Measuring the Micro Deformation and Crack of Rock Surface and Make Robot Intelligent Walking Path from Pulse Lidar Profiler

Tao Zhou and Li Tao*
School of Mechanical Engineering, Jiangsu Ocean University, Liangyungang, 222005, Jiangsu, China
*Corresponding author email: 287473451@qq.com

Abstract. Derived from accumulated lidar point cloud, 3D model building appears to be a crucial technology for autonomous navigation of car. In this paper, we present a method of monitoring rock wall cracks and micro rock top displacement of underground tunnel by using pulse lidar profiler, so as to achieve the purpose of timely and real-time early warning. With the help of the Internet of things, cloud data and fog computing, the pulse lidar profiler is regarded as an extended terminal of cloud computing. It performs many tasks such as daily contour data and key electronic equipment monitoring status data recording, danger alarm calculation and emergency situation uploading to the cloud database.

Keywords: Lidar; Profiler; Fog computing; State warning.

1. Introduction
With the development of advanced optics and algorithms, laser ranging technology is becoming more and more sophisticated. The latest frontier achievements in this field involve laser scanning water depth[1] and wood volume estimation technology on water surface[2], 3D scene modeling[1-7], aircraft attitude control and path planning[5-7]. In all the above contents, the first problem to be solved is the 3D scene reconstruction technology based on 3D point cloud. With the accurate and reliable scene model, the crack analysis, tunnel deformation analysis and robot autonomous road planning have the basis of accurate implementation.

Table 1. Content list of this study.

| Main task                                           | PULSE LIDAR PROFILER VALUE                                      |
|-----------------------------------------------------|-----------------------------------------------------------------|
| Daily monitoring of rock wall and roof profile data 1( 0+short message of state description) |
| normal( abnormal)                                   |                                                                |
| Daily monitoring of key equipment status data       1( 0+short message of state description) |
| normal( abnormal)                                   |                                                                |
| Fog computing of robot walking path                 Detailed analysis of point cloud |
| Danger alarm calculation uploading to the cloud database | Not too dangerous, dangerous, extremely dangerous |
| Emergency disposal downloading from the cloud database | Take emergency treatment, no disposal and force personnel to evacuate |
The original intention of this study is to lay a technical foundation for the unmanned coal mine with zero casualties. Although the number of coal mine casualties in China has decreased significantly, there is still much room for improvement. Whether from the economic point of view or the value of life, the necessity of this study is very convincing.

2. Overall Research Framework
As shown in Fig.1, in this study, the relationship between pulse lidar profiler and cloud database is established. This connection is realized by the data storage of pulse laser profiler and a set of fog calculation. The first step of fog calculation completes the transformation from the point cloud measured by the sensor to the 3D model. Then, the second step of fog calculation is to get the progressive action plan of robot autonomous path planning through deduction and key point extraction.

2.1. Noise Signal Filtering in Point Cloud
There are unnecessary points and points with wrong coordinates in the point cloud. These points will increase the cost of calculation. In more serious cases, false personnel evacuation alarm will be formed, resulting in adverse effects. Therefore, it is necessary to eliminate harmful data in the early stage of data processing and classification.
In this study, the big data monitoring technology is used to eliminate redundant and wrong data, and a variety of historical error data sets are recorded. The strategy of fast comparison and direct deletion of noise points is adopted.

2.2. Discrimination of Rock Crack and Abnormal Settlement at the Top of Rock Cave
The judgment of these two parts is based on historical data. Specifically, the conclusion that new cracks and new settlement occur suddenly at a certain time is obtained by comparing the cave morphology data files of different time periods. This real-time early warning mode is more detailed and accurate than manual observation. A crawler robot with a small pulse lidar profiler can be put into the tunnel or rock tunnel during no-load period. If a potential hazard suddenly occurs, workers can take timely measures.
Figure 2. (a1). Fine cracks in new initiation stage; (a2). If the crack is in the key position and reaches a certain scale, it is necessary to report the early warning to the cloud database; (b1). Initial cave height; (b2). The falling at the top of the cavern results in the decrease of the height of the cavern, which is one of the signs of the imminent occurrence of a large-scale accident, and the evacuation needs to be organized quickly.

See Figure 2. The shape features of the two types of pulse lidar profiler can be detected only when they reach a certain scale.

