The Use of Photogrammetryin Measuring Geologic Structures and Creating a 3D Model on Exposed Rock Faces

T. T. Dang[a]*

[a] *University of Mining and Geology, Hanoi, Vietnam*
* thanh.dangtrung@rub.de(*corresponding author's E-mail)*

Abstract

One of the most important tasks of geologists in the field is to measure fracture orientations on exposed rock faces. Measurements of these fracture orientations are normally done manually using a compass-inclinometer device on exposed rock faces as well as in tunnels, caverns, mines or other underground spaces. Doing so can be time consuming and sometimes a very risky process.

The objective of the paper is to present a simple survey equipment system and general algorithm for automatic measurement of fracture orientation (dip and dip direction) on exposed rock surface and for 3D reconstruction model and then combine the results of the engineering geological investigation to estimate the stability of the slope. Surface Mapper (SM) is a device that uses digital images to measure dip and dip direction of the geologic structures and create 3D model on exposed rock. The software is coded using Microsoft Visual Basic 6.0 with the help of GIS tools following photogrammetric concept. Few slopes have been used to test the survey equipment and the algorithm.

Keywords: Photogrammetry; Fracture orientation; Surface Mapper.

1. Introduction

Fracture orientation measurements on exposed rock faces are usually taken by compass inclinometer device. The drawbacks when using this method is that it is time consuming if many fractures are needed to measure at once and that measurement might be impossible if the rock face cannot be safely reached physically. In order to eliminate these problems, different techniques and methods are used recently in modeling and measuring fracture orientation as well as determining the roughness of the rock surface.Nowadays, the Digital Photogrammetry seems to be more advantageous in measurement sensitivity, practicability, functionality and in cost, as compared with other techniques (Unal, 2000) such as Laser, Profilometry and Stringline. Therefore, the use of Photogrammetry methodology is used in this study.

The American Society for Photogrammetry and Remote Sensing (ASPRS) in the Mapping Sciences defines Photogrammetry as *"the art, science, and technology of obtaining reliable information about physical objects and the environment through the processes of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena"*. The development from Classical to Digital Photogrammetry have simplified field and laboratory works. As a result, from the typical topographic mapping applications, photogrammetric techniques are now being used in the field of Architecture, Engineering, Geology, Archaeology, and Medical Science, to name a few. A method for applying a non-reflector total station for measuring fracture orientation is presented by Q. Feng, et al., (2001).Another method that uses Digital Photogrammetry was introduced by Poropat (2001), which is used for mapping rock masses. Aside from profilometer, a high resolution Kodak DCS 420 digital camera is also used (Lee. H, et al., 2001) for estimating roughness of rock surface. An application using laser sensor profilometer in measuring roughness of rock surface was introduced (Lee and Ahn, 2004). Each method presented usually has advantages and disadvantages, to reduce some of these disadvantages, the purpose of this study are to introduce and brief an algorithm for automatic measurement system to consider a new technique, a new method and a new way to measure geologic features and estimating tunnel and slope stability accordingly; and to improve field mapping of excavated surfaces, which is based on the concept of Photogrammetry. This will provide a new way of collecting measurements in an exposed rock. The software SM is developed, which is based on the concept of Photogrammetryand co-ordinating withMicrosoft Visual Basic 6.0. It can measure orientation of geological structures, can model rock surface in 3D and can analyze the failure criteria.

2. Methodology

The SM isestablished based on the concept of Photogrammetry.The methodology and algorithm implemented in the Surface Mapper (SM) is showed and illustrated in Fig.1.It can be briefed into 7 steps: (1) acquisition of image from the field; (2) calibration of the lens; (3) conversion of RGB to Intensity value; (4) determination of matching points using a fast matching algorithm; (5) calculation of overlapping areas of two images; (6) calculation of 3D coordinates of the matching point; and finally, (7) calculation of dip and dip direction using plane equation.Detailed procedure for each step, the papers of Dang (2007; 2008) are recommended for further reading.

