

# A Feature Window Weighted Correlation Spectral Matching Method for Rock and Mineral Resources

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**Abstract.** This paper proposes a feature window weighted correlation spectral matching method for rocks and minerals, which includes the following steps: (1) Assuming that the error caused by the natural environment is a random normal distribution, the remote sensing image is based on each band, and within the reflectance range, the reflectance of each band is extended to the range of 0 to 1 according to the normal distribution law, forming a matrix dataset X; (2) Using the standard spectral curve as a benchmark for each band, within the reflectance range, the reflectance of each band is extended to the range of 0 to 1 according to the normal distribution pattern, forming a matrix dataset Y; (3) Within the full wavelength range, classify the sensitivity intervals of rocks and minerals based on standard spectral curves, form feature windows, and set predetermined weight coefficients; (4) Calculate the correlation coefficient  $r$  of the feature window and combine it with the weight coefficient in step (3) to obtain the comprehensive correlation coefficient K; (5) Using the comprehensive correlation coefficient K as the final basis for identifying rock and mineral types.

## 1. Introduction

Rock and mineral identification is a very important topic in geology, playing an important role in mineral exploration, resource evaluation, and mineral processing. By analyzing geological samples, scientific basis can be provided for the efficient utilization of mineral resources, as well as important references for environmental protection and resource management<sup>[3]</sup>. Spectral matching is a method of remote sensing image recognition of land features, which determines the classification of land features by studying the similarity between two spectral curves. The key technology is how to measure and determine the objective similarity between the two spectral curves<sup>[1-2]</sup>. The different components of rock minerals determine their different spectral characteristics, which provides important theoretical support for remote sensing rock and mineral detection and identification<sup>[4-5]</sup>. In the past decade, hyperspectral remote sensing technology has developed rapidly and has been widely used in the field of rock and mineral identification. Its spectral matching methods mainly include binary coding matching, spectral angle classification, and spectral curve fitting methods<sup>[6-7]</sup>. The core of the methods is to compare and determine the spectra of samples obtained from laboratory measurements (or selected spectra from images) with the spectra of land features to be determined from remote sensing images. Due to the fact that remote sensing data is the energy information received by remote sensing sensors in the natural environment, which reflects

and radiates sunlight from land objects, natural environmental factors (terrain, clouds, temperature, humidity, mixed land cover, etc. ) have complex and variable impacts on solar radiation. Currently, the level of technology cannot accurately eliminate the errors caused by these factors<sup>[8-9]</sup>. Although the current mainstream technology uses the global unified model (such as 6S atmospheric correction model) to eliminate these errors, the accuracy and accuracy of the application results are not ideal because the global unified model lacks the pertinence of accurate regions, accurate times, real-time environments, and rock and mineral properties<sup>[12]</sup>. The feature window weighted correlation spectral matching method takes into account the instability and uncertainty of electromagnetic waves in rocks and minerals due to environmental factors, and is a targeted comprehensive spectral matching method for rocks and minerals. This method can effectively determine the type of rock and mineral resources.

## 2. Feature Window Weighted Correlation Spectral Matching Method

### 2.1. Basic ideas of algorithms

The feature window weighted correlation spectral matching method is a targeted comprehensive spectral matching method for rocks and minerals. Its basic idea is: (1) after the global unified model conducts error

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elimination processing on the remote sensing data of natural factors (such as 6S atmospheric correction model), the influence error of natural environmental factors on the electromagnetic wave of rocks and minerals still exists (residual error); (2) Assuming that these residual errors are random (quantitative indicators such as temperature, water vapor, and atmosphere have randomness) and exhibit normal distribution characteristics; (3) Within the full wavelength range, feature intervals are divided based on laboratory measured rock and mineral spectral data, and weights are allocated according to the sensitivity level of the intervals. The full window correlation coefficient is calculated, and the final correlation coefficient is the reference for rock and mineral identification.

