A PRELIMINARY STUDY ON A 3D POINT CLASSIFICATION METHOD FOR THEMATIC MAPPING

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ABSTRACT: This study evaluated the performance of the voxel-based classification method of 3D point cloud to be used for thematic mapping efforts. The features considered in the classification included not only RGB color information stored in individual points but also a geometrical property of 3D point cloud. The classification started with cluster analysis based on RGB color information to obtain N color classes of points. The points belonging to the i-th ($i = 1, 2, \ldots, N$) color class were then spatially partitioned into voxels. Subsequently, for the points of each color class, Principal Component Analysis (PCA) was performed to calculate a geometrical property of inner points at each voxel. By iterating this process for all color classes, the feature vector, which consists of statistics relevant to the geometrical property of each inner color class, was obtained. Finally the voxels were classified based on the feature vector by the level-slice classification method. Preliminary results showed that classification accuracy was improved in comparison with the classification result considering only the RGB color information or the geometrical property. Furthermore, the voxel-based approach was found to be efficient in reducing processing time, compared with point-based classification method.

1. INTRODUCTION

Extraction of thematic information from remotely sensed data is of an important application in the remote sensing domain. Conventional standard methods of thematic mapping have used remotely sensed imagery in conjunction with digital image processing techniques. Recent advances in surveying technology, such as Terrestrial Laser Scanner (TLS), small Unmanned Aerial Vehicle (sUAV), Structure-from-Motion (SfM) and Multi-View Stereo (MVS), have created new opportunities to collect 3D point cloud over a broad spatial scale. Although Digital Terrain Model (DTM) or Digital Surface Model (DSM) has been successfully derived from 3D point cloud, thematic mapping with 3D point cloud is still a challenging problem. The wealth of 3D point cloud cannot be fully realized when thematic information implicit in data is difficult to discern.

Brodu & Lague (2012) proposed a point-based method that classify 3D point cloud by considering a geometrical property called multi-scale dimensionality (MSD). The MSD characterizes the local 3D organization of the point cloud within spheres centered on the measured points and varies from being 1D (points set along a line), 2D (points forming a plane) to the full 3D volume. The scale-dependent variation of cloud geometry, which is measured by varying the diameter of the sphere, can be used as a feature in classification algorithms. Although the MSD approach is considered superior to the others based on RGB imagery or laser reflected intensity, success of the method depends on quality of 3D point cloud itself and a set of training samples. More robust method is expected to be developed.

This study evaluate a simple voxel-based classification method of 3D point cloud, considering not only the RGB color information stored in individual points but also a geometrical property of 3D point cloud. Preliminary results showed that classification accuracy was significantly improved by incorporating RGB color information and a geometrical property of 3D point cloud. Furthermore, the simple voxel-based approach was found to be efficient in reducing processing time in comparison with point-based classification method.

2. METHODOLOGY

2.1 Data

This study was conducted using the 3D point cloud obtained in the campus of the National Institute of Technology, Kisarazu College, located in Chiba Prefecture, Japan (Figure 1). The campus covers the area of a rectangle with the size of approximately 350 * 300 m, which has variation in terrain relief and surface features such as buildings, paved road, vegetation and bare ground. 3D point cloud was derived from a set of digital imagery, which was acquired using commercially-available inexpensive small UAV-based systems, and Structure-from-Motion (SfM) and Multi-View-Stereo (MVS) techniques. A subset of the 3D point cloud, which was corresponding to a rectangular ground coverage of approximately 46 * 36 m, was used for the subsequent analysis.

