Data Fusion Using Image Segmentation in High Spatial Resolution Satellite Imagery

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: This paper describes a data fusion method for high spatial resolution satellite imagery. The pixels located around an object edge have spectral mixing because of the geometric primitive of pixel. The larger a size of pixel is, the wider an area of spectral mixing is. The intensity of pixels adjacent edges were modified by the spectral characteristics of the pixels located inside of objects. The methods developed in this study were tested using IKONOS Multispectral and Pan data of a part of Jeju-shi in Korea. The test application shows that the spectral information of the pixels adjacent edges were improved well.
Keywords: Data Fusion. Spectral Mixing, Moving Window, Image Segmentation.

1. Introduction

Even though changing the spatial resolution improves the size of objects that can be discerned, spectral mixing can not be avoided. Spectral mixing in a pixel occurs when the instantaneous field-of -view falls on a region that includes more than one spectral class [1]. Then, the pixels located on the edges of objects have spectral mixing. Therefore, a finer spatial resolution may change the area of spectral mixing, rather than eliminate the mixed pixels. When data fusion is implemented with different spatial resolution data, it is difficult to avoid the problem of mixed pixels. Especially, when high resolution panchromatic data are fused with low resolution multispectral data, spectral mixing is more problematic because spectral mixing is more about the issue in multispectral data.

There are many approaches for fusing remotely sensed data from different multisensor or multiresolution to integrate them. Arithmetic methods are useful to merge data easily from various sources to varying degrees by using different weights to the different images [2]. High-Pass Filter (HPF) method adapts HPF to high spatial resolution image for emphasizing the high frequency information. The results of HPF are added to low spatial resolution data by different weights. Intensity-Hue-Saturation (IHS) method is popular to fuse different resolution images. This method separates intensity, hue, and saturation of low multispectral data, and the method substitutes intensity information with high spatial resolution panchromatic data [3]. Principal Component Analysis (PCA) method applies very similar concept to the IHS method for its data fusion. The PCA method separates the bands in multispectral image data into components. The first component is then replaced with panchromatic high spatial resolution image data, and inverted to RGB color model [4]. There are other data fusion methods such as wavelet method and Brovey method. However, with these approaches, it is not easy to overcome the spectral mixing in low spatial resolution multispaectral data. This produces fuzzy pixels around edges of objects in an image, and the fuzzy pixels are problematic to analyze the image such as classification.

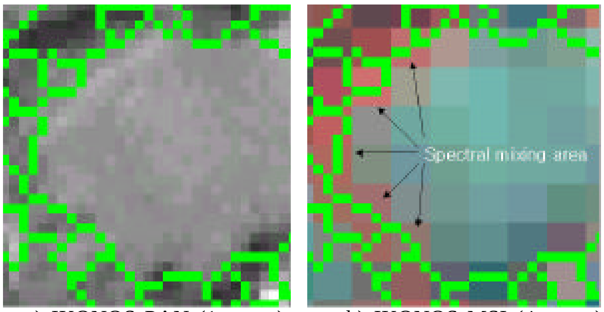
One of the reason for the past difficulties in applying data fusion methods to remotely sensed data is the traditional focus on a single element of the data structure, the individual raster pixel. The focus on the pixel has been driven in part by the very successful use of aspatial statistics to image fusion. With the advent of high spatial resolution, new approaches to data fusion will be required. With high resolution data, individual objects become potentially resolvable into relatively homogeneous spectral pixels. Remotely sensed data fusion could be much more useful if this pure spectral information of objects were used.

This paper investigates that how the spectral mixing in pixels that are adjacent edges of objects is adjusted by the pure spectral information of an object in high spatial resolution data.

2. Methods

It was assumed that each image segment represents relatively pure spectral characteristics. The pixels located around an object edge, however, have spectral mixing because of the geometric primitive of pixel. A larger a size of pixel is, the wider an area of spectral mixing is. It can be assumed that an object is dissolved sufficiently by small pixels, then pixels far from the edges of the object might keep better its pure spectral characteristics than the pixels around edges. This study suggested a data fusion method that adapts the idea previously described. Spectral measurement of pixels adjacent edges were modified by the spectral characteristics of the pixels located inside of objects. The data used are IKONOS panchromatic and multispectral data that have 1 meter and 4 meter spatial resolution respectively. A 1596 by 1572 meter area in Jeju, Korea, was selected for this study. 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.

