Adjustment of Spectral Information of Different Facets in a Surface Material using Image Segmentation

Jong Yeol Lee
Korea Research Institute for Human Settlements
1591-6, Kwanyang-Dong, Dongan-Gu, Anyang-Shi, Kyounggi-Do,
Republic of Korea 431-712
jylee@krihs.re.kr

Abstract: Geometric shape in a surface material sometimes produces different slopes that have different illuminations. It causes some difficulties to get same classification results or to identify as an object for the different facets in a surface material. A regression method is suggested to adjust the spectral information of different facets in a surface material using image segments. The method to adjust spectral information in a building facets was very successful. The most important advantage of this method is to keep the intensity of spectral information as well as spectral response. This method can also be implemented in an adaptive way.
Keywords: Spectral adjustment, Image Object Facet, Image Segment.

1. Introduction

Topography sometimes produces different slopes that have different illuminations even in a surface material. It is more serious in high spatial resolution imagery than low imagery because this phenomenon is manifested in more detailed level such as different facets of a roof in a building that may not detect in low spatial resolution imagery. It causes some difficulties to get same classification results or to identify as an object for the different facet areas in a surface material. It has been argued that the variance in an image caused by topographic factor is greater than the variance from spectral classes [1]. There are few methods to generate spectral information that are independent from variations induced by topography in illumination in remotely sensed data. These methods include Hyperspherical Direction Cosine Transformation (HSDC) [2], band ratioing [3], directed band ratioing [4]. The basic idea under these approaches is that the intensity of illumination would be reduced proportionally at all the bands gathered. HSDC assumes that ideal cover type would have the constant relationship between spectral bands even though for different facets that are from the same cover type. The relationship is identified by the radial of a line to the origin that is generated from a group of pixels' DN plotting. In the latter two approaches, when ratioing technique is adapted between any pair of bands, the result of ratioing would be expected to have similar measurements on different slope facets in a surface material.

Band ratioing is effective to eliminate the topographic effects on spectral measurements. The slope opposite to the slope faced to sunlight incident direction will have low intensity of illumination. Then the spectral measurements of pixels in the opposite slope will have relatively smaller than the faced slope. It should be the same to all the bands. The division process of band ratioing will compensate relatively small measurements on the opposite slope because small numbers are divided by small numbers. However, it loses band significance [2]. The reason is, for example, that small results of band ratioing can be produced from both small numerators and large denominators. HSDC is free from the loss of band significance. However, the problem of HSDC is to remove atmospheric effects and sensor bias. If these are not removed, the axe generated by spectral measurements of a group of pixels in a cover type does not pass through the origin. This produces different angles to origin for the pixels belonged to the same cover type. To avoid this, the intercept of axes that is caused by atmospheric effects and sensor bias is searched, and the offsets should be adjusted based on the intercept. However, it is very difficult to find common intercept for various cover types and environments. The common and another serious problems of band ratioing and HSDC are that the image produced by the methods is normally noisy and saturated, and that this is spectral response information, but does not have intensity information of spectral reflectance.

This paper is focused on adjustment of spectral information including intensity in a cover type, specifically a surface material using image segments in high spatial resolution imagery. The method developed consists of the following steps. First, image segmentation is undertaken for panchromatic 1 meter resolution IKONOS data set. Second, the offsets to origin and slopes of axes generated by the relationship between bands are investigated Finally, the spectral measurements of pixels in a surface material is adjusted by the offset and slope informations.

2. Methodology for Adjustment of Spectral Information

When geometrically induced illumination effects are removed from a surface material, the different facets of the surface material are expected to have same or similar spectral information. However, it is very difficult to separate the illumination effects because a scene has very complicate geometric structure. Even though the geometrically induced illumination effects are separated from the spectral information, there might still remain a result of different spectral reflectance characteristics of the surface material for different level of illumination or unexpected illumination effects. The method suggested in this study is to adjust the spectral information of different facets in a surface material using image segments that have different intensity of illumination induced by different geometric slope.

The major objective of image segmentation is to partition an image into regions that are spectrally and texturally homogeneous. If the pixels belonged to a segment are expected to be uniform, the relationship between bands of a material is constant. [2] But it is ideal assumption and there are still some variations caused by various reasons. The main reasons are that the segment may have slight twist of surface, and lack of complete uniformity of spectral response for each pixel. Under this situation, the relationship between bands shows a certain propensity that is linear shape. The propensity between bands is expected to be the same or similar for segments belonged to a cover type, specifically a surface material.

