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.
This research is supported by the Grant-in-Aid for Scientific Research (A), No. 15H01793, of the Japan Society for the Promotion of Science.

Keywords: penetrator, geophysical observations, disaster prevention

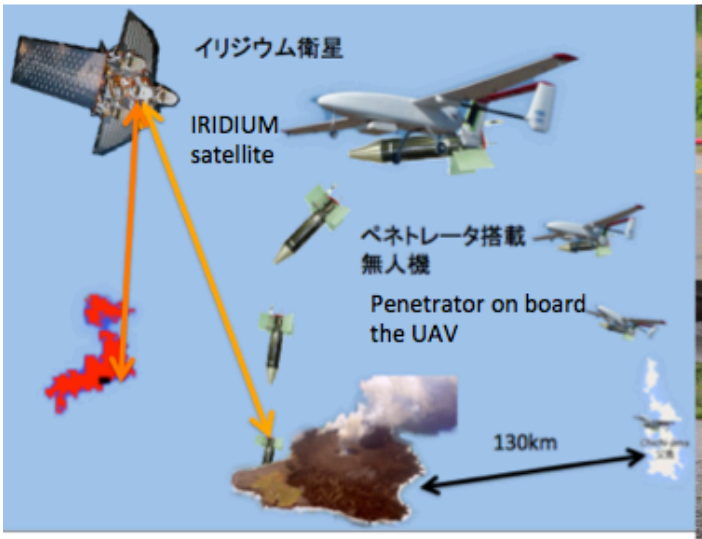

Fig.1

Fig.2

Shigaraki, UAV-Radar Experiment (ShUREX)

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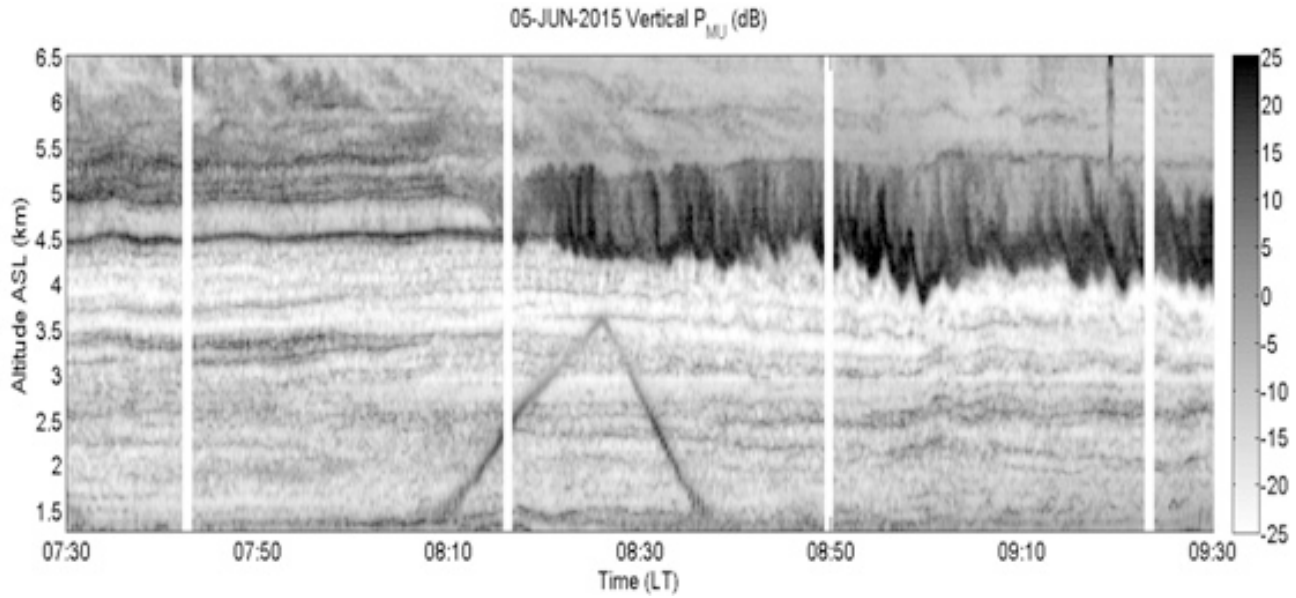
Turbulence mixing is an important process that contributes to the vertical transport of heat and substance, but it is difficult to be observed because its scale is very small. The atmospheric radar transmits the radiowave and receives backscattered echoes from turbulence to measure wind velocity profiles 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



