Research on Optimal Data Selection Technology of Optical Remote Sensing Satellite Images

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Abstract—The optimal data selection technique mainly studies which images and the contents of the images should be selected for processing in the process of natural resource survey using optical remote sensing satellites, so as to obtain the best processing effect. This paper realizes a data selection method for optical remote sensing satellite images. The method uses the image semantic segmentation technology to achieve refined cloud detection, uses the various indicator comprehensively evaluating the image quality, uses the regional coverage technology to form an optimal data selection and organization scheme. It can quickly select a set of optimal data sets that can cover the target area and ensure image quality from the massive candidate data according to the time and space range specified by the user. The method is applied to the optimal data selection software module of optical satellite for fine classification of forest land. The results show that the algorithm can effectively replace the manual visual data selection method and provide technical support for various types of natural resources survey tasks.

Index Terms—Data selection, cloud detection, quality evaluation, area coverage

I. INTRODUCTION

Data selection plays a very important role in the process of conducting natural resource surveys using optical remote sensing satellites. First, data is an essential element in any information processing process. Second, the pros and cons of data often have a decisive effect on the results of natural resource surveys. In the early stage of the development of space remote sensing industry, the number of satellites was extremely limited, the remote sensing image data was scarce, and the natural resource survey basically adopted the data-driven model. Whether the data can be achieved is the focus of attention, and the data selection problem is not prominent; currently, with the explosive development of the space remote sensing industry, various military and civilian satellites have been put into operation one after another, remote sensing image data has grown exponentially, natural resource survey is transforming from data-driven mode to application-driven mode, how to quickly select the optimal data from massive data to participate in processing has been a problem that must be faced and solved.

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At present, the data selection in optical remote sensing satellite image preprocessing is mainly done manually, and the degree of automation is still very low. Specifically, the operator first searches for satellite images in the space-time range of interest; then views the images in a manual visual view, and selects appropriate data in consideration of both image quality and full coverage of the target area; Carefully adjust the order in which the images are arranged so that the quality of the mosaic obtained after preprocessing is optimized. This process is time-consuming and laborious. It is a disaster for the operator when the task is heavy, the data is heavy, and the time is tight.

The data selection problem in optical remote sensing satellite image preprocessing has strong comprehensiveness and engineering. At present, researchers in the field of remote sensing image processing generally focus on hot-spots such as classification and recognition. There are few studies on data selection techniques, especially for engineering applications, and there is no mature technology route. On the other hand, there are some research related to data selection, mainly focusing on remote sensing image cloud detection, objective evaluation of image quality, and regional coverage of two-dimensional space.

Image cloud detection problems can be attributed to pattern recognition problems. The "pattern" can be regarded as a combination of features or features. The existing cloud detection algorithms are based on the selection, expression, combination and transformation of the radiation, geometry, phase or elevation of the cloud on the image, mainly including six types: 1) Luminance analysis. The brightness threshold method is the oldest and simple cloud area extraction algorithm. It is based on the difference of cloud and ground object brightness values, and the cloud area is extracted by the threshold for the image of a specific type of sensor [1]. 2) Chroma analysis. Analysis using only brightness will inevitably misjudge the highlights such as snow, sand, and rocks. Extracting chromaticity information from visible multispectral images as a basis for judgment can reduce such misjudgments to some extent [2]. 3) Texture analysis. By analyzing the differences in cloud and feature texture features on the image, extract appropriate features or feature combinations to distinguish between clouds and features [3]. 4) Phase analysis. Cloud detection based on two or more images with similar phases in the same region is also a common method [4]. 5) Process analysis. The three-dimensional geometric

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features of the cloud are obtained through multiple image intensive matching techniques, and the distinction between cloud and ground is achieved based on the comparison of existing elevation information [5]. 6) Comprehensive classification method. At the same time, the image is detected by the radiation, texture and time equal features of the image, or the image is divided into cloud, water, forest, bare land and other categories at one time [6].

