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Construction of 3D modeling based on vertical and oblique unmanned aerial vehicle imagery for efficient national park management

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ABSTRACT

In order to efficiently manage large forest areas, a large number of people and budgets are required. Additionally, areas where access is difficult cannot be managed. The management of forest areas using a unmanned aerial vehicle (UAV) has the effect of solving existing limitations. In this study, 3D modeling was carried out on October 22, 2020, using images acquired by UAV for Yongha Campsite located in Wolaksan National park, Chungcheongbukdo province, South Korea. Considering the lack of matching points in image matching due to the nature of forest areas, the ratio of image overlap was set high during UAV flight plan establishment, and vertical and oblique images were acquired by UAV. Afterwards, we validated the usability of the data based on a 3D model.

1. INTRODUCTION

As rapid urbanization progresses from the end of the 20th century, the proportion of green land, which used to be a large part of the country, has reduced to a great extent (Park and Choi 2016). Since the introduction of the Nation Park System in 1967 in Korea, 22 national parks have been designated and managed to preserve the environment, culture, history and heritage. The total area of the national park is 6,726 km, which covers 6.6% of the total area of the South Korea (Kim, 2008). Although the Korean government manages national parks by assigning managers, however, it is difficult to efficiently manage the larger through on-site surveying. This causes serious problems every year, such as economic losses caused by theft of expensive forestry products and damages to the natural environment caused by illegal campers dumping garbage. In addition, the importance of managing and preserving national parks has been emphasized due to the recent increase in the number of campers who enjoy camping.

Currently, various techniques for management of national parks replace the field. Among them, unmanned aerial vehicles(UAV), one of the critical technologies of the fourth industrial revolution are being presented as an advanced method for managing national parks. UAV can quickly acquire high quality data about area of interest. In addition, it is possible to produce orthophoto and digital surface models using images acquired by UAV. Especially, a three-dimensional (3D) model can be built based on images acquired by UAV to be able to manage the national parks by expressing them in realistic.

In this study, we aim to verify usability by constructing a 3D map to efficiently manage the national parks using UAV. To this end, images were acquired by setting the altitude and the ratio of overlap high in consideration of difficulty in extracting matching points of the forest area that have similar features. In addition, vertical and oblique images were obtained by adjusting the camera angle, and the utilization of the 3D models in the forest area was verified after constructing 3D models based on the acquired images.

2. SELECTION OF RESEARCH AREA AND ESTABLISHMENT OF FLIGHT PLAN

The Yongha Campsite in Wolaksan national park located in Chungcheongbukdo province, South Korea was selected as a research area for the construction of 3D models and verification of utilization of forest areas using UAV (Fig. 1).

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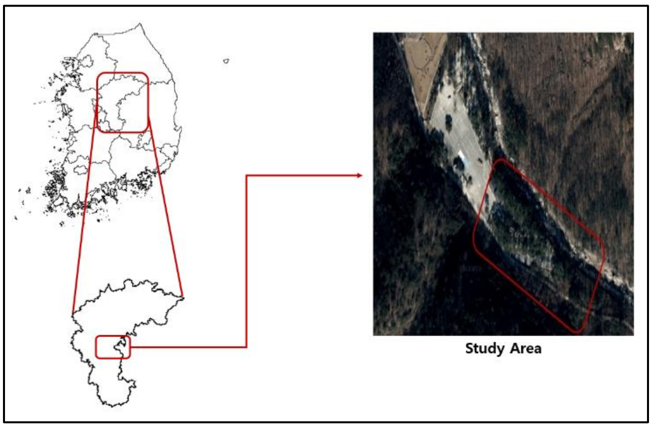


Figure 1. Study Area

The UAV used in this study is Inspire 2 model manufactured by DJI, and the Zenmuse X4S. The-optical sensor was mounted on the UAV platform and the data was acquired around 1 p.m. on October 22, 2020. The detailed specifications are given in Table 1.

Table 1. Specification of UAV and camera used in study

Inspire 2		Zenmuse X4S	
			
Weight	3,440g	Weight	253g
Flight altitude	≤ 2,500m	Resolution	5472 × 3648
Flight time	27min	Sensor	Optical
Speed	≤ 94km/h	Focal Length	8.8mm

For image acquisition, UAV as automatically flown using the Pix4d Capture application, and longitudinal (plan 1) and lateral (plan 2) flight routes were set for each angle to obtain images of the same area. Fig. 2 illustrates the flight route at the time of image acquisition.

Figure 2. Flight route of UAV

3. METHOD

3.1. Data Acquisition

The UAV image were acquired around 1 p.m. at the time of flight, with an altitude of 70 meters and a forward and side overlap of 80%. Both vertical and oblique images were acquired under the same flight conditions. Generally, the side overlap is set around 70~90%, the forward overlap is set as 60%. However, the study area was located in the forest area within the national park, therefore, many feature points of images cannot be matched during the image matching process, which can lead to a problem of reduced accuracy for 3D model. For this reason, to extract more matching points from the images, the flight was carried out by increasing the ratio of image overlap and altitude of UAV. Moreover, oblique images were acquired based on a flight plan 1, and 2 with an angle of 45°. Vertical images were acquired only with a flight plan 1. Fig. 3 shows parts of oblique and vertical images acquired by UAV.

