APPLICATION OF UNMANNED AERIAL VEHICLES AND DIGITAL TOOLS IN DAMAGE ASSESSMENT AND CRISIS MANAGEMENT SUPPORT

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ABSTRACT

The paper presents the application of unmanned aerial vehicles (UAVs) and digital tools in assessing damage after a storm in the area of the Municipality of Bošnjaci, Vukovar-Srijem County, Republic of Croatia. The Civil Protection Directorate conducted aerial photography of the affected area the day after the storm and again twenty days later. Approximately 1,250 residential buildings were photographed using orthophoto techniques, while public buildings were documented using photogrammetry and 3D modelling.

The aim of the paper is to demonstrate the possibilities of using UAVs in rapid damage assessment, creating digital records and supporting decision-making during crisis management. The advantages of this approach are analysed through the data collection rate, increased operational personnel safety, documentation accuracy and the ability to compare the situation before and after rehabilitation. Emphasis is placed on the integration of geospatial data and digital technologies into the civil protection system for more efficient planning and coordination of activities in the field.

Keywords: unmanned aerial vehicles, orthophoto, 3D modelling

INTRODUCTION

Digital transformation has significantly changed the way in which crisis management, risk assessment, and the execution of protection and rescue activities have been carried out in recent years. The development of unmanned aerial vehicles (UAVs), geospatial technologies, digital records and tools based on artificial intelligence have enabled faster data collection, more precise analysis of the situation on the ground, and more efficient decision-making in emergency situations. The particular importance of such technology comes to the fore during natural disasters and major accidents when it is necessary to assess the extent of damage in a very short time, ensure the safety of operational forces, and coordinate a large number of participants in the civil protection system. Climate change, the increasing frequency of extreme weather events, and the growing complexity of crisis situations further emphasise the need to modernise the protection and rescue system. In such circumstances, traditional damage assessment methods are often insufficient due to the slow data collection rate, limited terrain availability and increased risk for operational personnel. This is precisely why modern civil protection systems are increasingly using digital technologies that

enable the rapid processing of large amounts of data, the creation of orthophoto images, 3D models, and digital databases for the needs of crisis management. An example of such an approach was recorded after the storm and hailstorm that hit the area of the Municipality of Bošnjaci in the Vukovar-Srijem County, Republic of Croatia, on 1 July 2024. The disaster caused extensive damage to residential and commercial buildings, infrastructure and agricultural areas, and required the urgent activation of the civil protection system and the coordinated action of numerous operational forces. Immediately after the event, aerial photography of the affected area was carried out using unmanned aerial vehicles, during which orthophoto images and 3D models of the buildings were created for precise damage assessment and rehabilitation planning. The Civil Protection Directorate conducted a systematic digital recording of the situation on the ground, including the recording of approximately 1,250 residential buildings, while public buildings were documented with photogrammetry and 3D models. The obtained data enabled a comparison of the situation immediately after the storm and during the rehabilitation process, which significantly improved the coordination of the activities carried out by the operational forces, the assessment of priorities, and the transparency of the reconstruction process. In addition to the technical aspect, the application of digital tools and UAVs has also played an important role in the field of safety and health at work. The use of aerial photography has reduced the need for operational personnel to be exposed to dangerous and difficult-to-reach areas, especially during inspections of damaged roofs, infrastructure, and the power grid. In this way, digital technologies have contributed to reducing the risk of injury, faster hazard assessment, and more efficient planning of protective measures in the field. The aim of this paper is to present the possibilities of using unmanned aerial vehicles, digital records, and modern analytical tools in damage assessment and support for crisis management after natural disasters. Special emphasis is placed on the integration of geospatial data, digital documentation and the possibilities of applying artificial intelligence in data processing in order to increase the efficiency of the civil protection system, the safety of operational personnel, and the improvement of the decision-making process in crisis situations. The paper is based on experiences and activities carried out during the recovery from the consequences of a storm in the area of the Municipality of Bošnjaci, Vukovar-Srijem County, Republic of Croatia, and presents concrete examples of the use of UAV technology, orthophotography, 3D modelling, and digital data analysis as part of a modern approach to managing crisis events in the digital age.

