COMPARATIVE ANALYSIS OF CAVITY MONITORING SYSTEMS AND DRONE BASED LIDAR-SLAM IN UNDERGROUND MINES - A CASE STUDY

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United Nations Economic Commission for Africa

EIS

FIG International Federation of Surveyors
Fédération Internationale des Géomètres
Internationale Vereinigung der Vermessungsingenieure

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Presentation Outline

- Statement of Problem
- Objectives of Project
- Study Area
- Materials and Methods Used
- Results and Discussions
- Conclusions and Recommendations

Statement of Problem

- Underground surveying is essential for operational planning, safety, and resource estimation, yet certain survey systems face challenges in inaccessible or hazardous areas.

- In underground mining, surveyors often face the difficult task of choosing the right method for cavity monitoring.

- Commonly, Cavity Monitoring Systems (CMS) have been used for this purpose.

Statement of Problem

- However, CMS presents notable limitations, especially in hazardous, tight, or inaccessible stopes where manual setup is required, exposing surveyors to risk and creating delays.

- Drone based LiDAR SLAM offers remote, automated scanning that captures wider areas faster and delivers high resolution point clouds while removing repetitive physical setups at multiple brow points, thus improving safety and efficiency.

Statement of Problem

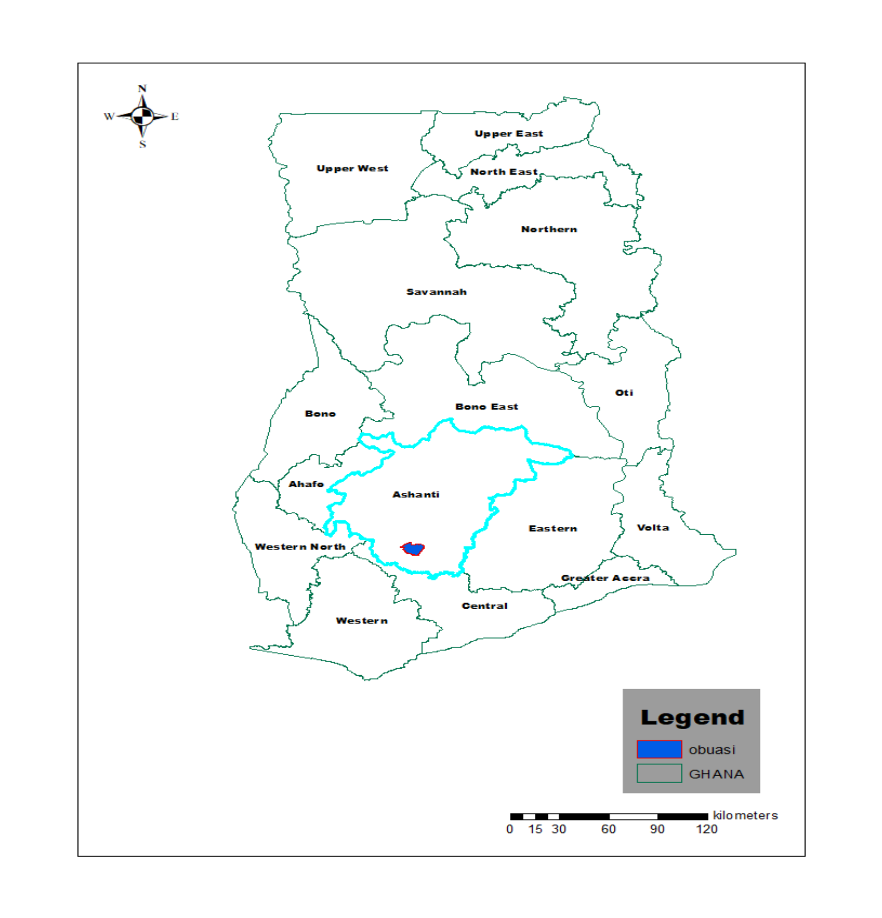
- This project therefore asks:
  - Which method is better for which kind of stope?
  - How can surveyors make informed decisions without first hand experience of modern systems?
- By comparing CMS and drone-based SLAM with real underground mine data, the study evaluate resolution, safety, coverage, efficiency and usability.
- Supplying data-supported insight needed to choose the optimal surveying method for any stope environment.

Objectives of Project

- To compare the level of resolution, reliability of CMS and drone-based LiDAR-SLAM in underground mines; and

- To evaluate the operational requirements, advantages, limitations, and challenges of each method in terms of safety, accessibility, time, and labor.

Study Area



Map of the study Area

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Materials and Methods Used

- Primary and Secondary data from AngloGold-Ashanti underground mines levels collected with both CMS and Underground drone LiDAR-SLAM;

- Cloud Compare Software used to process the drone point cloud data, including georeferencing, filtering and mesh creation;

Materials and Methods Used

- Geovia Surpac-Survey Software was used to visualize the mesh data, applied necessary adjustments, and generate the 3D model of the stope and also compute the volumes;

- Underground Drone equipped with a LiDAR-SLAM scanner (Figure 2) and

- CMS mounted on 7m boom (Figure 3)