The objective evaluation method of image quality is to describe the degree of image distortion by extracting features such as structure, texture and detail related to visual quality in digital images, thus replacing the quality of image recognition by human eyes. According to the degree of dependence of the degraded image on the reference image information, the image quality objective evaluation method can be divided into three types: full reference, no reference, and subtractive reference. 1) Full reference (FR) image quality evaluation. The quality of the degraded image is evaluated in the case where the reference image is completely known [7], [8]. 2) No reference (NR) image quality evaluation. In many practical applications, the original reference image is not available, and the image quality can only be evaluated using a non-parametric evaluation method [9], [10]. 3) Subtraction reference (RR) image quality evaluation. Compared with FR and NR image quality evaluation, RR is a relatively new research direction. It provides a solution between FR and NR that is designed to predict image quality using partial information from the reference image [11], [12].

Area coverage is the most widely studied type of coverage problem. Existing coverage algorithms can be divided into two categories: 1) Location-based coverage algorithms [13]. This approach considers the network node to be positionable, i.e. the absolute position of the node is known. These location-based overlay algorithms typically analyze and establish coverage criteria by computational geometry. 2) A coverage algorithm that is not based on positioning. This method is further divided into a relative position-based coverage algorithm [14] and a topology information-based coverage algorithm [15]. The relative position-based overlay algorithm assumes that the relative positions between the nodes are known. Coverage algorithms based on topology information currently use algebraic topology methods to establish coverage methods and rules. Such overlay algorithms do not require nodes of the sensor network to be located. They design coverage rules by analyzing the corresponding topological maps of the entire network.

Summarizing the research status, from the perspective of technology maturity, the regional coverage technology of two-dimensional space is relatively mature, but it is mainly used in sensor networks and agent networks. How to solve the data coverage problem of remote sensing images needs to be explored; Cloud detection and quality objective evaluation techniques of remote sensing images are still immature, especially the objective evaluation of image quality, which is closely related to HVS and has strong complexity. Relevant research is still in its infancy. From the perspective of engineering applications, all three technologies have strong application requirements. Although they are not mature enough, they have been used in many information processing systems, which fully reflects their application value. For the remote sensing image data selection problem to be studied in this paper, although the direct targeted research is rare, these related results provide a good research basis.

The data selection is located at the front end of the entire satellite image processing and analysis process, and is currently a bottleneck in satellite image processing. Affected by factors such as cloud layer, quality, and coverage, the received remote sensing data cannot be directly used, and it needs to be manually selected and organized before being pushed to the user. The research in this paper helps to solve the automation problem of image preprocessing process. Combined with Internet technology, satellite data can be received, processed, and distributed instantly, improving data timeliness. This will have an impact on almost all remote sensing application tasks, and the development prospects are very broad.

