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Road Detection from Satellite Images Using Image Mining

Fereshteh Massoumi[1], Mahdi Afzali[2*]
Islamic Azad university Zanjan Branch
Fereshteh_massoumi@yahoo.com

Abstract:- Roads are the most important part of transportation system. This importance led to many tries to extract road from satellite images and image mining. In this paper, we tried to extract roads in a dense urban area by using of image mining methods. Due to spectral similarity of urban objects in dense areas, there is no assurance to detect the urban objects properly based on spectral information. Therefore in current work, it is aimed to take advantage of two data sets including lidar data and aerial images. The proposed method increased accuracy and pace of road detection and also led to promote the overall accuracy till 95 percent.

Keywords: Image mining, Lidar data, Object base, Road detection.

1. Introduction

Nowadays, lots of data are stored as images. Satellite images are examples of these types of data. Recognition of patterns, independencies of features and detection of objects are role of image mining [1]. Image mining is a technique to explore the direct knowledge of image. It is needed to identify road networks to update the large-scale maps and GPS tools of intelligent emergency vehicles.

For extraction of urban information, satellite images are used by many researchers [2]. Information extraction from satellite images usually was done by manual or semi-automatic methods which are expensive and time consuming. To overcome these limitations, automatic methods of image mining are required. On the other hand, the development of image analyzing technology together with advantages

of computer processing led to development of automatic methods to extract image objects.

Various methods and algorithms for road detection were used by different researchers [3]. Taking risk of road detection in complex urban areas which includes many objects is the main motivation of this research. There are many cities through the developing countries without systematic urban development; therefore designing of a system for information extraction seems to be necessary. In this paper four feature classes are considered: Water, road, building and vegetation.

The paper is organized as follows. The following section gives a background of image mining that our approach is based on it. Section 3 presents proposed method. Finally, some conclusions are given in section 4.

2. Related Works

Many researchers studied road detection on satellite images. Cheng et al. extract road by presenting a road junction extraction method with two stages. First, global detection is performed to find the central positions of the road junction candidates by using morphological operators. Second, the shape of a road junction is identified based on a valley-finding algorithm. The proposed method is validated by airborne synthetic aperture radar (SAR) images of 1 m resolution [4].

Unsalan et al. proposed a novel system, which has three main modules:

- Probabilistic road center detection
- Road shape extraction
- Graph-theory-based road network formation.

These modules may be used sequentially or interchangeably depending on the application at hand. To show the strengths and weaknesses of the proposed system, the authors tested it on several very high resolution satellite image sets [5].

Clode et al, offered a new method for roads in Sydney, Australia, by using lidar data. This method relies on the region growing area and objective classification of the road. The new method has corrected some of the problems that were faced with the previous classification [6].

There is no possibility to compare the obtained result by other works because the inputs of algorithm and methods are different.

3. Image Mining

Image mining discuses about extraction of implicit knowledge from images and implied relations between the objects and their patterns [7]. Image mining systems are designed for special reasons and their goal is information extraction based on operator's demands [8]. This

research has two phases including firstly segmentation of images and, then classification of images in hieratical structure and interpretation of the results.

4. Data and Case Study Area

In this paper we used two group of data set; Lidar data and aerial images. Data obtained from center of San Francisco in 2010 and 2011. In this section we describe the data used in road network detection.

4.1. Pan- Sharped Image

Multi-spectral and panchromatic images of Quick bird obtained by Asturim service in October 2011 with a resolution of 2 m and o.5 m were used through this investigation. By co-registration of these two images, four bands raster file with a resolution of 0.5 m were obtained. Pan- Sharped image of the under study area is shown in Figure 1.

Figure 1: Pan-Sharped of the Case Study Area

4.2. Lidar Data

Lidar is a remote sensing system which determines distance of the target by estimation of the reflection time of emitted laser beam on the target. Also the intensity of reflected light can identify object's ingredients.

Lidar data includes DEM, DSM, and intensity layers. Lidar raster layers are shown in Figure 2.

Figure 2: Lidar Data (Left Image Shows Lidar Height Data and Right Image Shows Lidar Intensity Data)

5. Proposed Method

In this section the different steps of road detection are described as follows:

Step1: Data preparation, in this step Normalize Different Water Index[1] and Normalize Different Vegetation Index [2] are produced from Pan-Sharped image. These features are then calculated by the following equations:

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (1)$$

$$NDWI = \frac{Green - NIR}{Green + NIR} \quad (2)$$

[1] NDWI
[2] NDVI

For detection of vegetation, NDVI raster layer is analyzed and proper threshold is determined. Threshold of shade and water class is calculated by applying a threshold on NDWI layer.

