FLOODING MONITORING AND FLOOD INUNDATION ANALYSIS UGING UAV

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***Abstract*— The prompt flood monitoring could provide fast response and damage assessment. In this study, topographical data is constructed using UAV in order to estimate area or depth in flooding in advance. And flooding monitoring was conducted in flood season. And, the topographical data was used as basic input data for the flood inundation simulation. This study presents a series of processes for creating topographical data through UAV, monitoring floods, and verifying comparisons with the results of numerical models.**

Keywords—UAV; DSM; flooding monitoring; FLUMEN

I. INTRODUCTION

Annual floods cause a lot of human and property damage, and there is a huge economic loss in flooded area. Therefore, the forecasting, prevention, detection, monitoring, and flood damage assessment are of paramount importance for public authorities and people [1]. Flooding damage assessment in Korea is being investigated through a trace of flooding after flood, and then flood damage is calculated. The prompt flood monitoring could provide fast response and damage assessment. In this study, topographical data is constructed using UAV in order to estimate area or depth in flooding in advance. Recently, many studies to create three-dimensional terrain data using unmanned aerial vehicles (UAVs) have actively been conducted in the spatial information field. A UAV is equipped with a GPS and an inertial navigation system (INS), sensors for acquiring location and position information, and a camera for capturing images. In addition, UAV devices capable of conducting virtual reference station (VRS) surveys have been used in recent projects, allowing for faster terrain modeling. This study was conducted flooding monitoring through UAV. And, the topographical data was used as basic input data for the flood inundation simulation. This study presents a series of processes for creating topographical data through UAV, monitoring floods, and verifying comparisons with the results of numerical models.

II. STUDY AREA

The target area is about 1.0-km length of Nonsan river, a branch of Geum River in South Korea. The length of Nonsan river is 55km, watershed area is 665 ㎢.

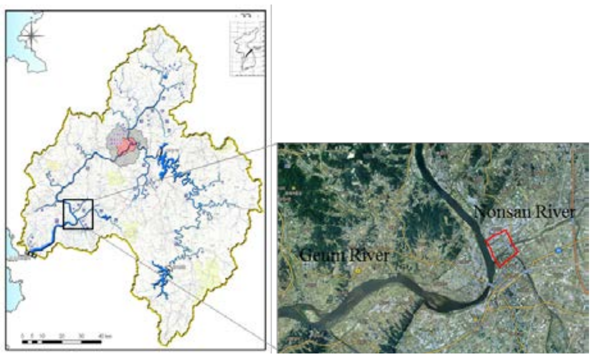

Fig. 1. Ground Control Point Survey

III. CREATION OF DSM DATA BY UAV

A. Ground control point survey

Images acquired from UAV photography use the WGS84 UTM coordinate system by default. To convert them into the GRS80 TM, a geodetic coordinate system used in Korea, a survey of ground control points (GCPs) requires. A total of six points for the GCP survey was selected. For the GCP survey, we used the virtual reference station (VRS) survey, which enables positioning based on virtual reference stations. Table 1 shows the GCP survey results acquired by the VRS survey.

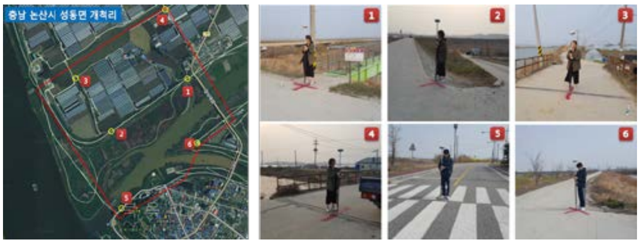

Fig. 2. Ground Control Point Survey

TABLE I. HORIZONTAL COORDINATE AND ELEVATION OF THE GCPS

No	Horizontal coordinate		EL.m
	East	*North*	
1	201365.30	397081.54	10.90
2	200920.75	396790.45	11.00
3	200714.74	397096.84	5.09
4	201244.85	397492.12	4.51
5	201057.65	396414.61	7.26
6	201440.79	396736.70	10.74

B. *Creation of DSM*

The UAV device for acquiring river terrain data was the eBee (SenseFly, Lausanne, Switzerland). The flight plan was designed with eMotion software. The lateral and longitudinal overlaps were set to be 80% and 70%, respectively. We captured a total of 877 images of the target area. The image mosaic processing used Pix4D software. Pix4D software can improve the accuracy of the three-dimensional point cloud data from the images and the GPS and INS information with a technique called "rayCloud," which ultimately creates an orthomosaic and DSM data with high reliability. Figure 3 shows the orthomosaic and DSM data created by Pix4D software. As references, the boundary and validation points for the evaluation of river terrain data accuracy are also shown in the orthomosaic.

