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UAV を用いた阿蘇大橋落橋の解析

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Analysis of Aso Big Bridge Collapse with UAV

by

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On April 14, 2016, a large earthquake with magnitude 6.5 occurred in Kumamoto Prefecture [1]. On April 16, 2016, the strong shakes with magnitude 7.3 occurred by Kumamoto earthquake in Kumamoto city and South Aso [2]. In South Aso, Aso Big Bridge collapsed on that day by this earthquake. On the other hand, in recent years, the spread of UAV has progressed rapidly, and it is used in many fields. The images of UAV are higher resolution than aerial photographs of satellites, and the shooting can be repeated [3]. UAV has automatic navigation functions, and the air dose rate is measured even in places where human intrusion is difficult [5]. In this study, the collapse distribution of Aso Big Bridge and the displacement of the slope collapse were analyzed with UAV. The authors visited South Aso on May 28 and June 11, 2016, and May 8, 2017. Aerial images were taken with UAV around Aso Big Bridge with two methods of manual and automatic navigation. Next, 3D models were created from the aerial images. Comparing the two 3D models created with the manual and automatic navigation, difference between them was examined. Construction of the DSM image after the earthquake and the spatial distribution of the collapse directions were calculated using ArcGIS. Furthermore, compared with DEM of the original hill from the satellite data, up-and-down of the slopes between before and after the earthquake, the main collapse point and the amount of sediment were estimated. From the data of UAV and the Geospatial Information Authority, Japan, four main collapse points were found out on the slopes of the Tatsuno hill. The sediment volume was estimated to be 250,000 m³.

Key words: *Automatic navigation, GIS, Kumamoto Earthquake, Photogrammetry*

1. INTRODUCTION

On April 14, 2016, a large earthquake with magnitude 6.5 occurred in Kumamoto Prefecture. The depth of the epicenter was 11 km [1]. On April 16, 2016, strong shakes with magnitude 7.3 and more than intensity 6 continued in Kumamoto city and the surrounding municipalities [2]. The depth of the epicenter was 12 km [1]. Landslide collapse occurred frequently in South Aso by the Kumamoto earthquake. Aso Big Bridge collapsed [2]. The aerial image of the Tatsuno hill where Aso Bridge existed and the horizontal image of the falling bridge are shown in Figs. 1-2. Landslides and cracks of the earth occurred frequently

Fig. 1 Satellite images of the Tatsuno hill in South Aso.

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Fig. 2 Horizontal Image of collapsed Aso Big Bridge (May 8, 2017).

around the bridge, and the field survey was difficult. On the other hand, in recent years, the spread of UAV has progressed rapidly. UAV became popular in the fields of earth science and archeology [3]. Compact digital cameras mounted on UAV are much higher resolution than aerial photographs of traditional aircrafts. The shooting can be repeated spatially [3]. UAV can be piloted for a long flight by general users in high performance of batteries, the weight reduction of aircrafts, and higher precision of GPS and IMU [4]. Small size GPS automatic recording systems with high portability, and general versatility were installed at low cost, and the air dose rate was measured. Spatial dose distribution was measured over places where the access was difficult by small UAV [5]. Photogrammetry with automatic navigation can be done in complicated terrains. The aerial images become three-dimensional using SfM-MVS software. High-resolution terrain images were obtained and analyzed [3]. Ortho mosaic images and DSM of several-cm-level spatial resolution were obtained from 3D models [4]. By computing these data with GIS software, landslide collapses, vegetation, and hydrological balance were analyzed. This method was very convenient to get natural disaster states. In this study, the authors visited South Aso in Kumamoto Prefecture on May 28 and June 11, 2016, and May 8, 2017. UAV flied over Aso Big Bridge. The aerial images were obtained. 3D models and ortho images were created from the aerial images. In combination with ArcGIS, analysis of Aso Big Bridge collapse was conducted.

2. METHODS

2.1. Aerial images of UAV

Phantom 4 and Phantom 4 Professional were used in this study (Figs. 3(a)-(b)). On May 28 and June 11, 2016, and May 8, 2017, the authors visited Aso Big Bridge in South Aso and took the aerial images of Aso Big Bridge collapse. In 2016, the images were acquired using manual navigation. On the other hand, in 2017, the images were obtained with

Fig. 3(a) Phantom 4.

