3D RECONSTRUCTION OF LANDSCAPE FEATURES USING LiDAR DATA AND DIGITAL AERIAL PHOTOGRAPH FOR 3D BASED VISIBILITY ANALYSIS

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ABSTRACT: Among components of digital topographic maps used officially in Korea, only contours have 3D values except buildings and trees that are demanded in landscape planning. This study presented a series of processes for 3D-reconstructing landscape features such as terrain, buildings and standing trees using LiDAR (Light Detection And Ranging) data and aerial digital photo graphs. The 3D reconstructing processes contain 1) building terrain model, 2) delineating outline of landscape features, 3) extracting height values, and 4) shaping and coloring landscape features using aerial photograph and 3-D virtual data base. LiDAR data and aerial photograph was taken in November 2006 for 50 km^2 area in Sorak National Park located in eastern part of Korea. The average scanning density of LiDAR pulse was 1.32 points per square meter, and the aerial photograph with RGB bands has 0.35m × 0.35m spatial resolution. Using reconstructed 3D landscape features, visibility with the growing trees with time and at different viewpoints was analyzed. Visible area from viewpoint could be effectively estimated considering 3D information of landscape features. This process could be applied for landscape planning like building scale with the consideration of surrounding landscape features.

KEY WORDS: landscape planning, LiDAR, 3D reconstructing process, visibility

1. INTRODUCTION

There are many studies concerned about 3D based landscape mapping, assessment, planning and management in South Korea. In the middle of 90's, aerial photographs or topographic maps published on paper were usually used to make 3D landscape maps(Do, 1994; Yu *et al.*, 1995; Kang *et al.*, 1995). Since NGIS(National Geographic Information System) plan started at 1995, topographic maps, aerial orthophotos and satellite imageries in digital form have been preferred to the previous materials(Jang and Lee, 1999; Han *et al.*, 2000; Yu *et al.*, 2002; Choi, 2002; Cho *et al.*, 2004).

However, in digital topographic maps produced by NGIS plan, contours and some ground points have 3D values only except buildings and trees that are demanded in landscape planning. Thus, additional survey and data construction processes are needed to make 3D landscape features like buildings and trees(Lee and Seo, 1999; Kang *et al.*, 2003).

In the meanwhile, aerial LiDAR mapping techniques were introduced in the opening part of this decade and used to make 3D landscape features for decision making of optimal electric-powerline paths near a recreational forest(Kim *et al.*, 2005).

In Canada, LiDAR techniques were already spread and 3D landscape features from LiDAR were actively used to be mapped, visualized and analyzed for landscape assessment and planning(Sheppard, 2004).

This study is performed to confirm 3D reconstruction processes of landscape features using aerial LiDAR data in a commercial part of a national park area, which has been strongly restricted with Korean natural environment protection laws and frequently questioned by the local residents.

2. STUDY AREA

The study area for this study is located in Sorakdong Valley, Sorak National Park, which is in eastern part of South Korea (Figure 1). The valley has the main entrance so shops and lodges near the entrance are used frequently by visitors.

