Deploying Drones for Spatial Modeling of Displaced Landmines in **Bosnia Herzegovina**

Heavy floods and landslides in Bosnia Herzegovina shifted minefields and explosive remnants of war (ERW) into inhabited areas. The Belgian Royal Military Academy (RMA) team worked with the Bosnia and Herzegovina Mine Action Centre (BHMAC) to use drone images that would help model the potential locations of some of the many displaced ERWs and mines. These models then were used to narrow down the search radius for demining teams.

Background

In May 2014, the worst flooding in the Balkans in 120 years of recorded weather measurements caused extensive damage and triggered landslides. In Bosnia and Herzegovina an estimated 1.5 million people—close to 40 per cent of the population—were affected. As a result, the Government of the Federation of Bosnia and Herzegovina activated the European Union Civil Protection Mechanism in order to request support for the response to the flooding. Moreover, the floods and landslides caused major displacements of ERWs. Some of these mines were moved by as much as 23 kilometres. When the floodwaters subsided and villagers returned to their homes, most were unaware of this imminent danger. The government sought assistance in identifying as well as clearing displaced mines.

As a result of the wars in the early 1990s, Bosnia and Herzegovina has one of the most serious landmine problems in the world. More than 5 000 people were killed or injured by landmines or unexploded munitions between 1992 and 2008. By 2013, landmines and unexploded munitions remained scattered in 28 699 locations across the country. Before the floods, approximately 540 000 citizens (of a total population of about 4 million) were living near these locations. Given that the displaced mines were likely to have spread over very large areas, ground searches would have taken too long, and the RMA team sought to reduce the search area by carrying out an initial analysis using up-to-date, high-resolution imagery.

Figure 1 Aerial image of flooded areas captured by the ICARUS UAV. © ICARUS.

Implementation

Between May and June 2014, the RMA team deployed MD4-1000 Multicopter Microdrones along with two types of sensors—a high-resolution digital camera and a near infrared (NiR) camera. The microdrone has a flight time of up to 88 minutes (depending on load and battery) and a flight radius of up to 40 kilometres. The RMA team logged a total of 20 flights (both manual and autonomous) from 13 locations in urban and semi-urban areas. The flight times ranged from 25 to 30 minutes and captured 200 to 500 images at a resolution of 2-5 cm on each flight. The temperature ranged from 20°C to 25°C with a maximum wind speed of up to 7 metres per second where the flights were carried out. Flights were rescheduled when wind speeds reached more than 12 metres per second. The team did not map the entire risk area since the size of the suspected hazardous area before the disaster was 1 207 square kilometres.

All flights were operated within a visual line of sight up to 150 metres in altitude as specified in the permits granted with the support of the Ministry of Security of Bosnia and Herzegovina and the national Directorate of Civil Aviation. The authorities issued the permits promptly. They had invited the RMA participation well before the flooding disaster, and the permits had been prepared for previous operations. In addition, the permission process was expedited given that the RMA drones were to be used in response to a major natural disaster. The flight permissions specifically granted RMA and their lead drone operator the legal right to operate their drones.

The team carried out their first mine-identification mission in the region of Olovske, which is riddled with cluster bombs, and where the massive rainfall in May 2014 triggered a large landslide. Part of the landslide ended in Grabovica creek, which prompted fears that explosive materials might have been further displaced downstream in the direction of urban areas. The team used the Agisoft Photoscan software to create a 2D ortho-rectified mosaic of the landslide area along with digital surface models (DSMs) and digital elevation models (DEMs). The spatial resolution of these data ranged from 3 cm to 10 cm. The

