Development of a Penetrator Probe Dropping from a UAV for Disaster Prevention

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We are developing a probe, so called “penetrator”, which can make geophysical observations by dropping from a UAV and penetrating into the ground from a UAV. This basic idea was originally developed by the lunar exploration mission “LUNAR-A”, and we re-designed it to use for earth observations.
The penetrator is attached to the UAV and will be transported to a disastrous or a dangerous area such as an active volcanic area, a landslide area and so on. The penetrator will be released at a target position at an altitude of one to several hundred meters. The probe will be penetrated at the velocity of several tens meters per second and fixed tightly into the ground. The probe can observe seismic events, precision position, inclination and other required observations and transmit the data via IRIDIUM communication system. The concept of the system is schematically shown in Fig.1.
We developed 1/4 scale size probe launcher and deploy 1kg penetrator monitoring acceleration and attitude during flight. The probe was attached to B-3M type UAV (Fuji-imvac co. Ltd: http://www.fuji-imvac.jp/product/index.html) and brought to a performance test on August and September 2015(Fig.2). The flight route and releasing point were programmed before taking off. We successfully released the probe at the altitude of 100m 300m and 500m respectively and the landing position were within the error of 20-30 meters The error may be caused by delay of the detection of the target position, and by the effect of wind while dropping the probe.
At the time of penetration, shock level of 3000 -4000G will be loaded to the probe. In order to ensure the shock durability, we selected commercial base products which seem to have tough structures, and we made some modification and replaced some parts as necessary. In this study, we planed to make geophysical observation sensors such as seismometer, infrasound microphone, GPS, and tilt-meter. We have completed shock proof tests for all the sensors and bus system, then we are now designing an integrate model of the probe with the weight of 9kg which will enable us to transport it at a distance of 100km.
We will make further experiments using a real size probe in the near future, and after that, we are planning to use the probe for real-time seismic observation of Nishinoshina-Shintou island (27N, 140E) where is it is prohibited to enter at 4km area from the island. The UAV will take off from Chichijima island and fly at a distance of 130km to the target area. We consider this system useful for the initial response action in the earliest stages.
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Keywords: penetrator, geophysical observations, disaster prevention

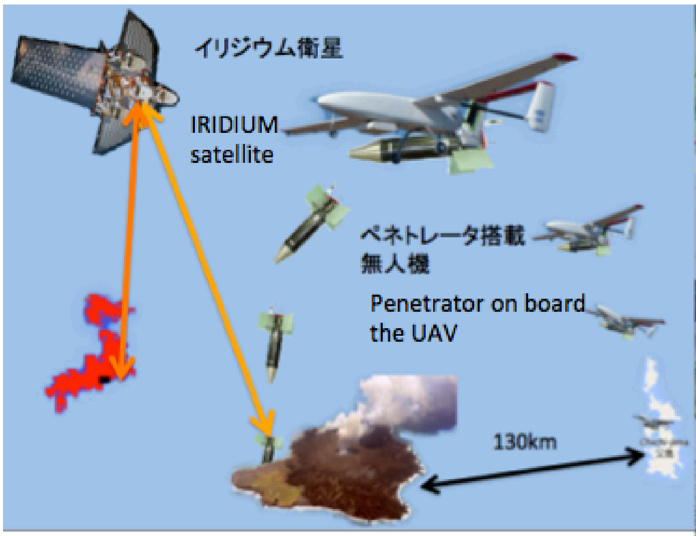
イリジウム衛星
IRIDIUM satellite
ペネトレータ搭載
無人機
Penetrator on board the UAV
130km

Fig.1

Fig.2

Shigaraki, UAV-Radar Experiment (ShUREX)

