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Evaluation of the Impact of Misregistration Error in Fused Images on the Accuracy of Feature Extraction

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Abstract

Hyperspectral images provide the abundant spectral data from ground surface in hundreds spectral bands, therefore has been considered in various remote sensing applications. The spatial resolution of these sensors is limited. In some of applications like urban feature extraction, in addition to high spectral resolution, also the high spatial resolution is necessary. Here, image fusion techniques are suggested for the enhancing spatial resolution of hyperspectral data. Image registration is one of the most important steps in the fusion process. The main objective in image registration is to bring the target image into alignment with the reference image by applying a set of transformation to the target image. Irrespective of what method of fusion is used, the main challenge in image fusion at pixel level is image registration. In this paper, the effect of misregistration error on the accuracy of road extraction algorithms is investigated. The roads are extracted using an object-oriented fuzzy classification approach. For evaluation misregistration error in accuracy of road extraction, a coarsened spatial resolution hyperspectral data and a multispectral data are generated from an original hyperspectral data. These images are misregistered by 0, 1, 2, 3 pixels in the diagonal direction. Then, the coarsened hyperspectral and shifted multispectral images are fused. After, roads extract through the fused data and the original hyperspectral data. For accuracy assessment of extracted roads, the correctness, completeness and quality indexes are calculated. This study clearly showed that misregistration error has significant effects on the accuracy of feature extraction and we need to achieve sub-pixel values of image registration accuracy to ensure a rational accuracy for road extraction.

Key words: Hyperspectral Image, Image Fusion, Image Registration, Feature Extraction, Object-Oriented Classification

1. Introduction

The attainability of high resolution satellite images such as Quickbird, Geo-Eye1 images, provides an accurate and detail data from ground surfaces. These data can facilitate the information extraction in dense area like urban areas. The road component in an urban environment is one of the most vital geospatial data. Road extraction from high resolution remote sensing images provides the efficient data to integrate in a geographic information system (GIS) for the urban management applications.

The common technique to extract the information from remote sensing images is the classification technique. When high spatial resolution images are used, due to the absence of sufficient spectral information, these techniques are ineffective, because different urban objects may appear in similar color e.g. asphalted roads and roofs or in similar shapes e.g. roofs and small parking lots.

Hyperspectral imagery is used in various science fields such as mineral exploration and military target detection application. In spite of the spectral resolution of hyperspectral image is high, the spatial resolution is low. Due to technical specifications of the sensors, that the spatial and spectral resolutions have trade off, the spatial resolution of hyperspectral images may not be improved when a signal sensor is used.

In the urban feature extraction application, both the high spatial and spectral resolutions are required (Borghys *et al.*, 2007). Here, image fusion methods are proposed for enhancing the spectral resolution of high-resolution multispectral images or improving the spatial resolution of hyperspectral images. Pohl *et al.* stated that the main goal of the image fusion is to replace the missing information in one of the images with the data from another image (Pohl *et al.*, 1998). Image registration is one of the most important steps in the pixel-based fusion process. Hong *et al.* stated essential pre-processing tool in image fusion is image registration and the accuracy's will affect the fusion result (Hong *et al.*, 2005). The purpose of image registration is to arrange the pixels of one image with the other image with applying one or a set of transformation such as affine transform or polynomials. Regardless of what method of fusion is utilized, the main challenge in image fusion is image registration (Jazaeri, 2007).

In this paper, the impact of misregistration error of pixel-based fused image on the accuracy of road extraction is evaluated. An object-oriented fuzzy classification is used for road extraction from fused data.

This paper is organized in 5 sections: section 2 explains the proposed algorithm; section 3 introduces the used data in this paper; section 4 clarifies and illustrates the conducted experiments and reports their results and in section 5 this theme is concluded.

2. Methodology

The general process of the proposed approach is illustrated in Fig. 1. The pre-process of hyperspectral image data is including dimensionality reduction. Afterwards a multispectral data is generated from the original hyperspectral data. Then pixel shifting is done over the generated multispectral data. Afterward spatial resolution of hyperspectral data is coarsened. Next, the shifted multispectral and coarsened hyperspectral images are fused through the multi-scale wavelet transform. An object-oriented fuzzy classification is applied to extract the roads from the fused and original hyperspectral images. Finally, the extracted roads are compared together.

