From underground laser scans to 3D urban geological and geotechnical models

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The near sub-surface geology, say down to 20-30-m-depth, of many cities has been massively exploited for extracting building stones and various other industrial or agricultural materials (gypsum, lime, etc…). The long-term instability of these cavities poses a significant collapse hazard conditioned by their geometry (void location, dimensions and shape) and by their surrounding rock mechanics properties. In this presentation, we show how handheld laser scanning surveys efficiently document geometric variables and can interact with 3D geological modelling of the surrounding rocks. The construction of near-surface urban geological models can then be turned into 3D geotechnical models by attributing geotechnical parameters to rock horizons and ultimately become a key subsurface knowledge component of BIM (Building Information Model).

Acquiring surface and subsurface geometry is no longer a challenge thanks to handheld laser scanners. Survey loop traverses can be pieced together to link surface and subsurface geometry with accuracies better than 1 m (an accuracy level compatible with urban risk management maps at 1/5.000) (DEWEZ *et al.*, 2017). However, the hundreds of-millions of 3D points describing the cavity surface cannot be integrated as such into geomodeling software. Too many points with not high enough information. We suggest two different scenarios to perform their integration: (i) as independent validation of geomodeling hypotheses, or (ii) as geomodel constraints.

In the first integration scenario, point cloud information is passed to the geomodeling software at a minimal level. A decimated triangular meshed model can be used to intersect the geomodel. Triangulation is performed at the point cloud processing software level (e.g. GeoSLAM desktop or Cloud Compare) and intersection is handled at the geomodelling software level with a generic query concept (here GeoModeller software with a generic query API – LOISELET *et al.*,2016). In this instance, cavity mesh triangular faces are refined based on the geological model queries (relying on the *marching triangles* algorithm) and provide geotechnical attributes based on the geological formations given by the geomodel. This scenario offers a visual display of geological properties (Fig. 1) for checking that modelled layers and structures match those observed in underground outcrops.

In the second scenario, which is more integrated, higher level information is passed to the geomodelling tool. Planar surfaces of marker horizons are segmented from the point cloud either manually using Compass (THIELE *et al.*, 2017) or semi-automatically with FACETS (DEWEZ *et al.,* 2016) and passed as structural data objects to constrain the geomodel (Fig. 2).

This data integration is demonstrated on a ca. 1 ha underground building stone quarry of the eastern suburbs of Orléans, Central France. The cavity was scanned at ca. 1pt/1cm with a Zeb-Revo (90 Mpts underground and 35 Mpts above ground). A geomodel of the subsurface area (Calcaire de Beauce, Tertiary) was created with the GeoModeller software as a tabular sub-horizontal multilayer environment. The geomodel infers rock distribution over a domain of *ca.* 200 x 200 m with geological and geotechnical information (e.g. limit pressure for dimensioning building foundations).

Both approaches leverage a generic API query tool informing which domain surrounds a point and whether a geological contact cross-cuts a triangular face.

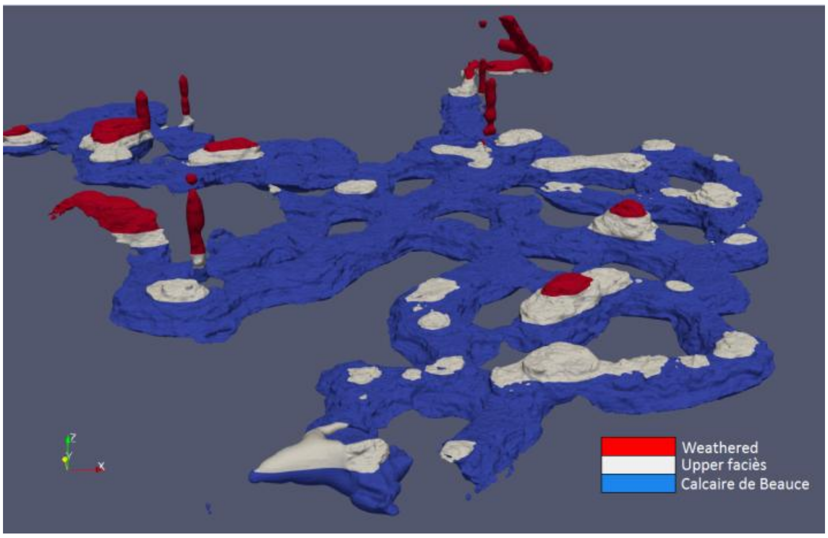

Figure 1: Intersecting the geological model (GeoModeller) with the cavity wall 3D mesh. Modelled layers interpolate limit pressure values (p_l) spatially. Weathered : p_l* 0.5 – 1 MPa; Upper facies: p_l* 1.5-2.5 MPa; Calcaire de Beauce : p_l* 4.0 MPa*

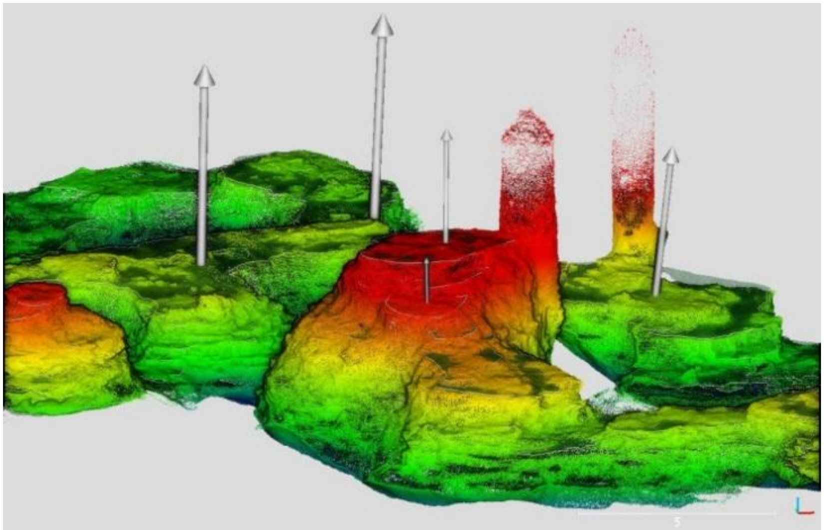

Figure 2: Capturing bedding orientations from the dense point cloud with the Compass plugin shipping with Cloud Compare.

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