Materials and Methods Used

Figure 2 Underground Drone equipped with a LiDAR-SLAM scanner

Figure 3 CMS on 7m boom

Materials and Methods Used

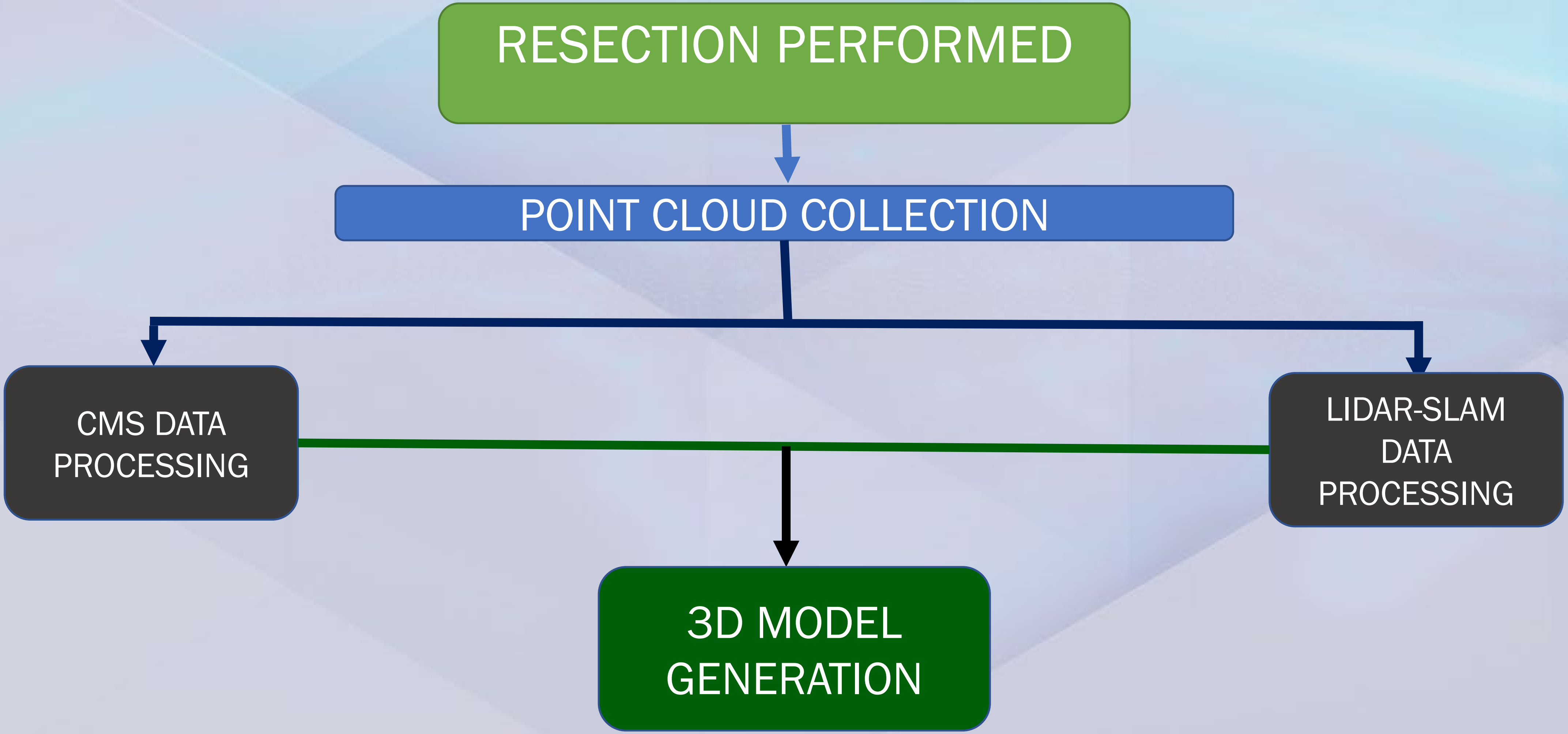


Figure 4 Flowchart of the Methods Used

Results and Discussion

Figure 5 Filtered point cloud of the CMS scan at 2603_363RDS

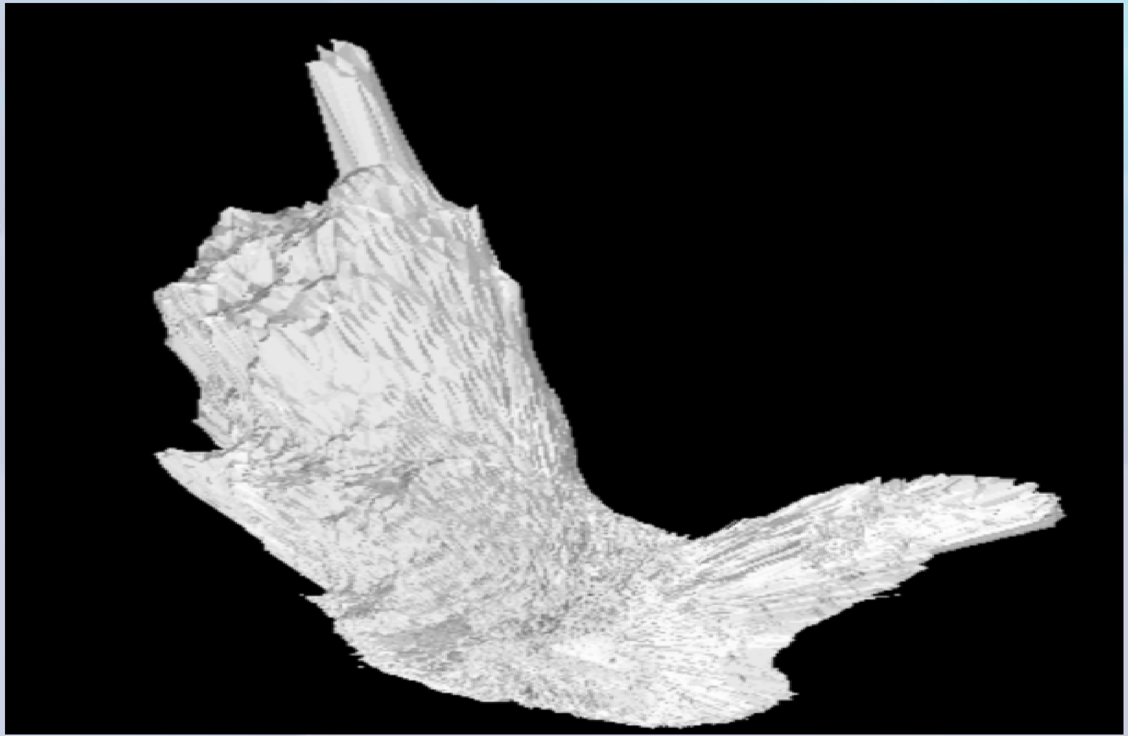


Figure 6 Mesh Surface (DXF Format) of 2603_363RDS produced from the V500 software

