Comparison of 3D point clouds produced by LIDAR and UAV photoscan in the Rochefort cave (Belgium)

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Comparison of 3D point clouds produced by LIDAR and UAV photoscan in the Rochefort cave (Belgium)

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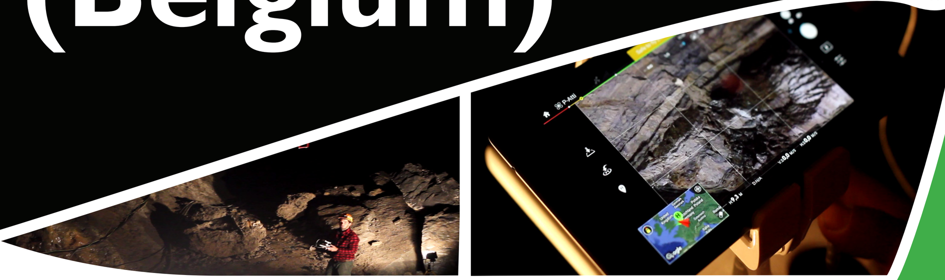
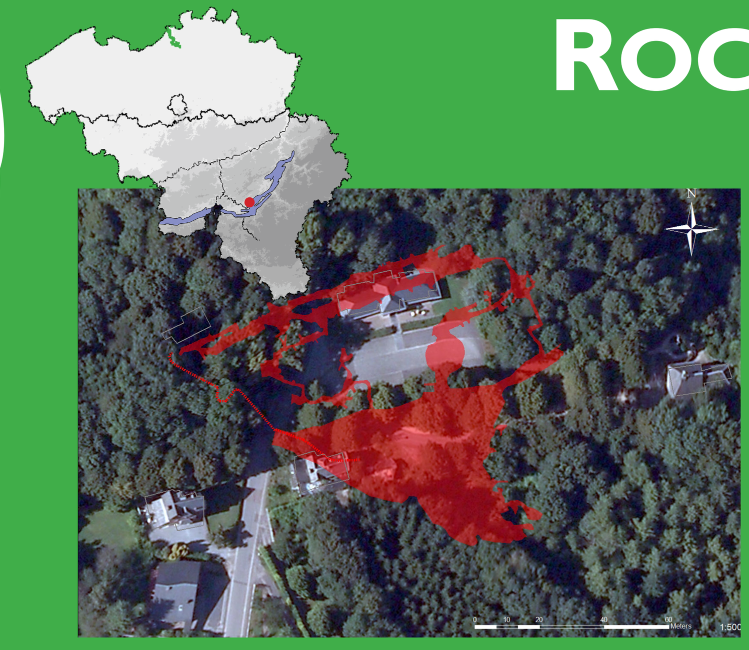


Rochefort Cave



This karst system is built within Devonian limestone units of the so-called Variscan fold-and-thrust-belt in Belgian Ardennes. It shows a well-developped karstic network (Camelbeeck, 2012) comprising large galleries with diameters of several meters oriented following the strike direction of the stratigraphic unit (N070°E) and smaller galleries along dip direction crosscutting the main ones. Its lithology is composed of alternating decametric series of well-preserved limestones and weathered/porous limestones strata.

Introduction & problematic

Amongst today's techniques that are able to produce 3D point clouds, LIDAR and UAV (Unmanned Aerial Vehicle) photogrammetry are probably the most commonly used. Both methods have their own advantages and limitations. LIDAR scans create high resolution and high precision 3D point clouds, but such methods are generally costly, especially for sporadic surveys. Compared to LIDAR, UAV (e.g. drones) are cheap and flexible to use in different kind of environments. Moreover, the photogrammetric processing workflow of digital images taken with UAV becomes easier with the rise of many affordable software packages (e.g. Agisoft, PhotoModeler3D, VisualSFM).