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.
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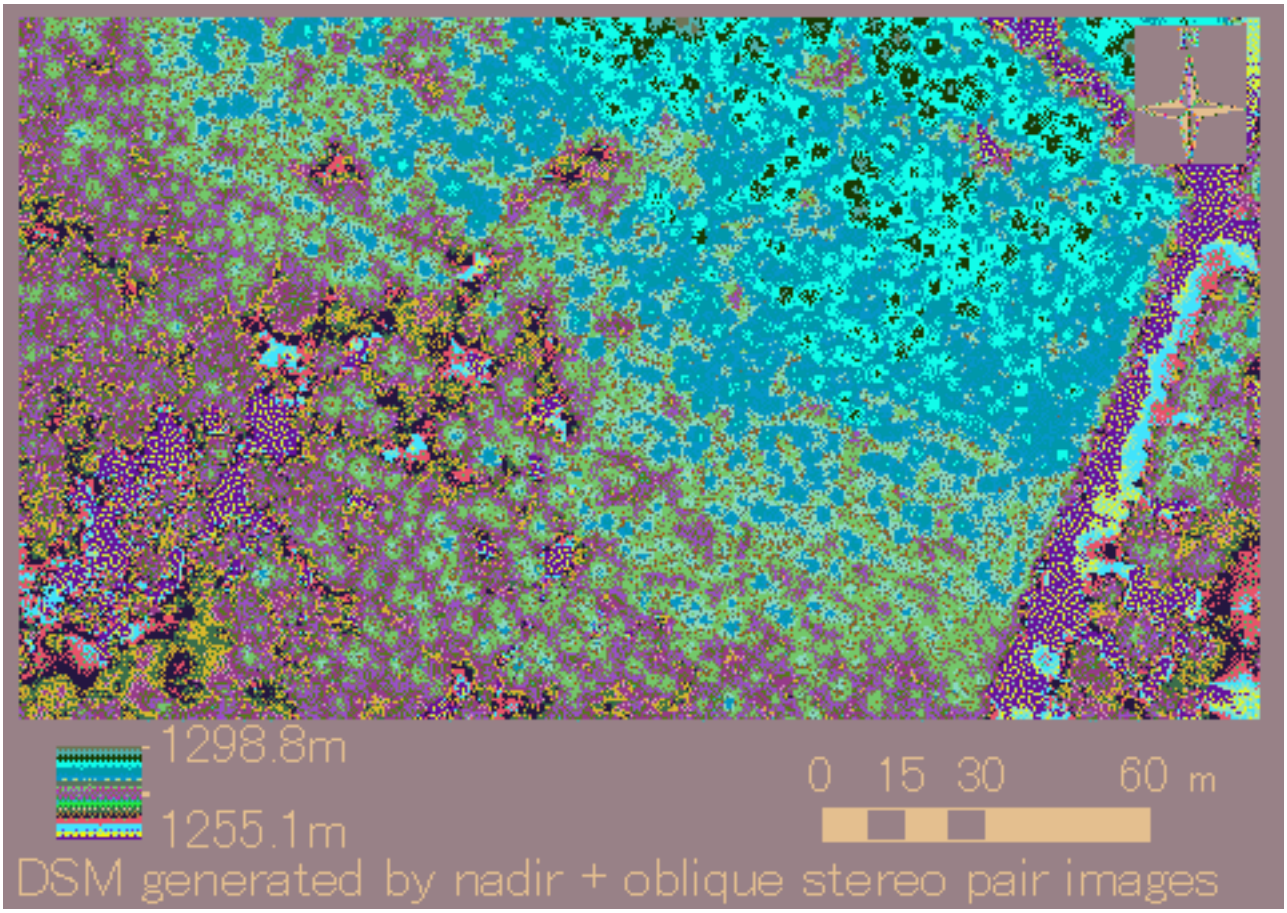
2012.

