

Land use/ land cover mapping using multi-scale texture processing of high resolution data

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Abstract. Land use/ land cover (LULC) maps are useful for many purposes, and for a long time remote sensing techniques have been used for LULC mapping using different types of data and image processing techniques. In this research, high resolution satellite data from IKONOS was used to perform land use/land cover mapping in Johor Bahru city and adjacent areas (Malaysia). Spatial image processing was carried out using the six texture algorithms (mean, variance, contrast, homogeneity, entropy, and GLDV angular second moment) with five difference window sizes (from 3x3 to 11x11). Three different classifiers i.e. Maximum Likelihood Classifier (MLC), Artificial Neural Network (ANN) and Supported Vector Machine (SVM) were used to classify the texture parameters of different spectral bands individually and all bands together using the same training and validation samples. Results indicated that texture parameters of all bands together generally showed a better performance (overall accuracy=90.10%) for land LULC mapping, however, single spectral band could only achieve an overall accuracy of 72.67%. This research also found an improvement of the overall accuracy (OA) using single-texture multi-scales approach (OA=89.10%) and single-scale multi-textures approach (OA=90.10%) compared with all original bands (OA=84.02%) because of the complementary information from different bands and different texture algorithms. On the other hand, all of the three different classifiers have showed high accuracy when using different texture approaches, but SVM generally showed higher accuracy (90.10%) compared to MLC (89.10%) and ANN (89.67%) especially for the complex classes such as urban and road.

1. Introduction

Land use refers to what people do on the land surface, such as agriculture, commercial, residential development, and transportation (Jensen, 2005), while the land cover is the type of material present on the landscape such as natural vegetation, water bodies, rock/soil, manmade features and others resulting due to land transformation (Jensen, 2005; Roy and Giriraj, 2008). Since the inception of the Earth observation satellites, land use / land cover map produced by remote sensing technique has been serving as valuable resource to support the decisions of the planners, economist, ecologist and decision-maker involved in the process of a sustainable development for the territory (John and Chen, 2003; Mustapha et al., 2010; Malinverni et al., 2011). Image classification for the land use and land cover mapping is also one of the important parts in many remote sensing applications. However, it is not easy to generate a satisfactory result for land use / land cover classification from remotely sensed

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data because of the limitation of data, image processing techniques and complexity of the land use / land cover types. Many factors are to be considered in order to get a good classification accuracy, which are the characteristics of the study area, availability of suitable remotely sensed data and ground reference data, proper use of the variables and the classification algorithms, the producer's experience, and the time constraint (Lu and Weng, 2005).

Landsat images maybe the most common data source for land use / land cover classification because of its long history of space-based data collection at global scale. However, its coarse spatial resolution often cannot meet the specific requirements of the LULC classification, especially the complex urban-rural interface (Jensen and Cowen, 1999). Besides Landsat, high resolution satellite sensors such as IKONOS can provide high resolution imagery with multispectral and panchromatic data for the LULC classification. Spectral, texture, and structural information can be extracted from high resolution images to investigate the characteristic of complex land surfaces and greatly reduce the mixed-pixel problem (Lu and Weng, 2009).

Apart from the spectral data, spatial image processing (texture processing) has greater importance for LULC mapping (Shivashankar and Hiremath, 2011). On the other hand, classification algorithm also plays an important role in the extraction and classification of the satellite imagery data. Traditional per-pixel classification algorithm such as maximum likelihood classifier (MLC) is still usually used due to its simplicity and ability. Besides that, Artificial Neural Networks (ANN) and Support Vector Machine (SVM) also commonly used to improve classification accuracy in contrast to traditional parametric classifier and to minimize classification errors (Florian, 2011; Tso and Mather, 2009). Therefore, the objectives of this paper are to classify land use / land cover information using a high resolution image, to evaluate the performance of different types supervised classifiers (MLC, ANN, SVM) for extracting land use / land cover information, and to investigate the efficiency of different image processing technique (single scale multi textures, single texture multi scales, multi scales multi textures).

