OBJECT-BASED CLASSIFICATION OF AN URBAN AREA THROUGH A COMBINATION OF AERIAL IMAGE AND AIRBORNE LIDAR DATA

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ABSTRACT

This paper studies the effect of airborne elevation information on the classification of an aerial image in an urban area. In an urban area, it is difficult to classify buildings relying solely on the spectral information obtained from aerial images because urban buildings possess a variety of roof colors. Therefore, combining Lidar data with aerial images overcomes the difficulties encountered with regard to the heterogeneous appearance of buildings. In the first stage of this process, building information is obtained and is extracted using the normalized Digital Surface Model, return information derived from the airborne Lidar data, and vegetation information obtained through pre-classification. In the second stage of this process, the aerial image is segmented into objects. It is then overlaid with building information extracted from the first step in the process. By applying the definite rule to the resulting image, it is possible to determine whether or not the object is a building. In the final stage, the aerial image is classified by using the building object as ancillary data extracted from the prior stage. This classification procedure uses elevation and intensity information obtained from the Lidar data, as well as the red, green, and blue bands obtained from the aerial image. As a result, a method using the combination of an aerial image and the airborne Lidar data shows higher accuracy and improved classification, especially with regard to building objects, than results that rely solely on an aerial image.

KEYWORDS: Object-based classification, Building extraction, Data fusion, Aerial image, Airborne Lidar data

INTRODUCTION

The urban landscape consists of a variety of man-made objects such as buildings, monuments, streets, roadways, and parking lots, and natural features like grasses, trees, and ponds (Bailang *et al.*, 2009). These objects become more complex and various as time goes on. A classification method has generally been used with satellite or aerial images to identify buildings among these objects. An object-based method is more often used in high-resolution images than a pixel-based method because the pixel-based method relies solely on the spectral information of a single pixel, often resulting in a noisy, cluttered classification pattern arising from differentiation of various urban surface materials (Bar and Barnsley, 2000).

However, no single type of data, such as a satellite image, can provide a reliable solution to a complicated mapping task. Misclassification often exists among spectrally similar materials like building roofs and roads.