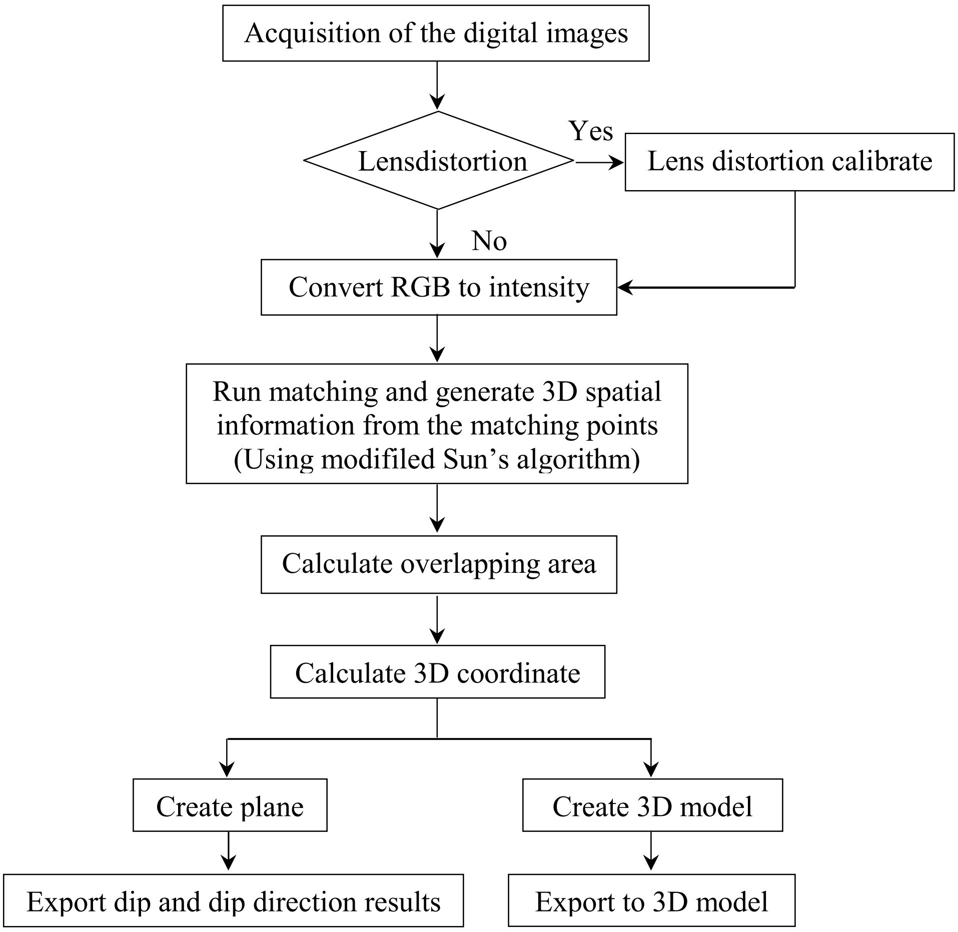


Fig. 1. Flow chart for the image processing

3. Hardware and Software

In theresearch, a portable system was designed and developed. It consists of a hardware and a software, named Surface Mapper (SM).The description of the entire equipments is provided in the next section.

3.1. Hardware

The entire equipments used for this set-up are digital cameras, lens, tripod, and Surface Mapper Equipment System (SMES).

3.1.1. Digital Camera

Photographs were taken using a Nikon D70 non-metric digital camera, as shown in the Fig. 2 below. The camera has high-resolution CCD (Charge Coupled Device) sensor, 23.7x15.6 in size, and the image is from 3008 x 2000 to 1504 x 1000 in pixel size. The system uses 4.0G CompactFlash™ Card for storing picture, making it easy for transferring photos to personal computer or laptop.