EQUIPMENT USED IN THE INTERVENTION

Drone DJI Matrice 300 RTK Technical Characteristics

The DJI Matrice 300 RTK is a professional drone designed for civil protection operations, infrastructure inspections, search and rescue, and crisis management. The main technical characteristics include:

-Maximum flight time: up to 55 minutes
-Maximum range of signal transmission: up to 15 km
-Maximum flight speed: approximately 82 km/h
-Weather resistance: IP45 protection against rain and dust
- Operating temperature: from -20 °C to +50 °C
- Maximum flight height: 7000 m
- Positioning system: RTK (Real Time Kinematic) for high precision navigation and mapping
- Six-fold sensor system for avoiding obstacles (vision + infrared sensors)
- Ability to carry multiple payloads at the same time
- Redundant control and power systems to increase flight safety
- AI functions for automatic object tracking and mission planning

Camera Zenmuse H20T

DJI Zenmuse H20T is a multi-sensor camera developed for security, civil protection, and technical inspection operations.
The system includes:
- 20 MP zoom camera
- 23× optical zoom
- 200× maximum hybrid zoom
- 12 MP wide-angle camera
- Radiometric thermal camera with a resolution of 640 × 512 px
- Laser rangefinder with a range of up to 1200 m
Key capabilities:
- detection of thermal anomalies,
- inspection of damaged facilities,
- search for people,
- night operations,
- precise marking of locations,
- documentation of damage from the air.
The thermal camera is particularly useful during:
- fires,
- technical interventions,
-inspection of electrical infrastructure,
- search and rescue,
- assessment of building safety after disasters.

Control and Transmission System

The DJI Matrice 300 RTK uses the advanced DJI OcuSync Enterprise data transmission system.
System features:
- three-channel 1080p real-time video transmission,
- automatic switching between 2.4 GHz and 5.8 GHz frequencies,
- AES-256 data transfer encryption,
- ability to work with two control stations,
- support for controlling multiple cameras simultaneously,
- integration with GIS and cartographic systems.
The control station enables:
- autonomous mission planning,
- RTK navigation,
- telemetry data display,
- sensor and camera management,
-automatic mapping and photogrammetry.

Operational Capabilities

The DJI Matrice 300 RTK system, equipped with the Zenmuse H20T camera, enables a wide range of operational activities in the fields of civil protection and crisis management:
-rapid reconnaissance of affected areas,
-damage assessment following natural disasters,
-creation of orthophotos,
-3D modelling of structures and terrain,
-thermal inspection of infrastructure,
-search and rescue operations,
-monitoring of post-disaster recovery efforts,
-surveillance of fire sites and critical infrastructure,
-support for decision-making in crisis situations,
-reduction of operational personnel exposure to hazardous areas.
In civil protection operations, the system enables:
-faster data collection,
-more precise damage recording,
-improved coordination of operational forces,
-safer fieldwork,
-digital archiving and comparison of conditions before and after recovery.

DIGITAL TOOLS USED TO PROCESS IMAGES

Agisoft Metashape Professional – A Program for Processing Orthophoto Images and Creating 3D Models

