A Study on Obtaining Tree Data from Green Spaces in Parks Using Unmanned Aerial Vehicle Images: Focusing on Mureung Park in Chuncheon

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ABSTRACT

Background and objective: The purpose of study is to analyze the three-dimensional (3D) structure by creating a 3D model for green spaces in a park using unmanned aerial vehicle (UAV) images.

Methods: After producing a digital surface model (DSM) and a digital terrain model (DTM) using UAV images taken in Mureung Park in Chuncheon-si, we generated a digital tree height model (DHM). In addition, we used the mean shift algorithm to test the classification accuracy, and obtain accurate tree height and volume measures through field survey.

Results: Most of the tree species planted in Mureung Park were *Pinus koraiensis*, followed by *Pinus densiflora*, and *Zelkova serrata*, and most of the shrubs planted were *Rhododendron yedoense*, followed by *Buxus microphylla*, and *Spiraea prunifolia*. The average height of trees measured at the site was 7.8 m, and the average height estimated by the model was 7.5 m, showing a difference of about 0.3 m. As a result of the t-test, there was no significant difference between height values of the field survey data and the model. The estimated green coverage and volume of the study site using the UAV were 5,019 m² and 14,897 m³, respectively, and the green coverage and volume measured through the field survey were 6,339 m² and 17,167 m³. It was analyzed that the green coverage showed a difference of about 21% and the volume showed a difference of about 13%.

Conclusion: The UAV equipped with RTK (Real-Time Kinematic) and GNSS (Global Navigation Satellite System) modules used in this study could collect information on tree height, green coverage, and volume with relatively high accuracy within a short period of time. This could serve as an alternative to overcome the limitations of time and cost in previous field surveys using remote sensing techniques.

Keywords: DSM, DTM, DHM, image classification

Introduction

To continuously maintain the diverse functions provided by urban green spaces, it is necessary to collect quantitative data on urban green spaces, analyze the current state, identify spatial changes, and constantly monitor the space (Ryu

et al., 2017). However, since urban green spaces change rapidly due to urbanization, there may be more difficulties in collecting accurate information about urban streets and parks compared to forests (Seo et al., 2015).

Field surveys and remote sensing techniques have been used thus far to survey urban green spaces. However, field

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surveys have limitations as they require much time and financial cost. Remote sensing techniques interpret and study imagery data obtained from satellite images, manned aircrafts, and unmanned aerial vehicles (UAV) according to the target scope, resolution, and filming cycle (Kim, 2019). In particular, satellite images can obtain information of extensive areas but have low resolution and have difficulty obtaining images from desired time points. Manned aircrafts can obtain high resolution images from relatively broad areas, but also have difficulty obtaining images from desired time points. However, UAVs can obtain desired images at a low cost and within a short time in small areas and also have the advantage in obtaining high resolution data. In fields such as the environment, ecology and forests, UAVs can be used to determine the status of sites or monitor sites on a long-term basis by collecting parameters of trees such as individual trees, crown width, and leaf area index (Park, 2017; Woo et al., 2019). Using the advantages of UAVs can be an alternative to overcome the issues of time and cost as well as accuracy in field surveys, aerial photographs, satellite images, and aerial LiDAR.

Technologies to measure tree parameters such as tree height, crown height, and crown width using UAVs in cities that are complicated and have high density due to various high-rise buildings and facilities can be an important element in evaluating and managing the functions and effects of urban green spaces. Moreover, high resolution three-dimensional (3D) images can be created with the development of software to create images in short time through SfM (structure from motion) processing, enabling quantitative assessment of urban green spaces using UAVs. Classification of trees using UAV images can be done applying filters such as local maximum or morphological method as well as image classification techniques like watershed and mean shift using the tree height estimation model generated from the digital surface model (DSM) and digital terrain model (DTM) (Hwang et al., 2012). In a study classifying trees with UAV videos Lim (2017) applied the Lambda schedule segmentation and bottom-up merging algorithm to images obtained from UAVs to classify the trees and checked the image combinations by band. Tree height showed similar accuracy in both DSM and the normalized digital surface model (nDSM), but crown width

showed higher classification accuracy using nDSM. Iizuka et al. (2018) classified crown area using the watershed classification algorithm with DSM created after filming the cypress forest with UAVs. However, while many previous studies estimated tree height and crown width in forest areas using UAVs, very few analyzed the 3D structure of trees. Therefore, based on previous studies, this study will examine the applicability and limitations of data obtained from UAV images.

