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Development of Auto Scaling Method for 3D Rock Fragmentation Measurement System

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Abstract

Fragmentation Distribution is one of the important aspects of mining operations as it affects productivities on the majority of Mine-to-Mill operations. Nevertheless the significance of fragmentation management, the mining industry has relied on 2D image based fragmentation measurement system which poses many downsides. To overcome the drawbacks of current 2D fragmentation measurement system, 3D Rock Fragmentation Measurement System has been proposed with using 3D photogrammetry technologies. One of the common difficulty of fragmentation measurement system is scaling of the object, which is an essential component to secure the accuracy of particle size distribution. In this study, the actual scales and size information of objects have been obtained by measuring the acceleration when moving between the photographing points and giving the information of the distance obtained from the acceleration. The developed system would be equipped with the 3D Rock Fragmentation Measurement System.

Keywords: Fragmentation; Blasting, Auto scaling system; 3D photogrammetry

1. Introduction

In mining industry, the main goal of rock blasting is to break the targeted rock into favorable sizes on its own purpose without damaging secured circumjacent objects. In other words, the efficiency of a blasting can be optimized by minimizing unwanted fines and oversizes that directly and/or indirectly affect the downstream of Mine-to-Mill processes. In spite of indefatigable endeavors of mining engineers, achieving favorable size distribution is one of the challenging tasks in rock blasting due to the complex physio-mechanical features of rock and their intricate responses to the dynamic blasting loads. Nevertheless, the favorable size distribution can be achieved by executing a well-established blasting reconciliation system that investigating fragmentation and back-analysis with its own blasting design.

The most certain rock fragments measurement methods are sieving and screening which directly measure sizes. They are still utilized in the laboratory scale test but limitedly applied in field test due to financial and physical limitations. The initial photo-based blasted rock pile fragmentation measurement methods in mining have been introduced in the 1980s (Nie & Rustan, 1987; Singh, 1983). Soon after, Maerz et al. (1987) introduced a digital photo based fragmentation analysis method that mounded an edge detection algorithm. Since then, many similar systems have been developed and exclusively utilized in mining industry nearly three decades. The mining industry is well aware of the significance of fragmentation management, however, the 2D image based fragmentation measurement system is widely used even it poses many downsides. To overcome the drawbacks of current 2D fragmentation measurement system, 3D Rock Fragmentation Measurement System has been proposed with using 3D photogrammetry technologies.

One of the common difficulty of fragmentation measurement system is scaling of the object, which is an essential component to secure the accuracy of particle size distribution. In this study, the actual scales and size information of objects have been obtained by measuring the acceleration when moving between the photographing points and giving the information of the distance obtained from the acceleration. The developed system would be equipped with the 3D Rock Fragmentation Measurement System.

2. Theories of Auto Scaling System for 3D Object

Stereo-photogrammetry is one of the photogrammetric methods that construct 3D geometry of an object by processing multiple 2D images of the object. In other words, the process of stereo-photogrammetry is simply converting 2D image coordinates (x, y) in multiple photographs into 3D coordinates (X, Y, Z) as illustrated in Fig. 1. As a brief explanation of constructing 3D geometry of an object, imagine that the projection center points (Camera stations: C_1 and C_2) and directions of the two imaging rays to the entity points (m_1 and m_2) are known. Then the object point (M_1) in the 3D imaginary coordinates would be represented by finding intersections of two matching entity points in photo 1 and 2 which is called 'image matching'. Also, if the position difference (distance) between m_1 and m_2 is known, the generated model has the scale. This is the basic principle of proposed "Auto Scaling System for 3D Rock Fragmentation Measurement System".

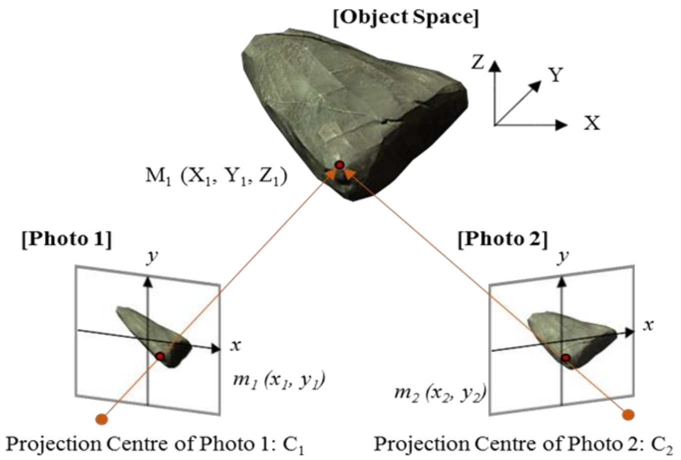

Fig. 1. An example of photogrammetric system (Degawa et al., 2016)

As the increasing application range of stereo-photogrammetry and rapid technical improvements in the areas of computer and digital-photography sciences over the last years, numerous 3D reconstruction algorithms have been introduced. Fig. 2 demonstrates a typical order of reconstructing 3D model. As different algorithms would be used in each stage but the prime procedures would be: data acquisition, data handling for each image, reconstruct 3D geometry, and the reconstruction of object texture (Furukawa & Hernández, 2015).

