



Unmanned Aerial Vehicle Utilization in Flood Monitoring and Simulation

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ABSTRACT

Recently, the frequency of water disaster occurrence and the scale of damage have increased due to the climate change. However, technology for effectively monitoring the flooding situation and the damage aspect is still insufficient. Since various studies are actively conducted on utilizing unmanned aerial vehicle (UAV) in the field of geospatial information, the utilization of UAV is expected to improve the timeliness and accuracy of flood monitoring. This study conducted a flood situation monitoring at Gap River on July 30, 2020 using UAVs. The comparison between the water boundaries derived from UAV images and hydraulic model simulations (FLUMEN) were performed. Results showed that the water boundaries simulated using FLUMEN only resulted to 2.85% difference with UAV images derived water boundaries. Thus, verifying that the UAV images can be used to provide supplementary data in providing spatial extents of stream variables. This study aims to introduce the technology for performing quick flood monitoring and the possibility of its utilization in flood inundation simulation.

Key words: water disaster, UAV, flood monitoring, flood inundation simulation

Introduction

Recently, the frequency of water disaster occurrence and the scale of damage increased because of heavy rainfall events caused by climate change, which led to flood damage that caused enormous human and property damages (Yu, *et al.*, 2017). Nevertheless, there are still insufficient technologies for effectively monitoring the flooding circumstances and the damage aspect. In the past, it was difficult to respond to immediate damages and to secure monitoring results with high timeliness and resolution when flood damage occurred. It was also difficult to roughly estimate the

damage until the sequential analyses (on flood marks, complete enumeration of the damage, and flood damage simulation, etc.) by the experts were completed (Jung, *et al.*, 2015).

Recently, various studies are being conducted on unmanned aerial vehicle (UAV) technology in the field of geospatial information. UAVs are equipped with GPS and inertial navigation system sensors for acquiring location and attitude information, as well as cameras for capturing images. Moreover, advanced UAV equipment that can measure virtual reference station have been recently used in some projects, which allowed performing the monitoring more rapidly (Lee, *et al.*, 2019). In the fields of water resources and rivers management, drones are used for dams, reservoir,

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and algal bloom monitoring, river topography monitoring and map generation, dangerous substance and development surveillance, and flood or drought monitoring (MOLIT, 2019). Therefore, utilization of UAV in flood monitoring is expected to improve the timeliness and accuracy of the monitoring, and its application in various fields of water resource management can be also increased. Restas (2015) suggests conducting river monitoring for flood management before, during, and after the flood events. 3D topographic data are constructed through dronography before the flood, and the flooding or water level is monitored during the flooding period. Finally, the monitoring is conducted to estimate the cost of restoration after the flooding period is over. Salmoral, *et. al.* (2020) suggested a guideline for utilizing unmanned aircraft systems in flood risk management. Karamuz, *et. al.* (2020) tried to use UAV images to update the boundary conditions of the hydrodynamic model used. Feng, *et. al.* (2015) also mentioned that UAV can be used to capture images of flooding areas for reviewing the accuracy of flood inundation mapping and suggested the possibility of using UAV for monitoring urban flooding. Perks, *et. al.* (2006) ratified the use of Kande-Lucas-Tomasi (KLT) algorithm to track features visible on water surfaces using UAVs to determine stream velocity. In Korea, guidelines for flood monitoring technology using UAV are often presented (Jung, 2016; Jung, 2020), but there are few cases where the technologies are actually applied in the field.

This study aims to introduce the technology for performing quick flood monitoring based on the UAV and suggest the possibility of generating topographic data by utilizing UAV at a river, as well as the possibility of its utilization in flood inundation simulation.

Methodology and Results

Development of UAV technology for flood monitoring

To immediately identify the area and scale of damage caused by flood, a UAV that can fly in rainy conditions before the flooding stops, and can shoot images at a certain wind speed is required. Thus, a UAV, which is operable during the flooding period, was developed in this study (<Figure 1>). Additionally, to estimate the damaged area by flood, a sensor board equipped with an RGB and NIR (Near Infra Red band) camera as an optical sensor, a near infrared red band sensor excellent for distinguishing the boundary between water body and land, and an IR (Infra Red) camera for shooting images at night was developed (<Figure 2>). The

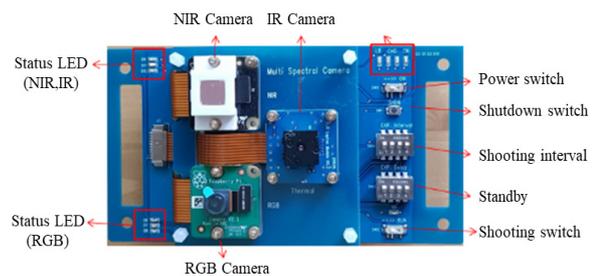
developed sensor board was installed on a commercial UAV to monitor the water body without temporal and spatial constraints (<Figure 3>).