II. RESEARCH PLAN

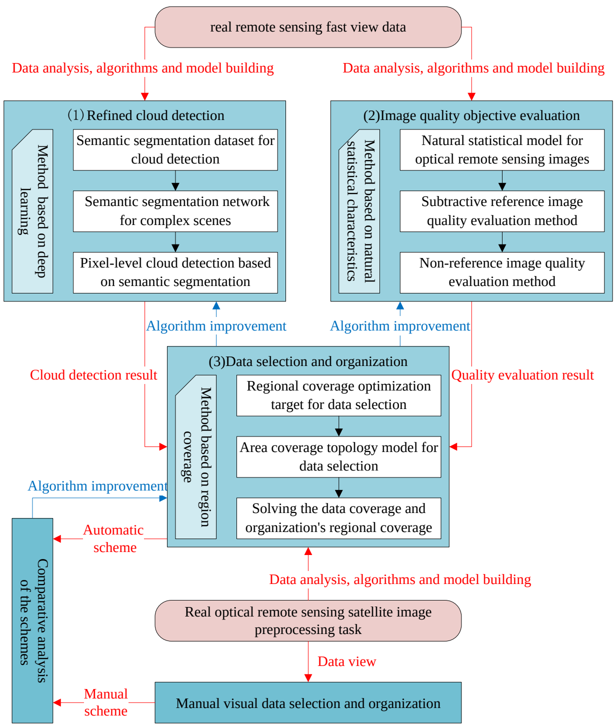

Fig. 1. Research plan

This paper uses the research scheme of Fig. 1. The optimal data selection in optical remote sensing satellite image preprocessing is a very practical work. This paper starts from the real remote sensing fast view data and uses the deep learning-based image semantic segmentation technology to solve the problem of refined cloud detection. The image quality evaluation technology based on natural statistical characteristics solves the objective evaluation problem of image quality. Finally, the objective function or optimization criterion is

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constructed by integrating cloud and quality factors, and the data selection and organization scheme is obtained by using the area coverage technology based on algebraic topology. After establishing a complete optimal data selection framework, the real-time optical remote sensing satellite image pre-processing task is verified, and the automatically generated data selection scheme is compared with the manual visual selection data selection scheme to analyze the generation between the two ways, and the improvement of related models and algorithms is made.

III. Technical Route

A. Refined Cloud Detection Method based on Deep Learning

Firstly, it is very difficult to accurately detect all types of clouds. There are many kinds of clouds, brightness, texture and shape are varied, and the characteristics of different scales are different. These factors bring inconvenience to automatic detection. Secondly, the amount of optical satellite image data is large, the update speed is fast, some methods with low computational efficiency, many pre-conditions or manual participation are difficult to meet the needs of massive data automation business processing; next, the evaluation criteria for cloud detection results It is also difficult to unify. Under different production requirements, the requirements for cloud detection and detection rate are different. It is impossible to measure the pros and cons of cloud detection results with fixed standards. Finally, the cloud image processing strategy for cloud is also required. Considering the problem, you can roughly estimate the cloud-containing image of the image and remove the cloud-containing image directly. However, a better method is to obtain a more accurate cloud mask. The subsequent steps are only for the effective area that is not covered by the cloud layer.

Cloud detection is regarded as an image segmentation problem in this paper. The deep learning method is used to solve this problem. The key technology is image semantic segmentation based on deep learning. It is divided into three parts: semantic segmentation dataset, semantic segmentation network and cloud detection.

1) Semantic segmentation dataset for cloud detection

Image semantic segmentation based on deep learning requires the use of a large number of images with annotation information for training and verification of semantic segmentation networks. Although there are many publicly available images semantic segmentation datasets, there are no datasets specifically for optical remote sensing image cloud detection and cloud classification. Therefore, it is necessary to face the cloud detection problem, collect the fast view of the optical remote sensing satellite, perform pixel-level semantic mark on the image content, and establish a cloud detection data set. This paper collects fast views remote sensing images as samples, the number of images is more than 100; mark the image content as thick cloud, thin cloud and cloudless, forming semantic annotation map; The sample image and the corresponding annotation map are put together to establish a semantic segmentation dataset for cloud detection.

2) Semantic segmentation network for complex scenes

The core of image semantic segmentation based on deep learning is the semantic segmentation network. Training, verification and segmentation are all carried out around the network. At present, in the field of semantic segmentation, convolutional neural networks are the most widely used deep learning models. Typical image semantic segmentation network models based on convolutional neural networks include: FCN, SegNet, U-Net, DeepLab v1&v2, RefineNet, PSPNet, DeepLab v3, etc., these network structures have been applied to many image processing tasks, but there is no public report about their performance comparison in cloud detection. In this paper, the problem is deeply studied, and each network model is used for cloud detection, and their performance indicators are comprehensively compared to find the most suitable network structure for cloud detection.