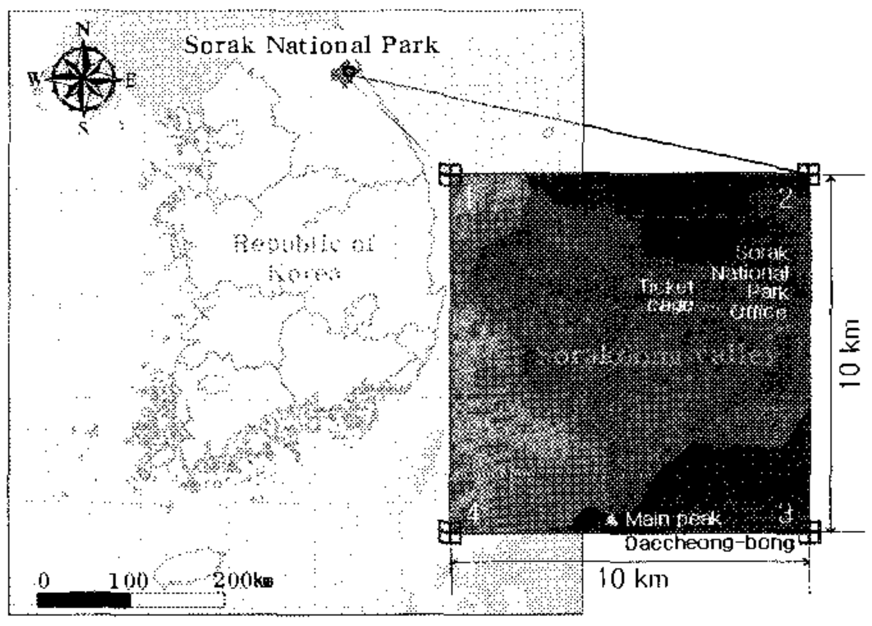


Figure 1. Location of study area

Most part of the valley is mountainous area and its landuse type is forest. Shops, lodges, temples, streets and roads are located in the lower part of the valley.

3. MATERIALS

3.1 LiDAR Data

For aerial LiDAR data acquisition, Optech ALTM 3070(a small footprint LiDAR system) was used and the flight to acquire data was performed on 17th November 2006. .In the valley, the area of aerial LiDAR acquisition is about 50km^2, which is represented as a dashed line in Figure 1.

Total number of collected points was 93,328,850 and mean number of collected points was 1.32 points per square meter. More details of data acquisition are described in Table 1.

Table 1. Data descriptions of aerial LiDAR

Specification		performance
Flight elevation		**2,450 m**
Accuracy	**Vertical**	**0.3 m**
	Horizontal	**1.23 m**
Number of Echo		**4**
Intensity capture		**12 bit**
Laser repetition rate		**Max. 70 ㎑**
Scan angle		**0 ~ ±25°**
Swath width		**0 ~ 0.93×altitude**
Beam divergence		**0.2 or 0.7mrad(1/e)**
Laser classification		**Class Ⅳ**
No. of collected points		**93,328,850**
Data size		**4,147 MB**
Area of the collected		**70,480,989 ㎡**
Mean of point density		**1.32 points/㎡**

(※Hanjin Information Systems & Tele-communication Co., Ltd.)

3.2 Digital Aerial Photograph

215 digital aerial photographs with red, green and blue bands were acquired simultaneously with LiDAR data. Then, a orthophoto was made from the digital sceneries in 0.35m×0.35m spatial resolution. More details of data acquisition are also described in Table 2.

Table 2. Data descriptions of aerial photograph

Specification	performance
Flight elevation	**2,450 m**
Resolution	**22 Mpixel (4,080×5,440)**
Image size	**36 x 48mm**
Pixel size	**0.009mm**
Lens	**Schnieder Krunznach**
Focal length	**50mm, F2.8**
Field of view	**51°×40°FOV**
Shutter speed	**30 ~ 1/1000 sec.**
Standard cycle rate	**4.5 sec/frame**
No. of collected photos	**215**
Data size of collected	**13.7 GB**
Data size of orthophoto	**1.5 GB**
Spatial resolution	**0.35 m**

(※Hanjin Information Systems & Tele-communication Co., Ltd.)

3.3 Post-flight Data Process

After the flight, Hanjin Information Systems & Tele-communication Co., Ltd., who was the data acquisition company, performed a general post-flight data processing as Figure 2.