The propensity produced by any pair of spectral bands of image segments can be expressed mathematically as Eq. (1). Where X and Y are the pair of bands under investigate, b is the propensity of line induced by geometrical slope of image segments, H is the intercept of the line generated by the relationship between the pair of bands, N is error term, and i is image segment ID.

$$\begin{bmatrix} Y_1 \\ \cdot \\ \cdot \\ \cdot \\ Y_n \end{bmatrix} = \begin{bmatrix} b_1 \\ \cdot \\ \cdot \\ \cdot \\ b_n \end{bmatrix} [X_1 \cdots X_n] + \begin{bmatrix} H_1 \\ \cdot \\ \cdot \\ \cdot \\ H_n \end{bmatrix} + \begin{bmatrix} N_1 \\ \cdot \\ \cdot \\ \cdot \\ N_n \end{bmatrix} \quad (1)$$

The line of best for the spectral measurements of pixels for an image segment can be calculated by method of least squares. With this method, the intercept of the line, H, and regression coefficient, b, can be expressed as Eq. (2), and Eq. (3).

$$H = \frac{\Sigma Y \Sigma X^2 - \Sigma YX \Sigma X}{n \Sigma X^2 - (\Sigma X)^2} \quad (2)$$

$$b = \frac{n \Sigma YX - \Sigma X \Sigma Y}{n \Sigma X^2 - (\Sigma X)^2} \quad (3)$$

These equations can be adapted to the spectral measurement data set of each image segment. Based on these equations, the spectral measurements of band Y can be estimated by that of band X. As is it discussed before, when image segments are belonged to the same cover type, the intercept of the line, H, and regression coefficient, b, should be the same or at least similar to each other. In case of different conditions for the intensity of illumination, even if image segments are from the same cover type, the estimations of H can be different each other, for example between an image segment under cloud shadow and an image segment without any cloud shadow. However, under the same condition as previously mentioned, the regression coefficient b should be the same or similar. When the b and H are similar enough for two or more adjacent image segments, they will be assumed to be from the same cover type or facets of a surface material. For these image segments, the spectral measurements of all the pixels can be adjusted by an equation estimated.

3. Results and Discussion

1) Test Data and Data Fusion

To examine the method suggested, the data used are IKONOS pan-sharpened data that have 1 meter spatial resolution. A 1596 by 1572 meter area in Jeju, Korea, was selected for this study. The pan-sharpened data set were produced by data fusion method by Lee [5], using IKONOS panchromatic and multispectral data that have 1 meter and 4 meter spatial resolution respectively. IKONOS data from September 9, 2000 was available for this site. In Korea, early September is during summer, matured stage to leaf-out of the deciduous trees. Thus the imagery is with obscuring deciduous leaves, maximizing the occlusion of ground objects.

2) Image Segmentation

The image segmentation method adapted for this study is an edge-based approach developed by Lee and Warner. [6], which has been modified to incorporate directional linear kernels. The image segmentation method has five steps that are edge enhancement, ridge finding, thinning, thresholding, and pruning. The strong point of the linear operators to enhance edge is very clear in the delineation of the acute angled corners of the rectangles. In the ridge finding step, the local highs were explored from the result of edge enhancement because those pixels best represent edges.

Then, the ridge pixels were skeletonized into lines one pixel wide. The thinning procedure was implemented iteratively by erosion from four directions toward target pixel. The thinning process results in skeletonized ridges that have many branches that terminate without forming closed polygons. Those branches were removed because object boundaries can not be defined by them. This process results in only closed polygons. In the next stage threshold method were adapted on the ridge pixels, in order to eliminate spurious edge pixels and to make simpler image segmentation.

Fig. 1 demonstrates the stepwise results in image segments identification. In this result, it is found that the edges keep object edges, but the objects are over segmented. It is because partly objects have spectral variations, and partly objects have geometrically different slopes of facets. For example, image segments numbered 3, 4, 5, 6 in red are belonged to a building. Among the segments, the segments 3, 4, and 5 might be caused by spectral variations of the same facet in a building. However, it can be recognized that the segment 6 belongs to a different slop facet of the same building, and the other segments 1, 2, 7, and 8 are from different objects.

Fig. 1. Image Segmentation to Confirm Different Facets

3) Identifying Intercepts and Regression Coefficients

Fig. 2 shows data clouds for the 8 segments in Fig. 1 for four pairs of band combinations, which are band B&G, B&R, B&I, and R&I. The scatter patterns of segments 3, 4, 5, and 6 are very similar each other, but segments 1, 2, 7, and 8 represent a little different scatter patterns. The data cloud b) and c), which are band combination B&R, and B&I respectively, show clearly the differences between the building segments and the other segments. It is identified in other data clouds, for example segment 8 in the data cloud with bands B&G, and segments 1 and 8 in the data cloud with bands R&I.

Regression method for every pair of bands are implemented on each image segments to find the effect of illumination and different spectral reflectance characteristics of a surface material for different level of illumination. Table 1 represents the result of regression for 6 pairs of band combinations with bands B, G, R, and I. In regression coefficients, the image segments 3, 4, 5, and 6 have relatively similar values each other than the other image segments. The segment 8 has very different regression coefficients from the building segments in all band combinations, which are seriously small except band combination G&I and R&I. Intercepts of the building segments also have relatively similar each other, and show some differences from not building segments.