2. Study area and Data

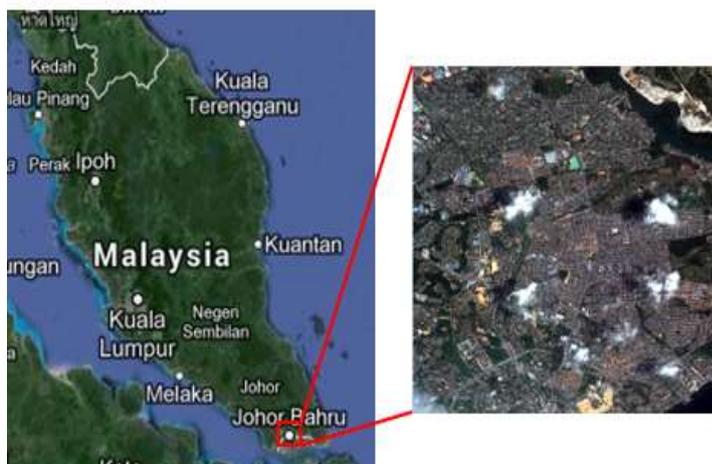


Figure 1. Study Area

The study area (Johor Bahru and adjacent areas) is located in the south of Malaysia Figure 1). It is situated approximately between $1^{\circ}30'55.38''$ N and $1^{\circ}27'50.04''$ N and between $103^{\circ}44'41.79''$ E and $103^{\circ}47'04.88''$ E. The LULC of this study area is changing rapidly due to rapid urbanization. However, the majority of the study area is covered by residential buildings, factories, forest lands, and canals. A high resolution satellite image from the IKONOS satellite was used in this research.

3. Methodology

3.1. Pre-Processing

Geometric and radiometric correction were performed at the initial stage of image processing. However, cloud masking and image subset were also carried out in order to get a cloud free study area for LULC classification.

3.2. Texture Analysis

Texture analysis has been widely used in image classification and image segmentation problems. There were many types of texture algorithms which can be used to improve the image pattern recognition and interpretation. However, only several types of texture measurements such as homogeneity, mean, entropy, and contrast, standard deviation, and GLDV angular second moment were used in this study. Several tests have been carried out among these textual measurements by five different window sizes: 3 x 3, 5 x 5, 7 x 7, 9 x 9 and 11 x 11.

3.3. Image Classification and validation

. In this study, only supervised classification method has been used to classify LULC features from the IKONOS image. Three types of supervised classification were used i.e. i) Maximum likelihood (MLC), ii) Artificial neural network (ANN) and iii) Support vector machine (SVM). All the pixels have been classified without null class and every pixel was assigned to the most probable class at the end of this process. The accuracy assessment also carried out in order to find best classifier and image processing technique for the LULC map. Same training and validation areas were used for all classifiers.

4. Results

4.1. Single-texture and multi-scales approach

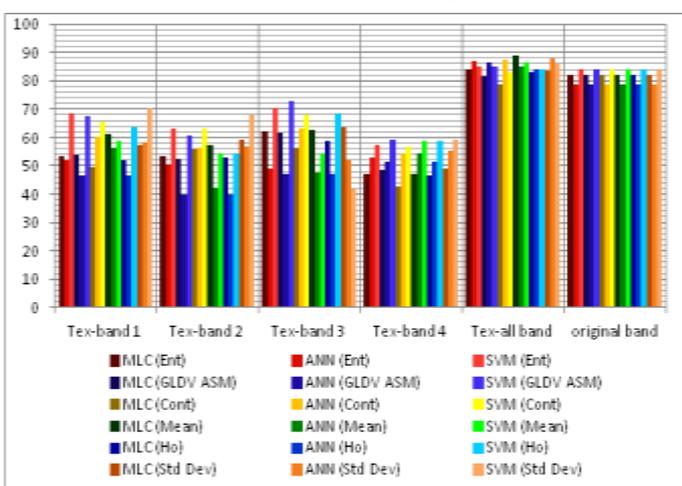


Figure 1. Overall accuracy of combination single-texture with multi-scales (3x3 – 11x11)

performance (OA=72.67%) of the single band and single-texture multi-scales technique for the LULC mapping is fairly low compared to the highest accuracy (OA = 84.02%) obtained using all original image bands. However, classification was improved when all texture parameters were in the classification algorithms and the highest accuracy of 87.93% was obtained. The performance of the three classifiers varied depending on the image processing technique, however, in general, Artificial Neural Network showed the highest improvement among the 3 classifiers using the texture algorithm, but MLC showed the highest overall accuracy using the original band.

In this section, results of LULC mapping using single-texture (all texture individually) and multi-scales (five different window sizes i.e. from 3x3 to 11x11) are presented based on a single image band and all image bands together.

