Towards Smarter Rock Mass Characterization: 3D Point Clouds and Semi-Automated Techniques

Finnish Rock Mechanics Day

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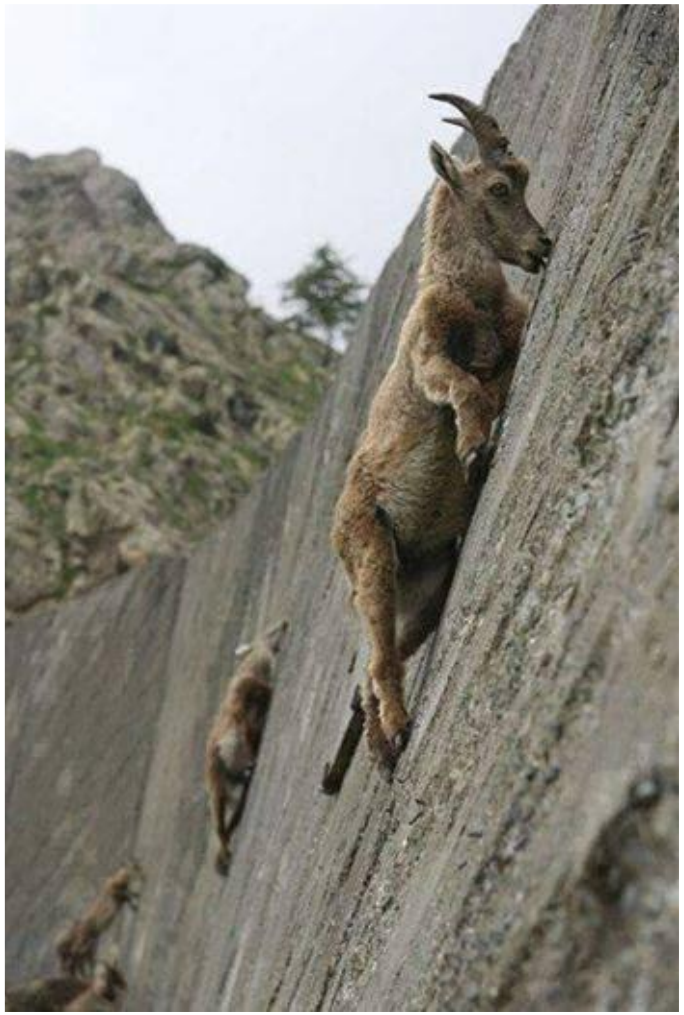
1. Introduction



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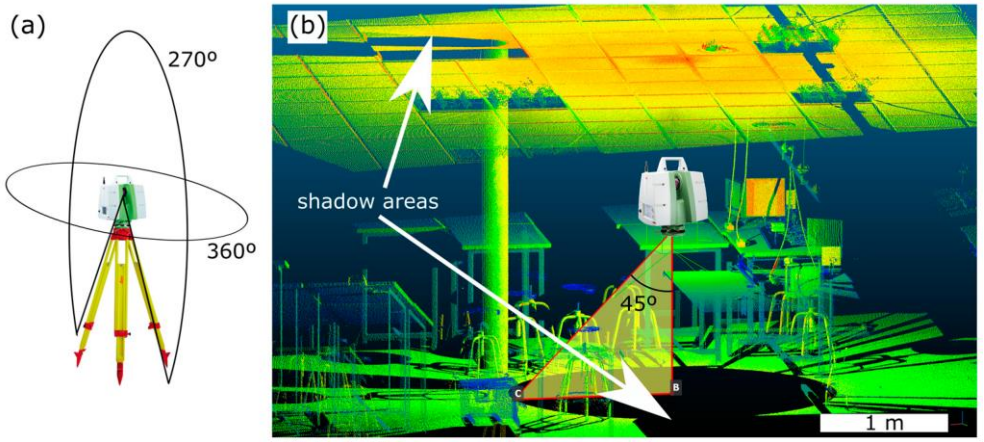
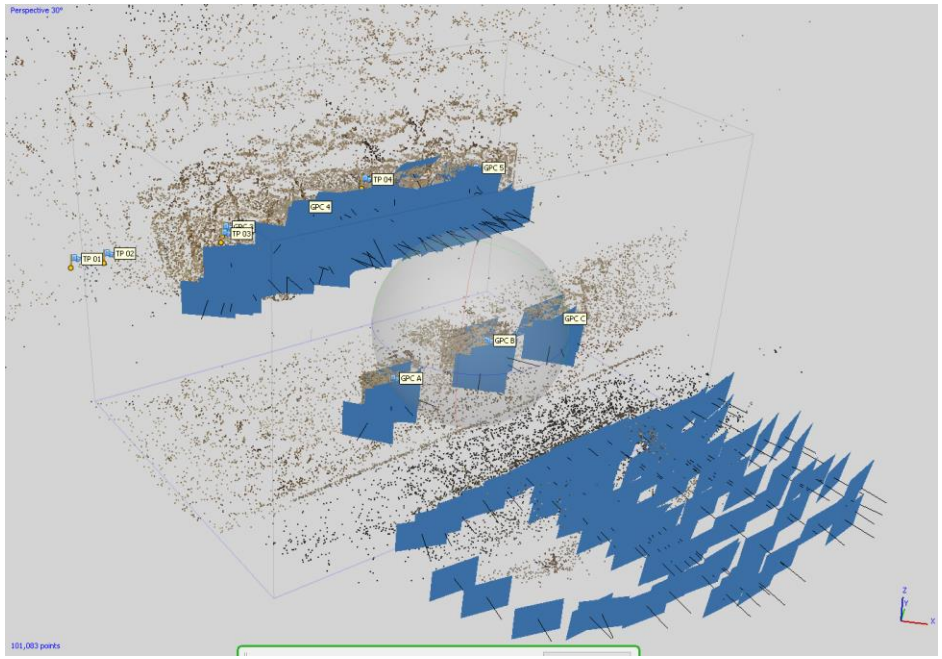
2. Data Acquisition: 3D Laser Scanning and Structure from Motion (SfM)



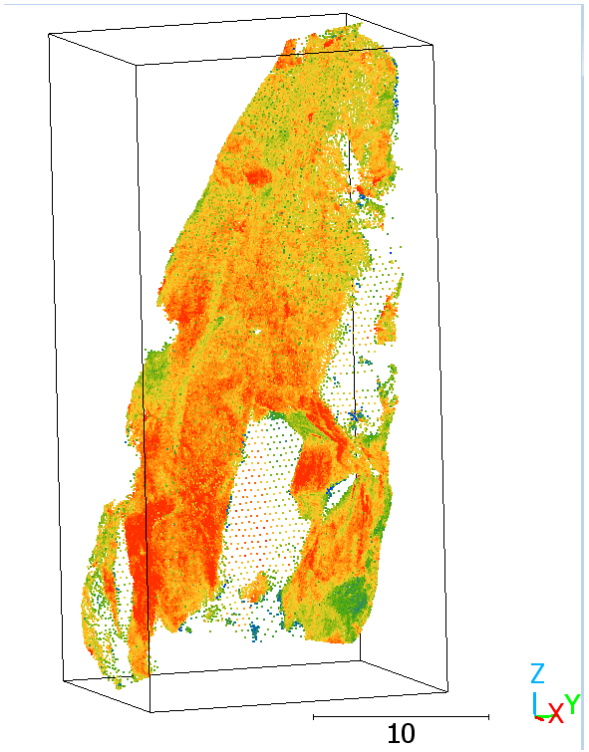
Pros:
✅ Effective for long-distance data acquisition
Cons:
⚠ Presence of shadow zones due to occlusions
⚠ Relatively high cost of equipment and operation

