Investigation on appropriate surveying method following the establishment of national disaster damage investigation system

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Key words: Korea National Disaster Management System. Landslide, Earthquake, Mobile Mapping System, UAV

SUMMARY

Since the Titanic sunk in 1912, a similar accident occurred in Korea on 15th of April 2014, over 300 passengers sunk together with the ship and passed away. This accident was one of the major causes to lead the President to be resigned for the first time in Korea. Afterwards, several other national-level natural disasters occurred, such as an earthquake in Gyeongju city (May 2016), measuring at 5.8 Richter scale, and a flood in Cheongju city (July 2017), all caused life and property damage.

In order to protect the lives of people and their property, the national disaster damage investigation system was designed on the basis of this study, which also was implemented by the most appropriate surveying method that should be applied during a disaster investigation through the two case studies for landslides and earthquakes.

Case Study 1) four different methods were compared and analyzed. The methods are tracking method using applications for a detailed investigation of landslide area, direct observation utilizing Total Station, disaster investigation utilizing RTK, and utilizing UAV. The analysis showed that utilizing UAV is the fastest and safest method for various disaster investigations.

Case Study 2) The Mobile Mapping System (MMS) and UAV methods for earthquake area investigation were compared and analyzed. As a result, a precise 3D mapping result could be produced using the MMS method, but it was not possible to obtain data in certain areas such as earthquake area, roof tops and upper section of buildings where vehicles are not able to approach. Therefore, it could be concluded that both of methods utilizing UAV and MMS should be applied in appropriate combination.

This study has identified the most reasonable method for prompt and accurate investigation when a specific disaster takes place. It could be expected that this method could contribute to minimize the damage from natural disasters in Korea.

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1. OVERVIEW

1.1 Background & Purpose

The public expressed huge dismay at the Korean government's disaster response after the Sewol ferry disaster that occurred in April 2014. Since the launch of the new national government in May 2017, various follow-up measures have been created with the aim of protecting people's lives and properties. However, more people were injured or killed and more financial losses were inflicted, with several disasters unfolded including the mountain fire in Gangneung in May, floods and mountain landslide in Cheongju in July, the hail in Chungju in September, and the earthquake in Pohang in November, 2017. Thus, South Korea has seen a daily increasing need for a strategy to effectively prevent and promptly respond to national disasters.

The study, which has created a national accident investigation system for disaster response with an organized and reasonable method, is designed to come up with the most reasonable land surveying technique that can be applied to investigate accidents and disasters through case studies targeting actual mountain landslides and earthquakes among others.

The first case study, which was designed to conduct a precision investigation into the areas of the landslides, made a comparative analysis of the four surveying techniques of tracking with an app, technical survey with total station, disaster survey using RTK (Real-Time Kinematic), and disaster survey using UAV (Unmanned Aerial Vehicle), and came up with the most reasonable and efficient surveying technique.

The second case study covering the earthquake in Pohang in November 2017 made a comparative analysis of the surveying technique with MMS (Mobile Mapping System) and the surveying technique with UAV which were involved in the investigation of the area affected by the earthquake and came up with the optimized and reasonable surveying technique.

1.2 Key Details about the Creation of Disaster Investigation System

To create the national accident investigation system for disaster response, we implemented the process with stages of 'establish the methodology → create the procedures → testing & investigations → revise the procedures → create investigation system'.

To design the methodology and create the procedures, we established the disaster investigation methodology as the first step. For this purpose, we established the four disaster types of mountain fire, mountain landslide, earthquake, and hail according to the three selection criteria of the need for disaster investigation, the possibility for applying space information technology, and applicability, and the investigation items for the different types were divided into early investigation and precision investigation. In order to observe the selected investigation items, we created the procedures by using the methods including the national land survey app, RTK, UAV, and LiDAR.