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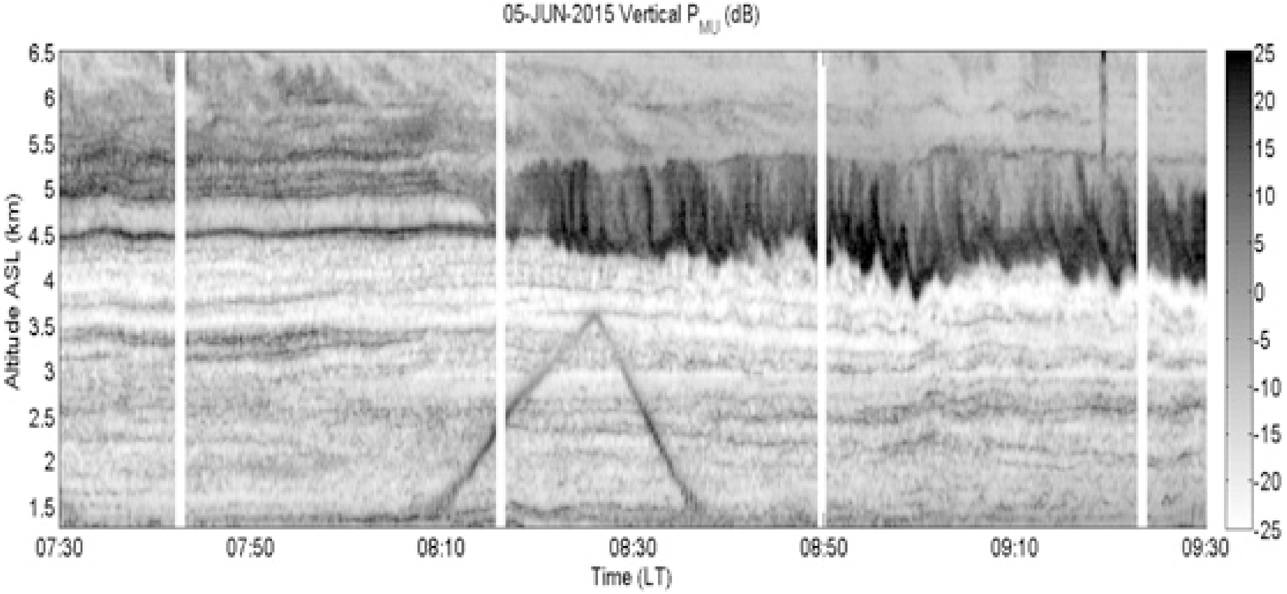
Turbulence mixing is an important process that contributes to the vertical transport of heat and substance, but it is difficult to be observed because its scale is very small. The atmospheric radar transmits the radiowave and receives backscattered echoes from turbulence to measure wind velocity profiles with high time resolution, so it has advantage in the observation of atmospheric turbulence. The MU (Middle and Upper atmosphere) radar is the atmospheric radar located at Shigaraki, Koka, Shiga Prefecture, has the center frequency of 46.5 MHz, the antenna diameter of 103 m, and the peak output power of 1 MW, and has been operated since 1984. In 2004 it is upgraded to enable radar imaging observation which provides us the improved range resolution data. The MU radar can be most accurately image the turbulence structure and is the most powerful tool to study the relationship to meso-synoptic scale phenomena. For example, although atmospheric turbulence due to the Kelvin-Helmholtz instability is known to occur in strong wind shear region, continuous turbulence structure under the cloud base has been imaged by the MU radar.
In recent years, small unmanned aerial vehicle (UAV) has been attracting attention as an observation tool of the lower atmosphere. As Japan-USA-France international collaborative research, ShUREX (Shigaraki, UAV-Radar Experiment) campaign using simultaneously small UAVs developed by the University of Colorado and the MU radar has been carried out in last June. The UAV is a small (wing width 1 m), lightweight (700 g), low cost (about $1,000), reusable, autonomous flight possible using GPS, and it is possible to obtain a high-resolution data of the turbulence parameters by the temperature sensor of 100-Hz sampling, in addition to temperature, humidity, and barometric pressure data of 1-Hz sampling. Take-off and landing of the UAV was carried out at a pasture in 1-km southwest from the MU Observatory. Since the UAV cannot take off with their own runway, a method of take-off by pulling a rubber (Bungee method) or a method of the release at the appropriate altitude from a meteorological balloon filled with helium (Balloon method) is used. The flight method previously programmed in advance takeoff before, it is also possible to change the flight method after takeoff according to the situation. It is possible to continuously fly about one hour.
The time-altitude cross-section of the echo intensity obtained with the range imaging mode of the MU radar is shown in figure. Triangular shape of the echoes underlying during 8:10-8:40 is due to UAV. Strong echoes (turbulence) in the vicinity of the cloud base at 4-5 km are observed.
Currently, we are analyzing the observation data of the MU radar and UAV in details. Atmospheric turbulence is present everywhere, impact on human life is not small, and the observation and prediction also for the safe operation of the aircraft is an important issue. We plan a second campaign using UAVs and the MU radar in the following fiscal year.

