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A Comprehensive Assessment of Applications of Drone Technology in the Coal Mining Industry

Rajneesh Kumar[1*], Mohit Rastogi[2], Chandra Shekhar Singh[3], Rakesh Ranjan[4], Tanmoy Pramanik[5] and Bhuvnesh Kumar Gupta[5]

[1]GM (Geomatics), Central Mine Planning and Design Institute Limited (CMPDI), Ranchi. E-mail: gmgeomatics.cmpdi@coalindia.in
[2]GM (Civil), Geomatics Division, CMPDI, Ranchi
[3]Chief Manager (Mining), CIL, Kolkata
[4]Chief Manager (Geomatics), CMPDI, Ranchi,
[5]Deputy Manager (Geomatics), CMPDI, Ranchi,

Abstract

An effort has been made to deliver a complete assessment of the present advancement of the drone technology adopted by Coal India Limited (CIL) through CMPDI and its application in the coal mining industry. Nowadays, drone operations are gaining more and more attentions to ease out routine jobs in the mining industry and unveiling new arenas of opportunity. To name a few, 3D mapping of the mine environment by generating ortho-photo mosaic, blasting monitoring as well as post-blast rock fragmentation measurements, inventory monitoring, survey of colonies and residential areas, monitoring of vegetation, settlement etc. been the new areas of interest. This paper offers an assessment of types of drone, their specifications, and specific applications of drones along with various sensors for mining applications. Possibilities of implementation of drone technology in underground mining conditions are also discussed.

Kdyword: *Advancement, of drone technology, Applications & operations, monitoring, VTOL, UAV ortho-mosaic*

1.0 Introduction

Unmanned aerial vehicles or UAVs, commonly known as drones, includes various types like quad-copter, hexa-copter in multi-rotor category, fixed wings, flapping wings with vertical take-off and landing (VTOL) facility, and have been used for a variety of civilian and industry applications like mapping, surveying, volumetric calculations, monitoring along with search and rescue operations, etc. Various sensors depending on the mission type may be mounted on drones, such as visual or photogrammetry camera – still or video camera, Laser Scanner (or Lidar), thermal sensor/camera, air quality monitoring sensors, multi-spectral camera, radiometer, ground penetrating radar, etc.. Design optimization of drones is continuously under improvement by the researchers and manufacturers to enhance the performance and efficiency of drones for specific mission oriented capabilities.

Depending on the size, drones can be classified into micro, small, medium, large and very large category. On the other hand, depending on the number of rotors and wing type, drones can be grouped into different categories, such as fixed-wing, flapping wing, rotary-wing, tilt-rotor, ducted fan, helicopter, ornithopter, and unconventional types (Hassanalian, M. et. al., 2017).

Various industries like agriculture, coal, oil and gas as well as other mining, construction, environmental protection, etc. are successfully using unmanned aerial systems for different operations (Hassanalian, M. et. al., 2015). Nowadays mining

*Author for correspondence

industries are showing growing interests in the use of drones for routine operations and monitoring in surface as well as underground mines (Green, J. et. al., 2013). The current objective of the paper is to conduct a review of the various usage of drone technology specially in the coal mining sector. In this paper, modern day usage of drones along with commonly used sensors in surface as well as possible usage in underground mines are discussed (McLeod, T. et. al. 2013).

2.0 Advantage of using Drone technology in Mining sector

Across the world, UAVs are used for various applications in almost all industrial as well as mining sectors (Lee, S. et. al., 2016). It has been seen that the use of UAVs not only saves time in the acquisition of data but also helps in improving productivity and efficiency with due transparency as results are based on user specified data acquired by the process of airborne scanning through specific UAV-based sensors.

Conventional survey uses equipment like Theodolite and Total Stations, which have to be moved into difficult terrains and areas while conducting the survey. Now, survey grade UAVs can easily conduct survey remotely through aerial mode with various specific sensors which can acquire information and data of the ground surface as per the requirement (Xiang, T.Z. et.al. 2028). UAV survey saves time and reduces the risk to survey personnel and equipment in comparison with conventional methods.

