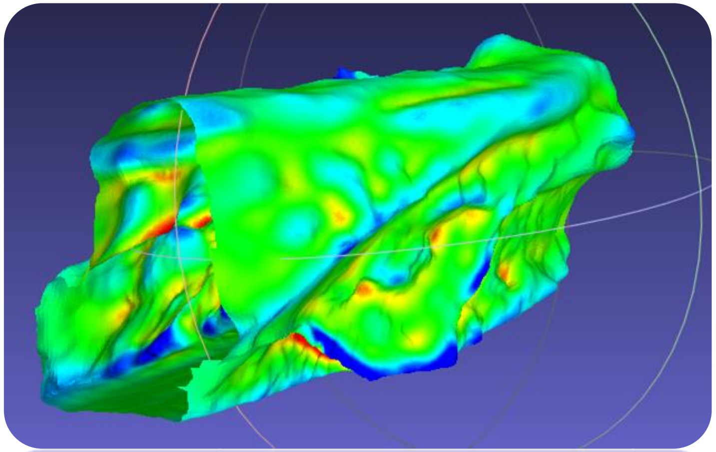

Mapping and geomorphometric analysis of 3-D cave surfaces: a case study of the Domica Cave

Michal GALLAY[1], Ján KAŇUK[1], Jaroslav HOFIERKA[1], Zdenko HOCHMUTH[1], John MENEELY[2]

1 - Institute of Geography, Pavol Jozef Šafárik University in Košice, Slovakia

2 - School of Geography, Archaeology and Palaeoecology, Queen's University Belfast, UK

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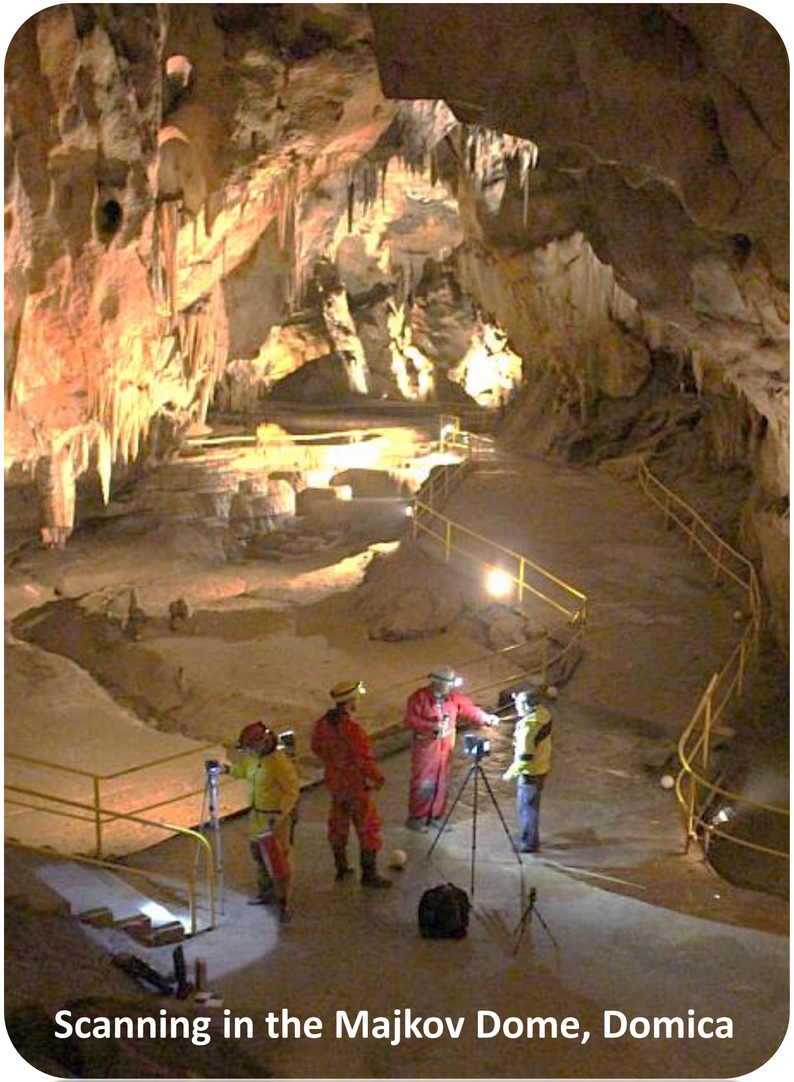
spatial3-D.science.upjs.sk

Motivation:
massive 3-D data vs. 3-D geographic analysis

- Caves are typical 3-D landforms
- TLS applied since 2004
- TLS + cave = example of **massive 3-D point data representing a 3-D landform**

Point cloud of the Majkov Dome, Domica



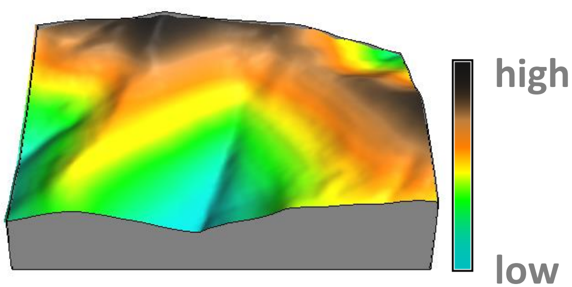
Scanning in the Majkov Dome, Domica

Motivation: 2-D geomorphometry

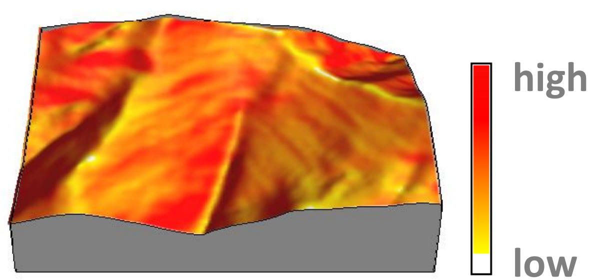
- **Terrain modelled as a bivariate continuous function z=f(x,y)**
- The methodological concept of digital terrain analysis well developed, as summarized in, e.g. Hengl & Reuter (Eds.), (2008)
- Targeted on raster data and 2-D analyses

Geometric analysis of a 2-D surface grid

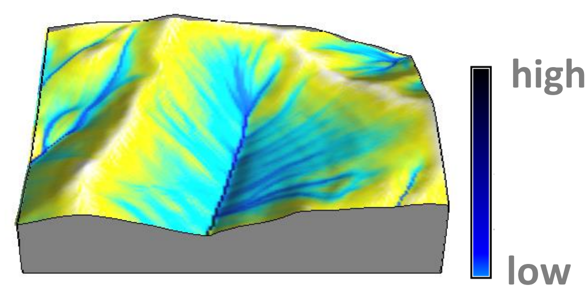
Interpolated 2-D elevations



Gradient of elevation (slope angle)