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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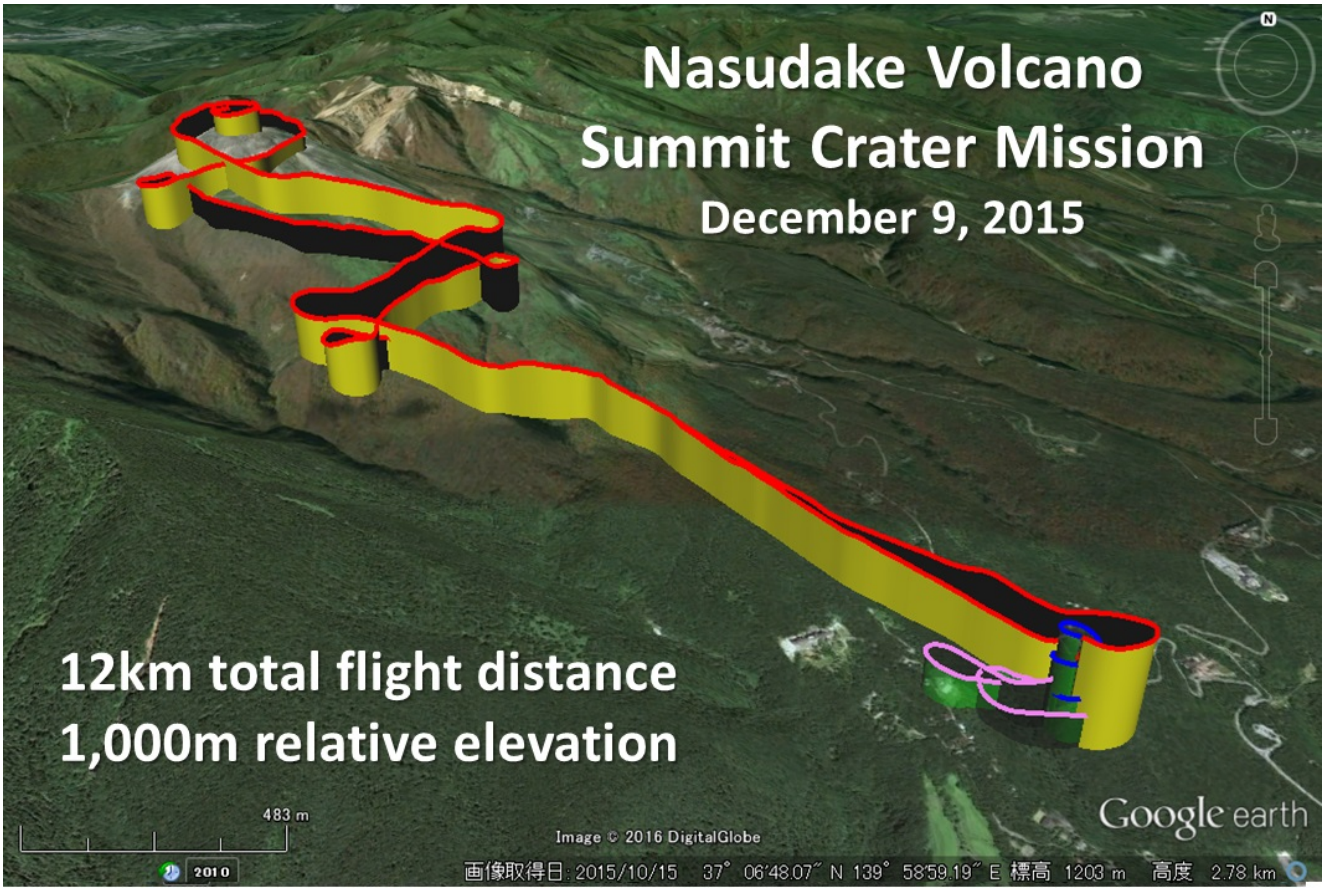
[Introduction]
We are conducting experiments of small UAV for applications to disaster risk assessment, monitoring and response. We first used multi-rotor UAV for our survey, which is easy to operate and can take-off and land at any topographic conditions. We now use fixed wing Styrofoam planes, which 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

Application and problems of UAV to use for the local government.