In the past, it was necessary to install ground control points (GCP) to obtain imagery data using UAVs, which required much time and cost (Lee et al., 2018). Accordingly, this study used UAVs with the real-time kinematic (RTK) and global navigation satellite system (GNSS) that can provide accurate data without GCP. UAVs with RTK module have relatively less time constraints and high spatial resolution by providing real-time centimeter location data and can also generate 3D modeling. Moreover, they can prevent jamming and thus fly stably in areas with weak signals such as densely populated cities, mines, and environments with complicated terrestrial magnetism such as high voltage and power (XAG, 2007).

Therefore, this study generates a 3D model with images filmed using UAVs with RTK module that have high accuracy in the city, estimates tree heights, classifies individual trees, and analyzes plantation area and volume of the study sites, after which it compares the results with measured data through a field survey and identifies applicability in measuring areas and volumes of green spaces using UAVs in the future.

Research Methods

Scope

The study site in this study is Mureung Park, one of the city parks in Chuncheon, Gangwon-do (Fig. 1). With residential areas concentrated nearby, Mureung Park provides a resting place for residents and is also equipped with a soccer field and badminton court for recreation. It also has an outdoor stage to hold various cultural events, serving as one of the major parks representing the region with various functions of urban green space.

Fig. 1. The study site: Mureung Park in Chuncheon, Gangwon-do.

Fig. 2. Flowchart.

Methods

Flow chart

We first measured tree height of each single tree using UAV image data as well as green coverage and volume of the entire study site, after which we analyzed future applicability by comparing with the data collected from

the field survey (Fig. 2).

Acquisition and processing of images

Phantom4 RTK used in this study has an RTK module integrated into the UAV, and also has a multi-GNSS module. The camera on Phantom4 RTK has a 1-inch CMOS sensor to accurately film images at the altitude of 100m

and ground sample distance (GSD) of 2.74 cm.

Filming was done in the daytime on May 22, 2019 when there was highest solar altitude and least pedestrian travel, considering safety issues that may arise due to light reflection or sudden airframe malfunction.

The GS RTK app, an automatic flying program developed by DJI, was used for filming. Total filming area was 88,228 m², filming time was 7 minutes and 58 seconds, altitude was 100 m, speed was 7 m/s, and duplication was 80%. The coordinate system used was WGS84/UTM zone 52 N.

For image processing, Pix4D Mapper was used for image correction and georeferencing, which was used to build data such as DSM and DTM.

Field survey

We identified the plantation status and land cover type of the study site based on images obtained from the UAV. Classifying into coniferous tree, broadleaf tree, shrub, lawn, and road and artificial establishment, we conducted a complete enumeration of the green structure three times in May 2019, such as tree species, diameter at breast height, tree height, crown height, and crown width for trees; and root diameter, tree height, and crown width for shrubs. Diameter at breast height was measured using a tape measure, and calipers were used for shrubs. Tree height, crown height, and crown width were measured in the evening when there is a clear view of the laser, using by Swiss company Leica Geosystems Holdings AG measuring distance and height with lasers. Herbs such as lawn were excluded from measurement.

Image classification

Classification algorithms are classified into edge-based and region-based approaches (Kwak et al., 2006). However, since it is not easy to distinguish the edges in images for the edge-based approaches (Park, 2004), this study classified the trees in the study site by individual using the mean shift algorithm that is one of the region-based approaches.

Methods used in image classification are divided into supervised classification and unsupervised classification (Kim, 2014). Supervised classification is used when the user accurately knows the information to classify in the

image, and this includes the minimum distance method (MDM), maximum likelihood method (MLM), and artificial neural network (ANN). Unsupervised classification classifies images using only spatial and spectral characteristics without information of the images, and this includes K-means and iterative self-organizing data analysis technique algorithm (ISODATA) (Kim, 2014). MLM is a classification technique that basically assumes normal (Gaussian) distribution and shows the best performance among statistical classification techniques (Lee et al., 2015), and thus this study used MLM for image classification. For accuracy analysis, we calculated the error matrix and measured Kappa index to determine the assessment results of the error matrix.

Generation of orthoimages, DSM, and DTM

Orthoimages and DSM were made with a resolution of 2.98 cm/pixel by registering and matching 183 images filmed with the UAV. DTM was generated with 5×2.98 cm/pixel, which is the minimum resolution recommended by Pix4D (2011).

