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Reproducible rock mass description in 3D using the JointMetriX3D system

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ABSTRACT: A novel system yielding unbiased geological mapping is presented. It uses high resolution 3D images of rock faces from which measurements can be taken. Without requiring physical contact dip and dip direction or distances are determined and parameters such as spacing or spherical aperture derived. The referenced 3D image represents an objective data basis leading to a reproducible rock mass description that can be analysed even if the original rock face is no longer existing. The flexible system improves data quality and makes work safer. It is used in tunnelling, subsurface and open pit mining, for rock slopes or the documentation of existing structures.

1 INTRODUCTION

Present methods for collecting rock mass data in order to get descriptive parameters require time, willingness and the ability for observing well, which altogether is often not available. Manual sketches together with a few compass readings result in biased data which cannot be termed reproducible.

With JointMetriX3D, a novel system for capturing rock faces, this can be overcome. Using JointMetriX3D high resolution referenced 3D images are generated which represent on the one hand an objective data pool and on the other hand enable metric measurements related to the surrounding (tunnel, quarry). Distances, areas, as well as dip and dip direction are determined on the computer in a simple way, contact-free, without pressure of time, and at an arbitrary number. This procedure decouples the data acquisition from the analysis process.

The resulting information can be termed as reproducible, as analysis can be made at any later time even when the actual rock face does no longer exist. Data are useful for the daily decision making on the tunnel site, but also helpful in the case of later discussions on rock mass conditions, as well as a valuable documentation source especially in pilot tunnels. The system is a step beyond the state of the art.

2 A NEW APPROACH

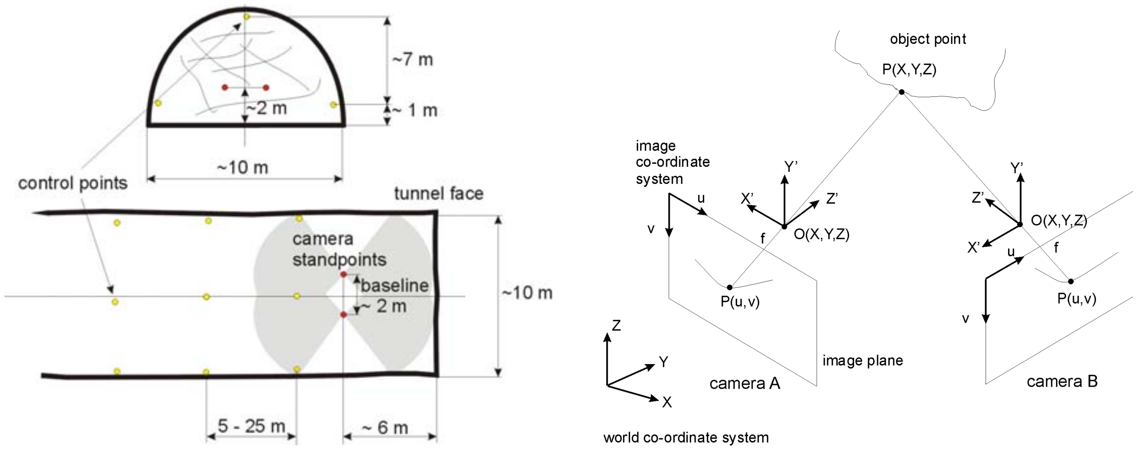
The background of the system was research work done at the Graz University of Technology, where a prototype was implemented (cf. Gaich, 2003).

Site investigation using JointMetriX3D consists basically of four steps: (i) image data acquisition, (ii) generation of 3D images, (iii) assessment of the 3D images, and (iv) derivation of descriptive rock mass parameters.

2.1 *Image data acquisition*

The core of the data acquisition step is the generation of high resolution digital images using a calibrated imaging system. Using a panoramic scanner, images of up to 360° field of view are taken. A panoramic camera has besides its high resolution (100 Megapixel) the ability to control the field of view in the two image directions independently (which is impossible for frame cameras). This means that a panoramic image can have 360° in one direction and a field of view ranging from 40° up to 320° in the other one which makes the system flexible and opens a wide range of applications.

Applying for example the system at a tunnel site, a single panoramic image contains both the actual face and the already excavated area which allows using already mounted displacement monitoring targets as reference points for the image. For the subsequent 3D image generation one needs at least two images of the same object taken from different angles. These two images can also be made sequentially. One full-scan takes about 3-4 minutes. Figure 1 (a) outlines the basic arrangement on a tunnel site.