Digital technologies have played an increasingly important role in the civil protection system in recent years, especially in the field of damage assessment, creating digital records, and supporting crisis management. After natural disasters and major accidents, it is necessary to collect accurate data on the situation on the ground in a very short time, assess the extent of the damage, and enable effective coordination of operational forces. In such situations, photogrammetric programs for processing aerial images and creating three-dimensional spatial models play an important role. Agisoft Metashape Professional is a professional software for processing digital photos and creating orthophoto maps, point clouds, and 3D models of objects and terrain. The program allows processing a large number of photos taken from the air and their automatic linking and georeferencing. Based on overlapping photos, the software generates precise geospatial data that can be used for damage assessment, rehabilitation planning, and analysis of the situation on the ground. The data processing process begins with loading the photos and their automatic alignment. The program recognises common points in the photos and determines the position of the cameras and the basic geometry of the scene. After that, a dense point cloud is generated, which represents a detailed three-dimensional view of the objects and terrain. Based on the point cloud, a 3D model with high-resolution textures is created, as well as orthophoto images that enable precise measurements and damage analysis. The special value of the program is reflected in the ability to create geometrically corrected orthophoto images of high precision. Such images enable the measurement of areas, distances and volumes and the precise recording of damage to objects and infrastructure. The obtained data can be integrated into GIS systems and used for operational planning, the creation of situational views, and keeping digital records during crisis situations. The application of the program is particularly important during natural disasters, such as storms, floods, fires, and earthquakes, when it is necessary to quickly collect and precisely process a large amount of data from difficult-to-reach areas. In the case of the storm that hit the Bošnjaci Municipality in Vukovar-Srijem County, Republic of Croatia, on 1 July 2024, a systematic aerial survey of the affected area was carried out to assess the damage and monitor the rehabilitation of the consequences. The obtained data were processed in the Agisoft Metashape Professional program and were used to create orthophoto images and 3D models of damaged objects. Digital processing enabled precise recording of damage to residential and public buildings, comparison of the state before and after rehabilitation, and better coordination of operational activities in the field. In this way, the process of damage assessment and decision-making was significantly accelerated, while at the same time, the safety of operational personnel was increased because the need for direct access to dangerous and unstable objects was reduced. The program also enables long-term storage of digital data, which is important for the needs of documenting events, analysing the effectiveness of rehabilitation, and planning future preventive measures. The integration of photogrammetry, orthophoto technology, and 3D modelling represents an important step towards the modernisation of the civil protection system and more efficient crisis management in the digital age. The application of Agisoft Metashape Professional shows how modern digital tools can significantly improve damage assessment, information management, and coordination of operational forces during emergency events. Such an approach enables faster, safer and more precise decision-making and contributes to the development of a modern and technologically advanced protection and rescue system.

Basic Functions of the Program

Agisoft Metashape Professional enables:
-creation of high-resolution orthophoto maps,
- generation of 3D models of objects and terrain,
- creation of a digital surface model (DSM),
- creation of a digital terrain model (DTM),
- georeferencing of data using GPS/RTK coordinates,
- measurement of distances, areas, and volumes,
- classification of point clouds,
- export of data to GIS and CAD systems.

APPLICATION OF UAV IN RECORDING THE AFFECTED AREA AFTER A STORM

The day after a strong storm hit the area of the Municipality of Bošnjaci, aerial recording activities using unmanned aerial vehicles (UAV systems) were carried out with the aim of quickly assessing the damage, collecting spatial data, and supporting crisis management. The activities were carried out by the State Civil Protection Intervention Unit Osijek in cooperation with the local field coordinator (head of the Vukovar Civil Protection Service), who provided logistical and operational support during the implementation of the task.

