Analysis of Accuracy Factor for 3D Reconstruction using 2D Image Obtained from Unmanned Aerial Vehicle (UAV)

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Abstract

Recently UAV has been used in various fields such as construction and civil engineering, disaster, terrain analysis, transportation, etc. In addition, many companies from all over the world are focusing on developing UAV technology. The market of personal UAV has been growing and attracting people's attention year after year due to the low cost of UAV. Especially, in construction industries where people work on large-scale fields, there are many methods to obtain space information and those methods can be done at low cost. However, the existing studies are mostly about utilization of UAV such as flight plan and acquisition 3d image methods. Therefore, it is necessary to study result values according to use of variable value.

This study focuses on the variables which affect the result of 3D reconstruction using 2D image obtained by UAV. First, we fixed values of flight planning of UAV and distortion correction of picture. After that, we took pictures of building and obtained point cloud that allowed us to make 3D model of the building. Second, we analyzed results of the 3D model according to variable of illumination. Then, we found number of point cloud from the previous results. Finally, we identified optimal illumination result to build an effective 3D Modeling. We present about optimal value of illuminance variation to improve current method of developing 3d model. This study can be a more efficient and accurate method to obtain images by UAV.

Keywords –

UAV; Structure from motion; illumination

1 Introduction

Recently, unmanned aerial vehicles (UAVs) are being used in many areas including agriculture, civil engineering, disasters, deliveries, and military operations. The global market for UAVs is steadily growing and is expected to form a large market in the future. In particular, the expansion of the market for spatial data portal services such as Google Earth and MS Virtual Earth is closely associated with the growth of UAV market. The contribution of aerial monitoring to the spatial data areas is also expected to increase gradually. The use of UAVs for the easiness and speed of aerial monitoring is emerging. A mapping system using UAVs allows monitoring with a high frequency because it is efficient in terms of time, cost, and manpower. Furthermore, the applications of UAV-based aerial monitoring systems are gradually increasing as it has now become possible to send data acquired through auto flight and wireless communication technologies to ground stations in real time.

As explained above, the research on UAVs is being conducted actively due to such various advantages of UAVs. Existing studies have focused on data capturing through UAVs and data processing with the acquired data. Various studies have been attempted to convert the acquired data to data that can be measured and managed instead of being explored. Among them, studies on 3D modeling with 2D images are mostly based on the point cloud generation algorithm. In this study, a 2D image environment that is more advantageous for point cloud generation is searched by adjusting the environmental values of 2D image that can directly influence the point cloud generation algorithm. For this purpose, an accuracy analysis is performed by checking the number of point clouds generated by the variation of illumination value.

2 3D Reconstruction using 2D Image

2.1 Literature review

3D modelling with 2D images is generally known as image-based modeling or 3D photography. It is also referred to as structure from motion. Multiview stereo (MVS) and reconstruction are core elements in the process of obtaining 3D modeling through multiple pictures or video images. These technologies are being used in various areas including TV, industries, surveys, cultural assets restoration, and games. Recently, Seitz et al. [1] showed that 1/200-scale objects have higher accuracy in low-resolution images in current MVS algorithms. They can be classified into several grades depending on the object model. First, Voxel-based approaches [2][3][4][5][6]. Faugeras et al present a novel geometric approach for solving the stereo problem for an arbitrary number of images [2]. Pons et al presents a novel formulation for the multiview scene reconstruction problem [3]. Hornung et al present a new volumetric stereo algorithm to reconstruct the 3D shape of an arbitrary object [4]. Vogiatzis et al present a quantitative comparison of several multi-view stereo reconstruction algorithms [5]. Sinha et al formulate multi-view 3D shape reconstruction as the computation of a minimum cut on the dual graph of a semi-regular, multi-resolution, tetrahedral mesh [6]. Second, Algorithms based on deformable polygonal meshes [7][8][9].

Thus, many studies are being conducted on the accuracy and algorithm of structure from motion. This study focused on 2D images that can directly influence point cloud generation.