Contributing area



Motivation: 3-D geomorphometry

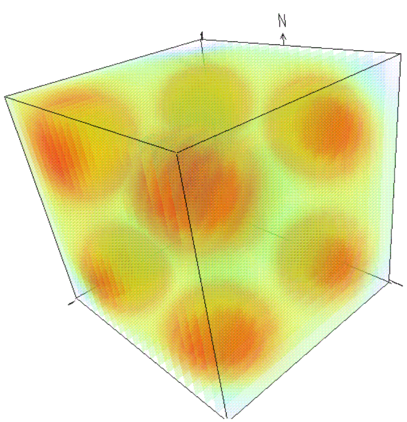
- 2-D geomorphometry -> **3-D geomorphometry**

  Trivariate function *w = f (x, y, z)*

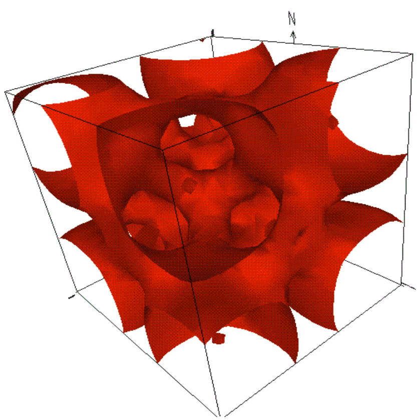
  Hofierka & Zlocha (1993), Hofierka (1997), Petrasova et al. (2014)
- **3-D morphometry of 3-D volumetric phenomena** already possible, e.g. Neteler & Mitasova (2008) (GRASS GIS, v.vol.rst, r3.flow)

Geometric analysis of a 3-D phenomena (3-D grid)

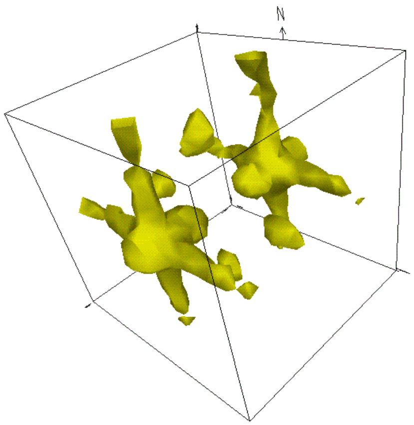
Interpolated 3-D values



Isosurface of the gradient value 1.5



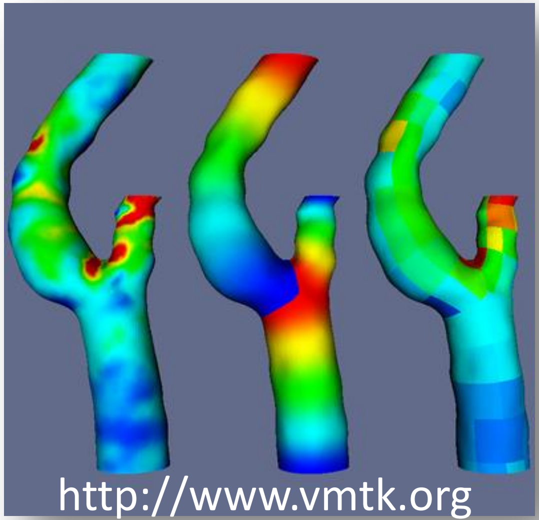
Isosurface of the contributing volume value 5 m³/m²

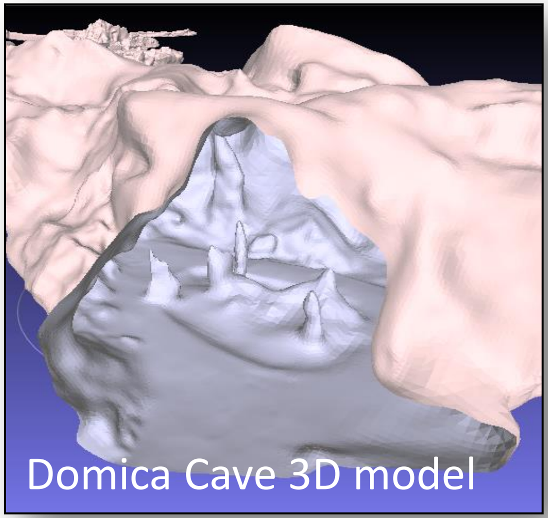


Motivation: 3-D terrain surface?

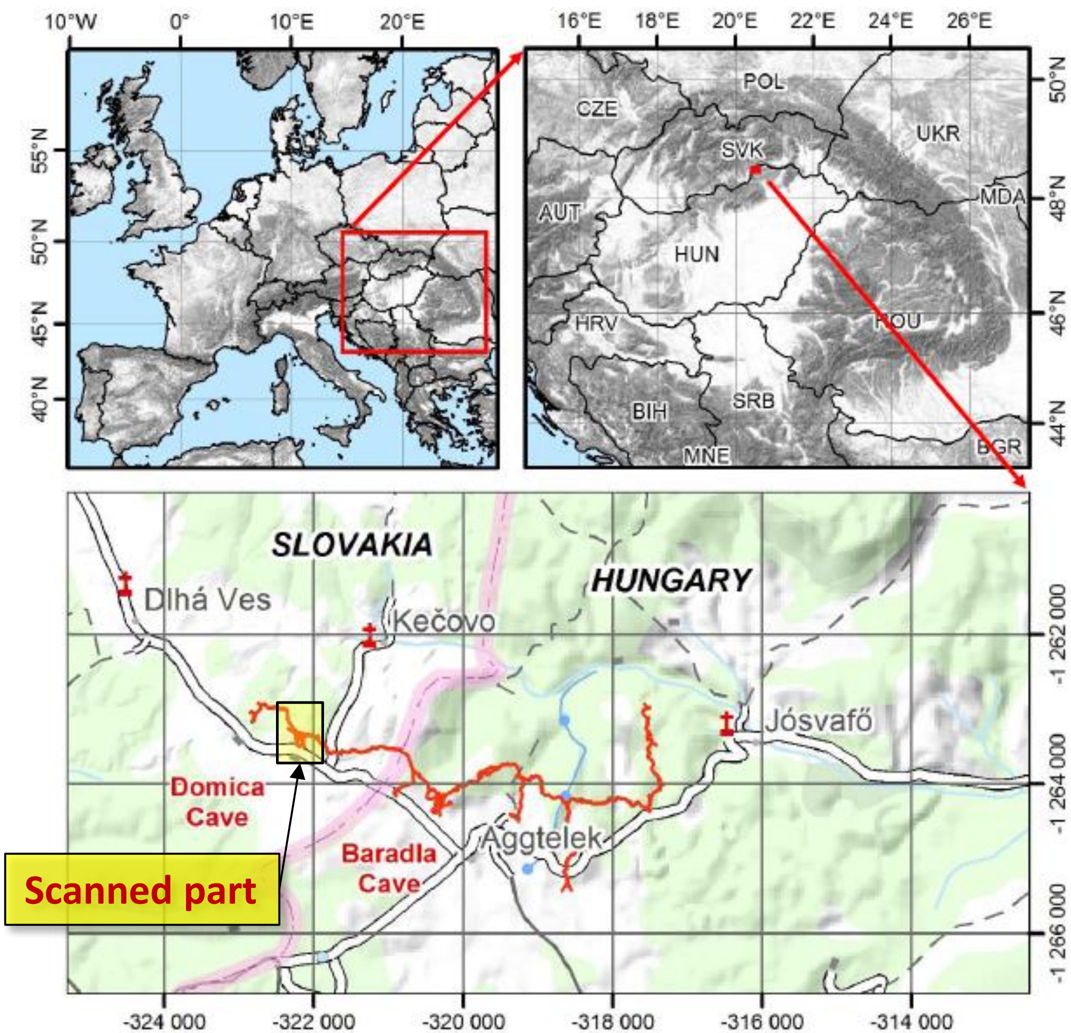
- Not applicable to **3-D interface surfaces** such as surfaces of **cave**, overhangs, tunnel
- **Not a trivariate function w=f(x,y,z)**
- „3-D terrain“ as a polyhedral mesh
- **Restricted capabilities in GIS**, more tools exist in 3-D graphic software, e.g. Meshlab, Blender, VMTK
- **Need for 3-D approach in geomorphometry of 3-D surfaces**
- **Challenge of massive 3-D laser scanning data**

