affected by various factors such as the sensor's own performance, orbit angle, and atmosphere, which are inevitable to be considered in the process of image processing. Therefore, not every remote sensing image obtained through the satellite is qualified in the application [3]. When there are clouds in an image, if the remote sensing image to be used is not preprocessed, it will inevitably cause a great interference to obtain the real information and affect the quantitative analysis and interpretation of remote sensing data, which will reduce the application value of high-score satellite images. Considering the actual situation, that is, the limitations of time and space, it is impossible for the satellite to shoot again, and the shooting cost of high-resolution images is high, so we can only use these images covered by clouds. Therefore, in order to improve the image definition, it is of great significance to realize high-resolution satellite image enhancement.

Reference [4] proposes a haze weather image enhancement algorithm based on the dark channel and multiscale Retinex. Firstly, twice-guided filtering is used to improve the transmittance calculation of the dark primary color prior model. Then, in Hue-Saturation-Value (HSV) space, the brightness V is enhanced by the improved multiscale Retinex algorithm, and the illuminance component is estimated by using a double-edged filter function instead of a Gaussian filter function. The spatial domain convolution is converted to the frequency domain product to reduce the amount of computation. The illuminance of the incident component L is corrected by gamma transform, and the contrast of the reflection component R is stretched by the sigmoid function. Finally, the image is converted to Red-Green-Blue (RGB) space, and the image is simulated by MATLAB. The visual effect and quality evaluation index show that the improved algorithm can effectively restore the color of the fog image and enhance the contrast of the image. Yu and Hao [5] proposed a fog image enhancement algorithm based on the combination of fractional differentiation and multiscale Retinex. Firstly, the original image is processed by the fractional differentiation algorithm to retain the low-frequency information of the image, and the processed image is converted from RGB color space to Hue-Saturation-Intensity (HSI) color space. Then, the Gaussian filter in the multiscale Retinex algorithm is replaced by the guided filter. The luminance component and reflection component are extracted, and the sum of these two components is used as a new luminance layer to enhance the saturation layer using a gamma correction function. Finally, the HSI image is converted into an RGB image to realize image enhancement. However, the accuracy of image enhancement by the above two algorithms is low, resulting in a poor image enhancement effect and poor image definition. Wang et al. [6] proposed a vascular image enhancement algorithm based on the directional adjustable filter. This method takes the machine vision system as the hardware platform, uses a directional adjustable filter to extract venous

vessels in all directions, uses wavelet transform for image fusion, obtains venous high-frequency information, and enhances vascular images hierarchically through a nonlinear antisharpening mask. The experimental results show that the proposed method can effectively suppress noise, reduce information loss, and achieve a better enhancement effect. Cui and Yang [7] proposed a single traffic image haze removal algorithm combining histogram equalization (HE) and improved color restoration multiscale Retinex (MSRCR). Firstly, the image is enhanced by HE and MSRCR, respectively. When MSRCR is enhanced, the guiding filter with a smooth-edged preserving function is used to replace the Gaussian function to estimate the illumination component. Then, weighted fusion is performed on the enhanced two images. However, the above two algorithms consume a long time for image enhancement, resulting in low enhancement efficiency.

In view of the problems existing in the above algorithms, this paper proposes a high-resolution satellite image adaptive enhancement algorithm based on feature fusion, and experiments show that the proposed method can carry out high-resolution satellite image adaptive enhancement in the shortest time, with high enhancement accuracy and good image definition, which proves the effectiveness and practicability of the algorithm in this paper. It solves the problems existing in the traditional algorithm. Section 2 of our paper gives a detailed analysis of adaptive enhancement of high resolution satellite images. Section 3 does experiments and studies the final results of the tests. Section 4 is the conclusion of our paper.

2. Adaptive Enhancement of High-Resolution Satellite Images

2.1. A Priori Information Collection. As the sample data before high-resolution satellite image processing, prior information can judge the subsequent uncertainty inference. How to use priori information reasonably is the essence of adaptive enhancement of high-resolution satellite images. Therefore, a priori information is constructed for the background distribution and feature structure of high-resolution satellite images [8].

Acquisition 1: image target individual amplitude distribution prior information.