Fig. 3.UAV device (eBee)

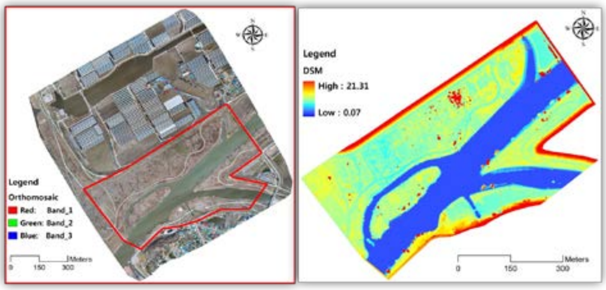

Fig. 4. Orthormosaic image and DSM

IV. FLOODING MONITORING

Flooding monitoring was conducted in 10:00AM, July 2, 2018. Although floodplain was flooded in upper site, located in Nosan observatory (located 7km upstream of the study site), study area does not flood. Inspire UAV and Sequoia sensor was used.

Fig.5. Flooding monitoring

V. FLOOD INUNDATION ANALYSIS

A. *FLUMEN simulation*

FLUMEN (FLUvial Modelling Engine) was used as inundation analysis. FLUMEN is a program for solving the depth-averaged shallow water equations on a cell-centred unstructured mesh. It allows for wet and dry domains, sub- and supercritical flow conditions and the specification of variable bed topography. FLUMEN is based on the depth-averaged shallow water equations that can be written in conservation form as

$$\frac{\partial U}{\partial t}+\frac{\partial E}{\partial x}+\frac{\partial G}{\partial y}+S=0 \tag{1}$$

with x,y = horizontal dimensions, t = time and U = (h,q,r)T = variable vector with the flow depth h and the components of the specific flow q and r. The flux vectors in x and y are

$$E=\begin{pmatrix} q \\ \frac{q^2}{h}+\frac{g}{2}h^2 \\ \frac{qr}{h} \end{pmatrix}; \quad G=\begin{pmatrix} r \\ \frac{qr}{h} \\ \frac{r^2}{h}+\frac{g}{2}h^2 \end{pmatrix} \tag{2}$$

and the source vector is

$$S=\begin{pmatrix} 0 \\ g\,h\frac{\partial z_b}{\partial x}+\frac{\tau_{bx}}{\rho} \\ g\,h\frac{\partial z_b}{\partial y}+\frac{\tau_{by}}{\rho} \end{pmatrix} \tag{3}$$

with g = acceleration of gravity, r = density of the fluid, zb = bed level, and tb = bed shear. These equations can be obtained from the Reynolds equations if hydrostatic pressure distribution is assumed. The conservative formulation of the equations remains valid in the presence of discontinuous variations of the flow variables such as hydraulic jumps.

B. Input data

DSM data was made by UAV was converted to node and poly data using Fluviz in order to provide topography data.

Also FLUMEN requires inflow and outflow boundary conditions. The inflow boundary is discharge and outflow boundary is water level. We calculated discharge and water level by HEC-RAS. The boundary conditions during 12 hours were inputted before taken UAV image.

TABLE II. INFLOW BOUNDARY CONDITIONS

No	**Inflow (discharge: m3)**	
	Inflow 1	***Inflow 2***
1	201.9	50.7
2	178.4	51.3
3	158.1	53.2
4	178.4	51.3
5	225.8	52.4
6	256.3	52.5
7	277.9	56.1
8	296.8	58.6
9	298.1	58.8
10	297.1	57.6
11	254.2	57.0
12	244.4	56.9

C. Verification between orthomosaic image and analsyis result

The orthormosaic image of flooding monitoring and result of simulation was overlaid in order to compare and verificate.

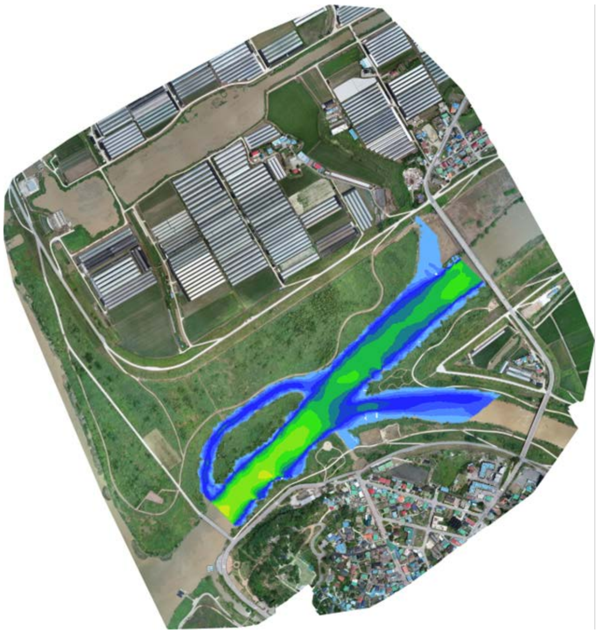

Fig. 4. Orthormosaic image and simulation results

ACKNOWLEDGMENT

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REFERENCES

[1] D. Popescu,. L. Ichim, and F. Stoican, “Unmanned Aerial Vehicle Systems for Remote Estimation of Flooded Areas Based on Complex Image Processing”, Sensors (Basel). Vol. 17(3), 446, 2017