Availability of Normalized Spectra of Landsat/TM Data by Their Band Sum

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Abstract: In satellite spectra, though the magnitude varies with intensity of sunstroke, dip angle of land and so on, the shape is less deformed with these effects. From this point of view, we have developed a spectral shape-dependent analysis utilizing a normalization procedure by the spectral integral and applied it to Landsat/TM spectra. Inevitable topographic and atmospheric effects can be suppressed. The correction algorithm is very simple and timesaving and the suppression of topographic effects is especially effective. Normalized band 4 is almost linear to NDVI values, and is available to the vegetation index.

Keywords: spectral shape, normalized spectral bands, topographic effect, vegetation vitality, NDVI

1. Introduction

Satellite sensors detect the radiance reflected by the earth surface illuminated by the sun. The observed spectra from visible wavelengths to the near infrared inevitably are reflective of surface properties, however, they include also both topographic and atmospheric effects [1]. To suppress these additional effects, we separate the radiant spectra into two factors; magnitude and spectral shape [2]. Magnitude of the spectrum varies with intensity of solar irradiance, atmospheric effects, angle of land inclination, observation angle of the sensors, density of leaves, and so on. On the other hand, spectral shape is less deformed by the factors just mentioned. Although spectral shape varies with the sort of land cover, the same materials give the similar shape. Therefore, topographic and atmospheric effects could be suppressed by normalizing the spectra with their band sum.

We have applied this normalization technique to Landsat/TM data, and surveyed the suppression of topographic effect and the relation between normalized reflectance and vegetation. We show here the applied algorithm and preliminary results.

2. Analysis Method

We have surveyed 30 Landsat/TM scenes of path 11 and row 36 acquired from 1984 to 1998. In this paper, we represent Landsat/TM spectra by reflectance. To calculate reflectance, we first transform DN values into radiance for each band using the calibration coefficients provided by the National Space Development Agency (NASDA). It is better to correct the offset component to approach the apparent reflectance to the ground reflectance as much as possible. In general, the smaller the wavelength (or band number) is, the larger the offset component is, and the offset component is larger than the Rayleigh scattering effect. Then, we regarded the Rayleigh scattering effect at sea level as the offset component, and subtracted it from the radiance, and normalized by the arithmetic mean of 6 bands, i.e. bands 1-5 and 7. By using these normalized reflectance, we made the following analysis.

3. Applied Results

1) Suppression of the Topographic Effect

First, we show the availability of our normalization procedure for the suppression of topographic effect by using Landsat/TM scenes on August 24, 1985. Here, we select a 370 x 400 pixels area around Mt. Hakken in Nara prefecture, Japan, where the maximum altitude is 1914 m and the surface is undulating. Both apparent reflectance of band 4 and its normalized one by 6 bands are shown in Fig. 1 (a) and (b). The normalized reflectance is flattered in the wooded region and rivers and roads appeared clearly. By comparing two figures in Fig. 1, it is evident that the topographic effect is powerfully suppressed by the normalization.

Spectrum shapes detected by the satellite are not so varied with incident quantity of light. In Fig. 1, thin clouds covered from center to the lower-right corner. This effect is small in the normalized band image as

(a) (b)

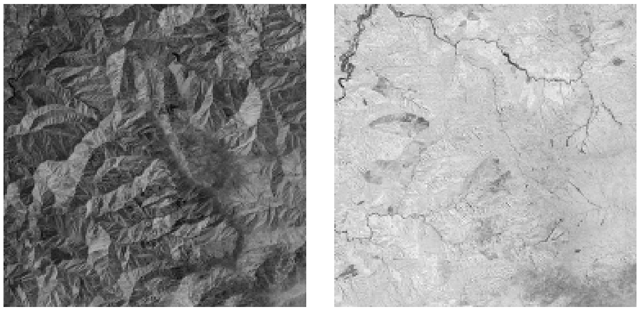

Fig. 1. TM band 4 images for Landsat/TM data around Mt. Hakken on August 24, 1985. The data used are (a) apparent reflectance values, (b) normalized reflectance values by the arithmetic mean of the six bands.

seen from the figure. At the shadow area, however, the spectrum is deformed and normalization effect is little at a recess of a mountain.

