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Discontinuity Orientation Mapping in Rock Slope using Digital Tools

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Abstract
This paper presents investigation into the extraction of discontinuity orientations using advanced digital tools and techniques. The research work develops a workflow for extraction of discontinuity orientations from 3D point clouds by using the integration of different digital tools.The methodology involves the collection of images from rock outcrops, followed by the application of structure from motion to generate accurate 3D object. These 3D models provide the basis for discontinuity extraction. This research work contributes to the advancement of rock engineering and geological studies by providing powerful solution for discontinuity orientation extraction. The versatility and importance of 3D point clouds is not only limited to geology but also in various domains such as construction, surveying, archeology, mining, agriculture, forestry etc.

Keywords
Joint Orientation, Point cloud, Structure from Motion, Stereonet

1. Introduction

The development of new technologies in the field of engineering has improved efficiency and accuracy. One of the developments that has made a large impact in the field of surveying is photogrammetry. Photogrammetry is defined as the art, science and technology of obtaining reliable information about physical objects and environment through processes of recording, measuring and interpreting photogenic images and patterns of recorded radiant electromagnetic energy and other phenomena [1]. Images from drone surveys can be used to make a 3D model using structure from the motion of a study area which contains a large number of point cloud data based on intensity, a reflection of lights, color etc.

The stability of rock mass primarily depends on the structural geology of the rock mass. Structural geology refers to the naturally occurring fractures in the rock masses such as joints, faults, bedding planes etc. These structures are also called discontinuities. The properties of discontinuities such as length, persistence, infilling, orientations, roughness etc. govern the failure behavior of rock mass. Discontinuity orientation is one of the major factors for governing rock mass properties as it determines the failure behavior of rock mass, the direction of movement of water in rock etc. The point cloud data of a rock mass can be processed further and helps in determining the detailed discontinuity orientation of rock mass. These techniques of using photogrammetry are not only limited to rock slopes. It can be used in tunnel face mapping, quick tunnel monitoring, deformation monitoring etc.

The collection of discontinuity data for stability analysis is much essential part of the overall stability of rock slopes. Discontinuities data can be collected using a compass by reaching a particular area. This process of measuring discontinuity orientation can be very risky process in critical slopes which is prone to failure. It is also a very expensive and time-consuming approach.The adverse condition and potential fatalities can be reduced by using modern photogrammetry. Difficult terrain slopes can be assessed by using drone surveys. Photos and videos from drone surveys can be used to determine the discontinuities orientation which can be used for further analysis of rock slopes. This process of using modern tools and techniques for discontinuity orientation data can be a faster, efficient and less risky method for data collection.

Figure 1: Traditional method of discontinuity mapping[2]

1.1 Objectives

The main objective of the study is to map the orientation of joints using digital tools.

2. Methodology

2.1 Point Cloud Generation

Point cloud is a three-dimensional representation of physical objects, surfaces or environments created by capturing the spatial coordinates of individual points in space. Each point in a cloud is defined by its X, Y, and Z coordinates, which corresponds to its position in a Cartesian coordinate system. Point cloud are generated using various technologies such as LiDAR, Photogrammetry etc. Point cloud offer a detailed and accurate depiction of surfaces and structures, capturing both geometry and spatial relationships. They can be thought of as a collection of data points that together form a comprehensive representation of objects. Point clouds containing denser point cloud has higher number of points and provide more accurate result. If RGB value of each point is recorded, colour information can also be recorded in point cloud.

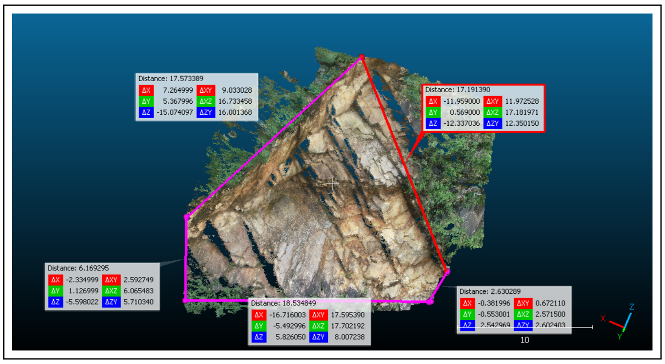

Figure 2: Point cloud

2.2 Structure from Motion

Structure from motion (SfM) is a technique which is used to construct the 3D structure of object using sequences of 2D images from different angles. SfM can be used with various types of cameras, smartphones, and drones. The process involves the detection of distinctive features from each image, such as corners, edges etc. These features serve as a reference point for matching different images. Extracted features are then matched across images to establish corresponding pairs representing the same scene points. Relative camera poses are estimated for each matched feature pair. Using the matched features and camera poses, 3D point cloud is computed which again converted to 3D model of object. The applications of SfM are far reaching and continue to shape various domain.