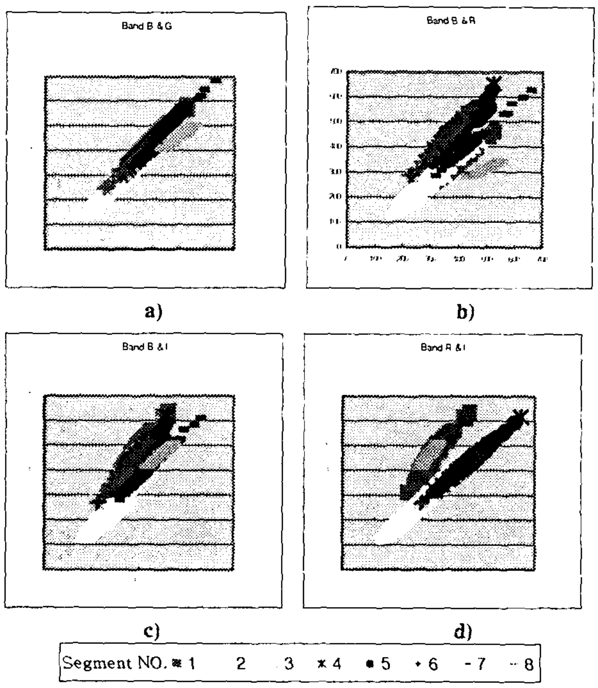


Fig. 2. Data Clouds of Different Facets in a Building and Other Surface Materials

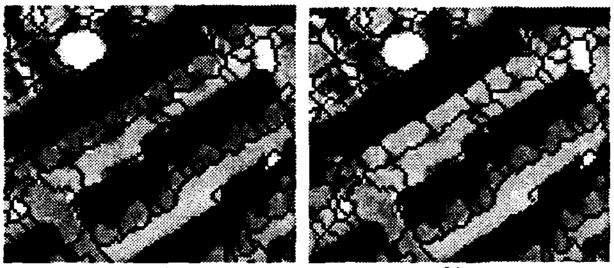
Table 1. Intercepts and Regression Coefficients for the 8 Image Segments in Fig. 1.

	Bands B&G		Bands B&R		Bands B&I	
Segment No	Intercept	Regression coefficient	Intercept	Regression coefficient	Intercept	Regression coefficient
1	-14.4623	1.1403	-16.7044	0.9073	-67.4402	1.3940
2	-10.8794	1.0651	-9.1948	0.9464	-23.2225	0.9578
3	6.2448	1.0552	17.2720	1.1777	19.4245	1.1095
4	1.5024	1.0689	0.8036	1.2192	-0.8927	1.1569
5	-3.6392	1.1125	12.2660	1.1353	10.9108	1.0710
6	7.3907	1.0689	9.7985	1.2106	14.1193	1.1167
7	-4.1509	1.1235	-14.4387	1.0002	-10.3419	0.9730
8	24.9423	0.8713	25.1009	0.5836	21.3471	0.8946

	Bands G&R		Bands G&I		Bands R&I	
Segment No	Intercept	Regression coefficient	Intercept	Regression coefficient	Intercept	Regression coefficient
1	-5.5372	0.7966	-49.9189	1.2229	-38.2718	1.5253
2	2.1544	0.8807	-14.4444	0.9040	-12.7787	1.0060
3	9.0007	1.1194	11.4306	1.0551	2.5899	0.9434
4	-3.7567	1.1477	-5.1380	1.0888	-1.8513	0.9493
5	15.2232	1.0220	14.5072	0.9625	-5.9259	0.9536
6	-0.5128	1.1375	4.3841	1.0498	5.0577	0.9225
7	-13.7754	0.8968	-9.5436	0.8720	4.1231	0.9717
8	7.3478	0.6720	-3.5926	1.0252	-13.3825	1.5211

4) Adjustment of Spectral Information of Different Facets

The spectral information of image segments in the building was adjusted based on the regression parameters of segment 6 because the segment was a facet toward incident sunlight. The sun-slope illumination effects caused by geometric shape of the building were removed by the regression equations of segment 6. The adjustment process is composed of two steps. First, averages of band B for the other slope image segments in the building were calculated and modified every pixel's band B's spectral measurements based on the gaps between the band B's average of segment 6 and each segments. Second, the adjusted band B's values were substitute into the regression equations for band pair B&G, B&R, and B&I to get adjusted band G, R, and I spectral measurement intensities. The original band G, R, and I's spectral measurement values for every pixels were substituted into the adjusted values resulted in the step two. Fig. 3 shows the result of adjustment for the building, which is located in the center of Fig. 3. Fig.3 a) is the image before adjustment, and b) is after adjustment. In a), the different facets of the building express a little different spectral measurements. However, the two different facets of the building recover their spectral homogeneity as shown in b). The method proposed improves the pure spectral information of different facets of a surface material very well.



a) b)

Fig. 3. Image Segmentation to Confirm Different Facets

4. Conclusions

The proposed method to adjust spectral information of different facets in a building was very successful. The different facets in a building recovered their spectral homogeneity. The most important advantage of this method is to keep the intensity of spectral information as well as spectral response, while the other methods only produce spectral response pattern, but not intensity information. This method can also be implemented in an adaptive way. This means the adjustment can be carried out selectively, not non- selective way.

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