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# The use of UAVs in engineering geological surveys: mapping along Scotland's south-west coast.

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## Abstract

UAVs have been used in engineering for at least two decades. While there is a wide range of recognition algorithms for the automatic identification of structural damage, structural geological features etc. from the acquired images, the parameters affecting the resolution of these images are often overlooked. As a result, the potential of the UAV technology is not maximized and at times, it is even regarded as leading to poor outcomes. We present a case study of the structural geological mapping of a coastal area in Scotland carried out using two types of UAVs: a fixed wing and a hexacopter. We compare the structural geological maps obtained from the orthophotos and conventional techniques and find that although the level of detail is the same, the time spent in producing a map is at least 5 times less when using a UAV. The fixed wing is faster and therefore, can cover large areas while the copter gives better resolution images as it can fly at lower heights. The level of detail achieved in this study was 1 cm which is sufficient for most mapping applications. The time required to produce a structural geological map of the studied area was a fifth of the time required when using conventional mapping techniques. The use of one or the other type of UAVs and the flight height depend on the needs of the project and should be chosen after taking into consideration the required resolution.

**Key words**: UAV, image resolution, fixed wing, hexacopter

## 1 INTRODUCTION

Over the last decades, extreme events connected to climate change, e.g., flooding, landslides etc., have considerably increased in numbers and seriously affected natural ecosystems, infrastructure and human life. Therefore, there is a growing need for the development of new or use of existing technologies, which will assist to the management of these effects, the minimisation of loss of properties and human lives, the protection of the environment and the design of sustainable and resilient infrastructure. The Unmanned Airborne (or Aerial) Vehicles (UAVs), or Unmanned Aerial Systems (UAS), or drones as they are commonly called, constitute a technology that can play a significant role towards this direction.

UAVs allow for the effective monitoring of large areas of land and existing infrastructure, within a few hours, a favourable characteristic, especially at cases where urgent intervention is required. The main principle is that a UAV takes aerial images over an area incorporated with spatial data based on GNSS to finally produce a high resolution 3D point cloud that can be used for a wide range of geological, civil/mining engineering applications and projects.

One of the most common uses of UAVs is 3-Dimensional (3D) mapping, with numerous applications in topographic surveys, photogrammetric solutions, progress monitoring, disaster analysis, archaeological mapping, agriculture and forestry (e.g., Remondino et al, 2011; Draeyer and Strecha, 2014). Applications related to monitoring of geological features in land and coastal study areas take advantage from the use of micro but integrated aerial vehicles supported by multisensory systems rather than employing greater platforms. This way the cost of field surveys is low while at the same time the captured detail of the aerial images is sufficiently high. Monitoring and 3D-mapping by micro-UAVs in geological applications focusing on surveying of geological structures and archaeological sites as well as on the detection of post-earthquake ground changes and displacements are described in several researches (e.g., Nagai et al, 2009; Jordan, 2015). In mapping of coastal areas the scale of detail can be at the level of 10 cm and may reach the level of 1 cm or better (e.g., Bemis et al, 2014).

This paper focuses on the use of UAVs for engineering geology mapping surveys. We present the mapping of structural geological features at an outcrop along the west coast of Scotland using two different types of UAVs, a fixed wing and a hexacopter. We compare the results obtained using these two types of drones. We also compare our results with those from a traditional geological mapping survey. Our aim is to test the efficiency of UAVs on a demanding (from the resolution point of view) project and investigate the level of detail that could be achieved.

## 2 MAPPING OF THE WHITEHOUSE SHORE OUTCROP

The field area for this study was near Girvan, a region at Scotland's south-west coast. The field area is located on the Whitehouse Shore, a rocky beach a few miles south of the town of Girvan, South Ayrshire. The outcrop has well exposed sedimentary and structural geological features (Figure 1).


*Fig. 1 View of the Whiteshore outcrop and location map (inset).*

The area has been mapped in detail as part of previous projects (for example in McCay, 2014) and therefore, constituted a favourable site that allowed for comparisons between the previously generated maps using conventional geological mapping surveys and maps generated as part of this case study based solely on orthophotos.

### 2.1 THE FIELD SURVEY

#### 2.1.1 The UAVs used

The UX5 HP (fixed wing) and ZX5 (hexacopter) of TRIMBLE (Trimble, 2016) were used for the data collection for this study. The UX5 HP was equipped with a Sony A7R, 36MP resolution, the focal length was 15mm, the sensor size 39.5mm x 24mm and the image dimensions 7360 x 4912 pixels. The ZX5 had an Olympus E-PL7, 16 MP camera, with a 14mm lens, a sensor size of 17.3mm x 13mm and image dimensions 4608 x 3456 pixels.