Generation of the digital tree height model (DHM) and estimation of tree height

Models showing the digital terrain include the digital elevation model (DEM) that shows the elevation of the geographical location, DSM generated by the elevation of man-made features and terrain features, and DTM with irregular intervals for accurate terrain description (Kim, 2017). However, since DEM does not have the elevation of the terrain including vegetation and man-made features, this study used DSM and DTM. (Equation 1) shows the DHM calculation method developed to estimate tree height from the UAV images, and it is the difference between DSM generated by elevation and DTM with irregular intervals (Fig. 3; Perko et al., 2011).

$$\text{DHM} = \text{DSM} - \text{DTM} \quad (\text{Equation 1})$$

We estimated the height of each tree by overlapping polygons of trees classified from images on the generated DHM. To test the accuracy of the estimated tree height,

Fig. 3. DSM, DTM, and DHM (Perko et al.(2011)).

we selected 40 samples that can obtain accurate tree height measures without interruption of surrounding trees or terrain features in the field survey data and conducted a t-test using IBM SPSS statistics (version 24).

Green coverage

We identified the green coverage that can be obtained from UAV to analyze the 3D green structure of the study site. The crown area in the field survey was calculated by combining all trees planted after calculating the area of each single tree using (Equation 2) on the crown width measured.

$$\text{Green coverage} = \pi * (L/2 * W/2)^2 \quad (\text{Equation 2})$$

where L is the length of crown, and W is the width of crown.

Green coverage using the UAV was measured by creating contour lines on DHM of ArcGIS and generating a raster file using Topo to Raster. The study site was extracting using Extract by Mask on the raster file, and the green coverage of the site was finally calculated using Surface Volume.

Green space volume

Green space volume was calculated by obtaining the crown volume of each single tree and combining them. The crown volume was calculated in parabolic (Equation 3) and conical (Equation 4) types (Husch et al., 1982). Shrubs were calculated using (Equation 5) used by Thorne (2002).

Parabolic crown volume

$$\text{포물선형 수관체적}(P) = \frac{1}{3} * \pi * (L/2 * W/2)^2 \quad (\text{Equation 3})$$

Conical crown volume

$$(C) = \frac{4}{3} * \pi * (L/2 * W/2)^2 \quad (\text{Equation 4})$$

Shrub volume / tree height

$$\frac{2}{3} * \pi * \text{수고} * (L/2 * W/2) \quad (\text{Equation 5})$$

Volume analysis using the UAV was conducted using the same method as the one used in green coverage analysis above on not a single tree but on the entire study site to analyze the volume including low layer planting.

Results and Discussion

Overview of the study site

The total area of Mureung Park is 11,669 m², and the plantation area was 7,405 m². By land cover type, trees covered approximately 55.6% of all area, followed by roads and artificial establishments (30.5%) and herbs (25.1%). The share of coniferous trees was highest at 44.2%, followed by broadleaf trees (17.8%) and herbs (21.9%). Most of the trees planted were nut pines (195 stocks), followed by 90 pines and 48 zelkovas. Most of the shrubs planted were Korean azaleas, followed by boxwood trees and bridal wreaths.

Generation of orthoimages, DSM, and DTM

Fig. 4 Shows the orthoimages, DSM, and DTM generated on Pix4D Mapper and DHM generated on ArcGIS. Total area was 18.7 ha, and the geographical errors of X, Y, and Z were 0.1 cm, 0.1 cm, and 0.4 cm, showing more elaboration than the 1:500-1:600 scale error limit standard deviation ± 0.1 m according to the aerial photograph survey guidelines.

Accuracy test of tree height through DHM

DHM generated by subtracting DTM from DSM had the value of minimum -0.1 m to maximum 14.9 m. We conducted a t-test on 40 samples of DHM and tree height

Fig. 4. Orthophoto, DSM, DTM, and DHM.

measured to test the accuracy and discovered that the average tree height measured was approximately 7.8 m and the average tree height estimated in DHM was approximately

7.5 m, showing a 0.3 m difference. The t-value was 1.62, and the significance probability that there would be lower t-value was .113, which was greater than the significance

level of .05, and thus there was almost no difference between the measured tree height and estimated tree height.

Previous studies estimating tree height with UAVs include Bang et al. (2018) who presented ways to estimate tree height with outputs generated using UAVs and tested the reliability of the tree height estimation method provided by comparing the measured tree height. The results showed that the average tree height of samples measured was 8.7 m, and the average tree height estimated from DHM was 9.2 m, showing a 0.5 m difference. Moe et al. (2020) compared the measured tree height to prove the possibility of UAVs in estimating tree height of three species of broadleaf trees (*Betula maximowicziana*, *Kalopanax septemlobus*, *Quercus crispula*). The results showed that the average tree height of samples measured was 25.35 m, 23.40 m, and 24.67 m in the three species, and the average tree height estimated from DHM was 25.21 m, 23.52 m, and 24.24 m, showing a difference of 0.14 m, 0.12 m, and 0.43 m. Compared to previous studies, there was almost no difference from the error value of tree height estimated in this study at 0.3 m, implying that this can be applied as a data collection method for urban green spaces.