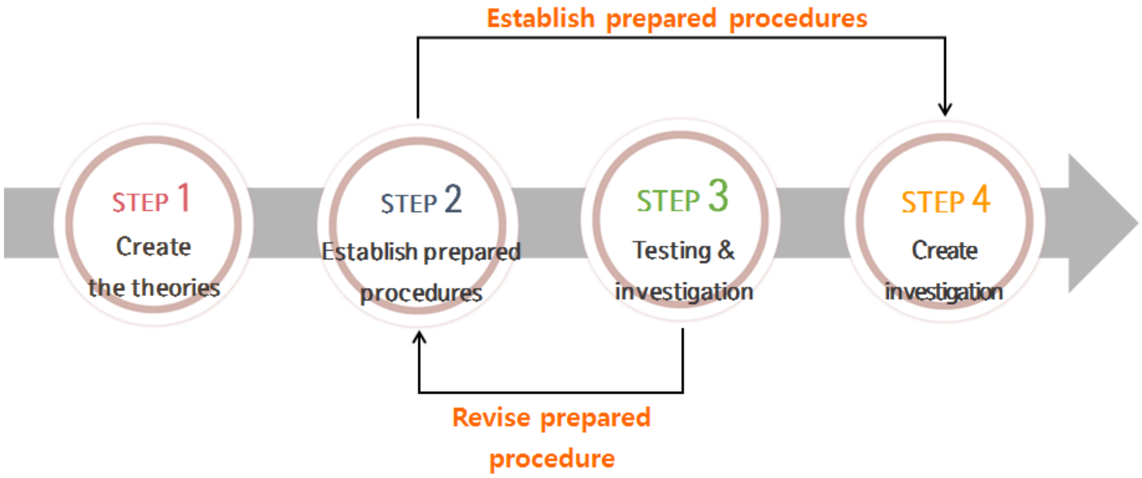
Second, according to the created investigation procedures, we conducted testing and investigation into the mountain landslide of Cheongju that occurred on Nov. 2, 2017. We then tested the investigations items and methods that were established in the disaster investigation methodology, based on which we modified and supplemented the investigation procedures, thus improving the reliability of the results. While the work was in progress, a 5.4 magnitude earthquake occurred in Pohang, Gyeongsang North Province on Nov. 15, 2017. In response, the testing and investigations were carried out in Pohang on Nov. 16 according to the promptly modified investigation procedures. The MMS surveying technique that was then performed was recorded as the first investigation conducted at an earthquake-affected area in South Korea.

Lastly, we modified and supplemented the investigation procedures through two testing & investigations, which finalized the procedures. Accordingly, South Korea is now able to perform early and precision investigation into mountain landslides, mountain fires, and earthquakes, using the disaster investigation procedures as described in this paper.

2. ESTABLISHING THE DISASTER INVESTIGATION METHODOLOGY

With a view to establish investigation methodology, we implemented the study in the sequence as shown in Fig. 1. First, we designed the investigation methodology and created the procedures, and then, modified and supplemented it through testing and investigations. Then, we selected disaster types that needed disaster investigations, and identified the items that should be investigated at disaster scenes. After we reviewed the investigation methods for different investigation stages and disaster types, we analyzed the appropriate investigation and land surveying techniques. Lastly, we designed the procedures for handling the investigation task.

Fig. 1 Flowchart for Establishing the Disaster Investigation Methodology



2.1 Selecting Disaster Types

The disaster types of South Korea was defined in the Framework Act on the Management of Disasters. To select the scope of disasters to be investigated in this study, we selected the four disasters such as mountain fire, mountain landslide, earthquake, and hail with the criteria of the need for disaster investigation, the possibility for applying space information technology, and applicability. The National Institute of Forest Science, which manages mountain fires and mountain landslides, needs to know the exact affected areas for removing damaged trees and planning forestation with the aim of restoring forests. This is because the mountain fires that occur in spring and autumn lead to landslides caused by torrential rain in summer, inflicting secondary damage. Relevant local governments need to assess the affected areas by street number for the purpose of identifying the property damage caused by mountain fires and mountain landslides. National Disaster Management Research Institute (NDMI) needs information on the damage immediately following an earthquake with the aim of being prepared for minimum fifty earthquakes that occur each year, but NDMI is understaffed for on-site investigations while the local governments are understaffed for large-scale damage investigation. Hail frequently inflicts damage to farmers during the planting and harvest season in April and November. We have seen that the local governments need to provide information by damage size and damage category to farming households in order to handle the additional damage caused by pests and it is important to calculate affected areas by category to provide funding for damage recovery.