Construction of topographic data before the flood period

The images taken by an UAV can not only display the flood events immediately but also can be utilized in studies on river changes by constructing topographic data before and after the flood period. In this study, the topographic data was constructed through photographing before the flood period to understand the situations during the flood events at Gap River (from Gasuwon Bridge to ~2 km downstream) and to compare the situations during and after the flood event. After establishing a flight plan (overlap,



<Figure 1> The developed UAV for flood monitoring



<Figure 2> The developed sensor board



<Figure 3> The sensor board installed on a commercial UAV

sidelap, resolution, etc.), the images at the study site were captured using the UAV (<Figure 4>) and accurate coordinates were obtained through ground control point (GCP) surveying (<Figure 5>). The collected images were converted from WGS84 UTM coordinate system to GRS80 TM coordinate system based on the GCP surveying results. Using Pix4D software, and ortho images, as well as DSM (Digital Surface Model) data were constructed (<Figure 6> and <Figure 7>). Additionally, using the method presented by Lee, *et. al.* (2019), the DEM (Digital Elevation Model) that can be utilized in river surveying was generated through the slope evaluation technique based on the point cloud data acquired from UAV images (<Figure 8>).

Flood monitoring

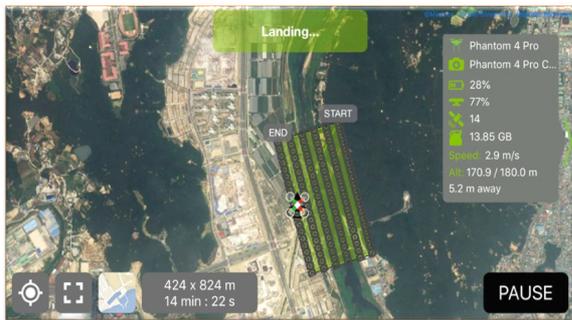
A flood monitoring manual was produced for UAV photography. Manuals for the sensor board, video shooting, and video uploading were distributed to provide information for experts with UAV licenses before flood monitoring. The developed sensor board was packaged

for distribution and provided together with each manual to the experts. Then, the experts were able to perform monitoring at the study site using the UAV, equipped with the sensor board, and upload the monitoring images to the platform server to provide quasi real-time videos.

On July 30, 2020, a flood warning was anticipated at Gap River in Daejeon due to a heavy rainfall of up to 100 mm per hour in the Daejeon area. The water level of the river recorded the highest in the history of the gauging station's data. On July 30, the sensor board was installed on the MAVIC 2 Pro and the flood monitoring was conducted at the study site from Gasuwon Bridge to Doan Bridge (<Figure 9>). The captured images and topographic data were created through the Correlator 3D software based from the images taken.

Flood Inundation Simulation

The topographic data generated from the UAV images can be utilized in the simulation of flood inundation of the river. Topographic



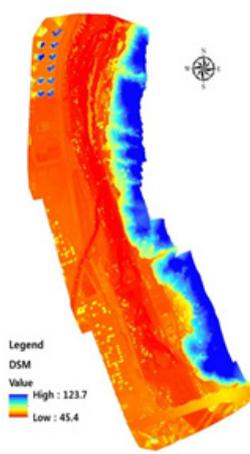
<Figure 4> Flight plan establishment



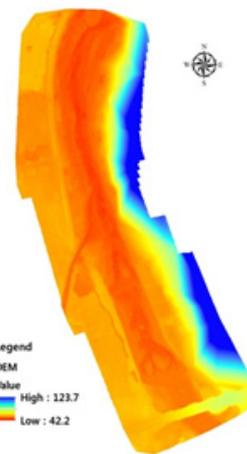
<Figure 5> Ground control point surveying



<Figure 6> Ortho image



<Figure 7> DSM (Digital Surface Model)