According to the geometric scattering rules, if the individual length of the target in the high-resolution satellite image is greater than or equal to the incident wavelength, the processed high-resolution satellite image information is composed of multiple independent scattering centers. At this time, a set at frequency i and position angle j, there are p independent scattering centers, and the target individual backscattered field $E_{i,j}$ can be described as follows:

$$E_{i,j} = \sum_{l=1}^{n} S_l \exp\left(a_l \cos j + b_l \sin j\right), \tag{1}$$

where a, b is the spatial azimuth coordinate of scattering center $l = 1, \wedge, n$ and S_k is the mean value of amplitude distribution. If the azimuth scattering value of the target

individual in the high-resolution satellite image is large, the scattering value of the background area is small, as described in the following formula:

$$g(x) \gg 0, \quad x \in T,$$
$$g(x) \approx 0, \quad x \notin T, \tag{2}$$

where T is the target individual coordinate sequence in the sample image [9].

Acquisition 2: image background a priori information.

For most high-resolution satellite images, the background will contain a large number of uneven noise and disorderly clutter, which cannot meet the requirements of equalization hypothesis [10]. In the image adaptive enhancement operation, the individual characteristics of the target are more important, and the background area can ensure the integrity of the light and shadow part and edge details. Therefore, in the nonedge, light and shadow, and target areas, it only needs to approximately meet $|\Delta g| = 0$, that is,

$$\Omega^{\psi} \int (|\Delta g|, |g|) d\Omega = 0, \tag{3}$$

where ψ is used to strengthen the weight of the background area in the limiting conditions, Ω is the central support area of the sample image, and d is the similarity of the edge image. Thus, the weights of regions such as edges and target individuals are reduced [11].

2.2. High-Resolution Satellite Image Preprocessing Based on Histogram Equalization.
Histogram equalization is a common algorithm in low-quality image processing. This method is usually used to reflect the size of each gray level in the image and the occurrence probability of corresponding image pixels. The gray range of pixels in a low-quality image is usually small. After histogram equalization, the dynamic range of pixels in the image to be processed is stretched to improve the overall brightness contrast of the original image [12] Therefore, according to the noise removal and quality enhancement regions of high-resolution satellite images determined above, the histogram is used to equalize the high-resolution satellite images.

Assuming that the gray level of the high-resolution satellite image to be processed is m, the total number of pixel points of the image is n, and P_r^k is the probability density function of the occurrence of the image gray level k; the calculation formula of P_r^k is as follows:

$$P_r^k = \frac{n^k}{nE_{i,j}}, \tag{4}$$

where r represents the k-th gray level, n^k represents the gray level of low-quality image, which is the number of pixels, and n is the number of pixels of the whole low-quality image to be processed [13]. The expression of pixel cumulative probability distribution function CDF of histogram equalization algorithm is as follows:

$$s_k = \sum_{j=0}^{k} P_r^k r^k, \tag{5}$$

where s_k represents the histogram equalization formula, which maps the pixels with the gray range of r^k in the low-quality image to the pixel value corresponding to the gray range of s_k in the enhanced image [14].

2.3. Image Feature Extraction.
According to the above equalization processing results of the high-resolution satellite image, the local features of the image are extracted by using the local variance theory to obtain the illumination information of the high-resolution satellite image. The application of the local variance algorithm is to judge the pixels containing effective information in the image, obtain the local variance image by calculating the gray variance between the central pixel in one pixel and several adjacent pixels, and realize the comprehensiveness and detail of texture feature extraction of the high-resolution satellite image in combination with the local binary algorithm [15].

Starting from the center point of a pixel, a circular area is planned with a fixed radius, and the regional texture features are expressed as follows:

$$T = \{g_0 - g_b, g_1 - g_b, \cdots, g_{w-1} - g_b\}. \tag{6}$$

In the above formula, T represents the regional texture feature, w represents the number of neighborhood points on the circumference, g represents the gray value, and g_b represents the gray value of the central pixel. Combined with LBP operator, a symbolic function is used to describe regional texture features, and formula (6) is transformed into

$$T = \{t, t, \cdots, t(g_{w-1} - g_b)\}. \tag{7}$$

In the above formula, t represents a symbolic function. The variance calculation results are fused to extract the local texture features of high-resolution satellite images:

$$T = V(\vartheta)$$
$$= V(g_0 - g_b, g_1 - g_b, \cdots, g_{w-1} - g_b). \tag{8}$$

In the above formula, $V(\vartheta)$ represents the variance of the elements in set ϑ [16].