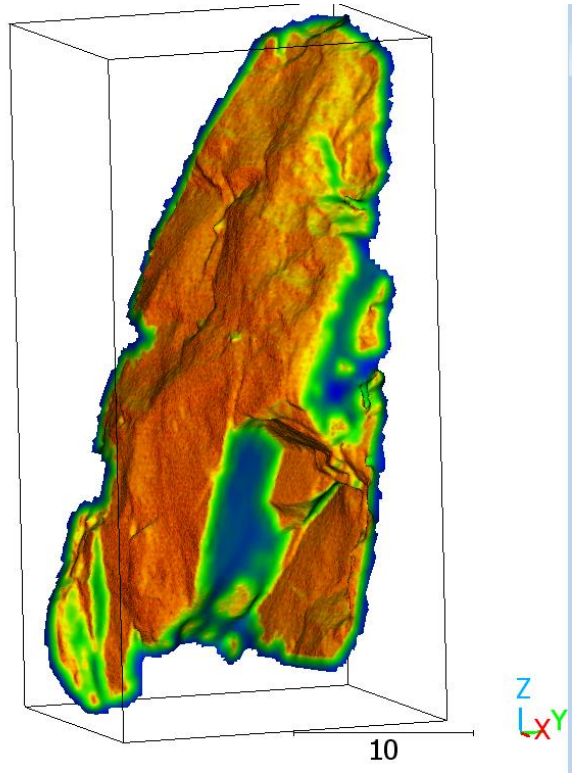


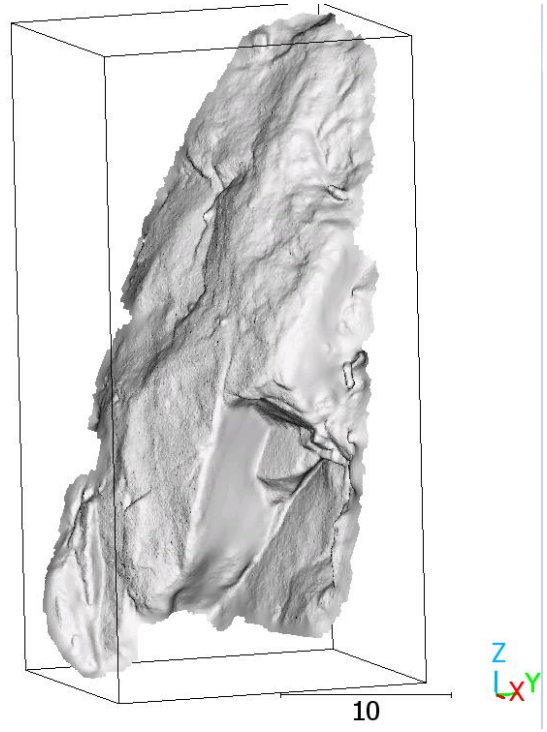
Pros:
✅ Cost-effective
✅ Wide coverage
✅ Rich colour data
Challenges:
⚠ Precision varies (camera, geometry, conditions)
⚠ Reconstruction depends on texture, lighting, overlap