2.2 Reviewing Investigation Methods

In order to examine the investigation methods for the identified categories, we reviewed on-site surveying, remote sensing, and video analysis. On-site surveying used the GPS tracking on the smartphone app, RTK, total station, and LiDAR (Laser Detection and Ranging) system to assess the affected area. Also, we considered using UAV for remote sensing in order to have a safe investigation at the disaster scenes. Thanks to recent advancement in science and technology, it is now possible to perform an accurate video analysis through aerial photography which is conducted with UAV equipped with high-resolution sensors. Other available methods are green algae monitoring with hyperspectral sensor, surveying the areas affected by pine wilt disease with NIR camera, and surveying areas affected by mountain fires with thermographic camera. We applied optimized surveying techniques for different stages and disaster types identified through testing and investigations.

2.2.1 Methods at Different Stages of Investigation

① Early Investigation

As we thought that using a smartphone would be the most appropriate to ensure prompt early investigation, we used the disaster investigation feature added to the existing national land survey app. With photography and video, we recorded the site and calculated the area with GPS tracking to get the ballpark figures for the scope.

② Precision Investigation

After the early investigation, we conducted the precision investigation to provide the local governments and the related agencies video and disaster area sketch for the purpose of identifying exact damage. To obtain high-resolution orthophoto with the goal of getting the latest image right after the damage was inflicted and calculate the accurate affected area, we performed a comparative analysis by using RTK, LiDAR, and UAV in the testing and investigations.

2.2.2 Methods for Different Disaster Types

For investigating hail, we selected RTK that was convenient for ground mobility and enabled real-time precision location acquisition, for the purpose of assessing damage such as fallen fruits and damaged greenhouses. We think that it is fit to use UAV and LiDAR for mountain fires and mountain landslides, considering their access to the sites. After UAV photography, it is possible to obtain orthophoto and calculate affected area by street number with serial cadastral map. For erosion and sedimentation caused by mountain landslides, it is also possible to calculate them by extracting DEM and rendering it in 3D by using UAV or LiDAR. For the purpose of investigating the earthquake-caused damage to large buildings, we compared the MMS which equipped a vehicle with camera, laser scanner, GPS, and INS, and UAV.

2.3 Investigation Procedures

For this study, we designed a method that would serve investigation results by registering the data collected through disaster investigations with national land survey system. National land survey system was developed to acquire an on-site support system which would support linkage between the data collected through the investigations (such as surveying of national or public land, seaside areas, road plaques) performed by Korea Land and Geospatial InformatiX Corporation (LX) and the internal services (such as SIMC and LX Land Info-e) and enables the creation of the survey data in various document formats and its automatic distribution.

The concept is that when there is a request from a local government or a related agency or when a report is filed by LX staff or an ordinary citizen who happens to be at the scene when a disaster occurs, the receiver designates a person for the site and Speed 4.0 team goes out to conduct early investigation and precision investigation. Investigation results such as site photos and videos, early investigation report, and disaster area sketch are immediately registered with the national land survey server. Fig. 2 is the investigation system block diagram which shows the procedures for using the results of an on-site investigation performed after a disaster is reported.