For the effective information contained in the local variance map, the variation function is used to extract and process the image texture features, and its calculation formula is expressed as follows:

$$\alpha(h) = \frac{s_k}{2\gamma(h)} \sum_{i=1}^{\gamma(h)} \left[\frac{g(k_i)}{g(k_i + h)} \right]^2. \tag{9}$$

In the above formula, h represents the step size, $\alpha(h)$ represents the variation function, γ represents the number of pixels meeting the specified step size in set K, q represents the total number of pixels in the set, and k_i represents the i-th pixel in the set [17].

Based on formula (9), it can be seen that the calculation result of the variation function value is often lower than half

of the local variance. If the gray value in the formula is changed to local variance, the variation function formula is changed to

$$\alpha(h) = \frac{1}{2\gamma(h)} \sum_{i=1}^{\gamma(h)} \left[\text{var}(k_i) - \text{var}(k_i + h)\right]^2. \quad (10)$$

In the above formula, $\text{var}(k_i)$ represents the local variance of the element. Considering the continuity of image pixel gray value distribution in space, this continuity will decrease with the distance between pixels. Therefore, in the process of image texture feature extraction, the step size of variogram is always less than half of the pixel length. According to the extracted features, the Gaussian low-pass filtering method is used to obtain the illumination component estimation $i(x, y)$, which contains a large amount of original structure information, which can avoid distortion in the process of high-resolution satellite image enhancement [18].

2.4. Illumination Component Enhancement Based on Feature Fusion.
It is usually defined by the product of illumination component and target reflection component. Assuming that the target reflection is r, the mathematical expression of high-resolution satellite image $f(x, y)$ is as follows:

$$f(x, y) = i(x, y) * r(x, y). \quad (11)$$

The light source and target determine the properties of illumination component $i(x, y)$ and image $f(x, y)$ respectively.

Due to the influence of illumination, the edge details of the target are prone to sudden change. Therefore, by separating the incident component and suppressing the interference of the light source, the adaptive gamma function is used to correct the illumination component. The expression of the adaptive gamma correction function is:

$$i_2(x, y) = i(x, y)^{r(x,y)}. \quad (12)$$

Since the variance, gradient, and entropy of the image reflect the image quality, clarity, and richness, respectively, the three parameters of variance, gradient, and entropy are selected to obtain the local features of the image [19]. The calculation methods of variance, gradient, and entropy are as follows:

$$Q(x, y) = \frac{1}{D} \sum_{n=1}^{k} \left(i_2(x, y) - i_p\right)^2,$$

$$E(x, y) = \frac{1}{D} \sum_{n=1}^{k} \left(i_p(m+1, n+1) - i_p(m, n)\right), \quad (13)$$

$$W(x, y) = \sum_{n=1}^{k} Dp\left(i_p(m, n)\right).$$

In order to obtain a better illumination correction effect, three image local features of variance, gradient, and entropy are taken to fuse the illumination information of the image [20]. In the fusion process, for each pixel (x, y), the variance,

gradient, and entropy of the pixel in its neighborhood are counted as the local features of the pixel, and the weight of the illumination component in the fusion is determined. The expression is as follows:

$$s(x, y) = \frac{Q(x, y)}{\sum_{i=1}^{3} Q(x, y)h + i_2(x, y)}, \quad (14)$$

where h is particularly a small positive number in order to avoid the denominator value of 0 in the above formula (14) [21]. The fused illumination component is the enhanced illumination component $I_e(x, y)$, and its expression is as follows:

$$I_e(x, y) = \sum_{p=1}^{3} s(x, y) + i_p(x, y). \quad (15)$$

The mapping from the membership degree to spatial domain is completed by using the following inverse transformation form of fuzzy domain:

$$x_{ij} = \mu'_{ij} * (x_{\max} - x_{\min}) + x_{\min} I_e. \quad (16)$$

The HSV (hue-saturation-value) color high-resolution satellite image is transformed into the RGB (red, green, blue) color image to obtain the color of high-resolution satellite image after adaptive enhancement [22].

3. Simulation Experiment Analysis

In this section, we conducted some experiments using custom software and hardware parameter configurations. Moreover, an in-depth analysis of the results is carried out. In this process, we first present the experimental preparation, which is followed by the test of index selection. Then, the image preprocessing process begins. Finally, the results of the experiments are achieved which are then investigated and systematically studied.