Results and Discussion

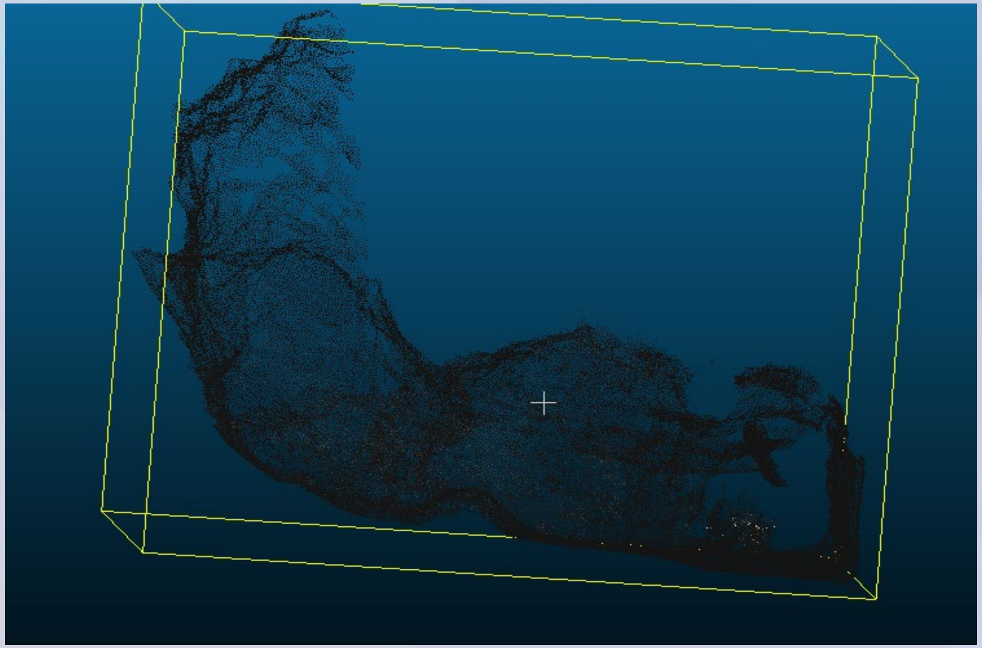


Figure 7 Filtered point cloud of 2603_363rds1 panel 4 from a drone scan

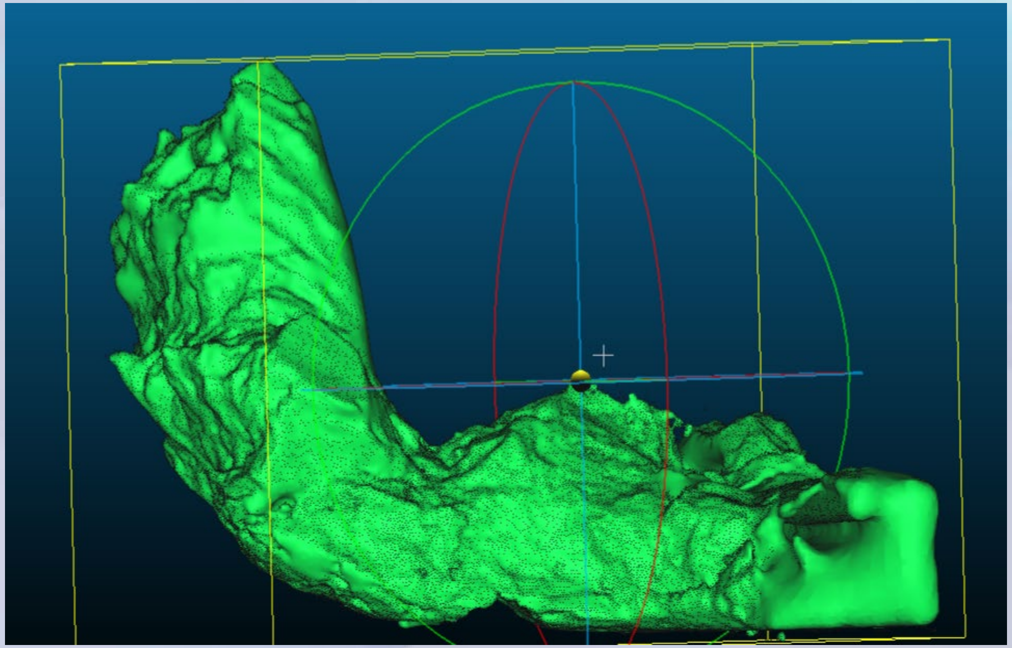


Figure 8 Mesh surface for the 2603_363rds1 panel 4 stope derived, using the CloudCompare software