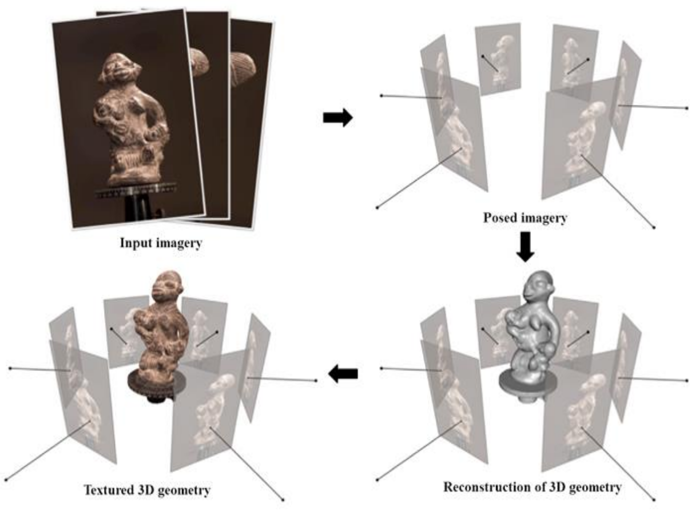

Fig. 2. Example of a multi-view stereo pipeline (Furukawa & Hernández, 2015)

3. Experiment for Auto Scaling System

3.1 Experimental setup

The experiment was conducted at the Akita University campus. The purpose of the experiment is to extract the size of a reference box (dimension of 29 × 42 × 89 cm^3) through creating a 3D model. iPhone was used to take photos of the box from the designed photo shooting location of an 8 × 5 grid pattern on the ground. Fig. 3 and 4 show the actual experiment preparation and the conceptual diagram of the photographing location. After taking photos respectively from the designated 40 points from the grid on the ground, another 71 pictures were taken from various places. Those photos were used to construct 3D models of the reference box adopting photogrammetry technologies.

Fig. 3. The state of actual experiment

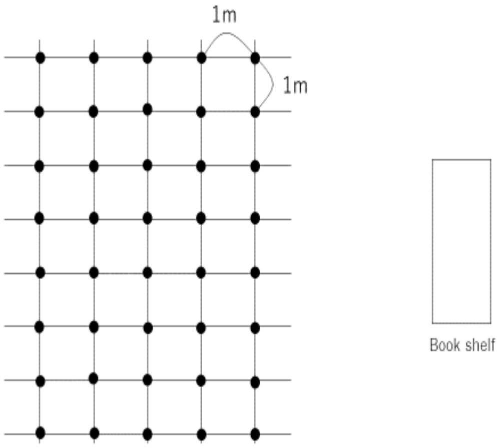

Fig. 4. Conceptual diagram of photo taking location

3.2 Experimental results

The created 3D model is shown in Fig.5. The scale accuracy of the created 3D model would vary according to the distance of each photo shooting location. To verify the scale accuracy among different photographing spots, the input of the distance information was calculated for distance differences 1, 2, 3, 4, and 5 m respectively. Finally, the length of the reference box (89 cm) was calculated from the 3D model for information from different photo taking locations. The results are shown in Fig. 6 and Table 1. As shown in Fig. 6, the larger the distance difference, the more the results were dispersed. When the distance difference was set to 1 m, the average error was 0.349 cm. The scale accuracy of the test was more than 99%, which verifies the applicability of the developed Auto Scaling Method to the 3D Rock Fragmentation Measurement System.

