Increased Accuracy of the Photogrammetric UAS Data Processing for the Detection of River Channel and Boulder Dimensions and Displacement after High Severity Floods

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Abstract

The rapidly increasing use of Unmanned Aerial Systems (UAS) at post-flood areas, has been considered particularly useful especially in cases of necessity for accurate quantification of displacements or volumes (Tsokos *et al.,* 2018). The number of field surveys conducted in the last decade combined with the use of UAS, especially in cases of natural disasters' mapping and management, either during the phenomenon or at the post-disaster stage has been particularly increased (Giordan *et al.,* 2018). It's only recently, that the use of UAS combined with the Structure from Motion (SfM) photogrammetric processing technique, assisted by the positioning of precisely measured Ground Control Points (GCPs) with Global Navigation Satellite System (GNSS) equipment have been used extensively for enhancing the accuracy of field surveys and special measurements after catastrophic events. We present a UAS-based optical granulometry method, as a new non-invasive technique of granulometric analysis based on the fusion of two individual techniques, such as the UAS photogrammetry and the optical digital granulometry, which could be considered as a significant advance in quantitative geomorphology and in the study of river and fluvial processes, in general (Graham *et al.*, 2012; Andreadakis *et al.,* 2020). Most of the traditional sediment analysis techniques are not suitable for clastic sedimentary material with size larger than 2 mm, while the whole process of digging, transport and sieving is time-consuming and high-cost intensive (Detert and Weitbrecht, 2013). Moreover, this technique is considered as invasive and not applicable in areas under preservation. These restrictions can be surpassed through the implementation of optical digital granulometry (Langhammer *et al.*, 2017).

Introduction

The use of UAS systems can provide useful information for areas suffered from extended flooding events, as well as they provide the opportunity to observe and map the changes of geomorphological features, such as the region of Cephalonia, that was severely affected during the Medicane named 'Ianos', in September 2020 (Vassilakis *et al.*, 2021). The detailed DSM model and the SfM technique products, in general, were notably useful for examining the channel geometry, and other characteristics of river flow (Fig. 1a). For the measuring of the size and the dimensions of the boulders, aerial images collected from the UAS system were used, alongside the streambed examined. We used ArcGIS software for visualizing the photogrammetry results, on which sixty-six (66) boulders that were identified, and their dimensions were measured. Alongside the riverbed examined, the size of the boulders appears to be notably reduced downstream. The a, b axis of the boulders located upstream near the northernmost GCP were measured at 0.88m and 0.55m on average, respectively, whilst the a, b axis located downstream near the furthest GCP were measured at 0.35m and 0.25m on average, respectively (Fig 1c). Consequently, the stream capacity is reduced considerably downstream in a range of 230m, which is in agreement with the flow mechanics described in the literature (see Diakakis *et al.,* 2020 and references therein).

Figure 1. Flight plan and image locations (533 images).

Figure 2. Set up of GCP points and DJI Phantom 4 RTK (Left and Right).

Methodology

The experiment described in this work was performed by using a DJI Phantom 4 RTK, with the onboard multi-frequency GNSS receiver, which allows the adoption of NRTK (Network-based Real-Time Kinematic) approach for the data processing. The high accuracy and resolution, dense point clouds, Digital Surface Models (DSMs) and ortho-photo mosaics, which were generated after the photogrammetric processing provided us with the valuable high spatial resolution datasets as inputs for the granulometric processing.

Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
3	-0.25865	0.629038	0.0325494	0.680917	1.834 (18)
4	1.00508	-1.52171	-0.122305	1.82777	4.174 (25)
5	1.73227	-1.46535	-0.0674837	2.26993	5.293 (25)
6	-3.69821	2.75844	0.0522842	4.61395	12.584 (20)
7	1.18609	-0.324279	-0.0291056	1.22997	3.008 (22)
8	0.356821	-0.273068	0.0304316	0.450348	1.376 (18)
Total	**1.79298**	**1.45185**	**0.0646514**	**2.308**	**5.993**

Figure 3. Ground Control Points Accuracy using Agisoft Metashape.

Field
Selection of Appropriate sites to Position Ground Control Points, Flight Planning and Execution

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Lab
Image Processing and Production of Sparse Point Clouds and Dense Point Clouds

↓

Lab
Productiong of Digital Elevation Models and Orthomosaics

↓

Lab
Processing of Orthomosaics in ArcMap in Order to Compare Their Accuracy, Based on the Different Approaches (NRTK Method and GCPs Method)

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Lab
Image Processing using BASEGRAIN and ArcMap, in order to Locate Boulders and Measure Their Dimensions