Step2: The second phase consists of image segmentation which isolates main components of the image (pixels) and turns them to the objects based on a certain criteria [6]. Generally there are two ways for image classification; pixel-based and object-based approaches. Pixel based methods analyze only based on the spectral characteristics of the pixels [9]. However, other features such as texture and the geometric characteristics are not considered in this type of analysis. Objects in urban areas are not pure so it causes errors in the final classification results and reduces the classification accuracy [6].

In object-based method pixels are divided into meaningful objects. Segmentation parameters were determined and as a result road detection becomes easier. In one level of segmentation, there are objects with different sizes. So we used objects in different level in hieratical manner. In first level of segmentation, high objects are separated from low objects and road detection is followed in each class separately. In second level of segmentation, objects are classified based on intensity and information of first level.

In addition of spectral features other characteristics such as shape, texture and geometry are considered in Object-based approach which makes this method more useful than pixel-based one [10, 11]. Therefore we used object-base analysis to reach high classification accuracy in urban areas.

Step 3: In third phase segmentation process is done. For this part we need some features to classify objects. Therefore several features are selected for demanded classes.

By using of height feature objects divide into high class and low class. Classification of vegetation and water is performed by NDVI and NDWI. By consideration of road network properties, some features are chosen to determine road classes which are consist of Intensity of LIDAR, length to width of the objects and composition of height and intensity features. Classification is applied in hierarchal manner so features will be inherited from parent class to child class. In this way search domain is limited and the time of process will be reduced.

Step4: Forth phase is followed by formation of hierarchal structure. First of all, parent classes (high class and low class) are identified by thresholding of height. SVM and fuzzy rule based method are performed on data to eliminate weakness of each algorithm.

In the next step fuzzy rule based method is applied on low class. It is worth to mention that

objects in low class have similar geometric and spectral properties.

Fuzzy rule based method benefits some fuzzy functions which are composition of some logical operators like And, or and Not. The least membership function considered equal to 0.2 that means objects with member function lower than 0.2 wouldn't be classified [12].

To solve problem of high dimensional feature space and prevent information loss in feature space reduction, SVM classifier is applied on high class which also increases the speed of process [13].

Step5: In fifth phase high level road class is combined to low level road class. In this way final road class will be introduced by post process. Trees, transmission lines, advertisement billboards, driving boards are removed from road class in post classification step.

Flowchart of the proposed method is offered in Figure 3.

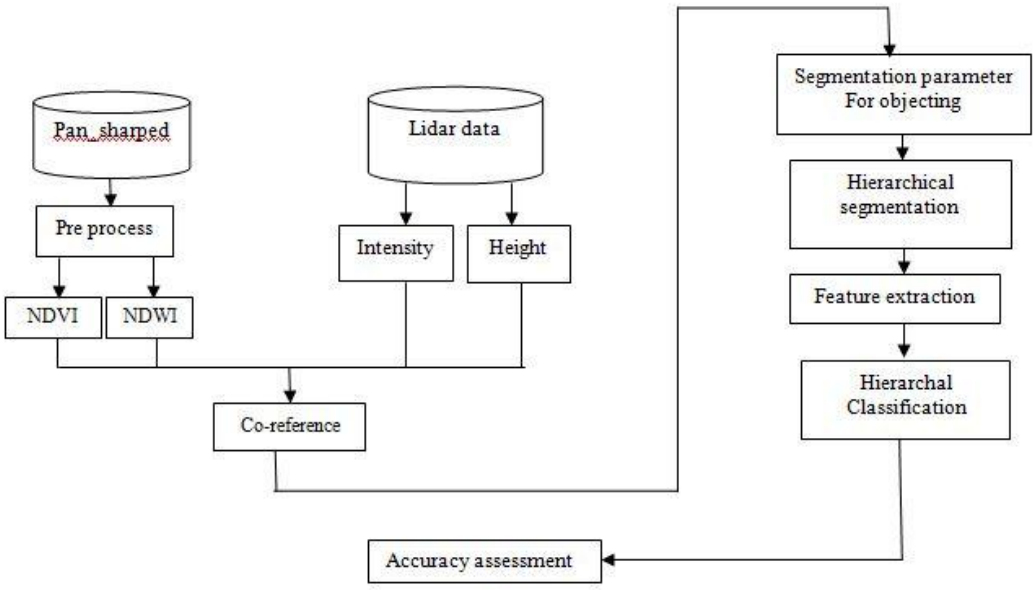

Figure 3: Diagram of Proposed Method

6. Results & Discussion

Table 1 shows classification results. The error matrix is obtained by e-Cognition software. Columns of error matrix indicate real classes and the rows show forecasted classes by classification algorithms.