Keywords: MU radar, UAV, Atmospheric turbulence


05-JUN-2015 Vertical P_MU (dB)
Altitude ASL (km)
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
07:30
07:50
08:10
08:30
08:50
09:10
09:30
Time (LT)
25
20
15
10
5
0
-5
-10
-15
-20
-25

Generation of DSM of forest crown generated by vertical + oblique stereo pair images taken by small-sized UAV

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1. Introduction

Recently, the photographic surveying using a small-sized UAV (Unmanned Aerial Vehicle) has attracted attention. The SfM (Structure from Motion) method allows to create 3D point clouds and a 3D model from multiple 2D images (i.e., a large series of photographs of the same scene). Besides, an ortho-mosaic photograph and DSM (Digital Surface Model) can be generated from the 3D model. Obanawa et al. (2014) concluded that the points clouds derived from UAV-acquired imagery are as precise as LiDAR data. In contrast, Harwin and Lucieer (2012) reported that the precision of the point clouds becomes low when the targets are vegetations, due to an insufficient resolution of images, moving target vegetation with the wind, and parts of shadow areas in the images.

By considering these situations, this study performed to create a DSM of forest crown using vertical + oblique stereo pair images taken by small-sized UAV.

2. Methods

The study was performed in the larch forests at the foot of Mt. Yatsugatake, Nagano Prefecture in July 2015. The UAV flied over study site to acquire crown images of nadir and oblique directions using an autopilot system. The camera onboard the UAV was a RICOH GR. We first generated dense point clouds from the aerial images using PhotoScan (Agisoft). Then, we generated ortho-mosaic photographs and DSMs through point clouds according to the following three patterns.

(1) 70 nadir images at an altitude of 100m above the ground level

(2) (1) plus 54 nadir images at an altitude of 50m above the ground level

(3) (1) plus 54 oblique images at an altitude of 50m above the ground level

3. Results and discussion

We obtained DSMs which had 2.0~2.5 cm spatial resolution in all these patterns. Some parts of DSM in pattern (1) showed less surface roughness. In contrast, such parts decreased in patterns (2) and (3). In order to show how much percentage of these parts exist in each DSM, we calculated the percentage of the area that did not have point clouds. As for the pattern (1), 17.5% of the total areas did not have point clouds. Those of the patterns (2) and (3) were 12.8% and 9.7%, respectively. In other words, reproducibility was improved when oblique images were added (pattern 3) than nadir images were added (pattern 2).

4. Summary and future issues

The present study demonstrated the improvement of the reproducibility by adding the oblique images than the nadir images. Although the target was vegetation in this study, this method is applicable to other targets which has some parts of shade, such as structures or terrains.

As for future issues, we have to check an accuracy of created DSMs, to increase resolutions, and to consider the best angle and direction for creating DSMs.

