Roof Slope Calculation by the Shape of Building through Utilizing UAV

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Abstract

In order to utilize the roof space of the building, correctly calculated roof area is required. However, existing calculation methods of roof area have problems such as the hassle of on-site measurements and use of the calculation formula which has an incorrect element. Therefore, this study conducted a basic research to establish a faster and more accurate calculation method compared to the traditional calculation method by utilizing UAV. Aerial photographs of the target site were obtained by using UAV and Orthophoto and DEM were generated based on this. Among 54 investigation target buildings, 41 buildings were classified by the roof shape of buildings, except for 13 buildings with a flat roof. Also, the roof slope of 41 buildings was measured by applying the Slope of ArcMap to generated DEM.

Keywords: UAV, 3D Modeling, Roof Slope, DEM, ArcMap

1. Introduction

1.1. Background and Purpose of the Research

Since the development of CGIS in the 1960s, application of GIS field has been gradually expanded such as Land Information System(LIS), Urban Information System(UIS), Surveying Information System(SIS), etc. Although currently researches using GIS have been actively conducted and the need for roof utilization increases, it's a situation that the study on the roof area which becomes basic data for roof utilization is still insufficient. In existing roof area measurement method, there's a hassle that target buildings need to be measured individually through on-site measurements. Also, in the way of using a calculation formula, there's an issue in accuracy as the roof slope is roughly estimated. Therefore, this is a basic research to establish a faster and more accurate calculation method compared to the traditional calculation method. The roof slope which is an output element of the roof area calculation is measured by generating Orthophoto and DEM based on aerial photographs acquired by utilizing UAV.

1.2. Research Method and Scope

In order to perform this study, aerial photographs of buildings in the target site were taken by using UAV and Orthophoto and DEM were generated based on this. Based on obtained maps and Orthophoto of the target site, roof types Plan type of buildings were classified and survey on buildings were conducted. As a follow-up of this, slopes were formed on DEM of the target site by using ArcMap so that the slope for each shape of buildings was measured. A flow diagram of study is shown in Figure 1.

Figure 1. Flowchart of Research

2. Theoretic Consideration

2.1. Overview of UAV

UAV refers to an aircraft which flies automatically without a pilot in the aircraft according to the program made in advance or a pilot controls it remotely from the ground and a system which aircraft need to fly. [1] UAV has been utilized in various fields, such as construction, broadcasting, environment, military, etc. and research on photogrammetry using a UAV in the spatial information field also has been actively in progress. Also [3] application researches using UAV which has a low operation cost, as aerial measurement equipment instead of [2] the traditional expensive aerial mapping system and its accuracy assessment have been actively conducted [4].

2.2. Overview of GIS

Regarding GIS, CGIS was developed for the first time for resource management in Canada in the 1960s. GIS is an information system to collect, observe and measure geographic information, convert to computer data and utilize effectively it. [5] While GIS is being developed, the study of application plans in numerical geologic map, topography, satellite data, etc. is underway in a wide range of fields. [6] The contour accuracy of mountains and hills are analyzed and the terrain slope measurement [8] through DEM [7] and measurement study of the amount of soil erosion by using the flow and coast slope [9] have been in progress. However, it's a situation that the study on building roof which is considered to be used mostly is insufficient.

3. Aerial Photography and Orthophoto of the Target Site and DEM Generation

3.1. Overview of the Target Site and Aerial Photography

The area of 137 to 141 street, Namsan-dong, Jung-gu, Daegu which is the class 3 of general residential area where the overall renovation is needed due to its old buildings in the area and it's difficult to measure the actual roof area was selected as a target site in this study. The area of the target site is 11,500 m² and 54 buildings based on the building registers were investigated in the area.

Figure 2. Target Area of Study (Source: Google Map)

For the aerial photography of the target site, automatic flight path of UAV was set up by utilizing the Mission Planner. The aerial photography range is 16,540 m² and a total of 110 aerial photographs were obtained by setting 140m for UAV flight altitude. The flight plan and aerial photographs were shown in Figure 3.

