Hyperspectral Remote Sensing for Agriculture in Support of GIS Data

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Abstract: When and Where, What kind of agricultural products will be produced and provided for the market? It is a commercial requirement, and also an academic questions to remote sensing technology. Crop physiology analysis and growth monitoring are important elements for precision agriculture management. Remote sensing technology supplies us more selections and available spaces in this dynamic change study by producing images of different spatial, spectral and temporal resolutions. Especially, the hyperspectral remote sensing should do play a key role in crop growth investigation at national, regional and global scales. In the past five years, Chinese academy of sciences and Japan NTT-DATA have made great efforts to establish a prototype information service system to dynamically survey the vegetable planting situation in Nagano area of Japan mainly based on remote sensing data. For such concern, a flexible and light-duty flight system and some practical data processing system and some necessary background information should be rationally made together. In addition, some studies are also important, such as quick pre-processing for hyperspectral data, Multi-temporal vegetation index analysis, hyperspectral image classification in support of GIS data, etc. In this paper, several spectral data analysis models and a designed airborne platform are provided and discussed here.

Keywords: Hyperspectral remote sensing, precision agriculture.

1. Introduction

The applications of remote sensing in assessing spatial variability of plants and land cover are becoming an increasingly popular management tool. In addition, the importance of mapping, quantifying and monitoring changes in the biophysical characteristics of crops has been also widely recognized in the agriculture community. Aircraft-based and satellite-based sensors play some unique roles in monitoring seasonally variable crop growths and for time-specific and time-critical crop management. With the development of remote sensing technology, a lot of remote sensors emerged, with various of spectral and spatial resolution. How to effectively analyze these remote sensed data, and especially how to use the data for monitoring the land cover and vegetation growth are the key problems in the study on global and regional environment. When and Where, What kind of agricultural products will be produced and provided for the market? It is a commercial requirement, and also an academic questions to remote sensing technology. However, there are two important problems that we must solve for meeting above requirements. One is the precision of information extraction from remote sensed data. Another is how to effectively connect the remote sensing data or its reflected information with GIS data, which is the usual tool for agricultural or regional management.

In the past five years, Chinese academy of sciences and Japan NTT-DATA have made great efforts to establish a prototype information service system to dynamically survey the vegetable planting situation in Nagano area of Japan mainly based on remote sensing data. For this concern, a flexible and light-duty flight system and some practical data processing system and some necessary background information should be rationally made together. Correspondingly, several data analysis models should be provided and discussed more, such as quick pre-processing for hyperspectral data, Multi-temporal vegetation index analysis, hyperspectral image classification in support of GIS data, etc.

2. Data Acquisition

This research is based on the international cooperation project between Chinese academy of science and NTT-data of Japan. On August, 2000, 80 spectral bands of hyperspectral data was acquired in Japan by Pushbroom Hyperspectral Imager (PHI) developed by the Shanghai Institute of Technical Physics, which was linked with a Position and Orientation System (POS). In addition, true-color air-photograph was also obtained. The PHI covers 400-850nm spectral region, with 3 meters (2000m flight height) spatial resolution. Air-king airplane with two-screw engine was selected as remote sensing platform. While the images were being acquired, some detailed ground measurements were carried out synchronously, including field spectra, digital photogragh and ground truthing map, etc.

The study area is one of important vegetable planting area, namely Minamimaki. Some popular vegetables in Japan, such as Japanese cabbage, Chinese cabbage, radish, lettuce, etc., have wide planting in this area. But, Japanese farmer have not large farmland just as what American farmer have. For economical reason, every farmer usually plant several vegetables in their relative small planting area. So, in a region, every field patch is small but the vegetable types are very intricate. For every field patch, vegetable types change several times according to its growing periods in one year.

3. Atmospheric Correction Calibration of Hyperspectral Image Data

1) Improvements to the empirical linear (EL) Calibration Method

Empirical Line(EL) method has been popularly recognized as an effective conversion for image spectra rebuilt. However, when we applied it directly on the PHI data acquired in Nagano,Japan, 2000, the reflectance spectra extracted from even the same area of the calibrated images were quite different as the different atmosphere conditions and other factors such as viewing angle, solar zenith angle. Therefore, the radiance correction and normalization were needed urgently before EL conversion. Moment matching algorithm exactly serves this purpose and has been proved excellent for the difference elimination of reflectance images acquired in different days. When the moment matching followed by El conversion was utilized on the images acquired by 80-band pushbroom hyperspectral imager (PHI) on Aug 23, 2000 and Aug 24, 2000, the image spectra of the same areas were nearly the same, implying that the improvements to EL was necessary and rational.

