UAS deployment and data processing of natural disaster with impact to mine action in B&H, Case study: Region Olovo

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ABSTRACT — In this paper, we present a case study report on how novel robotics technologies like the Unmanned Aerial System (UAS) and data processing methodologies could be used in order to support the traditional mine action procedures and be directly applied onto the terrain while increasing the operational efficiency, supporting mine action workers and minimizing human suffering in case of natural disaster with impact to mine action. Our case study is focusing on the region Olovo (Central Bosnia and Herzegovina) in response to massive flooding, landslides and sediment torrents in spring-summer of 2014. Such destructive impact of the natural disaster on the mine action situation resulted with a re-localizing of many explosive remnants of war which have been moved due to the flooding and landslides with significant negative environmental and security consequences increasing new potentially suspected hazardous areas.
What will be elaborated in this paper is the following: problem definition with a statement of needs, data acquisition procedures with UAS, data processing and quality assessment and usability in further mine action procedures.

KEYWORDS: Mine Action Support, Unmanned Aerial System, Natural Disaster.

1. Introduction

In the period between end of May and beginning of June 2014, Bosnia and Herzegovina, Croatia and Serbia were hit hard by a catastrophic massive flooding after abundant rainfall over a few weeks, causing floods and landslides. The countries suffered one of the greatest damages, as the rain has been the heaviest in the entire period of 120 years of recorded weather measurements. Only in Bosnia and Herzegovina, an estimated 1.5 million people were affected (39% of the population). Flooding has led to at least 57 deaths in Bosnia and Herzegovina and Serbia [1].

The EU Civil Protection Mechanism has been activated due to the catastrophic crisis 22 Member States have offered assistance through the Mechanism. In addition to destroying agricultural land, flooding caused thousands of landslides, displacing landmines and Explosive Remnants of War (ERW) buried during the 1992–1995 war conflict in that region. The change of the mine action situation created an extremely dangerous situation and resulted with significant negative environmental and security consequences for the local population and the relief workers [2, 3].

Natural disasters (floods, torrents, landslides, land shifting) have had intensive destructive impact on suspected hazardous areas (SHA) and mine fields in Bosnia and Herzegovina. According to the U.N., 70 percent of the flood-affected areas may contain landmines and unexploded ordnance (UXO) [1].

Only in Bosnia and Herzegovina, 831.4 km^2 were flooded, 37.48 km^2 of suspected hazardous area in 33 areas were under direct impact of torrents and landslides; by 4th July 2014, 1018 UXO, 92 mines and 3 cluster bombs were found, as well as 40.163 ammunition pieces. In addition, 80.2km^2 of new areas which previously had not been mine suspected became potentially hazardous (Northern part of Bosnia and Herzegovina). Bosnia–Herzegovina Mine Action Centre (BHMAC) have provided data and information about the affected regions, the kinds of influence, the impact intensity and the spatial distribution, as well as priorities [4]. In order to deal with such complex and dangerous situation, it was decided to deploy an Unmanned Arial System (UAS) for aerial assessment

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and mapping flights of the affected mine fields and new suspected hazardous, looking for indicators of where the minefields were shifted due to the floods and landslides [5].

2. Integration of UAS in mine action procedures

The use of Unmanned Aerial Systems for dangers and not easily accessible missions provides benefits for users due to their low cost, portability, and potential fields of use. In this context such systems can offer important support to human task forces in situation assessment and surveillance and in this way increase the situational awareness of the environment from the air. The UAS can be deployed without the need for extensive airstrips for take-off and landing. Operating costs are typically low, compared to conventional manned aircrafts. The use of small UAS may improve the response time and coverage for operations allowing search and ground teams to systematically survey and perform mapping and doing damage assessment of areas (high level of details and accuracy of ground pixel size 2-5 cm) of importance without any physical interaction within dangerous zones [2].