Fig. 2. NiKon D70 digital camera

3.1.2. Lens

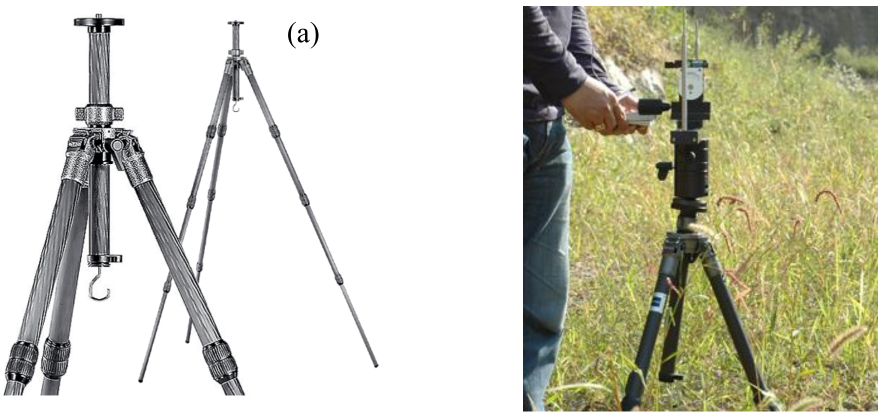
Camera lenses used is either 50mm or 105mm focal lengths from NiKon, as shown in the Fig. 3 below. For 50 mm, AF Nikkor 50mm f/1.8 D Lens is used for shorter distance from the camera setup to the target points. However, for greater distances, AF Nikkor 105mm f/2.8D Lens is used. Usually, lenses with a maximum aperture of f/1.8 and more need not require for distortion correction.

(a) (b)

Fig. 3. Nikon (a) AF 50 f/1.8D and (b) 105mm f/2.8D

3.1.3. Tripod

Any generic tripod can be used by the equipment. However, for this study, tripod system model G1227LVL from GitZo Company is used as shown in the Fig. 4. It is portable and easy to set-up in the field even in rough topography. It has a maximum height of 52.3 inches (132.842 cm) with extended center column of 61 inches (1554.94 cm), and closed length 21.6inches (54.864 cm). In addition, this tripod has four leg sections and weighs only 3.84 lbs.



(a) (b)

Fig. 4. Tripod (a) and set-up of tripod in the field (b)

3.1.4. Surface Mapper Equipment System (SMES)

The SMES is composed of a sliding bar with graduation, camera holder, and two iron sticks as show in Fig. 5. It is used for rotating, moving and leveling the camera.

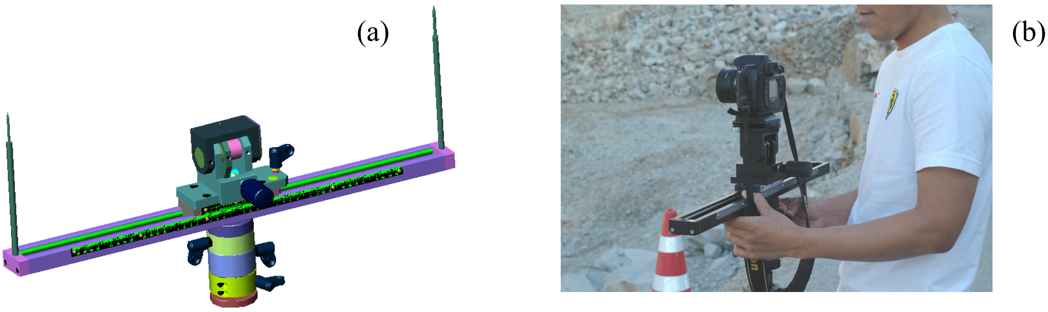


Fig. 5. 3D model (a) and set-up of SMES in the field (b)

3.2. Surface Mapper (SM)software

A software named Surface Mapper (SM) is developed. Fig. 6 show the main screen menu of SM system.

