IMAGE FUSION REMOTE SENSING FOR THE EXTRACTION OF URBAN FEATURES

Ahmad Nadzari b. Yahaya
Jabatan Sains Ukur dan Geomatik
Universiti Teknologi MARA Perlis
02600 Arau, Perlis

ABSTRACT

Rapid advances in computer image analysis have allowed for greater flexibility and the use of techniques for combining and integrating multiresolution and multispectral data. With the multiresolution and multispectral satellites the fusion of image data has become a valuable tool in remote sensing image evaluation. This study evaluated several methods to enhance the spatial resolution of multispectral images using a higher resolution panchromatic image. This was performed using Landsat7 ETM+Multispectral bands and Pancromatic band imagery satellite. The Landsat7 ETM+ panchromatic band is taken simultaneously with multispectral bands using the same system, therefore, are co-registered accurately. The study involved image and theme enhancement by applying Optimum Index Factor(OIF) using three techniques of image fusion : Intensity-Hue-Saturation(IHS), Brovey and Principal Component Analysis(PCA). Brovey was observed to be the best fusion technique for extraction urban features with respect to less spatial and spectral distortion as well as visualization. OIF is a powerful technique for the analysis and visualization of urban features. Based on training samples, ETM+ multispectral and fused images were subjected to the process of Iterative Self-Organizing Data Analysis (ISODATA) techniques using maximum likelihood decision rule to derive the classification of urban features classes. Signature separability using transformed divergence was used to evaluate between signature classes for classification. Ground truth for classification accuracy assessment were evaluated using error matrix and overall classification techniques. This would display the advantages and results of fused images classification.

1.0 INTRODUCTION

1.1 Remote Sensing and Image Fusion

Remote sensing is the observation and establishment of a permanent record of an object without actually touching it. Traditional methods such as terrestrial surveying and aerial photography, generally proved to be more accurate than classified remotely sensed images. However, remotely sensed images makes a more attractive and easier collection of land cover data about urban areas

Image fusion is a tool used to combine multisensor imagery using image processing techniques (Pohl *et al*,1998). The merging of multi sensor image data is becoming a widely used procedure due of the complementary nature of various datasets. Thus, image data obtained from different types of sensors could provide complementary information about a scene. To exploit sophisticated multisource datasets, fusion image techniques are being developed. Fusion images may provide increased interpretation capabilities and more reliable results since it combines data with different characteristics. The aim of fusion images are to integrate different data to obtain more information than can than be derived from each of the single data alone.

The selection of a colour composite of ETM+ multispectral bands in this study are based on the calculation of Optimum Index Figure (OIF). It can be applied because all three bands have the capability of extraction urban landcover . The highest values of OIF shows that the most potential information is contained in that combination. However, it is not always the case, where higher OIF value, may not necessarily mean more information content will be present in that band combination. Therefore the maximum OIF value band combination may not always give the best result. It depends on the purpose because occasionally band combination other than maximum OIF value can serve the purpose better.

The evaluation of fusion images becomes relatively complex due to the different aspects of images acquisition of various sensors that have to be considered as well as the approach of the role of the image fusion itself . An approach is to validate findings from fused image by testing the method on known parameters followed by a comparison with actual data sets. It is necessary to identify a variety of situation, relevant parameters and ground truth. This need more research to provide objective evaluation methods for fused imagery.

There are many decision rules available in remote sensing for classification. However, no classifier is hundred per cent accurate, since many earth surface exhibits similar patterns of reflectance in most commonly utilised wavebands. This results in incorrect assignment of class values in an image leading to an inaccurate classification. There are methods of dealing with the problem of inaccuracy in the classification of image satellite data. This includes accuracy assessment and the combination of external knowledge or ancillary information in the classification.