High-resolution image sensors or cameras integrated with GPS (Global Positioning System), PPK (Post Processing Kinematics), are used to generate DTM (Digital Terrain Model), DEM (Digital Elevation Model) etc. through UAV acquired data with centimetre level accuracy suitable for highly accurate photogrammetric results for volumetric calculations of overburden, coal stocks and mines voids.

UAV data are generally acquired in parts with certain amount of overlapping and after mosaicking in photogrammetry software using accurate Ground Control Points (GCPs), precise results can be obtained which is comparable or even sometimes better than the results obtained through conventional survey methods and instruments. Since the scanning of the objects through UAV based sensors involve generation of point cloud of the entire area instead of survey of limited number of points as done conventionally, the results are very accurate. Similarly, specific types of sensors or inspection equipment can be mounted on UAVs as per application requirements to ensure accurate results.

Today, the data acquired by UAVs can fulfil the daily and weekly needs of survey and mapping of infrastructure of any dynamic mining venture by allowing extraction of information for volume determination, slope determination, generation of point cloud for mine operational planning and other required information (Valavanis, K.P. et. al. 2015). The various developments in the field of machine learning have helped to enhance the current algorithm developments in the field of image processing. Geometric and data analytics helped to boost productivity by accurate and frequent surveying, plotting actual development with reference to targeted development, preparing and tracking monthly action plan, cross-checking day to day development of mine to the targeted action plan, preparing quarry operational plan etc. With the availability of huge data set recorded on daily basis, the study and optimization of expensive and risky assessment in mining operations can be done easily.

On basis of present day capabilities, UAV can be utilised in the following areas of mining:

- Stockpile management
- Inventory and financial data management
- Routine mine management
- Operational planning
- Haul road optimization
- Water and sediment flow
- Blasting/drilling monitoring
- Hazard identification and mitigation
- Tailings dams management
- Mining exploration
- Volumetric measurement
- Plantation height assessment
- Settlement mapping
- Equipment (HEMMs)/inaccessible areas/structure inspection
- Void measurement
- Coal mine fire mapping
- Solar panel inspection
- Transmission line inspection
- Air quality monitoring

3.0 Drones Acquired by CMPDI

Figure 1: Co-axial Hexacopter Fitted with Velodyne Lidar

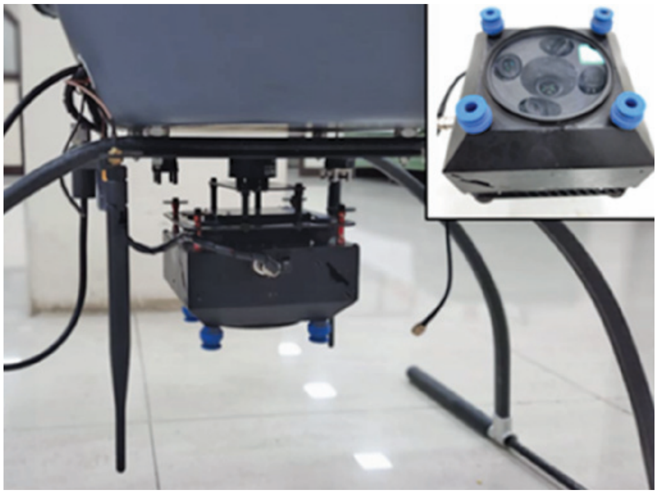

Figure 2: Drone mounted Sony 24 mp photogrammetric camera/ sensor

CMPDI has procured two co-axial, multi-rotor, VTOL type small category drones from Centre for Aerospace Research (CASR), MIT, Anna University, Chennai for use in survey and mapping applications (Fig.1). CMPDI also purchased high end sensor payloads like Sony Oblique Photogrammetry Camera (Fig 2), Velodyne LiDAR Sensor and FLIR DUO PRO thermal imaging camera compatible with the drones for various applications.