In the context of this mission we used a small vertical take-off aerial system UAS the md4-1000 from Microdrones as shown in Figure 1. Depending on the weight of the payload, state of the batteries, environmental and flight conditions, the UAS can fly for about 35-40 min. In addition, the overall UAS (system comprises of a field control base station with high gain antenna for providing command, control and data recording to and from the Unmanned Arial Vehicle (UAV). The UAV system is equipped with a Sony NEX-7 24.3 megapixel digital camera with an 18mm lens. The camera is mounted below the UAV on a 2-axis gimbal with high precision tilt and roll stabilization (because of the strong and multi-direction wind) in real time to provide better images for aero triangulation and mapping.

In general, two types of operations were performed:

- Manual Flights. End-users (demining teams) indicated points of interest they wanted to see investigated by the UAS, mainly for damage assessment and visual inspection. The flights were then executed by a trained operator.

- Waypoint-based mapping flights. An area to be mapped by the UAS was indicated by the end-users. A flight plan was then set up to map this area using an autonomous waypoint-based flight. Also under these conditions, a trained pilot always operated the remote control station.

A typical flight had a duration of 25 to 30 minutes, which enables to cover an area about few hundred sq meter. Multiple mapping missions were performed, maximum up to 500 images with a resolution of 24 megapixels and mapping areas not larger as 1sq km.

Figure 2 shows the complete workflow process of the UAS flight mission. Starting from the definition of the affected mine suspected areas, terrain reconnaissance, producing a flight plan, measuring D-GPS ground control points through flight execution with data acquisition and finally post-processing activities.

