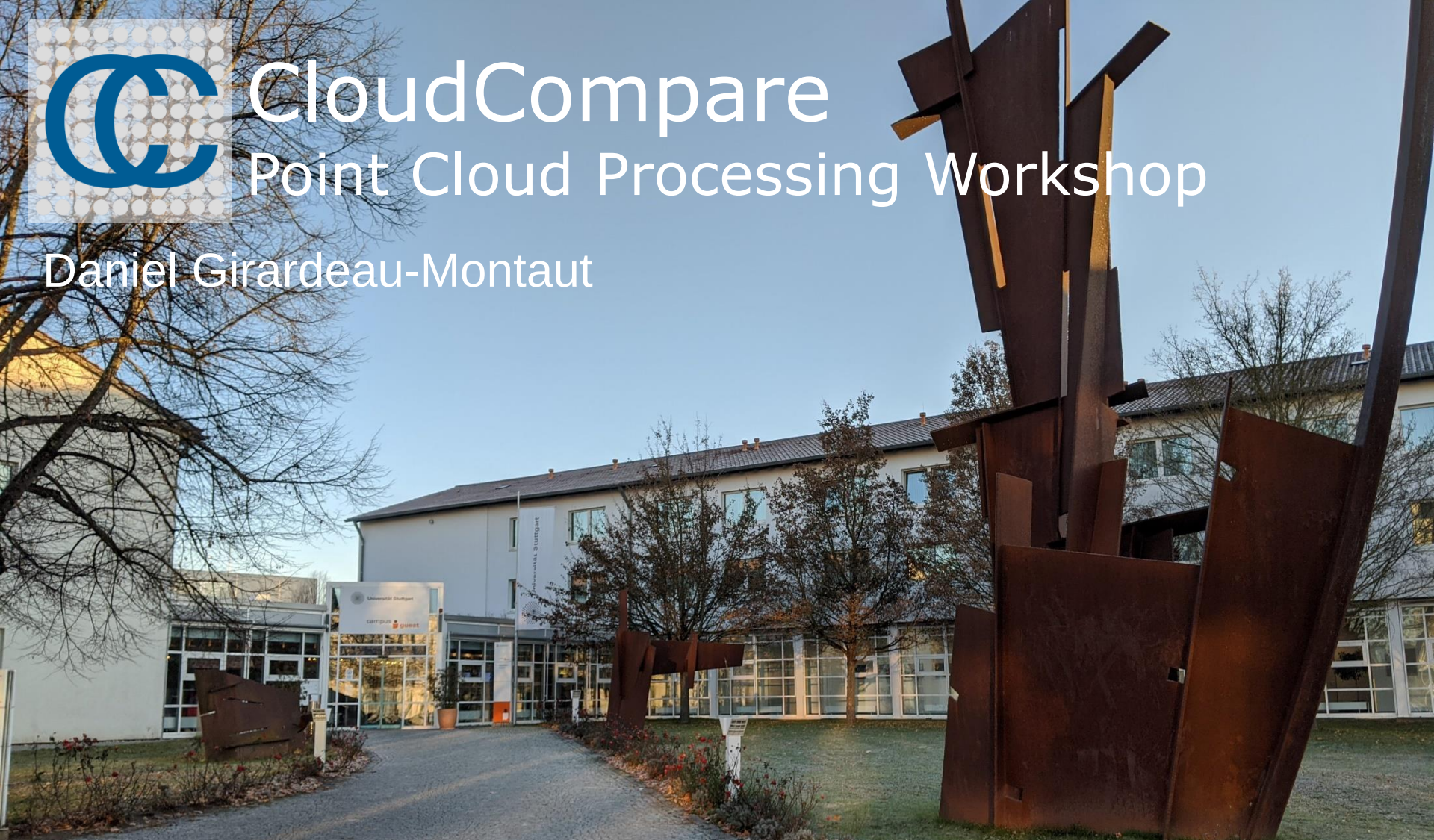




# CloudCompare

## Point Cloud Processing Workshop

Daniel Girardeau-Montaut



[www.cloudcompare.org](http://www.cloudcompare.org)



