Analysis of Hyper-spectral Discriminatory Methods on Typical Plateau Forestry Vegetation

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Abstract. Spectral characteristics analyzing is the foundation of classification and matching for surface features. In this paper, field spectrum measurement was conducted on typical plateau forestry vegetation types in upper reaches of Min Jiang River. Meanwhile, hyper-spectral similarity measurement indicators were established. This paper tested 5 spectral similarity measurement operators including Euclidean Distance (ED), Spectral Angel Measurement (SAM), Spectral Information Divergence (SID), Spectral Information Divergence-Spectral Angel Measurement (SID-SAM) and Douglas Peucker Spectral Dimensionality Reduction Distance (DPSD) on identification of plateau forestry vegetation in quantified analyzing methods. Analyzing results indicate that (1) the spectral characteristics differences of all the 5 plateau forestry vegetation types mainly fall into the crest or trough of reflection spectra; (2) Chinese China fir, palm, pilea notata, ferns and mottled bamboo generally have high standard of spectral discriminatory probability, meanwhile, the spectral discriminatory probability between pilea notata and ferns is quite low; (3) for plateau forestry vegetation types, spectral discriminatory ability for of all the 5 spectral similarity measurement operators shows in descending order: Spectral Angel Measurement, Euclidean Distance Measurement, Douglas Peucker Spectral Dimensionality Reduction Distance Measurement, Spectral Information Divergence- Spectral Angel Measurement, spectral Information Divergence Measurement.

Introduction

Vegetation is one of the crucial factors which significantly affect living conditions of human beings; therefore, accurately identifying vegetation characteristics is the primary work of vegetation ecology. At present, the forestry vegetation identification methods include field survey, image interpretation, and digital remote sensing. Field survey needs large expense on time, while exists obvious difficulty on identification; using regular remote sensing data usually just can get rough classification results. However, hyper-spectral remote sensing improves a lot on spectral resolution, thus enables its capability of accurately detecting surface features with slight spectral difference, which enhance the precision of identification and classification for forestry vegetation. Till now, there are abroad and domestic researchers obtaining fine results though applying hyper-spectral data on identifying surface features, but seldom has done research on using hyper-spectral data to identify typical vegetation types in west China.

The surface features’ spectral matching method, which identifies surface feature classification by comparing the similarity measurement results of spectra, has become the major work of spectral characteristics measurement during imagining spectrometer processing; meanwhile, it stands out as the fundamental work for surface feature classification and surface information extraction of hyperspectral data. At present, spectral similarity measurement models mostly focus on measuring methods based on distance and shape, such as Euclidean Distance (ED), Spectral Angel Measurement (SAM), Spectral Information Divergence (SID), and Spectral Information Divergence-
Spectral Angel Measurement (SID-SAM). Therefore, this paper designed a new Douglas Peucker Spectral Dimensionality Reduction Distance (DPSD) model, which compares and analyzes the various hyper-spectral discriminatory results of typical plateau forestry vegetation, provides a new kind of efficient technique for vegetation identification and classification of hyper-spectral remote sensing.

Data
Spectrum Collection
FieldSpec 3 portable spectrometer produced by ASD Company of USA with the valid band range of 350 to 2500 nm was applied in this study. Since the study area locates in the middle-upper reaches of Min Jiang River, the five types of local vegetation: mottled bamboo, fern, pilea notata, China fir, and palm were chosen as sample types for study.

Data Collection period lasted from April 12th to 16th, 2012. Under the condition of indoor manual simulated light source, 36 sets of spectral data were collected for each sample type. To eliminate the random errors caused by instruments, average spectrum value was computed out for each sample type, and then antialiasing process was done by applying 5 successive band windows on average spectrum.

Methods
Spectral similarity Measurement
Euclidean Distance (ED). Euclidean Distance is the most common operator in spectral similarity measurement, its decision function expresses as follow:

\[ \text{Eucl}(x, y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2} \] (1)

where x and y are two different spectrum that needs to be measured, n is the number of spectral bands. The smaller their distance value is, the higher their similarity presents, thus the respectively spectral discriminatory possibility is lower.

Spectral Angel Measurement (SAM). Spectral Angel Measurement (SAM) is the high-dimension vector formed between base point and actual spectrum point in high-dimension coordinate space, which is used as operator for spectral similarity measurement. The cosine function of spectral angel shows as follow:

\[ \cos(\theta) = \frac{\sum_{i=1}^{n} t_i r_i}{\sqrt{\sum_{i=1}^{n} t_i^2 \sum_{i=1}^{n} r_i^2}} \] (2)

where ti and ri are two different spectrum that needs to be measured, n is the number of spectral bands. While the spectral angel is small, the cosine value is close to 1, thus the spectral similarity is high.

