Computational framework for discontinuity network characterization

Thomas Poulet\(^1\), Ulrich Kelka\(^2\), Stefan Westerlund\(^2\), and Luk Peeters\(^2\)
\(^1\)CSIRO, Mineral Resources, Kensington, Australia (thomas.poulet@csiro.au)
\(^2\)CSIRO, Deep Earth Imaging FSP, Kensington, Australia

The topological and geometrical description of fault and fracture networks is an essential first step in any investigation of fractured or faulted media. The spatial arrangement, density, connectivity, and geometry of the discontinuities strongly impact the physical properties of the media such as resilience and permeability. Obtaining reliable metrics for characterizing fault and fracture networks is of interest for mining engineering, reservoir characterization, groundwater management, and studies on the regional fluid flow history. During large-scale studies, we mostly rely on two-dimensional lineaments obtained through structural mapping, outcrop analysis, or remote sensing. An efficient and widely applicable framework for discontinuity network characterization should therefore be based on the analysis of the frequently available two-dimensional data sets.

Here, we present an automated framework for efficient and robust characterization of the geometric and topologic parameters of discontinuity networks. The geometry of the lineaments is characterised based on orientation, length, and sinuosity. The underlying distribution of these parameters are determined, and representative probability density functions are reported. The connection between the geometric parameters is validated, e.g. correlation between orientation and length. The spatial arrangement is determined by classical line- and window-sampling, by assessing the fractal dimension, and via graph-based topology analysis.

In addition to the statistical analysis of lineament networks, we show how the graph data structure can be utilized for further characterization by linking it to raster data such as magnetic, gravimetric, or elevation. This procedure not only yields an additional means for lineament characterization but also allows users to assess dominant pathways based, for instance, on hydraulic gradients. We demonstrate the applicability of our algorithm on synthetic data sets and real-world case studies on mapped fault and fracture networks.

We finally show how our framework can also be utilized to design detailed numerical studies on the fluid flow properties of analysed networks by conditioning mesh refinement on the type and number of intersections. In addition, due to known scaling relationships our framework can help to determine appropriate parameters for the simulations. We provide examples of statistically parametrized fluid flow simulations in natural discontinuity networks and show the impact of conceptualizing the lineaments as conduits, barriers or conduit-barrier systems.