ISSN: 2769-545X

Research Article

Advances in Machine Learning & Artificial Intelligence

Unmanned Aerial Vehicle Application in Mining User case in Rwanda

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Submitted: 19 Aug 2022; **Accepted**: 24 Sep 2022; **Published**: 02 Nov 2022

Citation: *Abdulkarim Uwizeyimana, Lambert Kavamahanga*, Theodette Uwimbabazi, Damascene Uwizeyemungu, Fideline Umwangange. (2022). Unmanned Aerial Vehicle Application in Mining User case in Rwanda. Adv Mach Lear Art Inte, 3(2): 92-99.*

Abstract

Drones have piqued the interest of the mining industry, which has expressed a strong interest in the usage of UAVs/drones for regular tasks Unmanned Aerial Vehicles(UAVs)/drones, sometimes known as Micro Air Vehicles (MAVs), are mostly drones that are used for a number of commercial and military applications, including surveillance and reconnaissance. These unmanned aerial vehicles (UAVs)/drones are capable of transporting of a wide range sensors depending on the nature of their missions, including acoustic, optical, biochemical, and bio sensors. In order to improve the performance and efficiency of drones/UAV, researchers have concentrated on the design optimization of drones, which has resulted in the creation and construction of a variety of Aerial Vehicles/drones with diverse abilities and capabilities.

As a consequence, previous research as well as information from firms that supply drones for the mining industry are being explored further. An investigation of the application of drone/UAVs in surface and subsurface mines is presented in this research. The usage of drones/UAVs in abandoned mines, both on the surface and below, is also discussed. It also includes a thorough discussion of the instruments or sensors that are frequently used in mining drones. In this paper/article, we address the difficulties linked with the usage of drones technologies in underground mines, as well as potential solutions to these difficulties.

Keywords: UAVs; MAVs, Sensors, Drone Applications, Mining Industry

Background and Introduction

The mining business has evolved from being primarily a trade industry to being an investment industry; governments have opted to concentrate on the creation of geology and mineral primary data in order to encourage investment and ensure that the mining sector has access to global markets [19].

Private enterprises and cooperatives raced into the market, and the industry quickly established itself as a significant source of export money that would spur increasing growth and economic reform in the country. However, leads to other issues emerged, such as the difficulty in disseminating knowledge that was still in the process of changing.

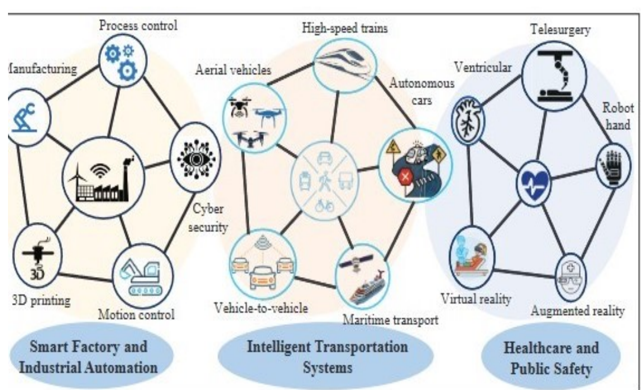


Figure 1: This example shows that most of industry has already find the benefit of using Drone/UAV to increases productivity and to customer emerged, such as the difficulty in disseminating knowledge that was still in the process of changing

A great interest in employing UAVs/drones for regular activities in surface and deep mines has been expressed by the mining sector as a result of the recognized conflict. Professionals who have integrated UAVs/drones into mining activities have rapidly understood the enormous additional value that they provide to their respective industries and businesses [9].

Specifically, the goal of this research is to assess the potential benefits of Drone/UAVs technologies in the mining sector.

Literature Review

Research undertaken by researchers on the application of drones/UAVs in mining production has revealed that certain commercially available drones have been employed by corporations for surface mining operations, according to the findings of their investigations and testing [15, 28].

Because it is exceedingly easy and uncomplicated to control, the mavic two Pro is the most often utilized drone for surface data-collection and some rudimentary mining. It must be connected in the advanced settings in order for it to work correctly.