Two operators of the State Civil Protection Intervention Unit Osijek were sent to the field with two unmanned systems, with the work organisation adjusted to the size and complexity of the affected area. In order to more efficiently perform aerial photography, the area of the Municipality of Bošnjaci was divided into six sectors, and the flight altitude was determined. Two operational teams were formed that operated in parallel, with each team responsible for photographing pre-defined sectors. This method of work enabled a significant reduction in the time required for data collection and better coordination of activities in the field. Logistics preparation was of particular importance in the implementation of the activities. The vehicle in which the operators arrived in the field was equipped with a gasoline generator, which enabled continuous power supply of the equipment with electricity. This ensured the conditions for continuous operation of unmanned systems, battery charging, and data processing in the field without the need for interruptions or additional equipment relocation. Such self-sufficiency of the operational team proved to be extremely important in conditions when part of the infrastructure in the affected area was damaged or out of function.
During the operation, special attention was paid to public facilities. 3D models were created for municipal buildings, a school, a kindergarten, a museum, a church, a cemetery, and other important infrastructure using the photogrammetry method. Based on a large number of overlapping photographs, three-dimensional models of the facilities and the surrounding area were created, which enabled a detailed overview of the degree of damage, structural stability and accessibility of the locations. Such models represent an important tool for further damage analysis, rehabilitation planning and documentation of the consequences of the disaster. The remaining part of the settlement was photographed using the orthophoto technique. The orthophoto images enabled the creation of precise, high-resolution georeferenced images of the area, on which damage to roofs, roads, economic buildings, and vegetation is clearly visible. The obtained data was used to quickly assess the extent of the damage and create situational images necessary for the civil protection headquarters and other operational services involved in the rehabilitation of the damage caused by the storm.
The total duration of the aerial photography operation was approximately four hours. In a relatively short time, a large amount of spatial data was collected, which enabled a detailed overview of the affected area without the need for a long tour of the field. The use of UAVs has proven to be extremely effective in situations of natural disasters because it allows for rapid data collection, increases the safety of operational forces, and provides a quality basis for decision-making during crisis management. This intervention confirms that the use of unmanned aerial vehicles, with good organisation of operational teams and appropriate logistical support, is an important tool of the modern civil protection system in assessing damage and managing the consequences of natural disasters. After 20 days of rehabilitation to eliminate the consequences of the hailstorm, the terrain was re-recorded in same way as it was recorded the first time so that the recordings could be compared with the initial state. The recordings were handed over to the municipality for use and are a permanent and indelible trace of the complex event.

Orthophoto and 3D Modelling

After conducting UAV imaging of the affected area, orthophoto images and 3D models of the settlement were created using specialised digital tools for spatial data processing. Orthophoto images enabled a precise overview of all objects and surfaces from the air with the possibility of detailed recording of damage to roofs, commercial buildings, roads, and agricultural areas. At the same time, 3D models were created for public facilities, which enabled a more detailed analysis of the damage and planning of rehabilitation activities. The obtained spatial data represented an important support for civil protection headquarters, local government units, and expert services during damage assessment and decision-making. The application of orthophoto and 3D technology significantly accelerated the process of data collection, increased the accuracy of damage assessment, and ensured a quality documentation basis for reporting, reconstruction planning, and monitoring the progress of rehabilitation in the field.

DATA PROCESSING AND ANALYSIS

After completing the field imaging with unmanned aerial vehicles, the collected photographs were processed in the Agisoft Metashape Professional program, one of the leading tools for photogrammetric spatial data processing. The program enables the automatic connection of a large number of recordings and the creation of precise high-resolution digital models of the space.

During data processing, the first step is to align and georeference the photos using GPS/RTK coordinates, ensuring the spatial accuracy of the results. Based on the processed images, orthophoto maps, digital surface models (DSM), digital terrain models (DTM)

and three-dimensional models of objects and areas affected by storms are created. The products thus obtained allow for a detailed overview of damage to buildings, transport infrastructure, agricultural areas, and other spatial elements. An additional advantage of the system is the ability to precisely measure distances, areas, and volumes, as well as classify point clouds for easier separation of individual objects or types of damage. The final data can be exported to GIS and CAD systems, making them available to civil protection headquarters, local government units, and expert services for further analysis, damage assessment, rehabilitation planning, and decision-making during crisis management. The use of such digital tools significantly increases the speed, accuracy, and efficiency of the damage assessment process compared to classic field visit methods.