LIDAR scan vs UAV Photoscan

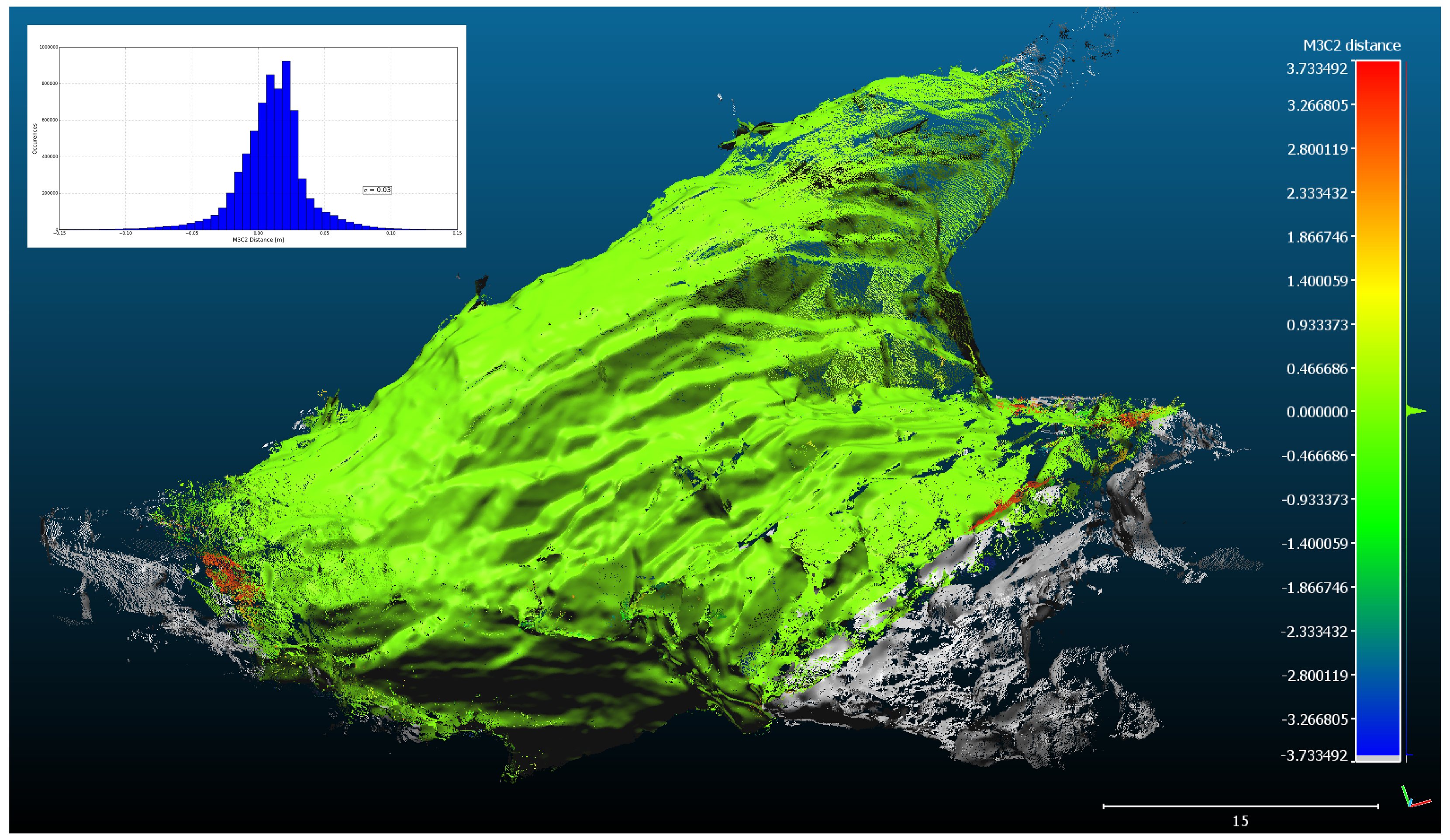
Theodolite surveys and compass measurements were crucial for georeferencing both point clouds

LIDAR scan
Leica ScanStation 2
Two ground stations
~3 hours of measurements
7 millions points reconstructed

UAV Photoscan
Drone Phantom 3 Pro
~2 hours of measurements for 305 UAV photos + 320 DSLR photos
Photogrammetry processed with AgiSoft
50 millions points reconstructed

We combined theodolite reference points with reference horizontal surfaces in the cave and known orientations between reference points (small cave conduits). Both LIDAR and photoscan point clouds were aligned on reference points. After this procedure the relative position of photoscan point cloud with regard to LIDAR point cloud was improved using the iterative fine registration method (ICP, via more than 500,000 common points), modifying the rotation and xyz scale object while conserving original scale ratios.