5. References

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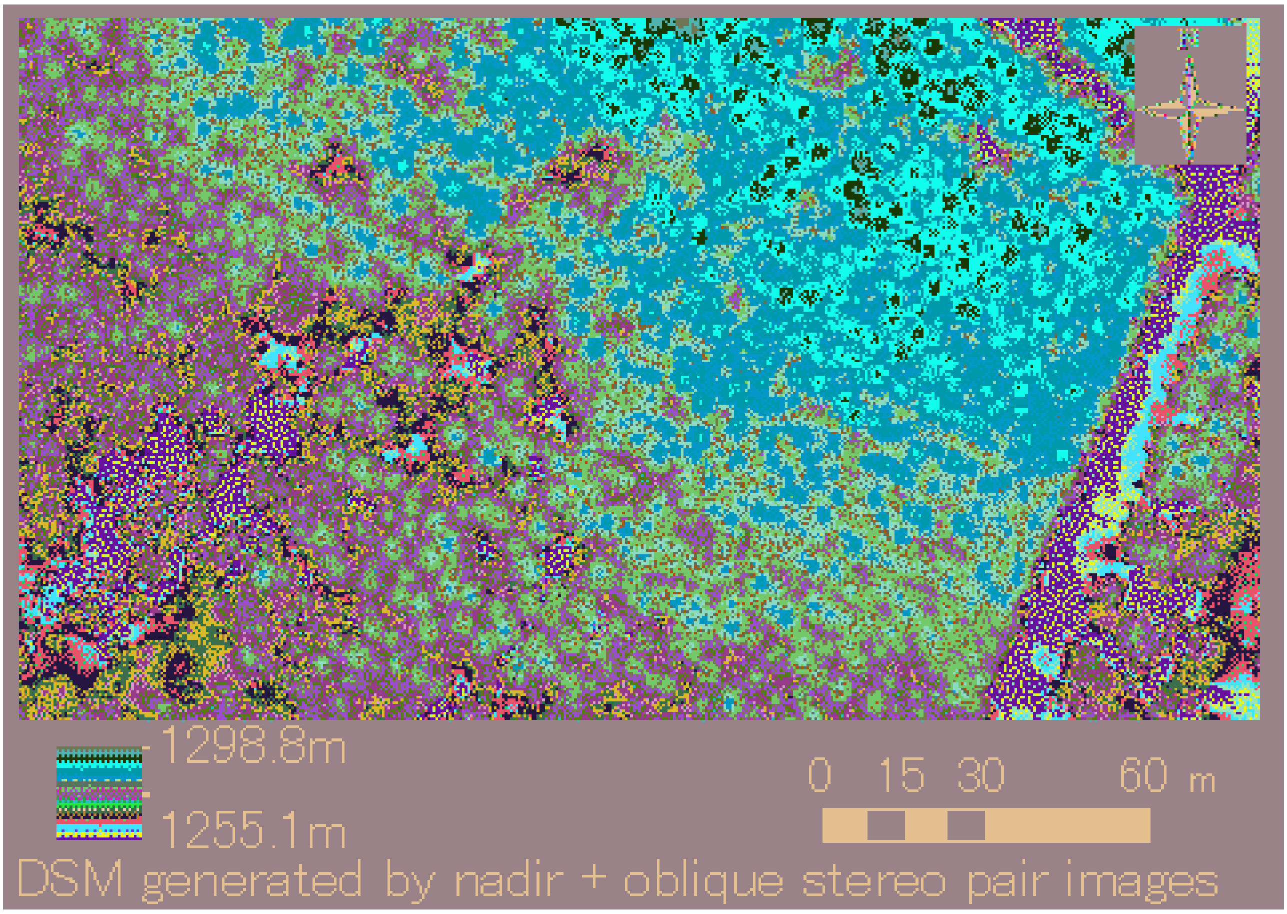
Harwin, S. and Lucieer, A.: Assessing the accuracy of georeferenced point clouds produced via Multi-View Stereopsis from Unmanned Aerial Vehicle (UAV) imagery, Remote Sensing, 4, pp.1573-1599,

2012.

Keywords: UAV (Unmanned Aerial Vehicle), SfM (Structure from Motion), DSM (Digital Surface Model), oblique images, forest crown



Long Range Aerial Photo Survey Experiments for Disaster Monitoring using Electric Foam Plane

