Integrated software design of dispersive spectrometer imaging system

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Abstract. Hyperspectral imaging technology is a new means of ground observation technology, which can simultaneously obtain the geometric image of the target and spectral information. It is the main instrument of high spectral remote sensing data acquisition. In order to facilitate the analysis of the motion imaging degradation mechanism of dispersive spectrometer and the high-precision real-time correction effect, we have developed a software system integrating motion imaging degradation of dispersive spectrometer, restoration correction and quality evaluation. Given the powerful image data processing function of Matlab and C# written form of the structure of the interface height flexibility and convenience, this system is compiled with the C# and Matlab mixed mode. Practical applications show that the software system has the characteristics of reasonable structure, complete functions, stable performance, and open system. It provides technical support for establishing a fast hyperspectral high-precision restoration correction processing platform and improving the accuracy of hyperspectral data, which will speed up the practical application of hyperspectral data.

1. Introduction

Imaging spectroscopy is the integration of image and spectrometer, which can get the more abundant spatial and spectral information of detection target. Therefore, spectrometer has a broad application prospects in aerospace and aeronautical remote sensing, military detection and identification, environmental monitoring and resource exploration[1, 2]. As the raster dispersion can achieve higher spectral resolution, and has good linearity, the grating dispersion type spectrometers are very popular in the world. The most of imaging spectrometer mounted on aviation and aerospace vehicles are grating dispersion imaging spectrometer[3].

Dispersion type imaging spectrometer has experience decades of development, has made a lot of progress in the theory and method. In recent years, with the development of high resolution earth observation technology and improvement of spectral imaging quality requirements, the platform of the complex motion error is the cause of spectral image degradation, high precision recovery calibration technology has become a new research hotspot[4, 5, 6]. So far, there have been no professional domestic spectrometer based on satellite platform movement imaging spectral degradation, recovery calibration and quality evaluation in the integration of the system software. Therefore, it is urgent to establish a set of system software, the integration of existing hyperspectral data processing technology and image restoration technique, developed with reasonable structure, perfect function, stable performance, open architecture software system, and gradually establish a rapid, process of
hyperspectral and high precision recovery correction processing platform, to improve the accuracy of hyperspectral data, accelerate the process of the practical application of hyperspectral data.

This paper developed a set of dispersive spectrometer spectral imaging degradation and restoration correction and quality evaluation in one of the demonstration software system, in view of the powerful image data processing function of Matlab and C# written form of the structure of the interface height flexibility and convenience, this system is compiled with the C# and Matlab mixed mode.

2. Requirement Analysis

In order to facilitate intuitive analysis of dispersive spectrometer imaging degradation mechanism and high precision real-time correction effect, concentrating the theory of each part, including motion image degradation, recovery calibration and quality evaluation, etc., fast and convenient service to practice, research developed a set of dispersive imaging spectrometer degradation, restoration correction and quality evaluation to the whole system software. The advantages of the software is reflected in the following aspects: 1) according to the vibration parameters of the satellite platform, the degradation simulation spectrum data can be given quickly and intuitively, and the results of image and spectral quality assessment can be given; 2) provides a variety of spectral data recovery correction algorithm for reference comparison, can be more efficient and convenient to find the best spectral data recovery algorithm; 3) in the design of the spectrometer system, some of the main parameters are difficult to determine, can simulate the different state to determine the best parameters; 4) provides reference basis for satellite platform vibration reduction.

3. The Basic Function of System Software of Dispersive Imaging Spectrometer

The main design principles of the structure of the system is open, repeatability and scalability, adopts the block structure system, making the system can be used iterative incremental approach to development, so as to improve the efficiency, reduce repetitive work, reduce the cost. This system divides the module structure, the module and the module is relatively independent, through the open interface for data interaction, the system is responsible for the modular decomposition of the system, reducing the complexity of the system.

Fig. 1 The structure of the system of dispersion type imaging spectrometer
The software contains a scene simulation module, module of motion spectrometer imaging and spectral data degradation module, spectral data recovery module, spectra data quality evaluation module, integrated database management module multiple module composition, the composition of the system as shown in Fig. 1.

The system structure can be divided into three parts, the first part is the user interface, the user can achieve direct interaction with the system in this part, select the operation and processing to be carried out; the second part is the main function of the operation module, also is the main component of the system, users can also develop other specific processing functions on the basis of this; the third part is about the data for reception processing data file, a spectrometer parameters settings, selection algorithm, typical spectral selection, evaluation of structural parameters of the output, etc., interacts with the functional operation module within the system. The basic design flow chart of the system software of the dispersive imaging spectrometer is shown in Fig. 2.