(a) (b)

Figure 1: Basic geometric arrangement for imaging at a tunnel site (a). Shape from Stereo Principle (b). Camera A and B can also be the same when taking the images sequentially.

Another important prerequisite is the calibration of the imaging system usually done when changing the field of view of the image scanner (i.e. changing the lens) or in case of having a fixed lens from time to time, e.g. once a week depending on the frequency of use. The calibration procedure comprises the comparison of the actual image formation geometry of the panoramic scanner with the underlying mathematic model from which correction parameters are derived that allow to minimise image distortions.

2.2 *3D image generation*

This process follows the principles of classical photogrammetry (Slama, 1980) supplemented by more recent insights from Computer Vision where among others the calibration of off-the-shelf cameras was addressed (Faugeras, 1993). Having two images of the same object taken from different angles the classical Shape from Stereo principle is applicable. The principle is shown in Figure 1 (b).

The 3D image generation requires following tasks:
Prerequisites:

1) Calibration of the imaging system
2) Reference points (only if a referenced result is wanted)

For every 3D image:

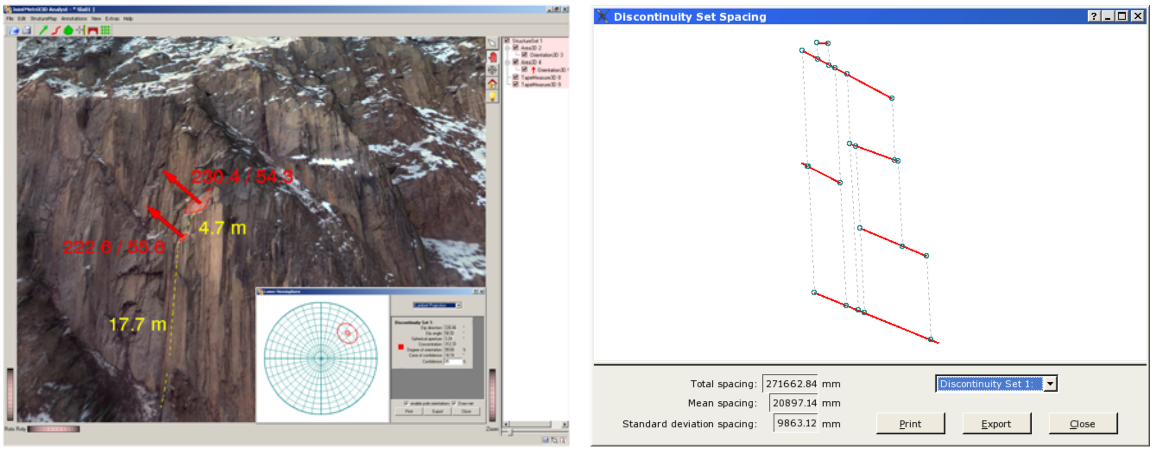
3) Determination of the relative orientation between left and right image of the image pair
4) Identification of corresponding image points
5) Computation of 3D points by spatial intersection using 3) and 4)
6) Connection of the 3D points to a surface description
7) Aligning image information and 3D surface description to a 3D image
8) Referencing the stereo setup using 2)

This way 25-30 megapixel referenced 3D images are currently possible.

2.3 *3D image measurements*

Once a 3D image is generated, measurements can be taken using a specially-developed software. It allows visualising the 3D image at arbitrary views (turn and zoom) which makes a realistic impression on the actual conditions. The 3D image is at full colour and shows detailed structures down to the mm range. This way overall views as well as regions of interest can be inspected and - through its three-dimensionality - analysed rather well.

The measurements itself are taken by setting graphical marks on relevant locations, e.g. on visible joints or joint faces. Dipping and dip direction is determined on joint faces similar to using a compass-clinometre device or automatically on joints when having a sufficient variation in depth along the surface, respectively. Distances are taken just by clicking on two locations. Figure 2 (a) shows an example for measurements at an inaccessible rock slope. On the right side of the image there is the structure list which supports the grouping of joints into sets by a drag and drop mechanism.