3.1. Experimental Preparation.
In order to verify the effectiveness of the high-resolution satellite image adaptive enhancement algorithm based on feature fusion in practical applications, a simulation experiment is carried out. The relevant software and hardware configuration of the simulation experiment are shown in Table 1.

In this paper, the high-resolution satellite image is taken as the experimental sample, and the image pixels of the experimental sample are $512 * 512$. The experimental sample is shown in Figure 1.

3.2. Test Index Selection.
In order to effectively test the adaptive enhancement performance of high-resolution satellite images, two quantitative indexes, peak signal-to-noise ratio, and entropy are used for relatively objective evaluation. Among them, the peak signal-to-noise ratio index is used to describe the changes of brightness component and chroma component of the image, and the quality of high-resolution satellite image improves with the increase of signal-to-noise ratio. The entropy index is a physical index

Table 1: Experimental software and hardware parameter configuration.

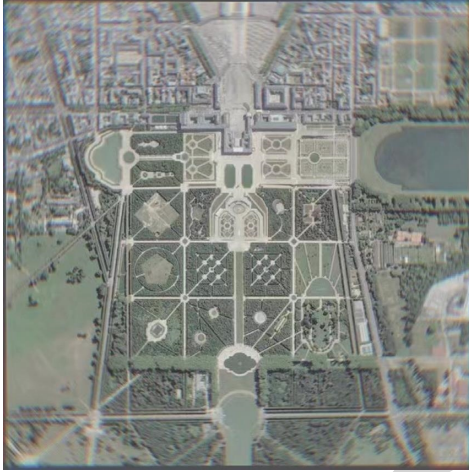| Equipment name	Model parameters
Processor	Intel Core i5-6400
Memory	16 GB
Dominant frequency	3.2 GHz
Operating system	Windows XP
Simulation software	Proteus 7.8
Programing language	C++, C#
Open-source database	OpenCV, OpenGL, etc.

Figure 1: Experimental sample.

based on Shannon information theory to enhance the richness of image information. It is used to describe the average amount of information contained in the image. The outline and texture of the image become clearer with the increase of entropy. The calculation formulas of the two evaluation indexes are as follows:

$$PSNR = 10 \lg \frac{255^2}{MSE},$$

$$E(i) = -\sum_{u=0}^{Gl(i)-1} C_u * \log(C_u). \tag{17}$$

In the above formula, C_u is the probability that the pixel gray value of the high-resolution satellite image is u after enhancement. When the gray level occurrence probability of the high-resolution satellite image is $C_u = 1/Gl(i)$ and $E(i)_{max} = \log[Gl(i)]$, the high-resolution satellite image has a great degree of information value, and the gray level is evenly distributed; when the occurrence probability of gray level of high-resolution satellite image is $C_u = 1$ and $E(i)_{min} = \log[1] = 0$, there is no information available in the image; MSE in the peak signal-to-noise ratio formula represents the mean square error, which is solved by the following formula:

$$MSE = \frac{1}{M * N} \sum_{0 \le x \le M} \sum_{0 \le y \le N} (f'(x, y) - f(x, y))^2. \tag{18}$$

3.3. Image Preprocessing.
Before the experiment, the image is preprocessed to remove the noise contained in the image. The experimental sample image is described as the histogram shown in Figure 2.

According to the preprocessing method proposed in this paper, the histogram of the above original image is equalized to obtain the preprocessed experimental sample image shown in Figure 3.

According to Figure 3, compared with the original image histogram, the gray value of the preprocessed sample image histogram changes greatly, which promotes the uniformity of image brightness and highlights the image details containing main information. The preprocessed experimental sample image is applied to the image enhancement experiment, which enhances the intuition of the experimental results.

3.4. Experimental Test Results.
The high-resolution satellite image adaptive enhancement algorithm based on feature fusion proposed in this paper, the haze weather image enhancement algorithm based on the dark channel and multiscale Retinex proposed in document [4], and the haze image enhancement algorithm based on the combination of fractional differentiation and multiscale Retinex proposed in document [5] are used to test the adaptive enhancement of experimental samples. The test results are shown in Figure 4.