Fortran programs were used to segment image, to built image segment identifier, and to fuse images. In the first stage of the analysis, the IKONOS panchromatic and multispectral image was geocorrected. Geocorrection was carried out using image to image method. The multispectral images was corrected based on the panchromatic image. Edges were identified using texture. The panchromatic image was used for edge detection with the methods suggested by Lee and Warner [5]. The distinction of the method is to adapt linear shaped operator to enhance edges instead of traditional rectangular shape operator. Experiments with simulated data indicated that multi-directional linear operators identified sharp edges more accurately than square shaped operators. A ridge finding algorithm was used to identify boundaries in the texture data. A thresholding procedure is then applied to suppress ridges of low magnitude relatively. Fig. 1 is a part of the image segmentation result for the study area overlapping on the IKONOS panchromatic and multispectral images. Image segmentation results in the labeling of each pixel according to the spatial grouping into which it falls. This data can be used for additional image processing analysis [6]. In this work, sub-patches are treated conceptually as proto-objects, with spatial topology that goes beyond the traditional pixel-based segmentation



a) IKONOS PAN (1 meter) b) IKONOS MSI (4 meter)

Fig. 1. Part of IKONOS images overlapped by the segment boundaries

Data fusion was implemented to amalgamate the IKONOS panchromatic and multispectral data. DN of each pixel in fused image were determined by an arithmetic technique. Each band's DN of low resolution multispectral image pixel was assumed to be an aggregation of the spectral contributions of member pixels in panchromatic image that correspond to the multispectral pixel. Each pixel's contribution in high resolution data is assumed to be proportional to its intensity.

The result was modified using moving window. In the next step, the algorithm developed by this study finds a pixel adjacent edges. Then moving windows search a window to identify the target pixel simultaneously has the biggest number of pixels in segmentation for all possible windows (Fig. 2).

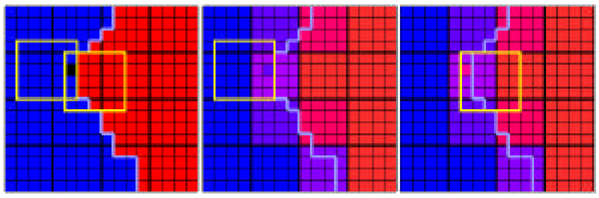


Fig. 2. Procedure to find moving windows that has the biggest number of pixels in a segmentation.

The size of moving window can be selected by the characteristics of image and a purpose of research. One concern in selecting a size of window is that the window can cover a sufficient area that will represent spectral characteristics of the segment. In this study, the adapted size was 16. Then the DNs of the pixels that belong to the same segmentation with the target pixel are aggregated within the moving window. This procedure was implemented to the panchromatic image and previously fused multispectral data. Then new DN of each pixel for each band was computed using the following equation:

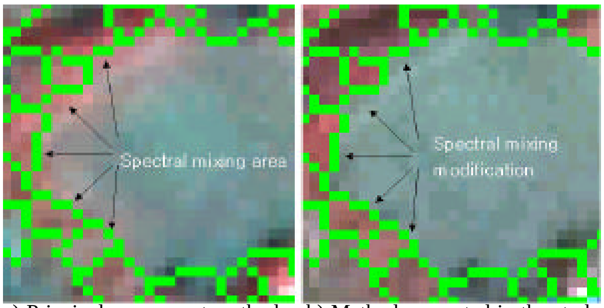
$$SHR(i,j) = PAN(i,j) \times SPAN / SMSI$$

where PAN(i,j) is the DN of target pixel in the panchromatic image, SPAN and SMSI are the summation of DNs that belong to the same segmentation with the target pixel within the biggest moving window, and SHR(i,j) is the modified DN of target pixel for each band. This procedure is applied to all the image.

3. Results

Fig. 1 shows the potential area of spectral mixing. In Fig. 1 b), many pixels are located on edges of segments. If it is assumed that the segments have pure spectral characteristics, the measurements of spectral reflectance from a segment should be the same. The pixels located near to the center of segment in Fig. 1 b) can represent the spectral characteristics of the segment better than the pixels that fall on edges.