3. Requirements and Expectations from Point Cloud Data

Density and completeness

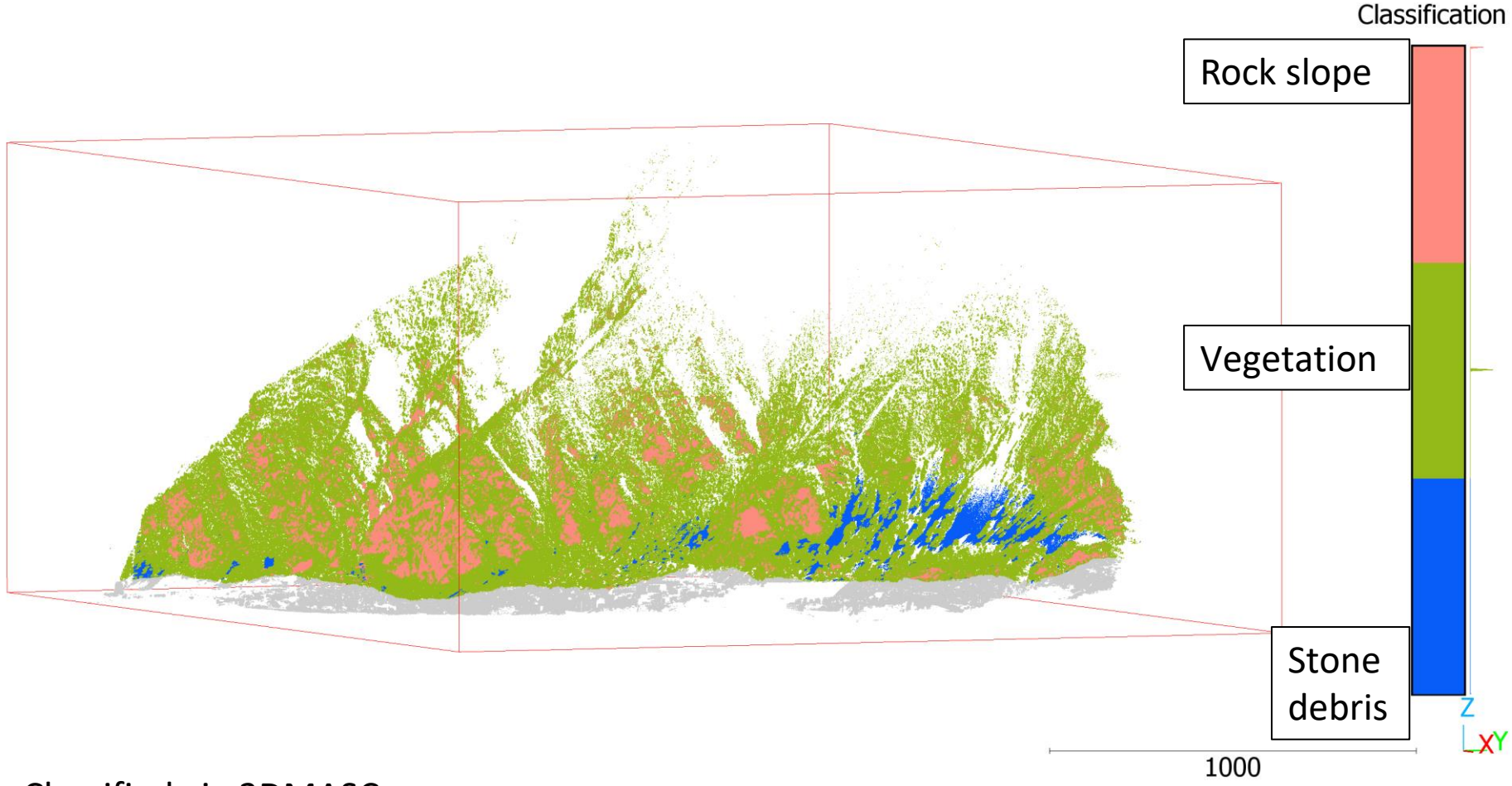






3. Requirements and Expectations from Point Cloud Data

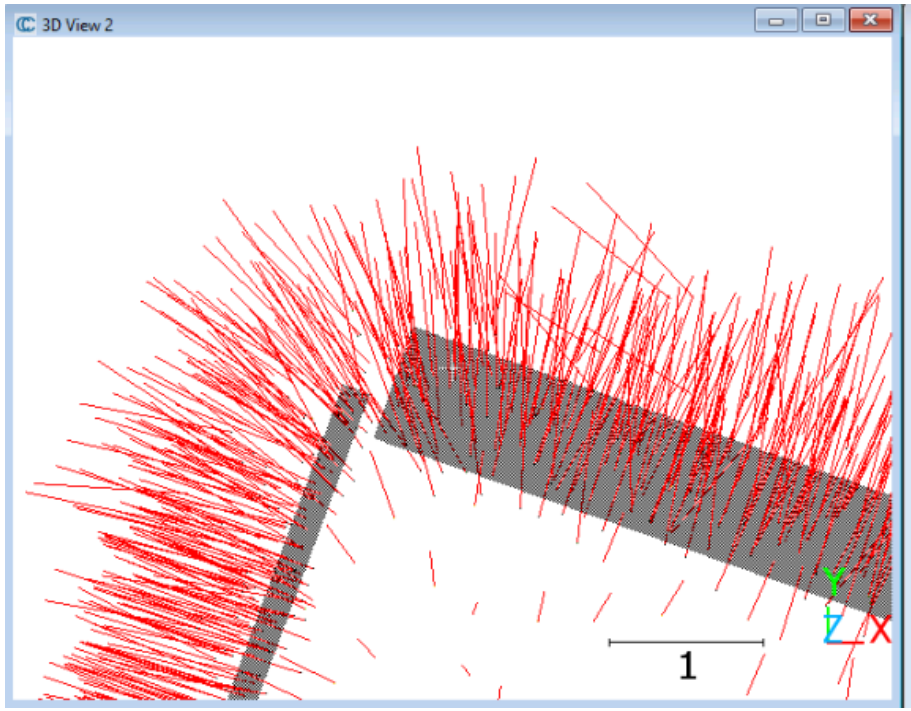
Noise levels and filtering



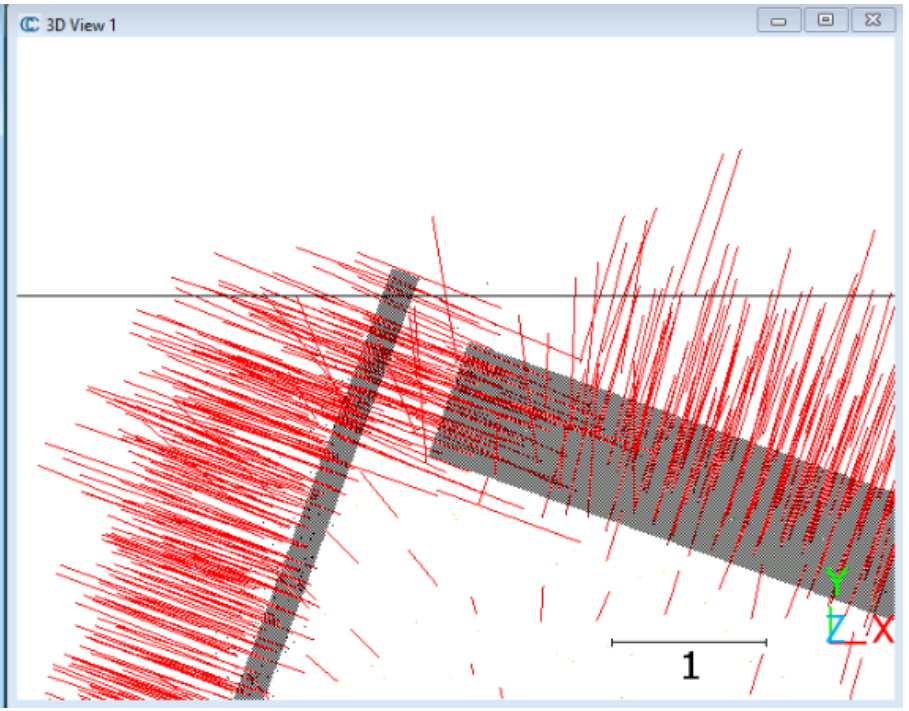
Classified via 3DMASC

Georeferencing and scale

- 1st step: calculate normals: crucial