A wide range (ca. 39.54 - 72.67%) (Figure 2) of overall accuracy (OA) was obtained from the single-texture multi-scales technique using only a single band, however, better estimation accuracy (OA ca. 46.52 - 72.67%) was mostly obtained from the single-texture multi-scales images of band-1(blue) and band-3 (red) using all texture algorithms except for the Std Dev where better performance (OA) was found from band-1 (blue) and band-2(green). The

4.2. Single-scale and multi-textures approach

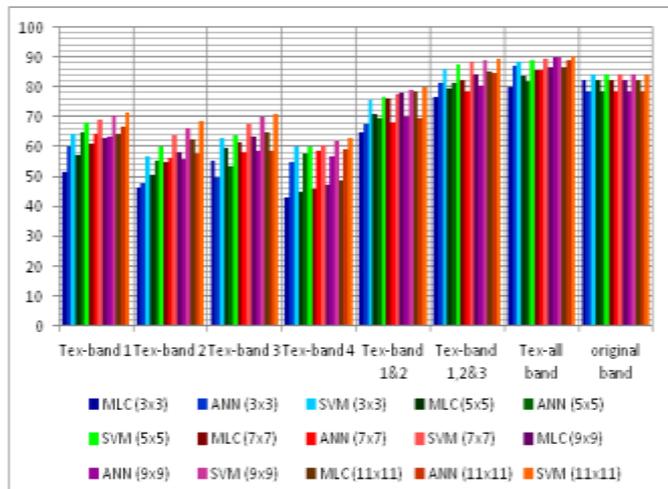


Figure 2. Overall accuracy of combination single-scale with multi-textures (Std Dev, Me, Ent, GLDV ASM, Cont, Ho).

Texture images generated from single window size (i.e. either 3x3 or 5x5 or 7x7 or 9x9 or 11x11) but six different texture algorithms (Std Dev, Me, Ent, GLDV ASM, Cont, and Ho) of each band were used in the land use/ land cover classification. A wide range of overall accuracy (42.73% – 71.29%) (Figure 3) was obtained from the single-scale multi-textures technique using only a single band. The best (OA=71.29%) and the second best (OA=71.04%) results were obtained from the SVM using texture of band-1 (blue band) and band-3 (red band) respectively from window sizes 11x11. The highest obtained accuracy (OA = 71.29%) is low compared to the highest accuracy (OA = 84.02%) obtained using all the original image bands.

However, the classification accuracy improved significantly when texture parameter from all bands were used together in the classification algorithms. The highest accuracies (OA) (Table 1) of 88.28, 88.83, 89.15, 89.67, and 90.1% were obtained from the 3x3, 5x5, 7x7, 9x9, and 11x11 respectively compared to the highest accuracy of 84.02% obtained using all the original bands in the classification algorithms. Supported Vector Machine showed the highest overall accuracy (90.1%) using the window size 11x11.

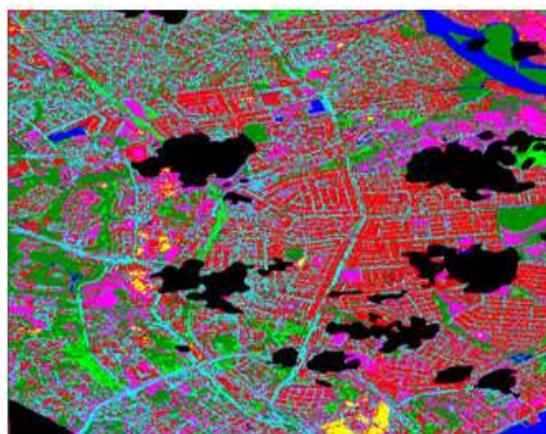


Figure 3. The best land use/ land cover map using single-scale multi-textures image processing technique.

