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Calculation of in-situ blocks volume distribution of rock masses with full persistent joints using 3D point cloud data obtained by digital joint mapping techniques

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Abstract

Prior to implementation of rock engineering projects, if there is sufficient information on rock mass structural condition and dimensions of rock blocks, proper designing of execution methods and appropriate equipment selecting will reduce costs. The advent of new technologies in the field of three-dimensional mapping of outcrops has made it possible to provide precise geometrical information of the rock mass structures to identify and survey discontinuities. This research presents a process where using dense cloud data obtained from digital 3D mapping techniques and by integrating capabilities of some software, the orientation and spacing of persistent discontinuities of rock mass and the volume distribution of rock blocks are calculated. Here, at first, the points belonging to each discontinuity plate are examined by performing the coplanarity test and categorized by statistical methods. In addition, the discontinuities that are perpendicular to the surfaces of rock mass outcrop and the discontinuity plane is not visible were visually identified along their trace line. After identifying the points belonging to each discontinuity sets, points were clustered according their spatial distributions and a single plane fitted to the points belonging to each cluster. So, all visible discontinuities in rock mass, by the assumption of persistent, were geometrically simulated. On the other hand, a volumetric 3D model of rock mass was created using point cloud data. By geometric combination of generated joint planes and volumetric model of rock mass, rock blocks were created and block volume distribution diagram was obtained. In order to validate the method presented here, a geometric model with orthogonal regular joint system with accurate analytical solution was applied, and also the results were compared with the previous block volume estimation methods.

Keywords: *Digital joint survey, Semi-Automatic discontinuity mapping, Discontinuity extractor software.*

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Extended Abstract:

1. Introduction

Structurally controlled instabilities are the predominant failure mechanism in rock engineering projects. This type of instabilities occurs when the discontinuities intercept with each other and forming rock blocks (Monsalve, 2019). Blocks volumes or seizes are limited to the intersection of discontinuities or fractures within the jointed rock mass and the range of sizes of such blocks is represented as the in-situ block size distribution (IBSD) (Elmouttie and Poropat, 2012). Therefore, measuring and understanding the main characteristics of rock discontinuities, such as joint sizes, number of joint sets and displacements, is more crucial in geo-engineering projects.

from an engineering point of view, a knowledge of the rock mass jointing is often more important and the observations and characterization of the discontinuities should therefore be done carefully (Palmstrom et al., 2001). Nowadays, application of remote sensing technics of surveying, such as LiDAR (Light Detection and Ranging), TDLS (Terrestrial Digital Laser Scanning) and CRDP (Close Range Digital Photogrammetry), are widely developed for creation of digital outcrop models of rock mass to characterise rock structures, mainly because of following reasons (Jaboyedoff et al. 2012; Lato and Voge, 2012):

- Joint mapping results are objective and are reproduceable
- Human faults and timing are reduced and accuracy is increased
- Huge amount of accurate geometrical detailed data is available in these methods
- Safety is increased and all points of outcrop are accessible
- Obtained data could be analysed using computer base semi-automatic algorithms

In this paper a procedure is described that demonstrate how a digital outcrop model of jointed rock mass could be analysed to determine discontinuities characteristics. Also, it is shown that, how in-situ size distribution of rock blocks could be determined using combining the results obtained from digital joint mapping technics and capabilities of some software.

2. Methods and Results

In this research, investigations conducted on a large 3D digital surface model that was downloaded from www.sketchfab.com (e.Rock). 3D model converted to point cloud using CloudCompare software. Point cloud was analyzed by discontinuity set extractor software (DSE) (Riquelme et al. 2014) and discontinuity trace extractor software (DTE) (Jiateng et al. 2019). Results obtained from this two software, which is shown in Figure 1, were imported to CloudCompare and using Compass plug-in of this software and engineering judgment all of deterministic discontinuity planes were detected. By assuming that joints are fully persistent, a planar polygonal surface was fitted on each discontinuity and results are shown in Figure 2. Thereupon, 3D digital outcrop model and discontinuities planes separately were converted to a DXF geometric model. The DXF model imported to OPS (Open Pit Siro Model) software and analysed to calculate the distribution of in-situ block sizes. Results are shown in Figure 3.