It is widely acknowledged that remotely sensed images constitute a valuable source of up to date large scale data for use in GIS. Integrating GIS with up-to-date information is useful in the sense of mapping applications. The demand for rapid mapping process is increasing, for example due to intensive urbanization area. Remote sensing can be used for timely and accurate information on current land cover for proper planning management. The function of an information system is to improve the ability to make decision. It enables the monitoring and mapping of urban-rural development, assessment of deforestation extents, evaluation of post-fire vegetation recovery and the revision of topographic maps among numerous other environment assessments.

1.2 Research Objectives

Fusion images should have more information that is useful for human or machine perception. This study aims to bring out maximum information and obtaining information of greater quality about urban features classification . The general method will involve image fusion techniques such as RGB-HIS-RGB, PCA and Brovey transformation. In order to select the best band combination of ETM+ Multispectral bands for extraction information, an OIF analysis were tested. The results of fused images were compared and evaluated using visually comparison techniques for spectral and spatial resolution. By studying the training area based on map interpretation , fused images and spectral analysis, classification for urban features were performed. Signature separability using transformed divergence were used to evaluate signature classes of classification. The study also aims to evaluate classification performance by using an accuracy assessment procedure. Accuracy assessment using an "error matrix" is the standard convention method used to represent classification accuracy.

This study are concerned with landcover of urban features (residential, commercial ,road and water). This study is not to accurately classify the land cover of any region, but to demonstrate the digital techniques and consider its potential as an adaptation of manual classification method.

1.3 Study Area

The study area chosen is between longitude 1° 20'W and 0° 58' W and between latitude N 52° 46' and N52° 32' based on datum of Ordnance Survey Great Britain 1936 - Transverse Mercator projection, approximately an area of 620 sq.km . This locations refer to 1: 50000 Landranger Ordnance Survey Map Great Britain .

This study area has a common and good mix landcover of urban areas , agriculture areas , water bodies and roads. Also it contained high frequency details such as buildings, residentials and commercial/ industrial services that can provides the capabilities of the imaging sensor of Landsat 7 ETM+ to map most of the common urban features classification .

2.0 METHODOLOGY

2.1 Data Used

In this study, the data required includes satellite data and information about urban landcover features. Satellite data are Landsat7 ETM+ PAN (band 8) and multispectral (bands 1 to 5) collected on 12 Mei 2001. The images are already coregistered with Transverse Mercator, Airy Spheroid, Ordnance Survey Great Britain (OSGB) 1936. The images dimension are 878 x 878 pixels. Urban landcover features comprises residentials, commercial buildings (industrial, educational and hospital), water bodies and roads.

The Ordnance Survey map from website of EDINA and 1: 50000 Landranger Ordnance Survey Map Great Britain sheet 129 , 140 and 141) are used as ancillary data which can be used as guide for training samples and accuracy assessment during classification. Table 2.1 show details of the map for this study area. This maps illustrate clearly urban areas including residential and commercial buildings (industrial, educational and hospital), water bodies and roads.

2.2 Software

ERDAS Imagine v 8.5 and ArcGIS v 8.2 are primarily used in this study. ERDAS Imagine is an image processing package which has limited GIS capabilities. ERDAS Imagine are used to process remotely sensed images. ArcMAP component parts of ArcGIS are used to produce land cover map classification of study area.

2.3 Methods

The objective of this study is to obtain information of greater quality and to extract maximum information of urban features from the data sets in such a way to achieve optimal spatial and spectral resolution using fusion techniques.

2.3.1 Optimum Index Analysis (OIF) Analysis

The primary step of remote sensing study is the RGB colour composite and deciding which combination to use for more information in order to interpret the image visually which is not easy and also time consuming. Therefore band combinations can be quantitatively evaluated by OIF. OIF analysis for selection of optimum bands to produced RGB colour combinations of ETM+multispectral data are used to extract optimum spectral features whereas ETM+ Pancromatic data are used to extract the spatial features.

2.3.2 Fusion Techniques

Image fusion can be used as a tool to increase the spatial resolution. Assumption for data fusion enhance the spatial resolution of low resolution multispectral data with the help of high resolution unspectral (panchromatic) data and both datasets must be georeferenced. The Landsat7 ETM+ has an advantage because Panchromatic band is taken simultaneously with multispectral bands using the same sensor system. The problem is virtually no coregistration error and quality fusion imagery data can be produced.