Mapping blood vessel surface





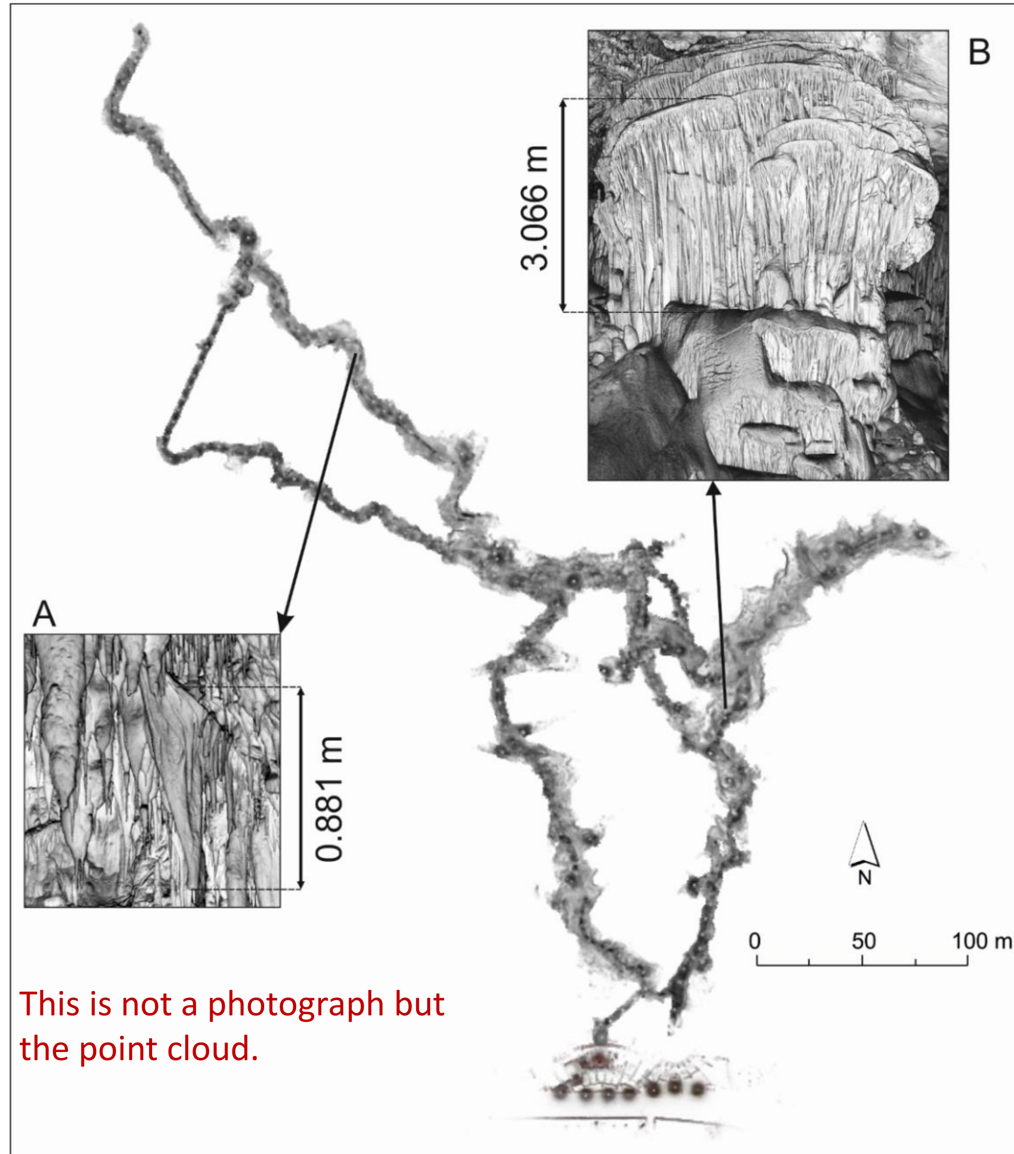
Our case study: the Domica Cave



High-resolution laser scanning in the Domica Cave: final 3-D point cloud

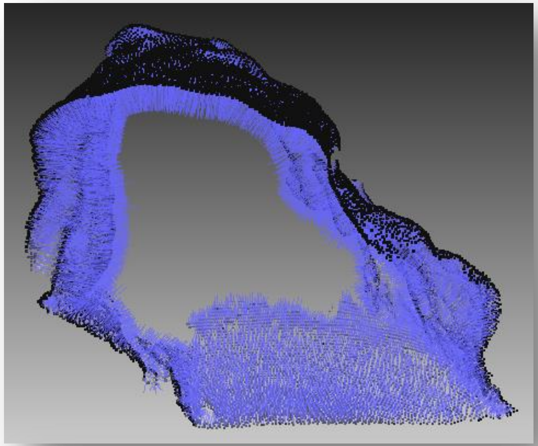
Data acquisition

- 5 days in March 2014,
- Faro Focus 3-D 120S scanner
- 1,600 metres of cave passages scanned
- almost 12 billion of 3-D points
- **Measurement sampling 7 mm at 10 metres distance**
- 327 scannig positions,
- Overall registration error 2.24 mm
- Georeferencing error 12 mm
- **Under review in:**

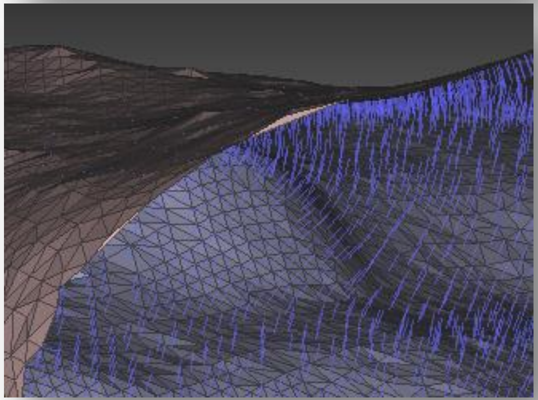


Generating the 3-D cave surface model

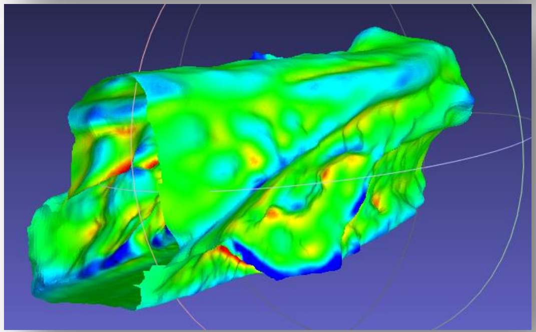
1. Processing, registration and **decimation of the original point cloud**
2. **Calculation of normals** for the points (future mesh vertices)