Fig. 3(b) Phantom 4 Professional.

Fig. 4 Route map of UAV using *Litchi for DJI Mavic / Phantom / Inspire.*

automatic navigation. The routes of the automatic navigation was created using *Litchi for DJI Mavic / Phantom / Inspire*. The route map is shown in Fig. 4.

2.2. 3D model

Based on six dimensional information which is GPS and colors of the images, 3D models were created using PhotoScan. 3D models of both automatic and manual navigation were created. The authors compared difference between them from two 3D models created by manual and automatic navigation. Ortho images and DSM (Digital Surface Model) images were created by the 3D models.

2.3. GIS Analysis

Collapse directions were calculated from the ortho images using ArcGIS analysis tools. Aerial images and DEM images of the original hill were obtained from Geospatial

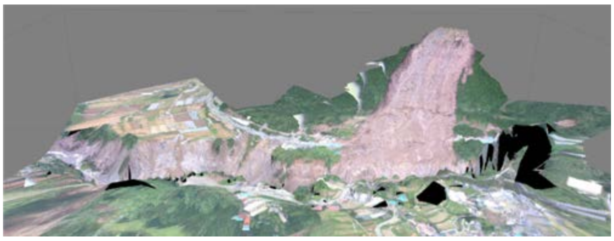

Fig. 5(a) 3D model of Aso Big Bridge by manual navigation.

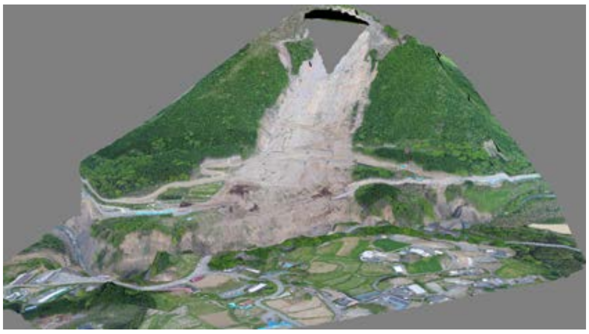

Fig. 5(b) 3D model of Aso Big Bridge by automatic navigation.

Information Authority, Japan. DSM images after landslide were obtained from UAV data. The displacement distribution of the surface was calculated from DSM and DEM images. Furthermore, the volumes of the hill before and after the landslide were calculated. The landslide volume was calculated from difference of these volumes.

3. RESULTS

3.1. 3D models

Two 3D models are shown in Figs. 5(a)-(b). Fig. 5(a) shows a 3D model with manual navigation. The collapsed slopes and the central river passing through the north to the south were synthesized. Mountainous areas, rice paddies, and corners of the images showed some cavities. Fig. 5(b) shows another 3D model with automatic navigation. There were no small holes scattered, but one cavity was formed at the top of the slope.

3.2. Image original hills

Fig. 6(a) shows a 3D model of the Tatsuno hill and Aso Big Bridge in 2013. Fig. 6(b) shows a bird-eye-view of the Tatsuno hill and Aso Big Bridge in 2013. They were created from two aerial images of Geospatial Information Authority, Japan.

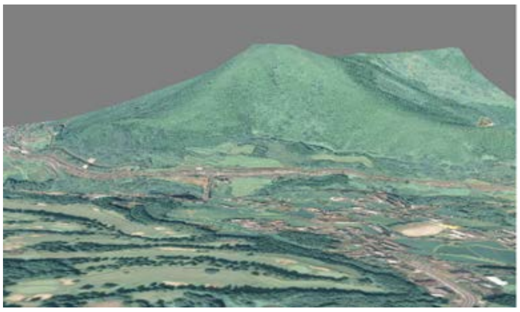

Fig. 6(a) 3D model of Aso Big Bridge and the original Tatsuno hill from GIAJ (2013).

Fig. 6(b) Bird’s eye view of Aso Big Bridge and the original Tatsuno hill from GIAJ (2013).