2.1 The Dimensionality Reduction

The computation complexity in further analyses and the correlation between bands increase whenever the number of the bands increases. Therefore, number of bands should be reduced, this is called dimensionality reduction. In this study, bands in the 402-899 nm spectral regions are utilized. Eventually, 106 bands of the ProspecTIR hyperspectral dataset are utilized.

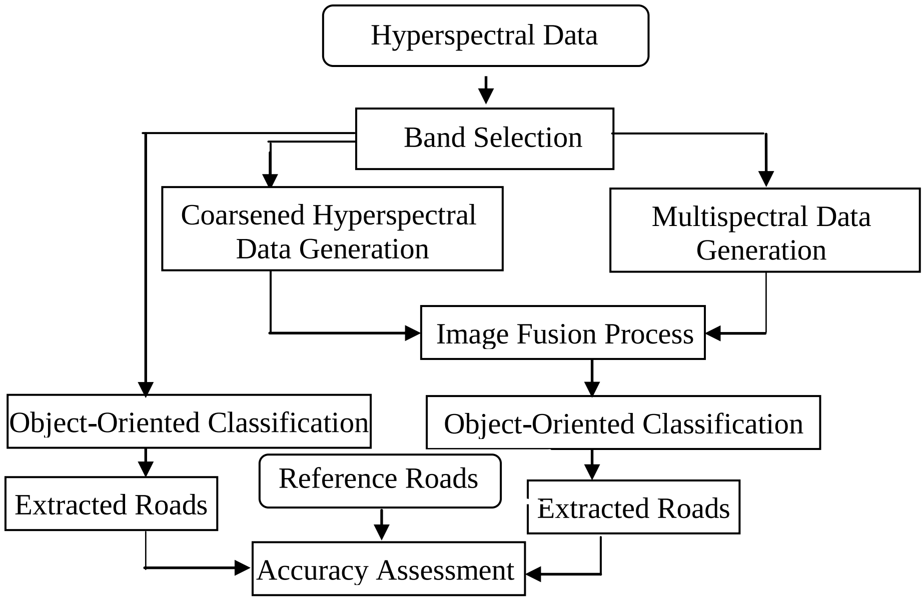


Fig 1: Proposed algorithm.

2.2 The Synthetic Multispectral Data Generation

To evaluate the impact of the misregistration error in image fusion, an error-free registration process is highly desirable. Therefore, we employ a synthetic data that generated from the original hyperspectral data. The benefit of this procedure is that the images are perfectly registered at the start, so that the impacts of any initial misregistration or of other factors like atmospheric effect are eliminated (Townshend *et al.*, 1992). In this study, the synthetic data is generated through the spectral bands averaging of original hyperspectral data. The characteristics of generated multispectral data and respective bands of hyperspectral data that multispectral data has been generated from those have been given in Table 1.

Multispectral Band	Wavelength range (nm)	Hyperspectral Bands
1	402-447	2-12
2	502-534	24-31
3	600-633	45-52
4	681-715	62-69

Table 1. The characteristics of generated multispectral data

2.3 The Spatial Resolution Coarsening of the Hyperspectral Data

The coarsened hyperspectral data are generated by sliding a square window over each band of original hyperspectral data and averaging pixels over it. The size of the window determines the actual size of the coarsened hyperspectral image.

2.4 The Pixel Shifting of the Synthetic Data

Since the two input images of the image fusion, the generated multispectral data and coarsened hyperspectral data, are completely registered, by keeping one of the images stationary and shifting the another image slightly over the other one, we can artificially insert a misalignment error. This work is done by sliding a window that can diagonally slide over the multispectral image. Thus we construct a "shifted" image. We can determine any value for the pixel shifting; therefore we can evaluate the misregistration error based on the arbitrary shift between two input images. In the Fig. 2, a pixel of image is shifted within 0.5 and 1 pixel in a 3×3 image.

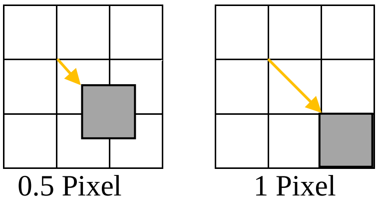


Fig 2: The two cases of pixel shifting

For the any value of the pixel shifting, image resampling is necessary that the image resampling is done by the cubic convolution or bilinear resampling methods.