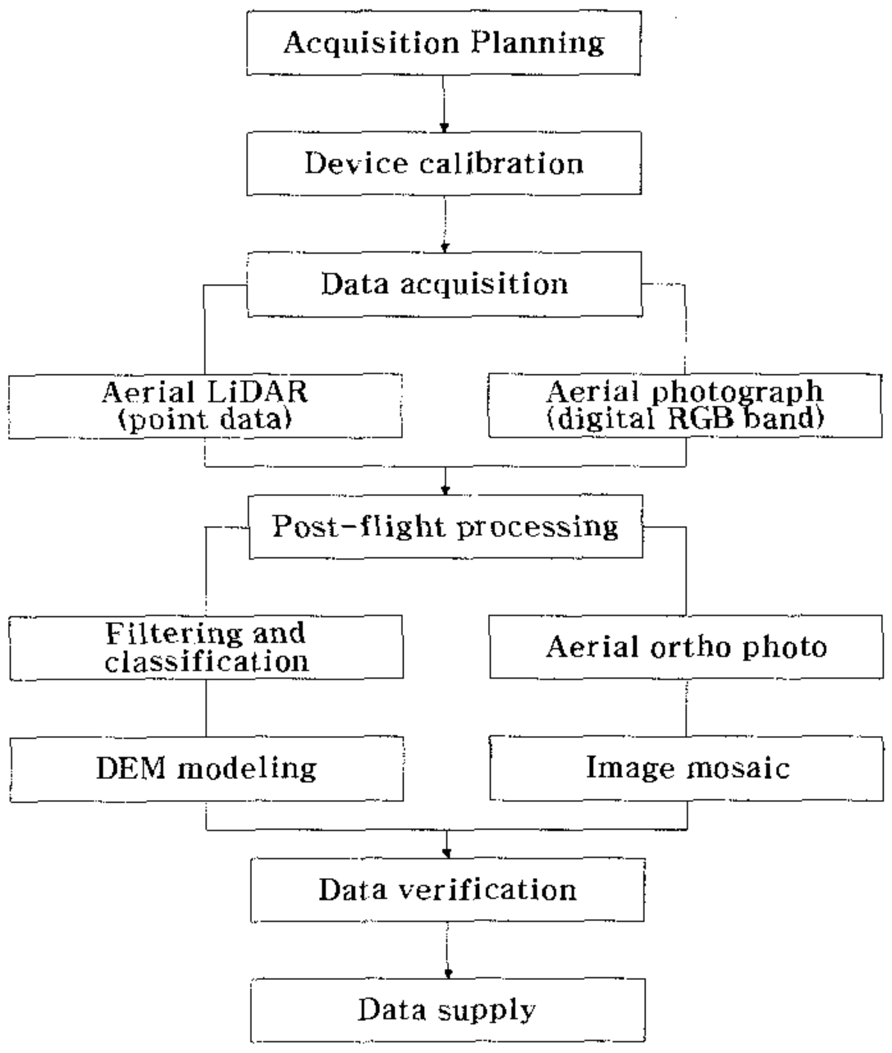


Figure 2. Post-flight data process

4. METHODS

4.1 3D Reconstruction Overview of Landscape Features

Draping digital orthophoto onto DSM(Digital Surface Model) from aerial LiDAR is a simple way of 3D landscape reconstruction(Figure 3). However, if the reconstructed model would be used for some detail simulations like the viewshed assessment of passenger's level, the simple way makes the landscape less realistic(Figure 4).

