HIERARCHICAL MULTI-SENSOR APPROACH FOR THE ASSESSMENT OF FLOOD RELATED DAMAGES

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KEY WORDS: SAR Imagery, UAV, Close Range Photogrammetry, Flood Analysis

ABSTRACT:

Flood-related disasters have been most serious and frequent in Korea, causing substantial suffering, severe loss of life, and economic damage. It is important to determine quickly the extent of flooding and estimate the damages during extreme cases. Even though Synthetic Aperture Radar (SAR), an active sensor, is highly applicable to flood monitoring owing to its sensitivity to the water area, detail information about damages is not easily extractable. Additional information such as from high resolution optic senor can be utilized to get detailed information needed to estimate the cost of flood damages. For this we utilized a spatial hierarchical approach to quickly estimate the flood related damages. SAR imagery, Unmanned Airborne Vehicle (UAV) imagery, and terrestrial photogrammetric method are used to estimate the flood related damages. We not only checked the accuracy of each sensor in a different occasion but also checked multi-sensor over a same site. As a result, overall accuracy is within the permitted accuracy for the flood analysis. The hierarchical scheme of utilizing the satellite imagery, UAV imagery, and ground-based observation suggested in this study for the estimation of flood-related damage can be the solution for the flood-related estimation of the damages. And this approach could save a lot of governmental money for recovering the damage due to its relatively very high accuracy compared to the current manual approach.

1. INTRODUCTION

Disaster monitoring using remote sensing technique has been frequently investigated by many researchers (Alsdorf et al., 2001; Liu et al., 2002). Three major disasters – flood, land slide, and forest fire - caused huge economic damages and severe loss of life in Korea. Among three major disasters flood is one of most serious and frequent disaster in Korea. Each summer typhoon brings a lot of precipitation in a short period of time, causing a lot of flood-related damages. For example, average damage due to flood between 1995 and 1999 was about 972 million dollars. The damages had been tripled between 2000 and 2004.

Huge increase amount of damages seems due to increase of human-related activities and global warming. Usually it requires lots of human power to estimate various damages such as privately owned properties and public properties. If the government only investigate the damages of public properties such as river, road, bridge, railroad, and so on, it sometimes took more than a year. Since Korean peninsula annually suffers flood-related disaster, it is urgent to have a fast, accurate, and economic method and procedure.

One more thing to remember is that we cannot obtain all the necessary information using a single sensor to investigate a variety of damages. The optimal combination of remote sensors may require for the investigation of flood-related damages. In this research we challenged combination of sensors to cover scale changing damages and checked the accuracy of each approach using a test-bed site.

2. HIERARCHICAL MULTI-SENSOR APPROACH

2.1 Scale-dependent Approach

Since a single sensor cannot cover scale-dependent damages, we proposed a so called hierarchical multi-sensor approach. Figure 1 shows the schematic diagram of our approach. Two things are to be considered for the effective damage investigation using remote sensors. First thing to consider is the ground coverage area. Second thing to consider is the detailness of the information.

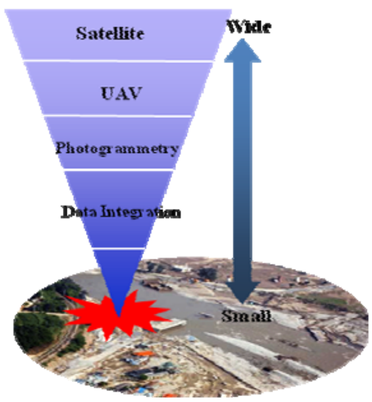


Figure 1. Layers for acquiring damage information

As shown in Figure 1, satellite data are used for the analysis of wide area, close range photogrammetric approach is used for the smaller area, and UAV (Unmanned Aerial Vehicle) data is utilized for the intermediate area. For the satellite data, we propose to use SAR (Synthetic Aperture Radar) imagery. For UAV we propose to use HD digital camcorder. And for close range photogrammetry, we propose to use off-the-shelf digital camera.

2.2 Wide-Area Flood Monitoring Using SAR imagery

In the previous section 2.1 we provided general approach for disaster monitoring. In this section the detail approach for each sensor is explained. For the wide area, we utilized satellite SAR imagery. Figure 2 shows approach for using SAR imagery and additional information such as digital map, land use map, and DEM (Digital Elevation Model) for wide area flood monitoring.