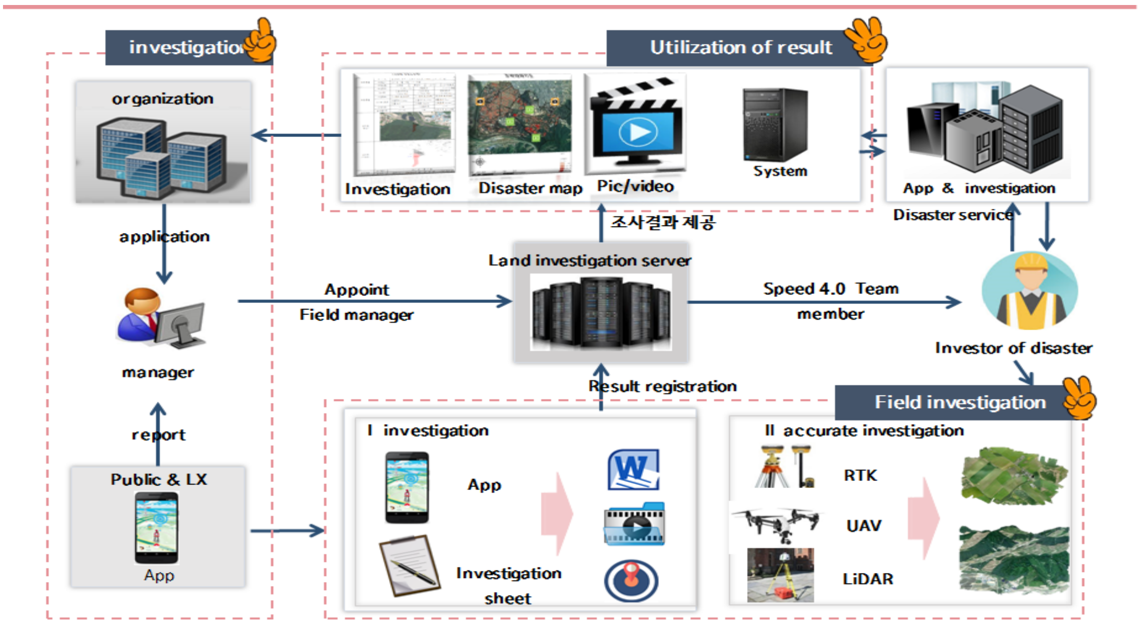


Fig. 2 Investigation system block diagram

3. TESTING & INVESTIGATIONS

3.1 Type and Scope of Testing & Investigations

For this study, we were going to perform testing and investigations on the four selected disaster types of mountain fire, mountain landslide, earthquake, and hail, but they were not conducted as no mountain fires or hail occurred during the research period. Therefore, we limited the scope of the testing and investigations to mountain landslides and earthquakes. For earthquakes, we selected Pohang which suffered damage, and for mountain landslides, we selected Cheongju which preserved traces of damage pretty well as its spatial scope and conducted testing and investigation.

