Roof Material Detection Based on Object-Based Approach Using WorldView-2 Satellite Imagery

Ebrahim Taherzadeh, Helmi Z. M. Shafri, Kaveh Shahi

Abstract**—**One of the most important tasks in urban remote sensing is the detection of impervious surfaces (IS), such as roofs and roads. However, detection of IS in heterogeneous areas still remains one of the most challenging tasks. In this study, detection of concrete roof using an object-based approach was proposed. A new rule-based classification was developed to detect concrete roof tile. This proposed rule-based classification was applied to WorldView-2 image and results showed that the proposed rule has good potential to predict concrete roof material from WorldView-2 images, with 85% accuracy.

Keywords**—**Urban remote sensing, impervious surface, Object-Based, Roof Material, Concrete tile, WorldView-2.

I. Introduction

URBAN areas have grown rapidly over the past few years. Nonetheless, cities only occupy a small portion of the earth's land surface, as in [1]. Urban areas are composed by large numbers of natural surface materials that affect energy and climate [2], [3], as well as ecological [4], [5] conditions. Impervious surface (IS), such as roof material is one of the most important land cover types that can affect runoff quality and land surface temperature [6], [7]. Several studies have demonstrated that urban heat island (UHI) influence is related to the amount of IS coverage [8], [9].

Detection and assessment of the percentage of IS in the heterogeneous urban areas is one of the challenging and important tasks in urban RS. Given the effect of IS on the environment, attention given to this field of study has significantly increased, as in [10], [11].

Detection of roof material and conditions of different types of roof is very valuable, and knowledge on the different types of materials can help in certain applications, such as determining run off quality [12], disaster preparedness [13], and UHI assessment [14].

Traditional methods which are based on filed survey are very time consuming and costly, and in some urban areas, data collection is very difficult due to building security. Remote sensing data can play the critical role in providing the information of the spatial distribution of IS in urban areas.

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The rapid growth of cities and the advent of new satellite sensors have led to increasing demands for new methods that can provide up-to-date information about cities because traditional methods are too expensive and time consuming [15].

Very high resolution (VHR) imagery is needed to classify the heterogeneity of urban land cover at the parcel level. In this study, VHR imagery such as Worldview-2 (WV-2) image was used, which, unlike other commercial sensors, contain 8 spectral bands with high spatial resolution (0.5 m pan sharpened).

Some studies have used other VHRs, such as Quickbird or Ikonos; however, these VHRs have certain limitations on spectral resolution, which leads to limitation on built-up and non-built-up to split-up, as in [16]. Several studies have shown that traditional methods, such as maximum likelihood (ML), are insufficient for classifying VHR images [17], [18]. In recent years, pixel-based classification has been considered to be an incompetent method because of spectral similarity and because only spectral information is used using for classifying IS in detail [19]. Therefore, other useful information such as spatial information should be taken into the account [20], [21]. With the aim of extracting and integrating spatial, spectral and textural information, the object-based (OB) approach is used. Studies show the discrimination between different land cover in the urban area is increased with spectral similarity when these types of information are employed [22]-[26]. The OB classification approaches, in general, show better results compared with pixel-based approaches when mapping individual landscape features [27].

The current study aims to detect roof material, especially concrete tile, using WV-2 satellite image. The OB approach was used to eliminate any misclassification caused by spectral similarity and overcome the limitation of spectral information.

II. Method

A. Study Area

The test site chosen was in a part of Kuala Lumpur (KL), which contains a mixture of historical and modern buildings. This area is covered by different type of pervious and impervious surfaces. The study area is surrounded by tall trees and a large number of different roof materials. Thus the Pan-sharpened WV-2 image with a 0.5 meter spatial resolution with 8 spectral bands was used for chosen area.

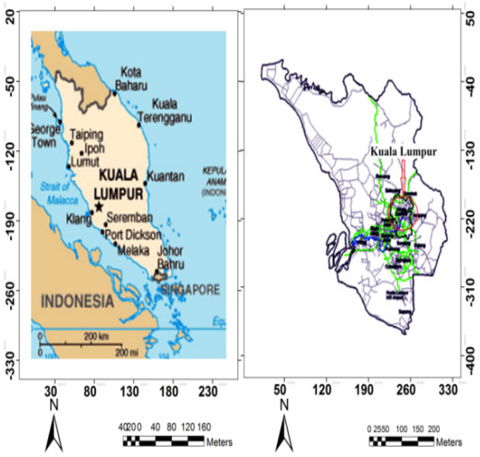

Fig. 1 Map of Kuala Lumpur, Malaysia

B. Data Set and Pre-Processing

In this study the Pan-Sharpened WV-2 images with 8 spectral bands (coastal, blue, green, yellow, red, red edge, NIR1 and NIR2) with 0.5 meter spatial resolution were used as shown in Fig. 2.