Figure 3. Flight Plan and Aerial Photograph

3.2. Orthophoto and DEM Generation of the Target Site

PhotoScan S/W made by Agisoft was used to generate Orthophoto and DEM based on obtained aerial photographs. Regarding the order of operation, it was carried out in the order of Align Photos - Build Dense Cloud - Build Mesh - Build Texture. Positioning the camera is made by sorting pictures taken in Align Photos

stage. Build Dense Cloud operation calculates the depth information to generate into a single Dense Cloud based on the position of the camera. 3D modeling is created by mesh after Build Dense Cloud operation and after that, the original image was mapped on the generated mesh through Build Texture operation. In Figure 4 and Figure 5 images after each operation, Orthophoto and DEM of the target site are shown.

Figure 4. Images after each Operation

Figure 5. Orthophoto and DEM of the Target Site

4. Classification of Building Roof Shape and Slope Measurement

4.1. Classification of Building Roof Shape and its Status

Based on the generated Orthophoto and maps of the target site, building roofs in the area were classified by shape. The roof type is classified into single type and hybrid type depending on its shape and they are further classified in detail by design. The single roof type of 54 buildings in the target site includes Dutch Gable, Flat, Gable and Hip and the hybrid includes Dutch Gable + Flat, Gable, Hip, Gable + Gable and Hip + Hip. In addition, they are classified into I, U, and L types

depending on roof's Plan Type. The status of building roof shape in the target site is shown in Table 1.

Table 1. The Status of Building Roof Shape in the Target Site

Roof Type	Design of Roof	Number of Building	Plan Type	Number of Building
Roof	Single	Dutch Gable	I	5
			L	14
			U	1
	Single	Flat	I	13
			I	6
			L	1
	Single	Gable	I	2
			L	3
	Single	Hip	I	2
			L	3
hybrid	hybrid	Dutch Gable + Flat	L	1
		Dutch Gable +Gable	L	2
		Dutch Gable + Hip	L	3
		Gable + Gable	I	2
		Hip + Hip	L	1

4.2. Slope Measurement of Building Roof

Slope was measured based on Orthophoto and DEM. After a polygon of roof shape is formed based on the Orthophoto, roof slope was measured by utilizing the Slope(Spatial Analyst) in ArcMap. The roof slope was measured at six points of the respective roof surface and through the arithmetic average it was calculated for the mean value of the slope for roof surface. The process for the measurement of roof slope was shown in Figure 6.

Figure 6. Workflow of Roof Slope Measurement

Roof slopes of buildings in the target site were measured based on the pictures obtained through UAV. Measured slope values of each shape are shown in following Table 2, 3, 4, 5 and 6.

Table 2. Roof Slope of Single Type U (Unit: °)

No.	Type	Design of Roof	Plan Type	A	B	C	D	E	F	G	H
1	Single	Dutch Gable	U	37.62	29.92	25.92	26.53	31.20	31.74	30.77	38.34

Table 3. Roof Slope of Single Type I (Unit: °)

No.	Type	Design of Roof	Plan Type	A	B	C	D
1	Single	Dutch Gable	I	31.77	37.91	25.76	28.69
2	Single	Dutch Gable	I	27.00	28.48	35.64	31.06
3	Single	Dutch Gable	I	26.07	26.32	34.91	29.58
4	Single	Dutch Gable	I	25.09	27.71	36.97	31.91
5	Single	Dutch Gable	I	26.77	23.80	31.69	32.67
6	Single	Gable	I	31.42	27.26		
7	Single	Gable	I	21.87	23.29		
8	Single	Gable	I	24.73	22.65		
9	Single	Gable	I	15.62	15.12		
10	Single	Gable	I	35.04	35.13		
11	Single	Gable	I	13.99	17.15		
11	Single	Hip	I	22.68	21.01	25.11	21.52
12	Single	Hip	I	29.69	28.00	27.51	29.77

Table 4. Roof Slope of Single Type L (Unit: °)