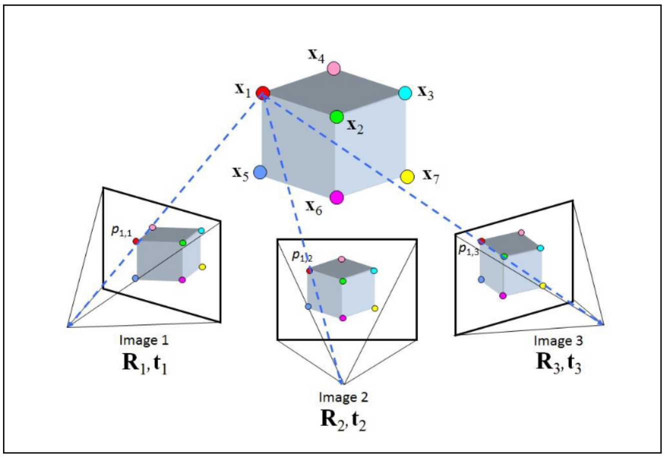

Figure 3: 3D model creation from Structure from Motion[3]

2.3 Point Cloud Processing

The generated 3D structure contains large number of point including noises.It involves various operations and techniques used to manipulate, analyze, visualize, and extract meaningful information from 3D point cloud. Processing of these point cloud is essential for application such as 3D modelling, mapping, simulation etc. The processing of point cloud involves various techniques such as data registration, alignment, noise filtration, subsampling, segmentation, feature extraction, meshing, surface reconstruction, normal estimation, object detection, change detection etc. Noise filtration of the point cloud is the process of removing unwanted data points from 3D point cloud. Noise in 3D point cloud can arise from various sources and can impact the accuracy and quality of point cloud. Unwanted data points are generally due to sensor errors, environmental factors (dust, rain, snow, fog), moving objects, object interference, lens distortion, etc.Subsampling of point cloud is defined as the process of reducing the number of points in point cloud data sets while attempting to preserve the essential features and characteristics of original data. It helps to reduce the computational memory requirement, removal of noise and simplification of geometry or structure.The point clouds were processed using CloudCompare v2.13 alpha.

2.4 Joints Orientation Mapping

The processed point cloud contains less number of points which can be easily handled to map joints orientaion.One of the features that is used in the study work is RANSAC shape detection which is used to detect planes.

3. Scope of Study

Photogrammetry plays a crucial role in tunnel face mapping, providing accurate and detailed information about geological conditions at the tunnel excavation face. Tunnel face mapping involves capturing and analyzing the geological features and structures in tunnel.

Once tunnel is in operation, photogrammetry can be utilized for structural monitoring. Regular scan and comparison with previous models help to detect settlement, deformations and other potential issues.

Photogrammetry also helps in the analysis of rock slopes by

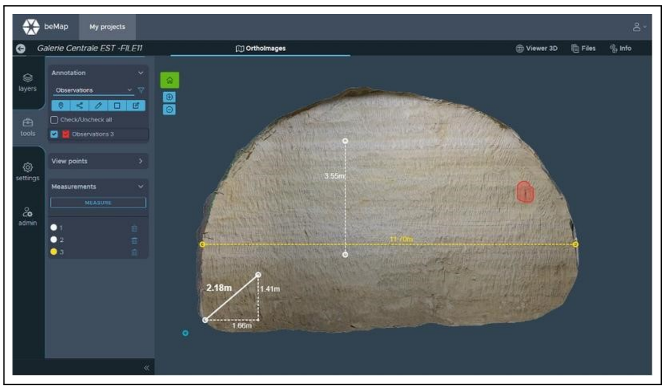

Figure 4: Tunnel face mapping[4]

providing accurate and quality measurements. In case of fractured rock mass, calculation of block size is important to prevent failure of rock mass. The calculation of all parameters such as length, breath helps to calculate the weight and to provide rock bolt.