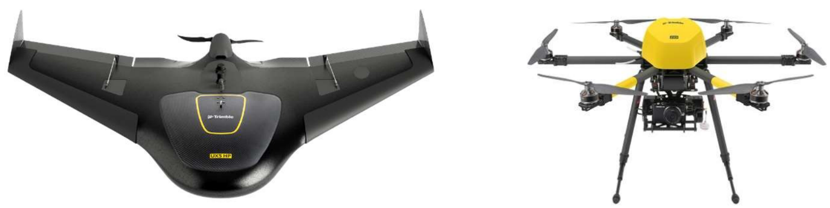

*Fig. 2 The two UAVs used in this study: (left) the Trimble UX5 HP (http://uas.trimble.com/ux5-hp) and (right) the Trimble ZX5 multirotor (http://www.trimble.com/Survey/ZX5.aspx)*

#### 2.1.2 Flight parameters

The field survey took place in May 2016 under good weather conditions. The field measurements lasted about four hours including necessary work before and after the survey. During the field measurements, two flights were carried out, one for each of the two UAVs used, at two different heights, respectively.
The flight altitude of ZX5 copter was 30 m. The duration of the flight was approximately 14 minutes and the speed of the copter was 3 m/sec. The copter took about 460 photos. The take-off and landing took place at the rocky beach area. The surveyed area had nominal dimensions 56 m x 64 m.
The take-off location of the UX5 HP was approximately 500 m away from the beach. This flight lasted 8 minutes with a speed of about 23m/sec at a height of 79 m. The UX5 HP covered a larger area (120 m x 55 m) than that of the ZX5, taking 62 photos overall.

## 3 DATA PROCESSING AND RESULTS

### 3.1 STRUCTURAL GEOLOGICAL MAPS BASED ON THE UX5 HP AND THE ZX5 SURVEYS

The tasks of processing of the acquired photos, the creation of the orthophotos and the final structural geological maps were carried out using Trimble Business Centre software. The geological maps contain the main geological formations of the area under consideration, such as thrust faults, strike-slip faults, fractures, joints and other geological structures. These formations were detected at the rocky beach of Girvan both from the work based on the UAVs aerial photos as well in the work of McCay (2014). The latter followed a conventional geological procedure based on a local visual inspection. The main geological characteristics shown in the aforementioned maps are presented in a detailed way. Initially, two orthophotos were produced using the photos by ZX5 and UX5 HP, respectively. The digitisation of the two orthophotos had as a result the compilation of the two final maps. The processing of the two maps lasted approximately three weeks. The compilation of maps was a demanding task, as it was based on a detailed computational and design work towards the identification of all geological information offered by the high resolution images of the two UAVs.

The maps of structural features derived from the ZX5 and UX5 HP are shown in Fig. 3 and 4, respectively.

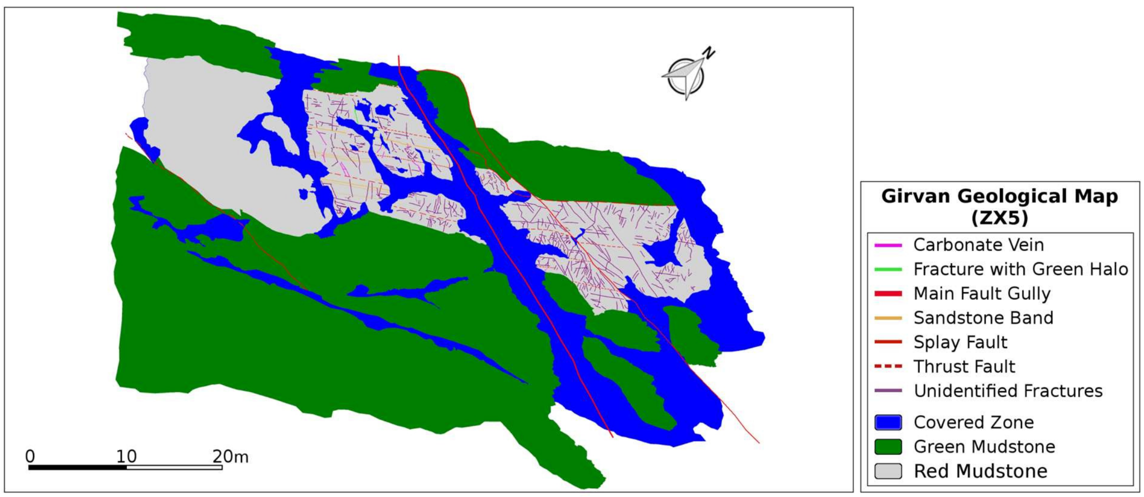


*Fig. 3 Detailed map of the test area derived from the data of ZX5 representing the distribution and locations of the structural features (Tziavou, 2016)*