2.6 The Image Fusion by Multi-Scale wavelet Transform

Image fusion is applied for integration of both the high spatial and spectral resolutions that cannot be provided by a single sensor. Here, the synthetic multispectral data have a higher spatial resolution and coarsened hyperspectral image have higher spectral resolution. Therefore, the fused image has the same spatial and spectral resolution as the original hyperspectral image. In this paper a multi-scale wavelet transform method is used for fusion of coarsened hyperspectral and shifted multispectral data. The multi-scale wavelet image fusion is carried out through the following four steps:

1. Each band of shifted multispectral image is decomposed by the wavelet transform into four components: vertical, horizontal, diagonal and approximation component. The decomposition process continued to specific scale.
2. Each band of the coarsened hyperspectral image is decomposed just like step 1.
3. At the last scale of decomposition, the approximation component of shifted multispectral image is replaced by the approximation component of the coarsened hyperspectral image; every band has to go through this process. Fig. 3 illustrates this process to the second scaling level.

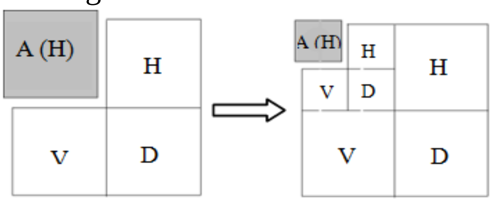


Fig 3: The multiscale wavelet based image fusion process

In Fig. 3, the gray and white squares represent the approximation component of the coarsened hyperspectral image and the detail components of shifted multispectral image, respectively.

4. By using an inverse wavelet transform, we reconstructed the wavelet components of the transformed images to a fused image in multiple levels. For every band, this process is repeated until the first level is reached (Jazaeri, 2007).

2.7 The Road Extraction Procedure

Object-oriented classification is a progressive data classification method that operates based on the objects. This method uses textural, spatial, and spectral information of image. Object-Oriented classification is started with multi-resolution segmentation. Objects provide the possibility of images classification based on the spatial, texture, and spectral properties of features; whereas, this possibility does not exist in pixel based classification (Blaschke et al., 2000). Next a set of spatial, spectral, and a band ratio attributes for each the object are computed. These attributes are presented in Table 2.

TYPE OF ATTRIBUTE	ATTRIBUTE
Spatial	Area, Compact, Convexity, Elongation
Spectral	Max*, Min*, Standard Deviation* * : value of the pixels including the region
Other	Band Ratio

Table 2. The Calculated Attributes for the each object.

In order to assign an object to a special feature, as road, a rule based classification technique is applied. Rule-based classification is an advanced method by which we define features through making rules based on the object's attributes (ENVI, 2004). Rules are made based on human understanding. Fuzzy logic can be applied in classifying an object instead of binary rules classification. The output of each fuzzy rule is a confidence map, where its value represent membership degree of an object to the feature that defined by this rule. In the end, an object is assigned to the special feature that has the maximum value in the confidence map.

2.9 Evaluation Methodology

The output of our proposed algorithm is five sets of roads; roads extracted from original hyperspectral image and roads extracted from the fused shifted multispectral data with coarsened hyperspectral data. The reference data are roads extracted by visual interpretation. For accuracy assessment, the completeness, correctness, and quality indexes are calculated. These indexes are computed as follow (Wiedemann et al., 1998; Koc San et al., 2007):

$$\text{Correctness} = \frac{\text{extracted road matched with reference}}{\text{extracted roads}} \quad (1)$$

$$\text{Compeletness} = \frac{\text{extracted road matched with reference}}{\text{reference roads}} \quad (2)$$

$$\text{Quality} = \frac{\text{extracted road matched with reference}}{\text{extracted roads} + \text{unmatched with reference}} \quad (3)$$

3. Data Used

For the present study, ProspecTIR hyperspectral dataset is utilized. ProspecTIR is an airborne hyperspectral sensor that has 356 contiguous spectral bands each 5 nm wide ranging from 0.4 to 2.5 µm. The field of view of the sensor is 1.31 milliradiance. This sensor acquires data with a spatial resolution of 1 to 5 meters.