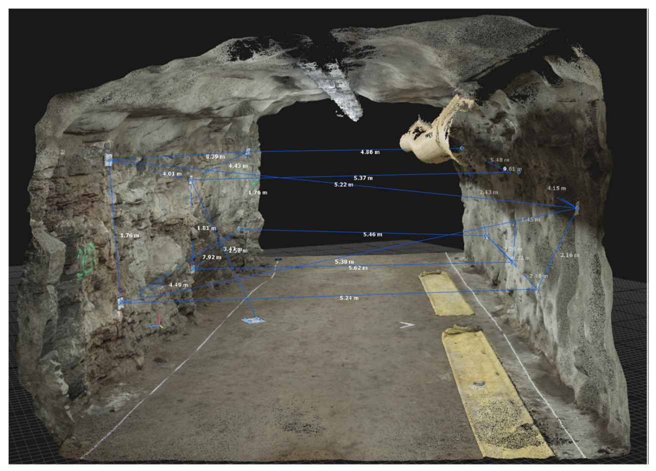

Figure 5: Tunnel deformation monitoring[5]

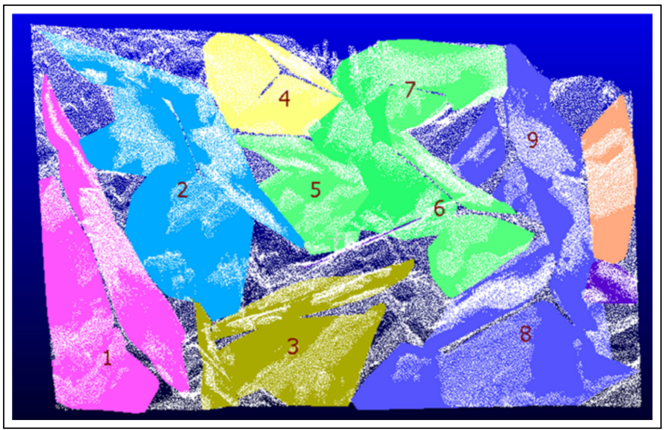

Figure 6: Block size detection in fractured rock slope[6]

4. Study Area

The study area is located at 28°08'30.1"N,83°51'43.13"E in Phedikhola Gaupalika of Syangja district.

Figure 7: Aerial view of study area

Bhalupahad is a steep hill located on the Siddhartha highway on the way to Syangja from Pokhara.The total stretch of the hill is about 800m but the selected section for research purpose is a small part of the hill stretch located at initial portion of the hill on the way to Waling from Pokhara.The selected area is a road cut rock slope of average length of 50m and average height of 20m. The study area comprises of metamorphic rock like phyllite, metasandstone of Naudanda Quartzite. The area consists of block rock mass as well as sheared rock mass which helps to know the consistency of the research work in all rock mass conditions

5. Data Collection

Data collection involves two ways. First one is collection of close shot images of exposed rocks from different angles with 60-80% overlap. Second one involves collection of discontinuity orientation data using traditional compass for validation of the research work.

Image acquisition is the foundation step in generating point cloud from photos. It involves capturing of images that collectively represents an object from multiple viewpoints. The images were taken in good environmental condition to reduce the noise. To take photos from multiple angles, DJI Phantom 4 Pro drone was used. The drone was flown over the rock cut slope to take picture of rock slope from all around it. The camera of the drone was good but the gimbal of the camera was shaky which might have affected the work.

Figure 8: DJI phantom 4 pro

The mapping of discontinuity orientation is done by using a Brunton compass. The total length and height of study area was 50m and 20m respectively. It was difficult to measure all the joints of the rock slope manually. So, the joints near the ground level which were identified and measured with compass. All the joints which were in reach from ground level were measured using compass and noted in the field book. Measured orientation of joints was plotted in stereograph to validate the result obtained from the photogrammetry work.