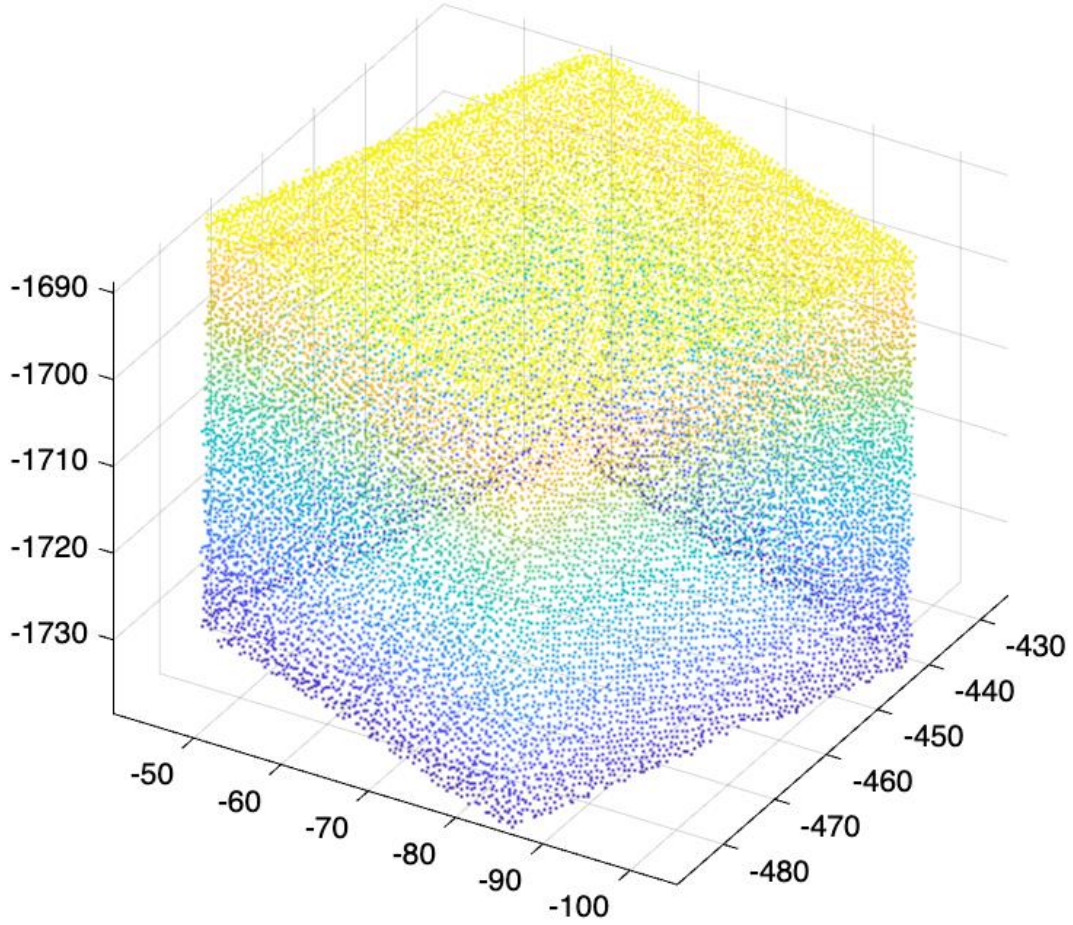


K-NN Neighbours

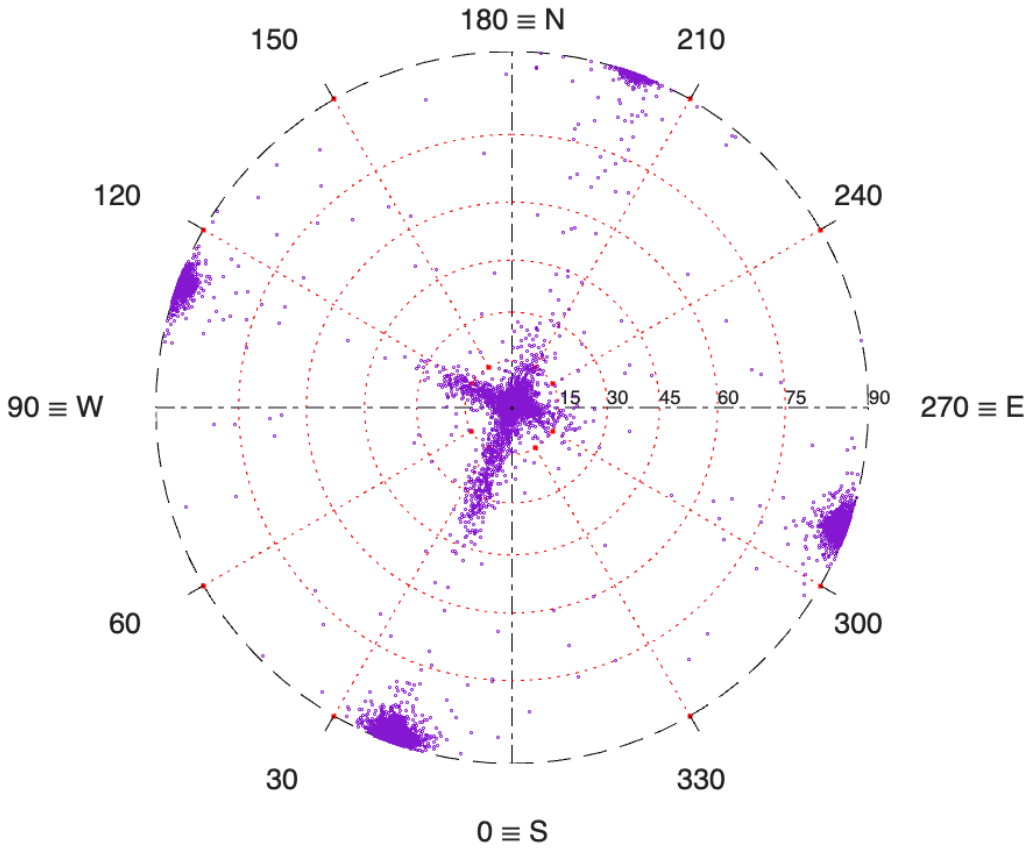


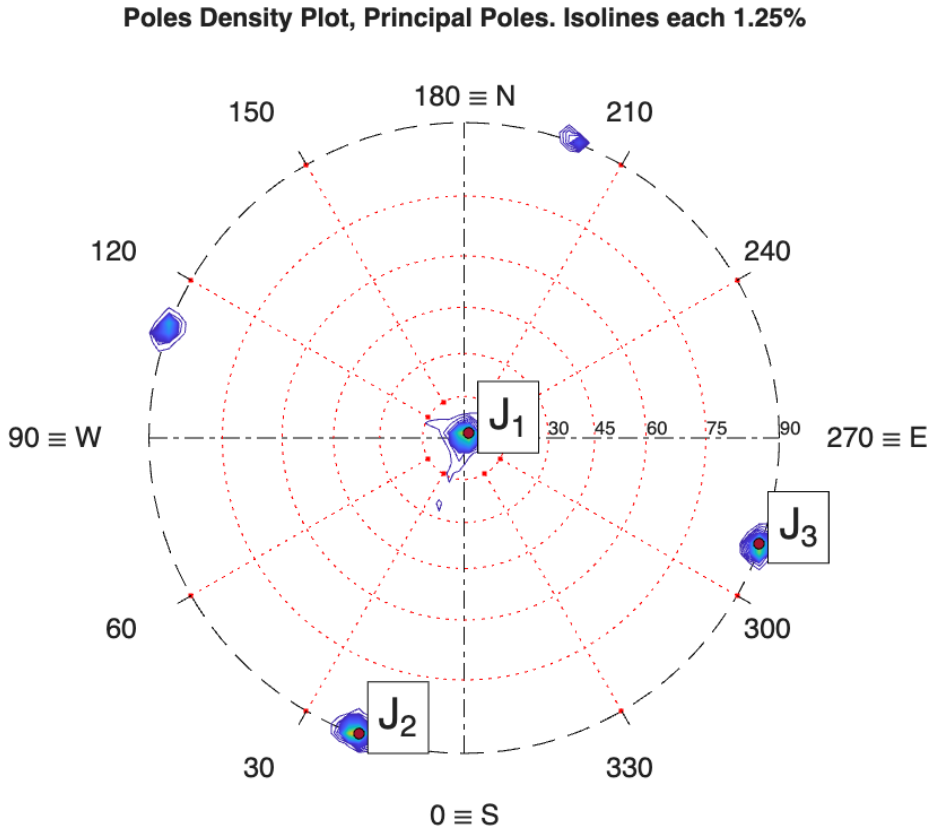
Hough normals

- From normals to stereonet or sphere (new)

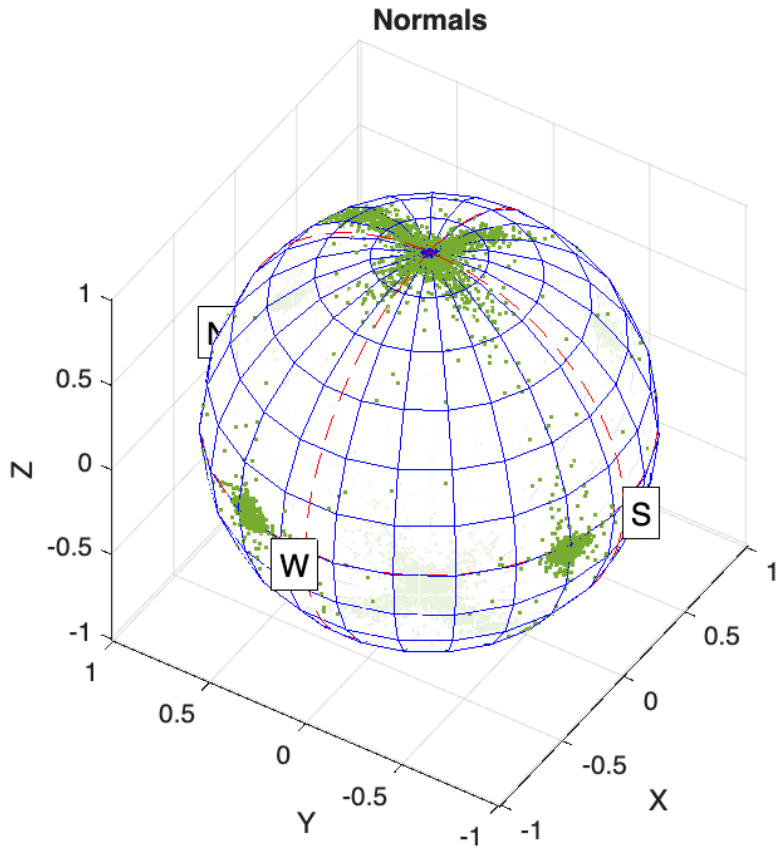


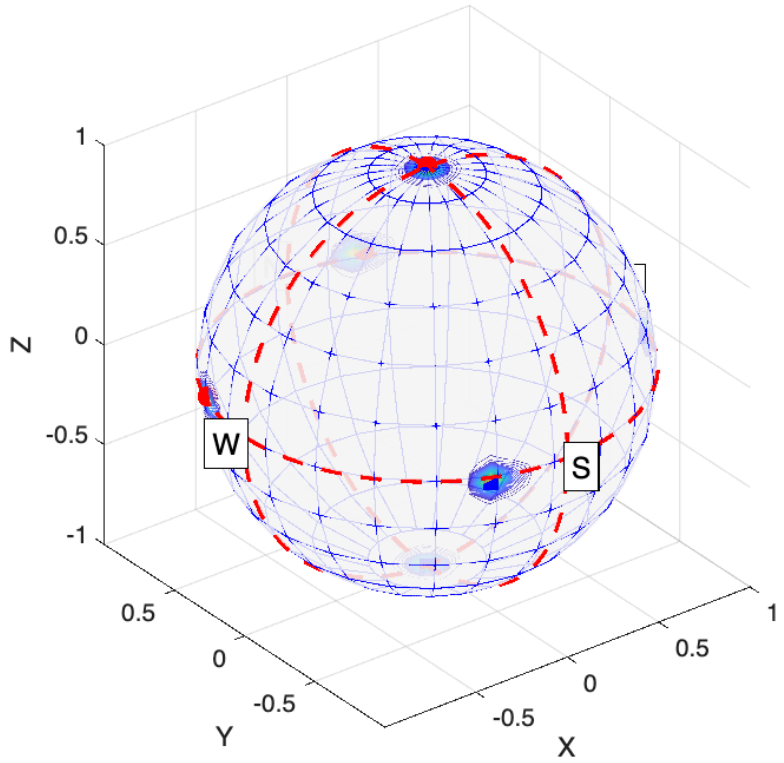
- From normals to stereonet or sphere (new)
- Edge effect, distortion (equal-angle, equal-area)