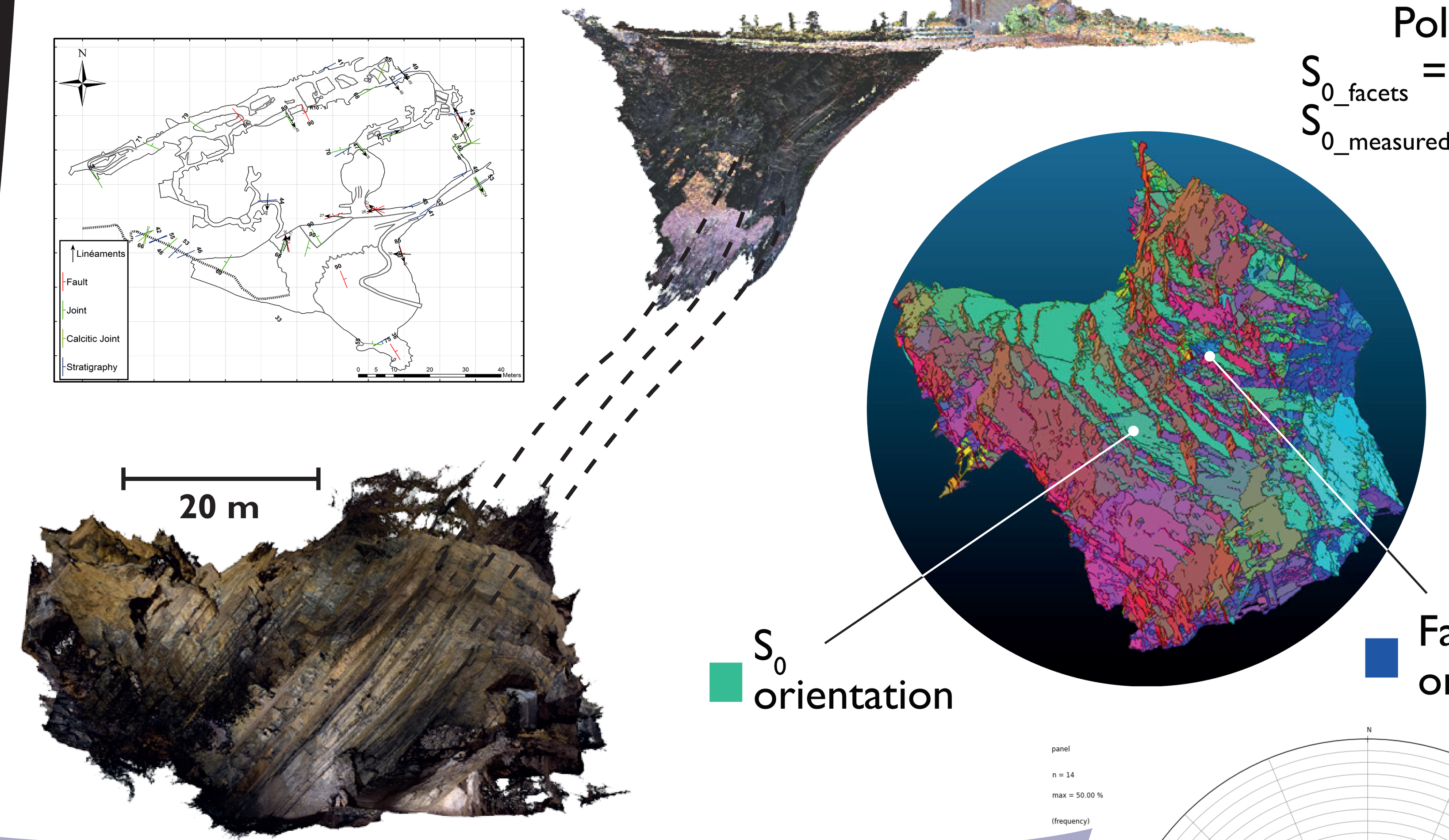
The M3C2 method (Lague et al., 2013) was performed to compute distances between the two point clouds using the LIDAR point cloud as reference. This method evidenced that both point clouds match standard deviation of 0.03 m. In other words, 6.45 million of photoscan points out of 6.9 million are -6 to 6 cm close to their corresponding LIDAR point.