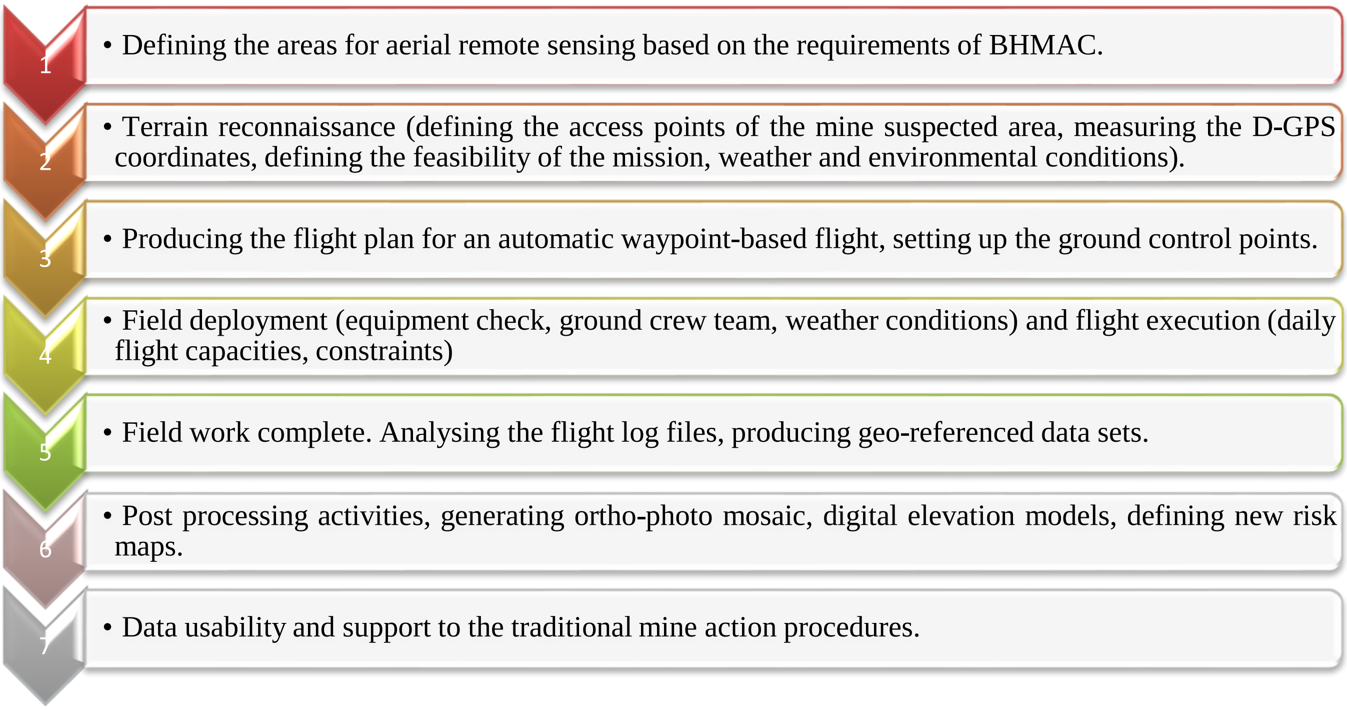

Figure 1 Workflow planning of the UAS flight mission

Figure 3 shows example images for an automatic waypoint-based mapping flight acquired by the UAS. Example of the landslide, which crosses the mine field from the region Olovo (Central part of Bosnia and Herzegovina).

Figure 3 Example of mine suspected area images acquired by the UAS

2.1 Problem defining - Region Olovo

Olovo Municipality is positioned within the central part of Bosnia and Herzegovina, 56 km N/E from the Capital Sarajevo and 75 km south from Tuzla. Before the Bosnian war[4], the Olovo municipality with its 44 surrounding villages counted 16.956 inhabitants. Nowadays, the municipality counts approximately 13.000 inhabitants. The density of population is approximately 32 people per square kilometre, which is significantly below the region's average (approximately 128 persons per km^2). Olovo is a medium-urbanized municipality with developed mining and forestry.

Our case study is focusing on the region Olovske Luke which belongs to the Olovo municipality. Location of Olovske Luke shows a clear mine situation, which is visible on mine situation map shown on Figure 4. During the war conflict, confrontation lines were steady and without significant movements. Combat lines were fortified and

[4] The Bosnian War was an international armed conflict that took place in Bosnia and Herzegovina between 6 April 1992 and 14 December 1995. Source: http://en.wikipedia.org/wiki/Bosnian_War (web access: 21/3/2015)

mine-explosive obstacles places with or without records, which is characteristic for this area. After the war activities in the period that followed, there have been operations of humanitarian demining in locations closer to objects relevant for infrastructure such as water line and elementary school of Olovske Luke (locations of number I priority), while locations of II and III category were marked with either semi-permanent fence or urgent signs of mine warning.

Due to the nature of combat, the location of Olovske Luke is mainly contaminated with a larger quantity of cluster bombs CB 1, fired from infantry weapons. At Olovo municipality area, since 1996 up to 2015, 31 mine incidents occurred; 22 persons were severely injured, with 9 fatalities, including two children.

