Journal of Geography and Cartography (2022) Volume 5 Issue 1
doi:10.24294/jgc.v5i1.1413

ORIGINAL RESEARCH ARTICLE

Dynamic reconstruction method of unmanned aerial vehicle aerial remote sensing image based on compressed sensing

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ABSTRACT

Aiming at the current problems of poor dynamic reconstruction of UAV aerial remote sensing images and low image clarity, the dynamic reconstruction method of UAV aerial remote sensing images based on compression perception is proposed. Construct a quality reduction model for UAV aerial remote sensing images, obtain image feature information, and further noise reduction pre-processing of UAV aerial remote sensing images to better improve the resolution, spectral and multi-temporal trends of UAV aerial remote sensing images, and effectively solve the problems of resource waste such as large amount of sampled data, long sampling time and large amount of data transmission and storage. Maximize the UAV aerial remote sensing images sampling rate, reduce the complexity of dynamic reconstruction of UAV aerial remote sensing images, and effectively obtain the research requirements of high-quality image reconstruction. The experimental results show that the proposed dynamic reconstruction method of UAV aerial remote sensing images based on compressed sensing is correct and effective, which is better than the current mainstream methods.

Keywords: Compressed Sensing; Unmanned Aerial Vehicle (UAV); Remote Sensing Image; Image Dynamic Reconstruction

ARTICLE INFO

Received: 2 October 2021
Accepted: 28 November 2021
Available online: 5 December 2021

1. Introduction

At present, there are two main trends in the development of UAV aerial remote sensing image dynamic reconstruction technology: one is to dynamically reconstruct by broadening the range of remote sensing image data acquisition and detection; the second is to reconstruct the image by improving the matching rate of feature data. With the continuous increase of remote sensing image data in recent years, the feature diversity and data volume of UAV aerial images are also increasing. In such an environment, the image reconstruction technology needs to be continuously optimized and improved in order to obtain accurate and effective data. Based on this, a dynamic reconstruction method of UAV aerial remote sensing image based on compressed sensing is proposed[1]. Because the feature sampling rate of UAV aerial remote sensing image is greatly limited, it is necessary to deeply collect the measurement data of dynamic image as much as possible, further simplify and denoise the coding process of compressed image, and eliminate a large amount of redundant data in the process of image reconstruction, to ensure the efficient transmission and storage effect of massive remote sensing image data, realize high-quality remote sensing image reconstruction, reduce the amount of data storage and improve the efficiency of image processing.

2. Dynamic reconstruction of UAV aerial remote sensing image

2.1 Degradation model of UAV aerial remote sensing image

Build the degradation model of UAV aerial remote sensing image, collect and process the characteristics of UAV aerial remote sensing image, and obtain the super-resolution degradation model, so as to reflect the feature mapping relationship between high-resolution target image and low-resolution observation image, as well as the causes of UAV aerial remote sensing image degradation. Suppose the target image acquisition coordinate is $X(n)$, where n represents the undistorted continuous signal obtained during the aerial remote sensing image acquisition of UAV; $Y(k, i)$ is the remote sensing image sequence; D is the degraded discrete image feature level and $D = 1, 2, ..., p$; B_k refers to the distortion free conversion to discrete digital characteristic parameters, and M_k refers to the deformation matrix. Combined with the degradation observation model, the original digital image characteristics of UAV aerial remote sensing image are calculated. The specific algorithm is as follows:

$$R = DB_kM_k\sum\sum_{n\to\infty}^{lim}[X(n) + Y(k,i)]^{n_k} \quad (1)$$

Based on this, the multi frame image super-resolution parameters of UAV aerial remote sensing image are further reconstructed[2]. If the size of dynamic resolution image of aerial remote sensing image taken by UAV is $N = L_1N_1 \times L_2N_2$, L_1 and L_2 represent the horizontal and vertical down-sampling factors respectively. The size of each low resolution image after degradation is $N_1 \times N_2$; the parameters H_1 and H_2 represent the horizontal and vertical image acquisition ranges respectively; the characteristic factors L_{min} and L_{max} are the reconstruction of high-resolution images with the maximum and minimum moving distance of UAV aerial photography respectively; t represents the number of frames corresponding to the image with low separation rate; B_{in} represents the number of blurred image frames; D_{in} represents the sampling matrix of image characteristic parameters; G_{in} represents the value of additive noise. Further, super-resolution reconstruction is carried out for a single image. In the process of aerial photography, due to the influence of external interference and other factors, image blur, noise and additional interference are easy to occur, resulting in extremely low resolution of aerial images. Therefore, it is necessary to first describe the characteristics of super-resolution reconstruction model of single frame image. The specific algorithm is as follows:

$$\Delta\eta = \frac{\prod D_{in}(L_{max}-L_{min})}{2t\sum\sum_{x\to\infty}^{lim}[(G_{in}+B_{in})+(H_1+H_2)]} - B_kX(n) \quad (2)$$

Based on the above algorithm, the transform domain reconstruction of remote sensing image is further carried out. When the signal is compressible or sparse, a small amount of measured data can be collected through linear projection. If the transform feature vector of remote sensing image is v_{zin}, if there is only one feature element to be converted in the image, it is recorded as K, and $K \neq 0$. The sparsity of aerial remote sensing image is m, and the approximate sparsity is m'. In the process of aerial image degradation of UAV, the random projection measurement matrix is $a \times b$. The measured value of image feature dimension is y, and $y \geq m - m'$, and further compress the original sampling signal of ship aerial remote sensing image feature and record it as ψ. Further, all the information of the original signal is denoted as x, A is the information operator, and the minimum measured value after compressed sampling is reconstructed. The specific algorithm is:

$$\Delta\eta min_x\|\psi x\|_p s.t. y = A_x \quad (3)$$

Where, $p = 0$ or $p = 1$, $\|*\|$ represents the 1 norm of the sum of the absolute values of all elements in the vector, that is, the number of non-zero elements in the vector. The following unconstrained optimization problems are further optimized. Unconstrained optimization result τ_p^{csT} is:

$$\tau_p^{csT} = min_x \frac{1}{2}\|p - Ax\|\|_2^2 + \lambda\| * \| + \|x\|_p \quad (4)$$

In the above algorithm, λ represents the regular parameter of image feature. If the non-convex characteristic value of uav aerial remote sensing image is L_p, the generalized iterative compression algorithm is further combined to minimize the solution of arbitrary value S_p^{csr}, so as to ensure that the research requirements of fast convergence can be achieved to the maximum extent in the reconstruction process of remote sensing image[3].

2.2 Noise reduction preprocessing of remote sensing image

In order to better realize the dynamic reconstruction processing effect of remote sensing image, it is necessary to denoise the remote sensing image, reduce the amount of calculation through block processing, and intelligently divide the features of small image blocks. The collected aerial image of UAV is decomposed into low-frequency approximate data, and the characteristic frequency details in the horizontal, vertical and diagonal directions of the image are denoised[4]. For the noise interference area, the image is denoised and decomposed in frequency domain. The decomposed sub images are hierarchically denoised according to different resolution parameters. The specific process is shown in **Figure 1**.

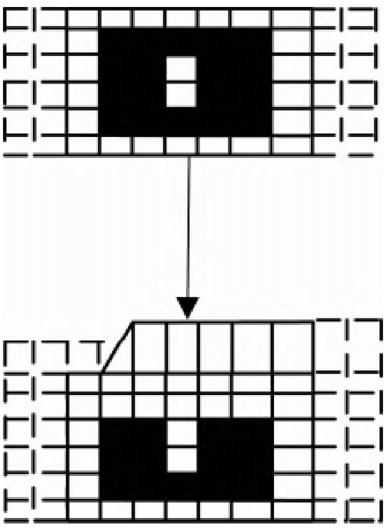

Figure 1. Image detail level denoising principle.