Figure 5 and Figure 6 presented the user accuracy and producer accuracy for each class, respectively. These figures compare the accuracy of fuzzy rule base, SVM and proposed method. User accuracy indicates reliability to classification algorithm and producer accuracy shows probability of correct classification in its

right class. Kappa coefficient computes classification accuracy in comparison with an accidental classification.

Overlay, the accuracy of road classification is 95% which shows strength of algorithms.

Road detection is performed by SVM and fuzzy rule based classifiers separately. Interpretation of results showed that segmentation and object-based method increase accuracy of classification. So Integration of both classifiers raises accuracy of results.

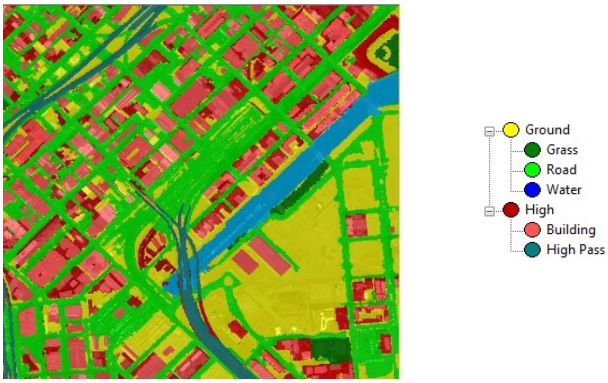

Figure 4: Fuzzy Rule Base Classification Result

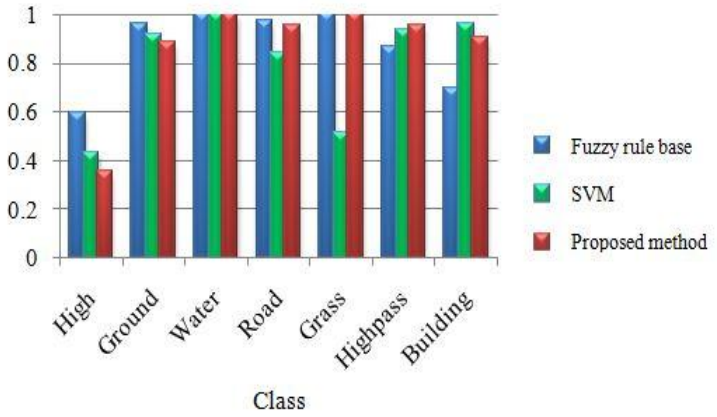

Figure 5: User Accuracy for Each Class

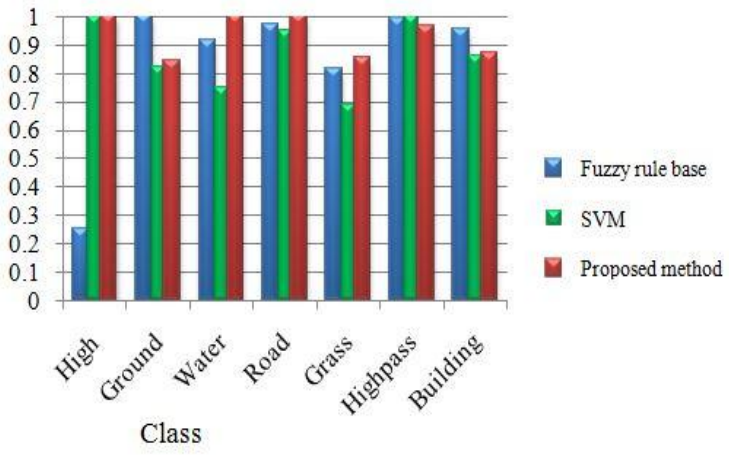

Figure 6: Producer Accuracy for Each Class

7. Advantages of This Research

- Consideration of all urban objects such as parking lots, high level roads, bridges, and waste land, industrial and residential buildings .
- Using of object-based method by considering the geometric and shape features.
- Proposed method is faster than earlier methods (process time of the method is lower than 10 minutes.)
- Road classification in this way is not expensive.
- Automatic classification leads to reduce user's interference.

8. Conclusion

Taking attention of results indicated the important role of LIDAR data in classification of complicated urban areas which helps users in crisis. Feature selection is an essential step in classification and segmentation phase.

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Authors Profile

Fereshteh Massoumi, is a MSC Software computer engineering student of Islamic Azad Zanjan branch. Her research interest is in the image processing that recognize object in satellite image. Additionally she studied road detection for emergency car.