2.2 2D Image processing for 3D reconstruction

There are various studies on the acquisition of 2D images using UAVs. UAVs are actively used especially for elevation and terrain analysis in construction and civil engineering. Furthermore, UAVs are also used in the management and real-time monitoring of building facilities. Many UAV-related studies can be also found among studies on the aforementioned structure from motion. Darren et al research a technique for geometric correction and mosaicking of UAV photography using feature matching and Structure from Motion (SfM) photogrammetric techniques [10]. Adam et al study explores the use of structure from motion (SfM), a computer vision technique, to model vine canopy structure at a study vineyard [11]. Francesco et al tests the utility of the Structure from Motion (SfM) approach to low-altitude aerial imageries collected by Unmanned Aerial Vehicle (UAV) [12]. Ronald et al demonstrates the use of genetic algorithms in optimized view planning for 3D reconstruction applications using small unmanned aerial vehicles (UAVs) [13].

Many different software applications implementing 3D modeling with 2D images are being developed lately. These applications are classified largely by their use or by modeled object size, such as measurement or land modeling, modeling of building and facilities, and modeling of people or small objects. Among them, Pix4Dmapper and Photoscan are software applications that contain various features and are used widely. These applications extract 3D models by applying option values in line with the object using a variety of image formats. Therefore, they are good for 3D modeling of large and small objects and objects of different environments. However, you must buy the professional version in order to use these various features. Thus, each application has its merits and faults. Pix4Dmapper (Table 1) is one of the most popular software applications. It is specialized for the aerial images of UAVs and is used in many different areas because it offers various features and expressions including project optimization, point cloud editor, area mixing and editing.

Another software application that is often used alongside Pix4Dmapper is Photoscan (Table 2), which has many shared features with Pix4Dmapper. It supports more various extensions for input images and increased the accuracy and shortened the time of camera tracing with the Align photo feature. The overall process is not much different, which consists of picture upload, mask area specification, picture alignment, point cloud building, point cloud editing, transformation into mesh-shaped polygon, mesh editing, high quality texture creation, and exporting as desired output values. However, the cloud editor provides various features such as automatic control by python, 4D processing, DEM data output, and change of the use of meshes. Thus, Photoscan shows good performance in sculptures, buildings, or topography in addition to aerial images. For output formats, OBJ, PLY, XYZ, U3D, ASPRS LAS, and PDF are available.

Autodesk developed a lighter software application called Memento (Table 3) which is more useful for extracting 2D images and point clouds compared to the existing Recap 3D scanner software. Even though it

Table 1. Pix4Dmapper

Software	Feature			
	Input	Process	Cloud editor	Result
Pix4Dmapper	• Edit and import ground control points (.csv, .txt). • Coordinate systems based on local, global, and random points supporting meter and feet units.	• Camera self-correction • Automatic aero triangulation (AAT) and bundle block adjustment (BBA) • Automatic point cloud filtering and modification • Automatic topography/object point cloud classification and DTM extraction (BETA)	• Limitation of size and direction • Project optimization • Point cloud editor • Reflectance map • Multi-area management	• OBJ, PLY, DXF, FBX, Zipped OBJ format • LAS, LAZ, XYZ, PLY • SHP, DXF, PDF • DXF, SHP, DGN, KML

Table 2. Photoscan

Software	Feature			
	Input	Process	Cloud editor	Result
Photoscan	• Automatic image alignment • High accuracy and time shortening of camera tracing with the align photo feature	• Specification of mask area for unnecessary part. • Transformation to mesh-type polygon • Mesh editing • Creation of high-quality texture (original)	• Build dense cloud • Automatic control by python • 4D processing • Creation of texture according to shape	• OBJ, PLY, XYZ text, U3D, ASPRS LAS, PDF

Table 3. Autodesk Memento

Software	Feature			
	Input	Process	Cloud editor	Result
Autodesk Memento	• HD3D mesh modeling based on image such as JPEG, TIFF, PNG, and BMP • Creation of HD3D after scanning the light of the model	• Mesh analysis, rearrangement and modification • Creation of size report • Analysis of differences between the real model and the 3D model	• Removal of unnecessary noises and rearrangement • Measurement of the distance of mesh and checking the size information • Analysis of differences between the real model and the digital model	• OBJ, .STL, .PLY, FBX, .RCM