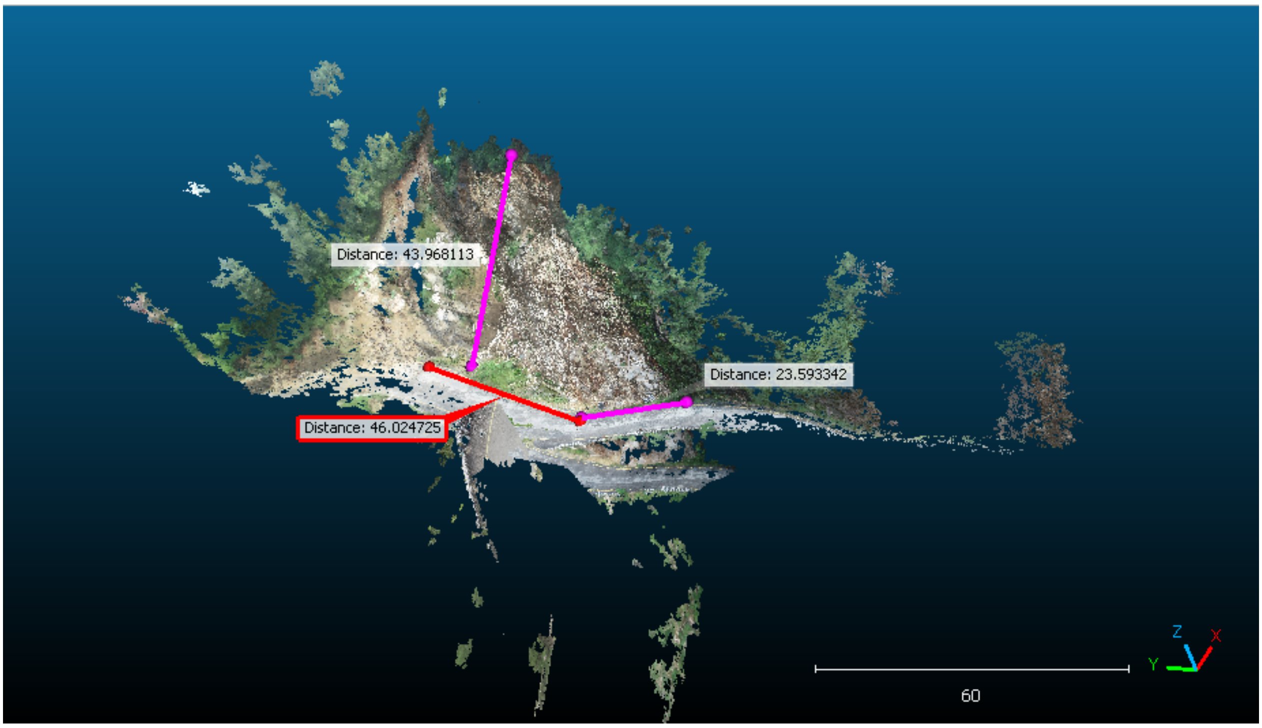

Figure 9: Generated point cloud visualized using CloudCompare

6. Result and Discussions

The point cloud provides a comprehensive dataset that allows for precise analysis of any object. Point cloud serves as a foundation of further analysis to extract discontinuity orientation extraction. The accuracy and richness of point cloud data are crucial for gaining deeper insight in the work. The generated point cloud contains 122541686 points. It also contains some noise which was filtered.

Table 1: Discontinuity orientation mapping using geological compass

S.N	Dip Direction	Dip Amount	S.N	Dip Direction	Dip Amount
1	202	44	17	7	49
2	250	71	18	225	39
3	286	66	19	337	74
4	205	49	20	355	39
5	295	65	21	299	85
6	305	85	22	200	39
7	336	55	23	334	70
8	296	79	24	341	73
9	295	66	25	296	80
10	285	61	26	285	85
11	220	85	27	205	45
12	295	69	28	344	61
13	214	40	29	236	40
14	275	62	30	332	69
15	270	83	31	210	39
16	347	45	32	297	76

The height study area was about 20m. Due to large height, it was difficult to access all portion of the area. So, only lower part of the area which was accessible was mapped using geological compass. The total number of mapped discontinuity orientations in lower part were forty-four and these data were plotted in stereonet to visualize the density of joints.

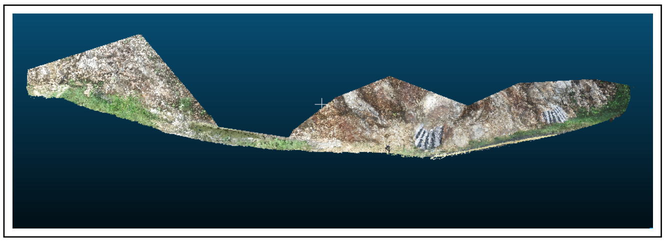

Figure 10: Mapped area using compass

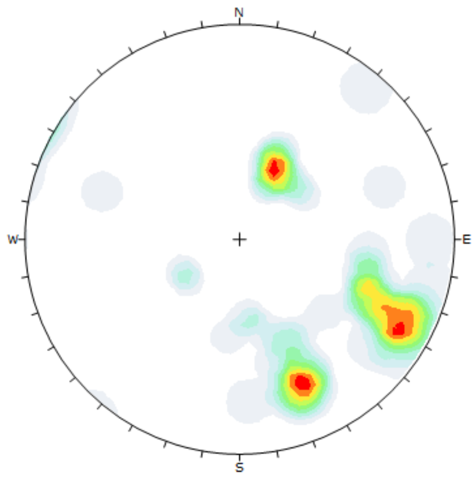

Figure 11: Joint density concentration(geological compass)