4.0 Applications of Drone based sensors in Opencast Coal Mining

CMPDI undertakes various kinds of survey jobs in coal mines of CIL which are very necessary for ensuring productivity and transparent operations in coal mines. CMPDI's endeavour has been to constantly upgrade its technology in order to make the process more efficient and transparent.

CMPDI engaged in a list of potential activities where UAVs could be utilized in coal mining industry. Following are the major drone based activities undertaken by CMPDI:

Topa and Rajarappa Opencast Project, CCL area

The purpose of this project was to explore the UAV technology by creating ultra-high resolution ortho-mosaic of the project and 3D model to solve environmental and theft related issues. The boundary of the total project area along with the time taken to complete the survey has shown in Figs.3 and 4.

Surface features are easily identifiable from the high resolution ortho-photo mosaic acquired by drone mounted camera (Fig.5)

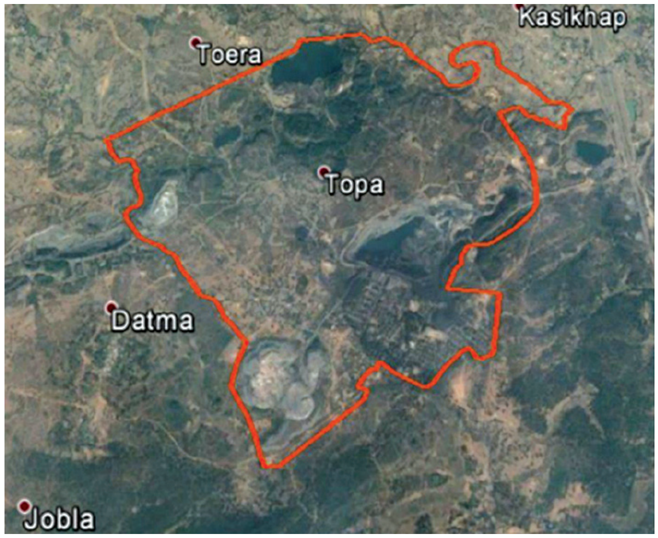

Figure 3: Boundary showing the Topa project, area 600 hectares, completed in 1 day

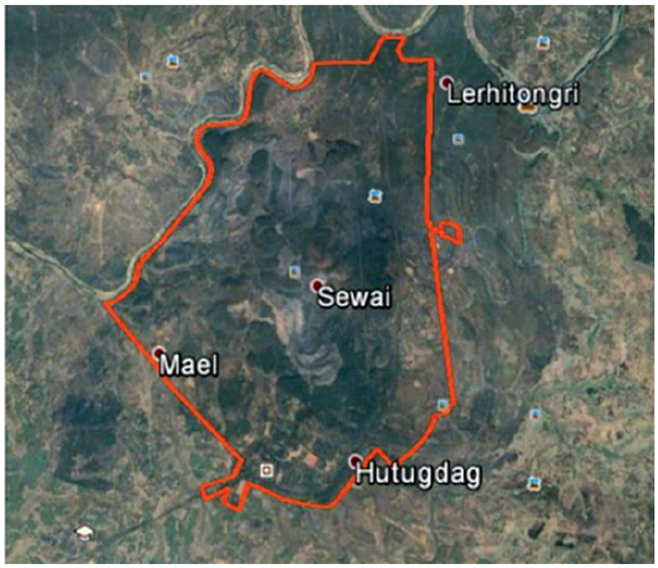

Figure 4: Boundary showing the Rajarappa project, area 2000 hectares, completed in 3 days

Volumetric measurement

UAV based photogrammetric sensors have been used for drone based survey in more than 60 mines, coal heaps and OB dumps of BCCL, CCL, WCL, SECL and NCL. The data was also validated through Terrestrial Laser Scanner Survey, simultaneously. The main aim of the project was to validate volumetric measurement through UAV based photo grammetry.

