Fracture Systems – Digital Field Data Capture

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Introduction

Fractures, such as joints, faults and veins, strongly influence the transport of fluids through rocks by either enhancing or inhibiting flow. To understand the control that these structures play on subsurface flow, a range of empirical measurements are collected and used for attributing 3D models for flow simulations.

Digital field data capture is becoming increasingly popular in the earth sciences as it allows for the rapid data collection and post-collection processing. There are many software platforms available including; SIGMA mobile, FieldMove and Strabo Point, however, these applications are either restricted to specific platforms or are designed for general field data capture and not specifically for fracture data capture.

The open source Kobotoolbox in combination with XLSform was used to create 4 forms; Scanline Survey, Circular Survey, Fault Survey and International Society of Rock Mechanics (ISRM) Discontinuity Survey for rapid digital field data capture of fracture networks and rockmass characterisation. The use of a digital form-based approach is advocated as it ensures that data is collected consistently and validated in the field. This system allows for platform independence as it can be run through a mobile application or directly from a web browser.

The aim of this application is to allow crowd-sourcing of fracture data through a well constrained and validated methodology that is quick to undertake and easy to understand. In return for data submission, users should be able to retrieve their data as well as any other open data and be able to produce professional reports.

ISRM Discontinuity Survey

The engineering community can play an important role in fracture data collection as it forms a key part in site investigations. The International Society for Rock Mechanics (ISRM) have set out a Suggested Method for the Quantitative Description of Discontinuities in Rock Masses (Barton, 1978) which this form follows. The majority of rock masses, in particular those within a few hundred metres from the surface, behave as a fractured rockmass, with the fractures largely determining the mechanical behaviour. It is therefore essential that both the structure of a rock mass and the nature of its fractures are characterised in order to understand how the rock mass will behave during and post construction.

ISRM
- ⦿ Number of Fracture Sets
- ⦿ Rockmass Weathering
- ⦿ Rockmass Seepage

Schmidt Hammer (Repeat for each reading)
- 123 Schmidt Hammer

ISRM Fracture (Repeat for each fracture set)
- 123 Fracture Azimuth
- 123 Fracture Dip
- ⦿ Spacing
- ⦿ Persistence
- ⦿ Roughness
- ⦿ Termination Type
- ⦿ Fracture Wall Weathering
- ⦿ Wall Strength
- ⦿ Apeture Width
- abc Aperture Filling
- ⦿ Aperture Filling Grainsize
- ⦿ Seepage Filled
- ⦿ Seepage Unfilled
- abc Note

Additional Collections

In addition to the key attributes as defined in the main form, the user has the option to collect an unlimited number of samples and photographs with corresponding ID and description.

Sample (Repeat for each sample)
- abc Sample ID
- abc Sample Description

Photos (Repeat for each photo)
- Photo
- abc Photo Description

Database

Site Description

All forms require site specific details to be recorded at the beginning of the survey. this includes a general description of the site as well as the location collected directly form inbuilt GPS units of manually entered. The co-ordinates are collected in decimal degrees latitude and longitude to allow for data collection across the globe. Photographs of the site can be added directly from an inbuilt camera if available or linked to from a file. Mobile phone based applications on some platforms allows for the capture of dip and strike/dip azimuth directly from the phones sensors. However, Novakova and Pavlis (2017) showed that there are large variation in the data collected from the sensors and there are many possible sources of errors. To ensure consistency in the data collected in these forms, dip and dip azimuth values are entered manually. Lithology classification is based on cascading sheets which build a lithology based on a number of successive options. In addition, metadata on the user is automatically collected including unique username, start time, end time, date, and device ID.

Site Description
- abc Site Name *
- abc Site Description
- ⦿ Data Privacy *
- Survey Photo
- abc Photo Description
- 123 Bedding Dip
- 123 Bedding Azimuth
- ⦿ What surface orientation is the exposure? *

Primary Lithology (Cascading Sheet)
- ⦿ Rock Group
- ⦿ Rock Type
- ⦿ Lithology

Faults Survey

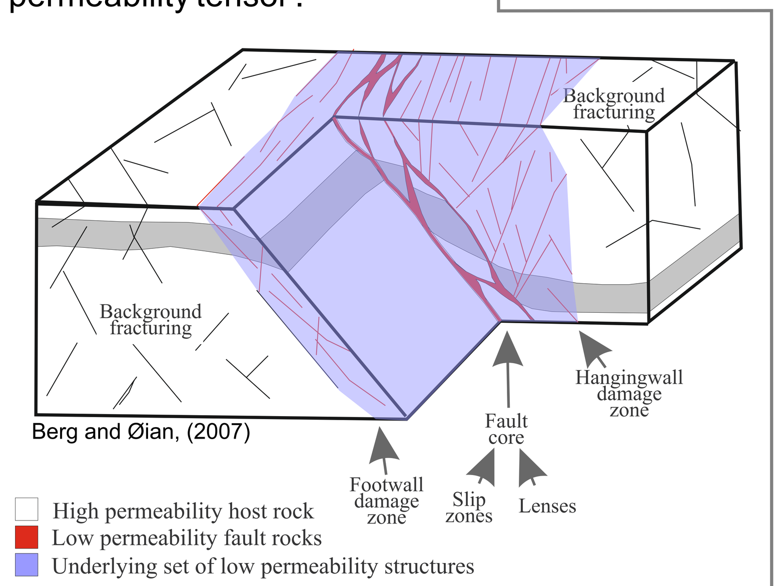
Faults are volumes of complexly deformed rock. Fault zones are often composed of a lower strain fracture-dominated damage zone surrounding a more highly strained heterogeneous fault core zone containing one or more slip surfaces, gouge and breccias, and oblique Riedel shears. The fault zone survey collects attributes (as described in McClay, 1987) related to the fault, fault core and fault damage zone. Additionally the damage zone can be surveyed using a scanline survey to understand the fracture intensity with distance from the fault core and hence an understanding of the permeability tensor .