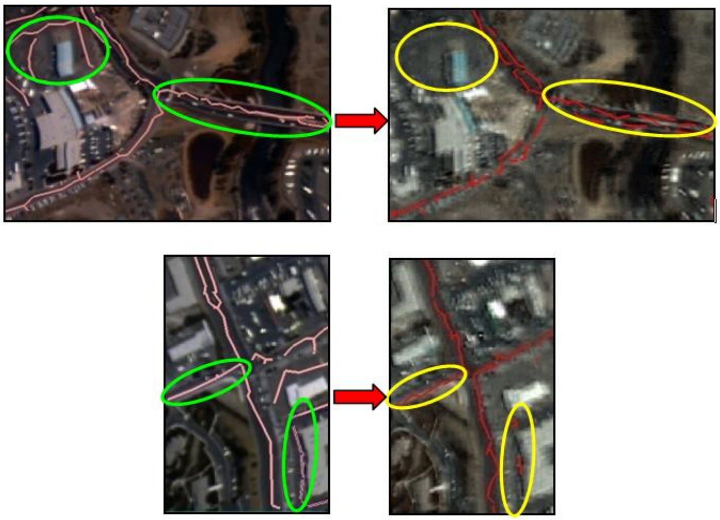
The study area is the central part of the city Reno. Reno is the county seat of Washoe County, Nevada, United States. This data is available in http://www.spectir.com/. Fig.4

shows the RGB composite (B: 12, G: 37, R: 54) of the ProspecTIR dataset of the study area.

4. Result and Quantitative Evaluation

Based on the experimental results, there is a significant deterioration in accuracy of road extraction using the fused shifted multispectral with coarsened hyperspectral data. In the Fig. 5, diminishing the correctness and completeness of the extracted roads through the misregistered fused data by 1 pixels in the diagonal direction is shown.

Fig 4: The study area



(a) (b)

Fig 5: The decline of correctness and completeness value of road extraction from fused data with 1 pixel misregistration error (a: The fused data with 0 pixels misregistration error and b: The fused data with 1 pixels misregistration error).

After comparing reference roads with roads extracted from original hyperspectral data and fused image resulting from shifted multispectral data with 0, 1, 2, 3 pixel misregistration error, the correctness values are 76.09%, 73.27%, 63.75%, 43.32% and 39.86% and completeness values are 70.09%, 68.77%, 60.04%, 42.08% and 37.66%. The correctness and completeness of the extracted roads through the fused data and the original hyperspectral data are shown in Fig. 6 and 7, respectively.

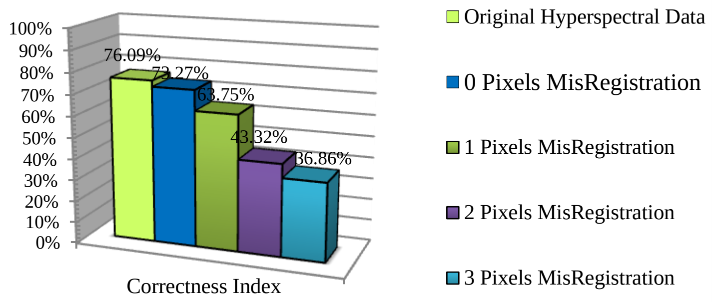


Fig 6: Comparison of the correctness of extracted roads through the original hyperspectral data and the fused data.

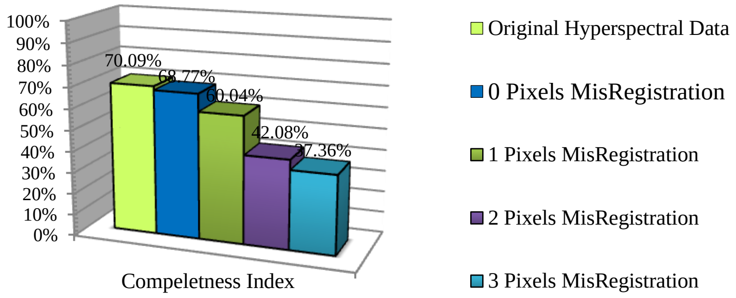


Fig 7: Comparison of the completeness of extracted roads through the original hyperspectral data and the fused data.

The correctness and the completeness values showed a significant decrease, from 73.27% to 36.86% (about 36.41%) and from 68.77% to 37.36% (about 31.41%) with increasing the misregistration error from 0 to 3 pixels.

The correctness and completeness indexes plots display a steep fall value for correctness and completeness values with relatively increase in misregistration error after 1 pixel misregistration.