Figure 5: Identification of surface features from high resolution drone imageries

Different drone based applications in Northern Coalfields Limited (NCL), Singrauli, MP

i. Mapping of built-up structures in the proposed expansion area of Jayant (Fig.6) and Dudhichua OCP (20 sq.km.)
ii. Vegetation cover mapping in Nigahi OCP and its expansion area (43 sq.km.)

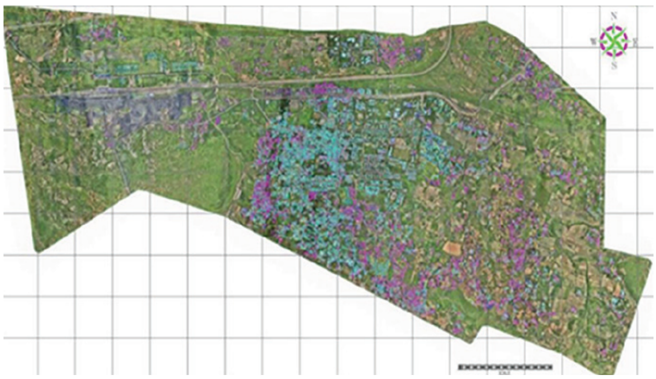

Figure 6: Built up Structure Mapping in the expansion area of Jayant OCP

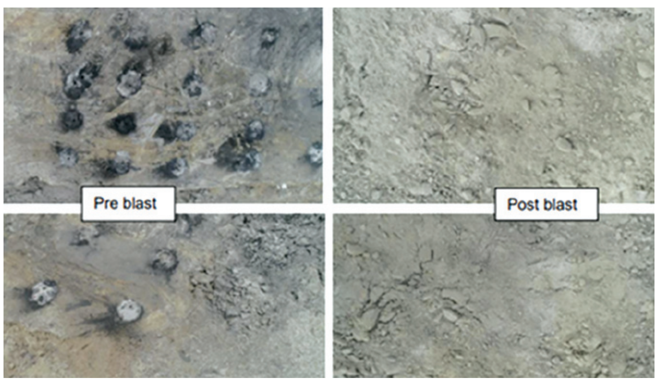

Figure 7. Pre blast and Post blast photographs of Dudhichua OCP

iii. Monitoring of blasting zone in Dudhichua OCP (Fig.7)
iv. Inspection of inaccessible areas of heavy earth moving machinery (HEMM) like dragline boom, head pulleys of shovels and draglines in Jayant OCP (Figs. 8 and 9) and silo tops, CHP structures and other inaccessible areas in Dudhichua OCP

Different drone based applications in South Eastern Coalfields Limited (SECL), Bilaspur, MP

1. Generation of orthophoto mosaic
2. Settlement mapping
3. Air quality monitoring, $PM_{2.5}$, PM_{10}, SO_X, NO_X
4. Plantation height assessment through drone based sensors can be used for temporal analysis of the growth rate of plantation.

An exercise has been carried-out at Dipka and Gevra mines of SECL for air quality monitoring through drone based Sniffer 4D sensor. Where level of PM2.5, PM10 (Fig.10), SO_x and NO_x were monitored.

Other Drone based Survey Applications

Drones are being used in regular basis for acquisition of data from UAV based sensors for various projects/ applications in CMPDI.

Figure 8: View of a frame of Dragline

Figure 9. View of the Top pulley of Dragline

Figure 10: Drone fitted with gas detection module and PM • Concentration Distribution

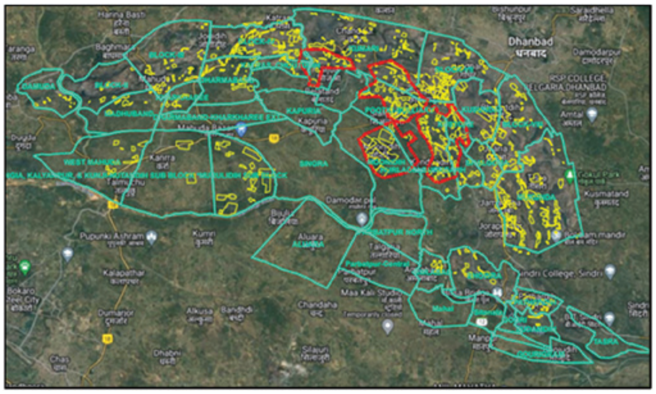

Figure 11: Area for drone photogrammetric survey in 595 unstable sites of Jharia coalfields, BCCL area