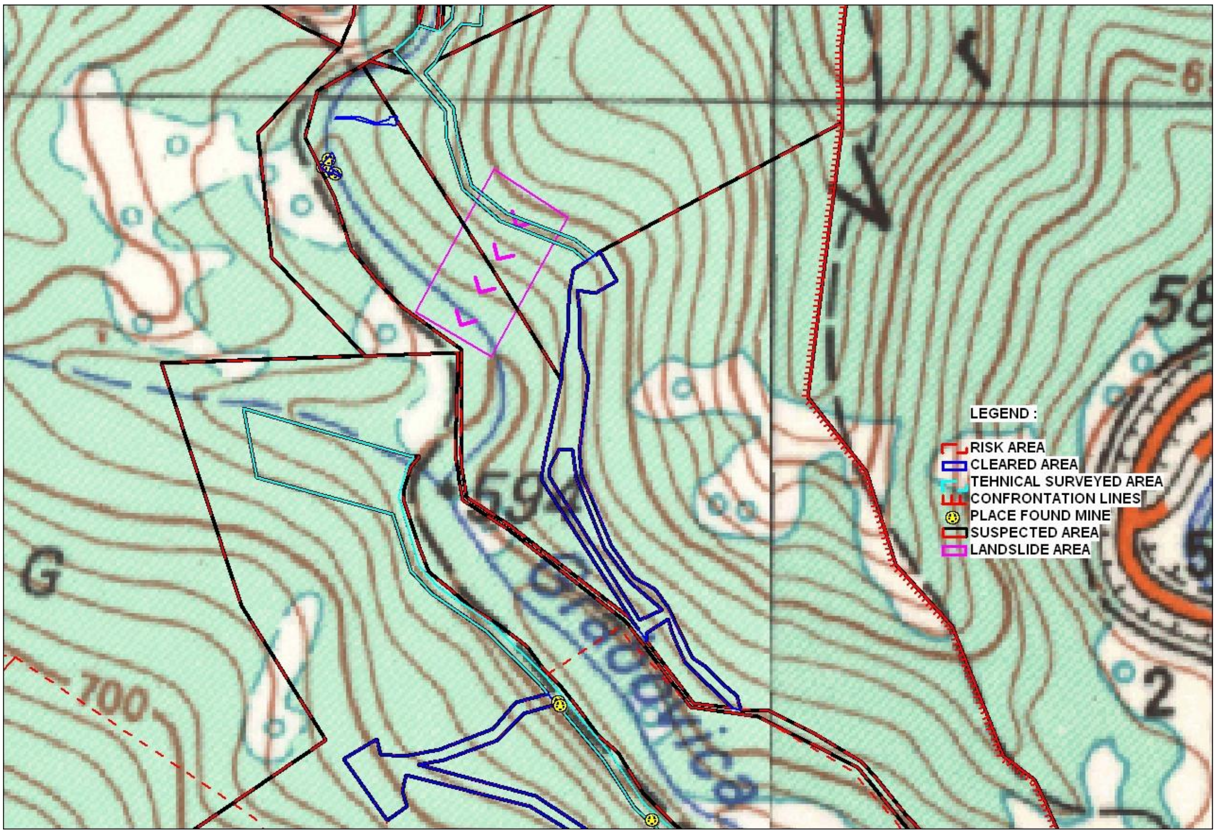

Figure 4 Location Olovske Luke – Topographic map (1:25000) and mine situation layers with influences of floods and landslides (Database BHMAC)

In May 2014 on location Olovske Luke, due to natural disaster that affected this area, a large landslide started off a previously marked mine suspected hazardous area. The landslide endangered formerly technically surveyed area that were partially demined due to restoration of the local water line. Since part of the landslide is situated in the mine suspected area, and it brought a large amount of slide material over formerly technically surveyed area, the demined zones within the landslide should be declared as mine suspected. Additionally, land erosion also brought a large amount of slide material onto Grabovica creek with great probability of mine-explosive materials displacement downstream in the direction of the urban areas.

Since the landslide is an active one and was not remediated, it is still a threat endangering the region with the risk of possible reactivation, expansion of the mine suspected area with significant negative environmental and security consequences for the citizens. Therefore, it was necessary to react urgently and it was decided to deploy the UAS for aerial assessment and mapping of the mine-suspected areas and to find indicators of where the minefields were shifted due to the floods and landslides. The data of the UAS mission was used for providing 3D-maps of the environment to analyze the effects of the landslides on mines. Fusing the obtained data from the UAS with pre-existing data (mine risk maps from the Bosnia and Herzegovina Mine Action Centre), it will be possible to predict the movement of the landmines and to generate updated mine risk maps and maps of mine-affected areas.

2.2 Data processing and quality assessment

Once obtained, the data acquired from the UAS were processed and new digital ortho-photo (DOF) mosaic and digital surface models (DSM) of affected mine suspected areas were produced. Main processing procedure was conducted in Agisoft Photoscan [6] software. The software generated the digital ortho-photo mosaic and digital surface models using an algorithm, which analyses all images of the aerial data set and searches for matching points. The best well-known feature matching algorithm is the scale-invariant feature transform approach. Those feature-matching points are combined with meta-data information from the autopilot (altitude, camera position and orientation) and are used in a bundle block adjustment in order to reconstruct the exact position and orientation of the camera for every acquired image. Based on this reconstruction, the matching points are verified and their 3D coordinates calculated. Those 3D points are interpolated to form a triangulated irregular network in order to obtain a Digital Elevation Model (DEM). This DEM is used to project every image pixel and to calculate the geo-referenced ortho-photo mosaic of the area. The reconstructed DEM and the resulting ortho-photo mosaic are shown in Figure 5. The quality of digital ortho-photo mosaic and DEM depends on the accuracy of the Ground Control Points (GCPs). If the quality of GCPs is excellent, therefore the result of digital ortho-photo mosaic and DEM can be anticipated accurately too. In this case we could reach an accuracy within few cm per pixel. Several processing procedures were tested due to large positioning error.