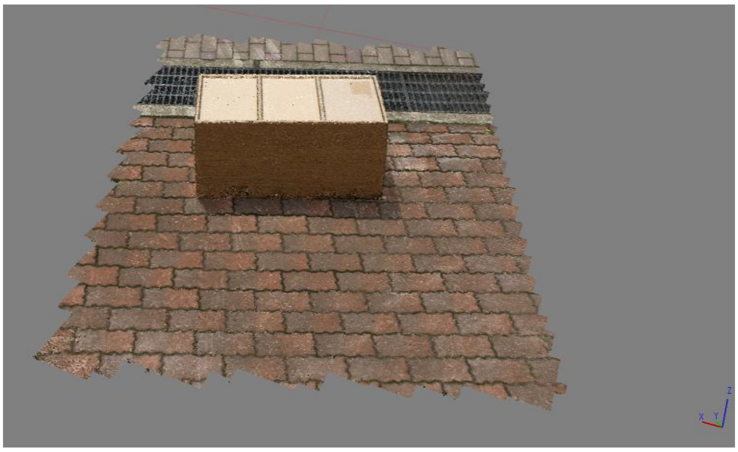

Fig. 5. The 3D model of a reference box

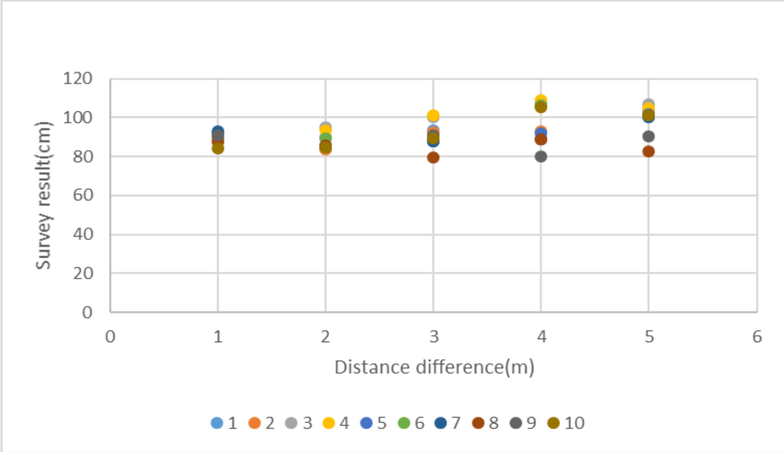

Fig.6. Distribution map of scaling results of the reference box

Table 1. Scaling results of the reference box

	1	2	3	4	5	6	7	8	9	10	Average
1m	90.36	90.1	87.06	87.63	92.1	90.56	92.72	87.69	91.15	84.12	89.349
2m	89.98	83.84	94.86	93.29	85.42	89.43	85.02	85.51	84.95	84.73	87.703
3m	93.41	92.28	100.37	101.1	87.66	88.7	87.89	79.51	90.78	89.36	91.106
4m	106.87	93.21	105.62	108.91	91.96	106.52	88.87	88.82	80.13	105.31	97.622
5m	104.51	102.58	106.79	104.73	101.59	100.85	99.95	82.65	90.59	101.23	99.547

4. System Verification on-site

A field experiment was carried out at Mikurahana quarry in Akita prefecture, Japan. The Mikurahana quarry is a quarry of the bench - cutting method, and the main rock type is the rhyolitic andesite. The state of actual muckpile is shown in Fig 7. As a reference, a yellow box of 44 cm in length was placed on the muckpile. 194 photos from 33 points of 3 × 11 were taken with the distance difference between iPhones as about 1 m and created a 3D model from a total of 227 images. The created 3D model is shown in Fig 8. As a result, the size of the box was 42.5 cm, which achieves 97% of accuracy.

Fig. 7. The muckpile on the site photo

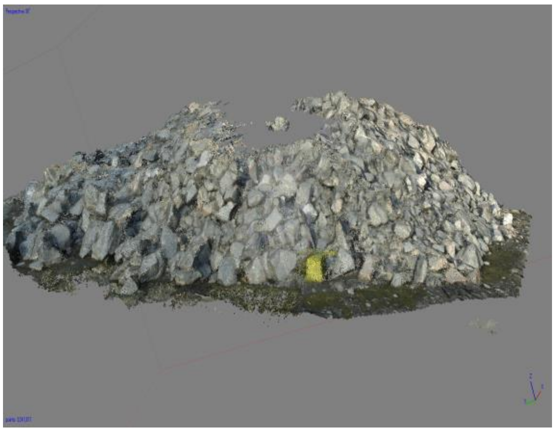

Fig. 8. The created 3D model of the muckpile

5. Conclusions

Auto Scaling Method for 3D Rock Fragmentation Measurement System has been proposed on this paper. The basic experiment has been done and confirmed its accuracy and possibility to use on-site. Later on, the system verification on-site was conducted at Mikurahana quarry in Akita prefecture, Japan. A 3D model of a muckpile on the site with a reference box has been created by using 227 images. The extracted size of the reference box from the 3D muckpile model was 42.5 cm, which gives 97% of the scale accuracy. The study realizes the automatic size scaling from the 3D model created through photogrammetry technologies, which will be equipped the 3D fragmentation measurement system.

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