

Accurate volumetric measurement of tsunami boulders using 3D point clouds

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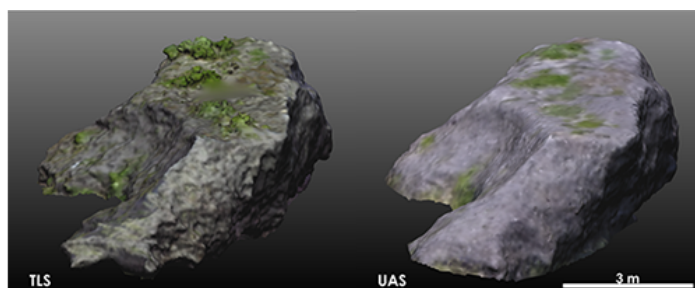
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Volumetric measurements of large tsunami boulders have been a challenging issue. Although manual measurements have often been carried out to estimate the size of boulders, the volume may not be directly measured in such a manner because of their complex shape and vegetation covers. Alternatively, three axes (long, medium and short) are often used as representative size parameter of a boulder. However, the accurate measure of the volume is necessary for quantitative assessments of the transport processes of tsunami boulders. Here we perform field measurements of three-dimensional morphology of tsunami boulders in the southern Ryukyu Islands using 3D technologies including terrestrial laser scanning (TLS) and structure-from-motion multi-view stereo (SfM-MVS) photogrammetry either by an unmanned aerial system (UAS) or ground-based camera. The 3D point cloud data obtained by TLS and UAS-SfM are registered and georeferenced, manually filtered to remove vegetation, and converted to 3D mesh data by calculating normal and reconstructing 3D surfaces. The TLS-derived data is used as the reference, while UAS-derived data is utilized for the measurements of widely-distributed tsunami boulders. Although detailed topographic features such as the surface roughness are much better represented in the TLS-derived data, the resultant mesh volumes are nearly the same for both data with <1% difference. The TLS- and UAS-derived volume data are compared with those by manual measurements, showing a good linear correlation. The accurate measure of the volume of tsunami boulders is used for the reconstruction of the potential kinematic energy of tsunami waves, suggesting the presence of higher tsunamis in the southwestern side of the Ryukyu Islands.

キーワード：地上レーザ測量、SfM多視点ステレオ写真測量、無人航空機、点群、3次元メッシュ

Keywords: terrestrial laser scanning (TLS), SfM-MVS photogrammetry, unmanned aerial system (UAS), point cloud, 3D mesh



UAV-SfMを用いた東南極宗谷海岸基盤岩風化状態の定量的解析

Quantitative analysis of bedrock weathering at Soya Coast, East Antarctica using the UAV-SfM

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南極氷床の過去の変動記録は、今後劇的に変化するかもしれない東南極氷床融解の将来予測のためにも重要である。東南極宗谷海岸南部では宇宙線生成核種を用いた表面露出年代測定法に基づく氷床後退年代が示されているが、地形学的な記載に乏しく、氷床の最大拡大期や後退のスピードといった時空間的な氷床変動の復元に至っていない。従って、スポット的な氷床後退年代と共に、基盤の風化状態などの地形学的特徴から氷床変動の同時期面を推定し、より詳細かつ広範囲な氷床変動を復元することが重要である。そこで本研究では、宗谷海岸北部 (West Ongul島) と南部 (Telen) において、Unmanned aerial vehicle (UAV) による空撮と Structure from Motion (SfM) 技術により取得した数値標高モデル (DEM) を用いて、基盤岩の風化状態の評価を試みた。また、空撮地域内において岩質がほぼ同等だと確認された地点で表層の岩石を採取し、コーチップ° 硬さ試験機を用いて深さ方向 (表層から5 cmまで) の岩石の反発強度を調べた。これらの現地調査は、第57次南極地域観測隊 (2015年12月から2016年2月) の一環として実施した。

West Ongul島とTelenのUAV-SfM解析領域内における地形的特徴を抽出するため、全体の傾斜を補正後のDEMに対して周波数解析を行い、5.0 m、1.0 m、0.2 mのハイパスフィルターを掛けることにより各周波数成分の抽出を行った。その結果、低周波成分(5.0 mハイパス)は主に地質構造に起因する起伏を反映するのに対し、高周波成分(0.2 mハイパス)はTelenにおいてやや卓越し、とくに地形の急傾斜に対応することが分かった。また、約5 cmメッシュにおける傾斜のヒストグラムからも、Telenには40以上の傾斜をもつ区画が多いことが明らかになった。このことは、Telenにおける高周波成分の卓越が、地形の遷急線にあたる地形の角が保存されていることを示している可能性がある。一方、West Ongul島では風化の影響で地形的に角張った部分が削剥されてしまったと考えられる。また、両地域のコーチップ° による反発強度(L値)を比較するとTelenのL値はWest Ongul島と比較して約1.2倍大きかった。さらに両地域とも深度が増すにつれ、L値が大きくなる傾向がある。このことは、West Ongul島の表層で物理的強度が減少していることを示しており、表層の風化による影響を強く示唆する。つまり反発強度の結果はUAV-SfMで得られた地形の特徴と整合的な結果といえる。以上のことから、今回得られた宗谷海岸北部と南部の地形情報の違いは氷床後退時期の違いに起因しており、West Ongul島がTelenに比べてより強く風化の影響を受けていることを示していると考えられる。しかし、今回の解析では地形の起伏には岩質の違いや地層の傾き、氷河底での環境など様々な要因をまだ十分に検討出来ておらず、今後の研究課題である。

キーワード : UAV-SfM、岩石風化

Keywords: UAV-SfM, Rock Weathering

Relationships between coastal sand dune vegetation and landforms: A preliminary analysis using TLS and UAV-SfM photogrammetry in Tottori Sand Dunes

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Coastal sand dunes have been closely related to human activities. In recent centuries, the landward sides of sand dunes have been modified by the creation of farmlands and erosion control forests, as well as the construction of harbors, airports, roads, and residential areas. On the sea side of sand dunes, coastal structures, including revetments and detached breakwaters, have been installed to prevent coastal erosion. By these reasons, the total area of sand dunes has significantly decreased in Japan, and the ecosystem therein has been greatly affected by these changes. The number of endangered species per unit area is particularly large when compared with those in forests and wetlands. These facts encourage the need for the conservation and restoration of sand dunes and their ecosystem.