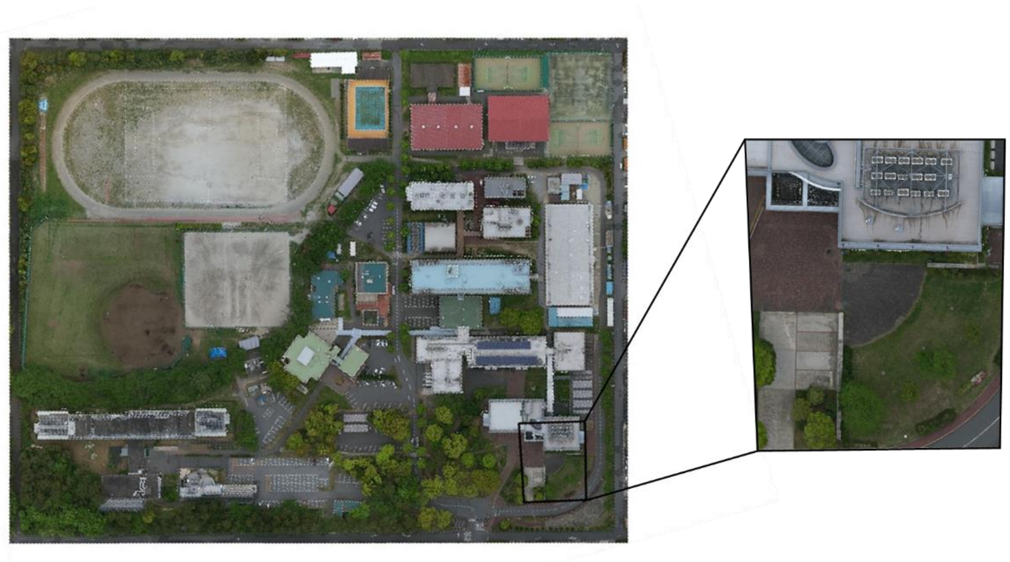

Figure 1. The area where 3D point cloud was obtained. The left image magnified indicates the test area.

2.2 Analysis Procedure

Analysis procedure was largely divided into two steps (Figure 2). The first step was based on cluster analysis using RGB color information of each point in the data. The cluster analysis was made by k-means clustering method, which was employed considering the merit of relatively shorter processing time. After the cluster analysis, 3D point cloud would be classified into 3 classes: Green; Grey; and Others. In the second step, the level-slice classification was performed for each of color classes based on a geometrical property of 3D point cloud.

The second step could be further divided into three sub-steps: (1) spatially dividing the 3D point cloud into a set of voxels; (2) performing the principal component analysis (PCA) on the x, y and z coordinates of the points within each voxel to derive a geometrical property of inner points; and (3) executing the level-slice classification of the point cloud by thresholding the value of geometrical property. After the level-slice classification, each voxel was assigned to one of class labels such as tree crown, grass, building, concrete pavement and brick pavement. These classes were dominant in the test area (Figure 1). When multiple classes were recognized within a voxel, the class comprised of dense points being at higher position was assigned to the voxel.

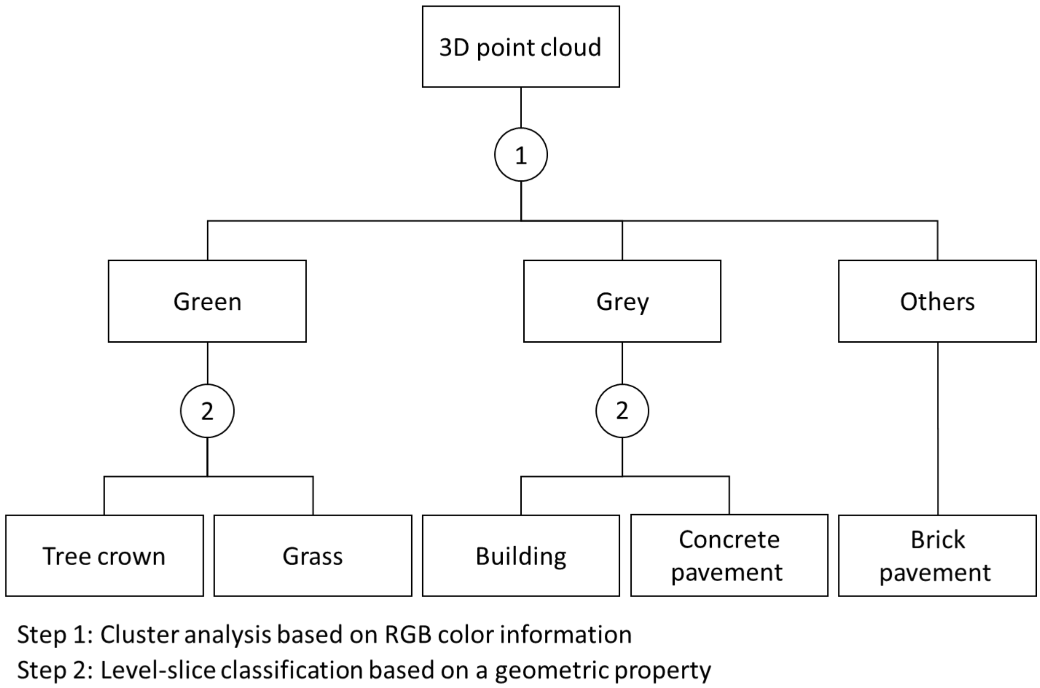

Figure 2. Analysis procedure of 3D point cloud classification. The number in circle indicates the processing steps of 1 and 2.

Although a various methods have been proposed to evaluate a geometric property of 3D point cloud (e.g., Belton & Lichti, 2006; Bremer et al., 2013; Brodu & Lague, 2012; Weinmann et al., 2015), we employed the PCA method in accordance with Brodu & Lague (2012). Here, our calculation was made only in the voxel and at a single scale in order to reduce processing time, while the original version was a point-based method considering multi-scale dimensionality.