General processing procedure consists of the following steps:

I. Data import: Photos and corresponding GPS coordinates of the projection centres
II. Photo alignment
III. Defining Ground Control Points
IV. Alignment Optimisation
V. Build Dense Cloud
VI. Build Mesh
VII. Build Texture
VIII. Generate Result: DOF, DSM

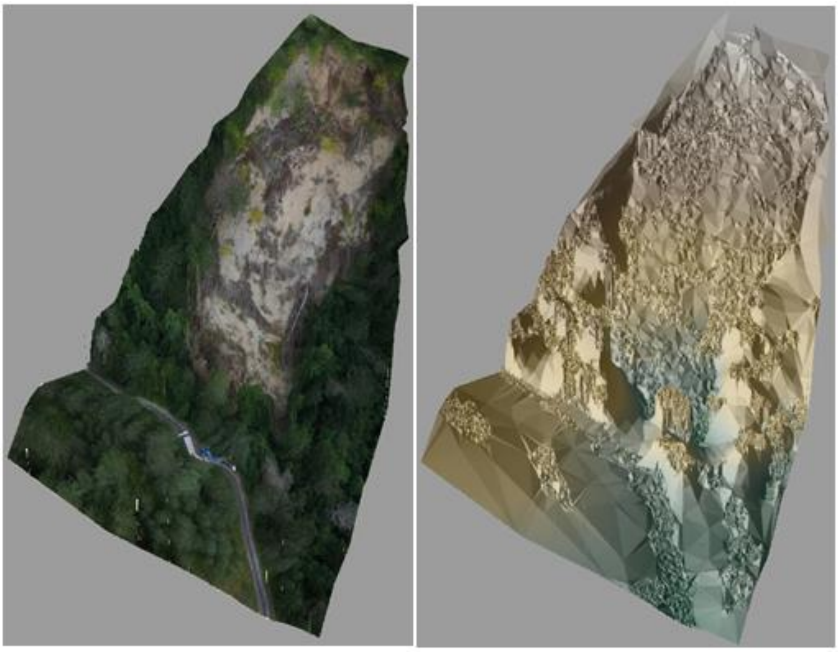

Figure 5 Left - Digital Ortho Photo mosaic of the recorded area Olovske Luke, Right - Digital Surface Model of the recorded area Olovske Luke

Applied processing procedures have not contributed to a significant reduction of positional error. Span of X coordinate positioning error is from 18.396 m to 15.685 m and for Y coordinate it varies from 21.164 m to 15.695 m. Position error was determined comparing well defined detail on both (official/state) DOF 1000 and generated micro DOF mosaic of this location. The best results were achieved after GCP ortho-metric height was corrected for geodetic undulation (difference between geoid and ellipsoid value) in the third processing step. Geodetic undulation value for this location was supplied from a web geoid calculator [7.].

Due to this reason it was necessary to conduct additional georeferencing of micro DOF mosaic on (official/state) DOF 1000. When applied, this procedure resolved the issue of large positional error. Achieved declared ground resolution of the DOF mosaic is 0.0174429 m/pix.

3. Data usability and support to the traditional mine action procedures

Once obtained, the data acquired from the air enables to define the estimated the size of the landslide and position it on cartographic and Mine Information System (MIS) database layers without further measuring on the ground, which diminishes the risk for the surveyors. It is also possible to estimate if ground erosion resulted in moving of the mine-explosive devices. In overlay of obtained micro ortho-photo mosaic with state/official DOF 1000 and MIS layers as shown in Figure 6, it is possible to assert that there has been ground erosion at places where mine-explosive devices are expected, thus it is necessity to re-declare the affected areas as risk areas.

Furthermore, it is possible to determine actual size of the phenomenon: the max length of the landslide is 142 m, it's max. width is 55 m while total landslide area is 6650 m^2.