Meanwhile, investigating sand dunes in the natural state is indispensable for future planning of such conservation planning. This study focuses on the vegetation in sand dunes, which is the primary producer of the ecosystem. In previous studies, it has been suggested that the accretion of sand has the greatest influence on the distribution and survival of vegetation in sand dunes. However, although many studies have explored relationships between coastal sand dune vegetation and environmental factors, effects of landforms on the vegetation growth and distribution have rarely been examined. Here we investigate the spatial relationships between vegetation and landforms in the Tottori sand dunes using high-resolution ground surface information obtained from terrestrial laser scanning (TLS) and unmanned aerial vehicle-based structure-from-motion (UAV-SfM) photogrammetry. Sand dunes vegetation was classified into several communities, and a vegetation map was created based on the orthorectified images obtained by UAV-SfM photogrammetry. We analyzed the spatial correlation between vegetation and landforms. In particular, there is a relationship between the aspect of slope and distribution of vegetation. The distribution of vegetation and landforms is likely affected by the constant wind from the south having a speed of more than 5 m per second, as well as the seasonal winter wind from the northwest having a speed of more than 10 m per second. Because coastal sand dunes are a part of the dynamic ecosystem, it is necessary to further explore the dynamic relationships of vegetation growth with changing landforms, which will be clarified by their continuous monitoring.

キーワード：海岸砂丘、植生、地形、TLS、UAV-SfM

Keywords: Coastal sand dune, Vegetation, Landforms, TLS, UAV-SfM

阿蘇地域における斜面崩壊の時系列解析

Time series analysis of TLS-derived point clouds for shallow landslides in Aso region, Kumamoto, Japan

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2016年熊本地震によって、熊本県阿蘇地域では多数の斜面崩壊が発生した。地上レーザ測量を用いて阿蘇市の仙酔峡で地震前後の斜面形状を取得し、標高の変化量に着目して、点群や縦断面に基づく解析を行った。この結果、過去の豪雨による崩壊地においても、今回の地震による新たな崩壊が発生したことが明らかとなった。崩壊深は約6 mで、これは豪雨による過去の斜面崩壊よりも深い傾向があることがわかった。縦断面の形状については、豪雨による崩壊が直線的であるのに対し、今回の崩壊はやや湾曲しており、従来と異なるすべり面、崩壊様式で生じた可能性が示唆される。また、地震後約半年の間にも、崩壊地周辺の尾根付近、崩壊地の中腹、崩壊地下部の谷底付近でも変化が生じており、崩壊の残土が下流へ流出したことが考えられる。こうした二次的な土砂移動は、2016年6月の比較的強い降雨と関連している可能性がある。

キーワード：平成28年（2016年）熊本地震、地上レーザ測量、点群データ、高精細地形データ、斜面崩壊、時系列解析

Keywords: The 2016 Kumamoto Earthquake, Terrestrial laser scanning, Point clouds, High-definition topographical data, Landslides, Time series analysis

Quantitative assessment of tree trunk inclination and topographic conditions using multi-temporal point cloud data in a hilly catchment

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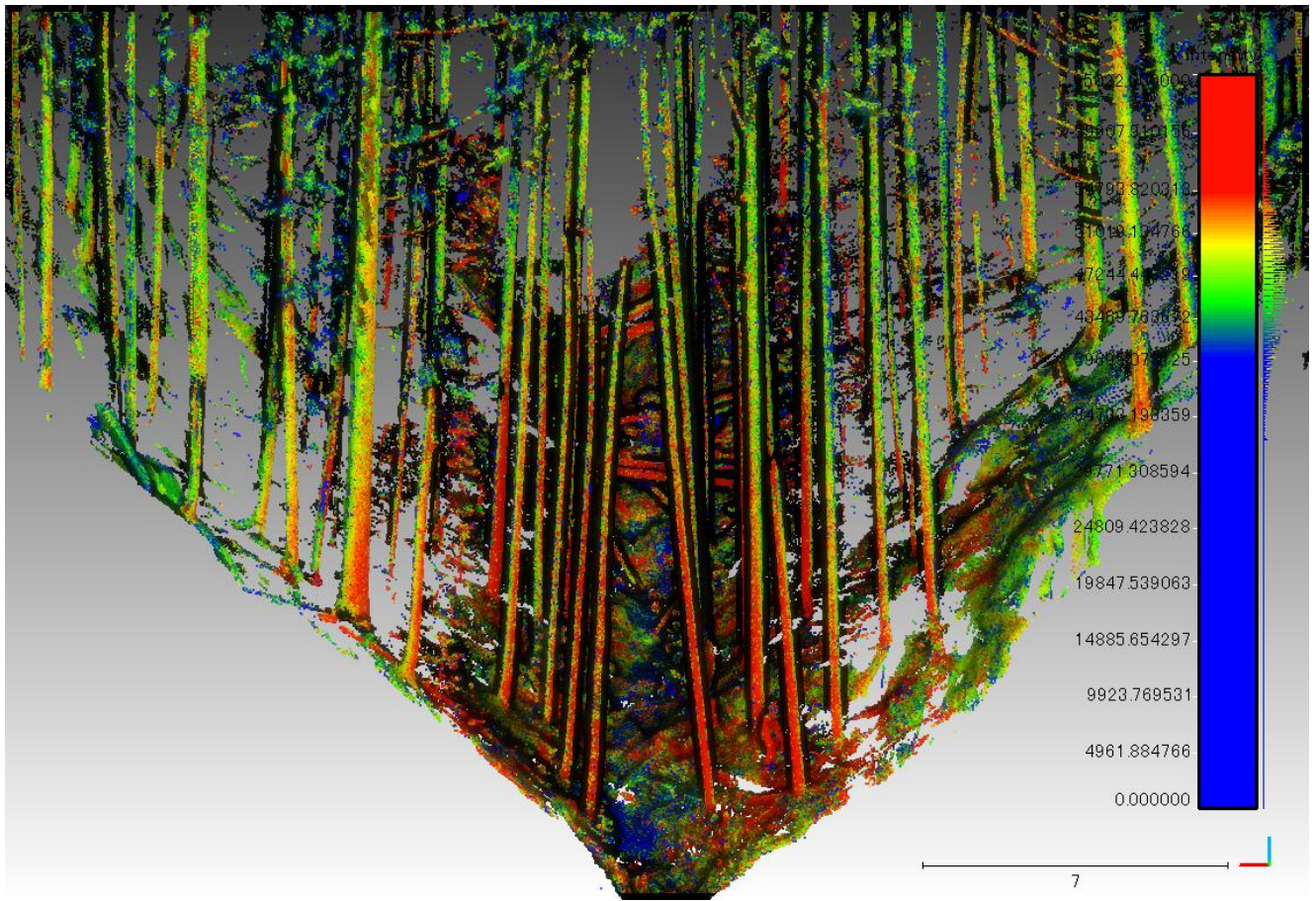
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Recent advances in the measurement approaches using terrestrial laser scanning (TLS) have enabled quantitative evaluation of forest environments with three-dimensional (3D) point cloud data. Several issues, including estimation of biomass, light transmission through canopies, and hierarchical structures of forests, have been investigated by point cloud analysis. However, the 3D structures of individual trees, as well as the relationships among such vegetation characteristics and topographic conditions, remain to be further examined. In this study, we examine the inclination of tree trunks, as a representative shape parameter of forest vegetation, in a small hilly watershed using 3D point cloud data. The effects of topographic conditions on the vegetation shape are further investigated. We use multiple time series of point cloud data obtained by TLS in 2005 and 2016, which enable us to detect decadal changes in the vegetation and topography in the study site. Spatial distribution of the tree inclinations shows topographic controls on the vegetation shape: for instance, more inclined trees are found around the valley bottom where slopes tend to be steep due to the channel incision. Comparisons of the multi-temporal point cloud data reveal the changes in both vegetation shape and topography. In particular, gradual erosion and deposition of sediments on the order of decimeters to meters are found to have occurred around the valley bottom following the occurrence of the debris flow in 2005. In the last decade, the sediment accumulation was dominant in gentle reaches along the channel, while the erosion occurred on the steep side slopes. Such the change in topography seems to have affected the tree trunk inclinations, probably due to the soil creep toward the steepest descent of the catchment slopes. Also, it is suggested that the tree crown have grown asymmetrically toward the sunlight that is more available in the forest gap around the valley bottom, leading the tree trunk more inclined toward the gap due to its unbalanced weight. This kind of analysis will also contribute to the disaster prevention issues in mountainous or hilly areas with forests.

