



**MINING AND METALLURGY
INSTITUTE BOR**

and



**TEHNICAL FACULTY BOR,
UNIVERSITY OF BELGRADE**



**55th International October Conference
on Mining and Metallurgy**

PROCEEDINGS

**Editor:
Ana Kostov**

**15 – 17 October 2024
Hotel “Đerdap” Kladovo, Serbia**



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A SHORT REVIEW OF APPLICATION THE UAV REMOTE SENSING TECHNOLOGY IN THE SURFACE COAL MINE RECLAMATION

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Abstract

The mining industry supplies the other industries with essential raw materials, thus enabling the stable national economy. Coal mining causes a land degradation and destruction of natural habitats. Reclamation phase is necessary for keeping the balance between the mining and nature. In order to maintain competitiveness in the market, the mining companies should embrace the innovative technologies of data acquisition and site inspection. In this study, a method of the Unmanned Aerial Vehicle (UAV) remote sensing for accomplishing the high-accurate topographic surveys is proposed. A review of positive practices in the world that support the idea of sustainable and inventive approaches towards the mine reclamation will be given.

Keywords: UAV, remote sensing, coal mine reclamation

1. INTRODUCTION

The surface coal mining activities have a negative impact on a surrounding environment. It is reflected through destabilization of a land structure, modified regime of water flows, soil contamination and a loss of biodiversity. Mine reclamation is obligatory for every mining company that plans exploitation of coal resources. By restoration a land for its previous use, the destructive effects on a nature are mitigated and a new economic value is obtained.

The methods are based on arranging the soil from a technical aspect, applying a humus layer and planting the plant cultures, which improves the physical, chemical and biological characteristics of the soil and ensures functionality of the recultivated surface for later use.

Reclamation can be optimized with the modern technologies of acquisition, processing and presentation of data on the observed parameters of degraded land. Since drones are used in many industries today due to their outstanding performance, there is an interest to implement them to a greater extent in the mining industry. The effectiveness of drones comes to the fore in the areas with a complex configuration, where the traditional methods of data collection would consume more time and material resources, with an increased risk to the safety and health of workers.

The mining sector faces numerous challenges every day in terms of the environmental protection, implementation of the new technologies to preserve the safety and health at work, organization and implementation of works to obtain the useful raw materials, coordination of further distribution the final products and satisfaction of market needs.

In order to adequately adapt to modern business conditions, it is necessary for companies to include the achievements of information technologies in the daily functioning of operational and business segment of work.

2. METHODOLOGY

Common workflow of the UAV survey process consists of choosing the adequate equipment, flight planning, data acquisition, data processing, visualization and analysis. [1]

The UAV remote sensing has a fast, flexible and efficient workflow that can be carried out with an automatic deployment of a drone flight. Alternatively, the drone can receive remote commands from an operator. Flight mission planning consists of adjusting the fly parameters, determining an optimal trajectory and image capture requirements. Desirable georeferencing is obtained by placing the ground control points. For accurate mapping the GCPs (Ground Control Points), RTK (Real Time Kinematic) or PPK (Post Processed Kinematic) method can be used. The ultimate accuracy and precision can be obtained by combining the GCPs and PPK.

High precision and accuracy of the terrain interpretation and photorealism contribute to the efficient management of mine production and reclamation phase. Modern methods of recording exploitation areas include the digital photogrammetry and LiDAR (Light Detection and Ranging) technology.

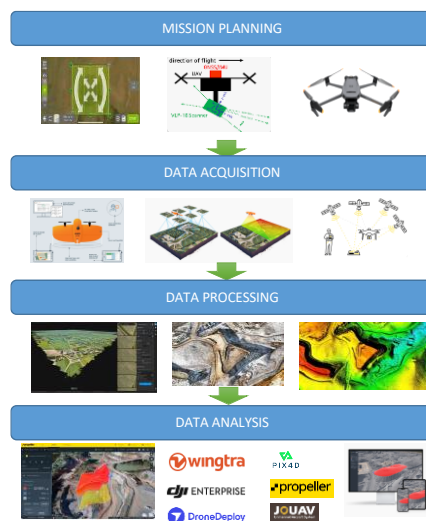


Figure 1. Workflow of the UAV remote sensing process [2]

3. SHORT REVIEW OF THE RELATED RESEARCH STUDIES

Martin et al., (2015) [3] proposed using the Unmanned Aerial System for a high-resolution gamma radiation mapping of the uranium mine in Cornwall, England. The integrated mapping platform used for this work was an AARM-X8 multi-rotor aerial vehicle supplied by ImiTec Limited, controlled by an Arducopter autopilot system. A high frequency GPS module was used to rapidly and accurately determine the system location.

At each recorded location, a spectrum of the energy of incoming incident radiation was recorded using a gamma-ray spectrometer. The data was later processed in software. A map was created based on the GPS location, height above the measured terrain and gamma spectrum. Using this method, they were able to generate the high-resolution radiation maps in

a short time over a large area. Besides obtaining the radiation intensity, the data gathered by the UAV system can be used to determine the nature of contamination.

