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# 3D modelling of geological outcrops using combined terrestrial laser scanning and hyperspectral imaging

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Geometrical modelling of outcrops using terrestrial laser scanning (lidar) is becoming an established technique within geology. As a means of efficiently representing surface topography with high precision and resolution, lidar is currently the method of choice, primarily due to its user-friendliness. Lidar hardware is constantly evolving, as is point cloud processing software, allowing increasingly more complex and detailed analysis of geological features to be carried out. In the same manner, advances in computer visualisation make the presentation of 3D products more accessible to a wider group of users. The relatively narrow spectral wavelength of the lasers used in terrestrial scanners, largely restricts analysis of the data to geometry. Integration of a digital camera extends the spectral range but the extent to which spectral processing can be carried out is limited. The simultaneous use of a close-range hyperspectral imaging device makes it possible to combine the high resolution geometric data of the lidar with advanced spectral classification techniques, for mapping outcrop mineralogy and lithology.

This work presents a combined approach to near-vertical outcrop modelling using lidar, hyperspectral imaging and computer visualisation to analyse and map lithological composition. The laser scanner is used to capture the 3D surface of the outcrop in high resolution, with an integrated digital camera providing images of the geological detail. The acquired point cloud is processed to form a terrain model, which is then textured with the digital images. This photorealistic model forms the geometric component of the presented workflow. A close-range hyperspectral sensor is used to capture images of the outcrop in the near-infrared part of the electromagnetic spectrum (240 bands between 1.3 and 2.5$\mu$m), with 320 pixels in a single line. The images are built-up in the scan direction using a rotation stage, resulting in panoramic image geometry. The very high spectral resolution allows a continuous spectral curve to be analysed for each spatial pixel of the resulting image. Although some differences in processing are apparent between close-range hyperspectral scanning and more conventional airborne/spaceborne applications, it has mostly been possible to adopt similar procedures for obtaining classification results. A photogrammetric model for panoramic cameras is applied to form a precise integration between the spectral images and the photorealistic lidar model, making it possible to superimpose hyperspectral results onto the existing lidar model, and allowing areas of classified material to be quantified in 3D space.

Results are presented from siliciclastic and carbonate outcrops, using different lithological and scan conditions to evaluate the combination of the lidar and hyperspectral scanning. Geometric accuracy and data quality are focussed on. Results indicate that the addition of spectral scanning to the toolbox of earth scientists is useful for enhancing our understanding of material distribution in exposed outcrops.