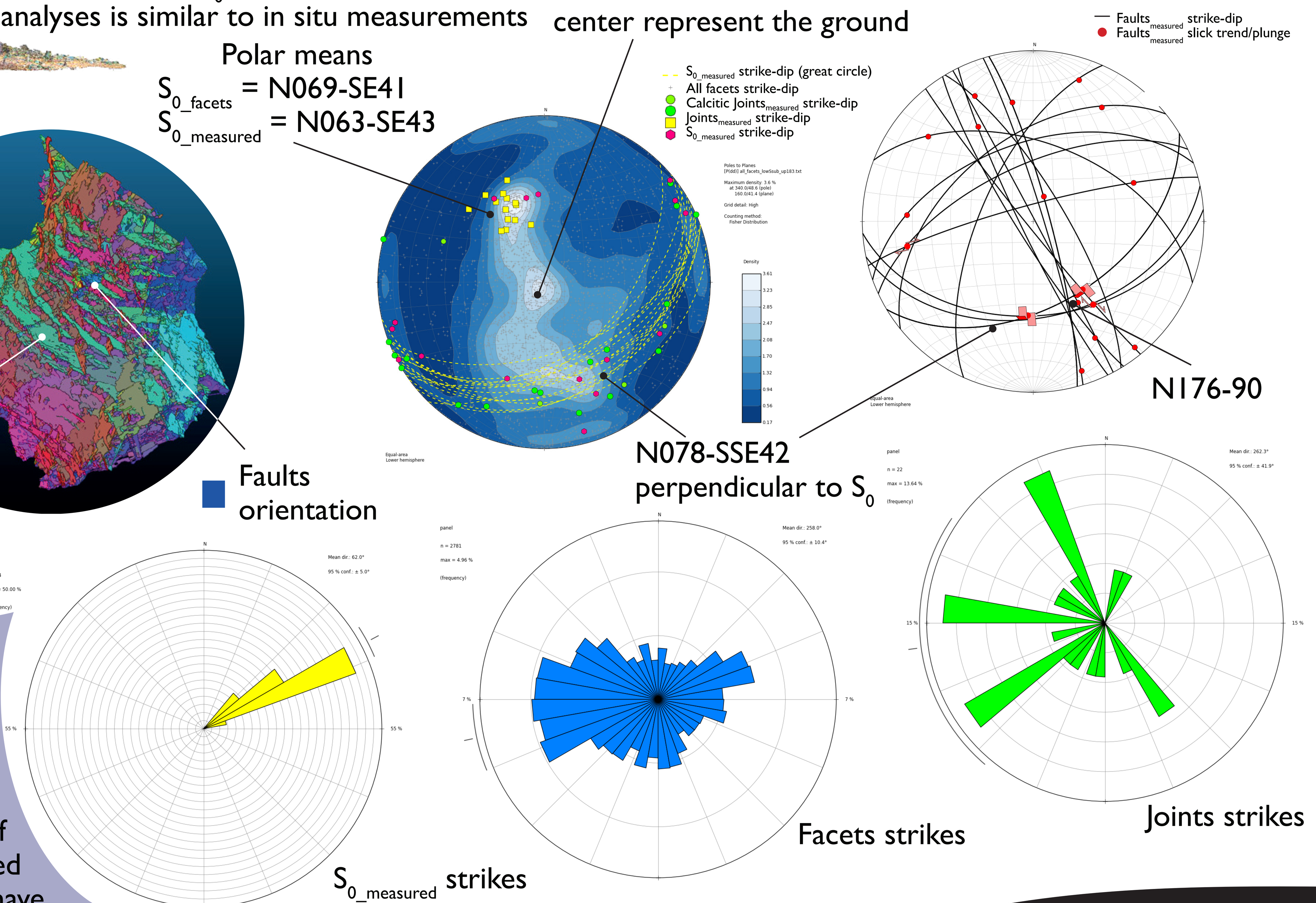


Clustering 3D data

The qFacets plug-in (T. Dewez, BRGM) of Cloud Compare allows to automatically merge neighboured model polygons that have similar orientations (here, less than 10° between planes pole). This routine acts as a subsampling method on the basis of polygons geometry and spatial distribution. Comparison between structures measured on the field and those extracted from the 3D models is possible. This allows to investigate and spatialize structures that are inaccessible to the fieldworker and to run statistical spatial analyses over large amount of indirectly sampled structural data.