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Production and field trials have been made in various scenarios using Uncrewed Aerial Vehicles(UAVs).Efforts of local governments have been promoted intensively.For local governments,staff reduction is a remarkable trend.Such streamlining of organizations for efficient performance is expected to delay the response to and assessment of great disasters.Lack of personnel can become a factor that delays the initial response.Many local governments are planning a review of the Great East Japan Earthquake in 2011,but the lack of personnel and human resource budgets is a daunting social problem.Therefore,UAVs are presented as effective and safe tools.UAV applications can be extended to include aerial photography, pesticide spraying,checking of power transmission lines,disaster prevention,service life of building structures,and disaster prevention and mitigation.

Keywords: UAV, local government, disaster prevention

Solar energy potential assessment and mapping in high-rise building area with UAV spatial modeling

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Assessment of renewable energy potential in urban areas is treated as important information in many energy design projects and engineering projects due to a surge of interests in global energy issues. Especially, with spatially restricted areas for energy production corresponding to increasing energy demands, photovoltaic (PV) panels sourced by solar energy can be the one of the most promise alternatives. In this study, we calculated solar energy potential, one of the renewable energy, specifically in urban area, which are fulfilled with artificial objects, with applying UAV (unmanned aerial vehicle) to building spatial model. A variety of spatial data to calculate the solar energy potential are required: environment, orography, and climatology factors. In particular, orography in complex area like cities with many high-rise buildings can be highly influenced as shading effect of these area is significantly affected solar energy potential. In past, these data highly consume both time and expenses to be obtained, however, by recent development of UAV technology, spatial model in high resolution can be easily produced. Because of advantages of UAV, such as easy accessibility to the target site, high resolution sensor, GPS (Global Positioning System) and IMU (Inertial Measurement Unit), it is convenient to generate aerial map and DEM (Digital Elevation Map) with lower expenses. DEM is extracted from overlapped aerial images by stereo depth calculation. With the spatial database, which consist of the spatial model obtained by UAV and other factors directly measured or offered from Korean Meteorological Administration, solar energy potential can be estimated. The analysis module is design with Matlab, which introduces multi-variables such as local solar irradiation data, annual cloud ratio, weather, solar orbit, solar panel information and shadow effect. As a result, the map with total solar irradiation map and solar irradiation map considering panel information are composed, which can be used in the stage of decision-making, such as site optimization for PV power plant system and its potential power generation estimation. To summarize, we designed the potential solar power estimation module, particularly for urban areas with the forest of high-rise buildings. It is expected that this study will help people working in renewable energy area calculating solar energy potential and mapping.

Keywords: Solar energy, Energy assessment, UAV

KT200: an experimental autopilot drone below 200 grams

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UAV (Unmanned Aerial Vehicle) has become very popular in these days and improper use of UAV has become an object of public concern. As a result, the Civil Aeronautics Act is amended, and flight of UAVs over 200 grams is restricted. In order to take low-altitude air photos for research purposes without being mindful of restrictions, we assembled an experimental autopilot drone below 200 grams using commonly available parts in the market, and successfully carried out its maiden flight.