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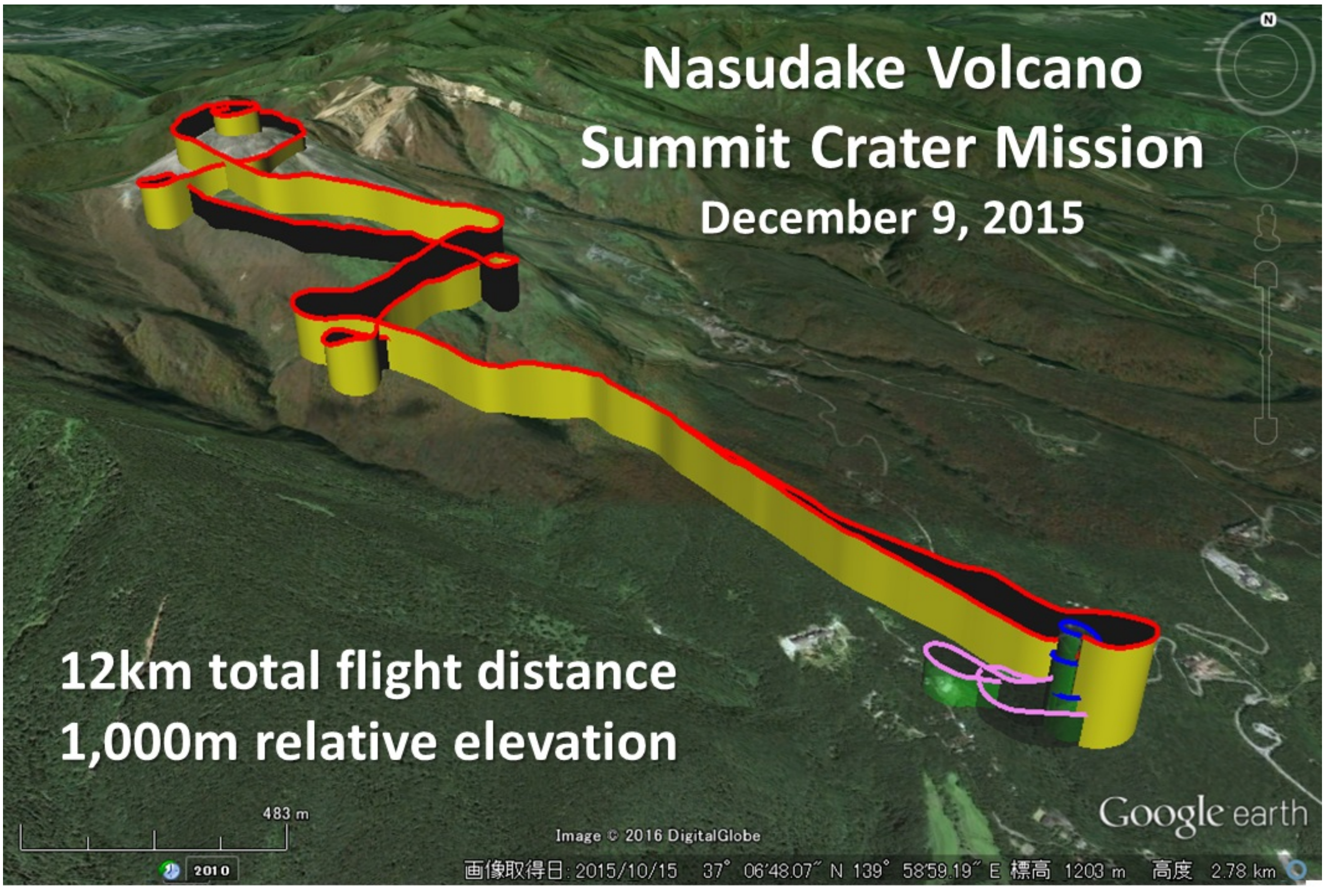
[Introduction]
We are conducting experiments of small UAV for applications to disaster risk assessment, monitoring and response. We first used multi-rotor UAV for our survey, which is easy to operate and can take-off and land at any topographic conditions. We now use fixed wing Styrofoam planes, which can fly faster and longer, and safer when it crashes. Our foam plane is a flying wing (tailless) type with 118cm wingspan, 750g weight without battery and camera, and with APM autopilot system. We use a light-weight GoPro camera for long-range flights. The cruise air speed is about 60km/h. It flies 60km in 60minutes to fully consume the 3-cell 5200mAh Lipo battery in circuit experiments at flatland under the no-wind condition.
[Experiment for application to disaster response]
We are carrying out experiments of utilization of UAVs as a part of a disaster information management systems. We demonstrated a long-range aerial photo flight at Kamaishi bay, Iwate prefecture on August 8, 2015, in the presence of Kamaishi city officers, fire fighters and police officers. The plane took off from a fishery port and flew over the Kamaishi-bay in clockwise for 15km at 140m ground altitude to take photographs along the coast.
[Experiments for application to river monitoring]
Fixed-wing UAVs are useful for monitoring river in both ordinary time and during and after disasters to watch the conditions of river dikes and other facilities along the stream. We demonstrated long-range aerial photo flights at Chikugo-gawa river in Fukuoka prefecture on November 20, 2015 and at Naka-gawa river in Tochigi Prefecture on December 9, under permissions of river management offices of Ministry of Land, Infrastructure and Transportation. The plane made 20km round trip (10km one-way) along the Chikugo-gawa river, and 24km round trip (12km one-way) along the Nakagawa-river at 140m ground altitudes.
[Experiments for application to volcano monitoring]
It is desirable to be able to monitor topography and temperature distributions of a crater and chemical components of gases and ashes to predict the activities of underground magma. Fixed wing UAVs can fly from outside the off-limit area few kilometers away from the crater when the volcano becomes active. We tested our UAV at Taal volcano of the Philippines on October 8, 2015, launched at 8km north from the crater with 200m elevation difference. We also tested it at Kirishima Shin-Moedake volcano of Kyushu on November 21, from 3km west of the crater with 400m elevation difference. An Asama volcano mission was made on December 8, from 5km north-east of the summit with 1300m elevation difference. The plane however accidentally hit the ground near the top. We found out that the baro-altitude meter on the flight controller had an +8% of systematic altitude error, which caused a wrong flight altitudes. We will climb the mountain to retrieve the craft when the snow melts. The crash point was recorded by the telemetry. We successfully made a crater mission for the Nasudake volcano in Tochigi prefecture on December 9, from 3.6km southeast of the summit, with 12km total flight distance and 1000m climbing up and down.
[Discussion]
Our experiments above were done all under weak wind conditions. The battery consumptions were only about a half or less. Calculations show a flight time to return to the launching point increases to 111%, 125%, 200% and 500% if the wind speed is 10%, 20% 50%, and 80% of the cruise air speed of the