<Figure 8> DEM ((Digital Elevation Model)



<Figure 9> UAV monitoring image
(top: captured images of the video, bottom: matched ortho image from Gasuwon Bridge to Doan Bridge)

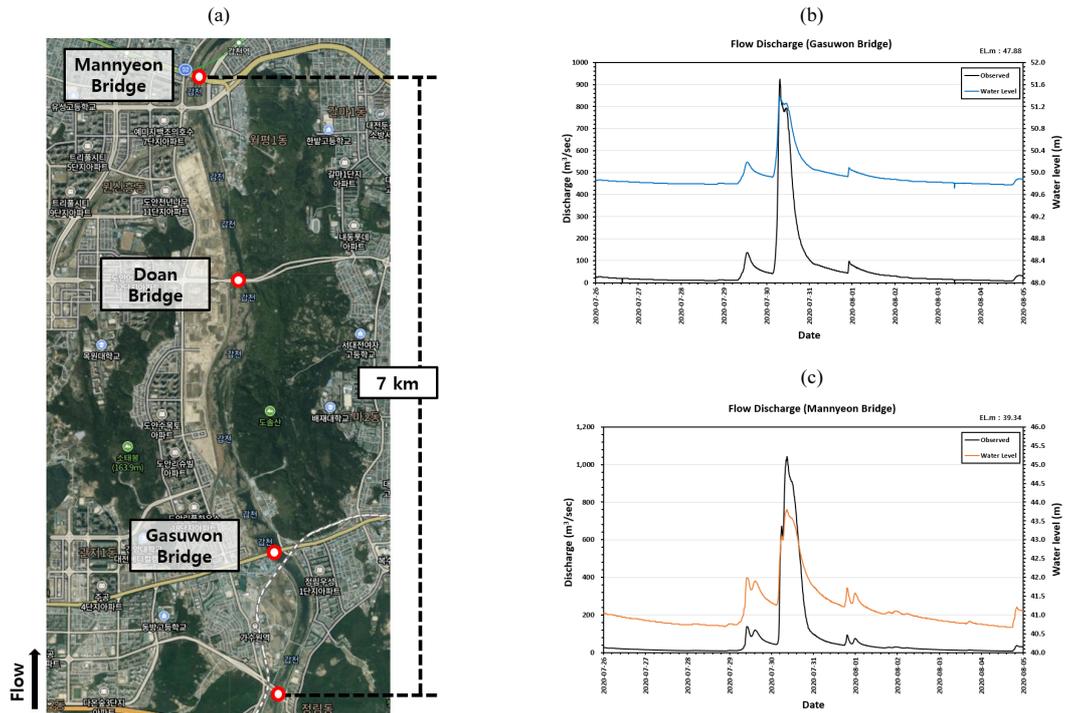
data is essential for flood inundation simulation to predict the flow, and extents of the flood inundation in the river. However, survey data from the basic plan for river maintenance were previously used, which are produced once in every 10 years. The survey data not only has a long data generation cycle but also conducts the survey at 200-m intervals in the case of cross-section; it cannot be considered the detailed topographic changes of the river. Thus, if the topographic data constructed using UAVs can be used, essential information with the resolution of 1m or less can be obtained at a desired time. Moreover, it can play a role of a mutual calibration that compares the numerical simulation with the actual UAV image to verify the accuracy of the image and calibrates the simulation data.

In this study, FLUval Modeling ENgine (FLUMEN), a two-dimensional flood inundation analysis model, was used to conduct numerical simulation. The FLUMEN model was developed by Beffa (2010) of Switzerland, and is now being used as an inundation analysis model in many countries (Shin, *et. al.*, 2019). The FLUMEN model is a two-dimensional model that uses a depth-averaged shallow water equation with unstructured grids and is proficient in modeling hydraulically complex areas such as river meanders and confluence areas (Shin, *et. al.*, 2019). In Korea, flood risk maps are made by FLUMEN model. The study site is a 7-km section that includes Gasuwon Bridge and Mannyeon Bridge on Gap River (<Figure 10> (a)) including the image recording sites. The topographic data of FLUMEN was generated by calibrating the generated DEM with the existing LiDAR survey data. The boundary conditions of the subject site were set using the water level and discharge

