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THE CONTRIBUTION OF UAVs IN IMPROVING THE LANDMINE FIELD DETECTION PROCEDURE

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Abstract: *The use of unmanned aerial vehicles is gaining more and more importance day by day and its applications are expanding. Monitoring, inspection, live stream and delivery are just some of the areas where UAVs play a dominant role. In recent decades, intensive attempts have been made to apply UAVs in coastal minefield inspections with the aim of improving the inspection process, increasing the efficiency of preparatory actions, the safety of teams in the field, and reducing the costs and time of operations. In this paper, experimental results will be presented that indicate the advantages of using unmanned aerial vehicles, as well as the possibilities of their future application, all with the aim of improving this area.*

Key words: *unmanned aerial vehicles, landmine, inspection, mapping*

1. INTRODUCTION

Unmanned Aerial Vehicles ("UAVs" – drones) – enable a very wide range of new services and applications such as aerial surveillance, environmental sensing infrastructure monitoring, live broadcast etc. Employing drones for such variety spectra of applications can improve safety aspects for human operators' injuries and reduce the overall operational cost. The UAVs is equipped with an on-board device to control a motion beyond visual line of sight - LOS. Thanks to developed cellular network coverage and broadband data rate support, the UAV does not require a nearby flight operator, but is controlled remotely over the internet at unprecedented distances**.** We can say that today, we live in UAVs era.

Landmines are acute problem of presents dangerous and costly obstacle in area where it has been scattered. Landmine has a serous effect on people and surrounding. It can not only injure or kill a person, but it can also block access area with the delivery of food and medical supplies etc (Ember, Kovács, 2020). Landmines are debris of war activities, and it can be found everywhere, fields, roads, farmers' fields, bushes, forests, deserts, along borders, in and surrounding houses and schools, and in other places (Kovács, 2008). Landmines fields block access to food, water, and other everyday needs and inhibit freedom of movement. In situation when land cannot be cultivated, when medical systems cannot access to all who needs a help, it is clear that we need a general activism (Krause, 2018). In situation when countries must spend money for clearing mines instead to spend money for education, health care, new energy sources, it is obvious that landmines not only cause appalling human suffering (Lukács, 2006).

According to data from the Geneva International Center for Humanitarian Demining, as of January 2021, 55 countries in five different parts of the world are facing the problem of the presence of minefields. This is a serious and complex problem, the solution of which requires a comprehensive multidisciplinary approach and solution (Landmine Monitor report, 2021) The combination of modern technologies with field experience as well as a proactive approach can represent one of the potential WIN-WIN-WIN solutions.

Unmanned aerial vehicles are becoming day by day more and more important tools in the improvement of processes and activities in the field of humane demining. Terrain mapping processes, using different technologies, thermal, hyperspectral, LIDAR (light detection and ranging), GPR (ground penetrating radar) in combination with UAVs, are the future in the daily struggle with the consequences of human disasters such as landmines (Robledo, 2004). At the basis of numerous research is the examination of the efficiency of various sensor systems in different technologies in the application of minefield inspections (Ahmed, 2014). Such systems have shown certain degrees of efficiency in examining the presence of unexploded ordnance - UXO on large, contaminated area (Gooneratne, 2004).

2. UAV TECHONOLOGY, DIGITAL MAPING OF LANDMINE TERRAIN

With RGB cameras on UAVs, a much higher level of detail is achieved, with significantly less time spent, and optimal accuracy. The main advantage of mapping using unmanned aerial vehicles is reflected in the fact that certain work can be carried out with a much higher level of detail, with significantly less time spent for data collection in the field compared to the application of conventional surveying methods, with the achievement of optimal accuracy that must be met. The drone mapping process can be divided into three basic phases: Mission Planning, Data Collection and Data Processing. The data processing procedure can be done in a short time, i.e., in less than one hour, if a small number of photos were collected during mapping, while for projects with a large number of collected photos, significantly more time is needed for data processing (Kurmi, 2019).

A realistic digital 3D model of an object can be obtained with a drone, if there are no physical obstacles between the object being mapped and the camera used for recording.

The quality and accuracy of the footage is affected by the characteristics of the camera mounted on the drone and the details of the flight plan - flight height, camera angle, values of the longitudinal and transverse overlap between the photos, the accuracy and mutual geometry of the set control points on the object that is the subject of the recording etc.

Based on the information obtained by processing Digital Terrain Model (DTM), adequate management of spatial resources, in this case forest vegetation in the area of cities or outside them, is enabled. UAVs produce high-resolution images and information that provide operational value in a wide variety of different applications while surveying terrain of interest. With the help of obtained photos and various techniques of their processing, the conditions are created for the creation of up-to-date cartographic images and the creation of terrain maps on which appropriate operations are performed in different Google Maps, ArcGis, GIS environments. On the basis of this, the geolocation of suspicious parts of the terrain can be carried out, which will greatly improve the process of operational planning, inspection and cleaning of the terrain. Namely, the data collected and processed by UAVs together with current and newly created maps for the removal of minefields can potentially predict the location of contamination, define accessible approaches, detect locations in some cases and georeference them (Borisov, 2015).