3. Production of the **3-D cave surface model** (a triangular mesh)



4. **Calculating mean curvature** of the 3-D surface model for multiple scales

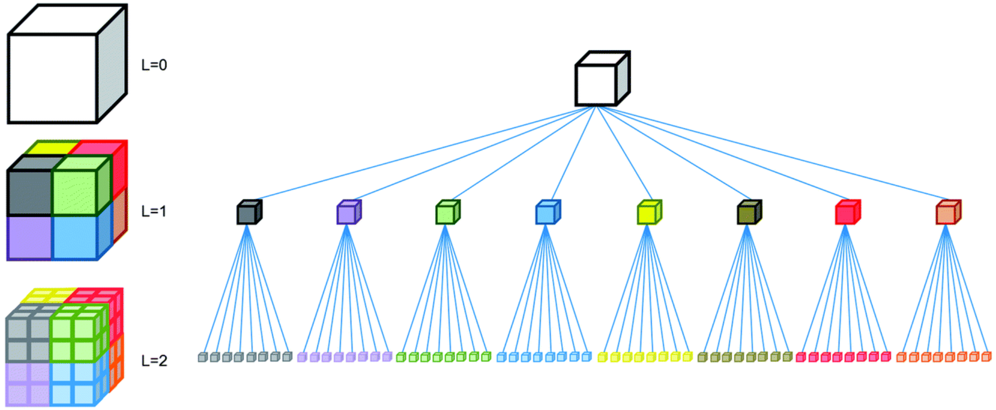


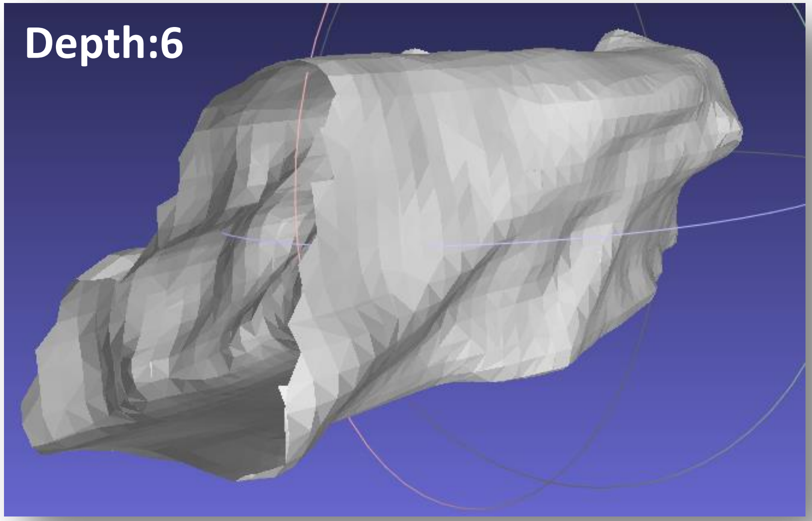
5. **Interpretation** of the curvature

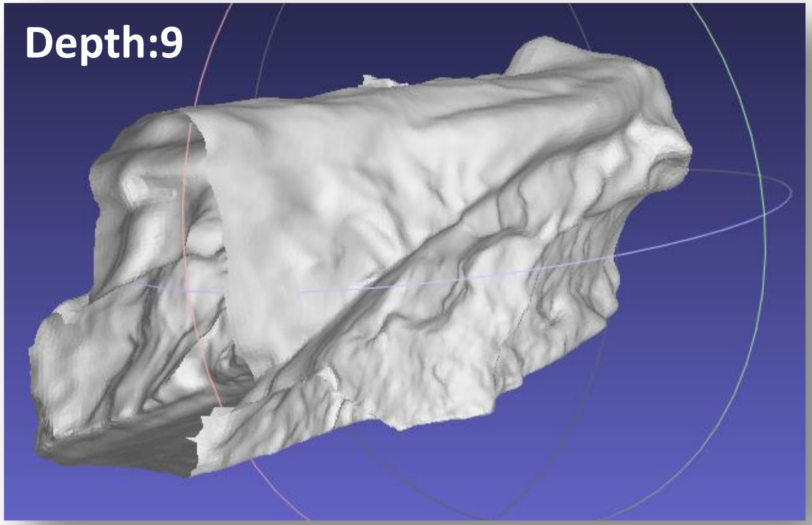
MeshLab

Generating the 3-D cave surface model

- Poison surface reconstruction
  - Khazdan et al. (2006)
- Resolution controlled by:
  - the input point density (kept constant)
  - the **octree depth parameter**







Generating the 3-D cave surface model

- Poison surface reconstruction
- Resolution controlled by:
  - the input point density (kept constant)
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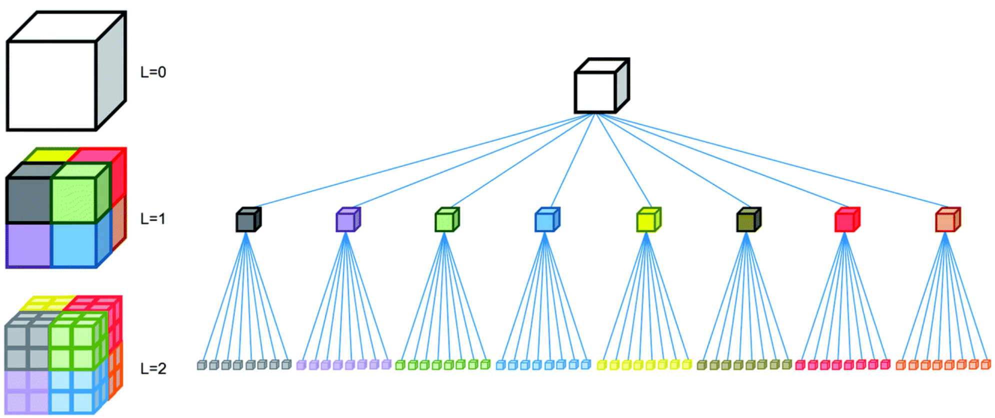
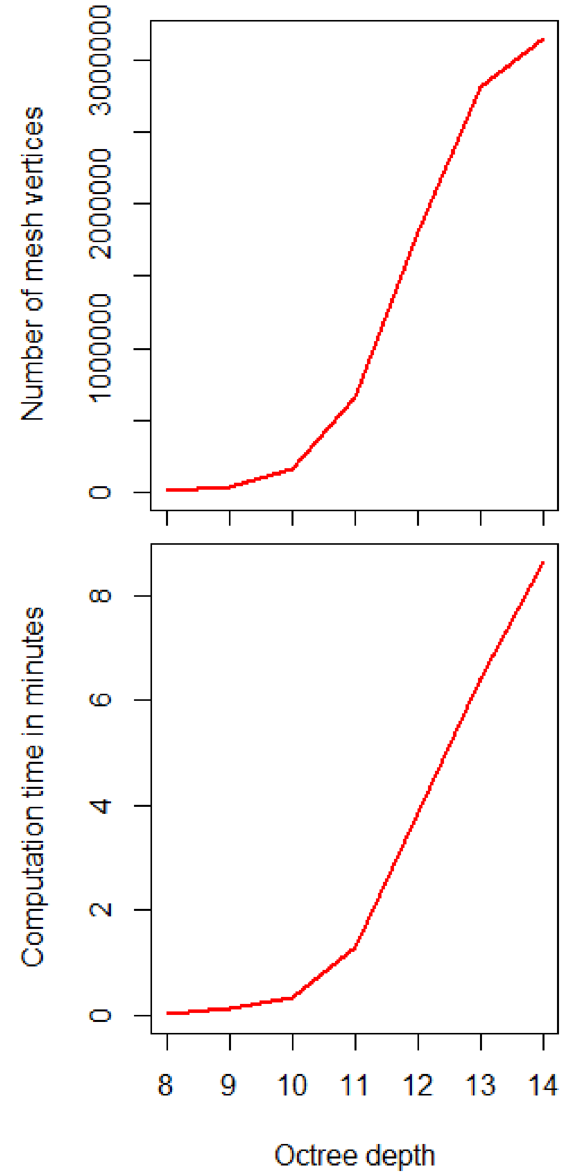
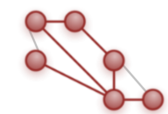