Urban et al., (2018) [4] compared the data collected from two UAV systems on a spoil heap, located in the north-west Bohemia, Czech Republic. The first system was the eBee by Sensefly, and the second one was the EasyStar system. Three typical vegetation areas were selected to determine the systematic and random errors of data. The authors offered different approach for comparing the accuracy of the two UAV point clouds. Same ground control points were used for image the processing. The results were then compared in terms of random and systematic error. The acquired aerial images were processed in the Agisoft PhotoScan Professional software. They came to the conclusion that the characteristics of the selected equipment had affected the accuracy. The analyzed data also showed that more precise results were achieved mostly on the bushy terrain compared to the grassy and forest areas.

Padró et al., (2019) [5] proposed the UAS imagery for monitoring the mine reclamation. The technology was implemented for a quarry restoration monitoring in Spain. They utilized a DJI Phantom-III Advanced quadcopter because of its flexibility with the other systems. The drone was equipped with a multispectral sensor. A field spectroradiometer measurements were carried out to radiometrically correct the UAS data. The imagery was processed with an adequate software. The spectral data and land cover classification were used for detection and quantification the mine waste dumping, bare soil and other land cover extension. Plant formation and vegetation development were also evaluated, thus enabling a comparison with the surrounding reference system.

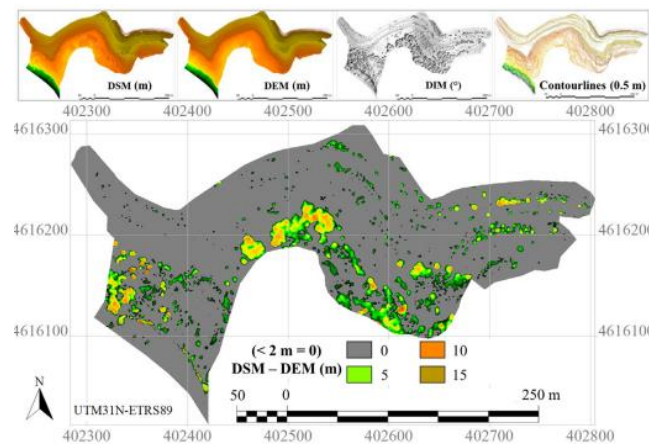


Figure 2. UAV data of the mapped terrain [5]

Xiao et al. (2022) [6] investigated the soil erosion and land degradation after 5 years of natural processes at the Xilinhote opencast coal mine dump in Inner Mongolia. A multi-source data acquisition method was applied. The vegetation fraction coverage (VFC) was extracted from a satellite imagery. In addition, the high-precision terrain characteristics, location and degree of soil erosion were obtained using a drone. The physical properties of the topsoil were obtained by the field sampling. To obtain the desired accuracy, they used the 20 GCPs and 19 check points. The Matrice100 was utilized as a drone platform.

The image processing was done in a Pix4D software. A 3D model was reconstructed using the Structure from the Motion (SfM) algorithms. They came to a conclusion that the combined methodology, consisting of the satellite remote sensing imagery, drone platforms and field sampling, could give the comprehensive insights related to the land reclamation monitoring, investigation and assessment.

Setyawan et al. (2023) [2] utilized DJI Mavic 2 Pro drone in identifying and mapping the land after revegetation the coal post mines in Tanjung Enim, Indonesia. They were able to generate the distribution map with the five land cover classes. Aerial photo data was processed in three types of software. Application of drones was highly recommended for the land observation, because they facilitate the process of data acquisition. The authors concluded that using the drone visual information can be obtained more efficiently, compared to the conventional methods.

In addition, there are numerous benefits from the UAVs, such as the low operational costs, high accuracy, versatility, system autonomy and fast deployment. This technology improves safety and productivity within the mining industry.