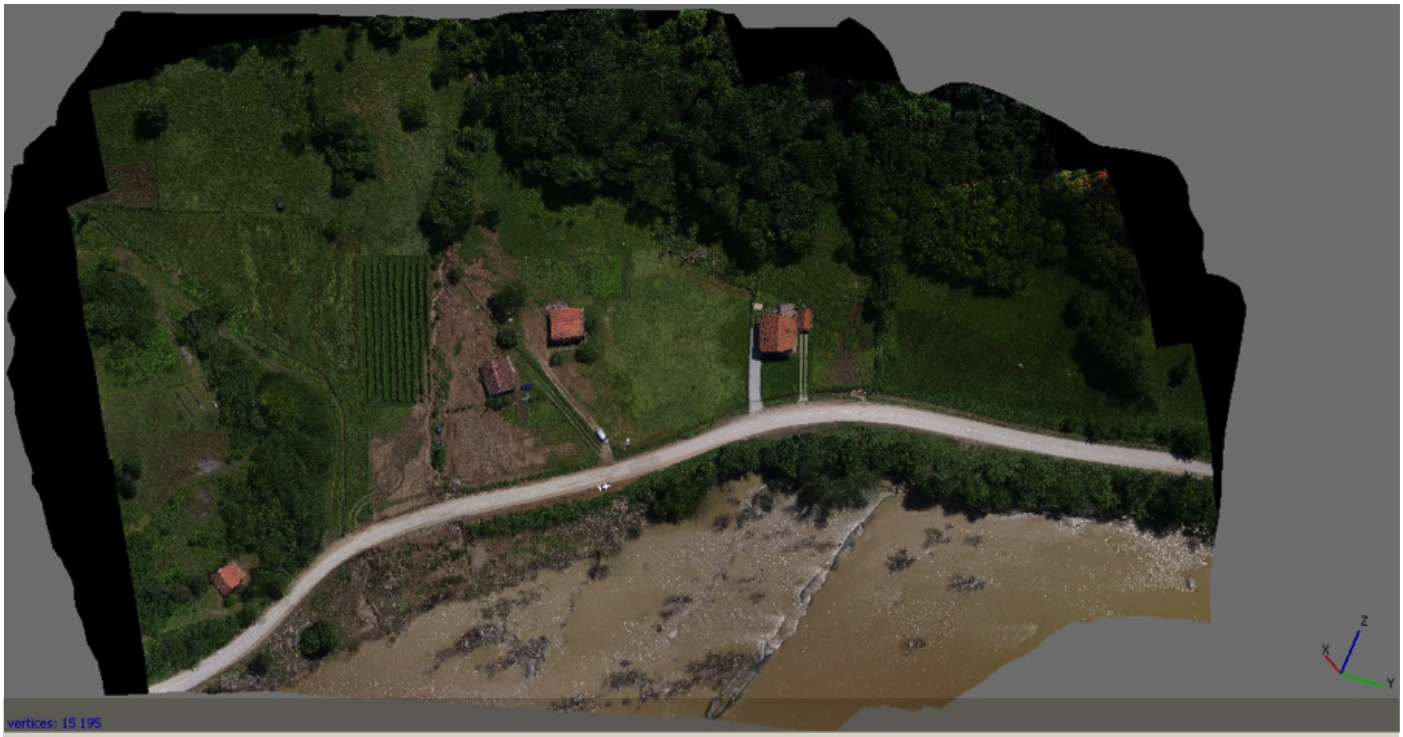

Figure 2 Example of a digital ortho-mosaic depicting a landslide that crosses a minefield in the upper part of the mosaic. The digital ortho-mosaic was derived from aerial images captured by UAVs.

models, which were accurate to within a few centimetres per pixel, enabled the RMA team to estimate the size of the landslide and to position it on cartographic and mine information system database layers. In fact, the RMA team was able to determine the maximum length of the landslide (142 metres), width (55 metres) and the total area covered (6 650 square metres). The mosaics, DSMs, DEMs and 3D models were then shared with the Department of Geodesy at the University of Sarajevo, where statistical models for assessing the impact of flooding on erosion enabled the team to determine whether ground erosion had potentially displaced any of the known mines. Taken together, these approaches allowed RMA and the University of Sarajevo to identify new areas where unexploded mines might now be located and therefore to declare them risk areas.

The RMA team also deployed to the heavily damaged city of Maglaj. The presence of many ERWs in this region made the humanitarian efforts in the area particularly dangerous. The team therefore used drones to inspect areas where mine-clearing teams were not able to operate due to the very high risk of ERWs. More specifically, the drones were used to create a high-resolution model of the high-risk areas in order to simulate the direction and distance that some of the known minefields might have shifted. In other words, the RMA team combined these 3D data with pre-existing mine risk data to predict the movement of the landmines and to generate updated mine risk maps and maps of mine-affected areas.