Keywords: Unmanned Aerial Vehicle, Civil Aeronautics Act, below 200 grams, KT200

Evaluation of Foam Plane under 200 grams for Aerial Photo Survey

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We are conducting experiments for utilizing small UAVs for natural disaster risk assessment, monitoring and response. Japanese Civil Aviation Law was amended on December 10, 2015 to more strictly regulate small unmanned aerial vehicles. Now we cannot fly UAVs above populated areas, beyond visible distances, and before sunrise or after sunset without permissions of Civil Aviation Bureau. The freedom of using UAV has now been considerably limited by the new law.
The regulation applies to, however, 200 grams or larger aircrafts only. Those below 200g are exempt from the new regulations and you can fly them anywhere without permission except airspace near airports and above 150m ground altitude. Also the lighter equipment is the safer when it crashes. Styrofoam plane of pusher type, with a propeller facing rear, under 200 gram is almost harmless when they crash. We therefore need to evaluate the performance of under 200 gram fixed wing foam planes. Our preliminary experiment shows it can fly 5 minutes in 30km/hour at 50m ground altitude. The 2.5km flight range is long enough for small scale surveys.

UAV images of before and after the 2014 Hiroshima debris flow disaster

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Before dawn of August 20, 2014 debris flow caused by a localized torrential downpour attacked out-skirt of Hiroshima City killing 75 people especially on gentle slopes at the foot of granitic mountain.
We described typical examples of human neglect against debris flow that resulted unnecessary loss lives, based on UAV photography taken before after the debris.
We also counted numbers of houses of different construction period in the debris flow area, demolished houses by debris flow and houses of victims, and came to know that ratio of demolished houses and victims were higher in post- high economic growth period.

Keywords: 2014 Hiroshima debris flow, GIS, Unmanned Aerial Vehicle

Rice Phenology Monitoring and Growth Parameters Estimation Using High Temporal Proximity Aerial Photos

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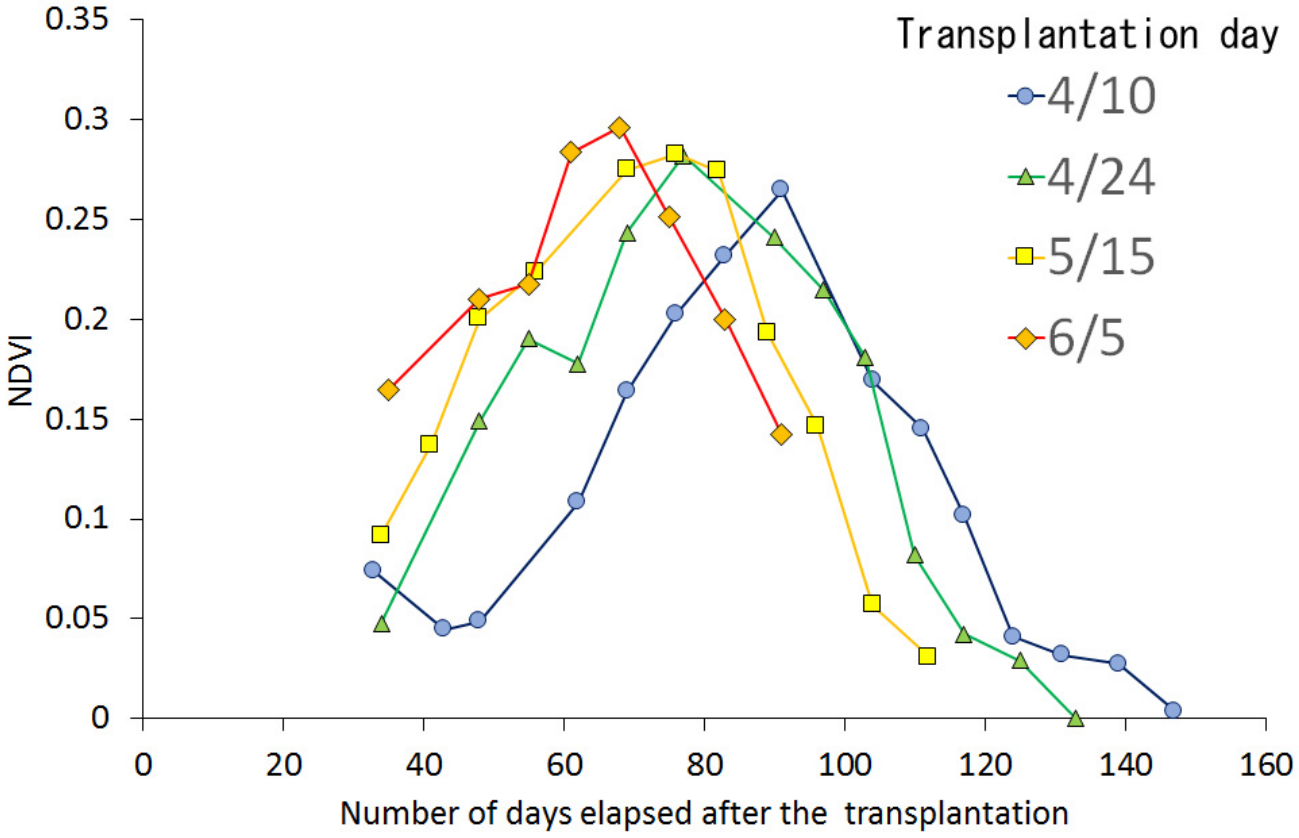
1.Graduate School of Science, Chiba University, 2.Chiba Prefectural Agriculture and Forestry Research Center, 3.Japan Map Center, 4.Center for Environmental Remote Sensing, Chiba University