4. CONCLUSION

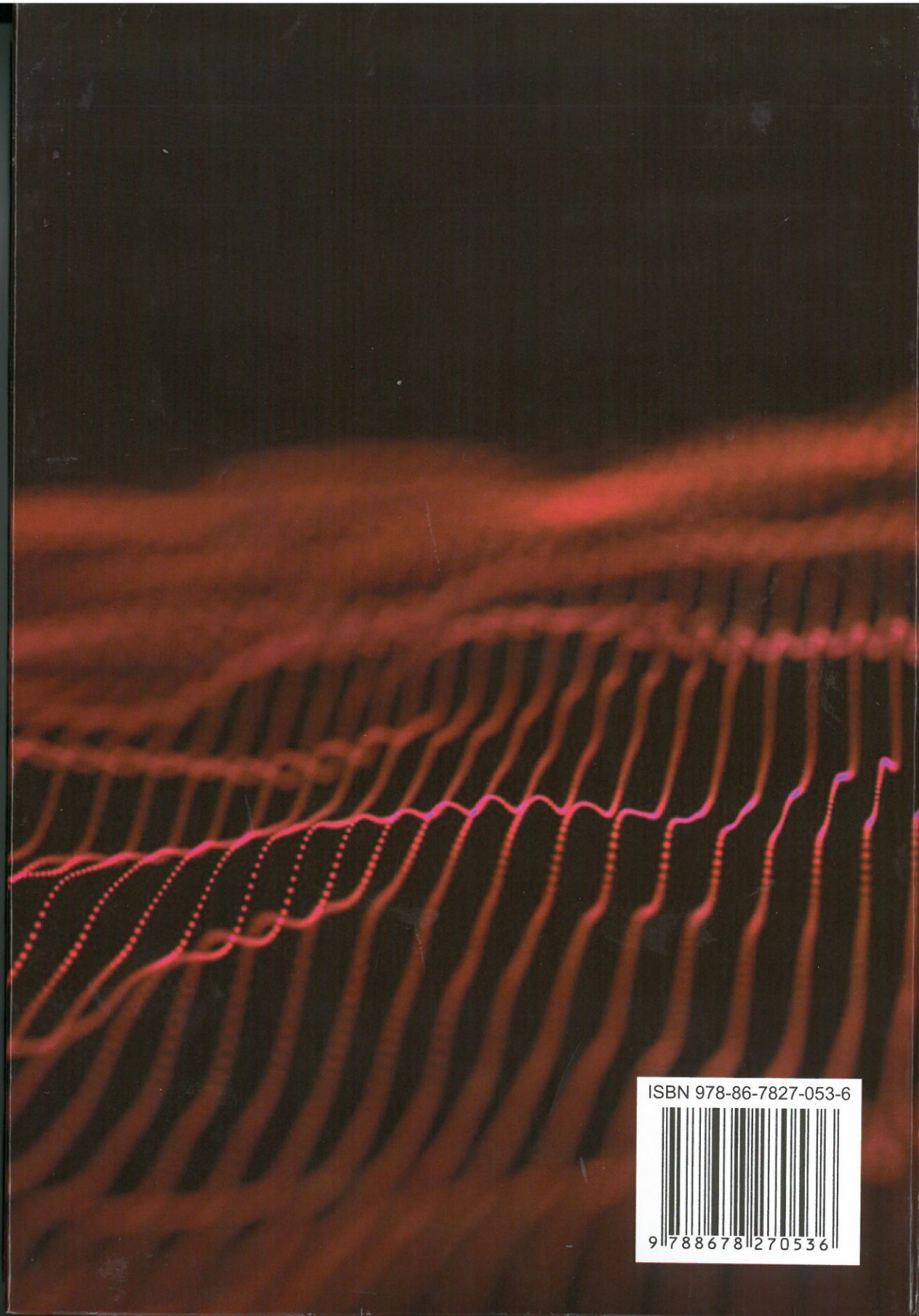
Examples from world practice, listed in this paper, indicate the efficiency and economy of using drones in examining the geomechanical characteristics of the terrain, the degree of contamination of post-exploitation areas and analyzing the impact on the ecosystem.

Although there are limitations of drones in terms of flight duration and weather conditions, in combination with the other modern terrain surveying technologies, these shortcomings can be compensated and the degree of safety, accuracy and efficiency of implemented technical solutions can be increased.

By fostering the business practices that include the preservation of the environment and safety of workers, the basis for further development of sustainable mining and development the country society is created.

REFERENCES

- [1] S. Park, Y. Choi, Applications of Unmanned Aerial Vehicles in Mining from Exploration to Reclamation: A Review, *Minerals*, 10 (8), (2020) 663.
- [2] D. Setyawan, H. Hanum, T. Achadi, K.D. Paserena, The Use of Drone for Identifying and Mapping of Revegetation Plant in Coal Post-mines in Tanjung Enim, South Sumatra, Indonesia. In *IOP Conference Series: Earth and Environmental Science* 1162 (1), (2023) 012012.
- [3] P.G. Martin, O.D. Payton, J.S. Fardoulis, D.A. Richards, T.B. Scott, The Use of Unmanned Aerial Systems for the Mapping of Legacy Uranium Mines. *J. Environ. Radioact.* 143, (2015) 135–140.
- [4] R. Urban, M. Štroner, T. Křemen, J. Braun, M. Moeser, A Novel Approach to Estimate Systematic and Random Error of Terrain Derived from UAV s: A Case Study from a Post-Mining Site. *Acta Montan. Slovaca*, 23, (2018) 325–336.
- [5] J.C. Padró, V. Carabassa, J. Balagué, L. Brotons, J.M. Alcañiz, X. Pons, Monitoring Opencast Mine Restorations Using Unmanned Aerial System (UAS) Imagery. *Sci. Total Environ.* 657, (2019) 1602–1614.
- [6] W. Xiao, H. Ren, T. Sui, H. Zhang, Y. Zhao, Z. Hu, A Drone- and Field-Based Investigation of the Land Degradation and Soil Erosion at an Opencast Coal Mine Dump after 5 Years' Evolution of Natural Processes. *Int. J. Coal Sci. Technol.* 9 (1), (2022) 42.



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