3) Pixel-level cloud detection based on semantic segmentation

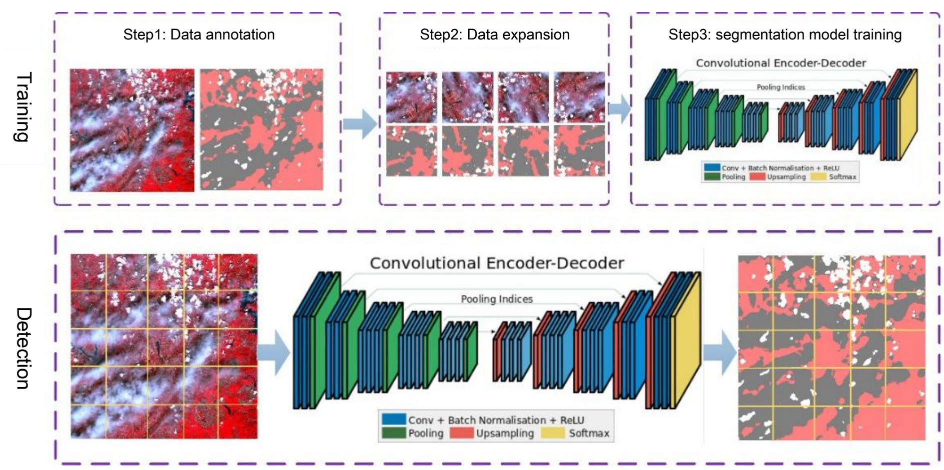

Fig. 2. Process of cloud detection

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Under the support of cloud detection dataset and semantic segmentation network, pixel-level cloud detection is realized through two processes of training and detection, as shown in Fig. 2. In the training process, the remote sensing fast view is first marked, which is completed when the cloud detection data set is established; then, using the data expansion technology, a small number (100 pairs) of the sample map and the annotation map in the cloud detection data set are expanded into a large number (More than 100,000 pairs) of sample and annotation tiles; finally, input these data into the selected semantic segmentation network (Fig. 2 shows the SegNet network as an example) to train the segmentation model. In the test process, the large-scale test image is first multi-scale segmented; then the test image block is input into the trained segmentation model for category (no cloud, thin cloud, and thick cloud) prediction; finally, each image block is spliced, and the segmentation result gives the cloud detection result of the test image.

B. Image Quality Objective Evaluation Method Based on Natural Statistical Characteristics

Image quality is the core value of the image system, and it is very important to evaluate the image quality. The subjective evaluation method is not convenient for application in the real-time image processing system, and it is affected by human cognition and psychological factors, and the repeatability and stability are poor. Therefore, people have been working on the objective evaluation of image quality using mathematical models, and hope that the evaluation results obtained are highly consistent with subjective evaluation. However, there are still many problems in the objective evaluation method of image quality that need to be further solved. First, the user's image quality requirements are getting higher and higher, which requires the subjective and objective consistency of the image quality indicators to be better, and more accurately reflects the image quality. Secondly, the non-reference image quality evaluation method is more widely used, and it can also reveal the principle of human visual perception. However, the general-purpose non-reference image quality evaluation method is still in its infancy, and the evaluation results obtained so far cannot be obtained. Meet the actual needs of people.

In this paper, the method based on natural statistical characteristics is used to evaluate the image quality. It is divided into three parts: natural statistical model research, reduced reference image quality evaluation method and no reference image quality evaluation method. The so-called natural statistical characteristics (NSS) are some common statistical characteristics of natural images (including exterior, artificial buildings, indoor environments), which is a statistical description of the human visual system.