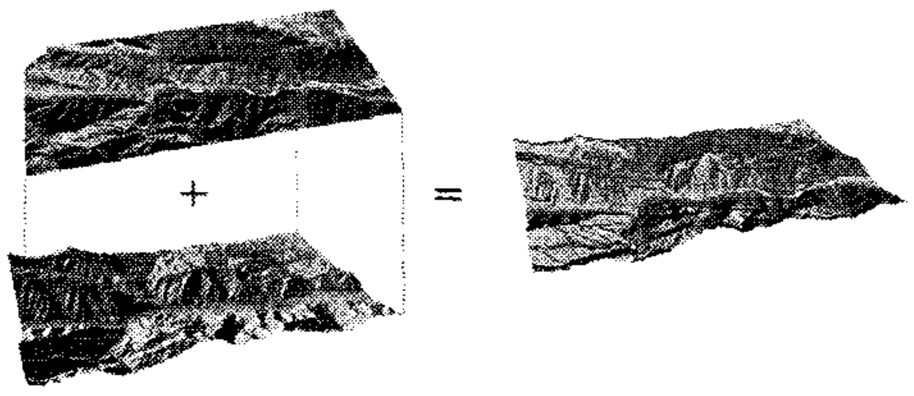
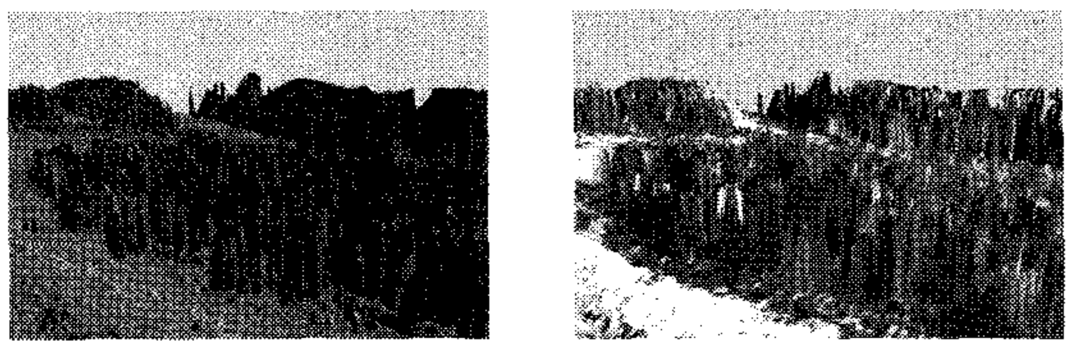


Figure 3. Draping digital orthophoto onto DSM



(a) DSM (b) orthophoto on to DSM

Figure 4. Less realistic 3D landscape by simple draping

The visualization results were caused by low LiDAR density(1.32 points/m^2) and orthophoto resolution (0.35m). It does not matter that these low density and resolution data are used if a landscape feature is in a long distance from the location of observation(Figure 5(a)). Moreover, DEM(Digital Elevation Model) of ground return pulses from LiDAR was not confused(Figure 5(b)).

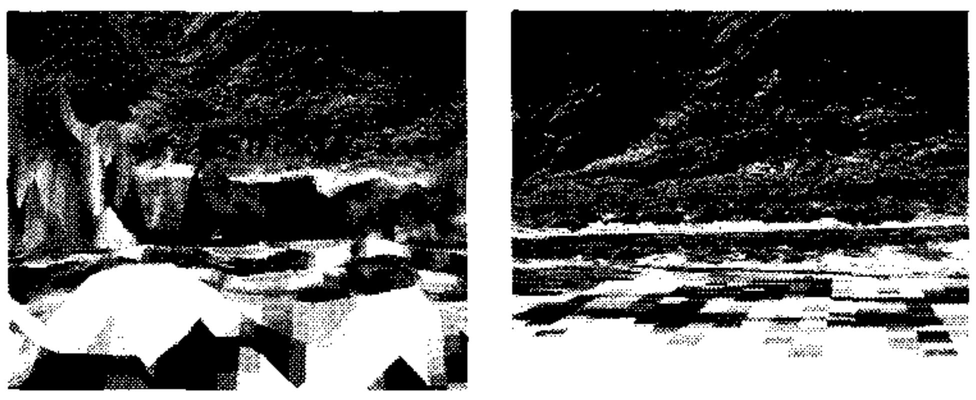

(a) DSM (b) DEM

Figure 5. Visualization results by difference of surface model

Therefore, the three major landscape feature types, which are terrain, trees and buildings, were reconstructed through separate and different data process flows(Figure 6).