The first image fusion technique is RGB-IHS-RGB. Pohl *et al* (1998) explained that the IHS transformation of Red-Green-Blue(RGB) colour composite fusion involves the transformation of a three band combination of spectral image to intensity, hue and saturation color space image. Intensity (I) refers to the total brightness of the colour, hue (H) to the dominant or average wavelength of the light contributing to the colour and saturation (S) the purity of colour. The IHS transformation separates spatial (I) and spectral (H,S) information from a standard RGB image. The stretched higher spatial resolution image replaces the intensity component image and hue and saturation components are over sampled to higher resolution before the images are re-transformed back to the original space. A main justification used for replacing the intensity component with the stretched higher spatial resolution image is that the two images are approximately equal to each other spectrally.The second technique is PCA. The major goal of Principal Components Merge is to retain the spectral information of the ETM+ bands (1-5). It is assumed that:

- PC-1 contains only overall scene luminance; all interband variation is contained in the other 4 PCs
- The high spatial resolution image is then remapped so that its histogram shape is kept constant, but it is in the same numerical range as PC1. It is then substituted for PC1 and the reverse transform is applied. This remapping is done so that the mathematics of the reverse transform do not distort the thematic information.

Finally, fusion image technique is Brovey transformation. The Brovey Transformation Merge was developed to visually increase contrast in the low and high ends of an image's histogram such as to provide contrast in water and high reflectance areas of urban features. Since the Brovey Transform is intended to produce RGB images, only three bands at a time should be merged from the input multispectral scene, such as bands 3, 4, 5 (multispectral) and band 8 (panchromatic) from a ETM+. The resulting merged image will then be displayed with bands 1, 2, 3 to RGB.

2.3.3 *Spectral Signature Analysis*

In order to determine the relationships between spectral response and characteristics of urban features such as residential areas, commercial building, roads, water bodies and vegetation. Spectral signature analysis for each classes were determined using random pixel sampling in each bands. Spectral signature analyse were used as guide for training sample in classification.

2.3.4 *Image Classification*

Based on the information obtained from fused images, map interpretation, OIF value and spectral signature, ISODATA utility using maximum likelihood classification are carried out for the following images :

The first bands combination ranking of OIF calculation(ETM+ multispectral with bands 3,4,5)
The fused image of IHS transformation
The fused image of PCA transformation
The fused image of Brovey transformation

In this study, an integral type of classification was used, unsupervised and supervised using ISODATA utility in ERDAS Imagine. Supervised classification was preferred due to it's greater accuracy and user input. However it is better to perform an unsupervised classification first. It is because landcover data for this study area difficult to find and therefore need for data for training sample to perform supervised classification. The unsupervised classification is a means to establish classes on the basis of spectral signatures of the data. Once the unsupervised had been run it is then possible to assign landcover types to the resulting classes.

A full evaluation must be considered for the categories used in the classification. For this purpose, classes are reclassified into five (5) categories based on map interpretation, spectral graph and fused images(Table 2.1).

Table 2.1 Categories in the reclassified urban features for accuracies evaluation

Categories of urban feature classes
Residential with low density including road area
Residential with high density including city centre area
Commercial building including educational, industrial, shopping centre, hospital
Water bodies
Vegetation including forest, grassland, agriculture field, bare land

ISODATA utility using ERDAS imagine was used to perform unsupervised classification because it was unclear to choose how many spectral classes would be needed to give an accurate representation of the urban landcover classes within the study area. After signature classes were determined, ISODATA supervised maximum likelihood classification was performed based on training samples to aggregate urban landcover classes (Table 2.1).