According to Figure 4, the haze image enhancement algorithm based on the dark channel and multiscale Retinex proposed in document [4] and the haze image enhancement algorithm based on the combination of fractional differential and multiscale Retinex proposed in document [5] have not been significantly improved after adaptive enhancement of high-resolution satellite images. The adaptive enhancement algorithm of high-resolution satellite images based on feature fusion proposed in this paper is used to adaptively enhance the high-resolution satellite image. The processed image is clearer, which improves the definition of the high-resolution satellite image and the adaptive enhancement effect of the high-resolution satellite image. The effectiveness of the adaptive enhancement algorithm for high-resolution satellite images based on feature fusion is verified.

The peak signal-to-noise ratio and entropy data are used to evaluate the adaptive enhancement effect of high-resolution satellite images of the three algorithms. After recording the data of each evaluation index, the change trend of each method evaluation index shown in Figure 5 is drawn.

According to Figure 5, the peak signal-to-noise ratio and entropy of the high-resolution satellite image adaptive enhancement algorithm based on feature fusion proposed in this paper are higher than the haze weather image enhancement algorithm based on the dark channel and multiscale Retinex proposed in literature [4] and the haze image enhancement algorithm based on fractional differentiation and multiscale Retinex proposed in literature [5]. It shows that the image obtained by this algorithm contains more information, clearer contour and texture, and higher image quality. The above results further verified the
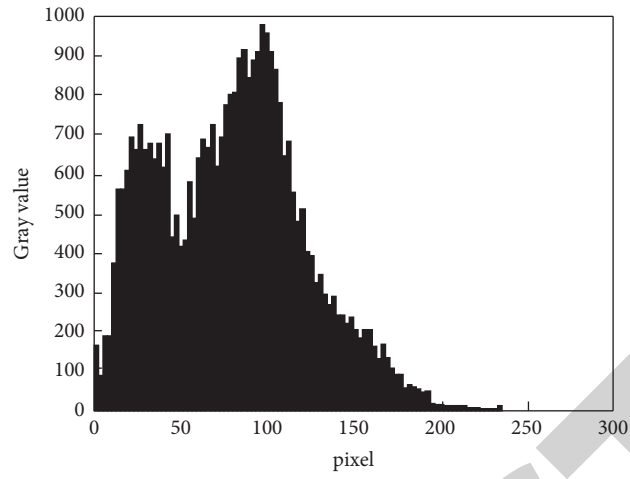
FIGURE 2: Histogram of original image.

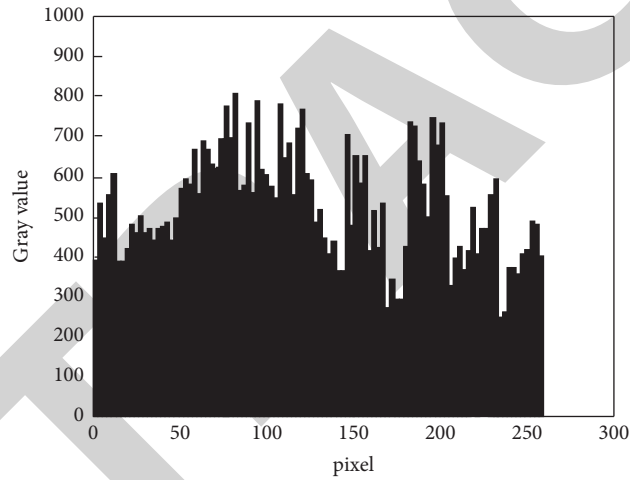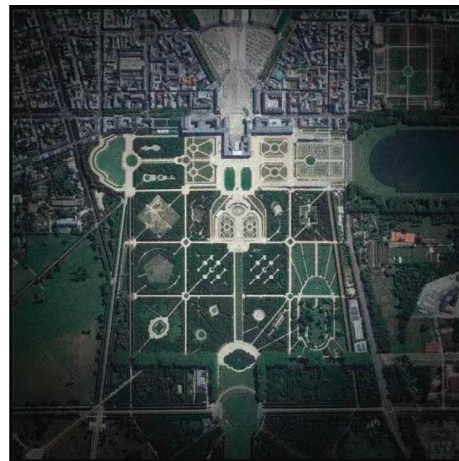FIGURE 3: Histogram equalization processing.

(a)   (b)

FIGURE 4: Continued.