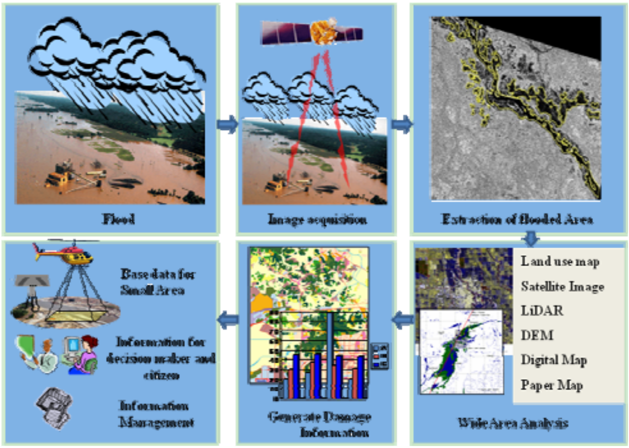


Figure 2. Wide area analysis concept by satellite SAR imagery

The reason we are using SAR is that its ability to penetrate cloud cover and its day and night imaging capability. We assumed we can obtain SAR imagery when the flood is occurring. Critical step for using SAR imagery is georeferencing. Since it is difficult to obtain GCP (ground control point) from SAR imagery, it is important to reduce the number ground control point without losing the accuracy of georeferencing. Sohn and others (2004) proposed a method to use a single ground control point to get similar accuracy with nominal number of ground points.

Once accurate georeferencing is done, SAR imagery during flood and SAR imagery before or after flood is compared. Since 70% of Korean peninsula is covered with mountains, it is not easy to differentiate water area and shadow area. The detail step for efficient water area classification over a mountainous area is explained in Song and others (Song et el., 2007).

The further analysis of automatically extracted flooded area is done using existing land use map or other source of information. It is possible since we are using georeferenced SAR imagery throughout the analysis. From this we can create approximate information about damages such as area, type of land use, and public sector or private sector. Figure 3 shows example of extracted flooded area and its comparison with existing land use map. Due to its resolution SAR imagery is only used for appropriate damage analysis. But this is still very helpful step for decision maker to send crew members for the detail analysis.

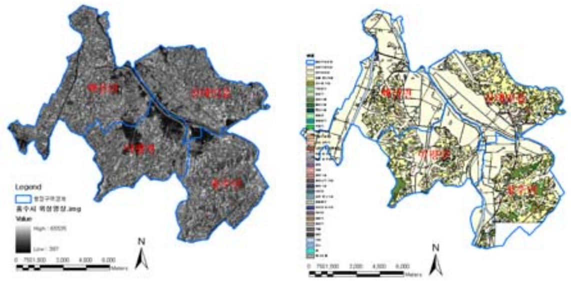


Figure 3. Overlay with flooded area and existing land use map during flood August 3rd, 2005 in Jung-up, Korea

2.3 Intermediate Area Flood Monitoring Using UAV

Due to its mobility and inexpensive platform UAV would be beneficial in many fields (Siribodhi, 2001). For the flood monitoring of intermediate area, UAV equipped with digital HD video camera is used for our study. Figure 4 shows UAV system we used for the intermediate area flood monitoring. It is Yamaha RMAX L18 with GPS. It can fly about an hour. We designed our own camera gimbals as shown in Figure 4.

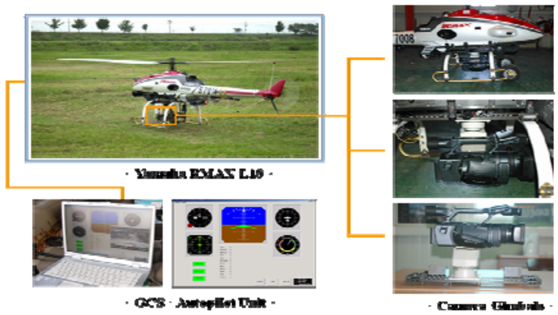


Figure 4. UAV system used for intermediate area analysis

With the previous information obtained from SAR imagery UAV is the powerful alternatives to improve the weakness of satellite remote sensing systems. These kinds of filed observation are suitable not only for real time flood monitoring, but also useful for getting in-situ local ground truth data to calibrate or compensate satellite data, by upgrading the systems with flight control and navigation subsystems, camera pointing control subsystems.

Figure 5 shows the captured two different video images obtained from our UAV system. The near-vertical video data were acquired from the UAV-helicopter mounted SONY DSR-PD150 camcorder at 500m altitude. It is only one frame shot out of 30 frames per second.

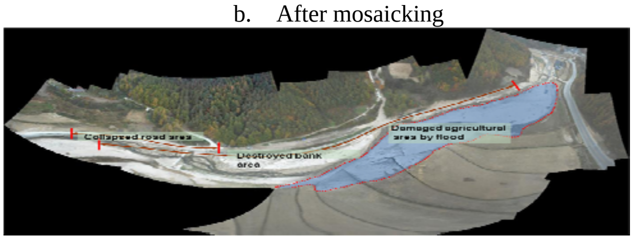
Figure 5. Video image captured the day after flood

A series of images were taken in an unstable geometric condition because the camera mounted UAV rolled over in the direction of flight due to air current. Thus the imagery acquired from UAV needs geo-referencing via geometric matching between an acquired images pixel and GCPs from a digital map or GPS (Global Positioning System) survey. The preprocessed imagery was geo-referenced with affine transformation using GCPs extracted from digital topographic map of the study area. Since detailed explanation of the image processing and noise removal is out of scope for this research, we want to skip the procedure.