Further, combined with the compressed image theory, the image feature noise interference sparsity is sampled and analyzed, and the specific transform domain is measured, decoded and reconstructed in small image blocks[5]. Rematch the wasted resources according to the noise interference sparsity of the image, so as to ensure that the image can still be reconstructed without distortion in the case of noise interference, and realize the research requirements of image noise reduction preprocessing. In the process of image denoising and coding sampling, it is necessary to process the sparse image characteristic signal in the transform domain, and after the transform domain processing, carry out subsequent noise reduction and signal reconstruction to improve the accuracy of signal noise reduction. After polynomial transformation, the pixels of UAV aerial image are unevenly distributed and need to be resampled[6]. This method transforms the gray value of the key pixel array coordinates of the image, analyzes the relationship between the pixel points, resamples the original image and establishes a new image matrix, resulting in great brightness noise when the UAV aerial image is illuminated. In order to eliminate the noise, the image must be smoothed. In order to ensure the accuracy of noise reduction processing, it is necessary to judge the noise sparsity index of remote sensing image. If the collected image interference elements are less and non-zero in the judgment process, it is considered that the noise interference signal sparsity is low. Based on this, it is necessary to further optimize the signal processing steps[7]. Combined with the principle of wavelet transform, the image features in wavelet domain are repaired numerically, so as to better restore the original image. The specific processing steps are shown in **Figure 2**.

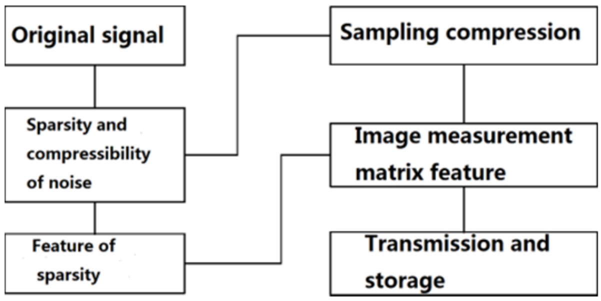

Figure 2. Original image noise reduction repair.

Based on the above noise reduction and repair requirements, the noise reduction algorithm is optimized, the Iterative Soft Threshold algorithm (IST) is further used to standardize the shrinkage y limit of compressed image, and a general threshold function algorithm is further proposed to better realize the requirements of compressed image and reduced degradation processing. The specific algorithms are as follows:

$$T_p^{csT}(y;\lambda) = \begin{cases} 0; if\ |y| \le \tau_p^{csT}(\lambda) \\ sgn(y) \times S_p^{csr}(|y|;\lambda); if\ |y| > \tau_p^{csT}(\lambda) \end{cases} \quad (5)$$

Based on the above algorithm, the UAV remote sensing image is segmented and divided into small image blocks with the same size and non-overlapping each other for sampling, compression and degradation preprocessing[8]. Accurate de-noising of general resolution images can effectively solve the characteristics of compressed sensing images, so as to improve the resolution and compression speed of each small image block. It is assumed that there are sparse signals in the collected remote sensing images $\theta_i \in R$ and image acquisition space $\psi_i \in R$. Based on this, the denoising image restoration algorithm is further standardized, and the results $\Delta\varepsilon$ are standardized as follows:

$$\Delta\varepsilon = T_p^{csT}(y;\ \lambda) \sum_{i=1}^{N} \theta_i\, \psi_i / x + \psi_i \theta \quad (6)$$

Based on the above algorithm, the dynamic reconstruction of UAV aerial remote sensing image is carried out. Based on the requirements of image feature reconstruction, the compressed image is sampled and decoded to improve the accuracy and speed of dynamic image reconstruction algorithm, and the research requirements of accurate block perception of compressed image are successfully realized.