## 2.2. Analysis of algorithmic scientificity

The scientific analysis of the assumption of residual randomness: The rock and mineral spectrum is the comprehensive response of electromagnetic waves of rock and mineral components and structures. Due to external environmental factors such as atmosphere, water vapor, temperature, humidity, etc., the electromagnetic wave data obtained by remote sensing technology will be affected and changed to varying degrees<sup>[10]</sup>. The quantitative indicators of these influencing factors are difficult to obtain in remote sensing data processing, and the understanding of their impact patterns is still in the research stage, making it difficult to quantitatively describe and express their change patterns under current technical conditions. It is a more scientific method to assume the randomness of the residual after using the global unified model to eliminate processing.

Scientific analysis of characteristic interval division: Rock and mineral components are important basis for determining rock and mineral types and categories. The electromagnetic wave response of components is the result of the vibration absorption and emission of atomic or ionic groups in rock and mineral components. Therefore, the electromagnetic wave absorption and

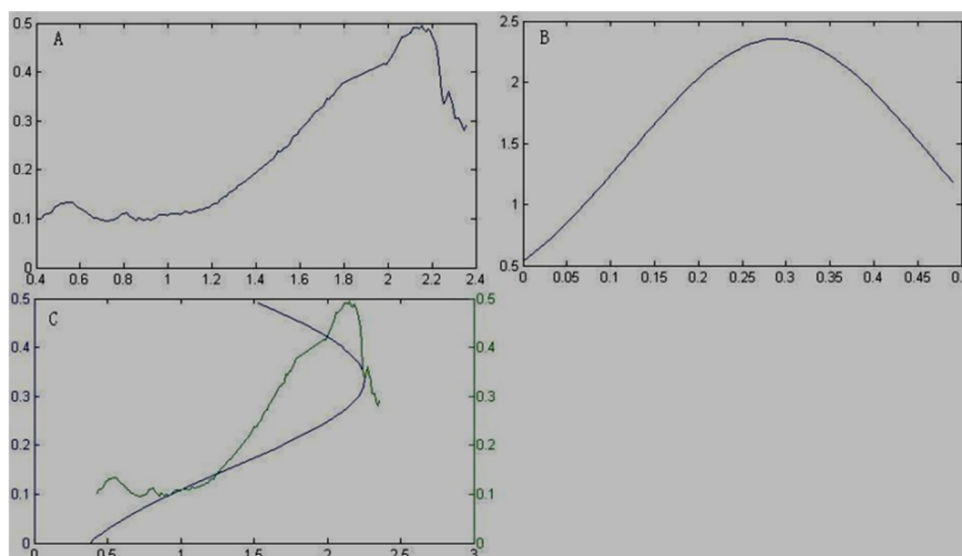
emission characteristics of rock and mineral have diagnostic significance, and these characteristics are regularly distributed in certain wavelength positions and ranges<sup>[11]</sup>. Therefore, within the entire range of the electromagnetic wave influence curve of rocks and mines, the response sensitivity of different wavelength positions is different, and their contribution to information extraction and recognition of rocks and mines is also different. The absorption and reflection feature positions in the near-infrared and short infrared ranges contribute the most, followed by the wavelength range of color representation. The wavelength positions with greater influence from atmosphere, water vapor, temperature, and humidity contribute less due to low reliability. Therefore, dividing characteristic intervals based on laboratory measured rock and mineral spectral data and assigning weights according to the sensitivity of the intervals is a scientific processing method.