Results and Discussion

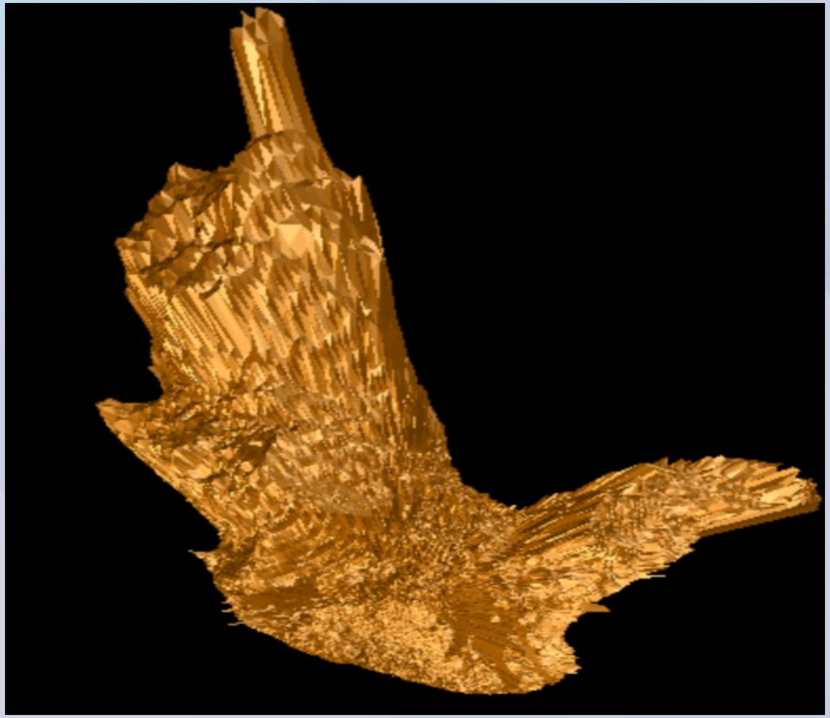


Figure 9 Front view of the Digital Terrain Model (DTM) of