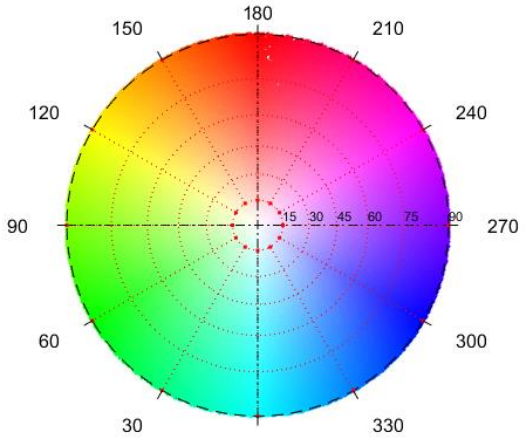


- Normals can be analysed on a sphere (R=1)
- No edges, no distortion

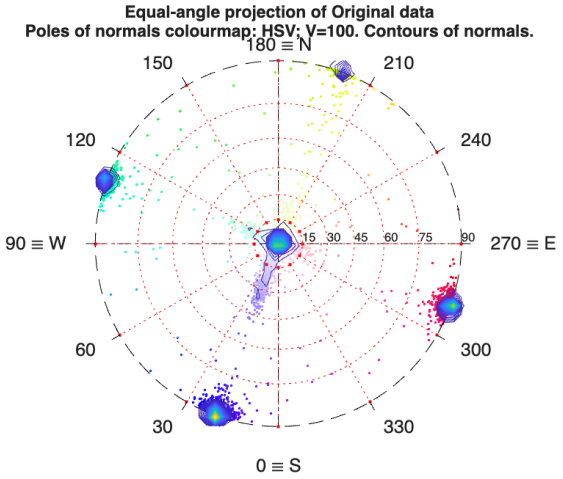


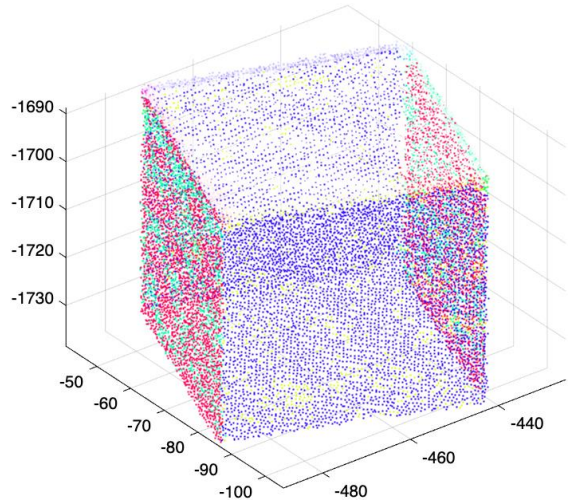


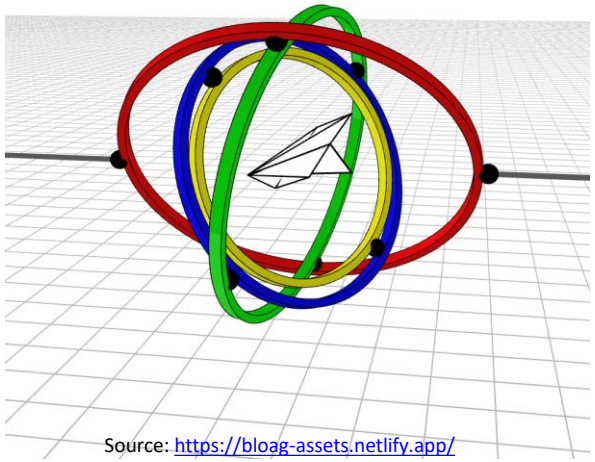
- Colour mapping via normals



HSV colourmap







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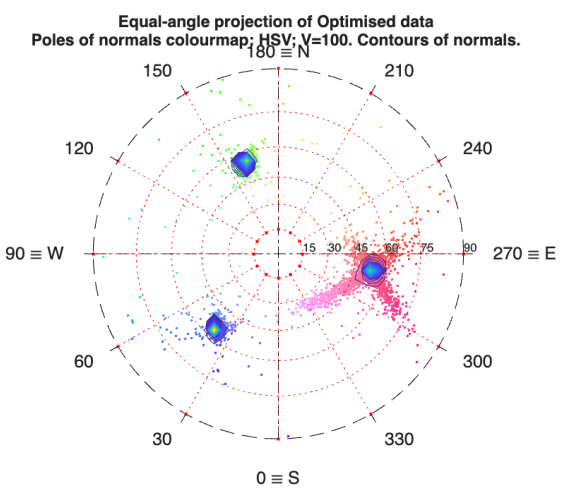
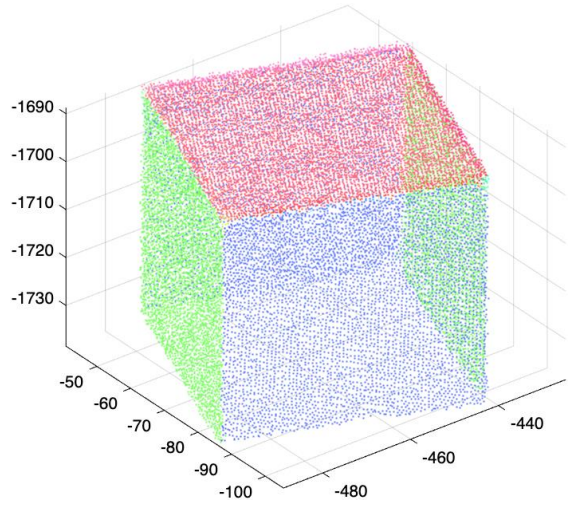
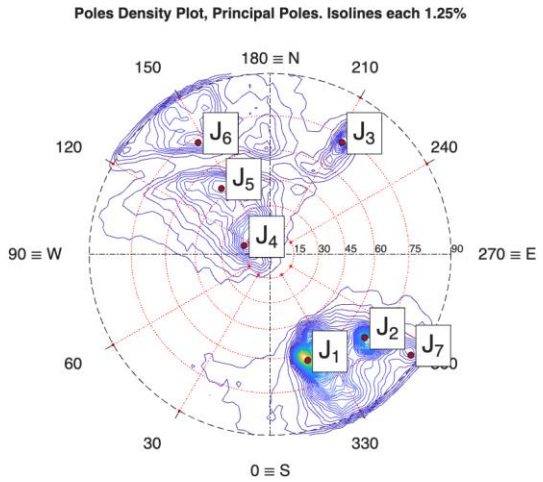
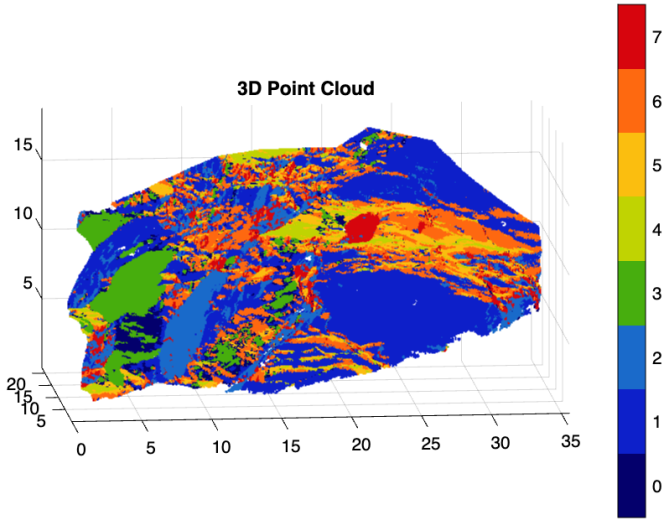
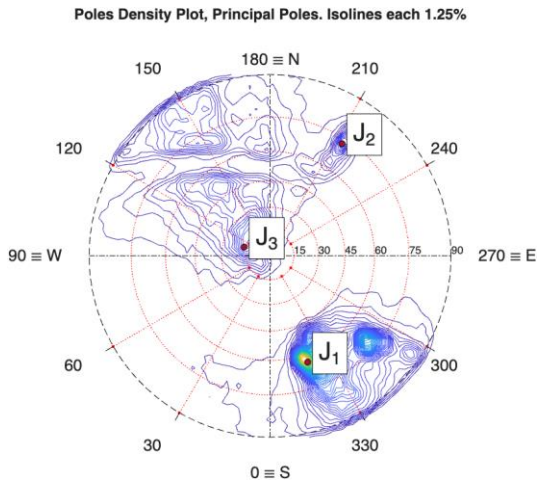