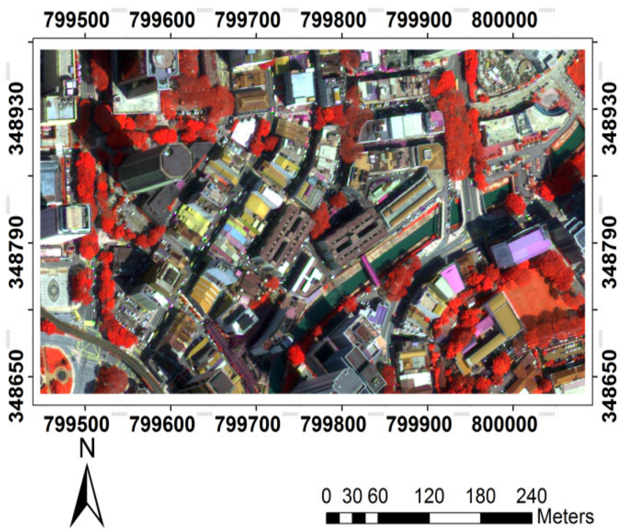

Fig. 2 WV-2 imagery over the Kuala Lumpur (False color)

Geometric correction was done in the UTM projection using zone 47N to correct the inaccuracy between the location coordinate of the picture and the actual location coordinates on the ground.

C. Processing and Rule Set Development

The Spectral information was combined with other source of information in the image, such as spatial and texture information, to get the better results and distinguish between similar urban land cover types to improve the classification. With the advent of a new generation of commercial high-resolution imagery, use of the OB method has been extremely increased, as in [28], [29]. The feature extraction module in the ENVI EX software was used in order to apply the OB approach.

The most important part of the OB classification is segmentation, as in [1]. There are different segmentation methods such as region method, edge and pixel. In this study the edge method was used because it's available on ENVI EX. This method only needs one input parameter and it is very fast. Another optional step is merging, which is used to aggregate small segments within larger segments.

Image segmentation is one of the essential factor for OB because it can convert the classification from pixel to object; therefore, the quality of segmentation determination will be affected the accuracy of the classification, as in [30]. Thus, the segmentation scale must be specified to avoid any kind mixed-object error in the classified image, as in [31]. In this study, scale level and merge level were selected at 30 and 80 respectively as shown in Fig. 3.

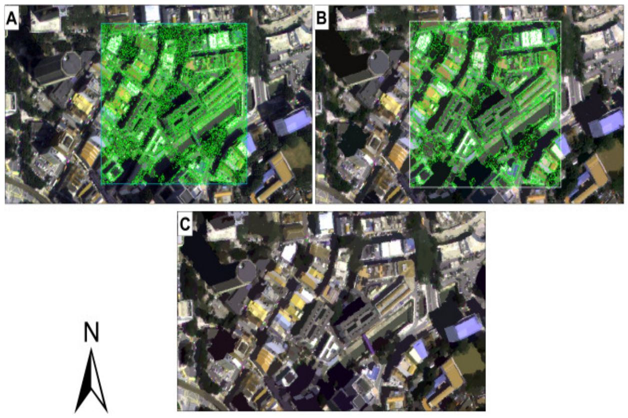

Fig. 3 (A) Segmentation at Scale level 30, (B) Merging at Scale level 80, (C) Result of Merging

In order to define the rule to extract the concrete tile roof, the different attributes (which are related to spectral, spatial, texture and color information) inherent in the WV-2 image should be defined.

D. Computing the Attribute

The benefit of an OO approach is that objects can be depicted with a variety of spatial, spectral, texture and color attributes. In this study, in order to create the certain rule-set to detect the concrete roof tile, these four attributes were calculated to fully utilize the information which inherent in the image. One valuable type of information inherent in the VHR is spatial information. For this purpose, fourteen spatial attributes were extracted from the image. The essential information to classify the RS data is spectral information. Four spectral attributes were extracted for each spectral band of WV-2 image. Four attributes were calculated for each type of remaining information such as texture and color. In this research, 54 attributes were extracted from the WV-2 image.

E. Accuracy Assessment

In order to assess the accuracy of spatial distribution of roof material extracted from the WV-2 image by the OB approach, the training data were collected from the field and allocated to the WV-2 images over the KL study area. A standard confusion matrix was used to evaluate the classification.