the 2603_363rds1pn4 stope by CMS scan

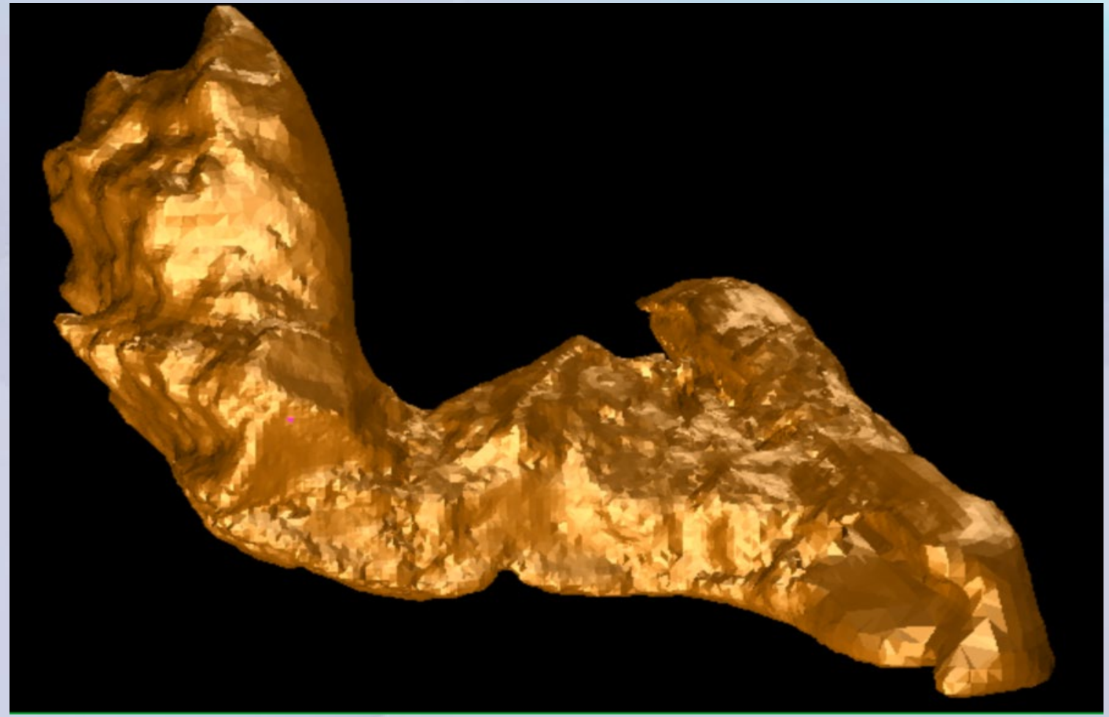
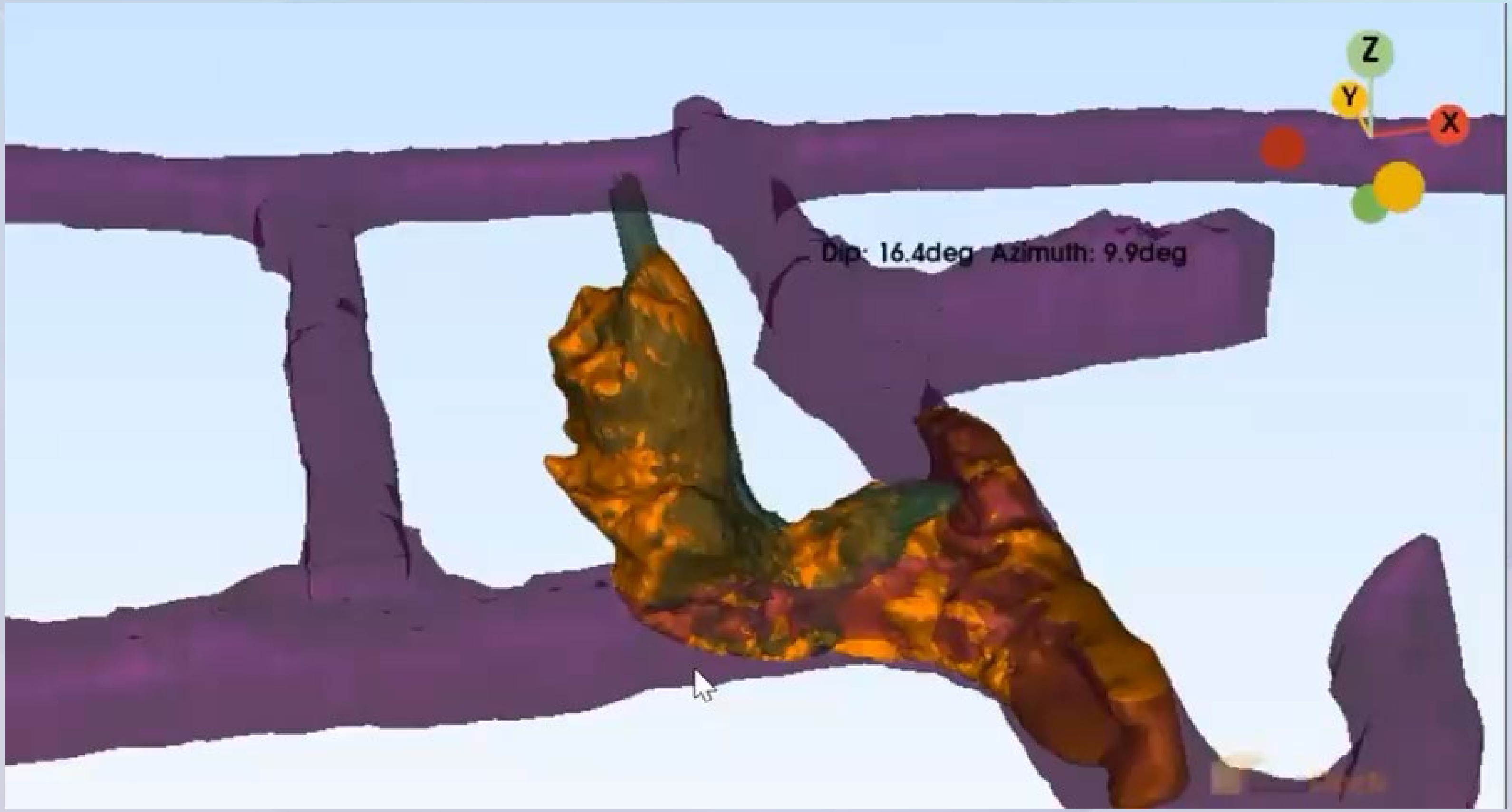