Drone based photogrammetry survey in sites identified as unstable in Jharia coalfields (JCF) of BCCL. Terrain mapping (Fig.13) and generation of high-resolution images for assessment of current status of 595 sites identified as unstable in JCF has been completed (Fig.11). Cracks/ damaged structures/fire/ash etc. were identified from high resolution ortho-photo mosaic at several sites (Fig.12).

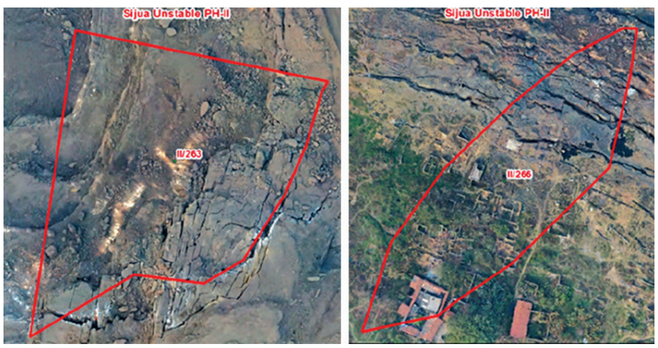

Figure 12: High resolution sample drone image showing cracks present at unstable sites

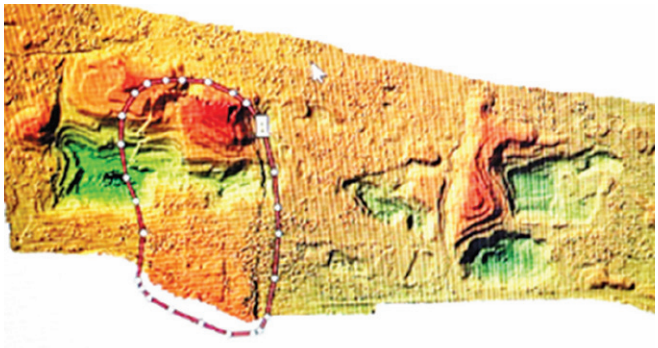

Figure 13: Terrain mapping of the entire newly constituted Block-C, Block-D, Block-E area of Jharia Coalfields

- Part initial and part final surveys in Dulanga coal mining project of NTPC using drone based photogrammetry technique
- UAV based survey for soil mositure conservation studies in Naini Block, Angul Odisha for Singareni Collieris Coal Company Limited (SCCL) to prepare orthophoto mosaic, contour map of degraded forest areas in collaboration with Environmental Division, CMPDI (Fig.14). Similar studies were also carried out for Radhikapur West Block of Vedanta and Utkal-E Block of NALCO in Odisha.

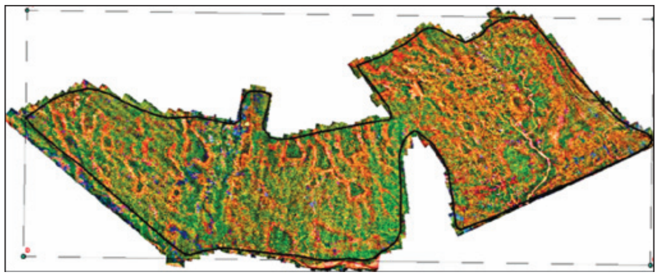

Figure 14: Soil Moisture Conservation (SMC) Study at Naini, Angul, Odisha under guidance of DFO, Angul