Table 4. Mobile software

Mobile	SmartMobileVision-SCANN 3D	• Implementation of 3D model using mobile devices • Automatic adjustment of the parameters of different mobile devices • Fast modeling by creating 3D images within 2 minutes
	Fuel 3D	• Automatic conversion of 3D objects to point clouds • Work at a high speed with a low-performance PC by applying video work • Cloud service • 0.1 second processing speed for 3D capture images
	itSeez3D	• Need for purchasing a scan sensor (iSense) device • Scan objects with object sensor or iSense ~ Check the initial 3D model and perform rendering after sending the model to the cloud system ~ Save as a desired file • Specialized for people and small objects

has a disadvantage in the supported formats compared to the existing applications, Memento is more efficient in implementing more vivid 3D objects that are called HD3D. Due to this advantage, Memento is optimized for scanning small detailed objects rather than large objects. The cloud editor shows a high loading speed even for voluminous meshes and offers such features as realistic expression of textures, wire frame mode, isolation mode for mesh arrangement, and analysis of differences between real and digital models, and modifications. Another advantage is the creation of 3D models immediately after saving in STL format for CNC or 3D printers. For output formats, OBJ, STL, PLY, FBX, and RCM are available.

Recently many 3D scanning techniques using mobile technology are being developed (Table 4). Even though their functionality is inferior to the aforementioned applications due to using mobile devices such as smart phone and tablet PC, it is an efficient application for non-professionals performing general tasks because it contains all the essential features. Mobile 3D scan applications offer the advantage of a high processing speed such as quick image scanning and instant modeling. Furthermore, the application is light because they are implemented on mobile devices. They are also good for instant uses because you can scan images anytime, anywhere regardless of time and place. Another mobile scanning