2.3 Implementation of dynamic reconstruction of remote sensing image

In the process of describing the characteristic image, it is necessary to accurately identify the fuzzy area of the image, collect and detect the noisy area in the image, that is, the fuzzy area, judge and analyze the characteristic point diffusion characteristics of the imaging area, and analyze the image blur characteristics in combination with the convolution principle of point spread function (PSF). The image features are converted into deconvolution characteristics[9]. Select the obvious feature points between the original image and the corrected image, establish the image dynamic reconstruction model, standardize the mapping relationship between the original image and the reconstructed image, and locate the real longitude and latitude of each pixel in the UAV remote sensing image. The distribution of pixels in the aerial image of unmanned aircraft after polynomial transformation is uneven, which needs resampling. The coordinate transformation of the dot matrix of the key pixels of the image is carried out to obtain the gray value of the pixels, then the relationship between each pixel is analyzed, the original image is collected again, and a new image matrix is established. By resampling the pixels of the original image, the mapping relationship is transformed into the corresponding position of the new image, the gray value is calculated, and the corrected image is generated. Further optimize the dynamic correction steps of remote sensing image, and the specific correction steps are shown in **Figure 3**.

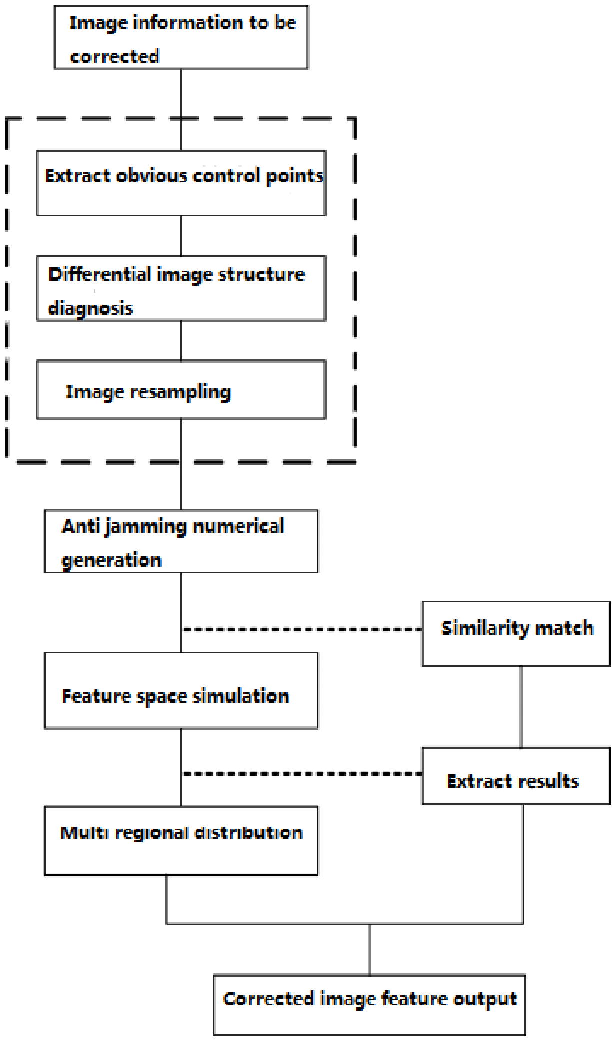

Figure 3. Dynamic correction steps of remote sensing image.

Based on the above algorithm, feature blocks are further extracted from low resolution images, and the features of each feature block are extracted with high-dimensional vectors. If the feature vector of the original image is $h(a, b, c)$, the feature vector is transformed to obtain $\hat{h}(a_1 \times b_i + c_1)$, so as to better combine into a group of feature blocks. The specific processing algorithm is as follows:

$$f(x) = h(a, b, c) \rightarrow \hat{h}(a_1 \times b_i + c_1) \quad (7)$$

The core of image reconstruction algorithm is image prior knowledge. Local smoothness and non-local self-similarity of image are two basic prior knowledge in remote sensing image[10]. The local smoothness of image refers to the local smoothness of 2D spatial domain of remote sensing image, that is, the similarity of gray values between adjacent pixels; the non-local self-similarity reflects the repeated texture or structural features in the non-local three-dimensional transform domain. Based on the above algorithm, the low resolution image features are further output, recorded as n_1 vector, the nonlinear mapping is transformed into n_2 dimensional feature vector, combined with the mapping network convolution algorithm, the image block is represented by the high-dimensional space vector containing multiple feature maps, the mapping network convolution specification is recorded as $\overline{\overline{g_{ui}}}$, and the low resolution image is further input for feature extraction, assuming that $f(m, n)$ and $g(x, y)$ represent the dimensional space transformation of the image respectively, the geometric transformation relationship of the image to be reconstructed shall be standardized as follows:

$$g(x, y) = \frac{(n_1 - n_2)\sum\sum_{x\to\infty}^{lim} f(m,n)}{\overline{\overline{g_{ui}}} + f(x)} \quad (8)$$

For image reconstruction based on the above algorithm, aerial image geometric correction is to correct the quality of the original image to meet the high-precision requirements of key target point spacing measurement results, that is, to determine the relationship between the pixel coordinates on the image and the actual key point coordinates, so as to reflect the mapping relationship between them. In order to ensure the processing effect and simplify the accuracy of image dynamic reconstruction, the steps of UAV image dynamic reconstruction are optimized, as shown in **Figure 4**.

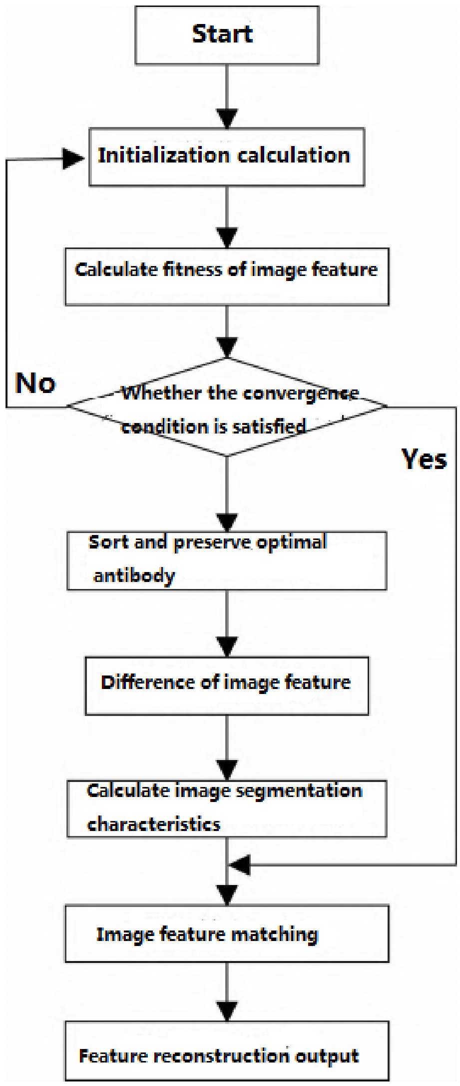

Figure 4. Steps of image dynamic reconstruction.

Based on the above steps, the compressed image is dynamically recognized and reconstructed to ensure the image reconstruction accuracy and improve the processing to the greatest extent, and effectively ensure the image dynamic reconstruction accuracy.

3. Analysis of experimental results

In order to verify the practical application effect of the dynamic reconstruction method of UAV aerial remote sensing image based on compressed sensing, the experimental detection is carried out. The aerial images of the same UAV are numerically analyzed, and four images of UAV remote sensing with the size of 256 mm × 256 mm and resolution of 96 × 96 dpi are taken as experimental samples to evaluate the performance of image reconstruction compared with traditional methods, and the experimental results are recorded. During the experiment, the peak signal-to-noise ratio of the compressed sensing image index is used as the evaluation standard for comparison. The higher the signal-to-noise ratio is, the better the quality of the reconstructed image will be.