1. Introduction
Crops monitoring, for example in the case of biomass monitoring, satellite remote sensing has the advantage for monitoring the large scale farmland. Because remote sensing technic can observe the wide area in the short time with no destruction. But, Satellite observation has the problem of certainly because of the clouds. Furthermore, when the problem of the growth heterogeneity in the field, more high resolution images are needed. So we used electric-powered Multicopter as the Unmanned Aerial Vehicle(UAV)which mounted the digital camera and monitored the phenology of rice using high temporal-resolution images by UAV. Then we also produced rice growth estimation models(LAI,Plant height).
2. Materials and Methods
We observed the two paddy fields in Chiba Prefectural Agriculture and Forestry Research Center between May 2014 and September 2015. These two fields are subdivided 48 compartments. And change the cultivation condition (transplantation day, varieties, amount of fertilizer).Observation equipment were electric-powered Multicopter (enRoute Zion QC630, MEDIX JABO H601G, DJI Phantom2) and digital camera (visible image: RICOH GR, GoPro, near-infrared image: BIZWORKS Yubaflex). Flight altitude was 50m.Ortho photographs and Digital Surface Model(DSM)were created by using the SfM/MVS software Agisoft PhotoScan Professional. The images taken with Yubaflex, after conversion to radiance in software(Yubaflex2.0), and created the ortho mosaic images using SfM / MVS software. After that, we calculated vegetation indexes (NDVI, etc.) using the ortho mosaic photos. At that time, we added $NDVI_{pure\ vegetation}$($NDVI_{pv}$)which pixels NDVI value are over 0 as a vegetation zone, as the one of the vegetation indexes. Actual measurement data of rice growth situation (heading day, plant height, LAI, etc.), using the observed value of the Chiba Prefectural Agriculture and Forestry Research Center.
3. Results and Discussion
In the time-series change of NDVI, there was a time that the amount of increase in NDVI were temporarily reduced before panicle formation stage. This time was almost the same time as the maximum tillering stage. At the highest tillering stage, some weak stems died without putting the head. And the number of stems is reduced. Such a characteristic influenced on the low increasing of NDVI. In this study, we showed the possibility to grasp the highest tillering period from the time-series change of NDVI. There is a difference in the time-series change of NDVI of the compartment for changing the only transplant day in cultivation conditions, the number of days from transplant to record the maximum NDVI became short at the compartment which transplantation day is later. This result is considered to be reflected that growth speed become faster at the high temperature. Furthermore, transplantation day became later, the maximum value of NDVI was increased. High NDVI means the good growth, and generally believed that increased yield. But yield was not increased. In the case of temperature become higher around the heading time, rice cause growth failure(Failure of fertilization, etc.). So we considered that yield was not increased in this study. We calculated the regression models(before heading time) of LAI and Plant height using the correlation between vegetation indexes and actual measurement data. As a result, NDVIpv and GNDVI showed good result. RMSE of the estimated results, 0.053m in plant height, 0.73 in the LAI in

NDVIpv, 0.043m in plant height, and 0.74 in the LAI in GNDVI. We showed the possibility of estimation of the growth parameters using this research method.