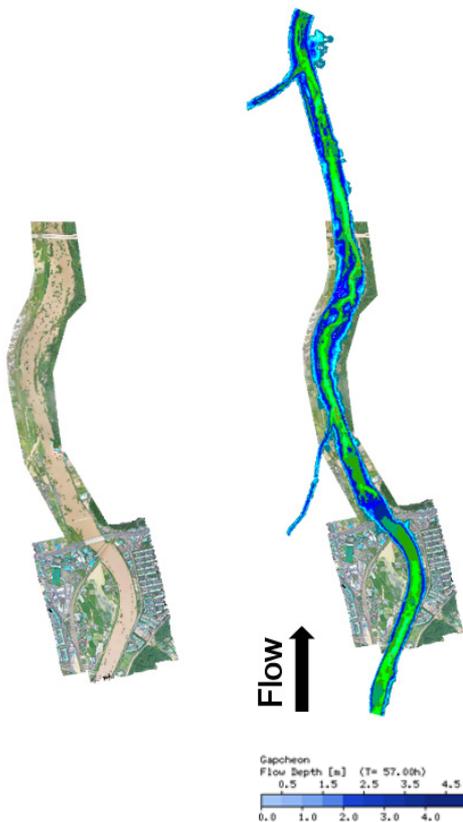
from the gauging station installed at the Gasuwon Bridge (upstream boundary) and Mannyeon Bridge (downstream boundary) from 12 a.m. on July 29 to 12a.m. on August 2 (<Figure 10> (b), <Figure 10> (c)). <Figure 11> shows the result of comparing and verifying the UAV flood monitoring image taken at 12 p.m. on July 30, 2020 with the result of the FLUMEN simulation conducted simultaneously on plans. Based from the comparison of water boundaries determined from UAV images, and FLUMEN simulations from Gasuwon Bridge to Doan Bridge, the areal error was determined to be 2.85%, which was calculated by overlaying both water boundary layers in GIS.

Conclusions

This study performed flood situation monitoring using UAVs. The water boundary from UAV images were extracted to serve as an observed data, which was used to validate the results from hydraulic modeling simulations. Based from the results of this study, UAV derived flood monitoring images can be used as supplementary data to the existing available information such as, water level, stream discharge, and CCTV images, which are only known for specific points known as stream gauging stations. Which supports the claims of Feng, *et. al.* (2015), which suggested that the use of UAV can be used to determine the accurate extent of the inundated areas, which is an ideal platform for flood monitoring.



<Figure 10> Flow data used for the study site (a) and the boundary condition of discharge and water level used model (Gasuwon Bridge (b), Mannyeon Bridge(c))



<Figure 11> Comparison of the ortho image (a) and the simulation result (b)

UAV technology can significantly reduce the survey time compared to the existing survey system, which was mainly performed manually, and also respond to disaster sites where it is difficult to access or perform the survey (Jung, 2019). While flood monitoring by satellite images and field survey was quite restricted because of meteorological and topographic conditions, UAV-based flood monitoring can conduct the monitoring and estimate the flooding areas in quasi real-time. Particularly, it is expected that the UAV image data can be used to analyze flooded areas and estimate the amount of damage to effectively support flood control tasks such as rapid DB construction, damage amount calculation, and compensation work.

Also, it can be utilized as verification and calibration data of the flood analysis model used for flood prediction and evaluation. In vice versa, the flood analysis model can be also used to determine the accuracy of the collected UAV flood monitoring images. Therefore, if the verification system and method are established between the floor analysis model and the UAV images, it can also contribute to the field of the flood analysis model.

However, according to Aviation Safety Act, a person who intends to perform flight operation using the UAV in the restricted areas or at an altitude of 150 m or higher shall obtain “aviation permit for dronegraphy” for the flight operation from the Ministry of Defense, or the military unit of the area, as well as go through “flight approval” procedure of the Regional Aviation Administration.

In general, it takes 7 days to obtain the aviation permit for drone photography and 3 days to go through the flight approval (Jung, 2016). Thus, it needs system and its modification to ease or supplement the legal system to improve the utilization of drones in the field of disaster.

In the future, it is also necessary to build a system or achieve technological enhancement for securing and transmitting real-time images based on autonomous driving, LTE communication and cloud server operation, and to utilize the drones in national institutions, such as Flood Control Center, for the flood monitoring. Additionally, flood monitoring technology utilizing UAV can improve the timeliness and accuracy of the flood tracking surveys compared to the previous surveys and contributes to rapid decision-making and response capability.

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