## 2.3. Algorithm implementation process

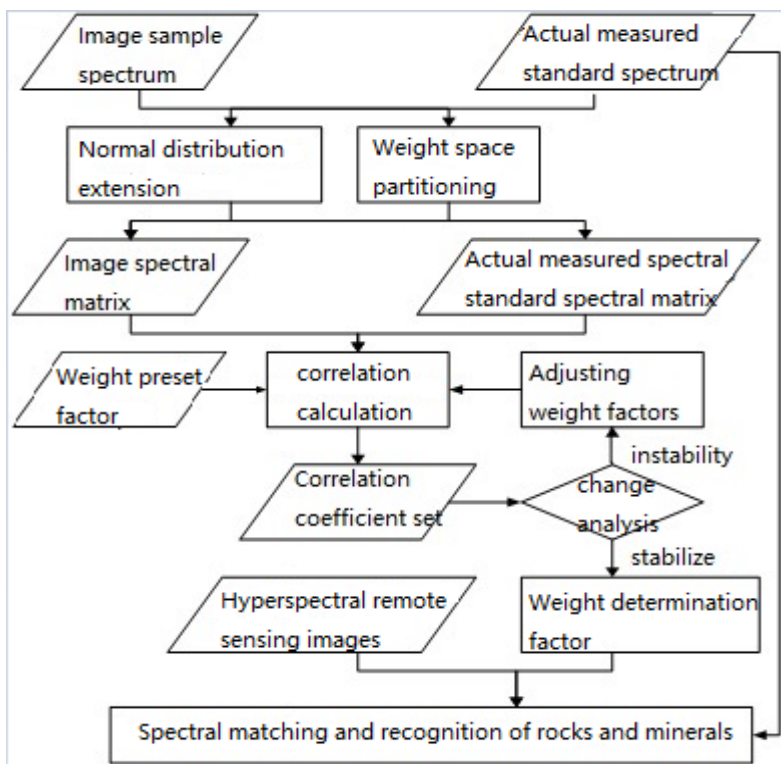
As the algorithm implementation is based on data, the process is also the processing of remote sensing and spectral testing data. The flowchart is shown in Figure 2. The main steps are as follows: (1) Firstly, perform atmospheric correction on the remote sensing image, convert the DN (Digital Number) value of the remote sensing data into surface radiance, and then calculate the apparent reflectance; (2) Based on the position of each band, within the reflectivity range (0 to 1), the reflectivity of each band is gradually extended to the 0 to 1 range according to the normal distribution pattern. The extension formula is formula (1):

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad (1)$$

Among them, the vertex of the normal distribution is the apparent reflectance value of the ground object in the remote sensing data, which is any point in the A curve. As it is a standard normal distribution, so  $\mu$  for 0, as shown in Figure 1:



**Figure 1.** The extension effect of the normal distribution of a certain apparent reflectance value (A is the spectral curve of a certain point on the remote sensing image; B is the curve of the normal distribution with a certain point on the spectral curve as the vertex; C is the result of the superposition of A curve and B curve).



**Figure 2.** Technical process of full window weighted correlation spectrum matching method.

(3) Based on the spectral curve of each pixel in remote sensing images, normal expansion calculation is performed point by point on the curve, and a two-dimensional matrix vector is obtained for each pixel. (Assuming that there are N pixels in the remote sensing image participating in the calculation, N matrix vectors will be obtained after step 3 is completed.) (4) Resample the standard spectral curve to maintain consistency with the image spectral curve, ensuring that the number of matching comparisons between the two spectra is consistent; Further process the resampled standard spectral curve in step -2 to obtain a matrix vector. (5) Within the full wavelength range, divide the sensitivity range of rocks and minerals (with obvious reflection or absorption range) based on the standard spectral curve, and set a predetermined weight coefficient as the reference for spectral correlation coefficient weight. (6) Calculate the correlation between the N matrices obtained in Step 3 and the matrix vectors obtained in Step 4, calculate the correlation coefficient, and then obtain a comprehensive correlation factor based on the weight factor in Step 5. The formula is as follows:

$$r_{XY} = \frac{\sum_{i=1}^N (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^N (X_i - \bar{X})^2} \sqrt{\sum_{i=1}^N (Y_i - \bar{Y})^2}} \quad (2)$$

$$K_{\text{comprehensive}} = K_1 r_1 + K_2 r_2 + K_3 r_3 + \dots + K_n r_n \quad (3)$$