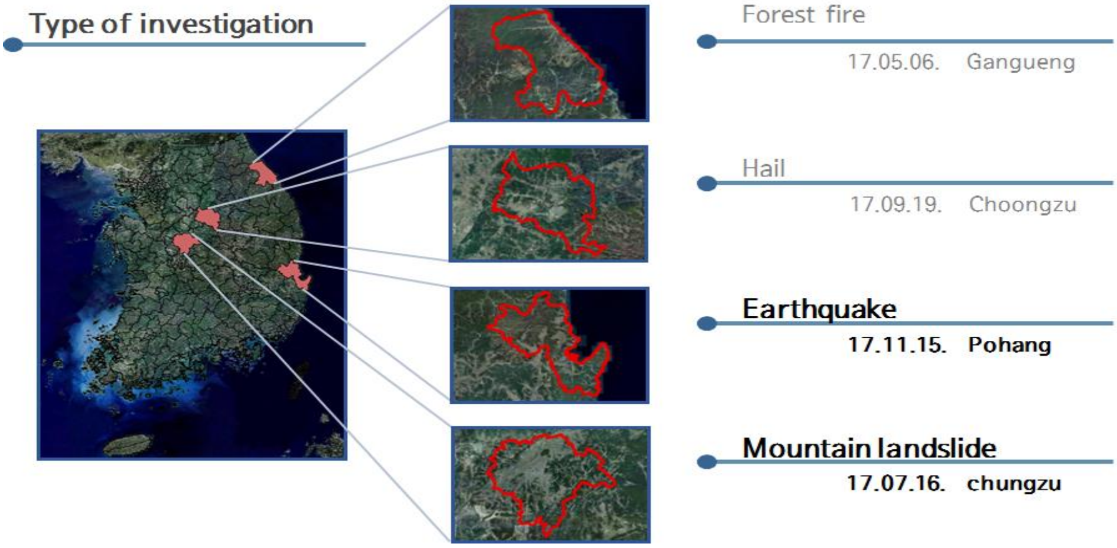


Fig. 3 — Type, time, and scope of testing & investigations

3.2 Conducting Testing & Investigations

3.2.1 Mountain Landslides

As for the mountain landslide in Cheongju, which occurred due to a torrential rain with daily precipitation of 290㎜ on Jul. 16, 2017, we were able to perform testing & investigation on Nov. 2 in the same year, as the traces of the damage were relatively well preserved. The testing & investigation was conducted according to the prepared procedures and was split broadly into early investigation and precision investigation.

① Early Investigation

a. For early investigation, professionals are promptly deployed to the site to collect data as specified in investigation sheet with the aim of collecting data for on-site investigation and responding with emergency situations.

Fig. 4 Collecting basic data for mountain landslide information system

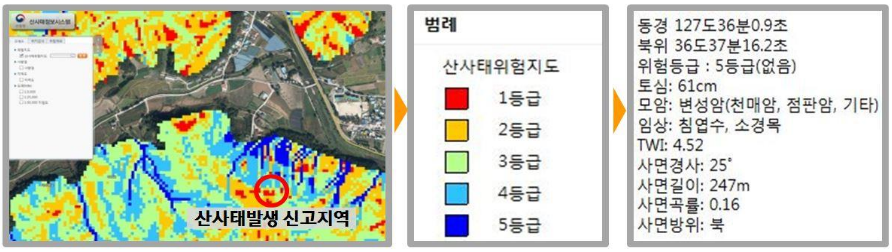
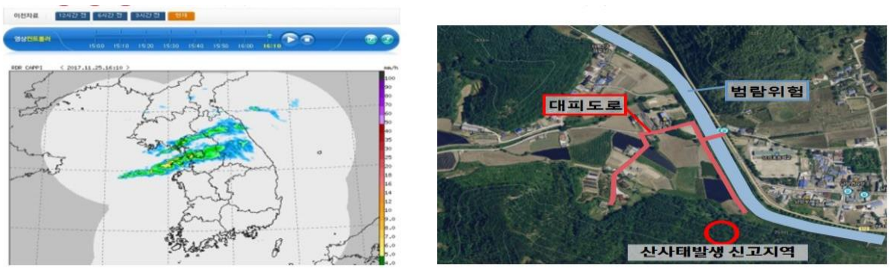


Fig. 5 Identifying weather condition and evacuation roads



b. An on-site investigation uses the app to record the damage with photos and videos and promptly sends data to related agencies.

Fig. 6 Estimating affected area and entering damage details by using the APP

c. An investigation by questioning records and investigates the situation at the occurrence of a disaster by interviewing affected residents and visiting the local government, fire station etc.

② Precision Investigation

With the view to obtain the optimized disaster investigation method for precision disaster investigation in national response to disasters, we made a comparative analysis of the various investigation methods including the app, total station, RTK, and UAV and came up with the optimized and most reasonable surveying technique with the investigation results as follows.

a. App: it enabled prompt information acquisition but generated relatively big errors in terms of accuracy.

b. Total station: it enabled accurate area measurement but took too long for an investigation due to obstruction of view in forest areas.

c. RTK: it enables prompt data acquisition with real-time obtainment of coordinates, but measurement is impossible in some areas due to radio jamming caused by trees.

d. UAV: it enables fast and accurate area measurement in areas safe from a disaster scene.