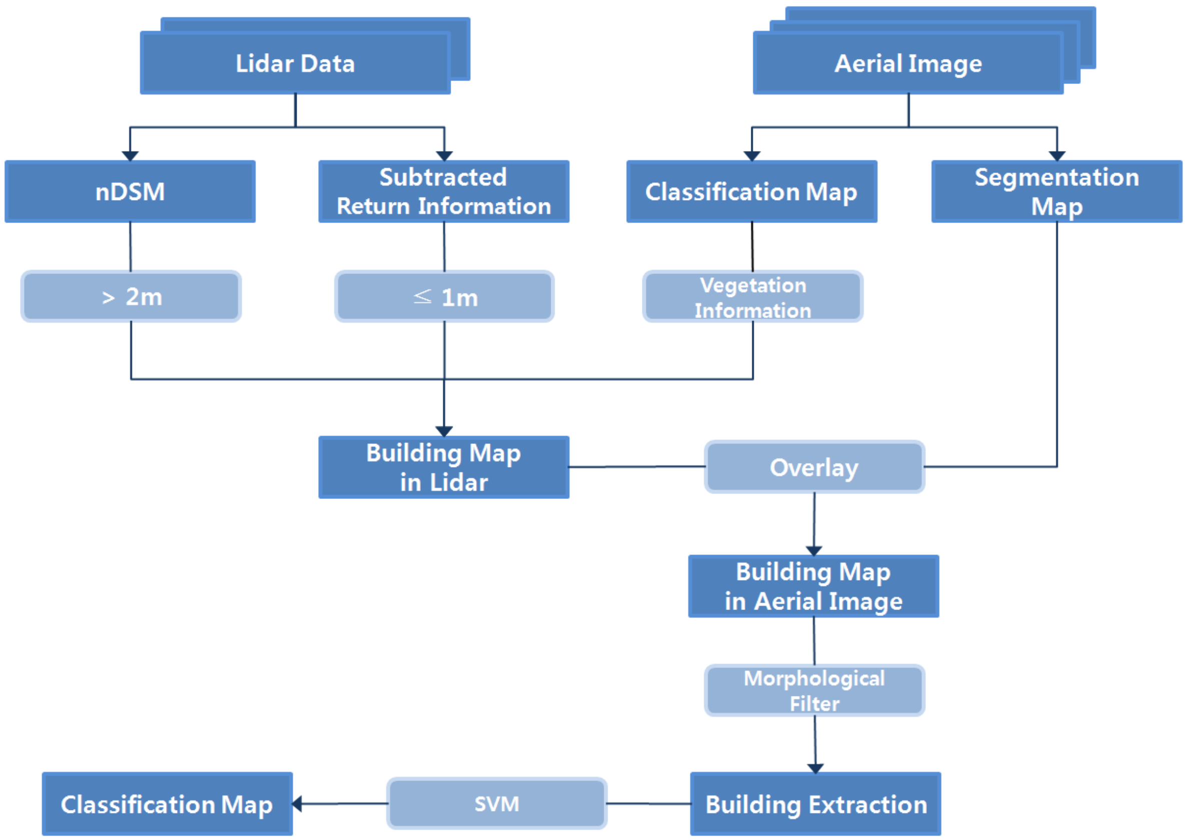

Figure 1. Flowchart for extraction of buildings from an aerial image.

Therefore, inclusion of additional independent information is needed. Combining Lidar (Light Detection and Ranging) data with information from images can be good way of overcoming these difficulties. Lidar is an active remote sensing system, which utilizes a laser beam for detection and measurement to provide three-dimensional information of the earth surface and objects. As a source of superior 3D data, Lidar has wide application in many fields, such as 3D city models, urban planning, design of telecommunication networks, vegetation monitoring and disaster management. The special advantages of capturing 3D urban data using Lidar are high speed, high density, high vertical accuracy, and low cost compared with traditional photogrammetry.

Building detection and reconstruction based on Lidar point cloud data is currently a key research area of Lidar data processing (Zhou *et al.*, 2009). For example, Lidar data has been used in extracting building objects in urban areas. Ekhatari *et al.* (2008) extracted high-elevation Lidar points, and then identified building objects by eliminating the vegetation points using the classification result of an aerial image. Chen *et al.* (2009) conducted hierarchical object-oriented classification (including high buildings, low buildings, and roads) by applying thresholds after generating Normalized Difference Water Index, Spectral Shape Index, Normalized Difference Vegetation Index, and nDSM(DSM-DTM) from a Quickbird image and Lidar data. Lidar data is also used as an additional classification band. Lee and Shan (2003) conducted mapping of a coastal area by utilizing Lidar elevation information as the additional band after transforming to 11 bits. However, use of height information with image information is not necessarily appropriate. It has the drawback that many urban objects have heterogeneous height values at pixel level inside the footprint of each object, such as trees, shrub crowns, and buildings with a non-flat roof (Bailang *et al.*, 2009). This detracts significantly from the accuracy of classification because there are various heights in the same landcover. Therefore, the objective of this work is to increase the accuracy of classification by first deriving building information from Lidar data and using this in extracting building objects from the aerial image. Figure 1 shows the flowchart of this study.

STUDU AREA AND DATA SET

The study area is located in Chon-an, a city in South Korea. It was selected as a suitable urban area having various landcovers and roof colors. In this condition, it is difficult to classify the area with only a single data source such as an aerial image or satellite image. Therefore, an aerial image and airborne Lidar data were simultaneously acquired and used to solve this problem. The two data were registered and resampled to 0.25 m spatial resolution.

METHODOLOGY

Building Information Extraction from Lidar

Building extraction using Lidar data is conducted through the nDSM, return information and pre-classification. nDSM is derived from the first return data and a DEM made through the method proposed by Lee *et al.* (2005). nDSM was used as not only the threshold for extraction of building information but also as an additional band in the process of pre-classification. Subtracted return information in this paper means the difference in height between last return and first return, and provides information about forest and non-forest cover. Pre-classification was used to extract vegetation information, and input bands for classification included intensity and elevation information of Lidar data, in addition to red, green, and blue bands of the aerial image.

In order to extract building objects from Lidar data, three conditions were applied:

- nDSM>2 m
- subtracted return information ≤1 m
- ≠vegetation area.

Generally, buildings are higher than 2 m and have subtracted return information lower than 1 m. Additionally, vegetation areas are removed by using the vegetation class of the pre-classification result.