With language C#, prepared based on the dispersive imaging spectrometer system software interface windows form, it is the use of familiar with the user's operating system similar to the same interface style, easy to operate and comfortable, real-time to provide users with the current task of state information, easy to use. Fig. 3 shows the main interface of the system and the main functions of the window controls.

3.1. Data read
The main function of the scene simulation module is to read data, read the data needed to be processed, completed in the "file" menu, to achieve the function of data cube generation and data loading. Data sources are mainly in the three types, one is the actual color image, using the solar spectrum as a source of radiation, resulting in spectral data cube; one is the system has been saved in the library graph spectrum cube; There is also a user wants to deal with the spectral data cube and the use of the existing spectral data cube, the scene as shown in Fig. 4.
As shown in Fig. 5, there are three menu items under the "File" menu: "Open Data", "Existing Data" and "Generate Data". Where "Open data" corresponds to spectral image data, "Existing data" corresponds to the inventory simulation of spectral data. Click the button, pop-up the selection file, you can select the data inside the dialog box. If the original data is BIL format, you need to perform spectral reconstruction. Click the "Generate Data" button to pop up the interface which is shown in Fig. 6. The original RGB image and the solar spectral data are loaded into the interface. The solar spectral data defaults to "txt" format. Click "Generate Spectral Image" to generate a simulated terrain image cube. These terrain spectral data is stored in the order of the spectrum, can be directly followed up with no rebuild.

3.2. The spectrum reconstruction

There are three commonly used data formats in hyperspectral remote sensing: row cross format (BIL), pixel cross format (BIP), spectral segment sequential format (BSQ) [7, 8].

In BSQ, the next line of data in the same spectrum is followed by the next line of each row of data. This format is most suitable for access to any part of the space (X, Y) information in a single segment of the image. According to the BIP stored image according to the first pixel of stored in the order of all the spectral information, the second pixel all spectral information, then the three pixels all spectral information and so on, interleaved memory, until the record for all of the pixels so far, the format of image data spectral information access provides the best performance. According to BIL stored image, store the first chart first period of the first line of the space information, followed by the second spectrum section of the first line of the space information, and then the spectrum section of the first line of the space information, the third cross storage, until the total spectrum, each spectrum then interleaved lines in a similar way. This format provides a compromise between spatial and spectral processing.

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Fig. 5 The opening interface of spectral data  
Fig. 6 Load RGB images

Fig. 7 Spectral data format conversion chart  
Fig. 8 BIL sequence diagram before rebuilding
For the convenience of data processing, the data are decomposed, BIL image data will be converted to the BSQ format, or in accordance with the order of the spectrum, family of BIL image file conversion for family BSQ image file, including the transfer of image data process as shown in Fig.7.

There are two types of data formats for the spectral data cube, one for the Network (IEEE) format and the other for the Host (Intel) format. The difference is that the order of the high status of the data is different and should be set according to the format of the original data. After the corresponding parameters are set, click "Show BIL Sequence" to display the sequence of the spectral data which need to be reconstructed. It is shown in Fig.8. Click the "spectral reconstruction" button to complete the spectral reconstruction. The reconstructed spectral cube shows spectral image of each band in a tree structure, and click on each band to see the corresponding band of the monochrome map. It is shown in Fig.9. Right-click on a point of monochrome image, and display spectral curve of the point. You can also view the spectral curve of the specified point by setting the coordinates of the image in the red box area of the lower right corner, which is shown in Fig.10.

3.3. Spectral data motion degradation
Spectral data motion degradation module can achieve a variety of motion patterns of spectral data degradation, including uniform degradation, harmonic vibration degradation (high frequency and low frequency), random vibration degradation, etc. After degradation of the spectral data space to evaluate image quality and spectral quality, get the platform vibration on spectral data cube of the general regularity of distortion. The structure of the degraded module is shown in Fig.11.

The degradation simulation module includes two menu items: "simulation parameter setting" and "degradation simulation". "Simulation parameters setting" includes "imaging parameters setting" and "attitude parameters setting" and "attitude vibration curve display" three sections, "imaging parameter setting" includes four parts: the focal length of the system, the size of the pixel, the height of the track and the exposure time. "Attitude parameters" can choose three kinds of vibration modes: uniform linear motion, sinusoidal vibration and random vibration, can also set the posture parameters corresponding to each model respectively. After setting the image parameters and pose parameters, click the "generate pose data" button to display the three attitude -pitch, roll and yaw vibration curve, as shown in Fig.12.
The attitude data set on the interface of "simulation parameter setting" is transferred to the main interface, and then in the main screen click "degradation simulation" menu item, the posture parameters passed to "degradation simulation" interface, by clicking the "degradation simulation" button, the simulation of the spectral image data in the main interface can be simulated based on the simulation of the attitude data.