1) Natural statistical model for optical remote sensing images

The basic assumption of the image quality evaluation method based on natural statistical characteristics is that the image has natural statistical characteristics, and the degradation destroys the "natural" characteristics of the image, making the image "unnatural", so that as long as the method can be found to measure the degree of unnaturalness (that is, the difference between unnatural and natural characteristics), the quality degradation of an image can be quantified. Therefore, how to describe and quantify the natural statistical properties of images becomes a core issue. Aiming at this problem, a mathematical model for describing and measuring the natural statistical characteristics of the image is established for the optical remote sensing image. At present, the most used is the natural statistical model based on wavelet transform, but there are few studies on the quality evaluation of remote sensing image. In this paper, wavelet transform, DNT transform, Roberts differential statistics, time domain statistics and other methods are studied, and a natural statistical model is constructed.

2) Subtractive reference image quality evaluation method based on natural statistical characteristics

Subtraction reference image quality evaluation provides a solution between full reference and no reference evaluation, which uses part of the information of the reference image (selected features) to characterize the image. At present, the most typical is the image quality evaluation algorithm (WNSIM) based on the natural statistical characteristics of wavelets. Although the algorithm has achieved great success, it has obvious limitations in terms of data adaptability, comprehensiveness of indicators, and computational complexity. Based on the research of natural statistical model, this paper focuses on the influence of satellite model, sensor type, shooting season, scene type, specific region, degradation type, degradation intensity and other factors on the quality evaluation algorithm, and builds a subtraction reference image quality evaluation algorithm with strong universality.

3) Non-reference image quality evaluation method based on natural statistical characteristics

When artificially subjectively evaluating image quality, a reference image is often not required. This shows that the non-reference image quality evaluation method is more in line with the human visual perception mechanism. At the same time, this method has low dependence on reference images and is more practical. No reference image quality evaluation can be divided into two approaches for specific application background and general purpose. Considering that the manual visual selection of data is not limited by the specific application background, the second technical approach is selected. Based on the research of natural statistical model, this paper studies the non-reference image quality evaluation method and establishes a general-purpose algorithm suitable for optical remote sensing satellite images, including training-based evaluation algorithm and “completely non-parametric” evaluation algorithm without training.

C. Data Selection and Organization Method Based on Region Coverage

The coverage problem is the basic problem of computer science research. At present, the main application scenarios in practice are usually networks distributed in space, such as wireless sensor networks and biological networks. The research work on the coverage problem mainly focuses on the design and analysis of the two optimization goals: the minimum number of nodes in the network and the longest network lifetime. Taking a wireless sensor network as an example, it is formed by spatial distribution of some network nodes with sensing and communication functions. The general application scenario is area monitoring. Since battery size and weight limitations will result in a shortage of power supply, an important issue in designing and analyzing wireless sensor networks is how to use a minimum number of sensor nodes to perfectly cover an area. Comparing the wireless sensor network design problem with the data selection and organization problems in remote sensing image preprocessing, we can see that they have many similarities, and they all pursue the minimization of the number of nodes, the maximization of the coverage area and the most effective operation. optimization. This similarity inspired us to consider introducing the widely used area coverage technology in spatial network design to the data selection process in remote sensing image preprocessing, so as to achieve the goal of perfectly covering the target area with a minimum number of images.

The choice of data in remote sensing image preprocessing is considered as a regional coverage problem: each image is a node, and how to cover the entire target area with the least number of nodes (the mosaic image has the best quality). Regional coverage is a typical problem in spatial network design. The algebraic topology method is used to solve this problem. It is divided into three parts: regional coverage optimization target, regional coverage topology model and regional coverage scheme.

1) Regional coverage optimization target for remote sensing data selection

The regional coverage problem is essentially an optimization problem. First, it is necessary to construct an objective function or an optimization criterion, which is the basis for solving the optimization problem. This problem is studied, and this special regional coverage problem is selected according to the data in the remote sensing image preprocessing, and the corresponding optimization target is established. The objective function is designed from three aspects: one is that the number of remote sensing images selected is the least; the second is that the selected remote sensing image set has the highest coverage ratio to the target area; the third is the selected remote sensing image set with the arrangement order. The quality of the stitched image is high. In addition, in the remote sensing image processing and application tasks, there are often some constraints, which need to be considered when the design area covers the optimization target.