Spectral Information Divergence (SID). Spectral Information Divergence is based on the theory of probability and statistics, by calculating out information entropy of spectra to measure the similarity between two spectrums. It is computed as follow [Wen]:

\[ \text{SID}(x,y) = D(x|y) + D(y|x) \] (3)

where x and y are two different spectrum that needs to be measured; while, presents the relative entropy from x to y; , presents the relative entropy from y to x.

Spectral Information Divergence-Spectral Angel Measurement (SID-SAM). SID-SAM is a mixing spectrum measurement combined Spectral Information Divergence and Spectral Angel Measurement. It is computed as follow:

\[ \text{SID}(\text{TAN}) = \text{SID}(x, y) \times \tan(\text{SAM}(x,y)) \] (4)
where \( SID(x, y) \) presents spectral information divergence and \( SAM(x, y) \) presents spectral angel measurement.

**Douglas Peucker Spectral Dimensionality Reduction Distance (DPSD).** Applying Douglas Peucker spectral algorithm on hyper-spectral spectra to reduce dimension, it could maintain the general trend of spectra while reducing the size of data. After obtaining the spectral characteristics sequentially, the distance between each characteristic point, which can measure the spectral similarity, is computed out according to function (5):

\[
D(p_i, q_j) = \sum_{i=1}^{n} [(p_{ix} - q_{ix})^{2} + (p_{iy} - q_{iy})^{2}]
\]

(5)

where \( p_{ix}, q_{ix} \) and \( p_{iy}, q_{iy} \) present one set of spectral band and reflectivity, and present the other one.

**Evaluation on Spectral Discriminatory Ability of Measurement Operators**

This paper chose Relative spectral discriminatory probability (RSDPB) and Relative spectral discriminatory entropy (RSDE) as parameters to evaluate the spectral discriminatory ability of 5 measurement operators: SID, SAM, ED, SID (TAN) and DPSDR.

**Relative Spectral Discriminatory Probability (RSDPB).** Measurement unit varies from different spectrum measurement operator; therefore, this paper standardized all the measurement values as follow [Azadeh]:

\[
p_m(i) = \frac{m(t, s_i)}{\sum_j m(t, s_j)} \quad \text{for } i = 1, 2, \ldots, j
\]

(6)

Where \( m(t, s_i) \) presents the number i similarity measurement value of operator \( t \).

**Relative Spectral Discriminatory Entropy (RSDE).** In order to analyze the ensemble identification ability of spectral similarity measurement operators, spectral discriminatory entropy was computed out as follow [Wu]:

\[
RSDE(t) = -\sum_i p_m(i) \log_2(p_m(i))
\]

(7)

Where \( p_m(i) \) is the relative spectral discriminatory probability. The minor the RSDE is, the higher the identification ability towards vegetation spectrum is, thus can get more precise classification results.

**Results and Discussion**

**Fundamental Spectral Reflection Characteristics of Typical Plateau Forestry Vegetation**

As shown in Figure 1, the general trend of all 5 types of typical vegetation’s spectra is quite similar. Strong absorptivity falls into two areas: around 490 nm (belongs to blue channel), around 685 nm (belongs to red channel), thus forming “blue trough” and “red trough” where the reflectivity ranges from 0.02-0.05 to 0.04-0.06. For the reason that the absorptivity for green channel drops, there’s forming a reflectance peak between blue trough and red trough, the peak value reaches to 553nm, while reflectivity ranges from 0.05 to 0.17. There’s a sharp increasing of reflectivity around 685-755 nm, forming a steep slope called “red edge”. Due to the influence factors such as biomass and leaf area index, there exist a high reflectance platform in the band interval of 760-1300 nm. In the region of infrared band (1300-1820 nm), affecting by leaf water content, absorptivity rises up, while reflectivity drops down. Besides, due to the influence from moisture content of the atmosphere, there form a trough around 1455 nm.

For the physiological and biochemical characteristic of each vegetation varies from other ones, there is obvious difference between the spectral reflectivity spectra taken from different leaves. It is clear in Figure 1 that, during the band interval of 430-1170 nm where belongs to optical channel and infrared channel, the reflectivity of typical plateau forestry vegetation sequenced from high to low is:
pilea notata, fern, mottled bamboo, China fir and palm. For the low content of chlorophyll and water, pilea notata and fern have higher reflectivity than other three. During optical channel, there is little difference in reflectivity among all the 5 types of typical plateau forestry vegetation, while the significant diversity exists within infrared channel.

Figure 1. Canopy spectra of typical plateau forestry vegetation.

Analysis on Spectrum Similarity Measurement Results

This paper conducted Visual C++ 6.0 to accomplish the program development for spectral similarity measurement operators which were applied to measure spectral similarity of typical plateau forestry vegetation. Table 1 to 5 in the following show out the matrices for relative similarity measurement results of different measurement operators, where MB, FE, PN, CF, and PA respectively refers to mottled bamboo, fern, pilea notata, China fir, and palm.

**Euclidean Distance Measurement (ED).** The distance of reflectivity spectra for mottled bamboo, fern, pilea notata, China fir, and palm were computed out, shown as Table 1.