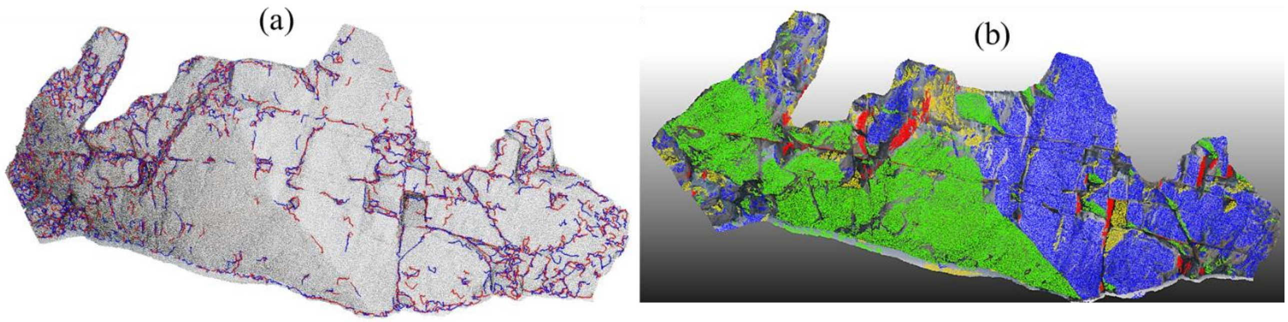

Figure 1. Results of Point cloud analyses by (a) discontinuity trace extractor and (b) discontinuity set extractor software.

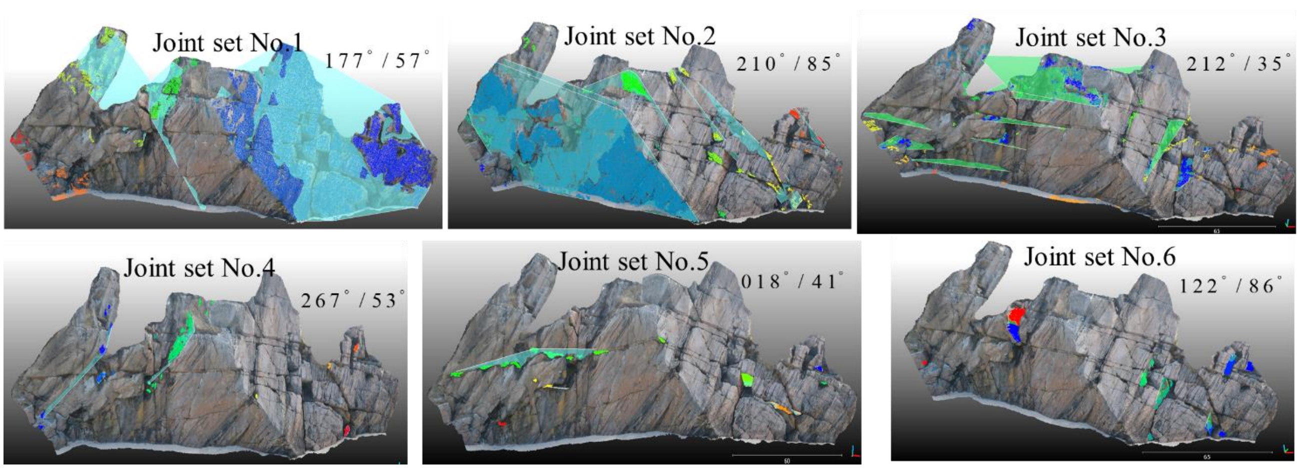

Figure 2. Orientation demonstration of detected joint sets planes using representative polygonal planar surfaces.

3. Conclusion

Most of the convinient in-situ rock block volume calculation methods were based on results obtained from scanline or scanwindow technics. Lack of information about expantion of discontinuity through the rock mass and exact trace length or persistenc of joints is the major limitation of linear or two dimentional syrveying technics. Although, three dimentional digital joint mapping technics (that was employed in this paper) are also limited in cognition inside the rock mass, but nevertheless the results obtained by these technics are more reliable than traditional rock mass joint mapping alternatives. In the other hand, application of average values of joint set spasing and lack of consensus about the definition of this characteristic (Priest and Hudson, 1976), is the another weakness of traditional methods. In addition, note that the traditional in-situ rock block volume estimation methods are not able to consider simultaniously more than three joint sets. While, using 3D joint mapping technics, all visible discontinuities in rock mass, by the assumption of persistent, could be geometrically simulated as they are. Then, the volumetric 3D model of rock mass structures could be created and by geometric combination of detected realistic joint planes and volumetric model of rock mass, rock blocks could accurately be created and block volume distribution diagram easily can be obtained.