SN	Authors	Topics	Contribution/ Achievement	Gaps identified
1	S.L. Madawalagama et al	Low-cost aerial mapping with consumer-grade drones	-Design the Phantom 3 Professional drone e was successfully used to map a landscape - High resolution images were processed using Pix4D software to obtain orthoimages and a digital surface model (DSM) of the area	- Costs -Accuracy - Complexity
2	A Putch	Linear Measurement Accuracy of DJI Drone Platforms and Photogrammetry (Drone deploy)	- provide quantitative data and guidelines for what users can expect from linear measurements on models created with cloud-based photogrammetry software - improve the quality of input data collected using DJI drone models and cameras when producing maps on the Drone Deploy platform - relative accuracy of data collected and processed with and without the use of ground control points (GCPs)	- manually capture data in dangerous areas
3	Javad Shahmoradi et al	Applications of Drone Technology in the Mining Industry	- design and implementation of drones for underground mining applications	- collecting geotechnical data from difficult or impossible to access regions - mapping discontinuity for slope stability could be done by terrestrial LiDAR methodology - Blasting
4	M. Rieke et al	High-precision positioning and real-time data processing of UAV system	- Integrating Real Time Kinematic positioning into micro-sized UAVs - Describing the data processing and synchronization of the high-precision position data for a workflow of orthorectification of aerial imagery	- The limited amount of payload -The limited capability of raw data processing

Figure 2: Surface Mining Applications.

"mavic two Pro has two flying modes," the University of Rwanda's UAV/drone professor was told," WiFi and remote control are both available, and both may be used concurrently." In order for the pilot to maintain track of where the drone is at any one time while in flight, the GPS must be turned on while the drone is in flight [31].

Problem Statement

In the lack of precise information about the soil mechanics and properties, and the absence of appropriate tools, environmental effects of direct and indirect mining can take place on a small, regional, or global scale practices, resulting in neighborhood, geographic, and worldwide environmental impacts.

Here are observed outcomes of these impacts:

Considering the coverage and labor expenses provided by the calculator. Output is impacted by a number of factors of factors, including overlap, camera model, and altitude. This concept consider only the process of datacollection and organization. This technique does not take into consideration aspects like as flight planning, GCP setup, data processing, and the length of time necessary to travel between aircraft [26].

Figure 3: Demostration of Drone/UAV when is about to mission.

With UAVs, there's no need to use an integrated strong PPK GNSS receiver to set out ground control points (GCPs).
Check your map's quality with as few as 3 way points.

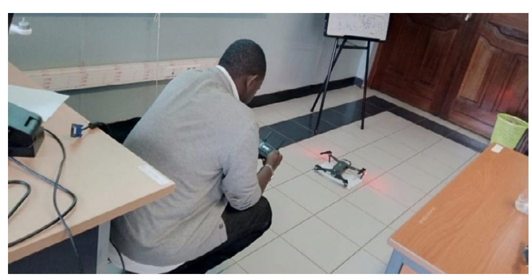


Figure 4: surface mining applications.

1) *Erosion is number one.*
2) *There are sinkholes.*
3) *Biodiversity loss.*

4) The chemicals produced by mining processes contaminate land, groundwater, and soil water.

A. Applications of drones/UAVs in the mining Sector

Using drones in mining activities has a significant edge, the most significant of which are as follows:

First and foremost, drones outfitted with various types of sensors may conduct a rapid scan of a given region, which is particularly useful in emergency situations or hazard detection. Drones/UAVs are useful in checking and clearing congested box holes and overpasses, which would otherwise be impossible.

A huge variety of alternative applications are possible for drones, including, such as blockage inspection, bomb detection, and package delivery. Using AUVs/drones, mining company's capability to conduct efficient and time-cost-effective exploration, inexpensive and time-effective monitoring and inspection, aerial photography for cost-cutting surveying and monitoring, accurate data to assist engineers in haul road design and construction for haulage road optimization, and tailing dam monitoring to avoid endangering onsite workers [1, 3].

B. Stockpile management

Using drone Aerial pictures, it is feasible to produce point clouds, digital terrain modeling which can created in all 3D reconstructions of mining sites and stockpiles, among other things [33].

It is now feasible to do extremely precise volume estimates thanks to the point cloud's large number of data points. This enables for high-accuracy stockpile value computation for monthly reconciliations or year-end audits, which enhances the consistency of inventory reporting on the company's balance sheet [30].

Because drone findings and post-processing tools are unbiased, you may also confirm the quantity of material carried by subcontractors using this method [22].

C. Better inventories and profitability:

According to the statistics, regular data collecting is proving to be a cost-effective alternative because of the rapidity where inventory surveys may now be put into action with the help of UAV/drones. This is true whether the data-collection is done weekly, monthly, or yearly, according to the numbers [4].

You don't have to wait for a semi-annual aerial survey audit; you may fly your site as frequently as you like [6].

In order to obtain information data on a regular basis, you can enhance inventory and operational management while also reducing the risks that surveyors who are physically on the site face [8, 18].