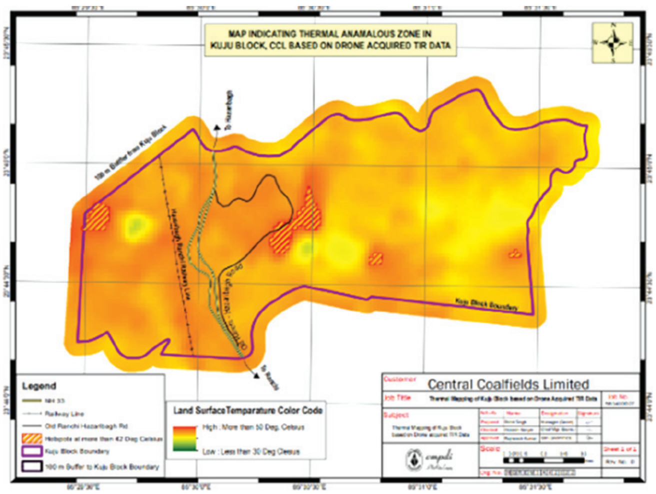

Figure 15: Map indicating thermal anomalous zone in Kuju block, CCL based on drone acquired TIR data

- Measurement of land surface temperature and mapping using drone mounted thermal infrared sensor was done at Ena area, BCCL and Kuju Area, CCL in the year 2022 (Fig.15).
- Pre-monsoon and Post-monsoon sand replenishment studies in 25 Districts in Uttar Pradesh (Fig.16).
- IICM campus, Ranchi and Dipka Colony, SECL was done through drone based photogrammetry sensor (Fig.17).
- Mine survey using drone based photogrammetry sensor at Jhingurdah and Gorbi Mines, Singrauli, MP (Fig.18).

The biggest advantage of drone is that 3D-data of any area can be generated on-demand.

Figure 16: Sand lease area of Beri 23-26, Hamirpur district, UP

Figure 17: Ortho-photo mosaic of Dipka Colony, SECL

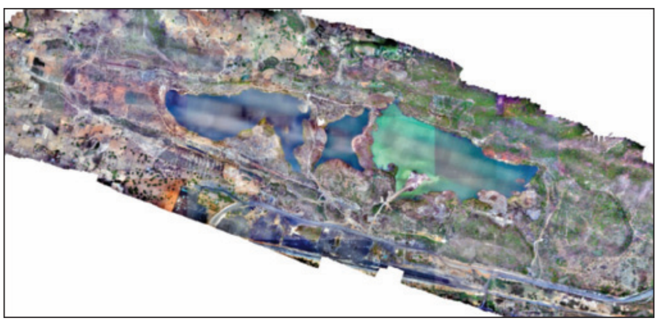

Figure 18: Ortho-photo mosaic of Gorbi mines, NCL area, Singrauli

5.0 Applications of Drone based Sensors in Underground Coal Mining

Drone based sensors have limited use in underground coal mines due to the adverse situations like confined space, reduced visibility, air velocity, dust concentration, and hindrances to wireless communication system required for drone operation.

Only intrinsically safe drones and its sensors can be operated in an underground mine. However, with the further advancement of drone technology the uses of drone may be considered in underground coal mines for surface roughness mapping, hazardous gas detection and seepage monitoring etc. in compliance with the safety features of DGMS (Mirzaeinia, A. et. al. 2019).

Underground mining and subsequent cave in process may result in subsidence on the surface. Drone based photogrammetry as well as Lidar sensors may be of great use to measure the amount of subsidence due to underground mining activity.