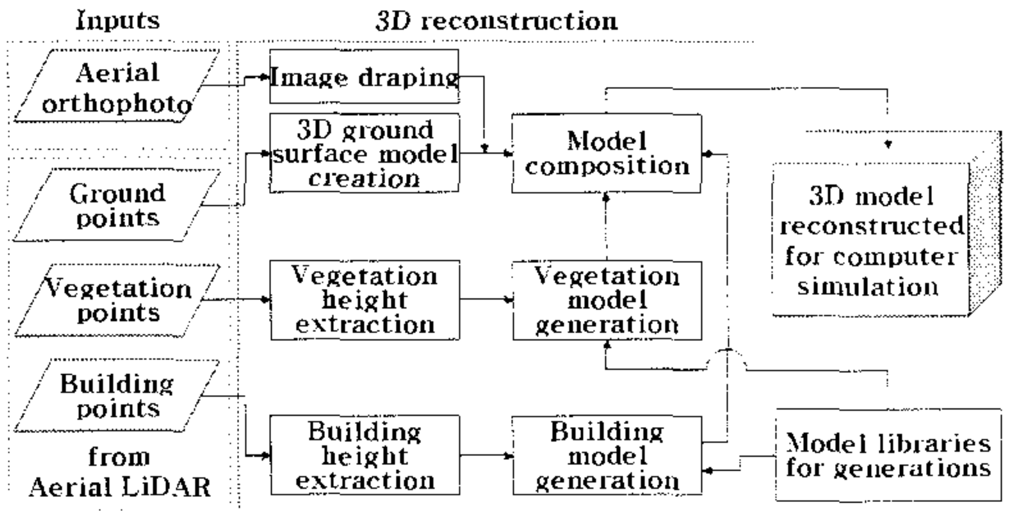


Figure 6. 3D landscape reconstruction flow

4.2 Terrain Reconstruction

Ground points classified as ground return pulses in the post-flight processing were selected to create TIN (Triangulate Irregular Network) and converted to 1m resolution DEM. Then, digital orthophoto was draped.

4.3 Vegetation Reconstruction

Vegetation points classified as high vegetation return pulses were selected to delineate tree crowns by watershed method. Then, a hundred of tree widths and heights were extracted in each crown near several observation locations, which were designed by some landscape simulation scenarios to assess visibilities in streets frequently used by passengers. To make the street tree models more realistic, tree model libraries were used. Those had already been modeled in variable sizes, species by species.

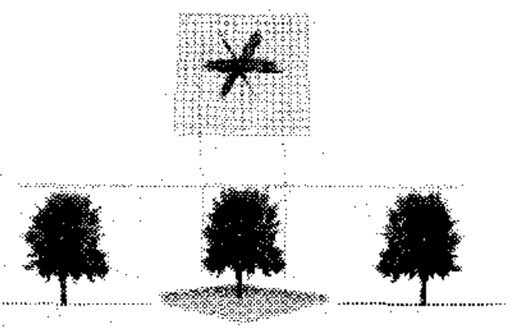


Figure 7. A 3D model structure of a street tree

4.4 Building Reconstruction

Building points classified as building return pulses were selected. Then, by manual, forty building boundaries near several observation locations from the landscape simulation scenarios were made and their mean heights were extracted. To make building models more realistic, building model libraries were used. Those had already been modeled as some primitives. The primitive model can be merged with each other, be changed in sizes and shapes and be mapped with texture images.

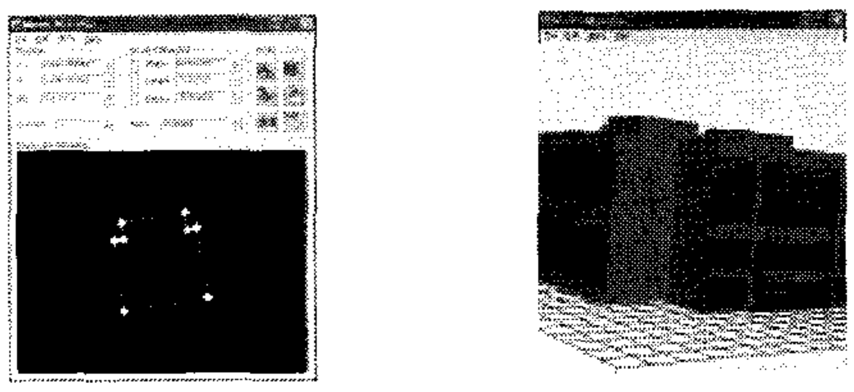

(a) an editable primitive (b) a mapped model

Figure 8. Building model libraries

4.5 Reconstructed Model Composition

Three kinds of models had been separately processed but extracted in the same data source which had a single coordinate system. Therefore, into a model-compatible software, all of models were loaded and integrated easily in a coordinate system.