Classification of individual trees and images

As a result of classifying individual trees analyzed through Segment Mean Shift, it was found that the study site has high density and similar tree height, making it difficult to classify single trees. To test the accuracy of classification, we used orthoimages and field survey data as verification data and the classified images as comparative data.

We classified the images into coniferous trees, broadleaf trees, shrubs, lawns, and roads and artificial establishments and calculated the error matrix to analyze the accuracy of supervised classification results using MLM. As a result (Table 1), producer's accuracy (PA) was highest for roads and artificial establishments (82.5%), followed by broadleaf trees (70%), showing an average of 64%, and user's accuracy (UA) was highest for roads and artificial establishments (82.5%), followed by broadleaf trees (73.7%), showing an average of 65.3%. Overall accuracy (OA) was 64%. The Kappa coefficient through the error matrix was 0.55, and thus there is 'good consistency of $0.4 < k \leq 0.6$ '.

Discussions on the 3D green structure analysis

In the UAV data, the green coverage and volume of the upper layer were 4,785 m² and 14,767 m³, and the lower layer were 234 m² and 130 m³. The upper layer green coverage and volume of the study site calculated by the field survey data were 6,047 m² and 15,426 m³, and the lower layer were 292 m² and 1,741 m³.

Comparing UAV data and field survey data, area showed a 21% difference in the upper layer and 20% difference in the lower layer, and volume showed a 4% difference in the upper layer and 93% difference in the lower layer. Comparing the results, we could find that both green coverage and volume were higher in the field survey data, and the lower layer volume especially showed a difference of more than 10 times.

This result may be obtained because the green coverage and volume calculated with the field survey data were cal-

Table 1. Error Matrix Accuracy and Kappa Index

Classification	1) PA(%)	2) UA(%)	3) OA(%)
Coniferous tree	50	51.3	64
Broadleaf tree	70	73.7	
Shrub	50	69	
Lawn	67.5	50	
Road and Artificial establishment	82.5	82.5	65.3
Average	64	65.3	
Kappa Index		0.55	

1) PA(Producer's accuracy)

2) UA(User's accuracy)

3) OA(Overall accuracy)

culated by interpolating even the empty spaces inside on the UAV data, and the parts where crowns overlap were not considered and thus double counted. Moreover, UAV images were filmed at 100m above ground and thus failed to film the lower layers planted under the trees. The lower layers are mostly shrubs, and thus there were limitations in calculating the volume with UAV images filmed in this study.

Warfield et al. (2019) proved that the 3D green structure that can be estimated by UAVs can be overestimated or underestimated depending on the space that has different structural characteristics (areas with high density or low density) and argued that there is a need for methods to overcome the limitations in order to more accurately estimate the 3D green structure. Therefore, to measure accurate areas and volumes of green spaces in parks using UAVs, it is necessary to film even the lower parts of trees in addition to using images that can be filmed above ground.

Conclusion

The purpose of this study is to generate a 3D model on Mureung Park, a park green space in Chuncheon, using UAV images and analyze the 3D structure such as green coverage and volume. To this end, we created DSM and DTM generated in 3D through SfM processing of images filmed by UAVs with RTK and GNSS modules on exclusive software. Based on that, we generated DHM to classify individual trees and selected single trees where accurate tree height can be obtained from field survey data with a complete enumeration as the samples and comparatively analyzed with measured tree height. Moreover, we used the mean shift algorithm to test the classification accuracy and used the classified images, field survey data, and orthoimages as verification data and used MLM for classification. The results of this study can be summarized as follows.

First, the average tree height of samples measured in the field survey was approximately 7.8 m, and the average tree height estimated from DHM was 7.5 m, showing about a 0.3 m difference. As a result of conducting a t-test to verify the accuracy, there was no significant difference be-

tween the actual measurement and DHM.

Previous studies that estimated tree height from DHM using UAVs showed an average difference of 0.14- 0.5 m from the measured tree height. The results of this study showed higher accuracy compared to previous studies, and the results show that it is possible to measure tree height with relatively high accuracy in a short time using RTK drones.

Second, we compared the total green coverage and volume of the study site estimated using the UAV with the field survey data and discovered that the green coverage and volume obtained from UAV data were 5,019 m² and 14,897 m³, and the area and volume measured from the field survey data were 6,339 m² and 17,167 m³, showing a 21% and 13% difference each.