Training samples are based on map interpretation, fused image and spectral analysis. Map interpretation refers to The Ordnance Survey map for residential areas, commercial buildings, city centre, roads, water bodies and also includes general features such as park grounds, mixed woods and non-coniferous wood. Urban features such as roads, city centre, residentials and commercial buildings was also recognized based on any or all of the visual elements of tone, shape, size, pattern and association. In the classification, there are various related type of vegetations. But they were merged into only vegetation field since this study do not to identify the type of vegetation.

The resulting signature files were examined using the Transformed Divergence of signature separability to estimate the quality of fused image between the signature classes. According to Jensen(1996), the scale of divergence value can range from 0 to 2000. As a general rule, if the result of a divergence is greater than 1900, this means that the classes are totally separable and if it is between 1700 to 1900, the separation is fairly good. But, if it is below than 1700, the separation is poor and finally if the value is 0, the classes are inseparable.

To evaluate the classification performance, accuracy assessment was created to compare the classified image with reference data(ground information). The simplest solution for accuracy evaluation uses the existing Landranger Map as a ground information. The properties of the existing Landranger map would be kept in mind such as it is not up-to-date and for Landsat7 ETM+, the accuracy of the input data is not well known. The test areas can be either homogeneous test areas selected by interpreter or areas selected randomly. In this study, 20 pixels are selected by interpreter and 50 pixels are selected randomly by ERDAS software.

From the Accuracy Assessment, two kinds of reports were derived. The error matrix simply compares the reference points to the classified points. The accuracy report calculates statistics of the percentages of accuracy such as overall accuracy, based on the results of error matrix.

In this study, classification was attempted not as a tool to evaluate the quality of fusion techniques. However, the training sites are used for the classification of ETM+ multispectral image and are used for fused images. This was done to verify the accuracy classification of fused images.

3.0 RESULTS AND DISCUSSION

As this study aims to evaluate the incorporation fusion techniques in the classification of urban features of remotely sensed images, the results only discuss the above aspect in this chapter.

3.1 OIF Analysis

Although studying the correlation matrix and curve between ETM+ bands can help to know bands correlation coefficient but we cannot obtain a quantitative result to select the best bands combination for information extraction. In order to overcome this problem, OIF was used which provide optimum band selection.

For this study area, the highest OIF value in band combination 3, 4 and 5. These combinations are low correlation to each other as well as high standard deviation within bands. Therefore these combinations can provides the most effective spectral information for information extraction. This technique can help to solve the problem, where three RGB combination are to be more appropriate although the purpose is important. This is a primary step in the selection for the optimum bands combinations in order to obtain maximum extraction of urban features prior to the next step of this study.

3.2 Fusion Techniques

3.2.1 Fusion Techniques On Spectral and Spatial Resolution

The ETM+ multispectral and ETM+ Pancromatic images has no co-registration error and are also taken simultaneously with the same imaging condition such as solar illumination, seasons etc, therefore spectral distortion by image fusion between the two is less significant than in the situation of TM / SPOT Pan fusion(Liu, 2000).

The colour composite of ETM+ (bands 3,4,5) in RGB and ETM+ Pancromatic fusion product for extraction urban features such as urban area(residential, city centre and commercial building), vegetation, water and road. The IHS and PCA fused image introduced spectral distortion in vegetations and urban areas whereas the Brovey does not. The Brovey transform images are stretched finely to archieve the best spectral similarity to the original. The water bodies are spectrally similar to the original and are well defined in the fused images.

Vegetation become brighter in the IHS and Brovey transform fusion images. The intensity replacement and modulation in the IHS and Brovey transforms using ETM+ Pan have boosted the intensity level in these vegetated fields. However the uncontrolled spectral change caused by the fusion process should be eliminated.

The IHS method was most distorted in the spectral characteristics of the data used in this study. The reason is that the intensity image that is replaced by the ETM+ PAN data can be different depending on the ETM+ multispectral band combination. In addition this method has the disadvantage that only three bands can merge at any one time. Therefore its not valid for the assumption that PAN image is similar to density image.