Vertical image **Oblique image**

Figure 3. Vertical images and oblique images acquired by UAV

3.2. Construction of 3D Model

In this study, for constructing 3D models, photoscan software from Agisoft was used. Image processing is performed in the UAV image matching software using Scale-Invariant Feature Transform (SIFT) algorithm. The SIFT method finds features such as building corners or road intersections in the image, and utilizes this information to estimate the position of the image relative to the sturcture from motion (SfM) algorithm to determine the 3D position. The SfM algorithm is a technique that enables the sequential adjustment of the matched images through the SIFT algorithm to restore the target and the photographed location relationship at the same time (Aicardi et al., 2016). After conducting the image matching, a 3D model was constructed using the build tiled model function in photoscan software. This function can visualize 3D models at high resolutions, and build 3D models based on dense clouds or mesh data.

4. RESULTS

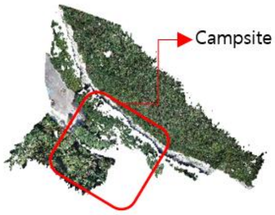
To find models applicable for the efficient national park management, we compared the number of point clouds and dense clouds. In addition, we carried out an analysis comparing visual differences between models. The extracted numbers of point and dense clouds per model are provided in Table 2.

Table 2. Number of point and dense clouds per model

Case	3D model components	Number of point clouds	Number of dense clouds.
A	Longitudinal 90 ° & Lateral 45° & Longitudinal 45°	218,652	159,973,964
B	Longitudinal 90° & Lateral 45°	209,943	139,631,410
C	Longitudinal & Lateral 45°	188,924	154,428,719
D	Lateral 45°	139,236	106,211,703
E	Longitudinal 90°	74,269	28,240,041
F	Longitudinal 45°	40,568	82,155,116

Table 2. shows that the more images acquired by 45°, and 90° angles with flight plan 1, and 2 are used together, the more point clouds and dense clouds can be extracted.

Table 3. Image of 3D model per m odel components.

	Point cloud of 3D model	Dense cloud of 3D model
A		
B		
F		

Among the results of generated 3D model, Case F failed to construct a 3D model in the densely wooded campsite area, because of the least point clouds and dense clouds (Table 3). Conversely, Case A has the numerous point and dense clouds, resulting in the effective construction of a 3D model.

In a 3D model using only vertical images (Fig. 4), the information of side texture was mostly distorted or missed. On the other hand, in the case of using vertical and oblique images, the side texture of the campsite was successfully generated, as shown in Fig. 5.

Through previous results, we can confirm that the 3D model based on vertical and oblique images is successfully generated. However, there was a problem of data loss at the edge of the 3D model, as shown in Fig. 6. It is judged to be a problem caused by not maintaining the degree of overlap on the edge when acquiring UAV images. Neverthless, the 3D model based on vertical and oblique images can express the detailed terrain as well as trees, which are clearly identified as shown in Fig. 7.

Figure 4. Missing data when using vertical images only

Figure 5. 3D model when constructed using both vertical and oblique images

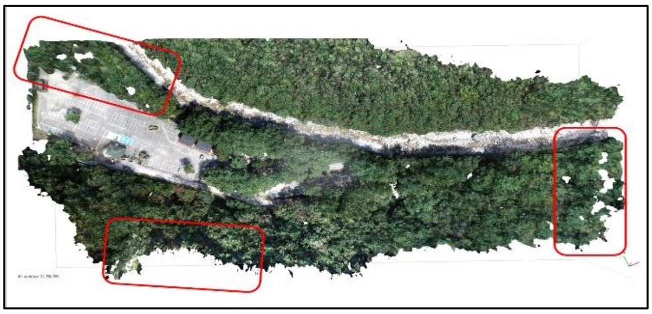


Figure 6. Modeling failure due to lack of image overlap

Figure 7. Forest area magnification image of Case A

5. CONCLUSION

In this study, we constructed a 3D model by mixing vertical and oblique images of campgrounds located within national parks taken using UAV. To evaluate the constructed 3D model, we compared with 3D models constructed with only vertical or oblique images. As a result, we could confirm that using both the vertical and oblique images together to generate the 3D model showed better in representing the detailed terrain including each tree object.

From the constructed forest 3D model, we were able to provide visual data for the safety, efficient conservation, and management of the natural environment of the national park users. It can have the following advantages for applications point of view.

First, a 3D map can be used for efficient conservation and management of forest areas. It can save a lot of budget by reducing manpower in the national park management.

Second, it is meaningful that 3D maps of forest areas can be produced quickly without additional equipment other than UAV. If a quick 3D map is produced for the area in the event of a disaster, it will be a great help in disaster monitoring work.

Further research will be conducted to improve the performance of 3D map side textures by adjusting flight conditions and setting camera angles with diverse. Moreover, we have a plan to build a higher density forest 3D model using GCP data together to be used simultaneously with other geographic information system data.

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