Figure 10 Front view of the Digital Terrain Model (DTM) of the 2603_363rds1pn4 stope by LiDAR-SLAM scan

Results and Discussion



Video Demonstration- Overlay of CMS and Drone DTM Models at 2603_363rds1 Panel 4

Results and Discussion

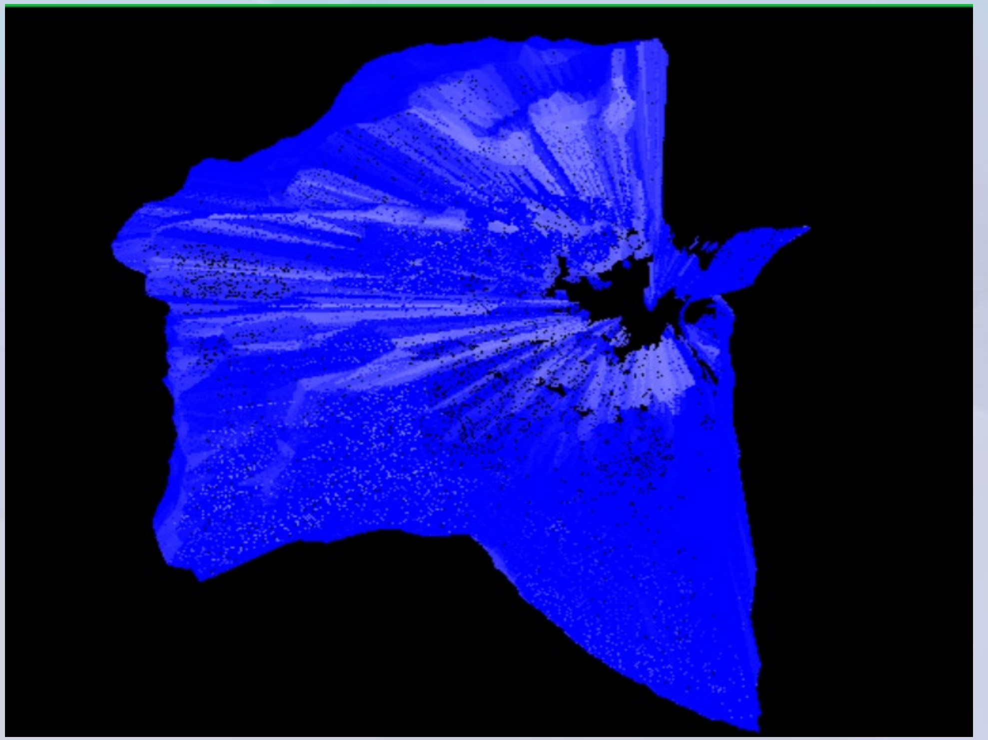


Figure 11 Filtered point cloud of 2800_325 Stope by CMS

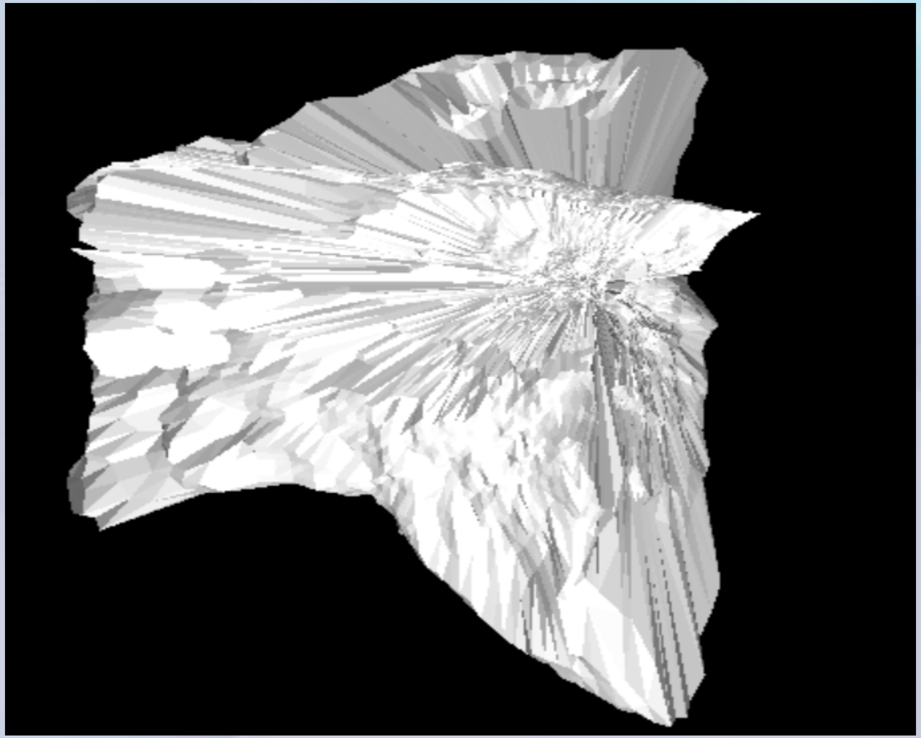


Figure 12 Mesh surface derived from the .dxf file (2800_325 stope)

Results and Discussion

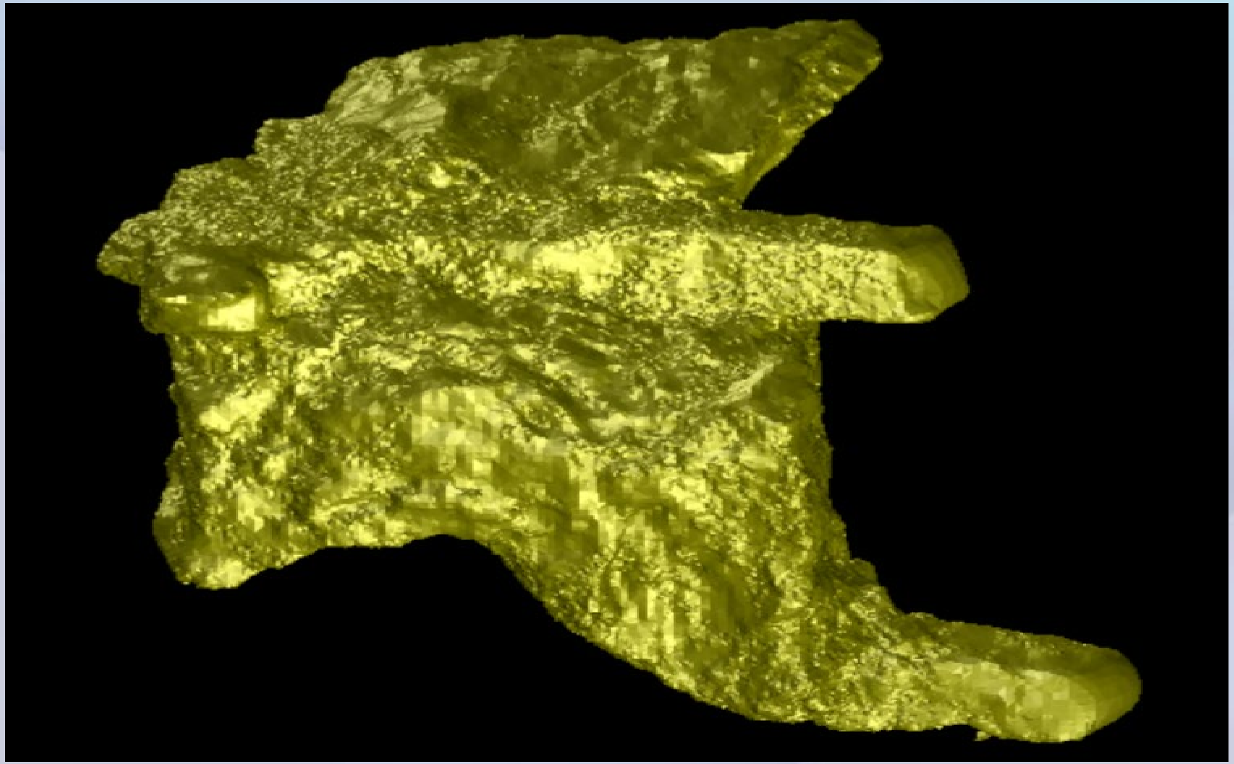


Figure 13 Mesh surfaced of the filtered point cloud of the 2800_325 stope by the drone produced using the CloudCompare