4.6 Landscape Assessment with Simulation Scenarios

Near several locations on the main passenger's paths, building features, which might be changed by more flexible laws, were enlarged twice in height. Trees, which might be changed by their own growths, were also virtually enlarged in each height by species.

To compare on differences between the present and virtual status, real-time 3D visualization and visibility analysis were performed.

5. RESULTS AND DISCUSSIONS

5.1 Results of 3D Landscape Reconstruction

Separately processed 3D landscape features were composed to visualize the present status as Figure 9.


(a) terrains (b) buildings (c) trees

Figure 9. Results of 3D reconstruction(location C1)

5.2 Comparison on Landscape Changes

Buildings were applied to a scenario in order to compare landscape changes between the present and virtual status. Then, the result of building scenario was tested in various directions using real-time visualization technique.

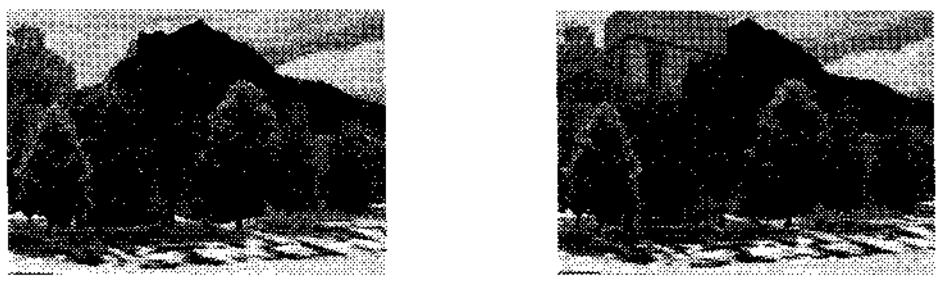

(a) the present (b) twice in a building height

Figure 10. Different building scenarios(location C1)

In a tree scenario that a forest could be composed of different species, which had different annual growth, and maintained without any forestry operations or hazards, the virtual realities were visualized as below.

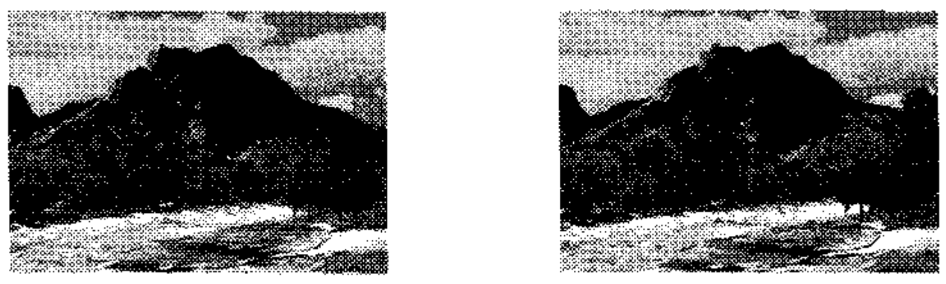

(a) the present (b) the virtual future

Figure 11. Different tree scenarios(location C2)

The visibility analysis was applied to quantifying the visible area, as a landscape assessment result, from the scenario's location C2. The differences between the present and virtual status might be quantified using an arithmetical map algebra.

6. CONCLUSIONS

In 3D landscape feature reconstruction, aerial LiDAR was more useful than the official digital maps because it had z-value in all of return pulses.

In the case of a low data density and low observation locations, the data process flow separated by landscape feature type was applicable.

To reconstruct a terrain model, ground return pulses were selected, converted 3D surfaces and draped by digital orthophoto as general.

The 3D tree model structure, which had only an attached image on three radial planes in shape, would make its performance better and storage need lighter.

Also, the building models could be attached by images of its walls so the weakness of aerial and orthographical data would be reduced.

Although visibility analysis had not been performed at all of the observation locations, visible areas could be estimated with the analysis and their ratio, as an index, between the present and virtual status could be used to quantify the changes among various situations.

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8. ACKNOWLEDGEMENTS

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