The PCA method also distorted the spectral characteristics of the data but less severe than those in IHS. The reason is the PCA method can merge the ETM+ PAN data with all the ETM+ Multispectral bands at the same timeand also if combination of three bands are used, the resulting first principal component images are more highly correlated to the PAN image than are the intensity images.

Fused images under comparison has resulted in higher recognition and enhance appearance of line features such as roads and pathways. The fused images show more spatial detail than ETM+ multispectral images, benefiting from the 15-m resolution of the ETM+ Pan. With 30m resolution can only show major street in the city but using fused images demonstrate significant improvements in showing all minor street and commercial building clearly. In general, IHS fused image are slightly less sharp than Brovey and PCA fused images

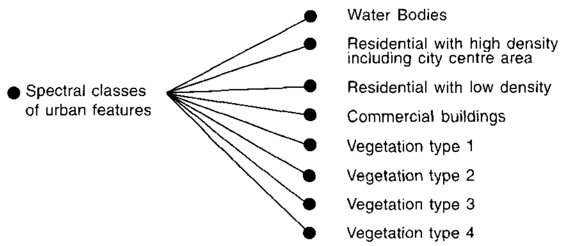
3.3 Spectral Signature Analysis

Here is a hypothetical the ETM+ multispectral satellite might recorded spectral classes of urban features.

The spectral signature graph of water bodies, this graph clearly indicates those water bodies have a low reflectance in bands 4 and 5. As water has almost no reflection in this bands range it is very distinct from other surfaces. Thus water surfaces are clearly delimited as dark areas in images.

Residential areas that can be separated as residential with low density including roads and residential with high density including city centre. Commercial buildings has a higher reflectance in band 3 than residential areas. This makes it possible to distinguish between residential areas. There are differences in bands 4 and 5 to distinguish between residential with low density including road and residential with high density including city centre .

The spectral signature graph for various type of vegetations indicated clearly as type 1 to type 4. Vegetation type 4 identify as mixed wood have quite similar reflectance in bands 3 but higher in band 4 and 5 to distinguish between water bodies. Vegetation has a high reflectance in bands 4 and low reflectance in band 3. The differences of reflectance in bands 3 and 4 is great for vegetation areas and in significant for residential areas. This makes it possible to distinguish vegetation areas and residential areas. This study will merge all type of vegetation as only vegetation for accuracy assessment purposes. The resulting spectral classes of urban features are shown below.



3.4 Classification

ISODATA unsupervised classification is used to derive the urban features classes from ETM+ multispectral and fused images. The algorithm produced 12 signature clusters. After signature classes have been identified, twelve(12) classes of signature classes from ISODATA unsupervised are then reclassified into five categories(Table 3.1) based on training samples and AOI file using supervised classification. These categories are used for evaluation purposes of classification accuracy assessment.

Table 3.1 Categories of urban features for accuracies evaluation

	Categories of urban feature classes
1	Residential with low density including roads area
2	Residential with high density including city centre area
3	Commercial building including educational, industrial, shopping centre, hospital
4	Water bodies
5	Vegetation including forest, grassland, agriculture field, bare land etc

3.4.1 Signature Separability

The classification were checked individually because a pixel might not be properly classified to a class before accuracy assessment are carried out. Signature separability using Transformed Divergence was carried out to create the cell array of each classification (Table 3.2)

Table 3.2 Average separability for supervised maximum likelihood classification of ETM+ and fused images of IHS, Brovey and PCA

Classification	Value of best average separability cellarray
ETM+ (bands 3, 4 and 5)	1983.66
HIS	1982.47
Brovey	1999.97
PCA	1999.99

The classes(or signatures) are probably separated with most of the calculated transformed convergence greater than 1900 with class pair having a divergence between 1700 and 1900 which is still fairly good. The classification has the value of best average separability cell array of 1983.66 and 1982.47 which means that the classes are correctly categorized with a good overall separation.