2) Area coverage topology model for remote sensing data selection

In the optimization problem, another element that corresponds to the optimization goal is the variable. The variable covered by the region is not a certain value, but a certain covering method. From the aspect of expression, it is a spatial network composed of many nodes. For the convenience of research, it is necessary to construct a suitable data structure to describe such a spatial network. The problem is studied. According to the characteristics of the spatial network composed of nodes, the topology model is used to describe it. In the topology model, each node has its own attributes; there are multiple relationships between nodes; all nodes form a topological relationship diagram. Each topology model corresponds to a spatial network structure, and each spatial network structure corresponds to a data selection scheme, and the topology model can be regarded as a description of the data selection scheme.

3) Solving the data coverage and organization's regional coverage plan

When the number of nodes is limited, the optimal regional coverage scheme can be found by ergodic method; when the number of nodes is large, it is necessary to study the fast solution method of the optimal regional coverage scheme. This paper studies the problem by referring to the connected dominating set method widely used in wireless sensor networks for topology control. Constructing the connected dominating set is an NP-hard problem. At present, there are a large number of approximation algorithms for solving the connected dominating set, but it is mainly used in the field of communication and computer. According to the data selection characteristics in remote sensing image preprocessing, these algorithms are researched and modified to form a fast solution method for optimal regional coverage scheme.

IV. Applications

The satellite optimal data selection method proposed in this paper can quickly select a set of optimal data sets that can cover the target area and ensure image quality from the massive candidate data according to the time and space range specified by the user. This method has been applied in the "Optimal Data Selection Software Module for Forestland Fine Classification" and achieved good processing results.

This software module can quickly and automatically optimize 1A data for fast view under the condition of meeting data quality requirements. Differentiate similar and duplicate data to reduce the amount of artificially selected work. The software module supports the data optimization of Chinese high-resolution optical remote sensing satellite data such as GF-1/-2 and GF-6. It has various scheme adjustment functions based on metadata and fast view, a variety of regional visualization methods, and the ability to output according to the sensor, quality, product number, and scene serial number.

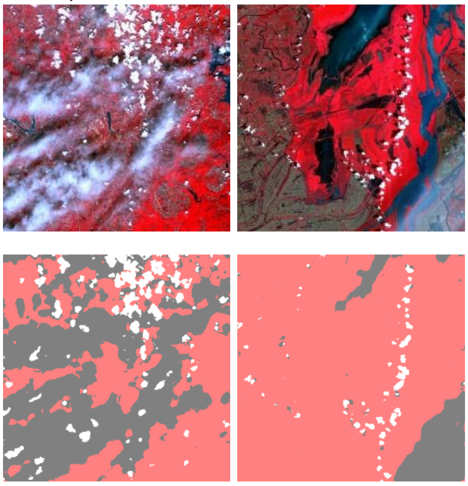

Fig. 3. Results of refined cloud detection

Fig. 3 is a refined cloud detection result based on deep learning. The SegNet network is used to establish the semantic segmentation model, and the image content is set to three types: cloudless, thin cloud and thick cloud. In the training process, the large-format remote sensing image is first cut into 20 small-area remote sensing images of 1100*1100 size and labeled; then random cropping, flipping, rotation, chromaticity change, light and dark change, noise interference are adopted. After the operation, the data is expanded into about 100,000 pairs of 256*256 size remote sensing image blocks and true valued image blocks; then the data is input into the SegNet network for training of the segmentation model, and the skeleton network adopts the VGG-16 model. In the test process, the large-scale test image is multi-scale segmented, the test image block is input into the trained network model for cloud detection, and finally the image block segmentation result is spliced to obtain the final segmentation result.