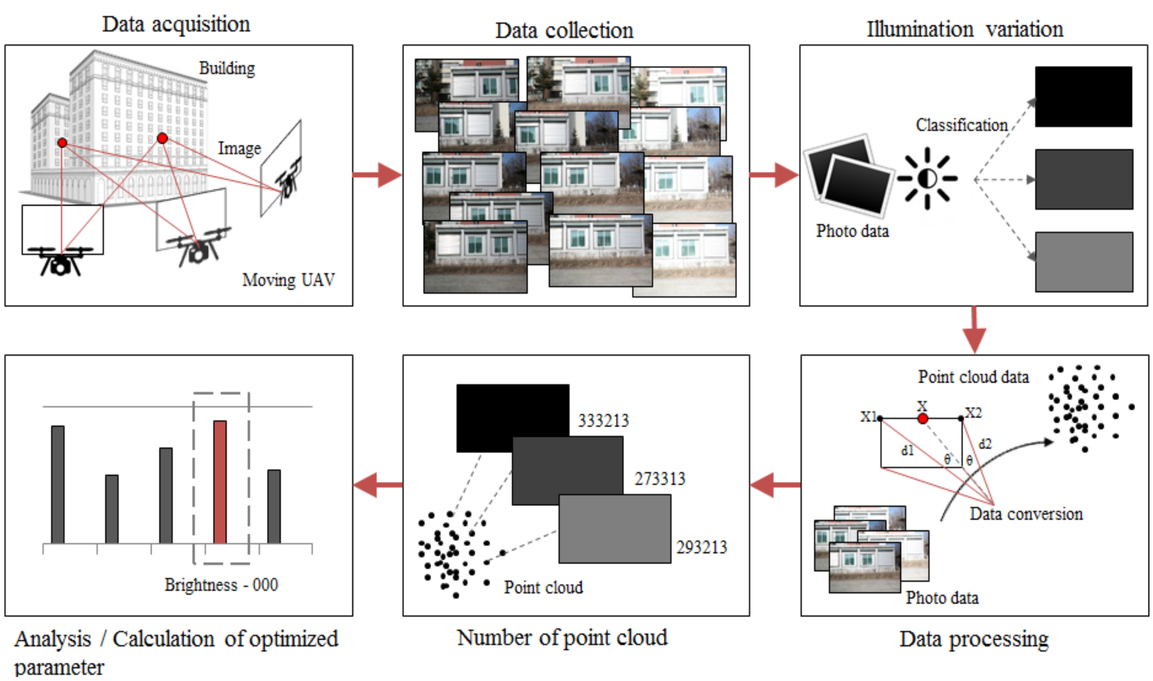


Figure 1. Research process

technique is to buy and mount a scanning device to a tablet PC, which can express 3D objects as effectively as other applications running on PC. Nowadays such various mobile scanning techniques and software applications are being developed.

3 Research methodology and scope

Before conducting this study, existing studies were analyzed through literature review. Most studies on accuracy were about algorithms. In this study, however, we focused on analyzing accuracy based on the changing number of point clouds according to the changing illumination of 2D images. For variations of illumination, camera shutter speed and aperture values were used (Figure 1). First, 2D images are collected using an UAV, and the 2D image data are classified by parameter values. Then the images are converted to point cloud values through data processing. The output values are derived after analysis based on the final values.

4 Implementation, experiments and results

4.1 Test condition

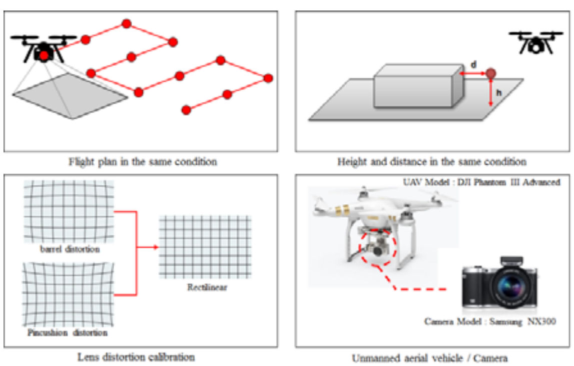


Figure 2. Test condition / Device

Before conducting this study, an identical flight plan for collecting picture data of the same location and angle was established. The distances and heights of buildings were also identical. For this study, two buildings of Sungkyunkwan University in South Korea were selected as subjects of experiment. DJI Phantom III Advanced was used for the UAV model and Samsung NX300 was used for the camera (Figure 2). Picture data are obtained from the identical location using an UAV. The photographed picture data are classified by illumination value. Then the number of point clouds of the data with each different illumination value is obtained using the Photoscan application. The numbers of point clouds by illumination value are analyzed to find the most efficient illumination value. The average illumination value of the pictures in this illumination value is determined. Finally, the illumination value that received the largest number of point clouds is determined.

For photographing, the combinations of aperture and shutter speed of F8 and 1/6000, F13 and 1/2000, F22 and 1/200, and F22 and 1/500 were used. A total of 40 pictures were taken with 10 pictures for each combination in Test1, and a total of 96 pictures with 24 pictures for each combination in Test2. The ground was marked every 3 m and the accurate position of the UAV to the vertical direction was verified. In Test1, the front view of the southward building was photographed to check the variation of illumination. In Test2, another building was photographed in two directions for comparison. The picture data of each environment and different illumination value were classified by aperture and shutter speed values. A total of four illumination values of F8 and 1/6000, F13 and 1/2000, F22 and 1/200, and F22 and 1/500 were used in this study. The average illumination distribution and average illumination value were determined for each group of pictures. The average illumination was converted to brightness value. The point cloud value of the classified picture data was created using the Photoscan application.