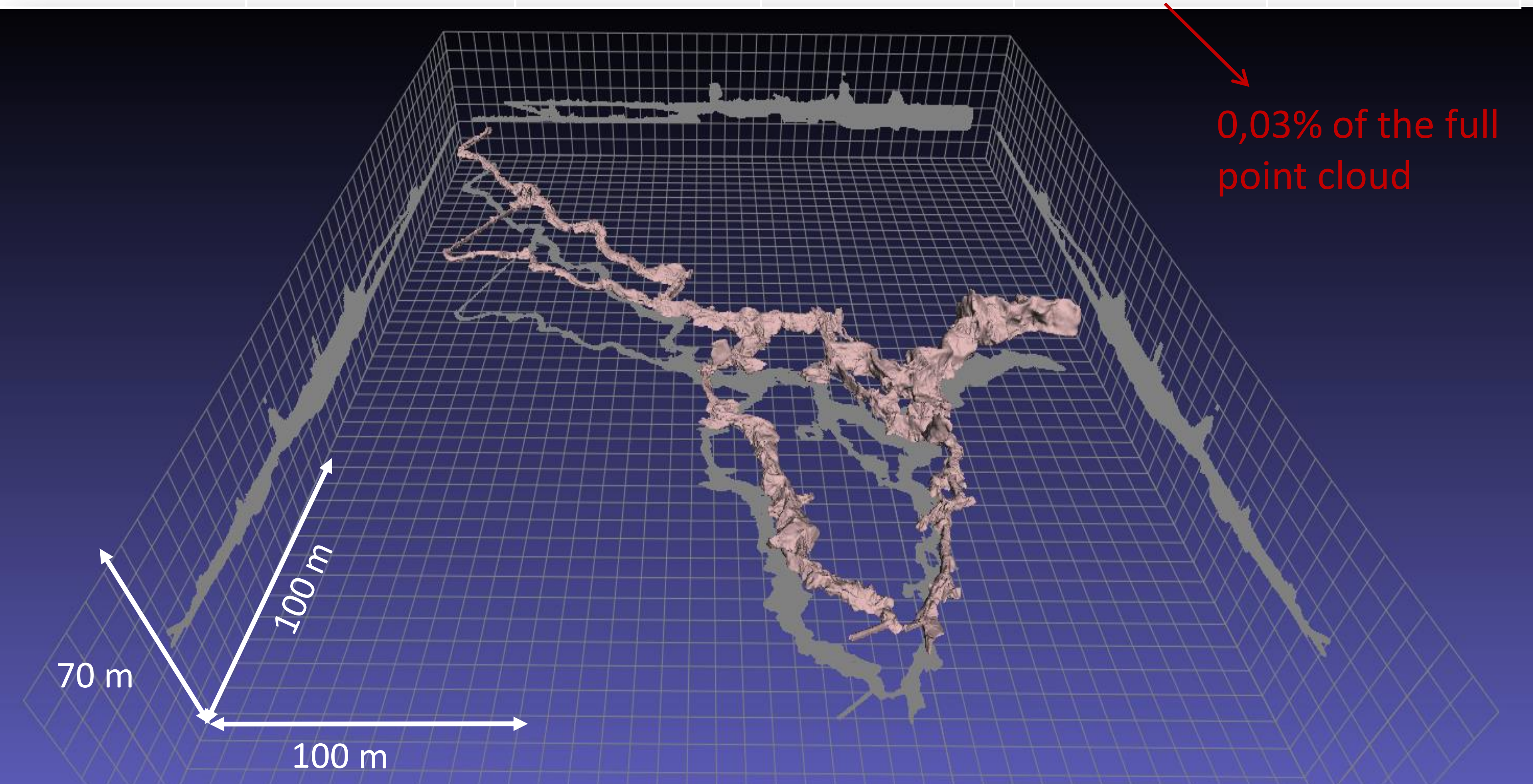




Generating the 3-D cave surface model

Octree depth	Computation time	Cave surface area	Mesh volume (Cave volume)	Number of vertices	Number of faces
14	8,6 minutes	33,835 m^2	45,915 m^3	3,139,386	6,278,872

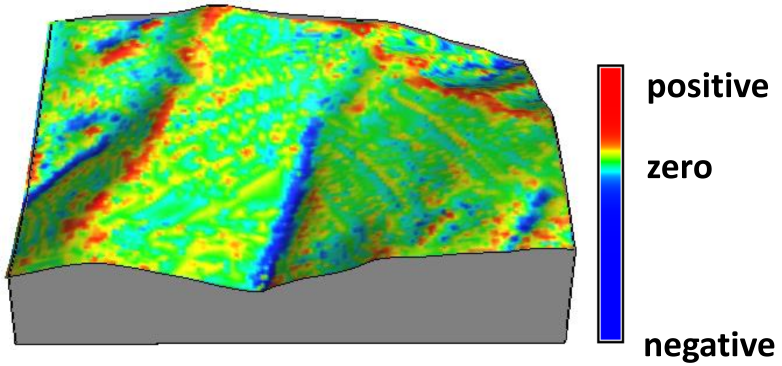
0,03% of the full point cloud



3-D cave gemorphometry

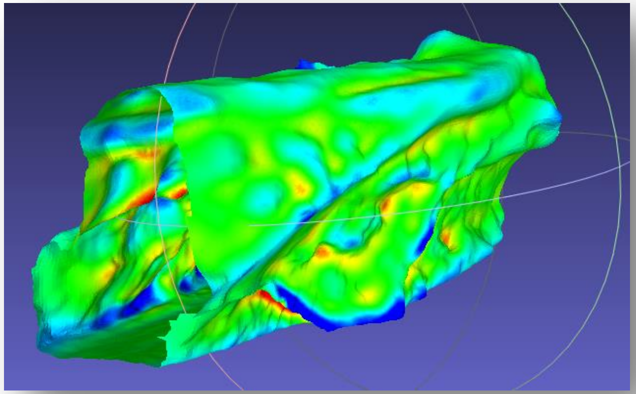
- Mean surface curvature
- Enables identification of particular forms, sharp shapes, flat tectonic lines, stalactites
- Concentration of water flow (e.g. dripping water generating stalactites)