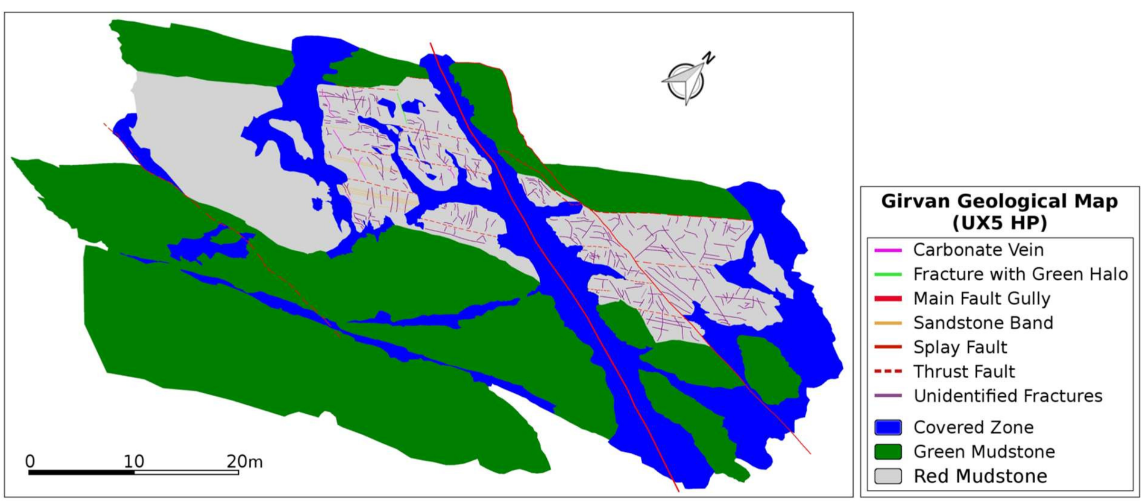


*Fig. 4 Detailed map of the test area derived from the data of UX5 HP representing the distribution and locations of the structural features (Tziavou, 2016)*

### 3.2 ESTIMATION OF THE ACHIEVED LEVEL OF DETAIL

One of the main goals of this study was to determine the level of detail that could be achieved by the chosen UAVs. In order to do this, we selected a well- defined joint (Fig. 5) and attempted to determine its length and width using exclusively the orthomosaic. As shown in Fig. 5 and Fig.6, a joint of length equal to 1.81 m can be determined with a level of detail better than 1 cm. The thickness of the same joint could be identified with at a level of detail better than 3 cm.


*Fig. 5 The length of a joint could be specified with at a level of detail better than 1 cm. (Tziavou, 2016)*


*Fig. 6 A maximum thickness of the same joint as in fig.5 could be determined at a level of detail better than 3 cm (Tziavou, 2016)*

# 4 DISCUSSION

## 4.1 COMPARISON BETWEEN THE MAPS OF THIS FIELD CAMPAIGN

Inspection of the maps of Figures 3 and 4 leads to some interesting findings regarding the mapping and resolution potential of the two aerial vehicles. The UX5 HP covered an extended area with relatively low resolution (Fig. 4), while the ZX5 covered a smaller area than that of UX5 HP but with higher resolution (Fig. 3). Thus, on the SW part of the test area represented in Fig. 3, the geological formation of green mudstone covers larger area than that of Fig. 4 due to the high resolution of ZX5. This means that the identification of the green mudstone in the orthophoto of ZX5 was possible, but it was difficult in the orthophoto of UX5 HP where the limits of the formation were not distinct.
The level of detail in Fig. 3 is higher than that of Fig. 4, either in the SW part of the field site mainly covered by the green mudstone or even in other regions. For instance, in the NE sub-region, in the area covered by red mudstone, more unidentified fractures are detected in Fig. 3 than those in Fig. 4 as they were compiled after processing and digitisation of the respective orthophotos. Furthermore, in the NW part of the study area the same conclusion is valid for the representation of the covered zone, more details of which are delineated in Fig. 3 than in Fig. 4.

## 4.2 COMPARISON WITH CONVENTIONAL GEOLOGICAL MAPPING SURVEYS

There are two main advantages for the use of a UAV in engineering geological mapping surveys. First, it requires significantly less time and effort to map an area of the same or even much bigger size compared to commonly used mapping techniques. In this study, we focused on an outcrop along the Whitehouse shore that had been mapped before by McCay (2014) using conventional mapping techniques (Fig.7). The smallest area that was surveyed in our study was that obtained by the ZX5. This area is approximately 3 times bigger than the area presented in Fig. 9 (see Fig.10). Yet, it took about a fifth of the time (including the time in the field and the post-processing time) to produce a structural geological map of the same dimensions and of the same level of detail as that in Fig. 7**Error! Reference source not found.** (personal communication with Alistair McCay on 12/9/2016).