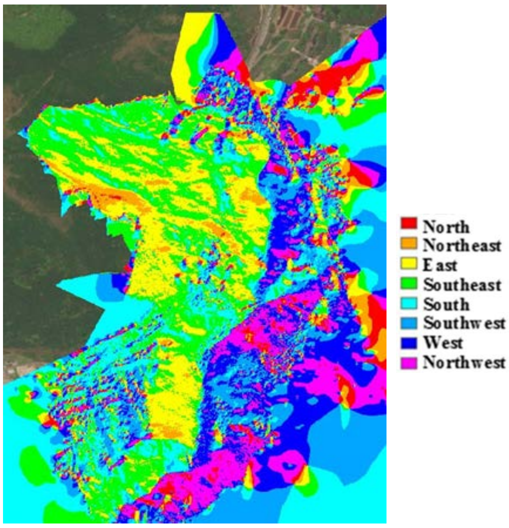

Fig. 7 Collapse spatial distribution in Aso Big Bridge and the Tatsuno hill.

3.3. GIS Analysis

The collapse spatial distribution of Aso Big Bridge was calculated using ArcGIS, as shown in Fig. 7. Fig. 8 shows enlarged slope views of the Tatsuno hill before and after the landslide. Fig. 9 shows a DSM map and contour lines with 10-m intervals after the landslide. Furthermore, an up-and-down distribution of sediments is shown in Fig. 10. Fig. 10 was calculated from after-landslide-DSM

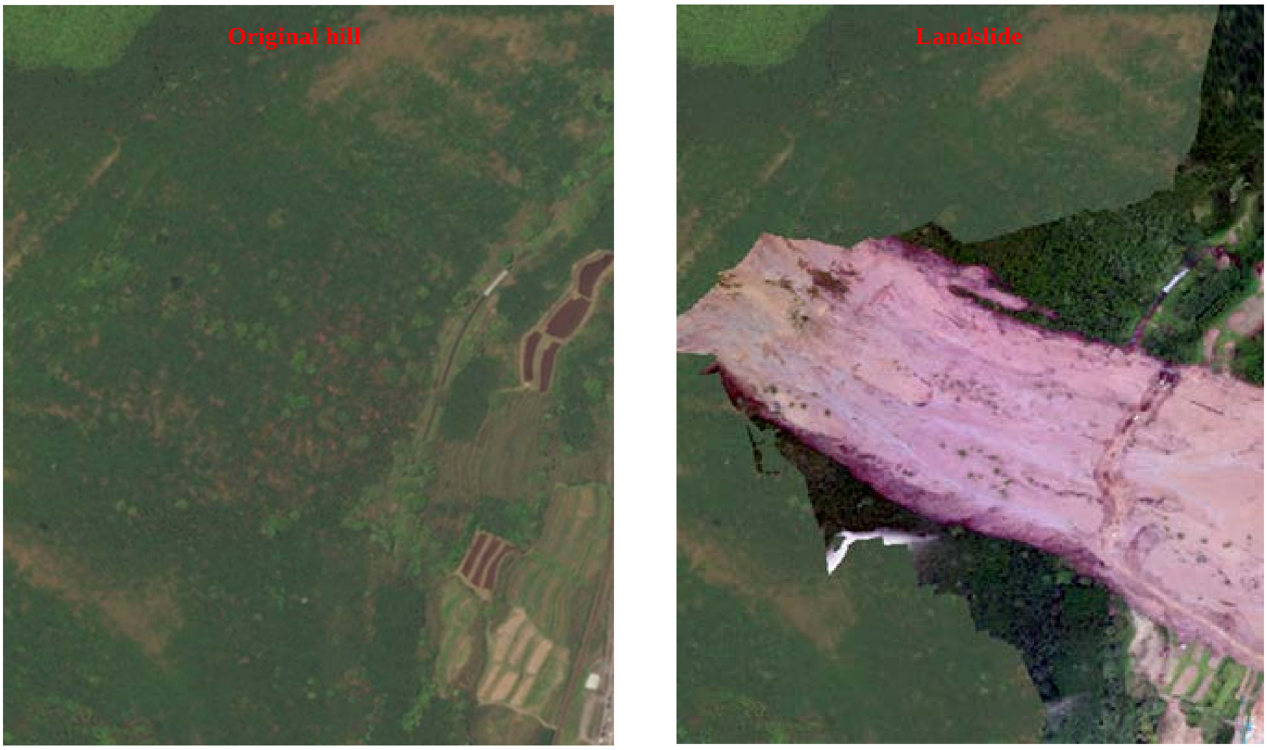

Fig. 8 West slopes of Aso Big Bridge (The original hill and after landslide).