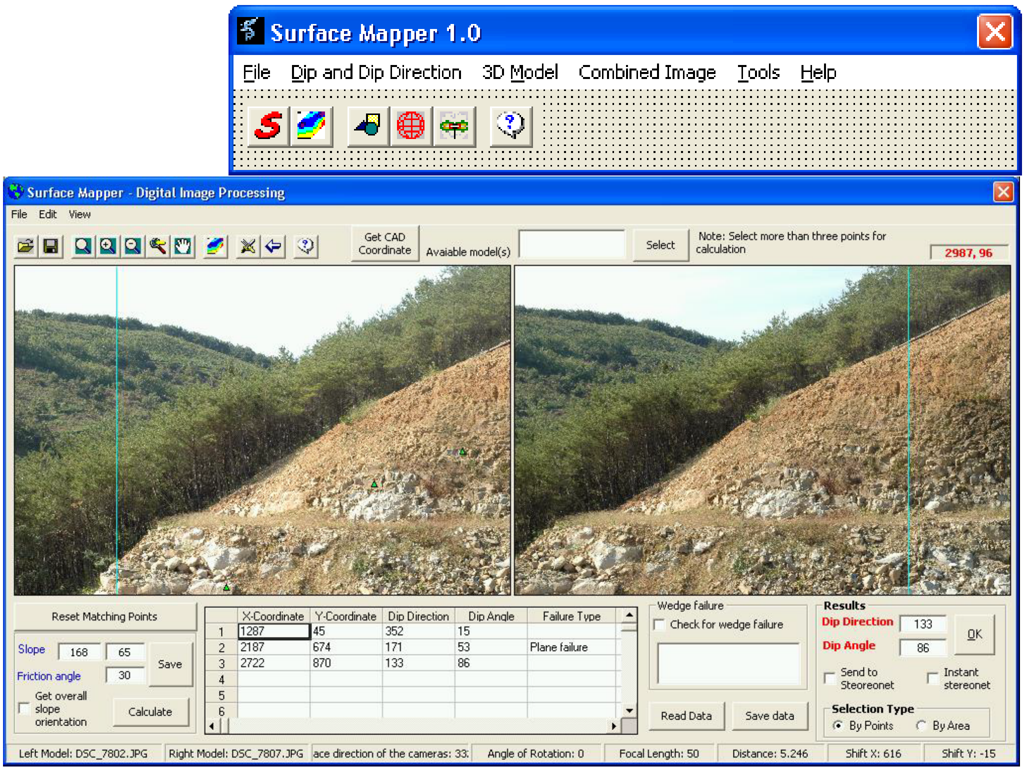


Fig. 6. Main menu of SM software

The menu of software consists of:

(i) File; creating and opening project files;
(ii) Dip and Dip direction; calculating dip and dip direction;
(iii) 3D Model; generating 3D model;
(iv) Combine Image; combining all photos in one slope, loading measured data to Autocad and drawing it's cross section;
(v) Tools; analyzing slope stability and plotting the measurements to stereonet and rose diagram;
(vi) Help; knowing more about the software.

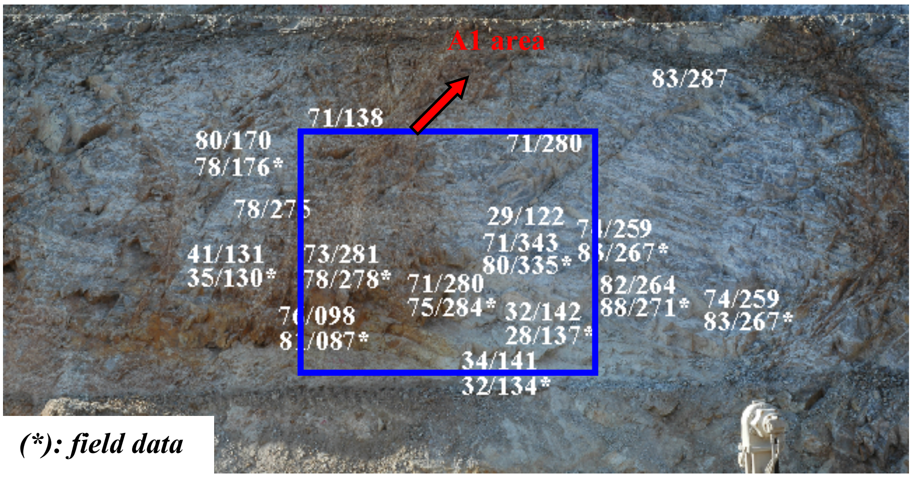
The main functions of SM system are schematically shown in a flowchart as shown in Fig. 7.