The role of the drones was to reduce the particularly large search area by creating high-resolution 3D models to predict the ERW movement and thereby limit the search area to a more manageable size. Aerial images of the Zavidovici-Dolac and Olovo regions (in central Bosnia and Herzegovina) were processed to create 3D maps, ortho-photos and digital terrain models of the environment to analyse the effects of the landslides on mines and ERWs. The results were used by the Bosnia and Herzegovina Mine Action Centre (BHMAC) to locate displaced ERWs, and for damage assessment and documentation purposes.

The near infrared camera was ultimately not used because the flooding had made the soil wet for several weeks, which meant that RMA statistical models—which were calibrated to work with NiR imagery of dry soil—could not be used to create probabilistic maps vis-à-vis the possible location of trinitrotoluene, commonly known as TNT, in the ground.

Figure 3 ICARUS and partners setting up their multi-rotor UAV to inspect flooding. © ICARUS.

Figure 4 Identification of mines displaced by flooding and landslides. © ICARUS.

Evaluation

According to the RMA team, helicopters were not used because minefields are typically small and widely distributed. The largest area surveyed via drone covered about 2.5 km^2. Using a helicopter to cover such a small area would not have been practical or cost-effective. Moreover, the helicopters would have needed to fly particularly low, and these suspected minefields were near urban areas; such flights would have created noise pollution for local residents. The RMA team did use helicopters in the north for a survey of 140 kilometres of a riverbank where some 30 landslides had been reported.

For the minefield surveys, the RMA team subsequently acquired a 3D model of the area used to determine the natural flow of water—information that they could not otherwise have acquired. According to BHMAC, the rapid mapping results from the drones were crucial for the damage assessment and for identifying the new locations of the many explosive remnants of war displaced by landslides. The mission experienced one crash (in the middle of a minefield) that required repairs to the drone. The RMA team noted how important continuous communication with authorities was. While the latter did not expect high frequency in communication, they were very appreciative and formally commended the team for their professionalism. In addition, a highly ranked representative of the Ministry of Security Bosnia and Herzegovina noted that «The results obtained by the UAV [unmanned aerial vehicle] and the professional work performed by Mr. Haris Balta [RMA] have been of utmost importance during the response period and also for post processing and investigation of future activities.»

Figure 5 The ICARUS multi-rotor UAV with camera and gimbal in flight. © ICARUS.

A technical operations officer also noted that, «The rapid mapping activities and the results we get from the UAV mission are crucial for damage assessment, and for identifying the new locations of the many explosive remnants of war which have been displaced due to the landslides and flood water. In this case we did not risk putting humans in the danger zones.» On a related note, the RMA team pointed out that their lead expert and drone operator, who spearheaded this mission, happened to be from the region and thus knew the language and culture. This was instrumental to the success of the mission.

The cost of the first mission following the flooding was approximately €15 000. This did not include RMA time, which was covered through a separate grant. The government also provided local transportation and accommodation. The above figure includes about €6 000 that went into repairing one of the drones.

Resources

http://www.fp7-tiramisu.eu
http://www.fp7-icarus.eu/project-overview
http://mecatron.rma.ac.be/pub/2014/SSRR2014_proj_037.pdf
http://www.microdrones.com/company/media-relations/md4-1000_Flyer_englisch_web.pdf
https://www.youtube.com/watch?v=7oI5YJjsjDE
https://www.youtube.com/watch?v=ThwH2jSwinQ&feature=youtu.be
http://www.fp7-tiramisu.eu/news/tiramisu-partners-spearhead-new-project-mine-action-after-floods
http://www.jmu.edu/cisr/journal/19.1/pdfs/bajic.pdf
http://mecatron.rma.ac.be/pub/2015/HUDEM_2015_Avdic_Balta_Ivelja_final_ver.pdf
http://iRevolutions.org/2014/07/07/humanitarian-uav-missions-during-balkan-floods

Acronyms

B-FAST	Belgian First Aid and Support Team
BHMAC	Bosnia and Herzegovina Mine Action Centre
DEM	Digital elevation model
DSM	Digital surface model
ERW	Explosive remnant of war
NiR	Near infrared
RMA	Belgian Royal Military Academy
UAV	Unmanned aerial vehicle

Technical Specifications & Credits

Type of system: MD4-1000 Multicopter Microdrone
Deploying Agency: Belgian Royal Military Academy
Piloting Agency: Belgian First Aid and Support Team (B-FAST)
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Author: Patrick Meier, ed. Denise Soesilo

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