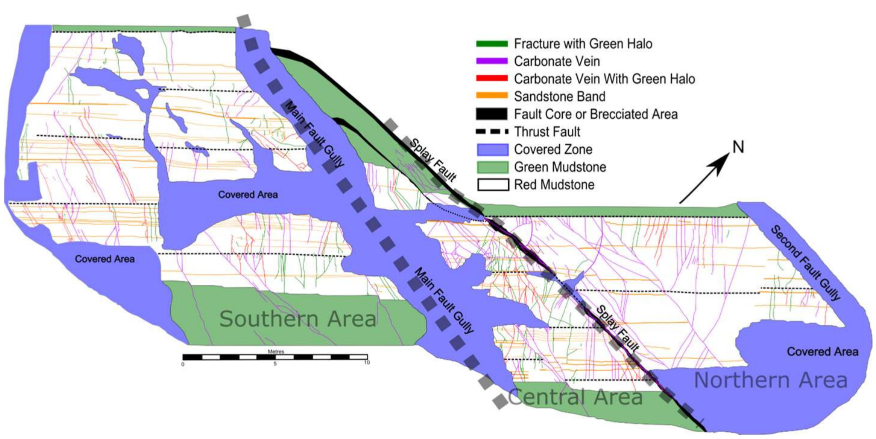


*Fig. 7 Detailed map of the test area derived from a conventional geological method (after McCay, 2014)*

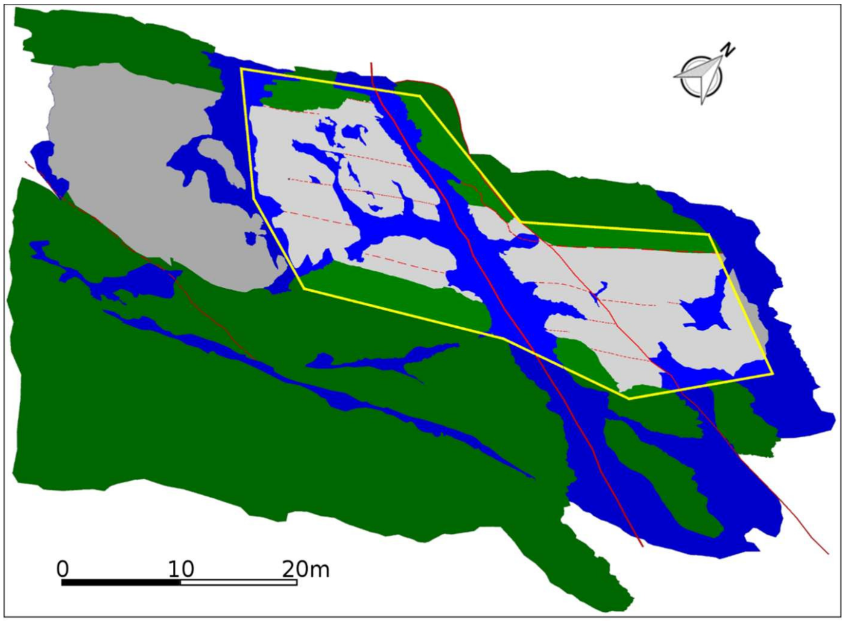


*Fig. 10 The size of the mapped area presented in this study is almost three times larger than the area mapped by McCay (2014) and shown within the yellow polygon (Tziavou, 2016).*

The second merit of using a UAV for structural geological mapping is that the produced orthomosaic is georeferenced. Where it lacks is the identification and characterization of some structural geological features. Although in our study it was possible to identify the feature type for most of them, there were some for which visual inspection was necessary and no safe conclusions could be made based only on the image. It should be noted that the amount of information that can be extracted from an image also depends on the camera calibration and the experience of the observer. A more experienced geologist or engineer would be more likely able to identify more feature types on an image compared to those identified by a less experienced person. This number would differ again if using an automated recognition algorithm.

## 5 CONCLUSIONS

Our results show that UAVs can be a powerful technology for engineering geological applications. This technology can efficiently handle geospatial and imagery data sets and provide detailed maps and other digital data and information. Although the conventional geological mapping methods have undoubtedly various advantages, they are time consuming. This restricts significantly their suitability for a range of applications, such as the mapping of landslides, flooding or disaster areas, etc., where an urgent reaction is needed. On the other hand, the UAV technology can be used for the mapping of large areas, in a short time with a high level of detail (1cm or better at times), and reliability.

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