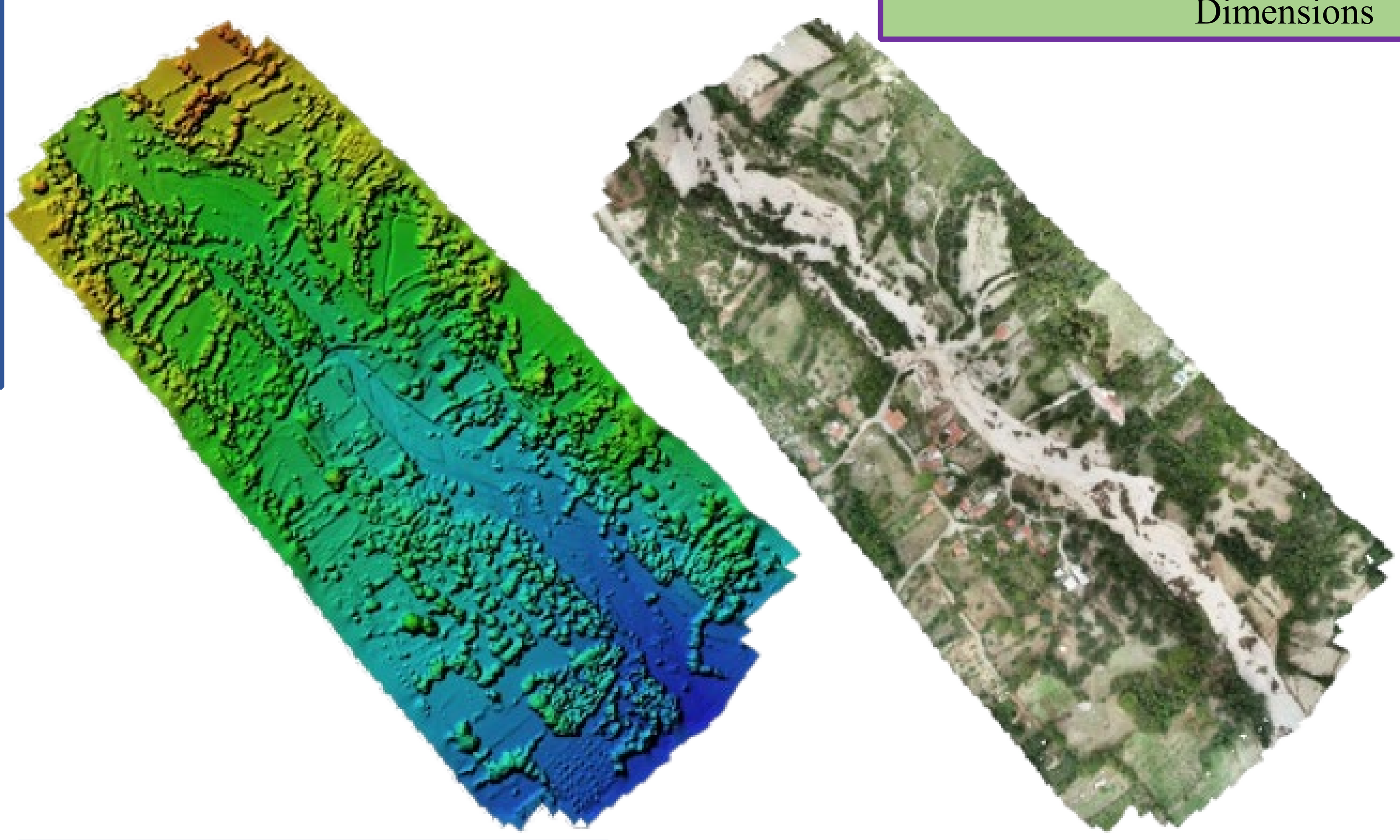

Figure 4. Orthomosaic and DSM of Bekatorata stream.

Figure 8. Area studied in Cephalonia, that was affected during the Medicane.

Results

Final results shows a gradual decrease of the boulders' dimensions downstream from 0.88m for the a-axis and 0.55m for the b-axis of marker 3, which is located northwestern, to 0.35m for the a-axis and 0.25 for the b-axis of marker 6 respectively, located southeastern. Consequently, runoff and peak velocity are reduced downstream. Most of the boulders located and measured are on the left part of the streambed.. The northeastern area is not enclosed by walls and buildings, a fact that facilitates the transport of boulders and debris. In contrast, the southwestern area is residential, the topographic relief displays mild fluctuations, and the stream shows less peak velocity and runoff.