Segmentation of Aerial Image

A segmented image is used as the medium to transform building objects extracted from the Lidar data to the aerial image. Segmentation is the most important process in this study because its accuracy affects the overall result. In particular, it provides the ability to clearly divide between buildings and non-buildings such as asphalt, bare soil, and grass in the aerial image.

Therefore, we segment the image using a segmentation method suggested by previous research, which consists of a method comprised of automatic seed selection, modified seeded region growing (SRG) and region merging. Initial seed points were extracted through block-based seed selection that uses the obtained multi-spectral edge and multispectral information in a local region. Initial segmentation is achieved by applying the modified SRG procedure, which integrates geometric structural and multispectral information to provide homogenous image regions with accurate and closed boundaries. We obtain the final segmentation result through a region adjacency graph (RAG)-based region-merging process, which merges the initial segments via a homogeneity cost measure that combines regional spectral and texture information.

Temporary Building Extraction Through Overlaying

Segments of the aerial image are determined to be building segments or otherwise after overlaying building objects from the Lidar data on the segmented image. If the area of Lidar building pixels forms more than 50 percent of a segment, the segment is classified as a building object in the aerial image. This process is applied to all segments of the aerial image. This process plays a role in transforming building objects of Lidar data to ones of the aerial image.

Application of Morphological Filter and Removal of Small Objects

This step involves post-processing using morphological filtering and filling the boundaries made during the segmentation process. A closing method is used in this step, and kernel size is 3×3. Although boundaries are filled after this filtering, there are still several non-building objects having small areas that were not removed in the previous steps. Therefore, we eliminated the objects that have areas smaller than 10 m^2 to minimize the errors in the aerial image. After this process, building objects are finally extracted as building shapes in the aerial image.

Classification of Aerial Image

In the last step, the aerial image is classified using an SVM (Support Vector Machine). The SVM is an appropriate method of high-resolution multispectral image classification because it works well with small training data sets. It is also robust to the overfitting problem as it relies on margin maximization rather than finding a decision boundary directly from the training samples (Osuna *et al.,* 1997). Generally, most of the dividing boundaries between classes have non-linear decision surfaces.

The point of this step is to conduct the SVM on the non-building areas of the aerial image. That is, building objects are classified to the building class without the process of classification at this step. The bands used for classification are the red, green, and blue bands of the aerial image and intensity and elevation information from the Lidar data.

RESULTS AND DISCUSSION

The proposed method was applied to the aerial image and Lidar data that were acquired at the same time. Figure 2 shows the results of each step. Figure 2(a) is the aerial image of the study area, which shows many buildings having various roof colors. Figure 2(b) shows the building objects extracted from Lidar data through three thresholds. Figure 2(c) is the segmented aerial image. Figure 2(d) shows the extracted building objects of the aerial image derived by applying the definite rule after overlaying. There still exist boundaries between objects. Therefore, the closing process and removal of small areas was applied to fill the boundaries and remove some errors (Figure 2(e)). Figure 2(f) shows the final result of classification through the proposed method.

The proposed method extracted well buildings that are higher than 2 m in study area by using an aerial image and Lidar data, and the described classification process. Therefore, buildings with various roof colors were classified into the same class. Also, although it is generally difficult to extract building areas covered by shade, the proposed method extracted these areas well with the use of Lidar data for building extraction. However, some vegetation areas were extracted as building class because they were not classified to vegetation class in the pre-classification step. This problem arose because the aerial image used in this paper does not have the Near Infrared band. If an NIR band is used in this process, the accuracy of the final result may improve, and the pre-classification step may also be skipped by using NDVI.

CONCLUSION

It is generally difficult to classify an object type having different colors into the same class using only optical data such as a satellite or aerial image. This paper proposes a method that solves this problem by combining Lidar data and an aerial image. The method extracts building pixels from Lidar data and then identifies building objects on the aerial image by overlaying the Lidar result to a segmented aerial image through the definite rule. This process plays a role in transforming building objects of Lidar data to ones of the aerial image. Therefore, we were able to classify building objects having various roof colors into the same class with high accuracy.

However, there was a problem in that some vegetation areas were extracted as building areas because of use of limited spectral information in the pre-classification step, even though the intensity and elevation information of the Lidar data were used as additional bands. We suggest that this problem could be solved by using an NIR band, as mentioned above. In the future, we will focus on the extraction of a more accurate DEM and the use of an NIR band within this method.