キーワード：樹木の幹の傾き、地形、TLS

Keywords: tree trunk inclination, topographic, TLS



UAVとSfM-MVSを利用した礫床河川計測の運用に関する検証と可能性

Verification and Possibility on the Operation of Gravel Bed River Measurement using UAV and SfM-MVS

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近年、UAV (Unmanned Aerial Vehicle) とSfM-MVS (Structure from Motion -Multi-view Stereo) を利用することで簡単に数cm～数十cm程度の高空間解像度の地形情報を取得することが可能になっている。日本の地形学においては特に災害が発生した際に現れる地すべりや地表地震断層の測量など、即時性の高いデータを整備することが行われてきた。UAVとSfM-MVSは、高空間解像度の地形情報を取得することを低コストで行うことができるという利点がある上に、調査設計者がデータを取得したいタイミングで自由に測量することができるという利点もある。これにより、従来の空中写真よりも高時間解像度の地形情報を取得することが可能になった。

高時間解像度の地形情報を取得できるメリットを生かして、発表者は礫床河川の地形変化のモニタリングを行うことを最終的な目的としている。まず、UAVとSfM-MVSで生成できる数値地形モデル (DSM : Digital Surface Model) の解像度は数cm～数十cmオーダーであり、河床礫を1つ1つ捉えることができる。また、日本の礫床河川は勾配が急でありかつ流量が多いため、流速が速い。これにより、頻繁に土砂移動現象が起こると考えられる。これを定期的に観測することによって自然現象下の土砂移動を捉えることが可能となる。しかし、既存研究では対象地を高空間解像度で一度撮影したデータをもとに解析した研究が多くを占めているため、継続的に変化量を定量的に算出する研究が少ない。また、礫床河川を測量できるレベルの空間解像度を誇るデータの差分抽出を行っている研究も少ない。本研究では、実証実験と現地での測量実験を通して、礫床河川の測量を行う際の運用に関して検証を行い、解析プロセスを提案し、地形変化量を算出するための課題を挙げる。

まず、河床礫を想定したサイズのレンガをUAVとSfM-MVSを利用して測量し、実際のレンガのサイズとどの程度精度が異なるのか検証した。

DSMの精度は、飛行高度を上げるにつれて低下する。これは、空間解像度の低下の影響である。また、画像の解析枚数を増やすにつれて精度が上がる傾向があるが、画像が増加することで新たな特徴点が抽出されるため、生成するモデルが異なってしまう場合がある。カメラの性能やGCPによりDSMの垂直・水平精度は大きく変化する。

さらに、DSMの精度に最も影響を与えるのが解析の際に付与するGCP (Ground Control Point : 地上基準点) である。GCPは測量する対象物のxy平面の端から端、z方向の最高点および最低点に付与し、対象物を内挿するように配置するのがよい。さらに、適切な高度情報復元精度を保つために、最も割合の大きい高度付近にGCPの個数を増やすことが必要である。

以上のことから、UAVとSfM-MVSでDSMを生成する際には、測量者の計画・解析方法が空間解像度や精度に大きく関わる事が明らかとなった。特に、地形学への応用を試みる際には、対象となる地形を計測するための適切な空間解像度を測量者が自ら予め設定することが必要である。さらに、実験セットを利用して差分の抽出を試みた。その結果、精度の高いDSMどうしを差分抽出することで垂直精度0.2cm程度の差分抽出が可能となった。

この結果を利用して実際に礫床河川の測量を試みた。対象地域は白山に源流を持つ一級河川である手取川である。100m×100m程度の河床を、2週間に1回程度の頻度でUAVを利用して撮影した。その際改正航空法に従って対地高度30mで飛行させた。撮影した画像をSfM-MVSで解析し、DSMを生成した。GCPは、一時期の

