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Estimating small-scale roughness of a rock joint using TLS data

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Roughness of a rock joint is an important parameter influencing rock mass stability. Besides the surface amplitude, also the roughness direction- and scale-dependency should be observed (i.e. 3D roughness). Up to now most of roughness measurements and parameters rely on point or profile data obtained on small samples, mostly in a laboratory. State-of-the-art remote sensing technologies supply 3D measurements of an in-situ rock surface and therefore enable a 3D roughness parameterization. Detailed morphology of a remote large-scale vertical structure can be best observed by Terrestrial Laser Scanning (TLS). In a short time and from distances of a few hundred meters, TLS provides relatively dense and precise point cloud. Sturzenegger and Stead [2009] showed that the TLS technology and careful fieldwork allow the extraction of first-order roughness profiles, i.e. the surface irregularities with a wavelength greater than about 10 cm.

Our goal is to find the lower limit; this is, to define the smallest discernible detail, and appropriate measuring and processing steps to extract this detail from the TLS data. The smallest observable roughness amplitude depends on the TLS data precision, which is limited mostly by an inherent range error (noise). An influence of the TLS noise on the rock joint roughness was analyzed using highly precise reference data acquired by Advanced TOpometric Sensor (ATOS) on a 20x30 cm rock joint sample. ATOS data were interpolated into 1 mm grid, to which five levels (0.5, 1, 1.5, 2, 2.5 mm) of normally distributed noise were added. The 3D surfaces entered direction-dependent roughness parameter computation after Grasselli [2001]. Average roughness of noisy surfaces logarithmically increase with the noise level and is already doubled for 1 mm noise. Performing Monte Carlo simulation roughness parameter noise sensitivity was investigated. Distribution of roughness differences (roughness of noisy surfaces minus roughness of reference ATOS surface) is approximately normal. Standard deviation of differences on average slightly increases with the noise level, but is strongly dependent on the analysis direction.

As proved by different researches within the field of signal, image and also TLS data processing, noise can be, to a certain extent, removed by a post-processing step called denoising. In this research, four denoising methods, namely discrete WT (DWT) and stationary WT (SWT), and classic NLM (NLM) and probabilistic NLM (PNLM), were used on noisy ATOS data. Results were compared based on the (i) height and (ii) roughness differences between denoised surfaces and reference ATOS surface, (iii) the peak signal-to-noise ratio (PSNR) and (iv) the visual check of denoised surface. Increased PSNRs and reduced roughness differences prove the importance of the TLS data denoising procedure. In case of SWT, NLM and PNLM the surface is mostly over smoothed, whereas in case of DWT some noise remains.

References:

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