Figure 6a shows the image before mosakcing several sequence of UAVvideo frame. Georeferencing and mosaicking were performed for the selected still frames.

a. Before mosaicking

b. After mosaicking



c. Actual damage analysis

Figure 6. Twenty eight still frames for flood damage area

Using the mosaicked image of Figure 6b, we could identify the detailed information of flood related damages (Figure 6c). The total length of collapsed road was 58 m, the total length of destroyed bank was 330 m, and the total area of agricultural land due to inundated water was 16,645 m^2.

2.4 Small Area Flood Monitoring with Close Range Photogrammetric System

In the previous two sections in 2.2 and 2.3, we explained damage analysis areal basis. This section is about using close range photogrammetric system on the ground basis. It is well-known fact that close range photogrammetric system can obtain reliable accuracy. Figure 7 shows our close range photogrammetric system for the quick flood analysis. Since it is important to get fast and accurate information, we fixed the baseline and orientation of the camera body. The reason for designing system like this is that the personnel who are going to use the system are governmental officer.

Figure 7. Close range photogrammetric system using amateur digital camera

We checked accuracy of our system and it is less than 50 cm, which is good enough for the quick flood monitoring. Figure 8 shows the result of our system for flood analysis. Actually several images are merged together for the analysis.

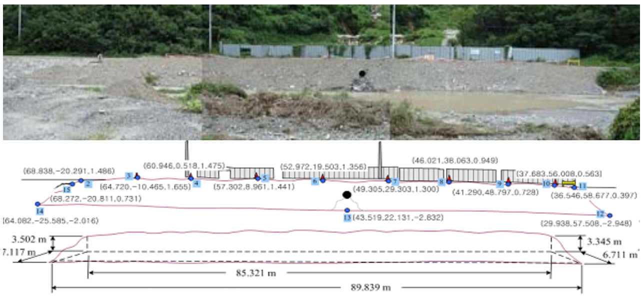


Figure 8. Analysis of flood damage using close range photogrammetric system

3. ACCURACY CHECK FOR HIERARCHICAL APPROACH

We checked accuracy of each sensor under different condition. Since it is important to check the accuracy of multi-sensor approach, we utilized test-bed close to Seoul, capital of Korea. The name of city we used for test-bed is Ansung. We used SAR imagery ordered in advance and at the same date and at the same time the UAV and close range system get the data over the test site. Additionally we also utilized Quickbird imagery. GPS surveying for GCPs and check point analysis is performed. Figure 9 is the result of overlay several sensors together.

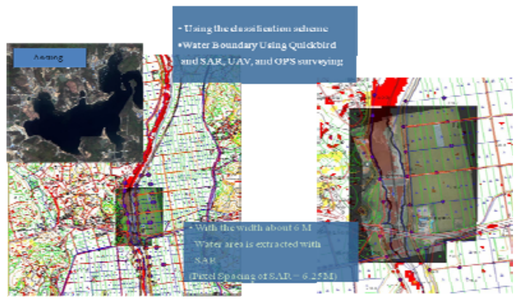


Figure 9. Accuracy check of multi-sensor approach over a test-bed in the city of Ansung

As shown in Figure 9, along the small width of river, SAR imagery with its nominal resolution 6.25 m could identify the water area. And all the other sensors match well with an existing 1:1,000 digital map as shown in Figure 9.

4. CONCLUSION

The current situation of flood-related damage estimation is usually done by human judge. In the event of flood it is not easy to approach the damaged site and the estimation can be very much distorted. Since the expenses to recover damages are very much dependent on the status of damage estimation, the accurate and fast method is essential especially in the disaster site. The hierarchical scheme of utilizing the satellite imagery, UAV imagery, and ground-based observation suggested in this study for the estimation of flood-related damage can be the solution for the flood-related estimation of the damages. And this approach could save a lot of governmental money for recovering the damage due to its relatively very high accuracy compared to the current manual approach. With the fast development of sensors which can be directly applied to the disaster event, this scheme can be easily applied to the other types of disaster event. Actually we applied this scheme to the mountain fire which took a year to estimate the damages. By using the satellite imagery, airborne LiDAR and ultra-red imagery, and ground-based LiDAR system, we could estimate the expenses and area of the damage in two weeks. Currently Korean government is pursuing the approach which the study suggested and all the local government officers also prefer to have a ground-based stereo camera system rather than their own risky judgment.

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