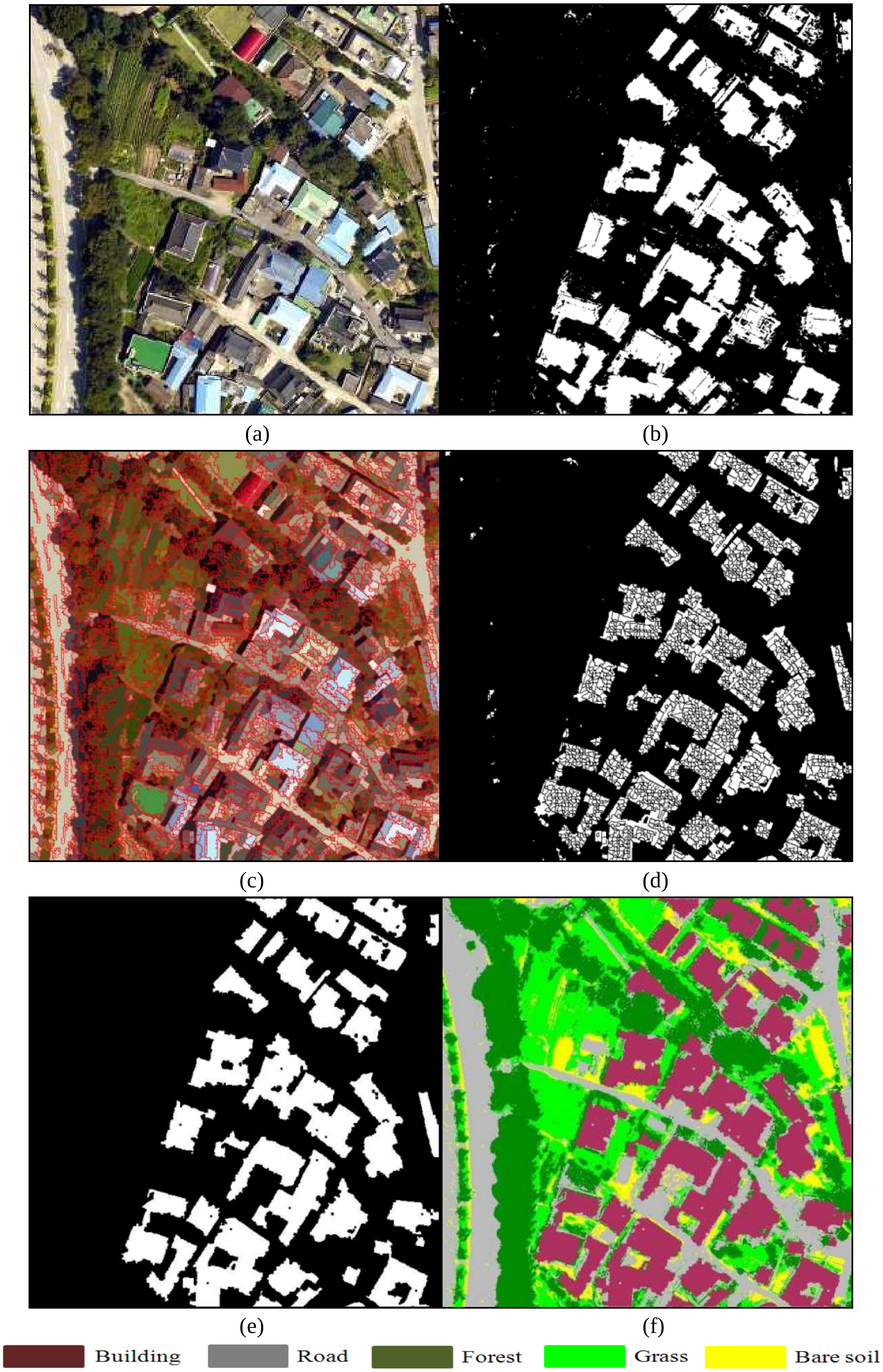

Figure 2. The results of the each step. (a) the aerial image of the study area, (b) the building objects extracted from Lidar data, (c) the segmented aerial image, (d) the extracted building objects after applying the definite rule, (e) the result after the closing process and removal of small areas, (f) the final result of classification through the proposed method.

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