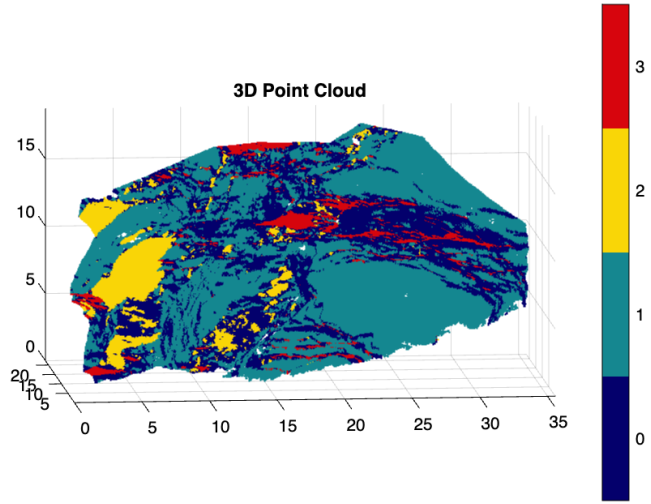


- Key: Identify the number of discontinuity

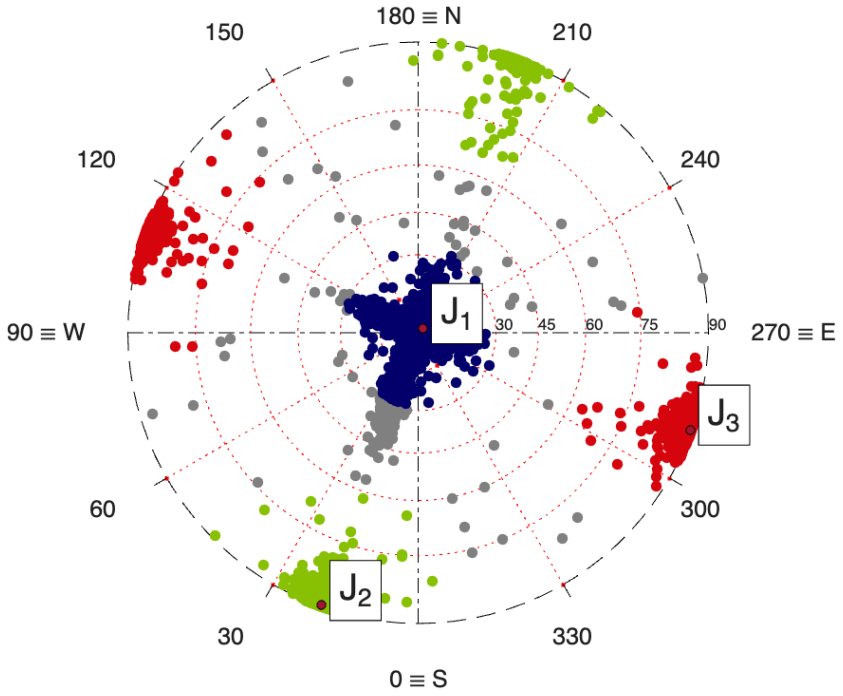


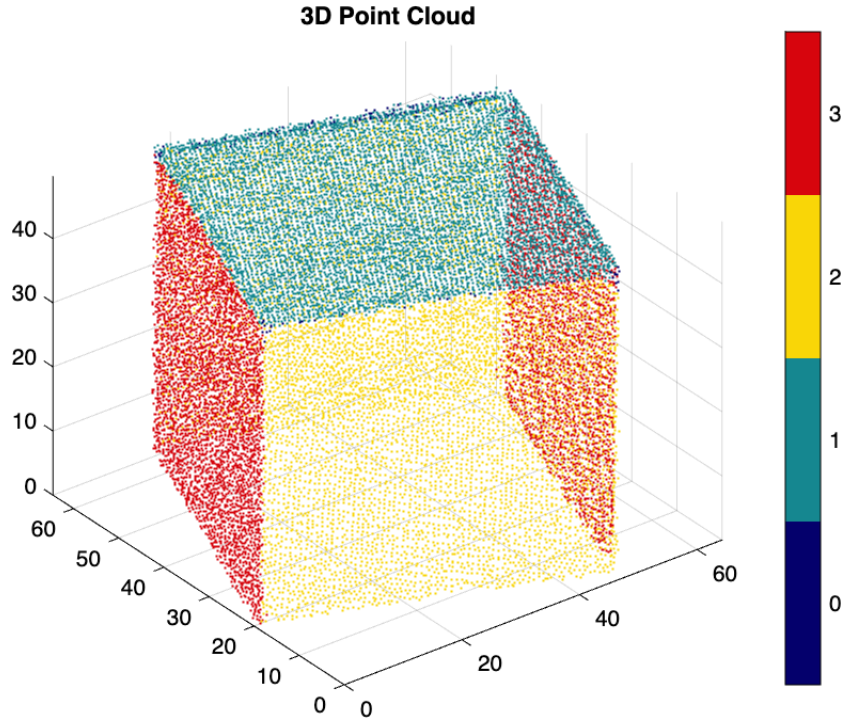






- Assign to each point a DS





4. Fundamentals of orientation Analysis in Rock Slopes

$$A \cdot x + B \cdot y + C \cdot z + D = 0$$

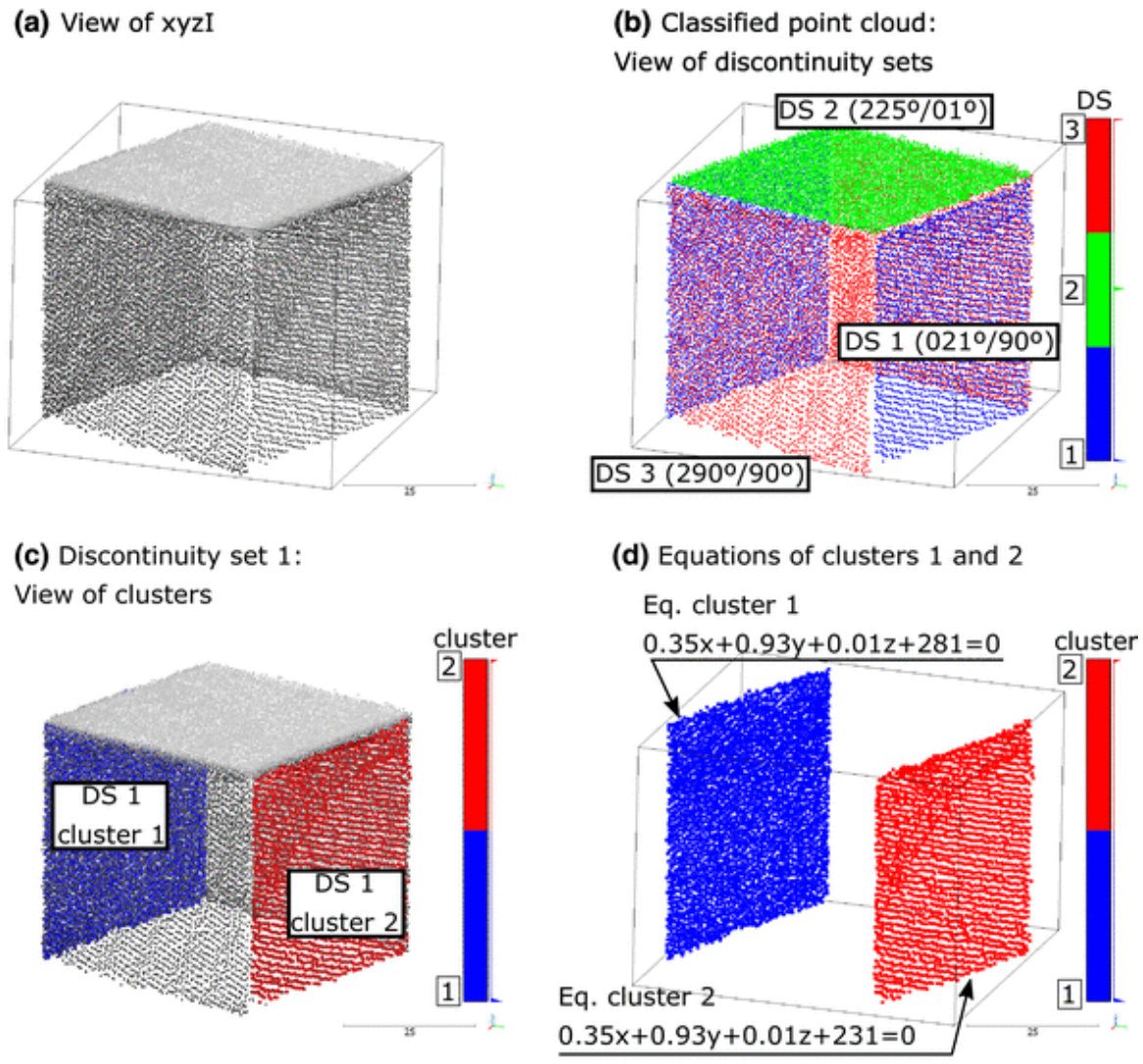
X – Y - Z | JS - Cl | A – B – C - D

cube_limpio_s05_Hough xyz-js-c-abcd.txt

1	-488.971710205078	-86.6408081054688	-1714.318359375	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645
2	-488.957611083984	-87.1498489379883	-1704.30285644531	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645
3	-488.9326171875	-87.2145080566406	-1703.09326171875	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645
4	-488.912658691406	-86.1306915283203	-1737.15368652344	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645
5	-488.909973144531	-86.4613494873047	-1732.451171875	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645
6	-488.898040771484	-86.869743347168	-1737.03173828125	1	1	0.341828124048606	0.939762487870957	6.12323399573677e-17	249.258579947995
7	-488.860534667969	-86.1357727050781	-1735.85400390625	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645
8	-488.853240966797	-87.1112976074219	-1734.05700683594	1	1	0.341828124048606	0.939762487870957	6.12323399573677e-17	249.258579947995