(c)

Figure 4: Image adaptive enhancement results of three algorithms. (a) The adaptive enhancement results of the algorithm in this paper. (b) Adaptive enhancement results of algorithm in reference [4]. (c) Adaptive enhancement results of algorithm in reference [5].
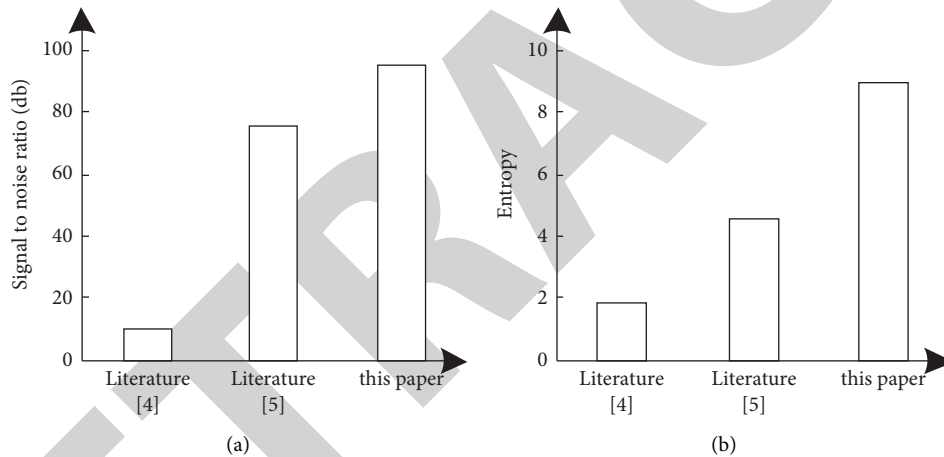

Figure 5: The schematic diagram of evaluation indexes of each algorithm. (a) Peak signal-to-noise ratio. (b) Entropy.

Table 2: Comparison results of image enhancement time of three algorithms (s).

Number of experiments/times	Paper algorithm	Reference [4] algorithm	Reference [5] algorithm
10	5.6	15.2	30.1
20	5.7	15.6	32.5
30	5.9	16.2	33.7
40	6.2	17.5	35.1
50	6.2	18.4	35.8
60	6.8	18.9	36.4
70	7.2	19.2	36.8
80	7.5	19.8	37.8
90	7.9	20.4	38.9
100	8	22.6	39.0

conclusion of the visual effect diagram and reflected the reliability of the index data from the side.

In order to further verify the effectiveness of the algorithm in this paper, the adaptive enhancement time of high-resolution satellite images of the three algorithms is compared and analyzed, and the comparison results are shown in Table 2.

According to Table 2, the time consumed by the high-resolution satellite image adaptive enhancement algorithm based on feature fusion for high-resolution satellite image

enhancement is within 8 s, which is better than the haze weather image enhancement algorithm based on the dark channel and multiscale Retinex proposed in literature [4] and literature [5]. The proposed fog image enhancement algorithm based on the combination of fractional differentiation and multiscale Retinex consumes a short time for high-resolution satellite image enhancement.

4. Conclusion

As we all know, remote sensing is a science and technology that obtains the characteristic information of the observed object through a certain sensor device without direct contact with the studied object and extracts, processes, expresses, and applies this information. A large number of remote sensing images obtained with the help of remote sensing technology have been widely used in various fields of national defense and national economic construction, such as military reconnaissance, crop yield estimation, land resource investigation, oil exploration, geospatial information updating, and other fields, which have produced huge economic and social effects. Satellite remote sensing images can quickly provide information on the earth's surface. The development and use of high-resolution satellite remote sensing images (such as IKONOS, SPOT5, cosmos, and OrbView) have created many new application fields. Due to the limitation of the imaging mechanism of the optical sensor, the quality of the image will be affected by the weather when obtaining the data; for example, it is easy to be affected by clouds and fog. However, atmospheric activities are very frequent, clouds and fog are common in the atmosphere, and a large number of remote sensing images will contain clouds and fog more or less. To obtain high-quality images, you need to select the best time and weather to obtain images. In addition to using aerospace remote sensing to obtain images affected by clouds and fog, common optical photography methods also depend on weather conditions. For example, the images obtained by intersection traffic violation monitors will also be affected by clouds and fog. Especially in foggy weather, the visual distance of the sensor is small, the image contrast obtained is low, and the color also has a certain offset, resulting in the failure of the monitoring system to work normally. Therefore, this paper proposes a high-resolution satellite image adaptive enhancement algorithm based on feature fusion. The experimental results show that the application of this algorithm can improve the quality of the high-resolution satellite image, and the efficiency of high-resolution satellite image adaptive enhancement is high.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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