craft, respectively. You have to make a short enough flight plan for the safe return, depending on airspeeds expected over the survey area. We plan to quantitatively evaluate the effects of battery capacity, payload, wind speed, elevation difference, cold temperature and rains. We also plan to make experiments for bigger planes for longer range, and smaller planes for easier and safer operations to find practical limitations of electric foam planes.

Keywords: UAV, Disaster, Fixed wing plane



Next generation tourism utilizing UAV

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The Great East Japan Earthquake has deprived the school and my city. We need to revive the city and create a new tourism. We've been introduced to the 1,100 the disaster area storyteller tour using the AR glass. Last year, we have developed a new tourism plan. It’s able to tourism from the sky by combining the AR glass and UAV.Next, we made the fields of buckwheat a tourist destination. We made art in red and white flowers, which is possible to see from an airplane. In this picture, one can see this art by airplane and Google map and UAV.I would like to propose a new UAV industry. This research was done with the cooperation of many organizations. We hope to spread this activity throughout Japan.

Keywords: Tourism, AR glass, UAV, Buckwheat, Airplane, Google map

Result of rice growth monitoring using small UAV from 2014 - 2015

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The purpose of this study is to monitor the growth of rice using UAV (Unmanned Aerial Vehicle) from 2014 -2015.The data collected were used to determine whether topdressing was required, assess the potential for lodging, estimate yield, create maps of rice growth for estimating eating quality. The monitoring of rice growth using UAV is both safe and cost effective for individual farmers. By producing objective data and maps for assessments of topdressing, lodging, yield, and eating quality, the findings presented here were shown to be useful for the detailed management of crop growth in fields.

Keywords: Unmanned Aerial Vehicle, NDVI, rice growth monitoring, orthophoto, DSM