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</table>

It can be seen that Euclidean Distance between pilea notata and palm is the largest one, with the lowest similarity of spectral characteristics, thus contributing to fine spectral discriminatory ability. Besides, the spectral characteristics of China fir and palm are very alike, with the highest spectral characteristics similarity and weak spectral discriminatory ability.

**Spectral Angel Measurement (SAM).** The cosine value of reflectivity spectra spatial angle for mottled bamboo, fern, pilea notata, China fir, and palm were computed out, shown as Table 2.

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</table>

From Table 2, it can be seen that the results of spectral angel measurement operator are very similar, all the cosine values are over 0.98. The cosine value from China fir to pilea notata is the largest one, that is, the angel between them is the smallest, thus with the weakest spectral discriminatory ability. The cosine value from fern to mottled bamboo is the smallest, with the fine spectral discriminatory ability.
Spectral Information Divergence Measurement (SID). The reflectivity spectral information entropy of mottled bamboo, fern, pilea notata, China fir, and palm were computed out, shown in Table 3.

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As it is shown in Table 3, mottled bamboo and fern have the high value of spectral information entropy among all the 5 types of vegetation, that is to say, the spectra patterns of mottled bamboo and fern differ a lot, thus contributing to fine spectral discriminatory ability. The spectral information entropy between pilea notata and China fir is the smallest one, with the lowest differences in between.

Spectral Information Divergence-Spectral Angel Measurement (SID-SAM). The SID-SAM mixing measurement values of mottled bamboo, fern, pilea notata, China fir, and palm were computed out, shown in Table 4.

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</table>

SID-SAM mixing measurement result between mottled bamboo and fern is the largest one, representing the lowest similarity of combined reflectivity spectra shapes and spatial angel measurement, thus contributing to fine spectral discriminatory ability. While the SID-SAM mixing measurement result between pilea notate and China fir is the lowest one, it leads to weak spectral discriminatory ability.

Douglas Peucker Spectral Dimensionality Reduction Distance Measurement (DPSD). After spectral dimensionality reduction, similar distances of characteristic quantities were computed out for mottled bamboo, fern, pilea notata, China fir, and palm, shown in Table 5.

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<td>48294.09</td>
<td>92711.03</td>
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</table>

The spatial distance between mottled bamboo and fern is the longest, representing the lowest spectral similarity. While the spatial distance between mottled bamboo and pilea notata is the shortest, representing the highest spectral similarity.

Evaluation on Spectral Discriminatory Ability of Measurement Operators. This paper used function (6) and (7) to standardize value unit of all the spectral similarity measurement results, which assist relative spectral discriminatory for plateau vegetation types.
As it is shown in Table 6, for typical plateau forestry vegetation types analyzed in this study, every spectral similarity measurement operator has unique sensitive standard which differs from each other. Specifically, fern and mottled bamboo have the highest relative spectral discriminatory possibility under SID measurement; China fir and mottled bamboo have fine relative spectral discriminatory possibility under SID, SID-SAM, and DPSD measurements; palm and fern have quite well relative spectral discriminatory possibility under all the five kinds of measurements; pilea notata and fern have quite low relative spectral discriminatory possibility under all the five kinds of measurements.

RSDE index in Table 6 shows that there is tiny difference of spectral discriminatory possibility among 5 kinds of measurement operators, sequencing as: SAM>ED>DPSD>SID(TAN)>SID.

Conclusions
(1) Reflectivity spectra of plateau forestry share the general trend pattern with similar spectral characteristics. For palm, effected by leaf cell structure, its reflectivity increases at 1165 nm. For fern, effected by water content of leaves, its reflectivity decreases significantly at 1323 nm.

(2) The 5 kinds of measurement operators differ in the spectral discriminatory ability for plateau forestry vegetation types. ED has strong spectral discriminatory ability towards pilea notata and palm. SAM is a kind of measurement operator to describe overview condition, while is not significant in partial spectral discriminatory, thus there is little difference of spectral discriminatory possibility among all the typical vegetation types. SID is based on spectral information entropy, which is mainly affected by spectra shape; it has strong spectral discriminatory ability towards mottled bamboo and fern whose spectra wave obviously. As for SID-SAM, due to the smooth results of SAM, SID-SAM shares the similar spectral discriminatory ability with SID. DPSD extracts spectral characteristic quantities to do similarity analysis, reducing data size as well as guaranteeing computational accuracy; it has the strongest spectral discriminatory ability towards mottled bamboo and China fir.

(3) China fir, palm, pilea notata, fern and mottled bamboo all enjoy fine spectral discriminatory possibility. While the spectral discriminatory possibility between pilea notate and fern is quite low. Towards plateau forestry vegetation types analyzed in this paper, the spectral discriminatory possibility of all the 5 kinds of measurement operators sequenced from high to low as: SAM, ED, DPSD, SID (TAN), SID.

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References