D. More and accurate data for management on a monthly orweekly basis

Using drones to conduct inventories studies has made it easier to collect data on a regular basis, whether weekly, monthly, or quarterly, is proving to be a cost-effective strategy for inventory management organizations. It especially enhances the forecasting of mineral supply that is accessible for purchase.

There is no need for you to wait for a semi-annual aerial survey assessment; you can fly your site as frequently as you wish. By collecting data on a frequent basis, you can enhance inventory and operational management while also lowering the hazards that surveyors working physically on the site are exposed to [2, 21].

Table 1: Shows How Choi and Lee Classified Drone Applications in the Mining Sector, Such As Surface, Underground, and Old Mines [18].

I. Classification of Drone Applications in Mining

Type of mining		
Surface Mine	Underground Mines	Abandoned Mines
• Mine operation • Slope stability • Mine safety • 3D mapping • Facility management • Construction monitoring	• Gas detection • Mine rescue mission • Rock size distribution • Geotechnical characterization	• Subsidence monitoring • Recultivation • Landscape mapping • Gas storage detection • Acid drainage monitoring

Here Is a Table of Summarized Examples of Drones Utility in Mining

Applications	Objectives
Safety and risk management	Slump prediction, stability monitoring
	Erosion detection
	Asset location
	Damage assessment
	Incident monitoring
	Livestock location
Daily routines and control	Regular safety site survey
	Management planning
	Security and asset protection
Monthly routines	Mapping inaccessible areas
	Boundary management
Strategic planning	Pit and leach pad design
	Road design
	Slope assessment
	Mineral exploration
Financial	Stockpile volumetric calculation
	Mobile and static resources calculation
Legal	Boundary dispute data
	Incident data capture
Environmental	Water leakage detection
	Vegetation encroachment
	Tailings management and assessment
Infrastructure	Track and access condition
	Watershed, drainage, hydrology
	Pipeline inspection
	Leach pad construction, change, and erosion

Views of the some utilized drones in surface mining and their Characterization

Type of Drone	Model	Goal	Wingspan (mm)	Length (mm)	Weight (g)	Endurance (min)	Payload (g)
Fixed-wing	Teklite 	Characterization of blasting plumes	900	575	900-950	45	200
Fixed-wing	GoSurv 	Characterization of blasting plumes	850	350	900-1200	50	>300
Fixed-wing	Swamp Fox 	Characterization of blasting plumes	1800	1000	4500	40	1000
Multirotor	Quadcopter 	Characterization of blasting plumes	-	-	2500	20	150
Multirotor	Phantom 2 Vision+ 	Topographic Survey	35cm	-	1240	25	-
Multirotor	Aeryon Scout 	Measuring fracture orientations	80x80x20	-	1300	25	400

Those was some examples of industrial encased drones. as well as research applications

II. Challenges

1. The Difficulties of Using UAVs/Drones in the Mining Sector.

When opposed to subterranean mines, weather conditions present a greater barrier with surface mines since they cause deviations from the drone's planned trajectories, which must be navigated around. In rare situations, weather conditions can be detrimental to drones, resulting in the failure of a mission. [11] The use of energy during a mission can create several issues in the mining Sector, and addition sectors to the economy. Drones/AUVs are normally powered by batteries and require energy for hovering, wireless connection, data transmission, and picture processing. Drones are also capable of recording video.

The choice must be taken as to whether data and picture analysis must be implemented onboard in real time or offline to decrease energy usage because of power limits. Underground mine workers are frequently subjected to restricted spaces, high temperatures and humidity, dusty air, and poor lighting conditions. Some proposals for employing drones in deep mines have been floated, but they mostly rely on manual control and navigation techniques to accomplish their goals.

At a bare minimum, the developed drone should be capable of fully autonomous navigation in a completely GPSdenied environment, as well as flying in an area with no additional lighting than that provided by the drone itself. It is necessary for the drone/AUV to be collision tolerant due to the nature of underground mining settings as well as other restrictions (e.g., adjacent walls, loose bolts, cables, and equipment). The drone should be able to identify and avoid obstacles while flying within the building, if possible [29].

In addition, the drone flies in dusty and smoky conditions, and in tough underground mining conditions. Because of this, the drone/UAV must be waterproof, dust proof, shockproof, and able to survive pressure, temperature, and humidity fluctuations throughout the mine site. As a function of methane's existence and the possibility of explosion/fire dangers in a coalmine underneath applications, the battery and electrical sensors must be well insulated [27].