In each voxel, eigenvalues for 3 axes were obtained by PCA (Figure 3). When one eigenvalue takes approximately 100% of the total proportion, the inner points were assumed to be forming a 1D object. Meanwhile, if each of two eigenvalues took approximately 50% of the total proportion, the inner points were considered to come from a 2D object. And in the case that the proportions of three eigenvalues showed approximately 33% for each axis, the inner points were regarded to originate from a 3D object.

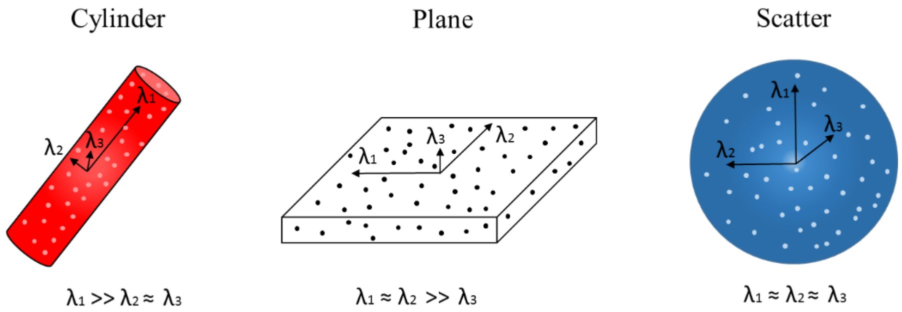

Figure 3. The algorithm to classify 3D point cloud using the proportion of eigenvalues with the PCA

The shape of voxel was defined as the column of which base was the square of 1 * 1 m on a x-y plane (Figure 4). The height of the column was defined by the difference between the maximum and minimum values of z coordinates. For each voxel, the PCA was performed and the proportion of the i-th eigenvalue P_i (i = 1, 2, 3) was calculated as an indicator of a geometrical property of inner points. The classification threshold on a geometrical property, more specifically P_i (i = 1, 2, 3), was adjusted based on trial and error procedures, relying on visual comparison between the result and apriori knowledge on the test area.

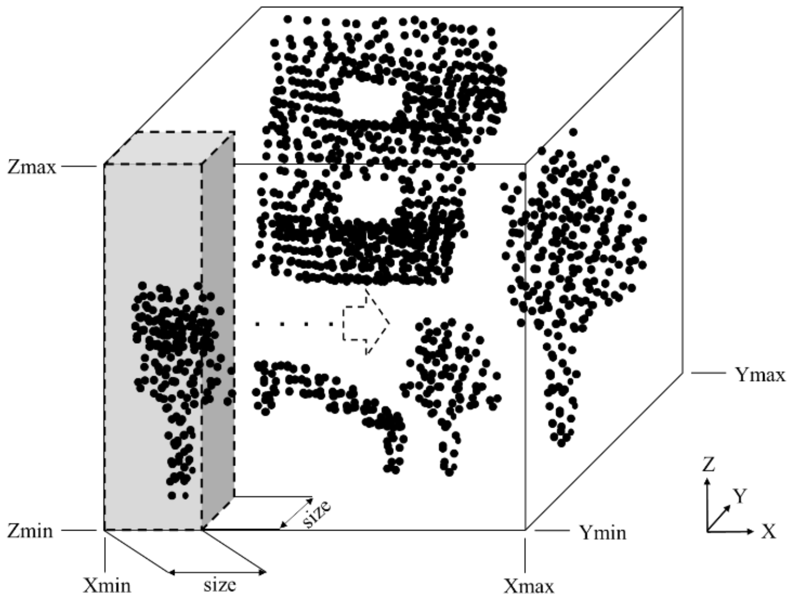

Figure 4. Schematic image of the moving voxel and 3D point cloud in the test area.

3. RESULTS AND DISCUSSION

The cluster analysis based on RGB information was appropriately completed (Figure 5). For the points of each color class, the level-slice classification based on a geometrical property was performed at each voxel. After careful adjustment of the classification threshold, one of the five classes were assigned to the voxels (Figure 6). The degree of conformity between the classification result and reality seems to be improved in comparison with the classification result considering only the RGB color information or the geometrical property. However, accuracy assessment with objective method hasn't yet done. Moreover, there are several concerns to be discussed in the classification method employed in the study.