測量データ（ここでは2016年12月8日撮影分）を利用して基準点を定め、他の時期のデータのものに付与して使いまわした。DSMの解像度は2.5cmであった。

その結果、図1のように実際の礫を捉えることができた。捉えることができた礫径は約50cm程度であった。また、等高線を描くことで礫の形状を表現することができた。これを、他時期のDSMとの差分抽出を行い、礫の運搬・堆積状況を計測しようとした。その結果、水平誤差が約45cm程度発生してしまい、礫サイズでの差分抽出ができなかった。GCPの水平精度は5cm程度であるのに対し、DSMの誤差にも目立った系統性がみられなかった。よって、相対座標を用いたGCPを用いるのではなく、絶対座標を用いた水平精度数mm程度の精密な（Global Navigation Satellite System：全球測位衛星システム）やRTK（Real Time Kinematic）などの高精度測量を行う必要がある。

本研究を続ける上でこの問題を解決することではじめて礫州の発達過程を従来の地形学的な研究成果とつなげることができる。そして、DEMで微地形の変化を捉えることで数十万年スケールの地形発達過程をシミュレートし、地形発達シミュレーションの実現が可能となる。手取川ではダム建設以降礫の流出が盛んに行われており、数十年でも河床の変化が激しい。今後は、手取川の地形発達シミュレーションを構築し、数十万年スケール程度の地形発達を推測し、河道変化と環境変化について考察を深めていきたいと考えている。

キーワード：地形計測、高解像度地形情報、礫床河川、DSM

Keywords: Topographic measurement, High-definition Topographic Data, Gravel bed river, Digital Surface Model(DSM)

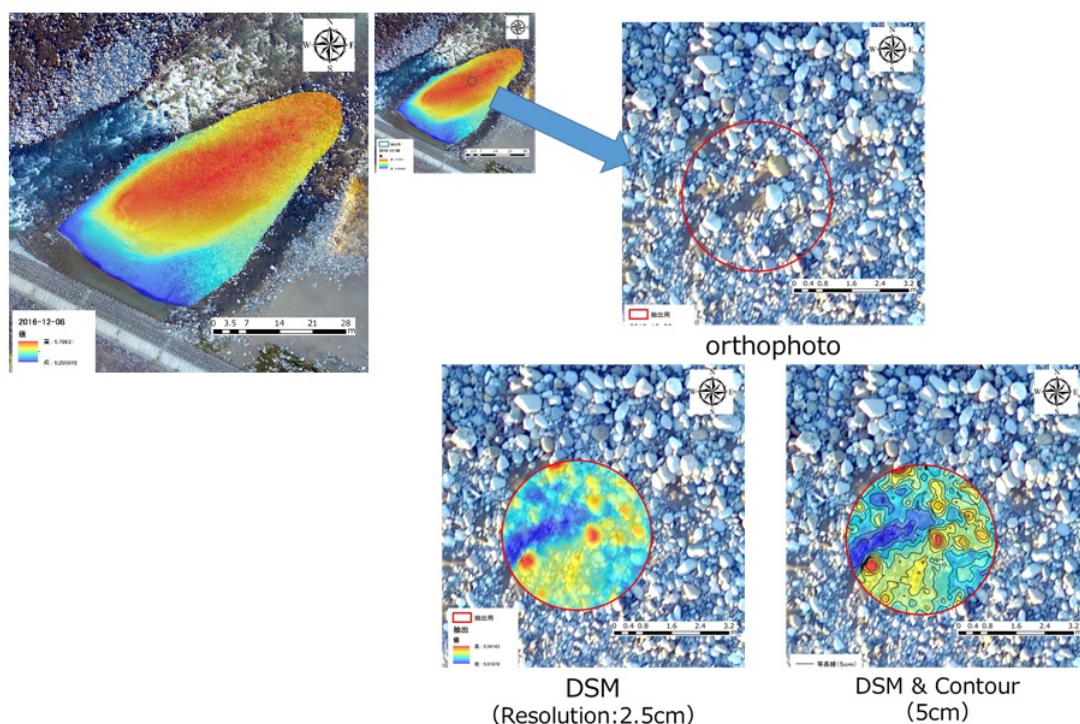


Fig.1 DSM and Orthophoto of the gravel bed river generated by UAV and SfM-MVS

Application of Structure-from-Motion Multi-View-Stereo Photogrammetry to the extraction of vertical deformation caused by an inflated magma chamber in an analogue experiment

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In recent years, SfM MVS (Structure-from-Motion Multi-View-Stereo) photogrammetry has become widespread in the Earth sciences. Although this technique has been applied mainly to topography measurement, it has been expected to have applications in the analysis of data from analogue experiments (model experiments).

In this study, we attempted to verify whether or not the SfM MVS technique could extract displacement of a sub-millimeter order when applied to a small analogue experiment. We employed an analogue experiment on surface deformation caused by inflation of a magma chamber, because this type of experiment has often been conducted and discussed for the purpose of understanding caldera formation, and excellent results have been obtained. In addition, the requisite knowledge for obtaining a good result has been accumulated.

We made an experimental apparatus using an aluminum tube (diameter 60 cm), a small balloon, a bicycle pump, and rice powder. We conducted experiments and analysis according to the following procedures. (1) We fixed the balloon (radius 2.0 cm) at the center of the base of the tube, and covered it with rice powder. The base is 19 cm below the top of the tube. The scale of this model experiment was 1/20,000, and the fracture strength of the material was estimated using the Coulomb-Mohr criterion for model experiments. (2) We took photos (80 pictures) of the non-deformed surface as an initial state, from various directions and distances. We employed a RICOH GR II digital camera to take the photos. (3) We inflated the balloon radius from 2.0 cm to 4.5 cm in 0.5 cm increments, and we took photos (80 pictures) of the deformed surface caused by the inflated balloon at each stage. (4) We analyzed these photos using PhotoScan software, and constructed a DEM (Digital Elevation Model). (5) We detected net surface deformations caused by inflations of the balloon by subtracting the DEM data obtained at an arbitrary stage from the DEM data obtained at the other stages, using QGIS software.

We repeated this experiment more than ten times, and found that vertical deformations of more than 1 mm could be extracted without conspicuous noise. In addition, we found that inhomogeneity of illumination affected the extraction of the net deformation field, when we attempted to extract vertical deformations of less than 1 mm. The effects of this inhomogeneity appeared as systematic noise or error, appearing like a shadow in the results. This systematic noise appeared in the results even if we illuminated the experimental apparatus using strong LED lights. From the occurrence pattern of the noise, we found that the ceiling lights were causing inhomogeneity of illumination. When we conducted the experiments without the ceiling lights, we were able to detect vertical deformation of 0.2 mm without conspicuous noise.