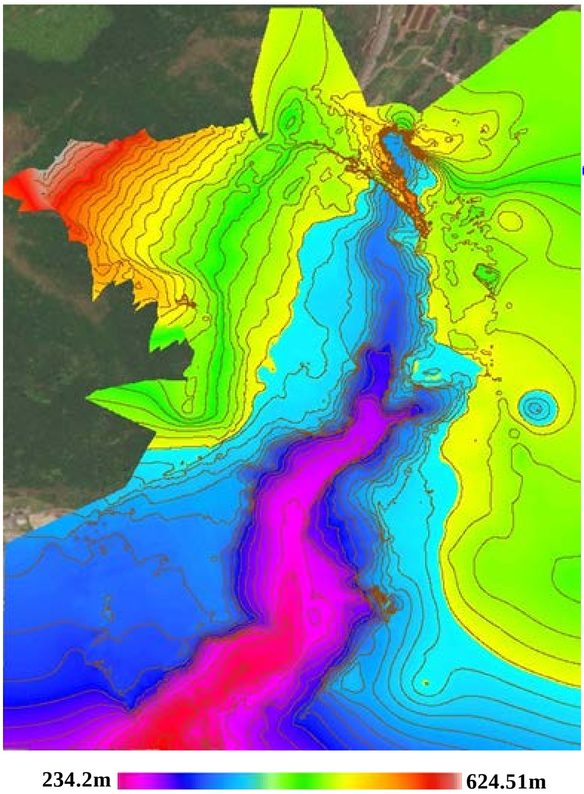

Fig. 9 DSM and contour distributions around Aso Big Bridge.

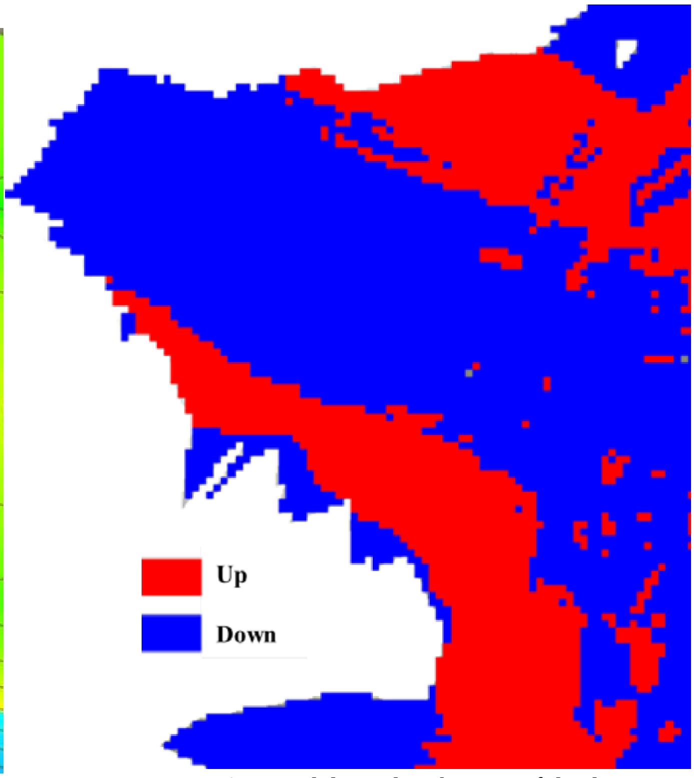

Fig. 10 Up and down distributions of displacement of the Tatsuno hill.

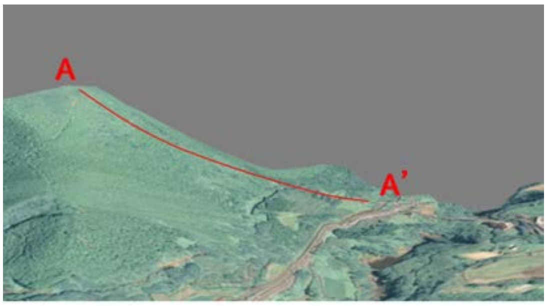

Fig. 11(a) Original profile of the Tatsuno hill.