9	-488.842132568359	-86.6592178344727	-1728.69262695312	1	1	0.341828124048606	0.939762487870957	6.12323399573677e-17	249.258579947995
10	-488.830841064453	-86.9435577392578	-1725.21252441406	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645
11	-488.814025878906	-86.8137741088867	-1727.92980957031	1	1	0.341828124048606	0.939762487870957	6.12323399573677e-17	249.258579947995
12	-488.796539306641	-86.7619094848633	-1706.23974609375	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645
13	-488.786285400391	-86.4976119995117	-1707.14074707031	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645
14	-488.783416748047	-86.7800445556641	-1712.07482910156	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645
15	-488.781219482422	-86.3961181640625	-1719.66394042969	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645
16	-488.761199951172	-87.0941925048828	-1721.31237792969	2	1	-0.94233559517433	0.334669428044214	6.12323399573677e-17	-431.109672481645

4. Fundamentals of orientation Analysis in Rock Slopes

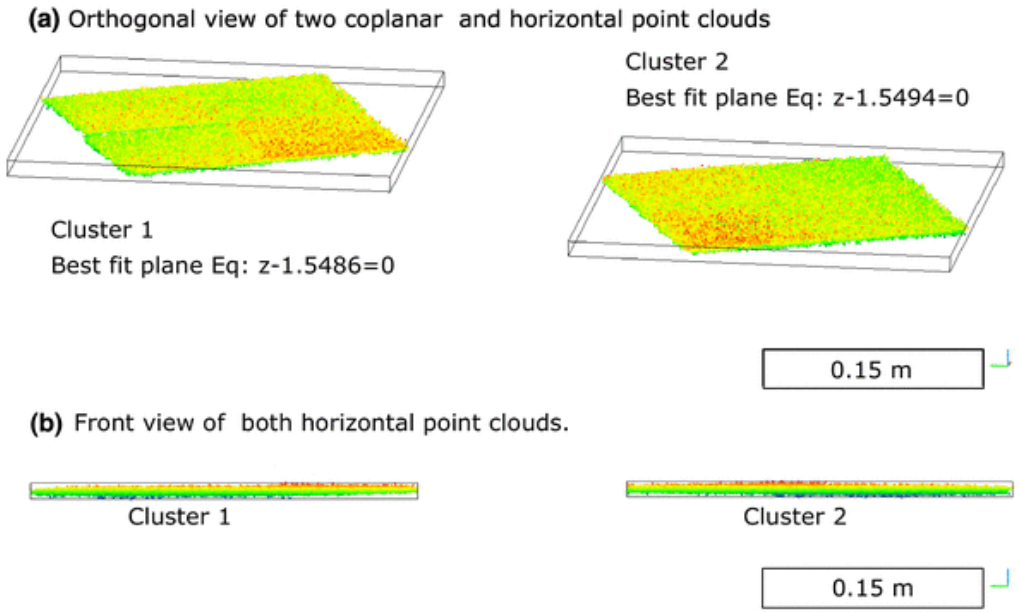
The 3DPC is classified in joint sets and clusters, with their corresponding plane equation



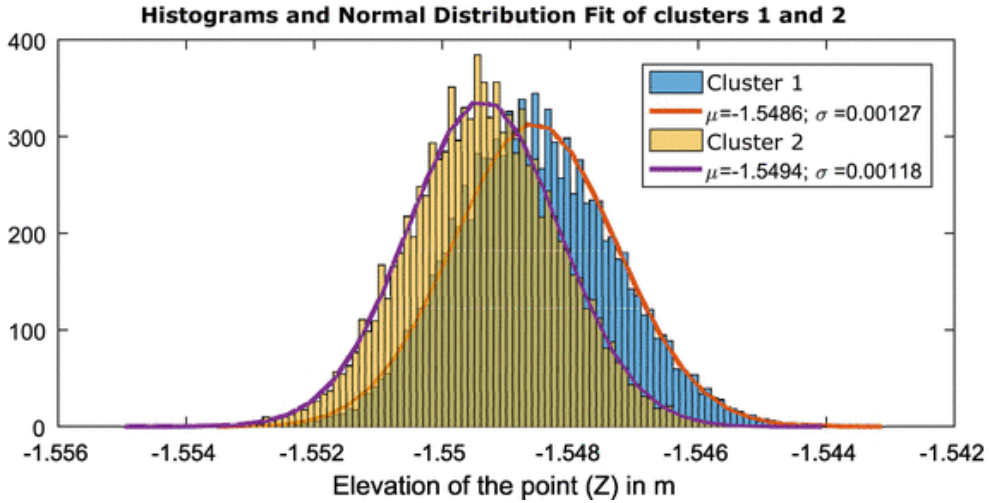
Source: https://link.springer.com/article/10.1007/s00603-018-1519-9/figures/2