Fault
- Fault Point *
- 123 Fault Azimuth *
- 123 Fault Dip

Bedding

Hangingwall Lithologies (Cascading Sheet)
- ⦿ Rock Group
- ⦿ Rock type
- ⦿ Lithology
- 123 Hangingwall Bedding Azimuth
- 123 Hangingwall Bedding Dip

Footwall Lithologies (Cascading Sheet)
- ⦿ Rock Group
- ⦿ Rock type
- ⦿ Lithology
- 123 Footwall Bedding Azimuth
- 123 Footwall Bedding Dip
- 1.0 Fault Length
- ⦿ Accuracy
- ⦿ Fault Termination 1
- ⦿ Fault Termination 2
- 1.0 Fault Width (core and damage zone)
- ⦿ Accuracy
- 1.0 Fault Offset
- ⦿ Accuracy
- 1.0 Hangingwall Damage Zone Width
- ⦿ Accuracy
- 1.0 Footwall Damage Zone Width
- ⦿ Accuracy



Berg and Øian, (2007)

Fault Core
- 1.0 Fault Core Width
- ⦿ Accuracy
- ⦿ Fault Rock Type

Movement Indicators (Repeat for each movement indicator)
- ⦿ Movement Indicators
- 1.0 Movement Azimuth
- ⦿ Accuracy
- 1.0 Movement Dip
- ⦿ Accuracy

Key:
- GPS point location
- Confirmation dialog
- Take/import photograph and annotate
- 123 Integer field
- 1.0 Real field
- abc Text field
- ⦿ Select one
- Question — Conditional question
- * Mandatory question

Scanline Survey

Scanline Survey

The scanline method (Priest and Hudson, 1981) tends to be favoured for field data collections as it is fast and records a wide range of fracture attributes. This method involves laying a tape on an outcrop and measuring attributes of each fracture that intersects the tape. To properly represent relative abundance between the fracture sets, multiple scanlines at different orientations should be used whereby a scanline is set up perpendicular to the strike of each fracture set on the outcrop. The scanline method can create orientation and length bias, and is sensitive to censoring, where large fractures are under-represented in data because their tracelengths are longer than the extent of the outcrop, so they are truncated and only a minimum size is recorded. The Scanline Survey may be more applicable where fractures are bed controlled or across fault zones to define fracture intensity in fault damage zones.

- Scanline Start Point *
- 1.0 Length of Scanline (m) *
- 123 Scanline Azimuth *
- 123 Scanline Dip
- 123 Azimuth direction working along scanline *
- Do you want to collect Samples?
- Do you want to take additional photos?

Database and Reporting

Once data has been collected and validated, the form is automatically uploaded to a local web server and stored in a database. This can either be done while in the field via mobile networks or be postponed until the user is in range of a local network with internet connection.

Future work will process the web server database and pass the data through an internal firewall to a relational database. This database will allow users to access their data as well as any open data collected. The user will be able to download the data as CSV files or ZIP files.

In addition to the data extraction, a number of processing options will be written in Python which will allow the user to generate automatic reports for each site. This would be of paticular importance to the engineering community based on the ISRM Discontinuity Survey.

Circular Survey

The circular scanline method is based on the augmented circular scanline method of Watkins et al. (2015) and the circular scanline method, outlined by Mauldon (1998), Mauldon et al. (2001) and Rohrbaugh et al. (2002). The method involves counting the number of fracture intersections with the circular line placed on an outcrop, and the number of fracture terminations within the circle. Fracture density, intensity and mean trace length within the area of the circle can be calculated based on a maximum likelihood estimator. This method is fast and unlike the scanline is not affected by length censoring. Using this method also eliminates orientation bias as fractures are not sampled along a single orientation like the linear scanline method.

- Circular Survey Centre Point *
- 1.0 Radius of Circular Survey (m) *

Circular Estimator for each fracture set (Repeat for each fracture set)
- 123 Mean Azimuth *
- 123 Number of fracture intersection with Circular scanline *
- 123 Number of fracture terminations within circular scanline *
- Do you want to measure fracture attributes?
- Do you want to take additional photos?
- Do you want to take any samples?

Fractures

To characterise fractured rockmass using outcrop analogues, several fracture attributes need to be characterised: orientations, degree and distribution of clustering, trace lengths, intensity/density and aperture. Individually and collectively, these attributes affect the connectivity and permeability of the fracture network in a rock volume.

Scanline Fracture (for each fracture intersection the scanline) (Repeat for each fracture)
- 1.0 Distance along Scanline (m) *
- 123 Fracture Azimuth *
- 123 Fracture Dip
- 1.0 Fracture Length (m)
- ⦿ Fracture Length Accuracy
- ⦿ Fracture Termination Left
- ⦿ Fracture Termination Right
- 1.0 Fracture Aperture (mm)
- ⦿ Fracture Aperture Accuracy
- ⦿ Fracture Open
- abc Filling

Contact Information

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