The obtained DSM will serve for better defining of geology and hydrogeology experts' opinion on the possible problem expansion tendencies, landslides depth (in this case from 6 to 8 m), the urgency of remediating actions necessary, and the need for updating the boundaries of mine suspected hazardous area.

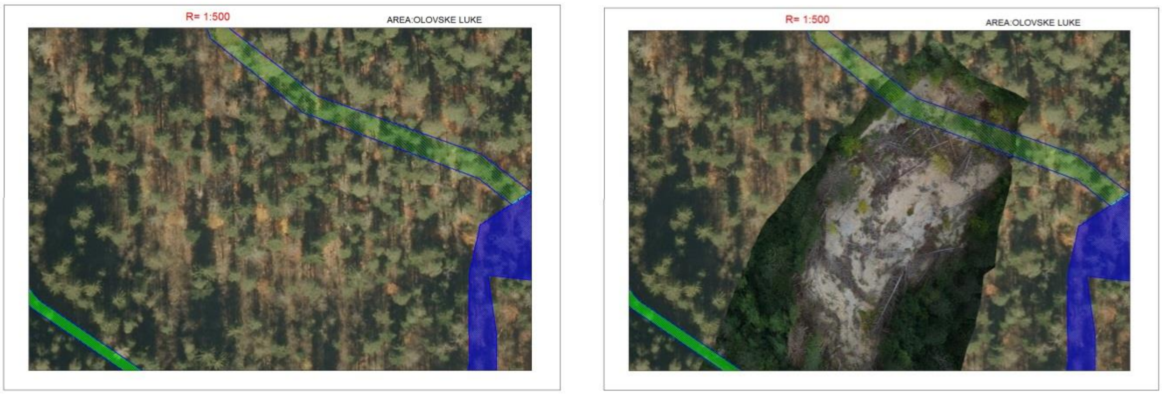

Figure 6 Left Figure: Ground situation before the natural disaster, overlay of DOF1000, technical surveyed area (green) and cleared area (blue) , Right Figure: Ground situation after landslide occurred, overlay of DOF1000, micro DOF mosaic, technical surveyed area (green) and cleared area (blue)

The use of UAS in mine action in Bosnia and Herzegovina is a new challenge towards more efficient and effective resolving of the problem of mine contamination. Based on the work and experiences gathered during the field missions, the direct and indirect benefit of UAS deployment in mine action procedures could be:

The data acquired from the air can enable identifying of mine presence indicators such as confrontation lines positions, combat facilities and reference points from minefield records in inaccessible areas. The data can also be used as quality control of created demining projects, in re-survey of risk areas processed within a demining project as well as in process of identifying areas without defined risk and in process of reduction of areas planned for systematic survey;

Also, it can be used for establishing facts of mine incidents by recording the mine incidents locations as proof of mine hazard, as well as recording technically surveyed area where remaining mines were found. Data obtained from UAS can also be useful in defining mine action procedure for future tasks, defining sizes of area intended for mechanical demining;

Gathering information on configuration, vegetation, soil type, infrastructure and establishing aggravating circumstances which might influence the conduct of planned mine actions;

In cases of mine accident the UAV data could be used for identification of the accident location in relation to the mine situation of the location, guiding deminers towards the indicators.

Documentation of activities conducted on the area of interest in mine action procedures (images and videos from the area).

4. Conclusion

In this paper, a report on the operational deployment of novel technological tools for mine action in an actual situation has been presented. An unmanned aerial system equipped with sophisticated 3D data processing algorithms was deployed to help with mine action efforts after the 2014 floods in the Bosnia and Herzegovina. The tools were used in support of ground teams for crisis assessment, and for helping in localizing landmine suspected areas affected by the natural disaster. The response from the response teams brought into contact with the unmanned tools was very positive. As a closing remark, one of the end-users (the BHMAC Technical operation officer), noted that the rapid mapping activities and the results we get from the UAS mission are crucial for damage assessment, and for re-localizing the many explosive remnants of war which have been displaced due to landslides and flooding water. In this case, we did not risk and put humans in the dangerous zones.

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