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Study on identification of altered rock in hyperspectral imagery using spectrum of field object

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ABSTRACT

In this article, the spectrum of a field object was used to match the pixel spectrum in the hyperspectral imagery, and determine whether there existed a dominant object in the pixel and to what extent the dominant object was present. Based on these recognition results, altered rock in the hyperspectral imagery was identified. The spectrum of a field object was obtained from field surveys in the study area, and in the spectrum, there was only one main object that could be effectively identified; this main object was named as the dominant object in this paper. In this study, the overall shape of the spectrum was matched firstly, and then the correlation coefficients between the pixel spectrum and the spectrum of field object in the corresponding wavelength ranges of the absorption-bands were calculated to determine the matching effect of these spectra as well as the possibility that the dominant object existed in the pixel. The recognition results were expressed by two images: the first image was a figure that illustrated the dominant objects in the pixels; the second image was a figure showing the correlation coefficients. The study area was a primitive forest covered region located in the Pulang porphyry copper mining area, Zhongdian County of Yunan province, China. The figures illustrating the distribution of the altered rocks and the correlation coefficient were obtained from this study. The on-site verification showed that using the spectra of field objects, it was possible to identify the dominant objects in the pixels, which favored the identification of altered rocks in the image. Moreover, compared to considering only the overall shape, the recognition results obtained by considering the overall and partial shape of the spectra had higher reliability.

1. Introduction

Hyperspectral remote sensing (RS) can provide spectral information of materials usually over several hundreds of narrow contiguous spectral bands, with high spectral resolution on the order of 20 nm or narrower in the visible and infrared wavelengths (Debba et al., 2005). Therefore, hyperspectral RS has a greater unparalleled advantage in the identification of surface substance than multispectral RS (Debba et al., 2005; Kruse et al., 2003). Hyperspectral RS has been widely used for mineral exploitation (Bedini et al., 2009; Bishop et al., 2011; Chen et al., 2007; Crosta et al., 1998; Debba et al., 2005; Gersman et al., 2008; Kruse et al., 2006; Rowan et al., 2000; van der Meer, 2006a). In its application, the mineral prospectivity is studied mostly by identifying the alteration minerals and effective results are obtained (van der Meer et al., 2012). However, in the environment of a complicated area (such as forest covered area), vegetation will lead to weak information of the alteration minerals in the pixel spectrum and therefore, the information regarding alteration minerals is difficult to be extracted effectively (Bishop et al., 2011). In addition to that, since some minerals can be formed under both alteration and no alteration (for example, the kaolinite is not only present in altered rocks, but also in sedimentary rock), the information of alteration minerals extracted from the RS image contains both the information of the minerals formed under alteration (namely actual alteration minerals) and under no alteration (namely false alteration minerals). However, only the information of the actual alteration mineral is useful for the mineral prospectivity.

Altered rocks contain some features of their protoliths besides the features of their alteration minerals, thus in RS images, they have more information than the alteration minerals on their surface. Accordingly, a new method is put forward to study mineral prospectivity by identifying altered rocks when the information of the alteration minerals is difficult to be extracted from the hyperspectral image, and this can avoid false alteration mineral information.

At present, some papers on field altered rock only focused on the study of the spectra of alteration minerals and aimed to extract the information of alteration minerals from the image (Petrovic et al., 2008; Van Ruitenbeek et al., 2012), however, some papers aimed to identify altered rocks as follows: firstly, the pixel spectra of the altered areas are extracted from the image as the reference spectra, then the pixel spectra of other regions are matched with them, and if the matching

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value of a pixel is greater than the assigned threshold value, it can be concluded that the pixel indicates information of the altered rocks (Rowan et al., 2000). In forest covered areas, the information from vegetation might be too much and may weaken the information gained from altered rocks in the pixels; therefore, it can cause high similarity of the reference spectra and consequently, make it difficult to distinguish different styles of altered rocks from their spectral characteristics. For example, Rowan et al. (2000) selected some reference spectra from the altered areas in the image, but these spectra were generally similar, differing mainly in overall reflectance level; therefore, there was no distinction in alteration styles in the information extracted. This study selected some field ground spectra of altered rocks with different surface alterations as reference spectra, and identified these altered rocks in the image.

In this study, in addition to the identification of altered rocks of different alteration styles, other ground objects such as vegetation and soil were also identified, which was conducive to the analysis of their effects on the information of altered rocks in the image. The reference spectrum used in this study was the spectrum of the field object, with which the pixel spectrum was matched to determine whether altered rocks or other objects existed in the pixel. The field object was the ground object (e.g. different types of rocks, vegetation and soil), the spectrum of which was obtained from the field surveys in the study area. In the process of surveys, the sensor of a spectrometer detected one or more field objects, the spectrum of which was collected and only one object's features played a main role in the spectrum and could be effectively identified, and this object was designated as the dominant object in the spectrum in this paper. All spectra of field objects in this paper had their own dominant objects. This is a new concept and no literature is available on this topic for the area under study.