The signature classes are totally separable as most of the classes have a calculated transformed divergence greater than 1900. It may be inferred from urban areas (residential with high density including city centre, residential with low density including road and commercial building) obtained with brovey and PCA fused techniques possess higher separability than IHS fused and ETM+ multispectral. Water bodies have the highest separability for all images. Vegetations has the least class separability in ETM+ multispectral image, owever this need further study to identify the actual type of vegetations.

The values of best average separability cellarray is quite high, which means that the training sites and the class signature have a good separation. The larger the separability values, the better the final classification will be. It may also infer that PCA and Brovey fused techniques has better classes separability than IHS fused image and ETM+ multispectral.

3.4.2 Accuracy Assessment

Figure 3.1 shows the result of the classification accuracy using ETM+ and fused images of RGB-IHS-RGB, Brovey and PCA.

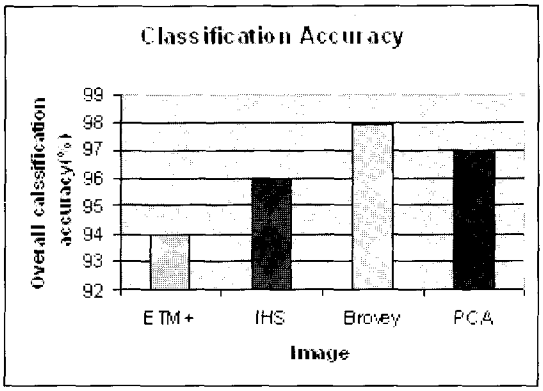


Figure 3.1 : Resulting overall classification accuracy of supervised maximum likelihood classification using ETM+ and fused images of IHS, Brovey and PCA

Water body and vegetation classes were displayed without much misclassification, other categories of classes such as residential with low density including roads, residential with high density including city centre and commercial building were displayed with some amount of misclassification. It is important to realize the difference between "information classes" and "spectral classes". In a remotely sensed image of residential it is likely to be commercial building. Jensen (1996) explained that the categories of interest must be carefully selected and defined to successfully perform digital image classification. Therefore certain classification scheme have been developed so that can readily incorporate land use and /or land cover data obtained by interpreting remotely sensed data such as U.S Geological Survey Land use/Land cover classification system.

The result of the overall accuracy classification of ETM+ multispectral image and fused images are quite high. However, fused images had better overall accuracy classification than ETM+ multispectral image. It should be noted that the level of accuracy sought and obtained in remote sensing projects involving per-pixel classification can be an arbitrary measure dependent on the level of classification employed, the scale of the area considered in the study as well as the spatial resolution of the imagery utilized in the analysis.

4.0 CONCLUSION

This study has demonstrated the potentials of fused images with Landsat7 ETM+ as a tool for improving the interpretability of low resolution images. Also advantages of ETM+ because there is virtually no coregistration error between the multispectral bands and panchromatic band, however it should be noted that atmospheric effects which can obscure the fine detail in image data must be taken into consideration. The accuracy of fused images classification depends on the accuracy of geometry accuracy and also the accuracy of classification.

All the fusion techniques, generated composite images with more detailed information than the original multispectral data; however brovey image is superior. The fused brovey image provide much sharper interpretation of line features such as roads and pathways and also spectrally quite similar to the original data. Fused images also improved the visual interpretation of area features such as water bodies and urban areas of residential with high and low density, city centre, road and commercial building but the efficiency of vegetation extraction and enhancement using fused images need further study. Visual comparison method of the fused images data indicate that the results generated with Brovey method are less spatial and spectral distorted than PCA and IHS methods. Among the three fused techniques, Brovey is found to be the best method for the whole study area than PCA and IHS in terms of spatial and spectral characteristics as well as for visualization.

This study also demonstrated that the OIF is a powerful tool for the selection of optimum bands to produce RGB colour combination of ETM+ Multispectral used to extract optimum spectrales. Signature separability as a quantitative indicator of the quality of the fusion tool has been successfully demonsrated. More study using fused images in classification needed as evaluation for quality of fused techniques. However it may be inferred that fused images can improve classification of urban features.

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