Fig. 3 a) shows the result of data fusion with principal component method, and b) represents that with the method suggested by this study. When the spectral reflectance near from the segment is pure, there are some pixels that show spectral mixing in a). It is found that the nearer the pixels are to edges, the more spectral mixing is serious. It is because some of the spectral mixing in low resolution data in Fig. 1 b) is succeeded to the result of data fusion with principal component method in Fig. 3 a). According to Fig. 3 b), spectral mixing in the pixels near to edges was prominently eliminated by the suggested method. The pixels around edges recover their own spectral characteristics, and the segment shows spectral homogeneity for the whole area.



a) Principal component method b) Method suggested in the study

Fig. 3. The comparison of the results of data fusion

Fig. 4 shows data clouds for a segment in the results of data fusion. The symbol '+' represents the data cloud for the result of data fusion without modification. The data cloud spreads widely because the purity of the segment was disturbed by spectral mixing around edges. The symbol 'Δ' is for the modified data cloud with the suggested method. The outliers in the data cloud without modification are diminished considerably. The effects of modification are shown in elliptic circles in the following figure.

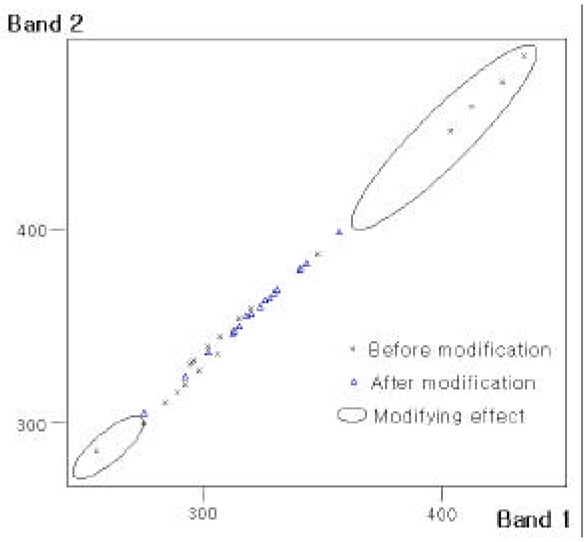


Fig. 4. Comparison of a segment data clouds before and after modification

The modification effect of this method is high for the window that has large variance, whereas the effect is low for the area that has small variance. This means that this method keeps the DNs of homogeneous pixels relatively well than the DNs of heterogeneous pixels. Even though low pass filter is applied to an image, the edges can be kept or sharpened, and the inner area of a segment can be smoothed with this method.

4. Conclusions

This paper describes a data fusion method for high spatial resolution satellite imagery. The methods developed in this study were tested using IKONOS Multispectral and Panchromatic data of a part of Jeju-shi in Korea. The test application shows that the spectral information of the pixels adjacent edges was improved very well. This method shows the potential to smooth images with keeping the sharp edges. The accuracy of image segmentation is crucial in this study because the segment unit mainly controlled modification of spectral mixing. However, there is no satisfactory method. Future work should consider this issue.

Acknowledgement

This Project is funded by the Ministry of Science and Technology.

References

[1] Warner, A. T., and M. Shank, 1997. An Evaluation of the Fuzzy Classification of Multispectral Data Using Artificial Neural Networks, *Photogrammetric Engineering & Remote Sensing*, 63(11): 1285-1294.

[2] Vrabel, J., 1996. Multispectral Imagery Band Sharpening Study, *Photogrammetric Engineering & Remote Sensing*, 62(9): 17-87.

[3] Carper, W. J., T.M. Lillesand, and R. W. Kiefer, 1990. The Use of Intensity-Hue-Saturation Tranformations for Merging SPOT Panchromatic and Multispectral Image Data, *Photogrammetric Engineering & Remote Sensing*, 56(4): 459-467.

[4] Chavez, P.S. Jr., S.C. Sides, and J.A. Anderson, 1991. Comparison of Three Different Methods to Merge Multiresolution and Multispectral Data: Landsat TM and SPOT Panchromatic, *Photogrammetric Engineering & Remote Sensing*, 57(3): 295-303.

[5] Jong Yeol Lee, Timothy Warner 2003. Image Segmentation and Identification of Individual Image Objects in High Spatial Resolution Satellite Imagery, *International Symposium on Spectral Sensing Research 2003,* Santa Barbara, California, USA, 2-6 June.

[6] Woodcock, C. E., and V. J. Harward, 1992. Nested-hierarchical scene models and image segmentation. *International Journal of Remote Sensing of Environment* 13 (16): 3167-3187.