From these results, we can conclude that the SfM MVS technique can extract vertical deformations of 0.2 mm when the technique is applied to model experiments of the scale of 1/20,000.

キーワード：多視点ステレオ写真測量、アナログ実験、マグマ溜まりの膨張

Keywords: Structure-from-Motion Multi-View-Stereo Photogrammetry, analogue experiment, inflated magma chamber

3D modeling of a damaged Sabo dam with a combination of a DSM and near-surface geophysical survey data

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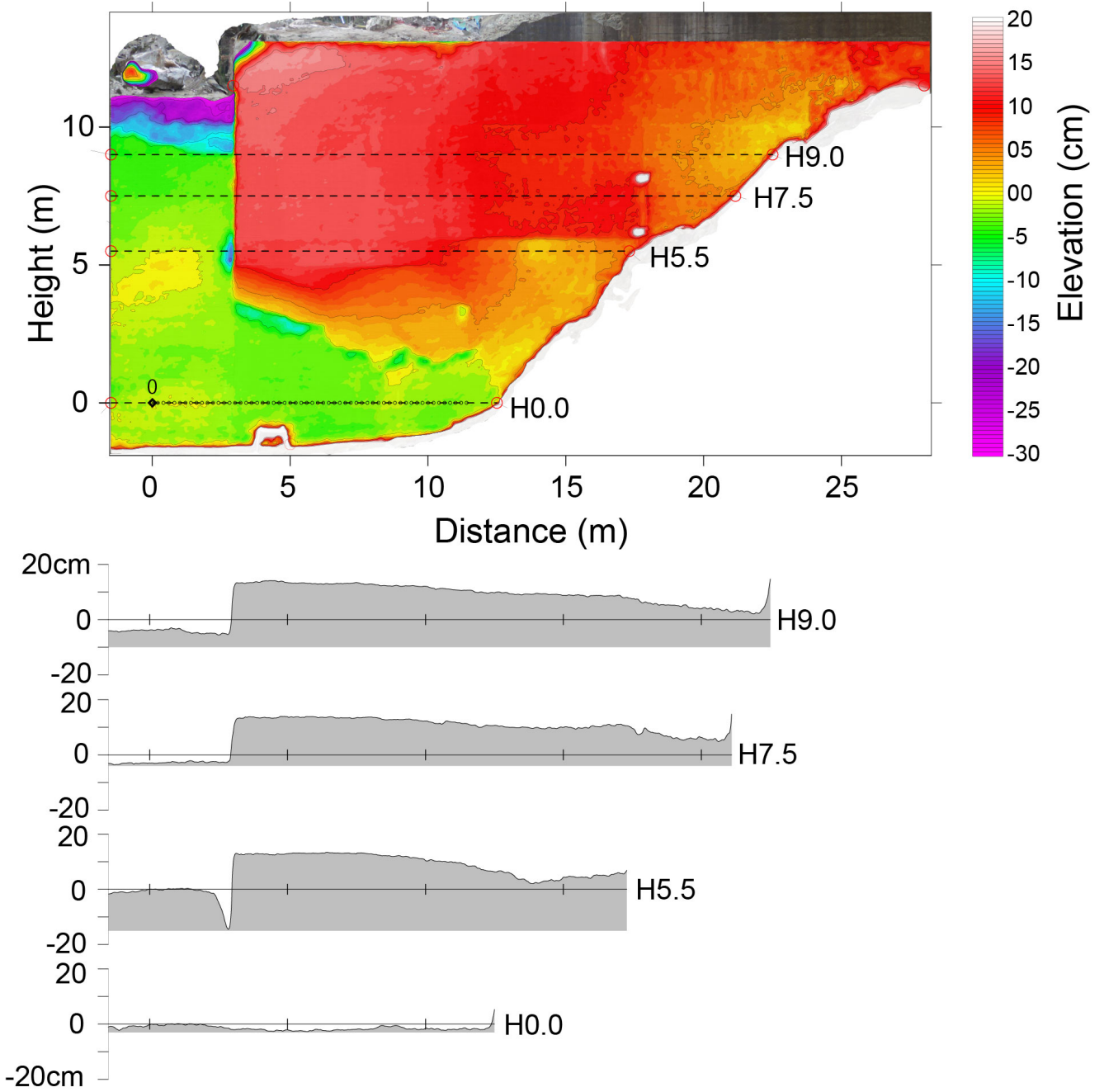
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We conducted an integrated analysis of high-resolution digital surface model (DSM) and detailed geophysical survey data obtained on the rear wall of a sabo dam, which had been damaged by a huge debris flow occurred in July 9, 2014. An orthophotograph and a DSM of the rear wall of the dam were reconstructed from a set of surface digital photo images at a spatial resolution of 1.2 cm using commercial multi-view stereo (MVS) software (Agisoft Photoscan). The debris flow swept away the top 5 m part of the dam, and segmented the dam body into several blocks associated with horizontal cracks. Estimated surface dislocation was at most 20 cm. Our DSM covered the right half surface of the dam (left bank side), about 30 m wide and 20 m high. We also carried out GPR measurements on the surface, 10 m wide and 15m high, by hanging and moving up the tool along the surface from the top of the dam. A total of 50 lines was scanned at 20 cm intervals. In addition, high-resolution seismic measurements were conducted along 5 survey lines set horizontally on the surface. Piezoelectric type accelerometers were pasted on the surface at 20 cm intervals, and manual hit using rock hammer was employed for generating high-frequency signals.

Because the dam surface was too steep and too high to place a number of GCPs by hand, only 3 points were set on the surface at reachable distances. Then we built a DSM projected on the inclined plane defined by these 3 points. Detailed GPR measurements successfully imaged fractures at the shallow depths up to 1 m, and high-resolution seismic survey detected dipping fractures extending into the deeper portion in the body up to 8m. In addition, photogrammetric analysis clearly mapped blocked deformation. Finally, we combined these planes to create a 3D model with aid of a 3D modeling tool named Voxler provided by Golden Software. In conclusion, joint interpretation of geophysical survey results with the photogrammetric analysis was quite helpful to interpret the dislocation process of the dam body. GPR and high-resolution seismic survey results also demonstrated their applicability for the delineation of internal fracture in large concrete structures.