GRASS GIS: v.surf.rst (Neteler & Mitasova, 2008)



Mean curvature of terrain surface
a 2-D object

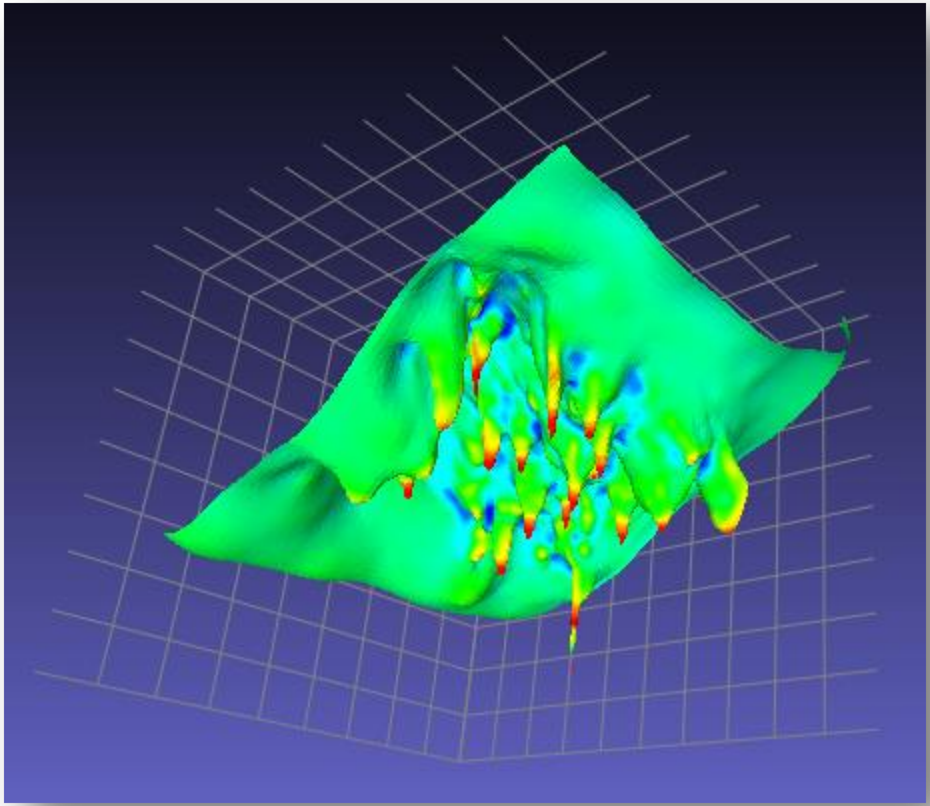
Meshlab: Guennebaud et al. (2008)

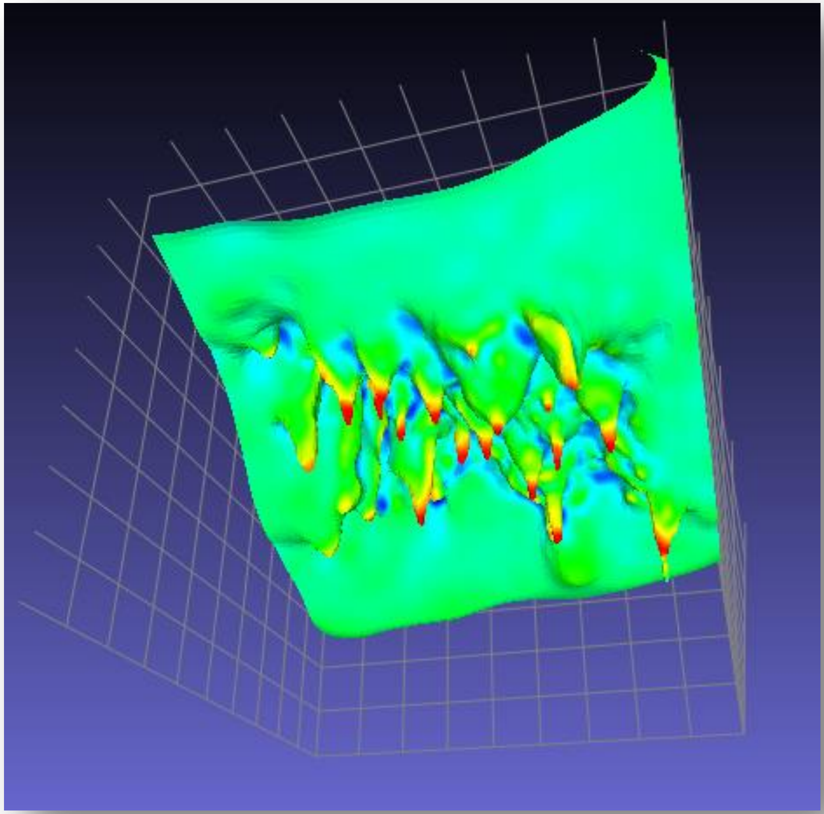


Mean curvature of a cave passage
a 3-D object

3-D gemorphometry

- Useful for classifying stalactites (strong convex features)

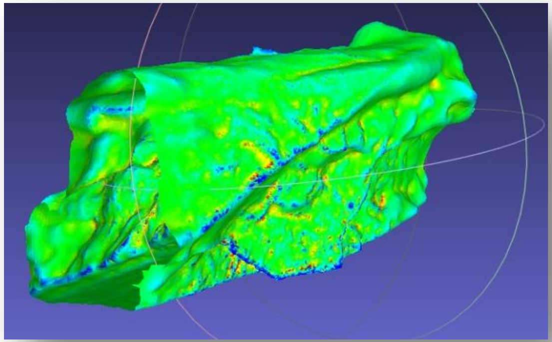


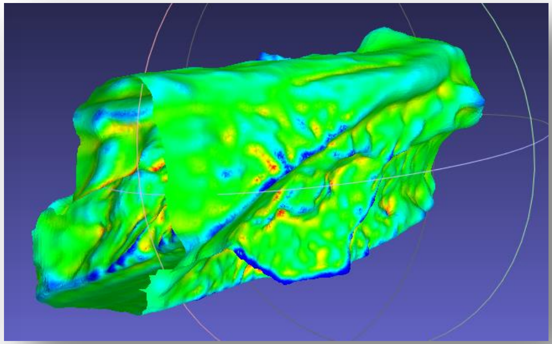


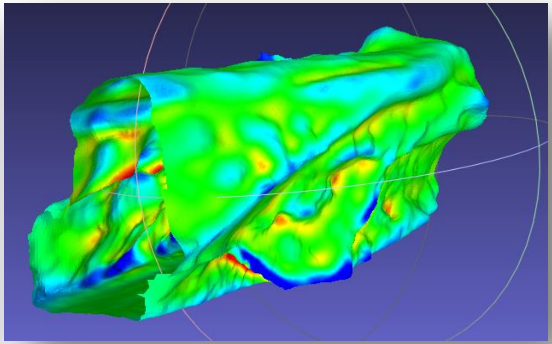
Mean curvature of 1x1 sq. metre of cave ceiling, 34,000 points, octree depth 13