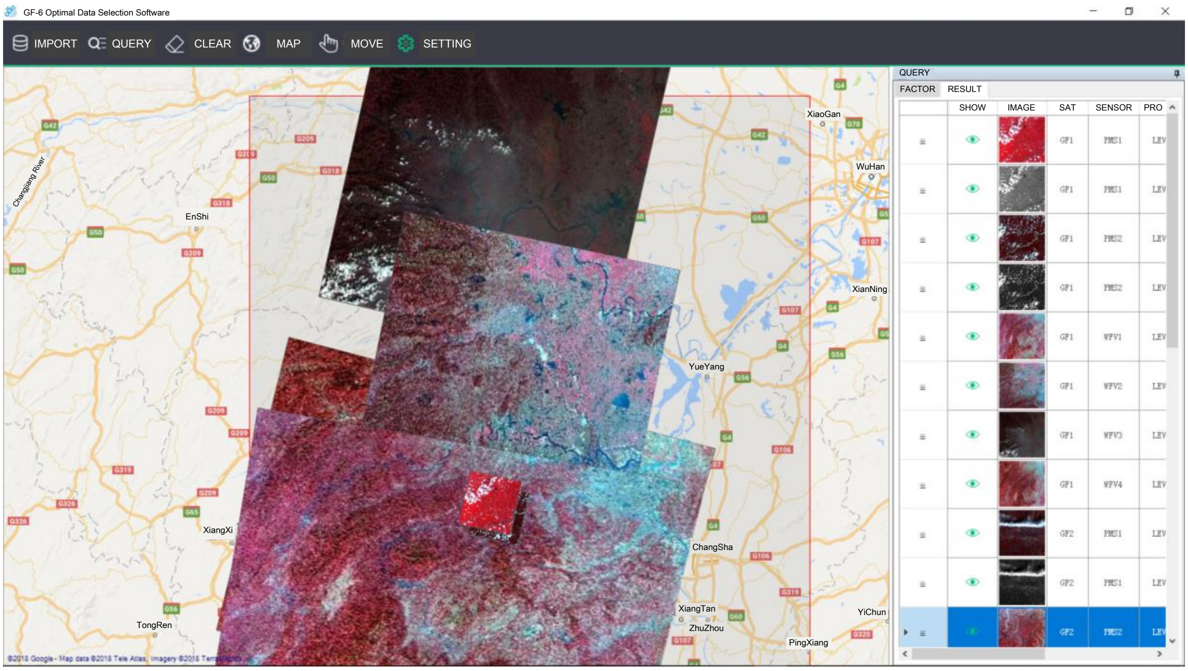

Fig. 4. Results of optimal data selection

Fig. 4 shows the results of optimal data selection. The software module can comprehensively evaluate the fast view of high-resolution satellites. According to factors such as time, space, cloud quantity, quality, and overlap, one-click data selection is preferred for 1A level, which significantly reduces the amount of manual visual data selection.

V. Conclusion

The data selection technique in optical remote sensing satellite image preprocessing is not only important, but also not solved. It is very necessary to carry out research and engineering it. This paper is aimed at high-resolution optical remote sensing satellite data, which realizes an optimal data selection method. It can eliminate the cloud information in the image, measure the quality of the image, and output the data selection scheme consistent with the manual visual. The method is applied to the "Optimal Data Selection Software Module for Forestland Fine Classification". The results show that this method can replace the current manual visual data selection method, reduce the workload of people and improve the automation level of the system. The method can be applied to various remote sensing information processing and application tasks.

Conflict of Interest

The author declares no conflict of interest.

AUTHOR CONTRIBUTIONS

Peng Zhang completed all the work of this paper and approved the final version.

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Peng Zhang was born in Henan Province, China, in 1974. He obtained a B.A. (Microwave Engineering) in 1997, an M.A. (Signal and Information Processing) in 2000, and a Ph.D. (Information and Communication Engineering) in 2004 from the National University of Defense Technology, Changsha, China. He joined School of Electronics and Communication Engineering, Sun Yat-sen University, Guangzhou, China in 2019. His research interests include image analysis and image understanding.