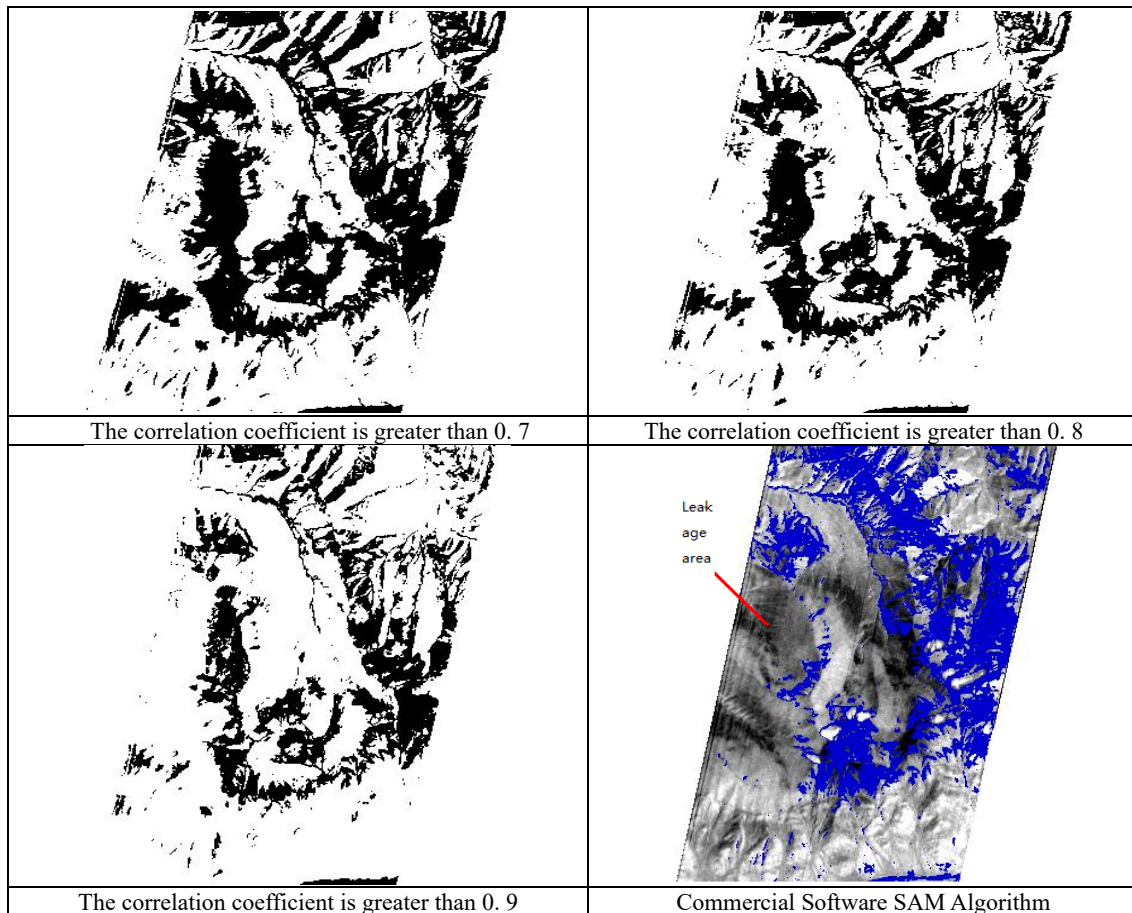
$K_n$  and  $r_n$  are the weight coefficients and correlation coefficients of feature window n. Among them,  $K_1 + K_2 + K_3 + \dots + K_n = 1$

The difference between the comprehensive correlation coefficient obtained from pixels and the comprehensive

correlation coefficient obtained from standard spectra is the final basis for determining rock and mineral types. The smaller the difference, the closer it is to the rock and mineral types obtained from standard spectra.