キーワード：オルソ画像、数値表層モデル、砂防ダム、地中レーダ、亀裂可視化

Keywords: Orthophoto, DSM, Sabo dam, GPR, Fracture Imaging



Preliminary Study of Scale Effect on Investigating Unknown Object Using Borehole Electrical Resistivity Tomography

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An in-situ experiment for investigating ground improvement using borehole electrical resistivity tomography method, also called BHERT, was performed and proposed at JPGU-2016 as well last year. In the study the simulated results from BHERT presented the roughly three dimensional distributing of the grouted materials of the ground improvement in deep underground soil layers. Despite the clear image being obtained, the operating parameters of BHERT and interpreting method make influence on the result, especially size effect. To clarify more details of the mentioned effect for further adoption, an in-situ with smaller size experiment was performed. A series tests with varies soil materials prepared and objects with different shapes buried inside was performed for setting up a standard reference. The result shows that a correcting factor is existing between object size, field size, and electrical parameters. The factors can be normalized to be unitless.

Keywords: Borehole Electrical Resistivity Tomography, Geophysical Investigating, Scale Effect



Making of a detailed DSM of a partially collapsed road embankment and correlation with 3D GPR data

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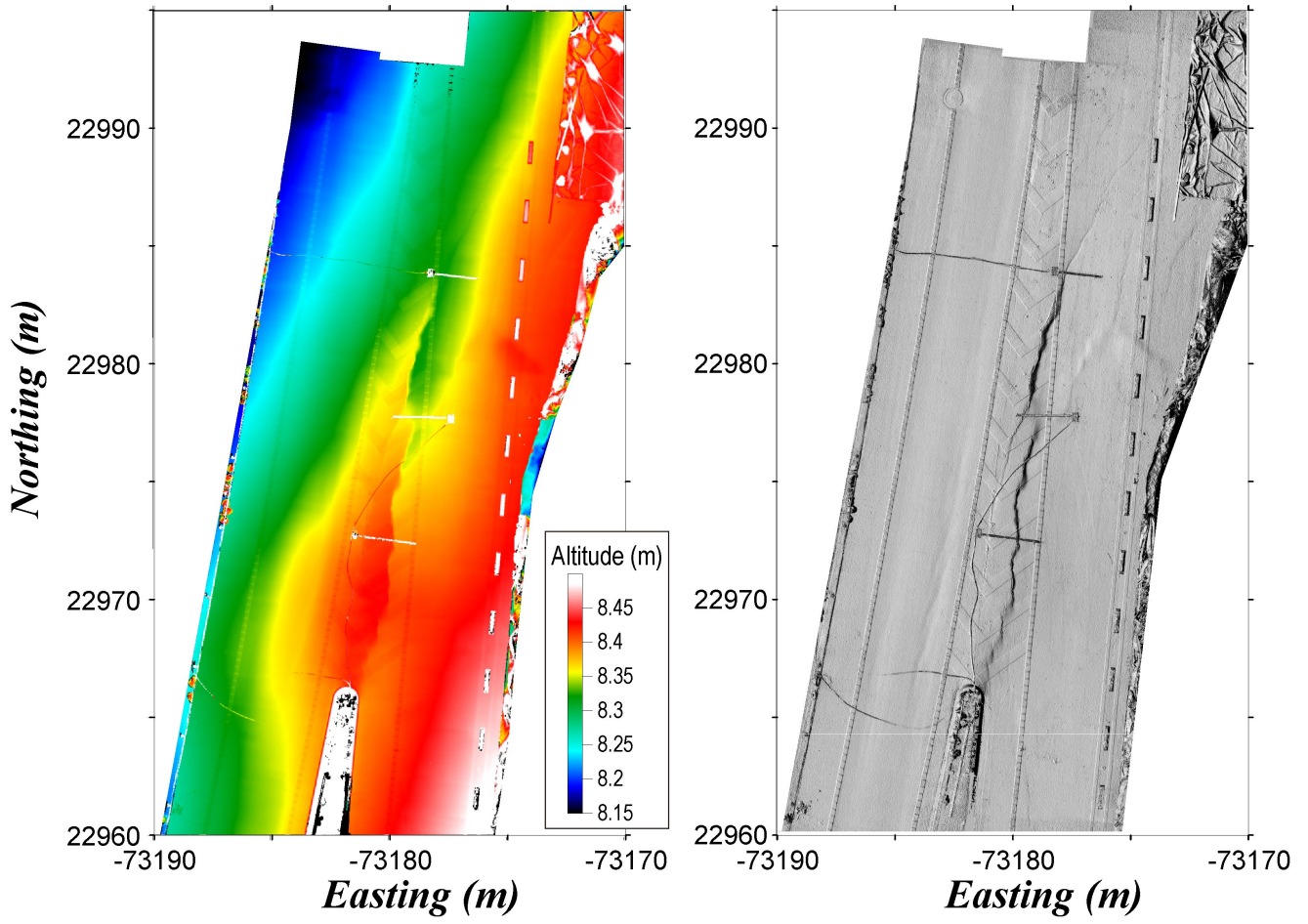
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We conducted an urgent but detailed field survey at a site where 8 m high road embankment slope had been partly collapsed by heavy rainfall along with strong motion of 2016 Kumamoto Earthquake 2 months before. The field measurements consisted of high-density surface photogrammetry and near-surface geophysical surveys. We employed a telescopic pole camera system and RICOH GR2 to take digital photographs in the air up to 6 meters. Finally, we made an orthophoto image and a DSM of a road surface which had escaped from collapsing at a spatial resolution of 2.86 mm using a commercial SfM-MVS (structure from motion and multi-view stereo) software package (Agisoft PhotoScan Professional). We used a total of 218 pole camera images and 7 GCPs to create the DSM. In addition, we processed UAV imagery taken on the day after the collapsing to generate a DSM of 2.5 cm spatial resolution of the site. The DSM, which covered 110 m x 90 m area, clearly imaged the embankment collapse and heaving of the ground in front of the failure caused by compression and thrusting. It was helpful to clarify the failure mechanism of road embankment and the role of geotextile-anchored concrete wall set at the foot part of the embankment to avoid entire collapsing of the embankment. Furthermore, we could identify non-tectonic structures from the road surface DSM. Number of cracks and small bulges were traced behind the failure crown, which indicated the co- or post-failure movement of the remained embankment. Then we conducted dense grid GPR survey on the road surface. As a result, cracks extended in the pavement up to 75 cm and the surface pavements were interpreted to be segmented and detached from the underlying road beds. Joint investigation and interpretation of the surface DSM and the near-surface geophysical data was capable to assess the safety conditions of remained road embankment. Namely, which types of restoration works were needed and what extent should be reinforced. In conclusion, combined analysis of surface DSM with the near-surface geophysical survey data is crucial to understand such surface deformation structures as slope failure.