3-D cave gemorphometry

- Curvature value is defined for a neighbourhod which extent is defined by the number of input points
- Multiscale approach



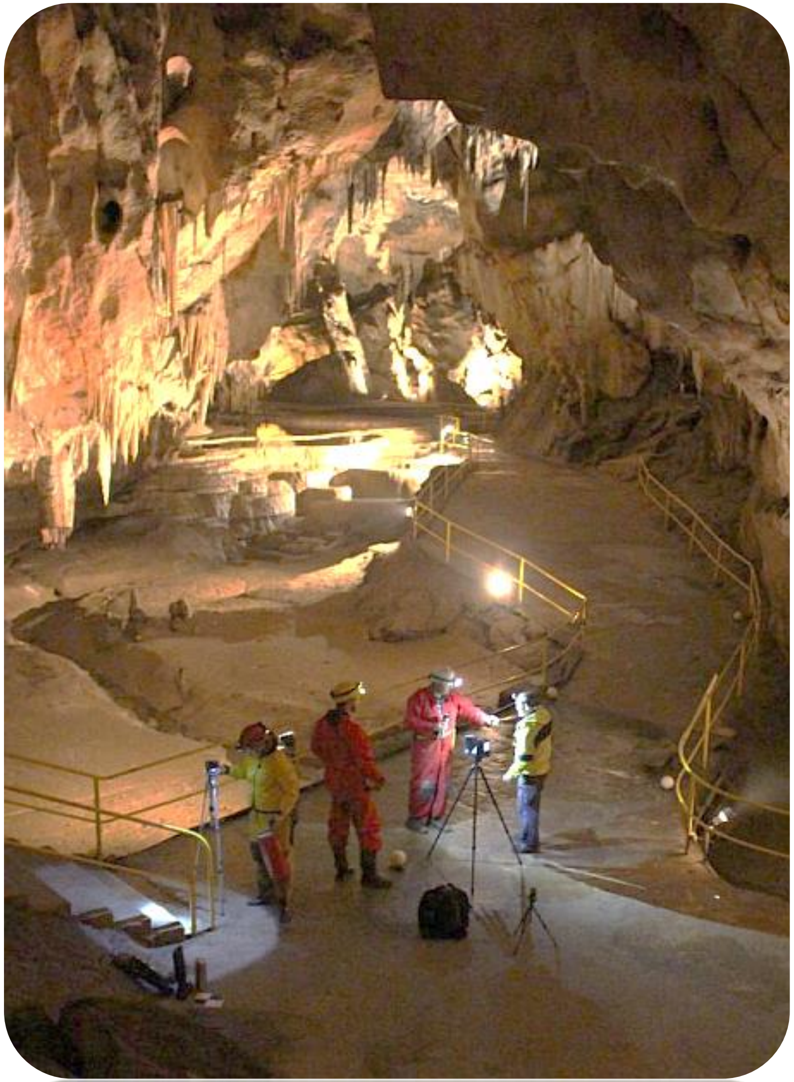


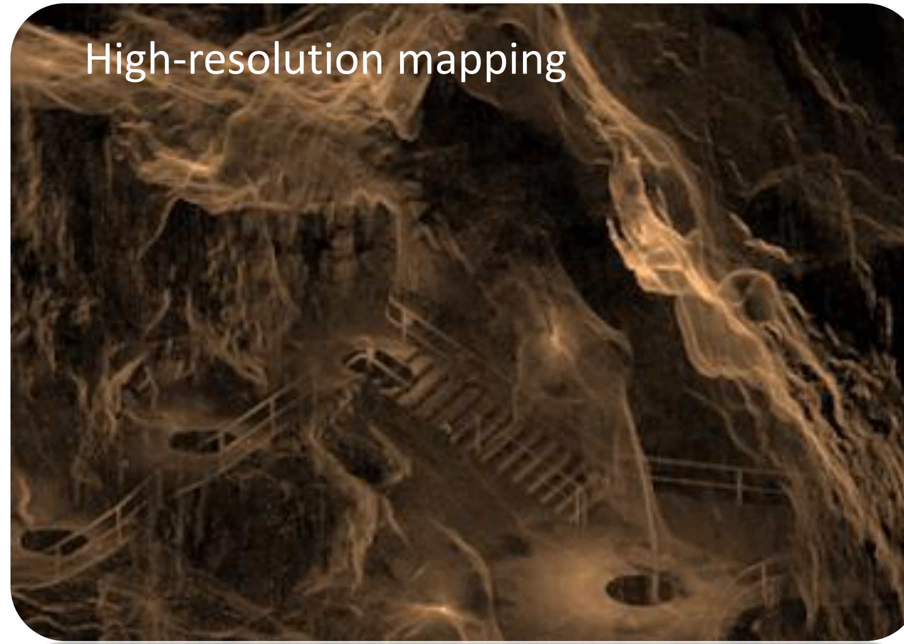


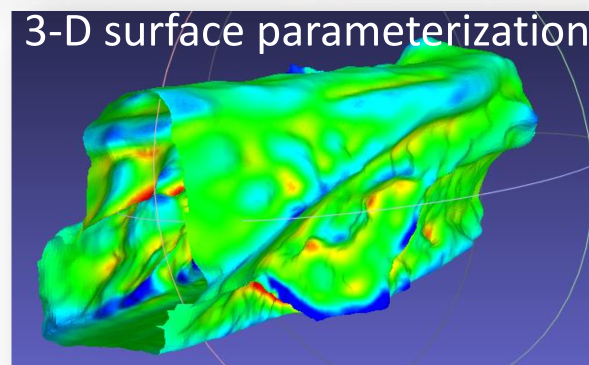
Neighbourhod defined by

5 points **10 points** **20 points**

Summary



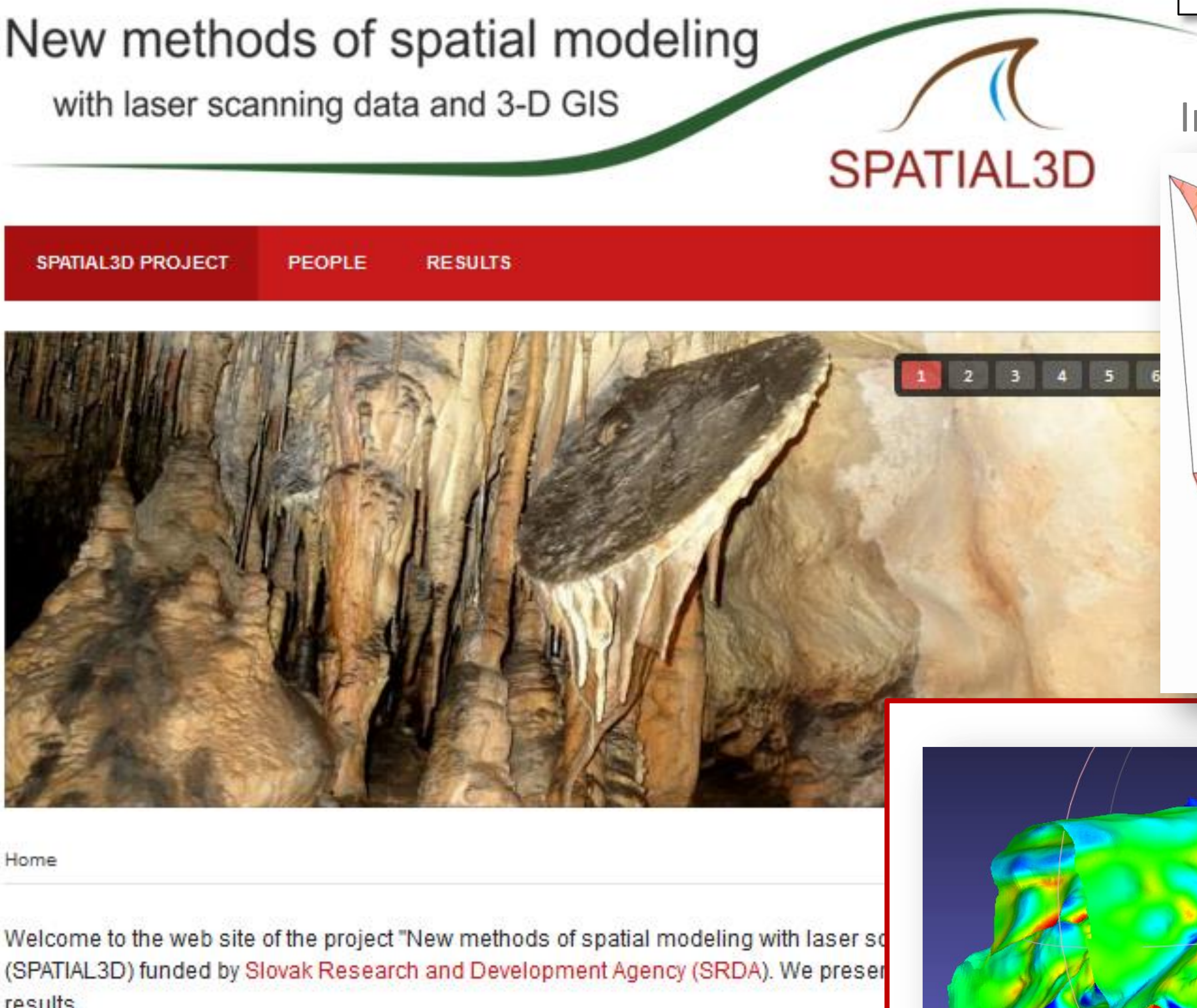




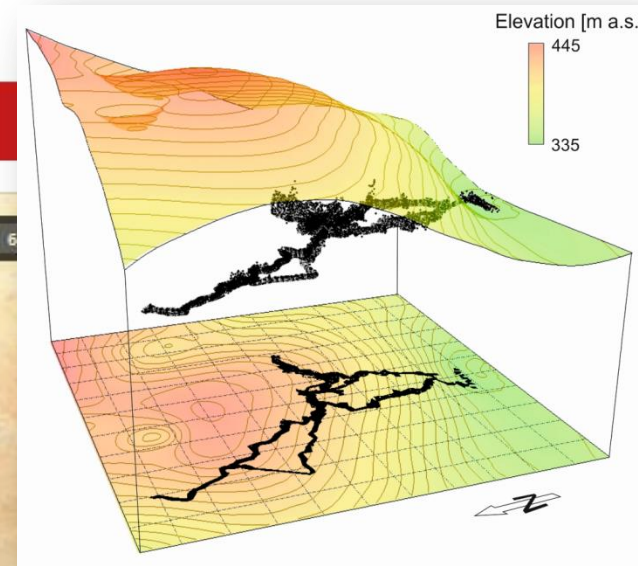
MeshLab

Future research

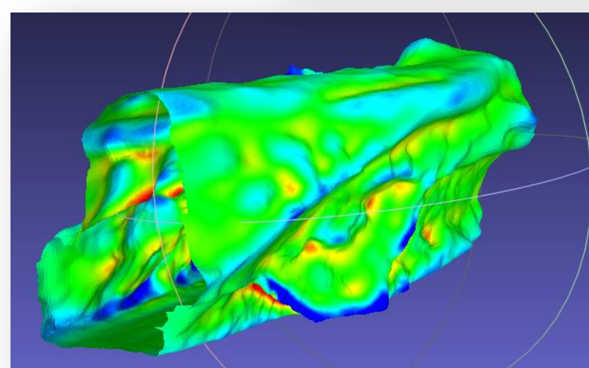
spatial3D.science.upjs.sk



Integrated 3-D modelling in GIS



GRASS GIS