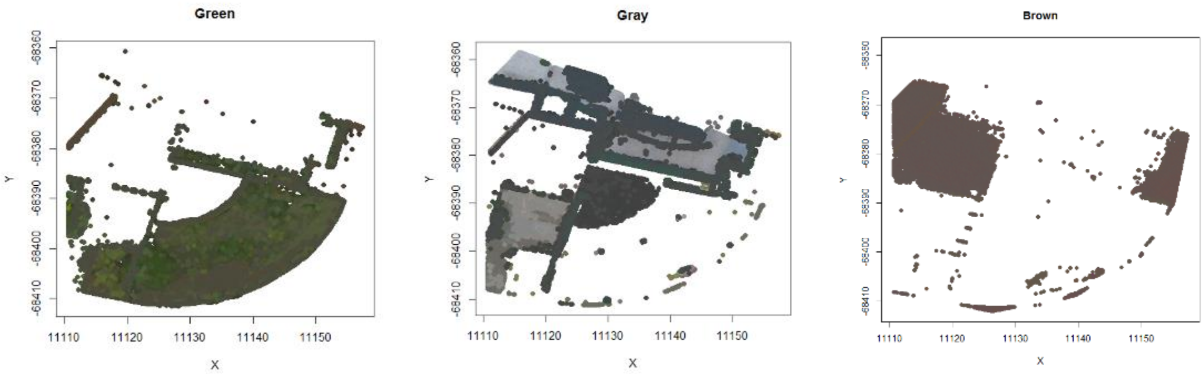

Figure 5. The results of cluster analysis based on RGB color information.

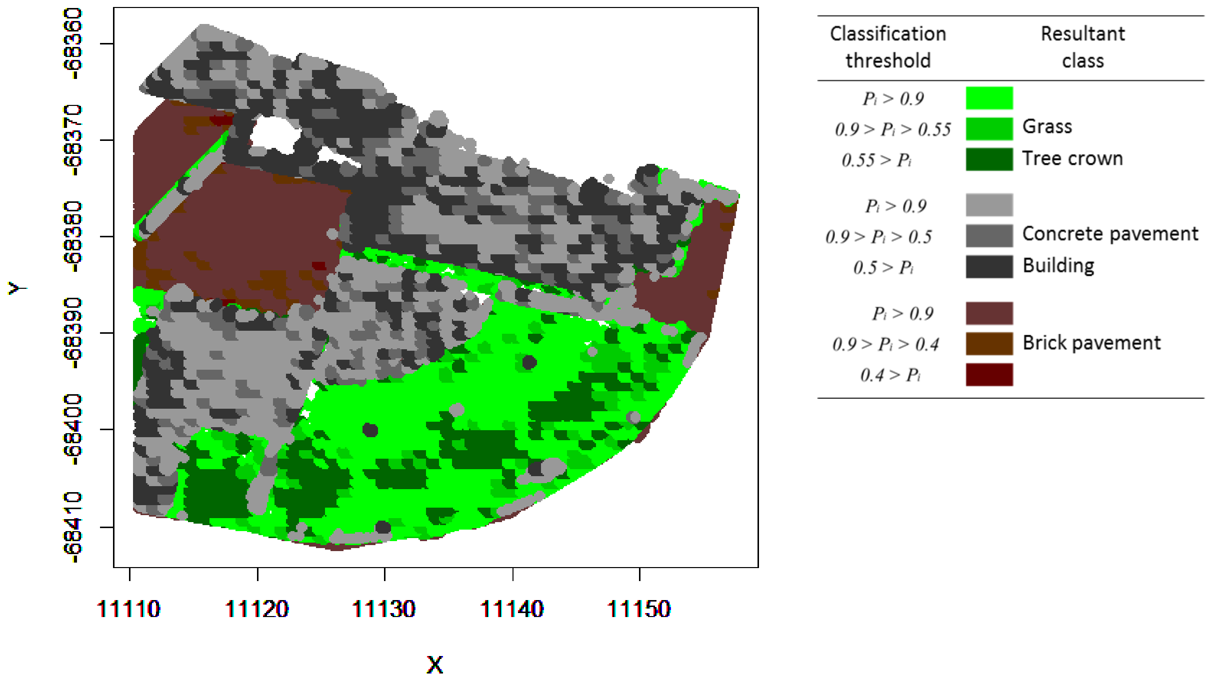

Figure 6. The result of the level-slice classification based on a geometrical property.

4. CONCLUSION

This study evaluated the performance of the voxel-based classification method of 3D point cloud to be used for thematic mapping efforts. The features considered in the classification included not only RGB color information stored in individual points but also a geometrical property of 3D point cloud. Preliminary results showed that classification accuracy was improved in comparison with the classification result considering only the RGB color information or the geometrical property. Furthermore, the voxel-based approach was found to be efficient in reducing processing time, compared with point-based classification method. However, there are several concerns to be discussed in the classification method employed in the study. Future work will be focused on: evaluating the effect of voxel size to the classification accuracy; exploring the objective method to define the classification threshold; employing the objective method to evaluate classification accuracy; and extending the method from unsupervised classification to supervised classification so that the method can be applied to the 3D point cloud obtained for a broader spatial range.

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