2) Seasonal Variation of Normalized Band 4

Next, we show the seasonal variation of normalized reflectance by using a 2000 x 1200 pixels area around Kobe City, Japan where vegetation, soil and water regions are included. Fig. 2 shows the histogram images of scatter plots for combination of normalized bands 4 and 5. Sampling histograms are arranged two months apart, but not in chronological order. Normally, three peaks are appeared in the histograms. The low band 5 peak is corresponds to water region, the high band 4 peak to vegetation region, and remaining low band 4 and high band 5 peak to soil region. Peak positions of both water and soil are fixed almost in all seasons. On the other hand, the peak of vegetation moves periodically on a line, and goes near the soil peak in winter and away from the soil peak in summer.

The color composite image of band combination (7, 4, 2) for (R, G, B) is adaptable to land cover view. Represented color is blue for water region, red-brick for soil region and green for vegetation region, and a tone of color is stable in all seasons. Two monochromatic images of normalized band composite 7-4-2 are shown in Fig. 3. We will show chronological series of color images for Kobe City in this conference.

3) Relationship Between Normalized Reflectance of Band 4 and NDVI

NDVI, Normalized Difference Vegetation Index is widely used as a vegetation index. In the case of Landsat/TM, NDVI is calculated from

$$NDVI = \frac{(Band\ \ 4\ \ -\ \ Band\ \ 3)}{(Band\ \ 4\ \ +\ \ Band\ \ 3)}\ . \qquad (1)$$

Therefore, NDVI is an example of the normalization

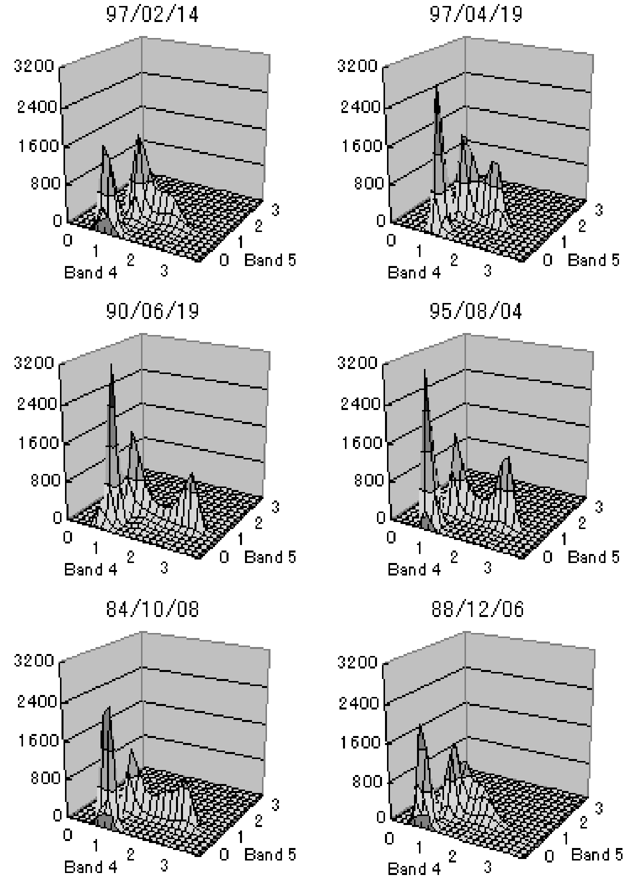

Fig. 2. Scatter histograms for combination of normalized bands 4 and 5. The applied area is around Kobe City. Acquired dates are indicated at each head. The order is seasonal and not chronological.