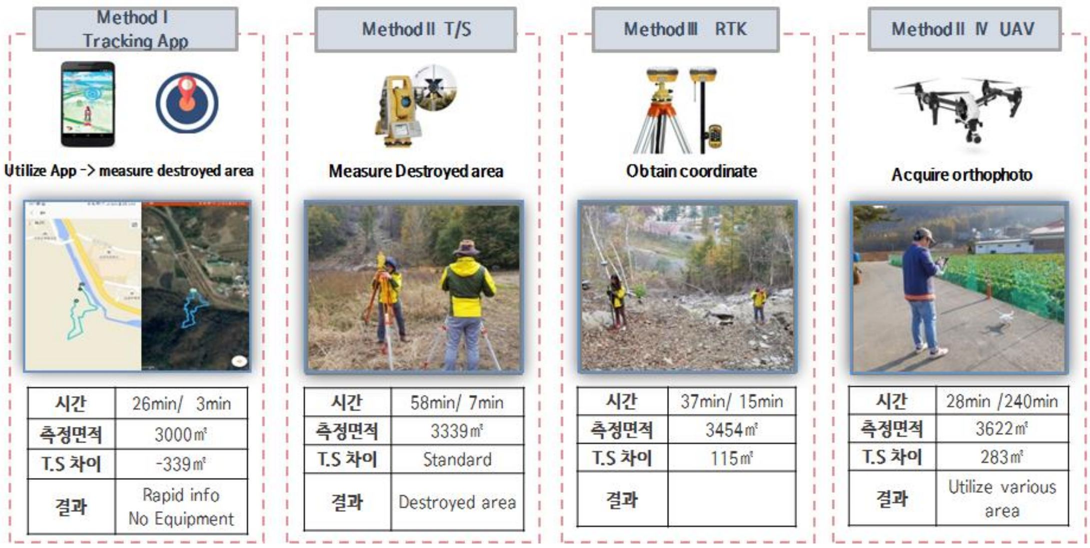


Fig. 7 Comparison of precision investigation methods

3.2.2 Earthquake

An earthquake with a magnitude of 5.4 occurred 9 ㎞ north of Buk-gu, Pohang, Gyeongsang North Province on Nov. 15, 2017. Accordingly, an early investigation was promptly conducted in the affected area on the same day according to the disaster investigation document created through this study. The secondary precision investigation was also performed the next day with a focus on what was left undone by the early investigation. For the Pohang earthquake, a total of 99 aftershocks occurred until Mar. 22, 2018, with six of them in the magnitude between 3 and 4 and two of them between 4 and 5.

① Early Investigation

a. In the basic investigation, we identified the epicenter with the data from Korea Meteorological Administration and verified the affected areas through wired and wireless communications and social media, while promptly creating a sense-based map with the help of nationwide staff.

b. In the on-site investigation, we checked on further risks and spreading and took photos and videos of the affected areas, dividing risks into minimum, minor, average, grave, and extreme.

c. In the investigation by questioning, we recorded the situation at the time of the earthquake and surveyed the damage from the earthquake based on the investigation questioning form.

② Precision Investigation

For the study, we promptly conducted precision investigation promptly by using MMS equipment and the UAV equipment, and the MMS survey, conducted on Nov. 16, 2017, is recorded as the first deployment of the MMS equipment to a scene of earthquake.