In the identification of ground object in the hyperspectral imagery, spectral matching techniques are used most readily for quantitative comparison. The spectrum matching techniques aimed to express the similarity of reference (library or field spectra of known materials) to test (image) spectra (van der Meer, 2006b, 2012), and this method has been widely used (Baugh et al., 1998; Clark et al., 1987, 1990, 1991; Crowley and Clark, 1992; Debba et al., 2005; Hecker et al., 2008; Kruse, 1988, 1990, 2008; Kruse and Lefkoff, 1993; Kruse et al., 1993b; Kruse et al., 2003; Kumara et al., 2010; Mountrakis et al., 2011; Swayze and Clark, 1995; van der Meer and Bakker, 1997; van der Meer, 2006b; Xu et al., 2011; Yamaguchi et al., 1987). In order to accurately identify the dominant object in the pixel, this study used a new concept: it considers both the overall and partial shapes of the spectrum (this article focuses on the absorption-band position in the spectral shape), and the spectra were matched by these two aspects. The thought process was: firstly, the overall shape is matched and then the partial shape is matched. In this study, the identification results of the pixel and the match value of the pixel spectrum were provided and from these, it was easy to determine the possibility that a corresponding dominant object existed in the pixel.

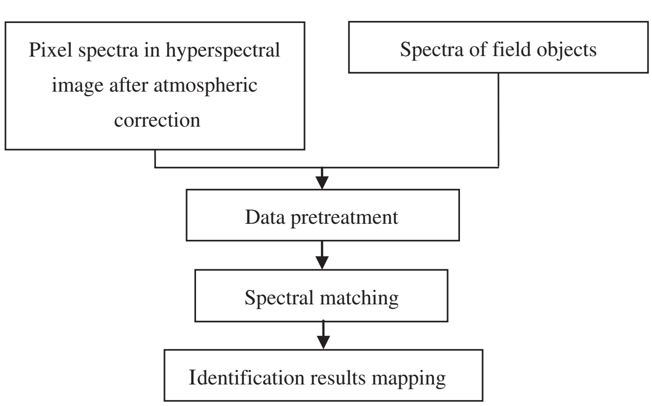

Fig. 1. Flow chart of ground object identification in hyperspectral image using the spectrum of field object.

2. Method

The purpose of this study is to use several spectra of field objects to determine which dominant object (mainly altered rocks) most likely exists in the pixel and to evaluate the possibility of existence of the dominant object. The former is realized by calculating the correlation coefficients between the pixel spectrum and all spectra of field objects within the entire band range and by choosing the spectrum of field object with the maximum correlation coefficient (hereinafter referred to as the "most likely spectrum"). It is possible that the dominant object in the "most likely spectrum" exists in the pixel (hereinafter referred to as the "most likely object"). The aforementioned possibility of existence of the dominant object in the pixel is determined by the values of the maximum correlation coefficient, the correlation coefficients of the pixel spectrum and its "most likely spectrum" in various absorption-band positions. The maximum correlation coefficient is represented by gray-scale value on the image (Fig. 4(c)).

The ground objects in the pixel spectrum were identified by spectral matching of the overall shape of the spectrum and the absorption-band position in the spectral shape; the flow chart is shown in Fig. 1. The procedure included data preprocessing, spectral matching, and mapping the identification results, and the author achieved these functions in a VC++ environment.

2.1. Data preprocessing

Hyperspectral image data comes from the American satellite EO-1's Hyperion. Hyperion is the first spaceborne hyperspectral sensor, launched in 2000 on board the National Aeronautics and Space Administration (NASA)'s Earth Observing Mission One (EO-1). While Hyperion has 242 bands with a spectral resolution of 10 nm, only 198 (426.82–2395.50 nm) are calibrated for the L1R product used in this study. This research used the FLAASH in the software ENVI to carry out atmospheric correction of the hyperspectral data.

The field spectra were collected with FieldSpectral Pro, an Analytical Spectral Devices (ASD) spectrometer which records 2151 channels throughout the 350 nm to 2500 nm wavelength range with a spectral resolution of 3 nm at 700 nm and 10 nm at 1400 nm and 2100 nm. The spectral sampling interval is 1.4 nm in the 350–1050 nm wavelength range and 2 nm in the 1000–2500 nm wavelength range. Since the field

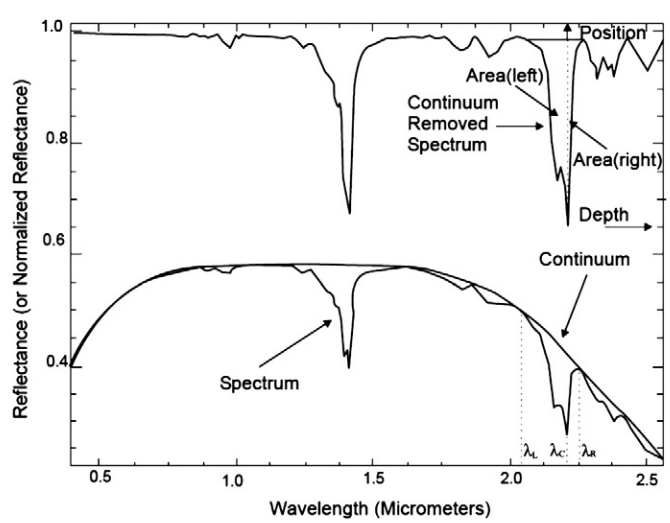

Fig. 2. Definition of the continuum and continuum removal and subsequent definition of absorption feature characteristics (van der Meer, 2004).