Low battery consumption and human body detection should be included in the drone's standard features, in addition to what has been described so far.

Choosing the Right Drones/AUVs Configuration for Underground Mining.

As previously stated, there are some difficulties in using drones in underground environments [24]. To that end, an optimized micro drone that can address all of these challenges is required. Configuration development is the first step in designing a drone. Thinking about an underground mine. A drone/AUV capable of hovering can be designed in this environment. Microdrones are one type of micro drone [7]. Because of their multirotor design, they fly in small spaces. Due to their rotating blades or propeller-based systems, these drones can hover and are fitted with cameras. Like fixed-wing versions, these drones may fly in any direction, horizontally, vertically, and in reverse. Unlike fixed-wing models. May endure long-term residence in a single location the steady spinning of the rotor generates lift for rotary wing drones, like helicopters. The rotor's blades are constantly swiveling. This drone can be equipped with a large number of blades.

Therefore, researchers are now designing and building a range of drones with one to twelve motors, which are available for purchase. This makes them suitable for scanning difficult-to-reach regions such as pipelines due to their unique properties. For example, bridges, mines, and so on In cases when the surrounding environment is harmful, it is vital to have drones that are contained in boxes. The surrounding environment is unknown. Drone/UAV safety structures must be created in order to achieve this goal. A number of different structural designs proposals have been put forth order to deploy these drones in different situations.

Underground mines, in the aftermath of natural disasters, and in public places (Figures 5 and 6).

The structure that surrounds the drones ensures the drone's safety while also allowing the drone to have a view.

A feature that rolls the drones, together with their encasing optimized construction, allows them to fly into limited locations such as mines while also having the capacity to roll on the ground and mine walls if required. When designing a drone, consider using a flexible spherical framework that is friendly to the environment. Which will be capable of flying in the extreme heat and dusty air of the mines several illustrations are presented in the next section. The several types of enclosed drones are covered in detail [12].

Contamination of soil aquifers, and surface waters by the chemicals emitted from mining processes.

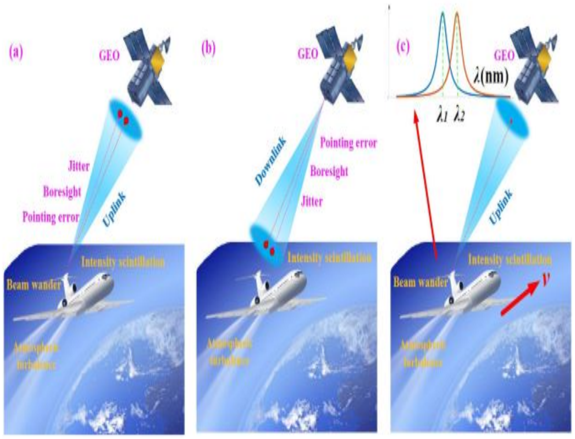
It is generally known that various multi-connectivity techniques can produce a diversity advantage, which can be utilized for increase the dependability of a computer system. Microscopically diverse transmission and reception from various cells/TRPs is also necessary in order to resist slow fading effects (or shadowing and/or blocking) and to provide mobility resilience during handovers [14].

III. Methodology

In this study, we take the influence of aiming inaccuracy on a UAV-to-satellite optical communication link into consideration while developing a model of the connection. The method of convolution is utilized to generate a joint probability distribution for a beam center deviation induced by the pointing error impact and the beam wander effect in an uplink for which the marginal probability distribution for received optical power is derived. If the downlink is to be designed using a UAV as the receiving terminal, a similar technique to [16] can be utilized for to create the model for the uplink.

In addition, deterioration effects such as the Doppler Effect, the aiming error effect, and the influence of air turbulence are thoroughly investigated and quantified. We go a step further and do numerical simulations to compute the BER vs. different system features in order to supply data references that will help in the optimal design of a UAV-to-satellite optical communication system, of which there will be an upcoming delivery.

Once a form is drawn over a stockpile, a trench, or any other large area, the cut, fill, net volume, and area are quickly determined.



Because of the time constraints in data-collection, there are fewer employees in the field and less time spent there, resulting in decreased man-hour expenditures associated with data gathering [10].

Map bigger refers to the use of a UAV/drone for largescale mapping projects, such as those of motorways, industrial complexes, and mines, according to the company. And it will only take a few hours of your time to complete.

Faster data-collection and wider coverage result in fewer workers in the field for a shorter period of time, resulting in a reduction in the man-hour expenses connected with data gathering [5].