4.2 Number of point cloud for performance evaluation

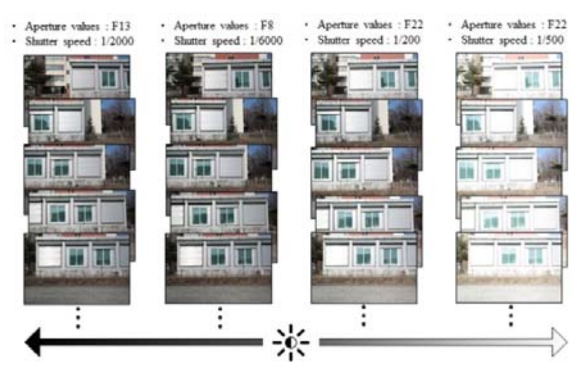


Figure 3. Data classification for data conversion

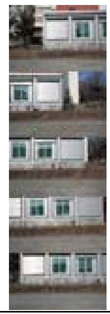
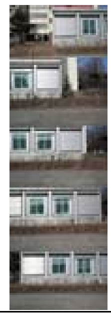
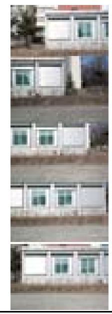
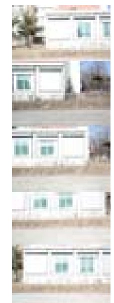
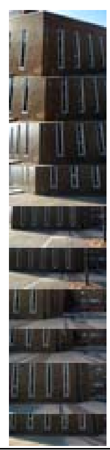
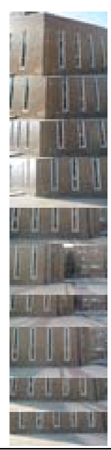
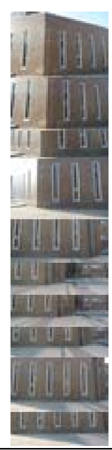
The brightness was analyzed and presented as lux value to standardize the brightness results according to the aperture and shutter speed values. The brightness values for F13 and 1/2000, F8 and 1/6000, F22 and 1/500, and F22 and 1/200 were 100lx, 120lx, 150lx, and 200lx. The number of cloud point values for each brightness in Test1 was 1269 for F13 and 1/2000, 1059 for F8 and 1/6000, 1180 for F22 and 1/200, and 1349 for F22 and 1/500. In Test2, it was 12339 for F13 and 1/2000, 11320 for F8 and 1/6000, 11639 for F22 and 1/200, and 12050 for F22 and 1/500.

4.3 Results

The final results were analyzed. The number of generated point clouds for the shutter speed 1/2000, aperture value of F13, and the average brightness (lux) of 100lx was 1,269 in Test1 and 12,339 in Test2. The number of generated point clouds for the shutter speed 1/6000, aperture value of F18, and the average brightness (lux) of 100lx was 1,059 in Test1 and 12,339 in Test2. The number of generated point clouds for the shutter speed 1/500, aperture value of F22, and the average brightness (lux) of 150lx was 1,180 in Test1 and 11,639 in Test2. The number of generated point clouds for the shutter speed 1/200, aperture value of F22, and the average brightness (lux) of 200lx was 1,349 in Test1 and 12,505 in Test2 (Table 5).

Consequently, the number of point clouds of 2D image data for 100lx and 200lx were greater by about 11% over the point cloud count by about 11% than the number of point clouds of 2D image data for 120lx and 150 lx.

Table 5. Results of number of point cloud

Shutter speed (sec)	1/2000	1/6000	1/500	1/200
Aperture values	F13	F8	F22	F22
Average brightness(lux)	100	120	150	200
Pixel	157464	157464	157464	157464
Test 1				
Number of point cloud	 1,269	 1,059	 1,180	 1,349
Test 2				
Number of point cloud	 12,339	 11,320	 11,639	 12,050

5 Conclusions

In this study, hypotheses for the 3D modeling of 2D images were defined and verified to analyze accuracy. It was demonstrated that the accuracy of 3D modeling can be increased by analyzing the changing number of point clouds according to the illumination value of 2D images. In conclusion, this study revealed that illumination and point cloud generation are correlated. However, this study was insufficient in the research of buildings and topographies with more diverse conditions, and in the use of more various types of equipment. More in-depth analysis will be possible if more diverse parameters and detailed RGB analysis are added.

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