Structural observations



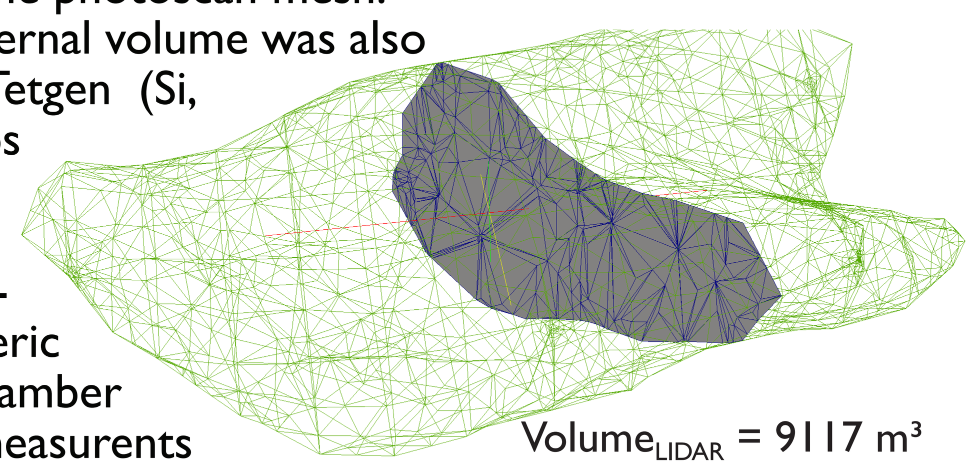


For in situ measurements, poles of joints and faults planes are spread along an average plane striking N069-SE35. This orientation is subparallel to sedimentation deposit orientation. Such a distribution of the joints suggests that the geometry of the strata pile strongly controlled their formation. Thus, they could be interpreted as a gravitary consequence concomitent to the formation of the cave. Additional field/3D models investigations would be required to make further conclusions with this particular point. Variation have also been observed between the photoscan data from the surface area and the one surveyed in the cave, which may be interpreted as a large-scale folding structure.

Volumes & modelling

Computing volumes of underground cavities brings invaluable information to karstologists. LIDAR data spatially cover a greater area of the surveyed chamber, wich explain the greater volume computed compared to the photoscan mesh.

Discretizing the internal volume was also performed, using Tetgen (Si, 2015). This helps modelling multiple problems such as, in our case, the effect of atmospheric pressure in the chamber on gravimetric measurements performed at the site.



$Volume_{LIDAR}$ = 9117 m^3
$Volume_{Photoscan}$ = 8403 m^3

Conclusions and perspectives

We illustrated via the Rochefort cave study case that using both sources of 3D information is applicable to quantify the orientation of inaccessible geological structures (e.g. faults, tectonic and gravitational joints, and sediments bedding), and compare these data to structural data surveyed on the field.

An additional drone photoscan was also conducted in the surface sinkhole giving access to the surveyed underground cavity to seek geological bodies' connections.

Further analyses are still needed to improve the comparison of both information such as an extensive colorimetric/spectral analysis of the photoscan data. Rugosity analyses would also be of interest on selected part of the 3D body.

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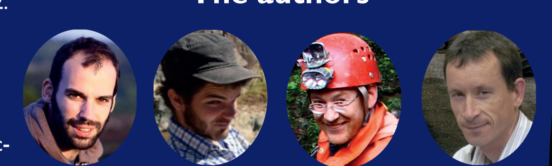

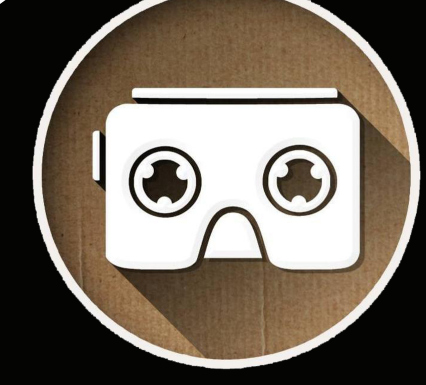

Let's have a look at Rochefort cave in 3D with Google Cardboard !