2) Development of reflectance conversion without concurrent ground spectral measurement

Reflectance conversion without concurrent measurements is researchers' ideal all the way. The flat field method is just the one that needs not auxiliary data. It is based on the terms that there is a homogeneous large-area field with relative flat spectral response on the image. But the method tends to be time-consuming because it is usually executed by selecting the so-called flat field manually, indicating that it is inevitably affected artificially to a certain extent. For this concern, we set the imge average spectrum within 500-700nm as the reference, areas over a certain times of reference spectrum values can be chosen as the possible flat field. In order to ensure the chosen region has a certain area, only one to three largest area was selected as the final flat field and was then calculated the mean spectrum (considered as the principal solar/atmospheric signal). Devided by this spectrum, reflectance conversion is completed automatically. When applying this automated flat field on one PHI image in Japan, we got nearly perfect result.

4. Estimating Biochemical Contents Using Hyperspectral Remote Sensing

Detection of relative pigment levels could provide useful insights into vegetation distribution and function. Hyperspectral remote sensing conquers the defects of conventional wet chemical methods for pigment quantification by obtaining the biochemial contents of vegetations rapidly and objectively at a large scale without tedious and destructive sampling. In this study, We used hyperspectral reflectance to explore alternate methods of pigment quantification at canopy or landscape scales.

We selected Kawakami village, Japan as the study site. there were three types vegetables, cabbage, lettuce and red lettuce. For the former two, chlorophylls are the dominant pigments, while anthocyanins are the dominant pigments for red lettuce. So we evaluate different pigments for different species.

Firstly, good correlations have been found between spectral reflectance and levels of three major pigment groups: chlorophylls, carotenoids, and anthocyanins.The inverted-Gauss fitting was used to filter the red edge region so that the credible red edge position were determined. It turned out that red edge position strongly correlated with cholorophyll content and cholorophyll mapping was got Anthocyanin is red pigment. By using a statistical correlative models of the reflectance ratio of red band and green band, Anthocyanin is red pigment. Some statistical correlative models have been built to estimate anthocyanin content so as to mapping.

In addition, ultilizing the high correlation between nitrogen content and red edge width, nitrogen content mapping was also acquired.

5. Crop Growth Monitoring study by Using Multi-temporal Index Image Cube Analysis

The importance of temporal information has been recognized increasingly for vegetation discrimination and classification, as every vegetation, especially crop, has its special phenological calendar, and the spectral reflectance factors of crops change during their growing seasons, correspondingly each crop has its unique temporal change patterns of vegetation index. In this way, remote sensing data plays a key role. But how to effectively analyze the multi-spatial, multi-temporal and multi-spectral resolution remote sensed data for monitoring the land cover, vegetation growth and so on has been the key problem for a long time. In this section, an effective data structure multi-temporal index image cube (MIIC) was proposed for supporting the dynamic analysis on vegetation phenological and physiological characteristics. Based on MIIC structure, temporal change curves of six common spectral indices were extracted and separability analyses were carried out to determine the optimal scene combinations for the accurate classification. The data used included seven temporal lettuce and cabbage spectra measurements of Japan, seven temporal spectra of four kinds crops: cotton, maize, soybean and rice in Datun experimental station, Beijing. Results showed that multi-temporal spectral index profiles can enable us to discriminate vegetations or crops more easily so as to improve the classification and identification precision. In our study, the profile of red edge slope showed its potential in classifying crops at earlier stage.

6. Image Classification in Support of GIS Data

As every field patch in this study site is small but the vegetable types are very intricate, it's a real challenge for us to distinguish the ground objects especially vegetables with only PHI image of one time. Because Hyperspectral remote sensing data provides us much more spectral information, enabling us to perform the precise classification. But on the other side, its spatial resolution is limited. In this study, the PHI image was geometrically corrected nearly perfectly by the POS data with it, and regional field patches were extracted based on the digital air photos so that relative farmland geographic information system were established, allowing it possible to combine PHI data with GIS data so as to classification on the basis of each field patch, not on pixel level, was processed. The mean spectrum of every field patch can be acquired. Because of the large sampling number, the mean spectrum of every field patch has high reliability and separability. Compared with spectral identification of isolated pixel one by one, only one spectra is taken out from a field patch, even though it is very large or small. This method satisfies the integrality of classification polygon. It is very suitable for the dynamic investigation of special area with background information.

In order to meet the need of thematic mapping, mixed patch(namely, more than one class in one field patch) was considered. One spectral unmixing method based on field patch was proposed. First of all, the pixels located at the edge of field patch were excluded. Then for each field patch, the sum of standard deviation of all bands was calculated. Pure patches have much less standard deviation than the mixed patches. Using such difference, mixed field patches can be easily extracted from large farmland areas. Some more detail spectral unmixing work will be carried out on them.

7. Conclusion

This paper summerizes several data analysis models for the prototype information service system that Chinese academy of sciences and Japan NTT-DATA have been engaged in establishing for dynamic survey of the vegetable planting situation in Nagano, Japan. These models serve for image spectra rebuilt, Multi-temporal vegetation index analysis, biochemical content mapping, hyperspectral image classification in support of GIS data, etc. they are of great importance for the application of hyperspectral remote sensing in precision agriculture management.

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