Results and Discussion

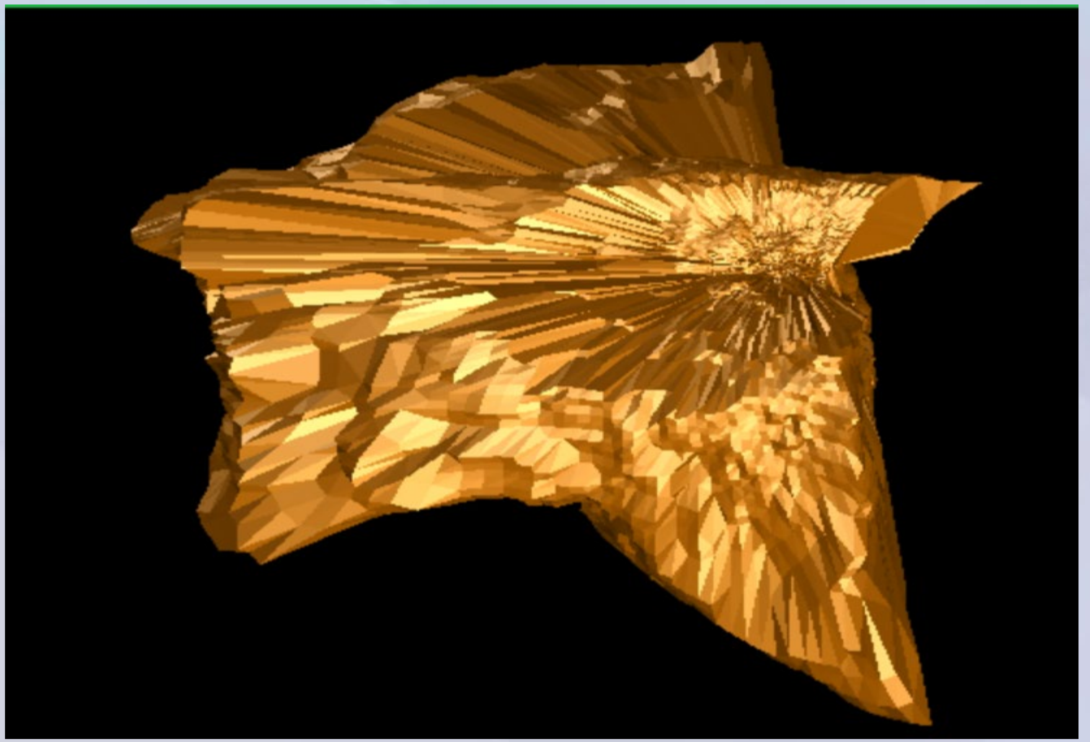


Figure 14 Front view of the DTM of the 2800_325 stope from the CMS scan

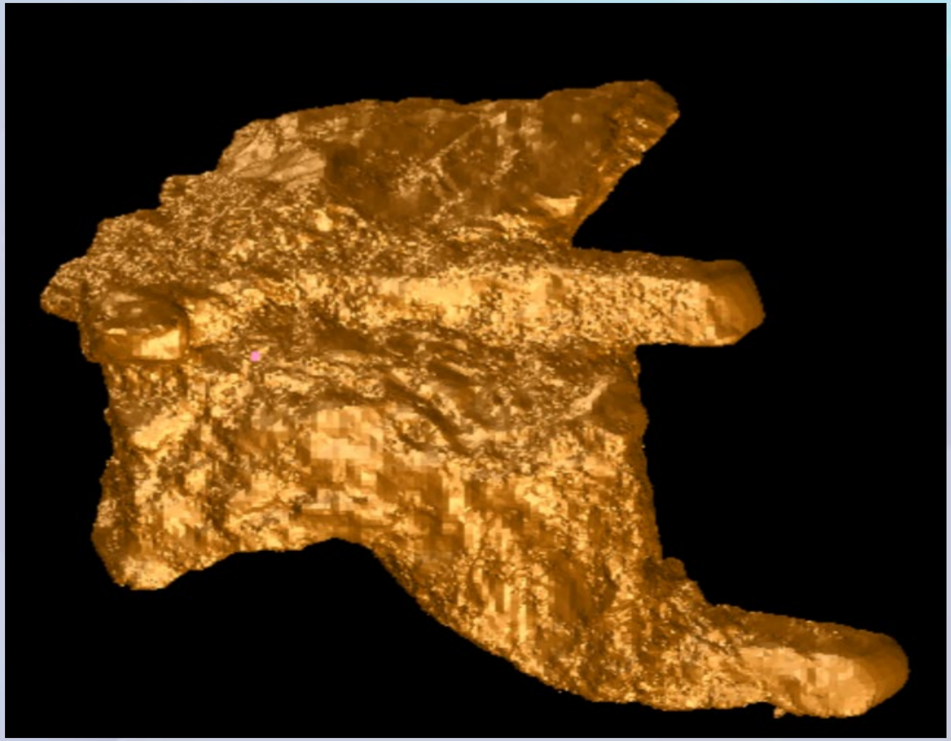


Figure 15 Front view of the DTM of the 2800_325 stope from the LiDAR-SLAM scan

Results and Discussion

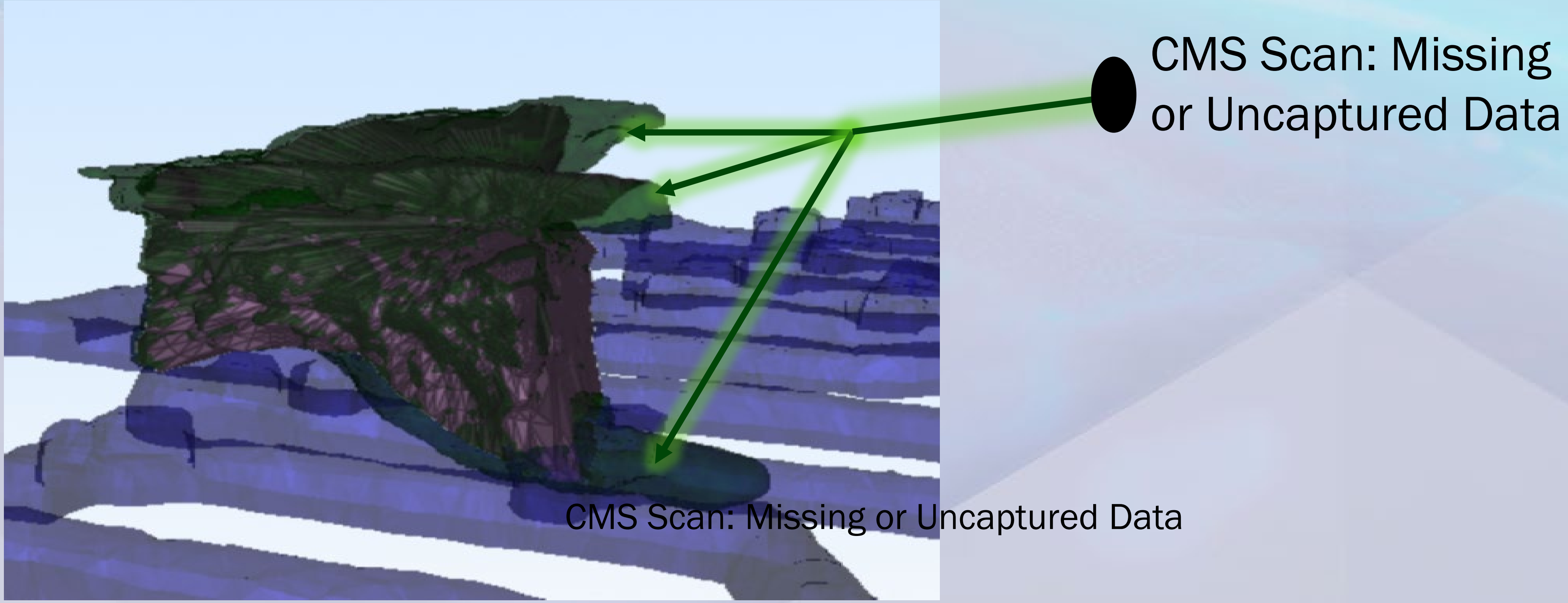


Figure 16 Overlay of CMS and Drone DTM Models at 2800_325

Results and Discussion

Figure 17 CMS Setup at the brow of the stope

Results and Discussion

Figure 18 Drone Setup at a safe distance from the stope

Results and Discussion

Table 1 Resolution and Reliability Comparison: CMS vs Drone

Location	System with its range resolution	Surface Area (m^2)	Volume (m^3)	Total Points	Point Density (pts/m^2)	Remarks
2603_363R DS Panel 4	Drone (5mm-10mm)	1663	2215	99999980	60,143	Dense data; incomplete mesh due to constrained flight
	CMS (10mm)	1232	1085	65073	53	Sparse data; reliable continuous mesh in tight stope

Results and Discussion

Table 1 Resolution and Reliability Comparison: CMS vs Drone

Location	System with its range resolution	Surface Area (m^2)	Volume (m^3)	Total Points	Point Density (pts/m^2)	Remarks
2800_325D Stope	Drone (5mm-10mm)	2137	2902	99999665	46800	Very dense data; full coverage with no loss
	CMS (10mm)	1858	2076	1000777	539	Moderate density; consistent mesh with slight surface detail limitations

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Results and Discussion

Table 2 Operational Evaluation of CMS and Drone-based LiDAR-SLAM.

Factor	Cavity Monitoring System (CMS)	Drone-Based LiDAR-SLAM
Safety	Requires operators near stope brow, with physical exposure to voids, unsupported grounds and hazards	Operated remotely; safer for personnel, especially in unstable areas.
Accessibility	Better in narrow or irregular stopes; can be inserted using the boom	Limited in tight or collapsed areas; best in open and accessible stopes
Setup Time	Longer (25–30 minutes); involves physical setup, alignment, and handling	Short (5 mins); quick launch and control point scanning

Results and Discussion

Table 2 Operational Evaluation of CMS and Drone-based LiDAR-SLAM.

Factor	Cavity Monitoring System (CMS)	Drone-Based LiDAR-SLAM
Advantages	Reliable in confined stopes; quick processing	Safer, faster scanning, more detailed 3D models in open stopes
Limitations	Labor-intensive setup, limited resolution at depth, fixed perspective, safety risk	Struggles in tight spaces, complex post-processing.