3. MATERIALS AND METHODS

In first steps of our experiment, we performed field validation and data collection. Field validation regarding the viability of airborne involved remotely collecting in-situ landmine data via drone over legacy minefields during the two days: March 31st and April 8th 2022 in object of Mine action center of Republic Serbia. High temporal and spatial resolution data was captured at a controlled field test site using production landmines – models, landmines free from explosives. These models were scattered inside the perimeter of actual landmines (100m^2). The several main landmine types have been presented at this location. The placement of the mine model was done by an employee of the Demining Center according to the random distribution model. The other members of the team that performed the experiment were far enough away, so that they were not physically able to see the locations where the mines were placed. Landmines were partially or completely masked. All this was done in order to simulate the most realistic conditions on the field.

Recording was done using the MATRICE 300 RTK drone and the ZENMUSE H20T dual camera (fig 1). The Matrice 300 RTK is the latest DJI platform for professional solutions with a wide range of applications, 55 minutes flight technology, sacra direction and avoidance and reliability without transport. The following features of DJI, such as portable and fast to set, high efficiency reflectors, speakers, headlights and RTK accessories are available, maximum range of 15 km (FCC) • 1/2.3" CMOS (12 MP) RGB sensor • 640K512P thermal Sensor • 1/1.7" CMOS (20 MP) RGB sensor • laser remote detection system enables high efficiency process of collecting high resolution date.

Figure 1. DJI Matrice 300 RTK with H20T and L1 system

The recording was made by H20T camera from a height of 10 m to 60 m, (IR and RGB mode) where the relative humidity of the air was 60%, the reflection temperature was 25°C and the emissivity of the surface was 0.90. These last two parameters are important for thermal analysis. Recording was conducted in accordance with legal provisions and security conditions. After that, ordinary orthophoto mosaic, thermal orthophoto mosaic were obtained by processing the images on weekdays and recorded on weekends in RGB and thermal image. The mapping process was carried out using a standard procedure through three basic phases - mission planning, data collection and processing. The H20T camera, with its technical characteristics, fully met the requirements of experiment (fig 2).

To realize aerial photography, a flight plan was drawn up. The elements of the flight plan were determined in accordance with the project task, in accordance with the regulations governing the area of photogrammetric surveying. Given that the project task did not define the values of the maximum radial displacement of the image of the object, the values of the longitudinal and transverse overlap of the images and the corresponding constants of the cameras, they were set to fulfill the given requirement of this report, which is the precise detection of active loggers in relation to the direction and time of flight to be acceptable in terms of avoiding excessive reflections, i.e., shadows, and to provide optimal contrast on the elements of interest in the images. The flyovers were made in the north-south direction to avoid potentially large differences in brightness between adjacent sets of images. For the creation of orthophotos, it was necessary to ensure a higher degree of overlap of the recordings than the standard one and the corresponding camera constants, which were determined in accordance with the project task.

Figure 2. DJI Matrice 300 RTK in operation flight

In parallel with the recording of the field, we realized a live broadcast of the camera recordings via live streaming and a simulated small command center for remote supervision of the inspection process from the command room. The goal of this activity was to create conditions for more effective monitoring and the possibility for more people to have access to the results in real time (fig 3).

Figure 3. Livestream of monitoring process in “command room”

4. RESULTS AND DISUCCUSION

After mapping in the field, the photos are imported into the Pix4D Mapper program for further processing. In this application, the coordinate system is selected, the accuracy is checked and the connection with the control points is carried out as necessary. In the next step, options for creating 3D models, orthophoto maps and radiometric maps are determined. Each of these options can be turned on or off individually and are independent of each other. In this step, we can also choose the option to create a “.kml” file that contains maps compatible with Google Earth application, QGIS application and other similar applications (fig 4).

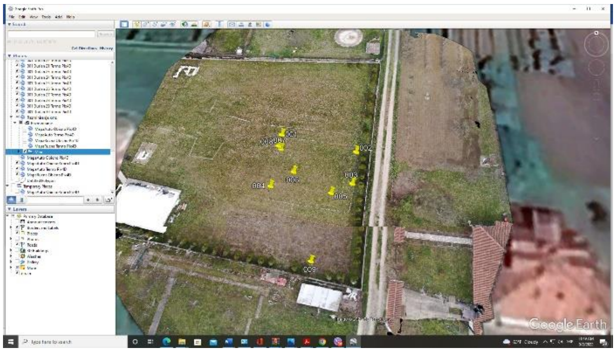

Figure 4. Google Earth map position of simulated landmine location with stickers on mine location

Photo processing and creation of all selected models and files is done automatically, so that the program first finds the common points on the photos, then performs an overlay and finally creates the desired files. After each completed step a report is generated that can be viewed in real time, immediately after creation. The processing time depends on the number of selected options, the type of files and their complexity. For the purposes of the experiment, we chose to present the results in the Google Earth open-source platform due to its interactivity and availability.