Computation of discontinuity orientation was done using compass plugin which is difficult to select plane and should be used precisely. The total number of planes detected were 115 using RANSAC and these data were plotted in stereonet.

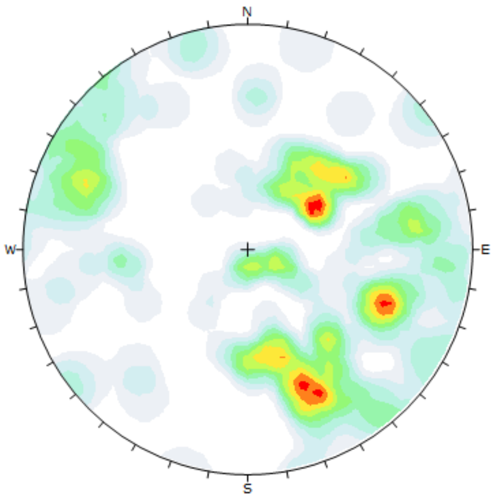

Figure 12: Joint density concentration(from point cloud)

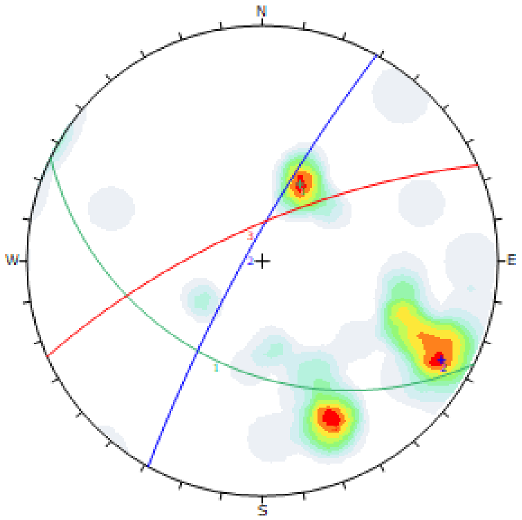

Figure 13: Major planes orientation (from geological compass)

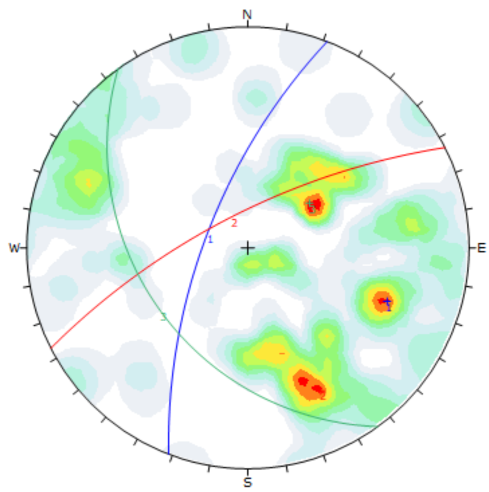

Figure 14: Major planes orientation (from point cloud)

Table 2: Major Plane (geological compass)

S.N	Dip Direction	Dip Amount
1	299	81
2	336	72
3	206	40

Table 3: Major plane(point cloud)

S.N	Dip Direction	Dip Amount
1	291	68
2	333	72
3	234	38

This study shows similarity in joint density pattern between geological compass data and point cloud data. There is a minimum deviation in major planes because of the differences in number of joints plotted between two plots on stereonet.

7. Conclusion

This study has demonstrated the effectiveness of utilizing digital tools for the accurate and efficient mapping of rock slope discontinuity orientations. These tools provide a comprehensive dataset, enabling a more robust characterization of rock slope conditions.Digital tools have significantly enhanced the accuracy and resolution of discontinuity orientation mapping compared to traditional manual methods.The study represents a significant step toward utilizing the capabilities of digital technologies to improve the safety, efficiency, and sustainability of rock slope management

8. Further Works

The mapping of discontinuity data using compass plugin takes longer time and it is difficult to select a plane. This problem can be solved using programming language which gives better result with faster computation time.

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