3D SCANNING AND MAPPING OF UNDERGROUND MINE WORKINGS USING AERIAL DRONES

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Laser scanning and mapping of underground mine workings have become a norm in the majority of underground mines. There are many operational benefits of scanning underground mine cavities including accurate excavation audits, geological assessments ground support assessments and generally mine scanning that is performed remotely, which allows for scanning areas where the risk to personnel is too great in areas that may be less stable than allowable for entry. Even though the scanning technology is fairly advanced, a number of challenges are still posed in underground mine environments including the possibility of equipment damage from falling rocks, narrow openings and cavities, limited time availability due to production schedules etc. These challenges have been addressed with systems that offer faster data acquisition and mobile scanning.

It is worth noting that with the recent push towards the concepts of "the digital mine" and Internet-of-Things (IoT), laser scanning and mapping have assumed central importance. More and more mines are now looking for autonomous vehicles that can minimize human presence in underground operations; thus, making the mine much safer and more productive. One of the main issues with autonomous vehicle operation in an underground mine is the unavailability of GPS-like positioning information. An efficient way to handle this issue is by employing a Simultaneous Localization and Mapping (SLAM) algorithm to simultaneously determine the position and create the map while the laser scanner is in motion. This paper presents a case study to determine the feasibility of SLAM-based scanning from aerial drones in underground mines.

SUMMARY

The underground environment requires various levels of ground control depending on the intended use of the excavation. In places where personnel will be attending, the ground control must have a factor of safety, which is costly unless the work can be carried out by remotely operated equipment. Arial drones are highly flexible in terms of navigating difficult terrain, can be fitted with various payloads and when LIDAR with Simultaneous Localization and Mapping software is employed the unit is a very cost effective tool for monitoring and decision making.

CASE STUDY

We mounted a LiDAR (V-SCAN3D) capable of mobile scanning using a SLAM algorithm onto a drone (Tilt Ranger) and flew it in two different underground mines (see Fig. 1).

For this study we chose two different types of stopes typically inaccessible by personnel: one that was only excavated from the top and the other with both top and bottom excavations.

For the latter we flew the drone twice, once with the scanner mounted on top of the drone and followed by a run through with the scanner mounted at the bottom. The two maps obtained from these separate runs were then digitally merged together to create the complete mine map.

The stopes we scanned are shown in Fig. 2, registration in the mine coordinate system was done by placing reflective crosses on known control points and then performing a stationary scan (see Fig. 3). The stationary scan was then merged with the mobile scan and then registered in the mine coordinate system using the control points visible in the point cloud.

The top two images in Fig. 2 show the scan results from the traditional scanning equipment (left) and drone scanner (right). The two scans, when merged together, were found to match very closely and within their margin of errors. This established that the system can be used in place of a traditional cavity scanning system. The bottom two images show the scans of two stopes from the drone. The left image has scan from the traditional scanner merged with the one from the drone.

The point clouds obtained from the scanner are in x,y,z position format with intensity of reflected light as the fourth column. The value of reflected light intensity can provide useful information on rock face geology

Fig. 1 Tilt Ranger drone (Inkonova AB) with V-SCAN3D scanner (Clickmox Solutions).

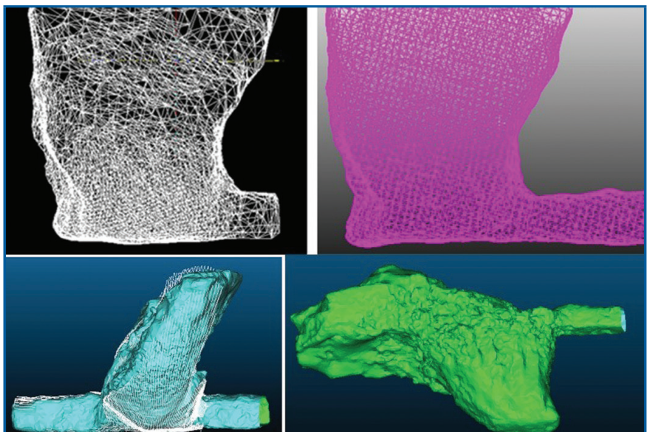

Fig. 2 (top left) Scan from traditional scanning system, (top right) scan from drone, (bottom) scan of two large open stopes.

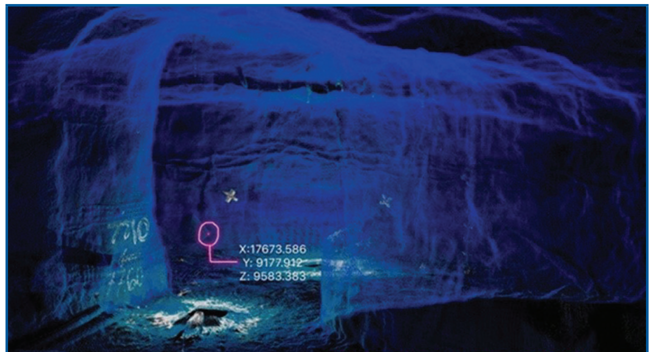

Fig. 3 Point cloud registration with reflective markers.

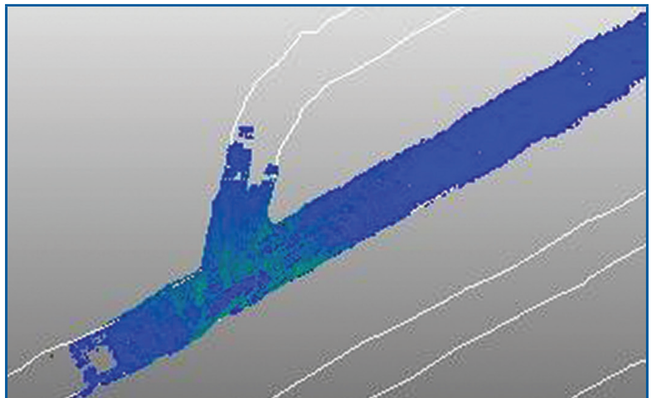

Fig. 4 Point cloud to measure convergence in underground mine drift.

including identification of large cracks and faults. Such information is highly important to design ground support structures as well to plan further lateral drift developments.

3D laser scanning also provides a means of convergence monitoring. High lateral pressures in an underground rock mass can induce slow convergence leading to eventual collapse of walls and pillars. Regular scanning of underground cavities and comparing them with previously captured data can be used to determine the extent and rate of convergence. This is possible by overlaying the new point cloud onto the previous one with both registered in the mine coordinate system. The point cloud of the section of a drift overlaid on a previous 2D profile is shown in Fig. 4. Note that the scan shows changes in the profile at several locations along the drift. In order to derive meaningful results from this exercise, it is important to understand the noise level, accuracy and precision of the system. Different scanning systems provide different levels of accuracy and precision and the choice depends on the monitoring requirements. Generally, accuracy of 3-5 mm is considered adequate for measuring convergence in underground mine cavities.

OUTCOME OF CASE STUDY

We conclude that mobile scanning provides an efficient and safer means of scanning and mapping underground mine cavities. The areas that were previously not possible to scan, can now be scanned using aerial drone-based scanners. This method not only provides time savings but also has huge advantages in terms of safety.