2.3. Robot Path Planning
Path planning based on point cloud is the most complex part of the whole research. But its value weight is also the heaviest. Here we omit the part of noise signal screening. Firstly, according to the shape of the robot or car and the actual measured cave height, ground pit and bulge amplitude, the pitch angle value of horizontal scanning is determined. Due to the interference of moisture and dust in the coal mine tunnel, the effective detection range of the pulsed lidar profiler loaded on the car decreases. For safety reasons, there is a positive correlation between the driving speed and the detection range of the vision sensor. Therefore, the speed of the car will not be very fast. Due to the cost limitation, the number of laser probes on each car is limited, and the scanning range is expanded by adjusting the optical path. For the geological dangerous position and the weak position formed by construction, the car or robot need to carry the pulse lidar profiler to scan repeatedly with emphasis to ensure the data is accurate and comprehensive.

Figure 3. Schematic diagram of non key scanning area and key scanning area.

As can be seen from Figure 3, the red area is more dangerous than other areas on the path and needs to be carefully scanned.

2.4. Cloud Database
In order to avoid the delay, visual error and high economic cost caused by manual operation, the intelligent device uploads the sudden crack and top drop data to the cloud database.
The result of this real-time operation is that the cloud database responds quickly and sends the disposal measures back to the fog processor, the pulse lidar profiler. The pulse lidar profiler sends the details of the danger and the cloud disposal command to the user's smart phone.

3. Conclusion

This study is based on the urgent need to solve practical problems. Specifically:

- The research goal is to develop a pulse lidar profiler with fog calculation function.
- The pulse lidar profiler is installed on the car or robot body, which can achieve the purpose of monitoring the shape of the tunnel and the running state of the equipment.
- The duty of fog computing unit is to remove the noise signal in the point cloud, and transform the effective lattice into accurate three-dimensional model. Finally, the reliable path planning is calculated based on the 3D model.
- From the point of view of Geology and construction, there must be serious danger areas in coal mines or tunnels, which need to be carefully scanned.
- Cloud database is the last link to ensure the safety of underground tunnels and coal mines. In the case of unattended, cloud data can still be used to release disposal measures.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (51675424 and 51105307), Natural Science Foundation of Shanxi (2018JM5090), 111 Project (Grant no. B13044), Key projects of Shaanxi Provincial Department of Education (Grant no. 17GG004).

References

[1] Filippo Bandini, Jakob Jakobsen, Daniel Olesen, et al. 2017 *Journal of Hydrology* vol 548, Measuring water level in rivers and lakes from lightweight Unmanned Aerial Vehicles (Denmark: Elsevier) p 237-250

[2] Gabriel Spreitzer, Jon Tunnicliffe, Heide Friedrich. 2020 *Journal of Hydrology* vol 581, Large wood (LW) 3D accumulation mapping and assessment using structure from Motion photogrammetry in the laboratory (New Zealand: Elsevier) p 124430

[3] Min-Koo Kim, Qian Wang, Joon-Woo Park, et al. 2016 *Automation in Construction* vol 72, Automation in Construction 72 Automated dimensional quality assurance of full-scale precast concrete elements using laser scanning and BIM (United Kingdom: Elsevier) p 102-114

[4] Molebny, Vasyl, Steinvall, Ove. 2018 *PROCEEDINGS OF SPIE* vol 9080, Multi-dimensional laser radars (SPIEDigitalLibrary.org: Elsevier) p 908002-1

[5] Ilpo Niskanen, Matti Immonen, Lauri Hallman, et al. 2021 *Automation in Construction* vol 121, Time-of-flight sensor for getting shape model of automobiles toward digital 3D imaging approach of autonomous driving (Finland: Elsevier) p 1

[6] Suraj Bijjahalli, Roberto Sabatini, Alessandro Gardi. 2020 *Progress in Aerospace Sciences* vol 115, Advances in intelligent and autonomous navigation systems for small UAS (Australia: Elsevier) p 110617

[7] Chih-Hung G. Li, Yi-Feng Hong, Po-Kai Hsu, et al. 2020 *Robotics and Autonomous Systems* vol 131, Real-time topological localization using structured-view ConvNet with expectation rules and training renewal (Taiwan of China: Elsevier) p 103578