Acknowledgment
In this study, we receive cooperation in other fields such as use various aspects that got the data provided to the Chiba Prefectural Agriculture and Forestry Research Center rice warming laboratory. We thank you for cooperation.

Keywords: small UAV, proximity remote sensing, growth management, SfM/MVS



Monitoring alien plants by small UAV and TLC in Kanno river, Inbanuma catchment

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1.Introduction
In a lake of Inbanuma located in northwestern Chiba Prefecture, an alien plant of Alternanthera philoxeroides is introduced and breeds. This waterweed is designated as Tokutei Gairai seibutu, and not only losses biological diversity but also invades into rice field and causes the trouble in the drainage work due to being washed ashore drainage facilities in Inbanuma. Therefore Industry-academia-government-Citizen collaboration is making Alternanthera philoxeroides exterminated mainly Inbanuma water cycle restoration conference. However, there are few studies about Alternanthera philoxeroides in Inbanuma. It is urgently necessary that we know the dynamics of Alternanthera philoxeroides communities. In this study, we took pictures of Kanno river, Inbanuma catchment where Alternanthera philoxeroides is crowd from the sky at a high frequency. Then, we created high resolution ortho mosaic images that performs a detailed monitoring by using the Structure from Motion / Multi-View Stereo (SfM / MVS). We also use Time Lapse Camera (TLC) to monitor in detail.
2. Methods
We took pictures of Kanno river from the sky (5/30,6/22,7/25,8/26,9/23,10/29). We used a small UAV of enRoute Inc. ZionQC630, and the camera of RICOH Inc. GR. We used the Mission Planner of free software, and made UAV fly with the auto pilot, at 50m height from the ground. We also took pictures from the sky at 1 second intervals. We created ortho mosaic images by SfM/MVS software (Agisoft Inc. PhotoScan Professional ver1.2) based on images taken from the sky by the UAV. Then, we did interpretation of the Alternanthera philoxeroides communities. We used the GIS (ArcGIS 10.2), and created the polygon of Alternanthera philoxeroides communities that had flourished near the bank at each surveyed time. In this way, we managed the area, location, shape and the like of the each community. TLC is setting at the bridge and taking pictures of river section at 10 minutes intervals.
3. Results and Discussion
Community area in Kanno river, was 1239.8m^2 in May and 2080.2m^2 in October. During this time, the extermination of Alternanthera philoxeroides communities had been carried out, its area was 740m^2. In addition, the community that had flowed naturally was about 309.7m^2 totally. This indicates community practically had expanded by 2.5 times. Community flown during 8/26~9/23 was 168.2m^2. It is considered that heavy rain by the typhoon No. 18 during 9/6~9/10 was the cause of this outflow. The best growing community's number in the area expand was the greatest during 6/22~7/25, but the period when the each community growth is the best varied. If communities grow and community area expands, the area expand is also increased in proportion. Therefore expanding of community area was bigger late than early during observation period. What has lost the impact of this community size is the rate of expand. Also in the rate of expand, the variation was observed in the period when the rate of expand is the best, during 5/30~6/22, the number of community that was the best in the rate of expand was the greatest. In Kanno river there is variation in the community size, even the same time, and that the growth amount in proportion to the community size became big, it is easy to grow during 5/30~6/22, and gradually growth is worse become a measure of growth prediction. Alternanthera philoxeroides extends the roots to riverbank again after the spill. However, while the number of the 12 m^2 or more of the community flowing out during the observation period is

eight, there is no community to appear newly. In brief, in Kanno river, the relatively large community was difficult to fix again. On the other hand, we can check the communities of less than $2m^2$ in great numbers, that is to say, the relatively small community is likely to be a community of high expansion capacity in Kanno river.

Keywords: UAV, invasive alien species, Industry-academia-government-Citizen collaboration