4. Application and discussion

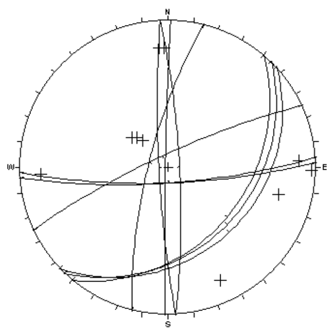
SM system has been successfully applied to some locations in Korea for different purposes. Areas include OkChon, Busan, YonGi, KongJu, Sosan-Nocsan, TongYeong, and Saengbiryang. This section presents one of the result obtained from these projects.

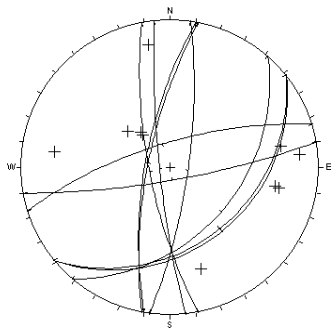
4.1 Application in Kumi slope

A slope along the highways of Kumi is used to verify the accuracy of SM method. The excavated surface is about 45m x 20 m. The distance between the setup and the rock surface is in the range of 25 to 35 meters.



Compass measurement Photo measurements Create 3D model for A1 area





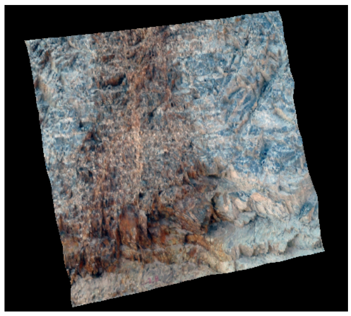


Fig. 7. Comparison of Compass and SM measurement in Kumi slope

In the field, 11 planar data (*) are selected and measured using conventional inclinometers and 16 planar data are selected and measured by SM system. Orientation measurements of these fractures are shown in Fig. 7 and listed in Table 1.

Table 1 Orientation measurements of fractures exposed on the rock face in Kumi

No	From SM		Compass		Deviation	
	DA (°)	DD (°)	DA (°)	DD (°)	Δ /DA/ (°)	Δ /DD/ (°)
1	80	170	78	176	2	6
2	41	131	35	130	6	1
3	73	281	78	178	5	3
4	76	098	81	087	5	11
5	71	280	75	284	4	5
6	71	343	80	335	9	8
7	32	142	28	137	4	5
8	34	141	32	134	2	7
9	74	259	83	267	9	8
10	82	264	88	271	6	7
11	74	259	83	267	9	8
			Average Deviation		5.545	6.28

Note:DD, dip direction; DA, dip angle; Δ /DD/, absolute value for deviation of DD between manual method and SM; Δ /DA/, absolute value for deviation of DA between manual method and SM

Results in Table 1 indicate that the deviation between SM system and compass inclinometer method is 0 ÷ 90 for the DA and 0 ÷ 110 for the DD and average errors are 5.545 degrees for DA and 6.28 degrees for DD. The deviation in DD is larger than that of DA compared to the case in OkChon slope. Comparing the stereographic projections of conventional and SM methods show no difference as shown in Fig. 7.