The green coverage and volume estimated using the UAV in this study were underestimated because even the empty spaces within the green area were interpolated and calculated during the field survey, and the parts where trees overlap were calculated redundantly, thereby producing high values of field survey data. Moreover, there were limitations in obtaining information on the lower part of trees or upper part of structures because UAV images were filmed in the air, and thus further research is needed to supplement the data.

This study has significance in verifying that it is possible to relatively accurately estimate the 3D green structure (green coverage and volume) above ground within a short period of time in park greens using UAVs with RTK and GNSS modules in the city where automatic flight setting is not easy due to terrain features and magnetic field issues.

The limitations of this study are as follows. First, since the UAV images were filmed in only one study site, it is necessary to compare results by filming various urban green spaces. Second, the study site had high plantation density and similar tree height, and thus single trees were not accurately classified. Third, low layer planting areas were not filmed, thereby not including some shrubs in multi-layer planting areas in the areas and volumes. It will be possible to estimate more accurate green coverage and volume by obtaining images using various filming techniques in the future.

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Appendix

Table A1. Tree's information

Sample	Species	Tree height from Survey (m)	Tree height from DHM (m)	Area (m ²)	Vo (m ³)
1	<i>Zelkova serrata</i>	6.8	7.1	18.5	30.6
2	<i>Zelkova serrata</i>	4.8	4.5	7.1	6.3
3	<i>Zelkova serrata</i>	7.6	7.6	33.2	56.8
4	<i>Zelkova serrata</i>	4.8	4.5	6.4	3.8
5	<i>Zelkova serrata</i>	6.7	6.5	16.3	25.9
6	<i>Zelkova serrata</i>	7.8	8.4	44.8	75.9
7	<i>Zelkova serrata</i>	9.3	10.2	39.0	70.5
8	<i>Zelkova serrata</i>	7.5	7.3	15.6	23.5
9	<i>Zelkova serrata</i>	6.7	7.1	21.6	34.5
10	<i>Zelkova serrata</i>	7.2	7.1	29.7	55.2
11	<i>Zelkova serrata</i>	7.7	7.5	26.0	27.7
12	<i>Zelkova serrata</i>	10.5	9.6	17.0	49.1
13	<i>Zelkova serrata</i>	6.2	5.8	9.9	10.8
14	<i>Pinus koraiensis</i>	14.1	13.5	24.6	177.2
15	<i>Pinus koraiensis</i>	12.0	7.4	26.4	162.0
16	<i>Ginkgo biloba</i>	11.5	11.4	7.8	44.1
17	<i>Ginkgo biloba</i>	10.1	9.8	10.2	49.5
18	<i>Cercidiphyllum japonicum</i>	8.5	8.4	11.3	18.9
19	<i>Zelkova serrata</i>	9.8	10.9	41.3	113.6
20	<i>Pinus densiflora</i>	6.8	8.7	37.9	47.5
21	<i>Zelkova serrata</i>	6.7	6.7	31.7	46.2
22	<i>Zelkova serrata</i>	7.1	7.4	59.4	87.1
23	<i>Acer palmatum</i>	3.7	3.7	4.9	2.8
24	<i>Acer palmatum</i>	4.1	4.6	6.6	3.5
25	<i>Magnolia kobus</i>	3.0	2.8	1.1	0.5
26	<i>Pinus densiflora</i>	5.0	5.7	45.4	41.6
27	<i>Pinus densiflora</i>	4.5	3.5	30.2	15.0
28	<i>Ginkgo biloba</i>	12.0	10.1	15.6	99.5
29	<i>Ginkgo biloba</i>	11.4	8.0	14.5	79.3
30	<i>Ginkgo biloba</i>	11.8	9.4	7.1	41.0
31	<i>Ginkgo biloba</i>	10.7	8.5	18.9	94.2
32	<i>Ginkgo biloba</i>	10.6	7.2	16.3	80.2
33	<i>Pinus densiflora</i>	5.7	7.0	26.0	12.7
34	<i>Pinus densiflora</i>	6.2	6.1	23.3	20.5
35	<i>Zelkova serrata</i>	4.0	4.7	4.5	1.8
36	<i>Pinus koraiensis</i>	11.6	12.4	25.5	139.4
37	<i>Pinus koraiensis</i>	10.7	11.5	21.2	106.1
38	<i>Pinus koraiensis</i>	10.0	9.4	19.6	96.8
39	<i>Cornus kousa</i>	3.9	3.6	1.0	1.7
40	<i>Acer palmatum</i>	3.1	3.1	7.1	3.3
Average		7.8	7.5	20.6	51.4