Challenges	Physical handling in unstable zones, shadowed areas behind obstructions	Navigation in confined areas, high point count slows processing

Results and Discussion

Table 2 Operational Evaluation of CMS and Drone-based LiDAR-SLAM.

Factor	Cavity Monitoring System (CMS)	Drone-Based LiDAR-SLAM
Data Acquisition Time	15–20 minutes, depending on stope size and coverage; static setup requires repositioning	Under 10 minutes per stope; mobile scanning enables rapid, continuous data acquisition
Labor	Requires 2-3 skilled personnel for safe boom handling and setup	Requires at least one licensed personnel; less physical effort
Processing Time	10–15 minutes	60–90 minutes; includes SLAM alignment, georeferencing, denoising, and export

Results and Discussion

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Challenges	Physical handling in unstable zones, shadowed areas behind obstructions	Navigation in confined areas, high point count slows processing

Conclusions

- Drone-based LiDAR-SLAM produced higher-resolution data and more detailed 3D models than CMS, especially in open and accessible stopes;

- CMS delivered reliable results in narrow and constrained stopes, though with lower point density and less geometric detail;

Conclusions

- CMS was easier to process but more labor-intensive during field setup, while the drone system was faster in data collection but required more technical processing;

- Drone systems enhanced safety by reducing the need for surveyors to enter hazardous areas, unlike CMS which requires manual setup near the brow; and

- The choice between CMS and drone-based SLAM depends on stope geometry, safety conditions, required detail, and accessibility.

Recommendations

- CMS is recommended for small or moderately sized stopes where there is line-of-sight access and high-resolution data is not essential;

- Drone-based LiDAR-SLAM is preferred for large, complex, or hazardous stopes where full 3D capture and operator safety are priorities;

Recommendations

- A hybrid approach is recommended to maximize both data quality and operational safety. CMS is best suited for smaller stopes, while drone-based LiDAR-SLAM is ideal for wider, risk-prone areas; and

- Drone-based SLAM is especially useful when high-resolution 3D models are required for volumetric analysis or future mine planning.

Thank You

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