6.0 Discussion

Drone survey mission sometimes faces challenges in mining areas due to weather conditions like heavy wind inducing deviations in drone's predesignated flight paths, rainfall and low light causing mission termination and heavy dust creating haze and therefore poor image quality which may eventually affect the ortho-photo quality as well as erroneous value in resultant Digital Terrain Model (DTM) and subsequent contour generation. Presence of high OB dumps, hillocks, mobile towers, chimneys, high-rise buildings and other high structures also poses risk in flight as the flight height been generally kept in 120m from the ground to achieve 1.9 cm Ground Sampling Distance (GSD) necessary for good quality high resolution ortho-mosaic generation. An open plain surface of approximately 5m radius is also suggested for risk free smooth take-off and landing of the approximately 21kg fully automatic Hexacopter presently used by CMPDI for drone survey. The survey area should not fall under red zone as delineated by DGCA and it must be confirmed from digital sky platform prior to mission planning. Local administration also need to be informed about the operation in advance as per the DGCA guidelines. Once every condition for flying are fulfilled satisfactorily then only the drone survey by DGCA certified drone pilots are performed. Photogrammetry data are usually processed in suitable photogrammetry software along with DGPS data of Ground Control Points (GCP) for ortho-photo generation.

Highly accurate and content enriched photogrammetric results, up to centimetre level accuracy can be obtained through UAV based survey with proper flight plans, setting of suitable Ground Sampling Distance (GSD), necessary percentage of frontal and side overlap as well as well distributed Ground Control Points (GCPs) as observed in the projects completed by the CMPDI.

7.0 Conclusions

Recent studies and drone services provided by Coal India Limited (CIL) through CMPDI in the coal mining industry are discussed in this paper. The possible application areas of drone in the underground mining areas are also discussed. Common sensors that have been mounted on drones and used by CIL in the coal mining industry are evaluated.

Nowadays, drone technology became a common tool in surface mining due to its efficiency and low cost compared to the traditional survey and monitoring methods. A variety of applications in surface mining may be performed by drones, such as 3D mapping of the mine environment, blasting management, post-blast rock fragmentation measurements, vegetation cover mapping, settlement mapping, air quality monitoring and much more. Multi-rotor drones for comparatively smaller area and fixed-wing drones to cover bigger areas in less time are commonly used for survey operations in the coal mining industry. The possible usage of drones in coal mining industry are suggested.

7.0 References

1. Hassanalian, M.; Abdelkefi, A. (2017): Classifications, applications, and design challenges of drones: A review. *Prog. Aerosp. Sci.* 2017, 91.
2. Hassanalian, M.; Khaki, H.; Khosravi, M. (2015): A new method for design of fixed wing micro air vehicle. Proc. Inst. Mech. Eng. Part G J. Aerosp. Eng.229, 837–850.
3. Green, J. (2013): Mine rescue robots requirements: Outcomes from an industry workshop. In Proceedings of the 2013 6th Robotics and Mechatronics Conference (RobMech), Durban, South Africa, 30–31 October; IEEE Computer Society: Washington, DC, USA, 2013; pp. 111–116.
4. McLeod, T.; Samson, C.; Labrie, M.; Shehata, K.; Mah, J.; Lai, P.; Wang, L.; Elder, J.H. (2013): Using video acquired from an unmanned aerial vehicle (UAV) to measure fracture orientation in an open-PIT mine. *Geomatica,* 67, 173–180.
5. Lee, S.; Choi, Y. (2016): Reviews of unmanned aerial vehicle (drone) technology trends and its applications in the mining industry. *Geosyst. Eng*. 19, 197–204.
6. Xiang, T.Z.; Xia, G.S.; Zhang, L. (2018): Mini-UAV-based Remote Sensing: Techniques, Applications and Prospectives. arXiv, arXiv:1812.07770v1.
7. Valavanis, K.P.; Vachtsevanos, G.J. (2015): (Eds.) Handbook of Unmanned Aerial Vehicles; Springer: Dordrecht, the Netherlands; ISBN 978-90-481-9706-4.
8. Mirzaeinia, A.; Shahmoradi, J.; Roghanchi, P.; Hassanalian, M. (2019): Autonomous routing and power managementof drones in gps-denied environments through dijkstra algorithm. In Proceedings of the AIAA Propulsion and Energy Forum and Exposition, Indianapolis, IN, USA, 19–22 August 2019; American Institute of Aeronautics and Astronautics Inc. (AIAA): Reston, VA, USA.