In order to ensure the effect of experimental research, the experimental environment is set uniformly, the core 8600CPU is selected as the equipment, and the Matlab7.12.0 software is selected as the data processing software. The simulation experiment is carried out in the 4G dominant frequency environment. In the experiment, the Gaussian random projection matrix is used to randomly sample four original remote sensing images, so as to better obtain the image sampling feature frequency. Further, the reconstruction algorithm proposed in this paper is used to reconstruct the image features. The numerical analysis is carried out by using the programming principles of Java and C++, and 5~3,210 MCPU@ 2. The numerical analysis is carried out in the hardware environment of 50 GHz, which verifies the effectiveness of the key target point spacing measurement method for the dynamic reconstruction of UAV aerial remote sensing image. Reconstruct the sampling rate remote sensing image, compare and record the peak signal-to-noise obtained by different image reconstruction methods, as shown in **Table 1**.

Table 1. Comparison of remote sensing image sampling rate reconstruction effect

Figure	Sampling rate	Peak signal-to-noise ratio/dB	
		Traditional method	Method of this paper
Figure 1	0.2	7.650	12.468
	0.4	9.162	15.662
	0.6	13.463	17.465
	0.8	15.124	19.485
Figure 2	0.3	12.415	15.468
	0.5	14.358	17.280
	0.7	16.841	19.897
	0.9	18.736	21.235
Figure 3	0.2	14.124	23.841
	0.4	15.840	25.640
	0.6	17.868	27.323
	0.8	21.654	30.156
Figure 4	0.3	18.456	33.489
	0.5	22.652	35.787
	0.7	25.361	37.652
	0.9	27.560	40.540

According to the dynamic image analysis based on **Table 1**, compared with the traditional methods, the dynamic reconstruction method of UAV aerial remote sensing image based on compressed sensing proposed in this paper has a significantly higher value of peak signal to noise ratio (PSNR) than the traditional methods in the process of practical application, which can better ensure the accuracy of image dynamic reconstruction, making up for the lack of visual effect. Further, the traditional method is used to detect and record the sparsity of the reconstructed image. The specific detection results are shown in **Figure 5**.

Contrast test results in **Figure 5** shows that compared with traditional methods, this paper put forward based on dynamic compression perception of UAV aerial remote sensing image reconstruction methods in the process of practical application can improve the effect of image reconstruction, safeguard the sparse degree detection precision and the stability of the calibration curves rise effect, fully meet the requirements of the present study.

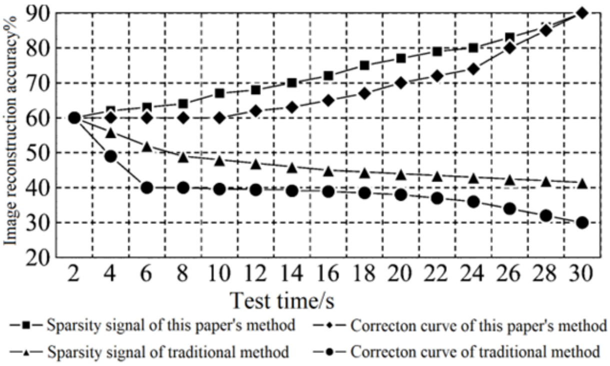

Figure 5. Comparison of test results.

4. Conclusions

In order to improve the effect of remote sensing image dynamic reconstruction, a UAV aerial remote sensing image dynamic reconstruction method based on compressed sensing is proposed. The generalized iterative shrinkage algorithm is used to optimize the remote sensing image dynamic reconstruction model, adjust the optimal parameters of image reconstruction, reduce the redundant information between data, and reduce the amount of observation data during reconstruction. The research shows that the dynamic reconstruction method of UAV aerial remote sensing image based on compressed sensing proposed in this paper has the advantages of simple calculation, high efficiency and low computational complexity. It can better protect the image edges and details and obtain high-quality remote sensing images.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgements

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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