### 3. Analysis of Test Results

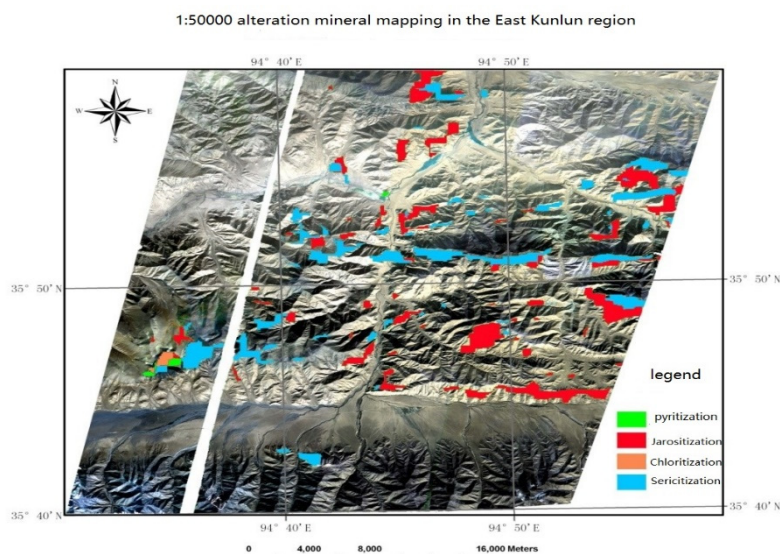
The experiment selected the East Kunlun region of the Qinghai Tibet Plateau and conducted the following two sets of experiments: (1) Using the spectral curve collected from the field as the standard spectral curve, the distribution of conglomerate was extracted from the hyperion data of the hyperspectral image EO-1. The absorption and reflection feature range of near-infrared and shortwave infrared regions is set to level I, and the weight ratio factor is preset to 0.7; The visible light range is set to level II, and the weight scaling factor is preset to 0.2; The sensitive area affected by environmental factors is set to level III, and the weight ratio factor is set to 0.1, the results are shown in Figure 3. After on-site verification and comparison, it can be concluded that the design method of the paper extracts information more comprehensively and has higher stability, and there are obvious areas of omission in the methods provided by commercial software. However, there is still room for improvement in the method designed in the paper, such as the inadequate consideration of the bidirectional reflection law of electromagnetic waves, which is also an important threshold for qualitative remote sensing to move towards quantitative remote sensing.



**Figure 3.** Recognition results of feature window weighted correlation spectral matching method.

(2) The alteration process mainly forms beresitization, sericitization, kaolinization, silicification, carbonation, chloritization, epidotization, potassic alteration, and jarositization, accompanied by pyritization, peacock petrification, and gold mineralization. Based on the genesis and alteration types of the mineral resources in the area, and based on the analysis of the relationship between different alteration minerals and mineralization, combined with the spectral characteristics of the rock minerals in the experimental area, mica, sulfate minerals,

chlorite, and pyrite were selected as the end element minerals for identification. Using the reconstructed spectral data after atmospheric correction, recognition and extraction were carried out on each strip, followed by geometric correction, tiling, and stitching of the strip, the results are shown in Figure 4. Figure 4 shows the distribution of four types of altered minerals identified after aviation belt inlay. Through experiments, the paper design method was used to extract mineral alteration information, achieving good results.



**Figure 4.** Comprehensive identification results of altered minerals in the experimental area.

## 4. Conclusion

The feature window weighted correlation spectral matching technique in the article can effectively determine the rock and mineral types in mining areas, provide effective decision-making and planning basis for the efficient utilization and sustainable development of mineral resources, and also provide important references for environmental protection and resource management. It plays an important supporting role in government decision-making and serves the ecological reconstruction and planning of mining areas. This technology has been tested in the East Kunlun region of the Qinghai Tibet Plateau, and the results are good, meeting the expected design requirements. Its application prospects are broad.

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