5. Analysing Classified Point Clouds for Discontinuity Characterization

Check whether two planes are coplanar
Adjust the parameter accordingly



(c) Histogram of the elevations of clusters 1 and 2

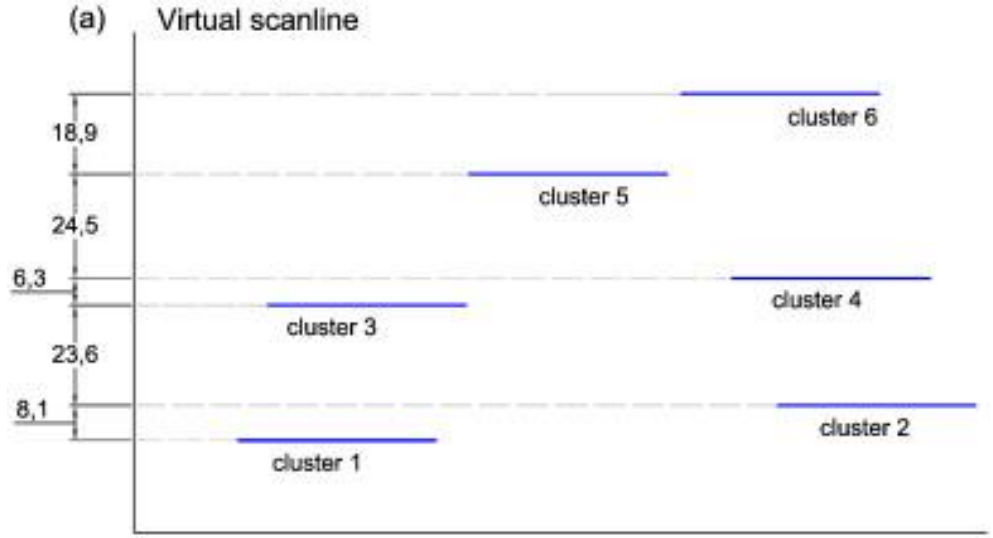


Source: https://link.springer.com/article/10.1007/s00603-018-1519-9/figures/3

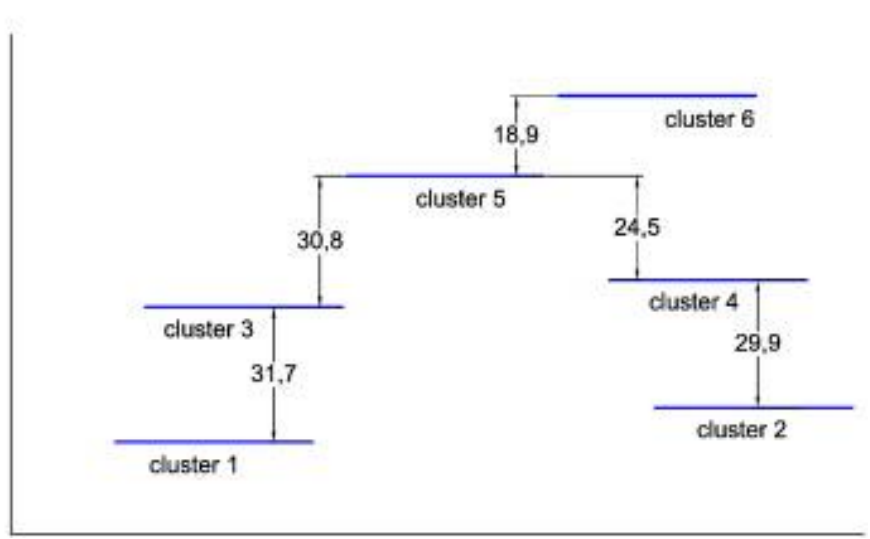
5. Analysing Classified Point Clouds for Discontinuity Characterization

Measure the normal spacing:

(a) Assuming persistence



(b) Assuming no persistence

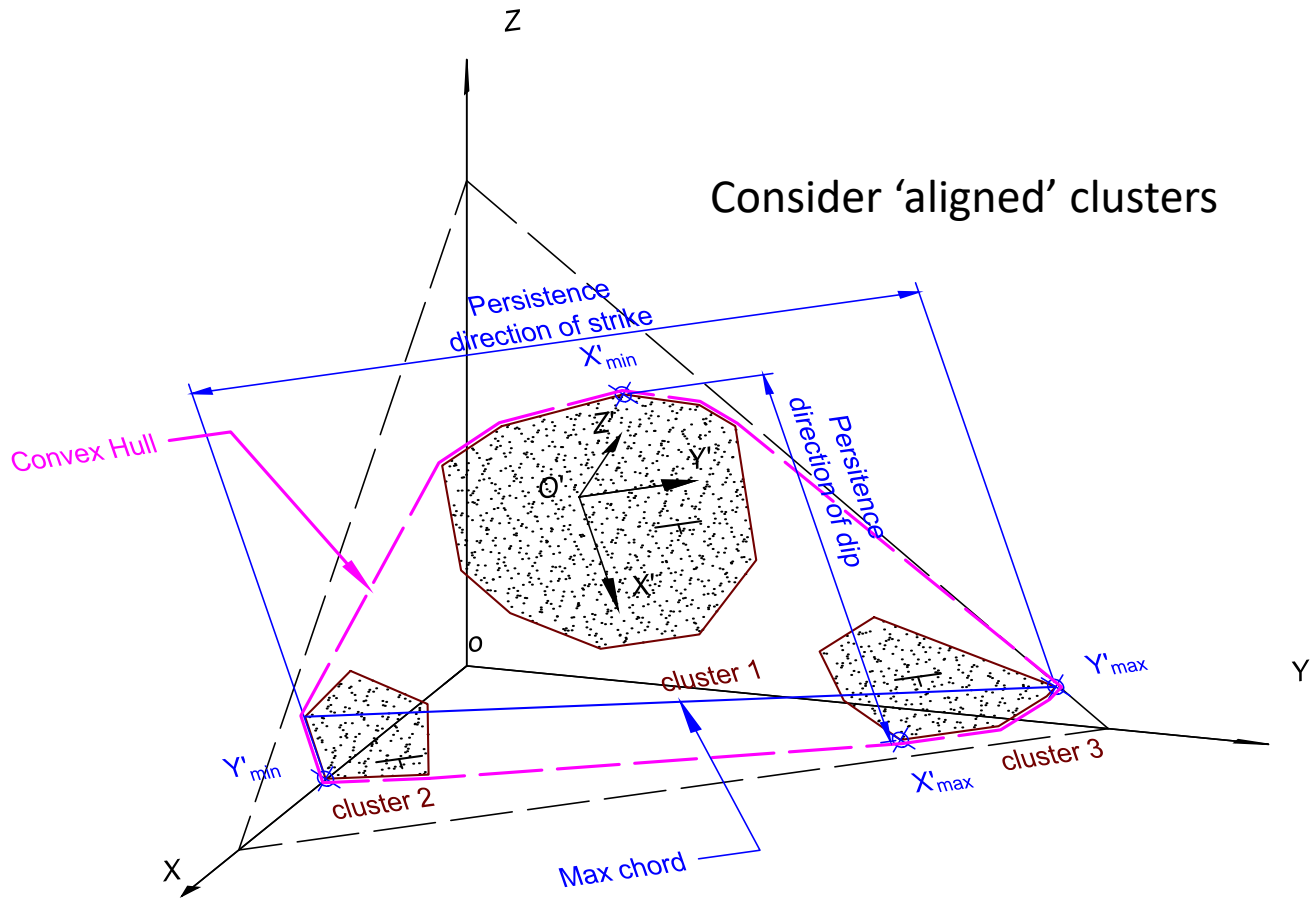


https://ars.els-cdn.com/content/image/1-s2.0-S0013795215002045-gr1.jpg

5. Analysing Classified Point Clouds for Discontinuity Characterization

Measure the persistence:

Consider ‘aligned’ clusters



https://link.springer.com/article/10.1007/s00603-018-1519-9/figures/5

Finnish Rock Mechanics Day

3D Point Cloud-Based Characterization of Discontinuities in Rock Slopes: Concepts and Perspectives

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