IV. Solution

When used before, during, and after all mining processes, drones have the potential to significantly enhance the whole mining sector in terms of development, social well-being of workers, and economic well-being. By giving precise and thorough information about the site's condition in a timely and effective period, drones can help enhance the overall productivity of major mining operations sites and quarry management. Examples of this include replenishing native soil and and grasses, cleaning excess waste, proper waste removal and inspections of the site as well the process of reforestation forests.

Moreover, they provide improved collaboration among teams both on-site and abroad while also providing dynamic monitoring of all activities, which leads in accident prevention and hence improved safety for mine employees.

Before anything else, on-site personnel with very rudimentary surveying knowledge may securely collect the data, resulting in cost savings over traditional approaches that cannot be achieved [13, 23, 25].

V. Results

UAV/Drone surveys are used in fully accessible mining and quarrying operations to report live data of a site. Drone surveys are most commonly used in open pit mining and quarrying operations when access to the site is not restricted.

Photogrammetry software may be used to create contouring outlines, and referenced three-dimensional maps, digital terrain models, and Surface drawings created using digital data from the gold mine from the images captured at the site.

Mining operators may also easily determine the exact volume of stockpiles or regions to be mined by using a computerized system. [32] Certain modern mining systems may create data such as the heights of safety berms, their crests and toes, the limits of road networks, their widths and crests, and the length and altitude change of slopes. In addition to these constraints, artificial intelligence incorporated into the application may automatically identify objects that do not meet regulatory requirements [20].

• Numerous volume can be monitored concurrently

Drone-captured aerial photography may be used to create data points in the form of point clouds and digital surface representations models, and a three-dimensional reconstruction of a mining site, including stockpiles, from which point clouds can be generated. There are several statistics in each of the points in the point cloud, it is now possible to do highly precise volume estimates with relative ease.

Because of this, the stockpile value may be calculated with high precision for monthly reconciliations or yearend audits, resulting in improved consistency of inventory reporting in the company's balance sheet. It is also possible to confirm the amount of material carried by subcontractors using drone results and post-processing tools because the results are unbiased.

Another flight is utilized as a starting point for to do cut/fill and net volume calculations. This graphic depicts the evolution of the intended region over time.

• More and better data for monthly or weekly management.

Drone inventory surveys may now be completed in record time, making regular data-collection more cost-effective than ever before; whether it be weekly, monthly, or quarterly data gathering is becoming more common. [17] To be more specific, it provides for more accurate forecasting of mineral supplies available for sale. Your site may be flown as frequently as you like, without having to wait for a semi-annual aerial survey audit to take place. Because you have the capacity to gather data on a regular basis, you can enhance inventory and operational management while also minimizing the hazards that surveyors working on-site encounter [16, 17].

VI. Conclusion

UAV integration into mining operations immediately demonstrates to workers the tremendous value that UAVs provide to their respective companies and industries. Drone technology has been extensively used in surface mining operations.

In comparison to traditional monitoring methods, it is more efficient and less costly. There are numerous surface mining applications where drones are used, in control, rock discontinuity mapping, 3D modeling , blasting management (including post blast rock fragmentation measurements), tailing stability monitoring, and stability tracking, to mention a few. Heavily used in the mining sector for both research and commercial purposes, fixed-wing and rotary-wing drones are the most prevalent types of drones.

UAV/drone mining, in particular, contributes to the increased efficiency of big mine sites and quarry operations by giving exact and full data detailing site in time span that is quite brief. They also enable increased cooperation among onsite and remote personnel, as well as dynamical supervision of all activities.

Above all, this data may be generated securely on-site by workers with minimum mapping expertise at a fraction of the expense of traditional research approaches.

Recommendations

To maximize the potential development advantages of mining, the research suggests that Rwanda continue on its present efforts to modernize its mostly small-scale mining industry by establishing a fresh strategic focus on wider development outcomes that go beyond raising export revenues.

In order to do this, the update identifies five areas of policy concentration that might aid in unlocking Rwanda's mining potential:

- Enhance working condition,
- Enhance local collection and process,
- Develop an investment-ready geological knowledge and understanding
- Enhance fiscal collections and revenues ,
- Assure an investment-friendly legal and regulatory framework.

Acknowledgment

We want to convey our heartfelt gratitude and thanks to Eng. Evariste Twahirwa for making our lecture (UAVs/DRONE) unforgettable and providing support and guidance.

In the end, we want convey thank to the management of ACEIOT Center. Without them, we would have been unable to conduct a pleasant and fruitful class.

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