In additional to, the fused unshifted multispectral with coarsened hyperspectral data haven't significantly different compared to the original hyperspectral data in the feature extraction task, this issue is obvious in the correctness and completeness value of extracted road from these images (see Fig. 6 and 7).

According to the experiments conducted in this study, misregistration has a major impact on the road extraction since narrow wide roads cannot extract correctly and completely within one-pixel and more misregistration error. The results also indicate the need to achieve higher values of image registration accuracy to ensure a rational accuracy for road extraction from remotely sensed imagery. At the end, increasing misregistration error in the fused image for road extraction lead to the extraction of fewer road features and to be worse discriminates between road and non-road features; therefore, non-road features are extracted as roads. Thus, the quality percentage of the extracted roads is reduced. The achieved quality percentage for the roads extracted from the original hyperspectral data and the fused data are compared in Fig. 8.

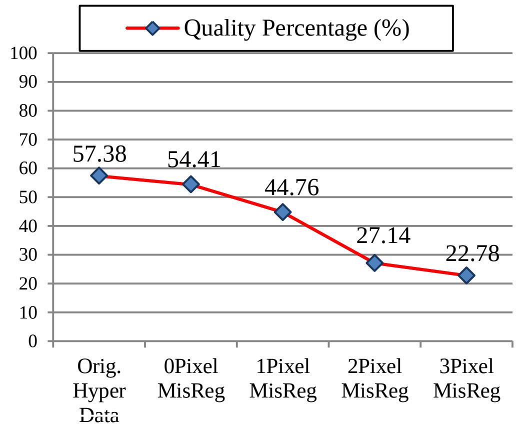


Fig 8: Comparison of quality percentage of extracted roads through the fused data with misregistration error and original hyperspectral images.

5. Conclusions

Due to spectral information defects existed in the high spatial resolution images despite having high spatial characteristic, the image fusion methods have been suggested in literatures for the spectral information increasing of multispectral data. Image registration is most susceptible and time consuming step in image fusion process. In this paper, the effect of misregistration error on the accuracy of road extraction was investigated. According to the experiments conducted in this study, we concluded that the image registration process is determinant step in image fusion process. The comparison of extracted roads through the fused shifted multispectral data with coarsened hyperspectral data with respect to original hyperspectral data indicated that increasing misregistration error in fused images provide extracting less road features and a decrease in discrimination between road and non-road feature.

In the end, the experiment strongly demonstrated that misregistration has significant effects on the accuracy of remotely sensed feature extraction and we need to achieve sub-pixel values of image registration accuracy to ensure a rational accuracy for road extraction.

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References

Blaschke , T., Lang S, Lorup E, Stroble J. (2000). Object-oriented image processing in an integrated GIS/remote sensing environment and perspectives for environmental applications. Computer Science for Environmental Protection ’00, Metropolis Verlag, Marburg, Vol. II, pp. 555-570.

Borghys, D., Shimoni, M., Degueldre, G., Perneel, C.(2007). Improved object recognition by fusion of hyperspectral and sar data. *Proceedings 5th EARSeL Workshop on Imaging Spectroscopy*. Bruges, Belgium.

ENVI, (2004). User Guide. ITT VIS, Colorado, USA.

Hong, G., Zhang, Y.(2005). The image registration technique for high resolution remote sensing image in hilly area. *International Society of Photogrammetry and Remote Sensing Symposium*.

Jazaeri, A. (2007). Enhancing hyperspectral spatial resolution using multispectral image fusion - a wavelet approach. *College of Science* p. 209. Fairfax, VA George Mason University.

Pohl, C., Genderen, V. (1998). Multisensor image fusion in remote sensing: concepts, methods and applications. *International Journal of Remote Sensing*, 19(1), pp. 823-854.

Koc San, D., Turker, M. (2007). Automatic building extraction from high resolution stereo satellite images. *Commission VII ISPRS 2007*, Istanbul, Turkey. http://www.isprs2007ist.itu. edu.tr/39.pdf.

Townshend, J., Justice, C., Gurney, C., McManus. (1992). The impact of misregistration on change detection. IEEE Transactions On Geoscience and Remote Sensing, Vol. 30, No. 5, pp. 1054-1060.

Wiedemann, C., Heipke, C., Mayer, H.(1998). Empirical evaluation of automatic extracted road axes. *Bowyer and P. Phillips, eds, IEEE Computer Society,* Los Alamitos, pp. 172-187.