キーワード：オルソ画像、数値表層モデル、無人航空機、地中レーダ、浅層物理探査

Keywords: Orthophoto, DSM, UAV, GPR, Near-surface Geophysics



遠隔調査船と高性能魚群探知機を利用した水底地形図の作成および底質マッピング

Bathymetry and bottom classification mapping by a remotely controlled watercraft and a high performance fish finder

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小水域と浅水域における音響調査は地球科学の諸分野や防災研究で重要である共に高い潜在的価値が見込まれる。例えば、氷河湖や地すべり閉塞湖における湛水量の推定は突発的な決壊洪水災害の予測としての有用であり、火口湖の水底のイメージングは水中の不可視の火山活動を観察する手段として有用である。しかしそのような調査はそのコスト、可搬性、有人観測の高い危険性があるが故に困難であった。筆者らは近年、軽量、低コストの最近の魚群探知機を利用して浅い水域の調査を行っている。今回、筆者らは前述の小水域・浅水域を調査する手段として同様の魚群探知機を備えた無人調査船システムについて開発を行ったのでそれを本講演において発表する。

開発したシステムは田房ほか（2013）を参考に、一般市販品や低価格電子デバイス、無償ソフトウェアで構成されている。無人船船体はエレキモーターと呼ばれる電気式の船外機と木製またはプラスチック製フロートをを用い、双胴船構造になるようにした。その理由は、実験によって、このタイプの小型船においては、双胴船形態が波のある状況でも安定であったためである。エレキモーターは12Vで駆動し、リモコン制御機構を持つものである。この制御機構にZigBee無線デバイスをセットすることでその制御距離を約1kmまで拡張した。GNSS受信機をこの船体に設置し、その位置情報を同様の無線伝送デバイスで地上の操縦者に送信した。位置情報とGNSS情報から計算したスピード、船首方向をリアルタイムでPCディスプレイに表示させた。

筆者らは本装置を使用した調査として神奈川県芦ノ湖における研究を紹介する。湖の北部では湖底に多数の水没した木が発見されていた。そのうちのいくつかは立ったままであり、「逆杉」と呼ばれている。大木ら（1988）はこれらの水中林は地すべりによりもたらされたと推定していた。筆者らはもし地すべりによって水中林がもたらされたのであれば、水中林の周辺の地形とその底質が湖のその他の場所と異なると仮定し、その地域を開発したシステムにより調査した。その結果、得られた等深線図では、水中林の周辺に他の湖底とは異なる特徴的な高まりがあることが示された。また、得られた相対的な表面の硬さ値および表面粗度値の分布は水中林の底質が湖の大部分と異なることが示された。これは水中林が地すべりによって運ばれたという考えと矛盾しない。

<文献>

Yamasaki, S., Kamai, T., 2015. A novel method of surveying submerged landslide ruins: Case study of the Nebukawa landslide in Japan. *Engineering Geology*, 186, 28-33.

田房友典・澤村幸樹・向井利夫・葛目幸一, 2013. 小型自律走査艇の開発とメコン川の川底三次元地形図の作成 (<特集> 航法システム研究会) *Navigation*, 日本航海学会誌, 186, 15-23.

大木靖衛・袴田和夫・伊東博, 1988. 箱根の逆さ杉. 神奈川新聞社, 180p.

キーワード：魚群探知機、ソナー、浅深測量、遠隔調査、地すべり、芦ノ湖

Keywords: fish finder, sonar, bathymetry, remote investigation, landslide, Lake Ashinoko

Finite Element Modeling of Volcanic Ballistic Impacts in Soft Ash and on Buildings - a Hazard Approach

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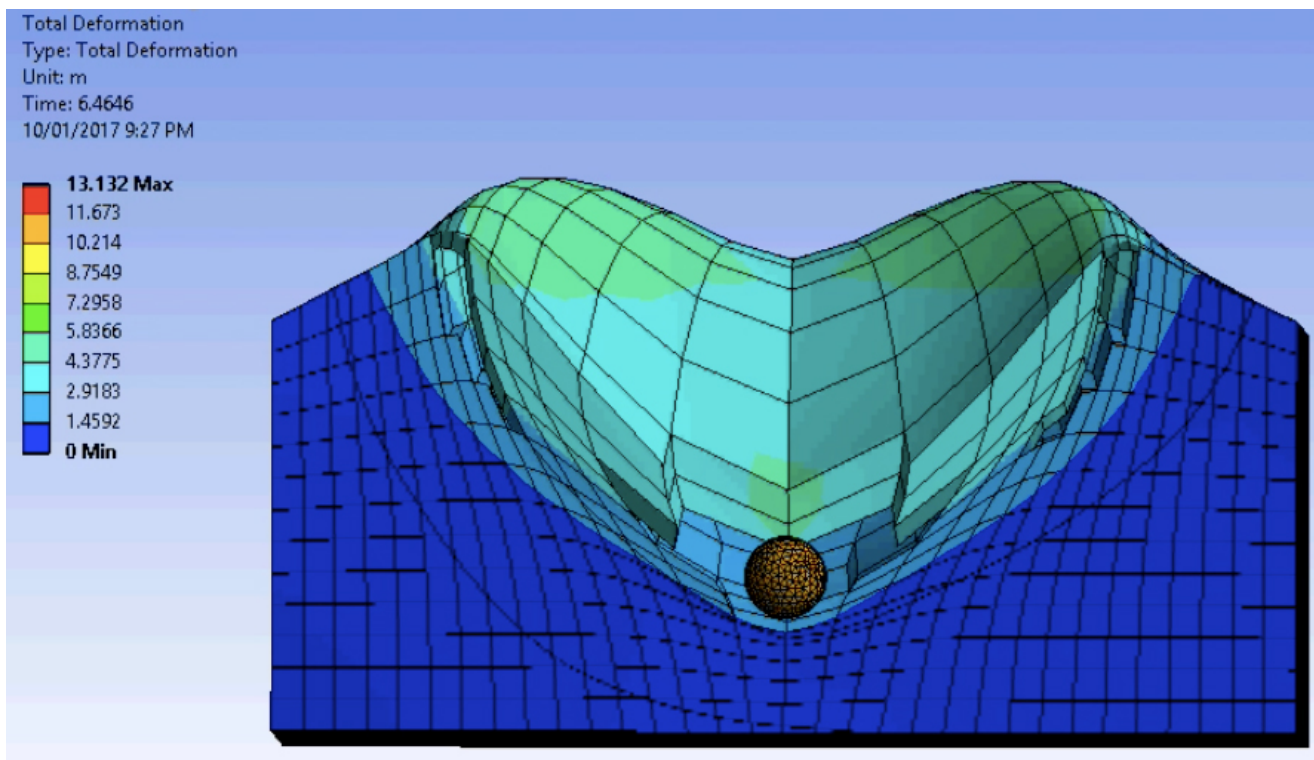
Volcanic eruptions, such as the phreatic eruption of 2014 at Ontake Volcano can produce large number of ballistics, which often turn into craters near the summit of the volcano, and which can have devastating effects on buildings.