a. MMS surveying procedures

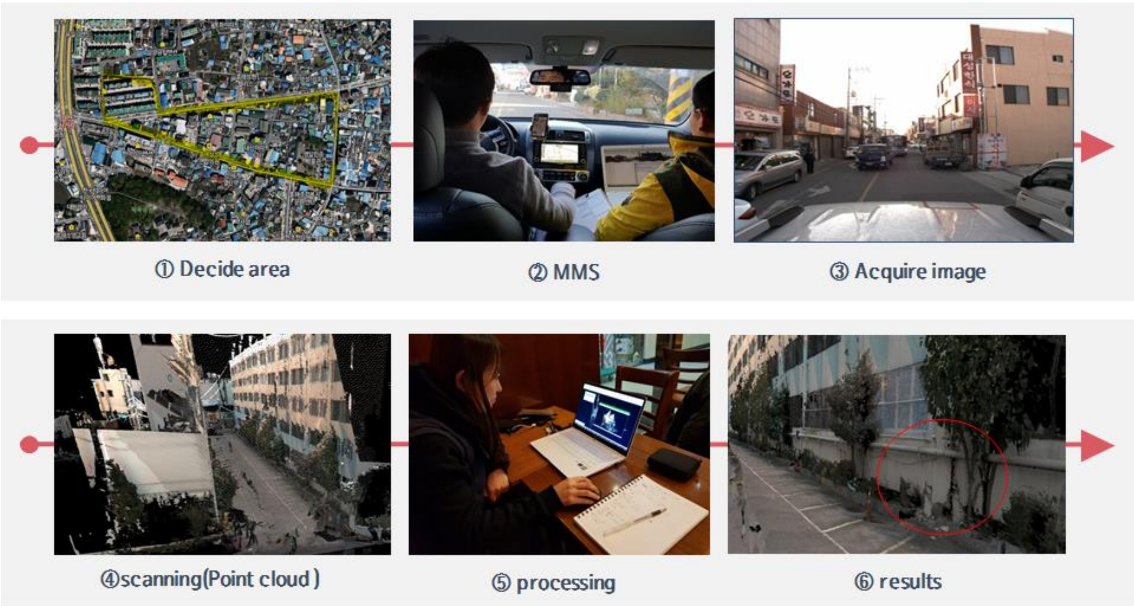
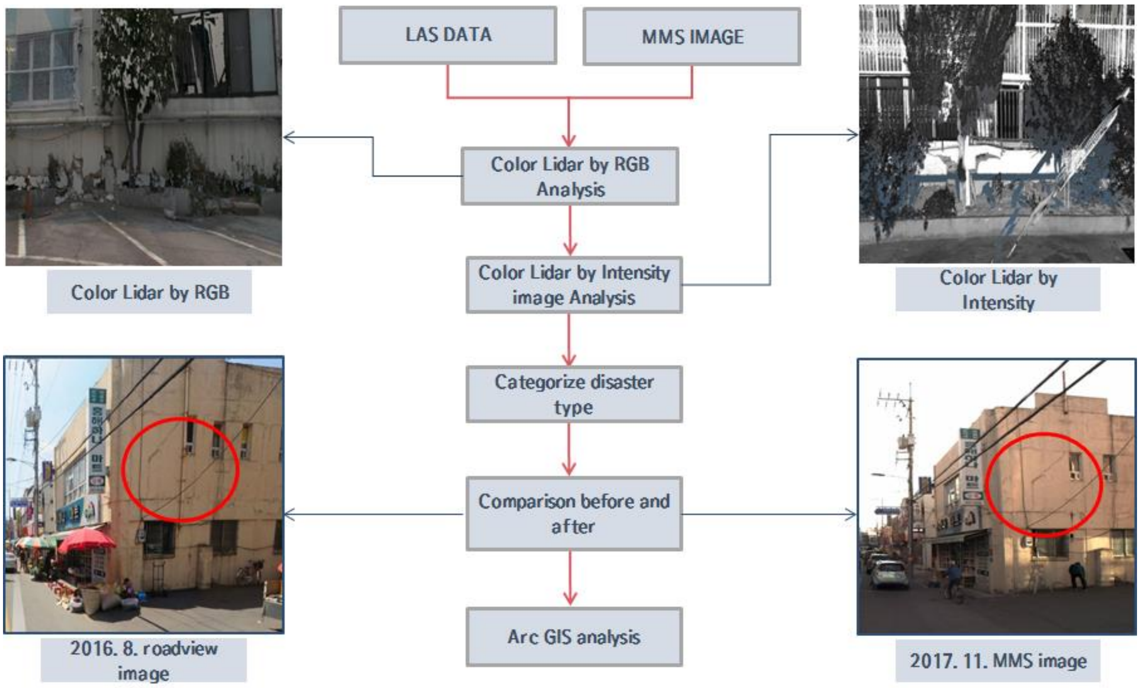