No.	Type	Design of Roof	Plan Type	A	B	C	D	E	F
1	Single	Dutch Gable	L	29.03	36.82	31.77	29.16	34.20	32.32
2	Single	Dutch Gable	L	35.93	31.92	32.01	30.41	30.84	32.79
3	Single	Dutch Gable	L	30.27	41.05	35.36	31.68	34.68	36.78
4	Single	Dutch Gable	L	27.54	31.39	28.21	27.36	31.11	31.14
5	Single	Dutch Gable	L	35.25	30.57	32.08	38.20	33.45	34.69
6	Single	Dutch Gable	L	28.53	31.92	30.1	30.96	32.3	14.63
7	Single	Dutch Gable	L	29.37	21.13	22.21	25.79	28.93	28.00
8	Single	Dutch Gable	L	33.45	24.12	27.68	26.81	22.99	27.79
9	Single	Dutch Gable	L	29.17	31.88	33.16	34.79	36.36	31.64
10	Single	Dutch Gable	L	36.42	31.61	27.24	29.74	32.05	36.93
11	Single	Dutch Gable	L	28.73	23.09	30.07	28.16	26.31	27.10
12	Single	Dutch Gable	L	31.79	22.23	26.87	24.07	24.49	28.33
13	Single	Dutch Gable	L	30.64	28.18	27.02	28.24	29.92	29.62
14	Single	Dutch Gable	L	31.74	34.69	30.35	30.50	33.64	33.46
15	Single	Gable	L	15.74	13.43	12.35	12.11		
16	Single	Hip	L	31.75	38.90	32.06	28.98		35.48
17	Single	Hip	L	34.03	28.42	17.48	18.83		24.24
18	Single	Hip	L	28.64	29.15	24.56	27.25	27.90	40.09

Table 5. Roof Slope of Hybrid Type I (Unit: °)

No.	Type	Design of Roof	Plan Type	A	B	C	D
1	hybrid	Gable + Gable	I	23.55	23.82	24.58	22.61
2	hybrid	Gable + Gable	I	36.01	26.04	26.93	25.22

Table 6. Roof Slope of Hybrid Type L (Unit: °)

No.	Type	Design of Roof	Plan Type	A	B	C	D	E	F	G	H
1	hybrid	Dutch Gable + Flat	L	24.65	27.44	29.62	20.85				
2	hybrid	Dutch Gable + Gable	L	25.30	27.86	19.58	19.46		30.53	32.36	
3	hybrid	Dutch Gable + Gable	L	25.16	21.91	25.59	25.39		27.02		
4	hybrid	Dutch Gable + HIP	L	39.86	30.11	27.07	29.44		28.46	34.86	
5	hybrid	Dutch Gable + Hip	L	27.25	33.31	28.95	24.71		31.36	31.53	
6	hybrid	Dutch Gable + Hip	L	33.26	33.02	34.39	29.65		27.45	29.60	
7	hybrid	Hip + Hip	L	18.96	22.44	21.28	19.90		20.71	20.66	25.54 27.21

5. Conclusion

In this study, Orthophoto and DEM are generated based on aerial photographs obtained by utilizing UAV. Buildings in the target site were classified by Shape of Building by utilizing Orthophoto and map of the target site and then were measured. The results of this study are as follows.

First, aerial photographs of the target site were obtained by utilizing UAV and Orthophoto which shows the elements of the building roof was generated based on this.

Second, roof types were clarified based on the Orthophoto of the target site. Regarding the status of buildings in the target site, it was classified into 5 buildings of Dutch Gable I, 14 buildings of Dutch Gable L, 1 buildings of Dutch Gable U, 13 buildings of Flat I, 6 buildings of Gable I 6, 1 buildings of Gable L, 2 buildings of Hip I, 3 buildings of Hip L, 1 buildings of Dutch Gable + Flat L, 2 buildings of Dutch Gable + Gable L, 3 buildings of Dutch Gable + Hip L, 2 buildings of Gable + Gable I, and one buildings of Hip + Hip.

Third, the roof slope of buildings in the target site was measured by utilizing DEM based on classified roof elements and from this, the roof slope of buildings in the target site was measured by using UAV. The roof area calculation method conducted in this study is believed to be used as basic data in the future for the roof area calculation formula which is needed for the exact roof area calculation to take advantage of roof such as BIPV and RWH system installations.

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