(a)

(b)

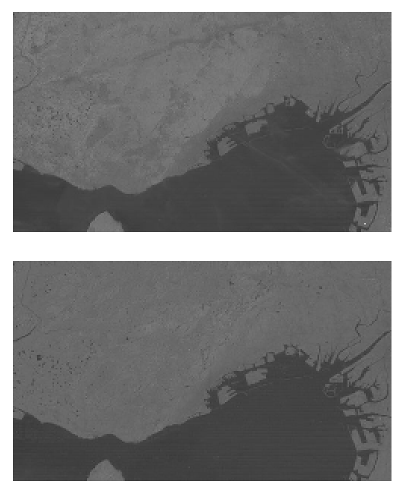

Fig. 3. Color composite images of the area around Kobe City for Landsat/TM data on (a) August 24, 1985 and (b) February 22, 1988. (R, G, B) colors assigned by bands (7, 4, 2, respectively). The reflectances shown are values normalized using the arithmetic mean of bands 1-5, 7.

procedure by 2 bands, i.e. bands 3 and 4.

First, we show the relationship between normalized band 4 and NDVI for the same area of Fig. 2. The selected area is around Kobe City shown in Fig. 3. The scattered histograms for combination of normalized

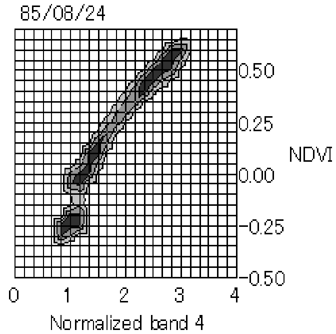

Fig. 4. Relationship between NDVI and TM band 4 values normalized using the arithmetic mean of bands 1-5, 7 for Landsat/TM data for Kobe City.

Fig. 5. NDVI images for Landsat/TM data around Mt. Hakken on August 24, 1985.

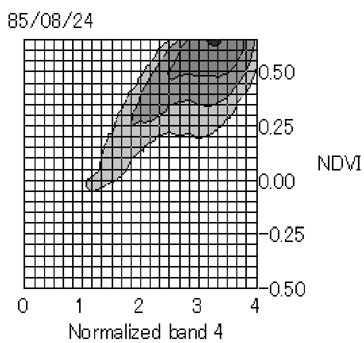

Fig. 6. Relationship between NDVI and TM band 4 values normalized using the arithmetic mean of bands 1-5, 7 for Landsat/TM data. The data used are around Mt. Hakken on August 24, 1985.

band 4 and NDVI are shown in Fig. 4. An isolated peak appeared in the negative NDVI area corresponds to water region. For soil and vegetation regions, the relation between normalized band 4 and NDVI is almost linear and vegetation region expands and contracts periodically. Therefore, normalized band 4 could be utilized as a vegetation index.

Second, we show the NDVI image in Fig. 5 for the same TM data used in Fig. 1. The topographic effect is also suppressed but lies slightly in the wooded area. We show the scattered histograms for combination of normalized band 4 and NDVI in Fig. 6. By comparing with Fig. 4, partial plots have lower values of NDVI and are shifted to the lower position.

For 30 TM scenes surveyed, the topographic effect is suppressed well in normalized band 4 images. By comparing with the normalized one, this suppression effect is low in NDVI images. This might be caused by the number of bands and adopted bands used for normalization. From these results, it would be concluded that normalized band 4 is better than NDVI as a vegetation index in all seasons.

4. Summary

We developed a new analysis algorithm by using the normalization method for Landsat/TM data. Here, the normalization factor is the arithmetic mean of bands 1-5 and 7. In order to verify the effectiveness of this normalization method, we studied first how the normalization process suppresses the inevitable topographic effect. As a result, it is evident that the topographic effect is powerfully suppressed by the normalization.

NDVI is widely used as a vegetation index, so that we next studied the correlation between normalized band 4 and NDVI. The normalized reflectance of band 4 is almost linear to NDVI. From the survey of NDVI images, it was found that NDVI is not enough to suppress the topographic effect especially in mountainous area of the undulations. Therefore, the normalized reflectance of band 4 is better than NDVI as a vegetation index in all seasons.

For DN values of Landsat/TM, normalization by bands 3-5 and 7 is available. The topographic effect is suppressed pretty well. The normalization procedure could be applied to other sensors. This procedure is very simple and should be a useful technique for the analysis of remote sensing data.

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