Figure 5. Inserted picture of landmine on location

All nine landmines were detected within four hours at the mentioned location, by comparing the footage in real time in the simulated command room. The potential problem appeared in areas of denser vegetation, because that area was flown over more times than the area we used to simulate rocky terrain (fig 5). The applied methodology proved to be successful not only when detecting mines on the ground and in the surface layers of the earth, but also in cases where the mines were placed at a certain height above the ground (fig 6). In the latter case, the approach was performed from different angles on several occasions, which required much more attention, more experience and concentration from both the operator on the UAV and the observers in the “control room” (fig 7).

Figure 6. Detected landmine on the location

Communication between observes in control room with operator has been communication between the control room and the operator is also an important segment and can be maintained in several ways, with a radio station, mobile devices, enabling access of persons from the control room to the UAV console, etc.

Figure 7. Detected location of landmine on the position over the land

In the final phase of the experiment, the images were compared with the situation on the ground, with mapped views. It should be noted here that in parallel with the RGB recording, thermal imaging and thermal mapping of the terrain were also performed. The introduction of thermal analysis significantly advanced and enriched the amount of information we collected about each location, its condition in terms of physical elements as well as thermal elements. All this allowed us a deeper and more detailed insight into the state of the environment around the mines, based on which more accurate decisions can be made.

However, it is very important to emphasize that precise thermal imaging requires appropriate specific conditions that were not met during the implementation of this experiment, so that a more detailed thermal analysis was not carried out, and the co-melting is the future of our work. However, in addition to that, the thermal images and pictures showed us certain terrain anomalies in terms of reflection, which was a good reason to pay extra attention to those locations, i.e., to fly over that location several times from different angles and from a lower height (10 m) (fig 8).

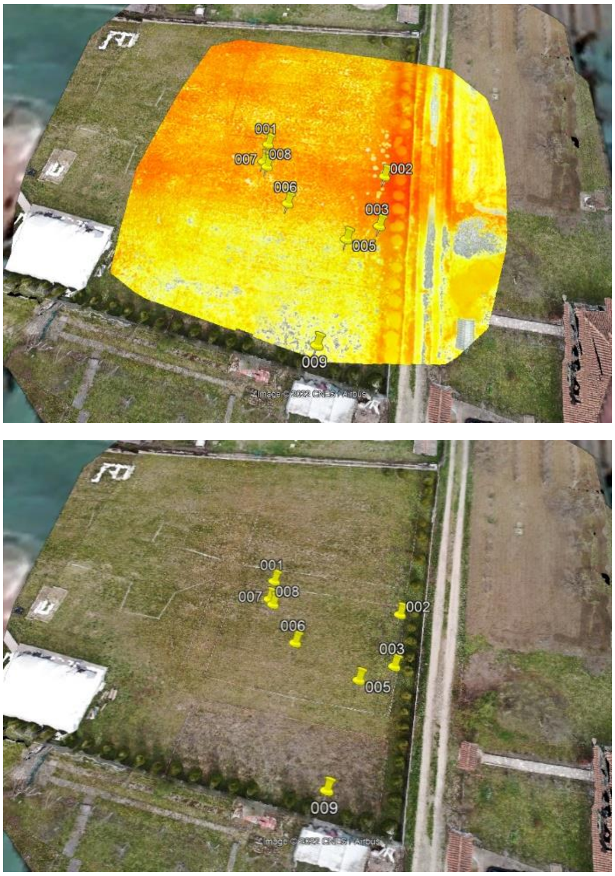

Figure 8. Thermal /RGB mapping of location

5. CONCLUSION

The use of drones is gaining importance every day. The increased availability of commercial solutions facilitates our research and increases the reliability of the results. Experimental results obtained during the recording of the location of interest encourage us and provide a good basis for further research. The goal of the experiment, which was related to establishing the correlation between the appropriate parameters of the flight technique, flight conditions, resolutions and available tools for photo processing, was fully achieved. The obtained results point to the need for further research and development in this area with the application of all available technologies (LIDAR, thermal hyperspectral GPR, etc.) To conclude, using UAVs in this area improves operational efficiencies safety and time cost. Effective and successful application of UAVs need precisely defined project an assessment of available capacities. In further special attention will be paid to raising the precision of the shots and the accuracy of the prepared orthophoto mosaic weapons in the various GIS environment. As the ultimate goal of this experiment, the pre-cheap georeferencing of locations of interest should be obtained. In addition, a further direction of development of new methodology will go in the direction of the optimal model of planning and performing activity demining.

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