CONCLUSION

The storm accompanied by hail that hit the Municipality of Bošnjaci on 1 July 2024, posed an extremely demanding challenge for the civil protection system and required rapid data collection, damage assessment, and coordination of a large number of operational forces. In such circumstances, the use of unmanned aerial vehicles (UAVs) and digital tools has proven to be an effective solution that significantly improves the processes of crisis management and assessment of the consequences of natural disasters. The conducted UAV imaging enabled systematic and comprehensive documentation of the affected area in a very short time. The division of the settlement into six sectors and the engagement of two UAV teams of the State Intervention Unit of Civil Protection Osijek enabled the imaging of the entire area of the municipality in approximately four hours. The collected data was processed in the Agisoft Metashape Professional program, where high-resolution orthophoto maps, digital surface models, and three-dimensional representations of public buildings were created. Such products enabled a detailed overview of damage to residential and commercial buildings, infrastructure, and public buildings, and provided a quality basis for making operational decisions. The special value of the application of UAV technology is reflected in the ability to quickly collect large amounts of spatial data with significantly less human resource involvement. While the classic damage assessment required the engagement of 75 civil engineers and 20 municipal employees over eight working days to assess damage to residential buildings, with an additional sixteen days to record damage to commercial buildings, agricultural land, and movable property, UAV enabled obtaining a complete overview of the situation during the first day after the disaster itself. This resulted in significant savings in time, human capacity and organisational resources, and reduced the impact of subjective assessment present in traditional methods of assessing damage. From the aspect of occupational safety, the use of unmanned aerial vehicles represents an important contribution to the safety of operational personnel. Instead of entering potentially dangerous areas with damaged buildings, unstable structures, or compromised infrastructure, the assessment of the situation can be carried out remotely, thereby reducing the exposure of workers to risks and increasing the overall safety of intervention activities. This approach is in line with modern principles of risk management and occupational health protection, which emphasise the application of technologies to reduce direct exposure to hazards. The resulting digital products have proven to be extremely useful for the work of civil protection headquarters at all levels of management. Orthophoto images and 3D models have enabled a more precise assessment of priorities, more efficient planning of remediation activities, better allocation of resources and better quality communication between local governments, operational forces, and state institutions. An additional advantage is the possibility of permanent data archiving, their subsequent analysis and comparison of the situation before and after the implementation of remediation measures, which creates a valuable knowledge base for future interventions and assessments. The results of the presented case study confirm that the integration of UAVs, photogrammetric methods and geospatial information systems represents a significant step towards the digital transformation of the civil protection system. Such an approach increases operational efficiency, shortens reaction time, improves the quality of damage assessment, and contributes to safer work of all intervention participants. At the same time, it enables the creation of reliable spatial databases that can serve the needs of planning, prevention, education, and development of local communities' resilience to future disasters. Based on the executed activities, it can be concluded that unmanned aerial vehicles and digital tools no longer represent only technological support for classical work methods, but are becoming one of the key elements of the modern disaster management system. Their further integration into the operational procedures of the civil protection of the Republic of Croatia, along with continuous training of operators and the development of standardised application methodologies, represents an important direction for the future development of the protection and rescue system and increasing the safety of the population and operational forces in emergency situations.

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PRIMJENA BESPILOTNIH LETJELICA I DIGITALNIH ALATA U PROCJENI ŠTETA I PODRŠCI KRIZNOM UPRAVLJANJU

SAŽETAK

Rad prikazuje primjenu bespilotnih letjelica (UAV) i digitalnih alata u procjeni šteta nakon olujnog nevremena na području Općine Bošnjaci, Vukovarsko-srijemske županije, Republika Hrvatska. Ravnateljstvo civilne zaštite provelo je zračno snimanje pogođenog područja dan nakon nevremena te ponovno nakon dvadeset dana. Ortofoto tehnikom snimljeno je približno 1250 stambenih objekata, dok su javni objekti dokumentovani korištenjem fotogrametrije i 3D modeliranja.

Cilj rada je prikazati mogućnosti primjene UAV-a u brzoj procjeni šteta, izradi digitalnih evidencija i podršci donošenju odluka tokom kriznog upravljanja. Analiziraju se prednosti ovakvog pristupa kroz brzinu prikupljanja podataka, povećanu sigurnost operativnog osoblja, preciznost dokumentovanja te mogućnost poređenja stanja prije i nakon sanacije. Naglasak je stavljen na integraciju geoprostornih podataka i digitalnih tehnologija u sistem civilne zaštite radi učinkovitijeg planiranja i koordinacije aktivnosti na terenu.

Ključne riječi: bespilotne letjelice, ortofoto, 3D modeliranje

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