Fig. 8 MMS surveying procedures

b. MMS data processing flowchart

Fig. 9 — MMS data processing flowchart



c. MMS performs measurement by loading camera (scanner), GNSS etc. on a vehicle, so, it can't perform a survey on an area where the vehicle can't access. Especially because it can't survey the damage caused to building rooftops which are hard to visually observe, we deployed a UAV vehicle in addition and compared the two surveying techniques.

d. By using the two surveying techniques of MMS and UAV, we investigated the building tilt, damaged outer walls, cracked outer walls, and damaged roofs.

③ Comparison of MMS and UAV

With MMS, it was possible to promptly obtain information through vehicle-enabled mobility and create an accurate 3D map, but we could not check the damage done in the areas where the vehicle couldn't enter or on the upper portions of buildings. We think that MMS would be useful in creating diverse precision maps as for identifying road cracks or assessing tunnel safety. With UAV, we were able to identify the scenes of earthquakes promptly and accurately from a safe area and promptly verify the damage done to narrow areas or upper portion of buildings, which MMS couldnʹt accomplish. However, it took as many as fourteen days from the occurrence of the earthquake to the approval for the photography and even the post-processing took a long time. We found that with its diverse sensors, UAV could be put to various uses such as rescuing people, photographing mountain fires, or surveying pests.

4. CONCLUSION

In this study, we have created the National Accident Investigation System for Disaster Response in a reasonable manner with a view to protecting peopleʹs lives and properties when national-scale disasters occur. By conducting case study on the mountain landslides and earthquakes according to the created disaster investigation process, we have identified the most reasonable surveying techniques that can be applied to disaster investigation.

The investigation procedures have been designed to register with the national land survey system the data collected through the disaster investigations and thereby provide the investigation results. When there is a request from a local government or a related agency or when a report is filed by LX staff or an ordinary citizen who happens to be at the scene when a disaster occurs, the receiver designates a person for the site and Speed 4.0 team goes out to conduct early investigation and precision investigation. Investigation results such as site photos and videos, early investigation report, and disaster area sketch are immediately registered with the national land survey server.

For a precision investigation into the area in Cheongju where a mountain landslide occurred, we compared the four methods of investigation that used app, total station, RTK, and UAV. We also verified that the UAV method could achieve the fastest, safest, and the most diversified disaster investigations.

When we compared the MMS and UAV methods as we surveyed the areas in Pohang right after they were hit by the earthquake, we saw that while the MMS investigation enabled a 3D precision map creation, it was impossible to get data for areas inaccessible by the vehicle and the upper portions of the buildings. Therefore, we think that a combination of the UAV method and the MMS method would be necessary to effect a precision investigation of earthquakes. Now that this study has identified the most reasonable method for promptly and accurately investigating specific disasters, we hope it will be used to minimize damage caused by any future disasters in Korea.

BIOGRAPHICAL NOTES

Mr. Bong-Bae JANG graduated with an MSc in Geo-Information Management from ITC, The Netherlands, in 2008. He is PhD completion in the Department of Geo-informatics, University of Seoul. He is working for the global business department of the Korea Land and Geospatial InformatiX Corporation as a deputy general director since 1994, and he is professional engineer both in cadastral survey and geodetic surveying.

Prof. June-Hwan KOH is professor at the Department of Geoinformatics, University of Seoul, South Korea since 1996. He graduated with a Post-graduate diploma in GIS for Urban Application from ITC, The Netherlands, in 1991. He holds a PhD from University of Seoul. He was director of the Korean Society of Cadastre since 2008 and He was the dean of the graduate school of Urban Sciences at University of Seoul (2011-2013) and also president of the Korea Spatial Information Society (2010-2011). From 2004 until 2005 he was visiting professor at Rutgers University, USA.

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