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FSAT - An Open-Source Fracture Surface Analysis Toolbox

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Fracture morphology influences various physical processes within a fracture, such as fluid flow, contaminant, and heat transport as well as mechanical shearing. Through the increasing availability of affordable high-precision scanning technology of open surfaces, drill cores, and broken rock samples, digital rock surfaces are easy to obtain and become a common tool to study hydraulic and mechanical processes inside fractures. Through statistical fracture generation and 3D printing technology, even custom-made fracture surfaces have been applied in numerous studies.

However, the complexity to describe and quantify fracture surface morphology is a major obstacle in evaluating and comparing results from laboratory and numerical experiments across studies and rock samples. While many so-called roughness parameters exist, there is no single parameter representing all features of a fracture surface. Only through a combination of parameters, which often is problem depending, a fracture surface can be suitably characterized to enable reproducibility of experiments and analysis across samples and studies. The effort of calculating various parameters is impeding scientists to sufficiently and quantitatively describe fracture surfaces.

We introduce an open-source MATLAB toolbox that allows the determination of over 25 different roughness parameters for height profiles as well as full 3D fracture surfaces. The selection of parameters includes statistical parameters, amplitude and spatial metrics, joint roughness coefficients, and fractal parameters. Variation of those parameters across a fracture surface as well as anisotropy is also calculated. For three-dimensional profiles, also surface measures are determined. If the top and bottom surfaces of a fracture are provided, even an estimated aperture distribution can be obtained, which is analyzed as well as provided for subsequent calculations, e.g., regarding the flow field. Further, the toolbox includes pre-processing routines for digital fracture surfaces of different sizes, shapes, and orientations. The toolbox is validated with standard profiles and synthetically generated fractures with known characteristics.

The toolbox massively simplifies the quantitative description of fracture surfaces, unifies the methodology of determining roughness parameters, and allows an easy generation of digital fractures with known characteristics. On the other hand, the toolbox enables easy customization for advanced users with specific demands. The toolbox consists of well-documented MATLAB scripts and functions that require a minimum of user-defined metadata. Extensive examples are

also provided. The source code is freely available for download at <https://gitlab.com/thomhGeoCode/fsat>