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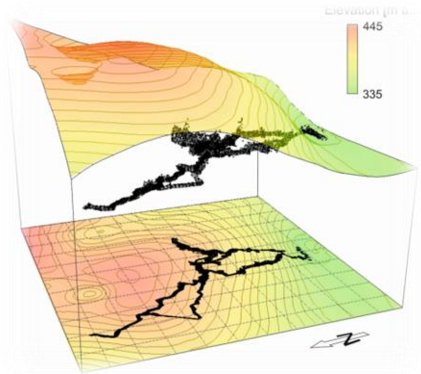
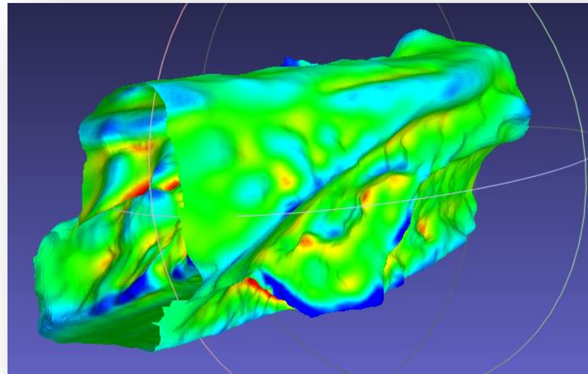
- **University Science Park TECHNICOM** for Innovation Applications Supported by Knowledge Technology, ITMS: 26220220182, supported by the Research & Development Operational Programme funded by the European Regional Development Fund.





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Thank you for attention and questions!

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michal.gallay@upjs.sk

geo.ics.upjs.sk

spatial3D.science.upjs.sk