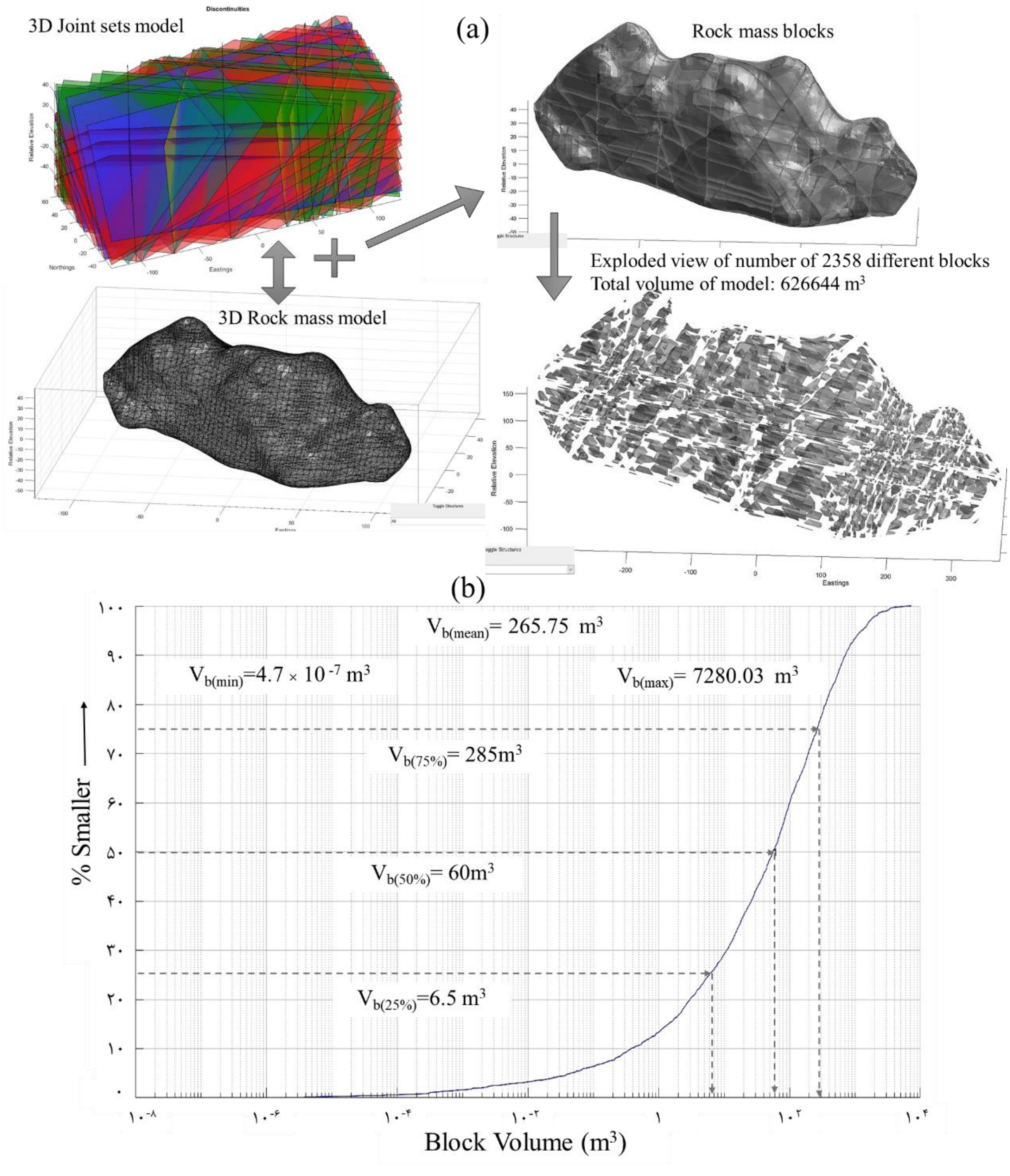

Figure 3. (a) Combination of rock mass 3D model and 3D deterministic joints model and rock blocks forming demonstration. (b) In-situ block size distribution curve of the concidered rock mass.

With all of these advantages, 3D methods also have some limitations such as, disability in detection of folded structures in rock mass and recognition of blocks with concave facess which is resulted from fully persitent assumption. Therefore, the development of studies in these two fields will be very valuable in the future.

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