Fig. 11(b) Landslide profile of the Tatsuno hill.

images from UAV and the original hill DEM images by the Geospatial Information Authority, Japan. A profile of the original hill and another profile of after landslides is shown in Figs. 11(a)-(b). A landslide profile graph comparing both the original hill and after landslide is shown in Fig. 11(c). From Fig. 11(c), the number of major collapse points in this landslide were four. Furthermore, the estimated landslide volume was 250,000 m³ from Geospatial Information Authority, Japan DEM data with 10 m/pixel spatial resolution and UAV- DSM data with 14.7 cm/pixel spatial resolution.

4. Discussion

4.1. Two 3D models

In Fig 12 (a), when checking the aerial image of UAV, the images of landslide parts and the river in the center were taken more than other parts. When constructing a 3D model, PhotoScan concentrated on the synthesis of the river and collapse areas. This shooting was not unified to the camera direction. The overlap of some parts was less than 60%. These problems tended to occur in manual navigation. In Fig. 12(b) with automatic navigation, the highest area images could not been obtained because the width of UAV routes was too wide. However, the intervals of photograph points were constant. Other images were nothing. Automatic navigation would be a useful tool in

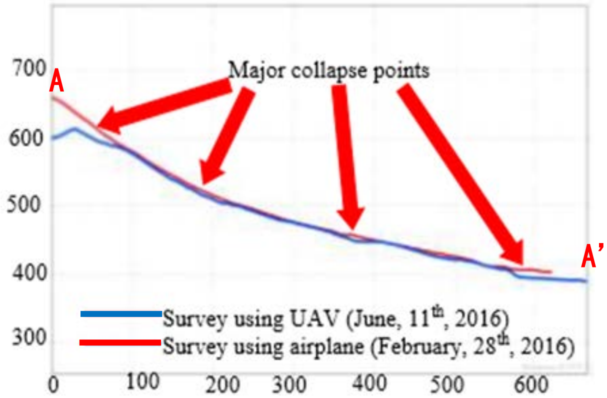

Fig. 11(c) Original and landslide profiles of the Tatsuno hill.

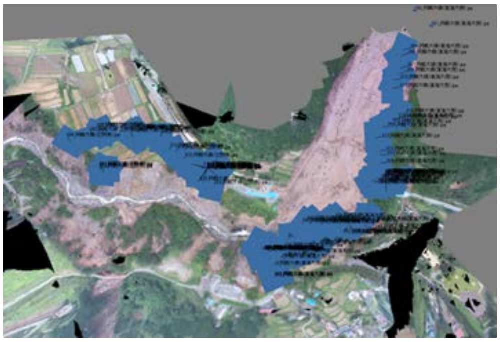

Fig. 12(a) Shooting position of the manual navigation.

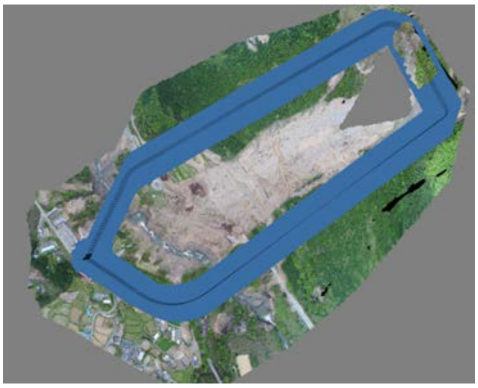

Fig. 12(b) Shooting position of the automatic navigation.

investigating difficult objects.

4.2. Collapse points

In Fig. 9, the elevation of landslide area decreased 10-30 m from the adjacent hill without damages. In Fig. 11(c), no change points in height was estimated to be sediments of the same height as trees were deposited on the place where a forest were lost. The elevation near **A'** increased. Sediments by the landslide were accumulated on the original hill. The biggest collapse occurred at the top of the slope. Considering the height of trees, the estimated deepest scraping was approximately 40m. According to the research of Asian Air Survey Company, the major collapse points were two. The research of Asian Air Survey Company did not consider the second and third collapse points in this study.

5. Conclusions

Photogrammetry using UAV is capable of quantitative analysis for natural disasters. In this study, a DSM distribution, four major collapse points, a collapse direction distribution and the collapsed sediment volume were estimated. The main cause of Aso Big Bridge collapse was estimated by excess sediment loading of the earthquake from these data. In this study, the number of obtained aerial images and the photographs were small because manual navigation was limited for operating UAV. In manual navigation, complete photogrammetry may be difficult for steep slopes and long distance areas. However, more accurate photographs and analysis could be done with automatic navigation.

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