Table 1. Overall accuracy and kappa coefficient of different single-scale multi-textures by using all bands and 3 classifiers (MLC, ANN, SVM).

| | Overall Accuracy (OA) | | | Kappa Coefficient (KC) | | |
|----------------|-----------------------|-------|-------|------------------------|------|------|
| | MLC | ANN | SVM | MLC | ANN | SVM |
| 3x3 | 80.02 | 87.13 | 88.28 | 0.76 | 0.84 | 0.86 |
| 5x5 | 83.48 | 81.67 | 88.83 | 0.80 | 0.78 | 0.86 |
| 7x7 | 85.38 | 85.41 | 89.15 | 0.82 | 0.82 | 0.87 |
| 9x9 | 86.63 | 89.66 | 89.60 | 0.83 | 0.87 | 0.87 |
| 11x11 | 86.44 | 88.91 | 90.1 | 0.83 | 0.86 | 0.88 |
| Original Bands | 82.11 | 78.57 | 84.02 | 0.79 | 0.75 | 0.81 |

The best land use/ land cover map (Figure 4) was obtained from single scale (11x11) with multi textures using Support Vector Machine from the all bands with all the texture algorithms (Std Dev, Me, Ent, GLDV ASM, Cont, Ho). In this LULC map, some land use/ land cover classes such as forest, water, bare land, clear cut, and polluted land were classified with validation accuracy more than 90%, while the validation accuracy for the other land use/ land cover classes varied from 76% - 84%.

4.3. Multi-scales and multi-textures approach

Texture processing was carried out for all bands of IKONOS data using multi window size (3x3, 5x5, 7x7, 9x9, and 11x11) with six different texture algorithms (Std Dev, Me, Ent, GLDV ASM, Cont, Ho). The classification was carried out based on single image band and all image bands. The best result (OA = 72.37%) from single band using multi-scales and multi-textures technique was lower than the highest accuracy (OA = 84.02%) from original band. But significant improvement of overall accuracy (OA = 89.80%) was obtained for land use/ land cover mapping using texture parameters from all bands together (Table 2).

Table 2. Overall accuracy and kappa coefficient of multi-scales multi-textures technique using all bands and 3 classifiers (MLC, ANN, SVM).

| | Overall Accuracy (OA) | | | Kappa Coefficient (KC) | | |
|----------------|-----------------------|-------|-------|------------------------|------|------|
| | MLC | ANN | SVM | MLC | ANN | SVM |
| All band | 85.94 | 88.68 | 89.80 | 0.83 | 0.86 | 0.87 |
| Original Bands | 82.11 | 78.57 | 84.02 | 0.79 | 0.75 | 0.81 |

SVM showed the highest accuracy (89.80%) compared to all the other classifiers (MLC and ANN). The improvement of classification accuracies of 3.83%, 10.12%, 5.78% were observed from the MLC, ANN and SVM respectively compared to the overall accuracy (Table 2) obtained using all original bands. Artificial Neural Network showed the highest improvement. Although the highest accuracy (89.80%) obtained using this image processing better than the accuracy (OA= 87.93) using single-texture and multi-scales approach (section 4.1.), however, it is lower than the accuracy (OA=90.1) obtained from the single-scale and the multi-textures approach (section 4.2).

5. Discussion and conclusion

Land use/ land cover mapping is important in town planning, environment study and resource management. High resolution satellite data has an advantage in providing a high accuracy image in land use/ land cover mapping but needs spatial data processing techniques and robust algorithms in order to get higher accuracy for land use/land cover mapping. This research found that texture processing has the potential for the improvement of the classification accuracy although it depends on the selection of the texture algorithm, window sizes and the classification algorithms. Overall, the accuracy of the LULC mapping was improved using all the texture processing approaches compared to the accuracy of using original data. In this research, 6.5% improvement of classification accuracy was achieved using a combination of texture parameters compared to the original data. This improvement is in agreement with previous studies (Lillesand and Kiefer, 2000; Franklin et al., 2001) who found significant improvement in classification accuracy using texture features as additional inputs to the classifier. However, among the three texture processing approaches, single-scale and multi-texture approach provided the highest accuracy (91.10%). However, multi-scales multi-textures cannot provide higher accuracy compared to the single-scale and multi-texture approach although all the texture images have been used in the classification algorithms, probably due to redundancy of information. The improvement of accuracy using single-scale and multi-texture approach is in agreement with the studies who found that the accuracy of the classification can be improved using multi-texture algorithms due to complementary textural information of multi-texture algorithms that help in discriminating between different features (Coburn and Robert, 2010). Moreover, our finding of inability of improving the classification accuracy using multi-scales multi-textures approach agrees with previous study (Fabrio et al. 2009) who stated that a large input texture data rarely yields high classification accuracies due to information redundancy. In this research, performances of three classifiers (MLC, ANN, and SVM) have been compared, and found that SVM superseded the performance of the other two other classifiers probably due to efficient algorithm for this specific LULC types.

Acknowledgement

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