4.2 Discussion of some factors affecting the accuracy of SM

The exposed patterns of fractures on the rock face can be divided into four cases as shown in Fig. 8. In case 1, fracture surface is well exposed, therefore, matching points can be selected easily on the fracture surface and the fracture plane can be easily defined. In case 2, fracture surface is exposed as two or more non-collinear trace faces. In this case, the matching points can be selected along the trace lines of the fracture surface, and the plane can be defined. In case 3 however, fracture surface is exposed as a straight line on the rock surface wherein in this case, fracture plane can not be obtained. In case 4, exposed surface of a fracture lies is a shadow area. In this case, fracture surface can be obtained correctly if the matching points are carefully defined.

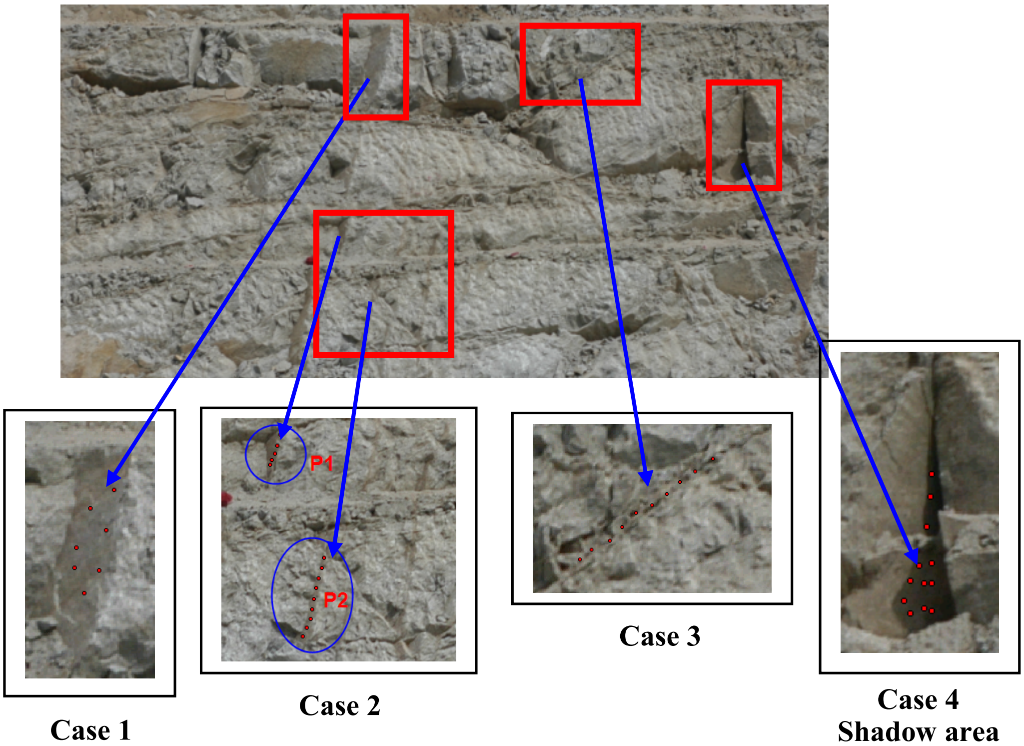


Fig. 8. Four exposure cases of fractures exposed at rock face

5. Conclusions

In the paper, the use of photogrammetric algorithm in order to develop of SM software was short described. Within the research, a digital cameras measurement system of fracture orientation is described in detail. The SM is based on Microsoft Visual Basic 6.0 with the help of GIS tools following photogrammetric concept. The measurement of rock faces on the slope is integrated in SM. The system can help to measure geological structures fastly and accurately. The system is particularly useful for mapping inaccessible rock faces. SM gives new ways of collecting measurements in an excavated slope or tunnel and used for general slope stability analysis such as toppling, wedge failure, plane failure, and daylight as well.

In the future, the SM software can be expand to include sub-modules to reduce the error as mentioned in the discussion section above. In addition, the upgrade version SMsoftwarewill be released and it can be calculated and analyzed the data more faster.

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