III. Results and discussion

In order to detect the concrete tile based on the OB approach, the WV-2 image was used. Different attributes were applied to create the rule-set of OB classification. The result shows that 15 were selected over the 54 attributes: band ratio; average bands 1, 3, 7 and 8; texture range, entropy and mean; maximum value of the pixels comprising the region in band 1, 2, 5 and 6; minimum value of the pixels comprising the region in band 1 and 4, and Majaxislen attribute that can be helpful in discriminating between concrete and other roof materials, Thus, the new rule set was developed to detect the concrete roof tile as shown in table below.

TABLE I
Rule Set Development

If avgband_1 [365.8018, 480.9681] AND bandratio > -0.2665
AND minband_1 < 395.7105 AND maxband_2 < 602.0004
AND tx_mean < 446.9194 AND maxband_1 [310.0321, 569.8611]
AND tx_entropy < 0.1892 AND minband_4 < 514.8199
AND avgband_8 > 273.3808 AND avgband_7 [180.1425, 678.5887]
AND maxband_6 [377.1495, 1015.3998] AND bandratio > -0.2222
AND tx_mean < 400.0000 AND maxband_5 > 187.1194
AND avgband_1 [361.4742, 414.4887]
AND avgband_3 [322.2796, 438.6571]
AND majaxislen > 6.7541, then object belongs to "Concrete_tile ".

The new rule-set was applied on the WV-2 image. Fig. 4 shows the spatial distribution of concrete tile roof in the study area.

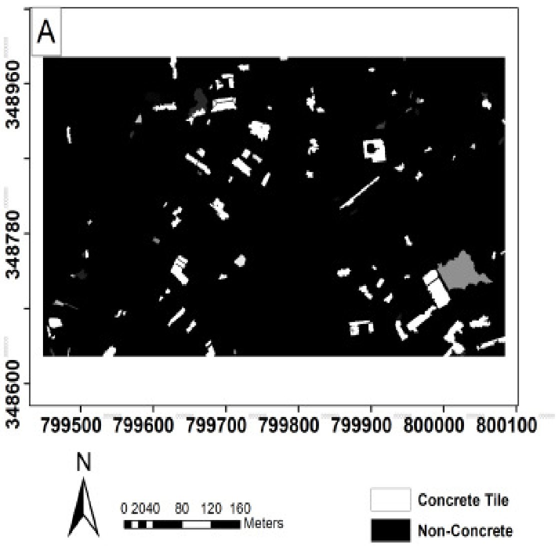

Fig. 4 (A) Spatial Distribution of Roof Materials in KL Image Based on the new rule-set

The results show that 15 out of the 54 attributes were effective in detecting the concrete roof tile which is related to the spectral, spatial, texture and color information. In order to assess the accuracy, ground truth data were collected via in situ observation. The table below illustrates the accuracy of new rule set on concrete tile.

TABLE II
Accuracy Assessment Using Confusion Matrix

	Concrete	Non-Concrete	Total	User's accuracy
Concrete	1068	20	1088	98.16%
Non-Concrete	0	197	197	100%
Total	1068	217	1285	
Producer's accuracy	100%	47.58%		
Overall accuracy	85.3576%		Kappa	0.6625

Finally, the results show that the new rule-set can detect the concrete roof material with an overall accuracy of 85% in KL area with Kappa coefficient of 0.66. Nevertheless, still there is some misclassification due to have a spectral similarity in texture and illumination of the different roof material.

The rule-set illustrates good potential for detecting and discriminating among different roof types and the concrete roof material from WV-2 imagery.

IV. Conclusion

Due to a wide variety of material, urban area is considered as a heterogeneous area. Thus, detection of these materials is one of the important tasks in urban remote sensing. Roof material is an essential factor of IS, which plays important roles in environmental quality.

The main goal of this study is to develop a new concrete tile detecting rule set, using the spectral, spatial, texture and color information which is inherent in high spatial imagery. The training data were collected based on a field survey from the KL area. The OB approach was applied to extract different attributes. There were 15 attributes selected out of 54 based on their spectral, spatial, textural and color information.

The experimental results show that this new rule-set can detect concrete roof material which is widely used in Malaysia. However, there are some limitation on detect the concrete roof tile, which affects the final results such as shadows and other existence errors. Despite this, overall accuracy was 85% and the kappa coefficient was 0.66 which was deemed.

One possible direction in future research is to incorporate other types of data, such as UAV imagery or even LiDAR and Radar datasets. These can be integrated with the data to model different roof materials. In addition this study focuses on extraction of different roof types that are mostly used in Malaysia. Further work is needed to apply and improve the proposed method to extract the difference IS in urban areas such as pavement, road, sidewalk and parking lots.

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