(a) (b)

Figure 2: Example for taking two orientations and two distances from a 3D image of an inaccessible rock slope. A stereonet is instantly available (a). Intersection lines from measured discontinuity orientations and a reference plane from which spacing is determined (b).

All measurements taken from the 3D image are inherently also in 3D. And if the 3D image was referenced by taking at least three reference points into account, all derived data are referenced as well. An important aspect of the measurement stage is that the user should know what to do during the assessment. However, the system itself is a basic tool for strongly supporting site investigation.

2.4 *Derivation of rock mass parameters*

The 3D image measurements enable the determination of geometric information in a given object co-ordinate system. Therefore all descriptive rock mass parameters that rely on geometric information of the discontinuity network can be derived from those measurements, e.g. joint length distribution, spacing, or spherical aperture.

In order to determine spacing, all measured orientations of a joint set are projected onto a reference plane resulting in intersection lines from which the distribution of distances is computed. This is analogous to a scan-line technique (Priest, 1993) but having now the possibility to use as many scan-lines as wanted, having no restrictions on a sampling window, and to deal with non-parallel discontinuities. Figure 2 (b) shows an example.

3 APPLICATIONS AND DISCUSSION

The imaging system can be adapted to various object sizes and working distances. So far rock faces from 3 – 300 m were recorded at working distances from some metres up to more than 500 metres, which showed even not to be the limits for the system. However, main applications are within tunnel face mapping, in subsurface and open pit mining, as well as analyses of rock slopes and the documentation of existing structures.

3.1 *Tunnels*

The application in tunnelling bears some major advantages. First of all the 3D image is an objective document of the actual rock mass conditions allowing reproducible analyses. Next, the decoupling of the data acquisition from the assessment process allows an arbitrary number of measurements in a given object co-ordinate system leading to a tremendously improved data basis. Site investigation does not longer require manual access to all locations where measurements are wanted. Finally, the resulting 3D images and measurements can be exported and connected with existing software tools, such as CAD systems.

As the Austrian Guideline for the Geomechanical Design (ÖGG, 2001) suggests for tunnelling to continuously update the geological model in order to compare the actual system behaviour with the predicted one, it is obvious that best possible data - detailed and unbiased - should be used. Besides, better knowledge on the rock mass itself allows optimising excavation.

3.2 *Mines and rock slopes*

As the imaging system is adaptable, it is also useful for surface mining, where usually two or three benches or a whole quarry is captured with a single 3D image. Mapping time can be reduced by more than 80% as no access is needed for measurements and data itself gets more reliable. An important aspect in this context is the possibility to quickly change the observation scale, since being close to a large rock wall the overview might have got lost resulting in compass readings at sub-optimal locations. Data can be incorporated in existing site modelling software or numerical programs. As a by-product the excavated volume is derived from 3D images taken from time to time. This is also valid for subsurface mining applications.

4 OUTLOOK

Great advantages can be achieved by the 3D image measurement method. However, ongoing work shows extended possibilities, such as supporting the 3D image assessment by algorithmic image processing components resulting in trace maps at a shorter time. Another development is to use the measured discontinuity network together with the computed 3D surface in order to determine removable blocks from which (i) instabilities in rock slopes are detected and (ii) a warning system for tunnelling can be implemented (Pötsch, Schubert & Gaich 2004).

REFERENCES

Faugeras, O. 1993. *Three-Dimensional Computer Vision*. MIT Press, Boston, MA.

Gaich, A. & Fasching, A. & Schubert, W. 2003. Improved site investigation. Acquisition of geotechnical rock mass parameters based on 3D computer vision. In: G. Beer (ed.) *Numerical Simulation in Tunnelling*: 13-46, Springer, Wien.

ÖGG. 2001. *Richtlinie für die Geomechanische Planung von Untertagebauarbeiten mit zyklischem Vortrieb*. Österreichische Gesellschaft für Geomechanik, Salzburg.

Pötsch, M., Schubert, W. & Gaich, A. 2004.Computer based stability analysis of rock slopes in a blocky rock mass. Accepted for the Eurock 2004 & 53rd Geomechanics Colloquium, Salzburg, Austria.

Priest, S.D. 1993. *Discontinuity Analysis for Rock Engineering*. Chapman and Hall, London.

Slama, Ch.C. (ed.) 1980. *Manual of Photogrammetry*. *4th edition.* American Society of Photogrammetry, Falls Church, VA.