Click on the "degraded image display" under the tree node, show that the selected bands of degraded image, right click on the image to save the image, click any point on the degraded image, it will show the original spectrum and degradation spectrum in the "degenerate spectral curve contrast" interface, red is the degradation of the spectrum. It is shown in Fig. 13. From the Figure can be seen directly to the degree of distortion of the degradation of the spectrum, but also in the lower left corner of the degradation of spectral contrast display plate set specific points to observe the degradation spectrum.

3.4. Spectral data recovery

Data flow chart of the spectral data recovery module is shown in Fig.14. The specific software operation is to read the need to restore the correction of spectral data, click on the main interface of the "degradation correction" menu item, it can pop up "degenerate correction" interface. It is shown in Fig.15. The calibration system includes the Wiener filter, L-R, neural network and chaos genetic algorithm, such as a variety of hyperspectral image restoration algorithm [8-12], correction method for users in the "select" column to select the required method, and then click the "correction" button to recover correction, the correction results will be displayed as a tree structure of each band view, click
on the tree node can be in the right area ground of the selected band image, click on the tree node to see the selected band image in the right area. Click any point of the image to view the spectrum of that point, including the original spectrum (black line), the degradation spectrum (red line) and the recovery spectrum (blue line). Can intuitively see whether the recovery spectrum is significantly improved compared to the degradation spectrum and whether it is close to the original spectrum. Users can also be based on their own needs, load their own recovery correction algorithm, and the software system has been compared to the existing algorithms.

The lower right corner of the interface displays the location of the specified coordinate point, and click the “Display Spectrum Curve” button to display the original spectrum, the degradation spectrum and the recovery spectrum of this point at the same time. It is shown in Fig.16.

![Fig. 15 The spectral curve of some point](image1)

![Fig. 16 Simultaneous display of the original spectrum, degradation spectrum and restoration spectrum of a point](image2)

![Fig. 17 Data flow of spectral data quality evaluation](image3)

![Fig. 18 Interface of spectral quality assessment](image4)
3.5. Spectral data quality evaluation

The data flow of the spectrum data quality evaluation module is shown in Fig.17. Read the hyperspectral data cube to be evaluated, if the parameters are evaluated, the original hyperspectral data should be read.

On the main interface of the software, set up the "quality evaluation" main menu, and in its drop-down menu has two sub menu items: "image quality evaluation" and "spectral dimension quality evaluation", as shown in Fig.18.

The image quality evaluation interface is shown in Fig.19. You can open the reference image and the image to be evaluated at the same time on the interface. The evaluation index is divided into two parts: "parametric evaluation" and "non-parametric evaluation", and the evaluation indexes such as mean square error, peak signal-to-noise ratio, gray average gradient and Laplacian operator[13] are selected respectively. By clicking each button, you can calculate the index value. Click the "Save Data" menu item to save the index value to the "txt" file, and click "clear data" to reload the data and recalculate. Users can compare the quality of the calculated value, to determine the image quality, can also load other image quality evaluation index, compared with the existing index analysis.

The spectral dimension quality evaluation interface is shown in Fig.20. It can load the original spectrum, degradation and restoration of spectral data, the default format for "txt", the evaluation indexes of spectral mean square error, spectral information divergence, relative mean square error and spectral correlation coefficient are listed[15, 16]. The evaluated data can be saved as a "txt" document by clicking the "save data" menu item. Similarly, users can also be based on their own needs, so as to load their own preparation of the spectral quality evaluation method, compared with the existing evaluation indexes of the system.

4. Conclusion

This paper mainly introduces the basic design concept and process flow of the dispersive spectrometer system software, the main function and design idea of each module, and explains the use mode and operation result of the software. The software contains a dispersive imaging spectrometer for all motion-degraded images. Users can design various parameters of the spectrometer, select the motion degradation model or input the attitude parameters of the satellite platform to obtain the degraded spectral data cube. The software provides a variety of dispersive imaging spectrometer motion imaging degradation mechanisms, multiple hyperspectral image restoration algorithms and
hyperspectral image and spectral quality evaluation indexes for users to restore and analyze hyperspectral data, speeding up the actual application of hyperspectral data.

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