In the present contribution, the authors have performed a visual analysis of the ballistic impacts at the summit of the Ontake Volcano on building materials and in soft clastic sediments and reproduced the time of impact between the ballistic and the impacted material.

The simulation was performed with the ANSYS engineering suite using andesite material for the projectile and timber and aluminum sheets to work on the impact on building. The timber planks had a 20 mm thickness and the aluminium sheets 0.5 mm. They were anchored along two parallel edges to simulate the supporting carpentry. Results reproduced the erosion of the impacted materials as observed in the field, with different effects depending on the penetration angle.

On the ground, the ballistic impacts recreated realistically the craters observed around the summit of the Ontake, showing an interesting feature of plastic decompression at the point of impact, allowing the projectile to slightly rebound.

Keywords: Ballistic, Impact Hazards, Ontake Volcano, Disaster Risk



Rockfall Simulation from DSM Data generated by SfM from UAV-based imagery: Analysing the rockfall hazards in the touristic Fox Valley.

Rockfall Simulation from DSM Data generated by SfM from UAV-based imagery: Analysing the rockfall hazards in the touristic Fox Valley.

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The Fox Valley, on the West Coast of the South Island of New Zealand, is a highly praised destination for tourists wanting to come up close to an alpine glacier and a majestic landscape. It is popular sightseeing spot and one of the main tourist resources, but such a dynamic environment can present several hazards, such as rockfalls. These events in the Fox valley are the results of some incidents, for instance valley deglaciation during the Quaternary and historic oscillation, eventually liberating multi-metric blocks. And one of the most active area where the tourists are concentrated is the Gunbarrel tributary, which threatens the carpark and the walking track.

In order to better understand the rockfall hazards and eventually reduce tourists' vulnerability, the present contribution proposes rockfall modelling using a Digital Surface Model (DSM) acquired by Structure-from-Motion (SfM) photogrammetry using a commercial quadcopter UAV and Terrestrial Laser Scanning (TLS). The model results were then analysed to assess the hazards and potentially the risk of rockfalls by using a GIS software and Flow-R which has been developed at the University of Lausann, Switzerland.

Results have shown that most of the rockfalls are meant to stop in the vicinity of the apron of the Gunbarrel tributary, being less of a threat to the walking track. But as the walking track cannot be placed too low due to potential river surges, which can be generated by glacier terminus collapse, the management remains a delicate issue. A talus formed by a large amount of rockfalls can become debris flow when it contains abundant water because due to rainfall. The model did not account for blocks that jump out of the present catchment and towards the carpark, although recent events in 2016 have shown that such rockfalls had happen. This limitation can be imputed to the model, but most certainly to the limitation of UAV-based DSM, which are difficult to acquire in terrain where the altitude change is ~1000 m, as it is at Gunbarrel. Another limitation to this analysis is the progressive change of the apron, where the accumulation of loose material has been increasing in 2016, due to a large number of debris-flows. The debris-flow fan deposits tend to reduce the slope break at the bottom in the apron, pushing the blocks further in the valley. Regular monitoring and repeats of the modelling are therefore essentials.

キーワード : rockfall、 UAV、 SfM、 tourism、 TLS

Keywords: rockfall, UAV, SfM, tourism, TLS

根尾谷断層水鳥断層崖における2013年と2016年のUAV飛行による DSMとオルソ画像の計測精度の比較

Comparison of measurement accuracy for DSM and orthomosaic between 2013 and 2016 UAV flights at Midori fault scarp, Neodani fault

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本研究の目的は、根尾谷断層水鳥断層崖で2013年と2016年のUAVによる観測で得られたDSMとオルソ画像の計測精度を比較することである。空中写真の解像度はそれぞれ3cmと1cmだった。そして、対象地区をカバーする写真枚数は109枚と498枚だった。DSMとオルソ画像は、SfM (Structure from Motion) の処理による高密度点群から生成された。RTK-GNSS測量によって、4つのGCPと7つの評価点3次元座標が得られ、GCPによってDSMとオルソ画像が幾何補正された。そして、評価点上の水平座標と標高がオルソ画像とDSMから計測され、最後に、計測値からGNSS測量値を差し引いた。水平方向の平均二乗誤差 (RMSE) は2013年については0.45m、2016年については0.05mだった。そして、標高のRMSEは2013年の0.32mと2016年の0.02mであった。この結果によって、2013年観測よりも、2016年観測のほうが水平方向で9倍、標高方向で16倍精度がよかったことがわかった。

キーワード：無人飛行機、SfM、精度

Keywords: UAV, SfM, accuracy

Detection of surface changes in sandstone blocks by weathering in a coastal environment using TLS

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Compared to the traditional measurement method, i.e., point to point, or cross-sectional measurements using scale bars, recent advantageous measurements using terrestrial laser scanning (TLS) enables more efficient and accurate measurements of the amount of weathering on the surface of vulnerable materials in coastal areas. We carried out multi-temporal TLS measurements to monitor the changes in the surficial morphology of sandstone blocks used for masonry piers of a bridge on a shore platform at Aoshima, Miyazaki Prefecture in western Japan. While the blocks have suffered from salt weathering above the sea level since the construction of the bridge in 1951, the weathering-induced depressions are still developing in the spray zone. The multiple measurements of the detailed morphology reveal the contemporary weathering rates.

キーワード：風化、砂岩、地上レーザ測量、岩盤強度

Keywords: weathering, sandstone, terrestrial laser scanning, rock strength