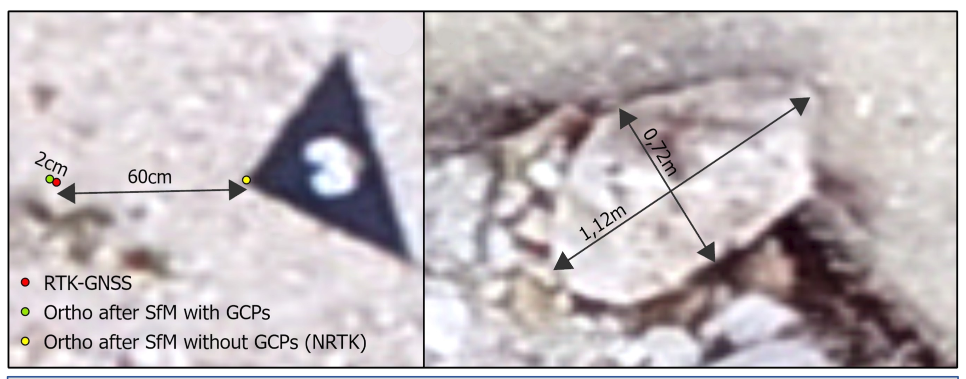

Figure 5. Checking the accuracy of the final ortho-photo-mosaic with the precise coordinates of the GCP and accurately measuring the a and b axes of a boulder.

GCP Id	Average a-axis (m)	Average b-axis (m)
3	0.880909091	0.553636364
8	0.677272727	0.519090909
7	0.644545455	0.451818182
4	0.584545455	0.448181818
6	0.354545455	0.252727273

Figure 6. Average a, b axis dimensions of the boulders near to the Ground Control Point that were measured.

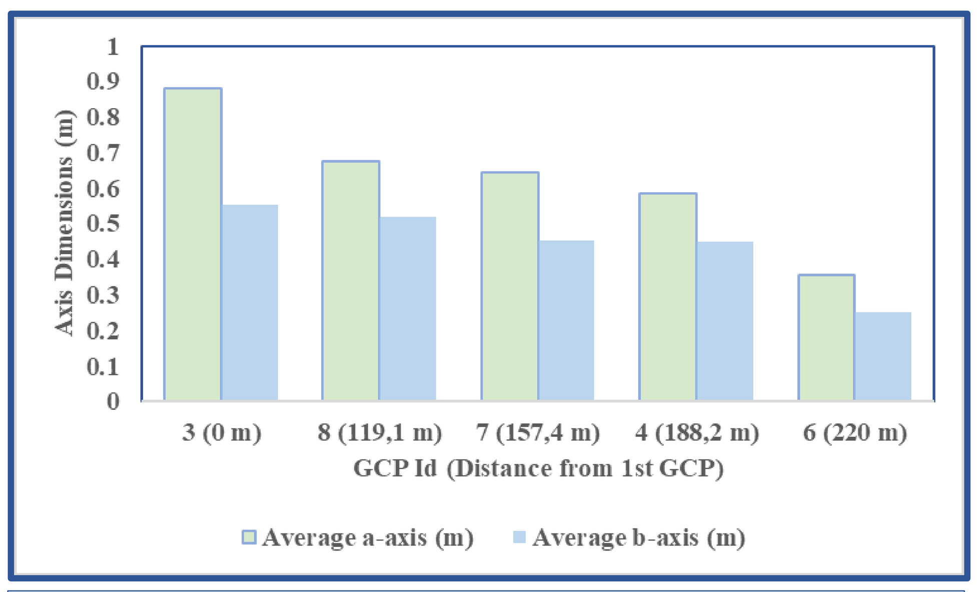

Figure 7. Average a, b axis boulder's dimensions decrease downstream, near to the ground control point area that were measured.

Conclusion

Since the accuracy is of high importance for the granulometry, we present a thorough analysis for the use of GCPs within the overall photogrammetric processing. The analysis yield that using GCPs demonstrates a significantly increased accuracy into the photogrammetric processing (Panagiotopoulou *et al.,* 2021). However, despite the high accuracy, the positioning of GCPs may offer, the amount of time spent during the fieldwork (placing and measuring each GCP), as well as the time spent during the processing for locating them in the images, could be considered as unproductive and cost-effective.
Therefore, the NRTK approach was adopted, since the overall accuracy is quite high and, in some cases, higher than the GCPs-only method (Fig 1b). We argue that this also allows the gaining of time, which is rather precious, especially during the post-catastrophic stage. Regarding the precision of the DSMs and the ortho-photo mosaics, the placement of six GCPs in the experiment captured area, permits the comparison between the aforementioned strategies/techniques, along with observations in high detail (in case of the boulders) larger than a few centimeters (2cm in this case). The latter can be achieved during the first few days after the disaster, as it is apparent that when time passes, the risk of losing crucial data is increased. Although the precision of the DSMs and the ortho-photo mosaics with the placement of GCPs is considerably higher, however this method provides us with more flexibility and less time is needed to complete the campaign. The well-organized field campaign for correct UAS data acquisition shortly after the post-catastrophic stage and the accurately applied SfM technique is proved to offer two considerable advantages, (i) quick study of the affected region, especially in relatively small areas with limited access to road network, and (ii) create the basement data of the area of interest, ready to use for further examination in several ways (flood mechanics, erosion processes etc). The main objective is the assessment of a correct geospatial accuracy for the image products acquired during the aerial mapping of the affected region.

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