[@CloudCompareGPL](https://twitter.com/CloudCompareGPL)



[daniel.girardeau@gmail.com](mailto:daniel.girardeau@gmail.com)

**PCP 2019**

December 4-5, 2019, Stuttgart, Germany



# Outline

- About the project
- Quick overview of the software capabilities
- Point cloud processing with CloudCompare

● ● ● The project



# 2003: PhD for **EDF R&D**



## o EDF

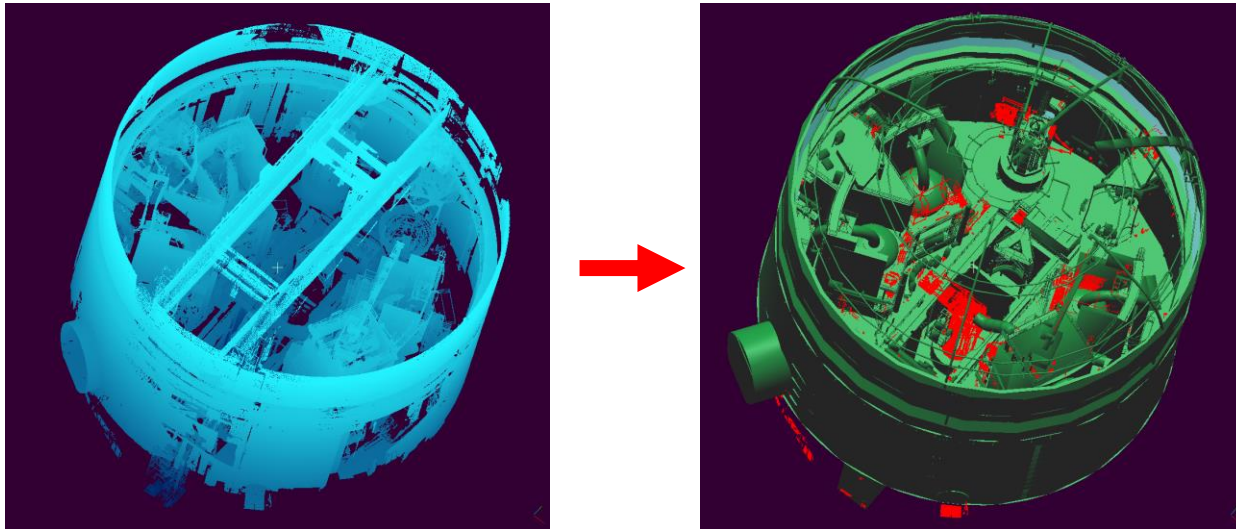
- Main French power utility
- More than 150 000 employees worldwide  
2 000 @ R&D (< 2%)  
200 know about CloudCompare (< 0.2%)
- Sales >75 B€
- > 200 dams + 58 nuclear reactors (19 plants)





# EDF and Laser Scanning

- **EDF** = former owner of **Mensi** (*now Trimble Laser Scanning*)
- Main scanning activity: *as-built* documentation



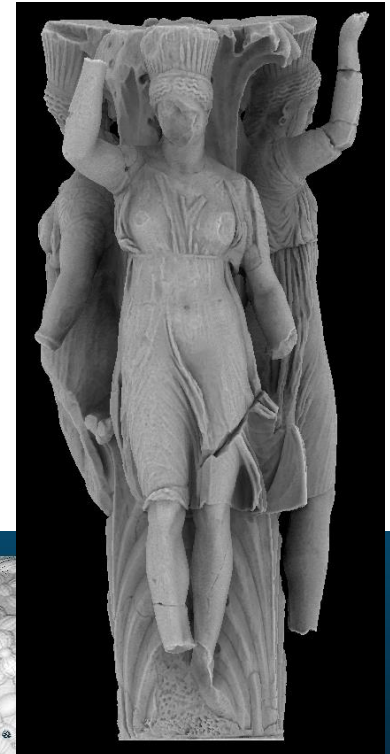
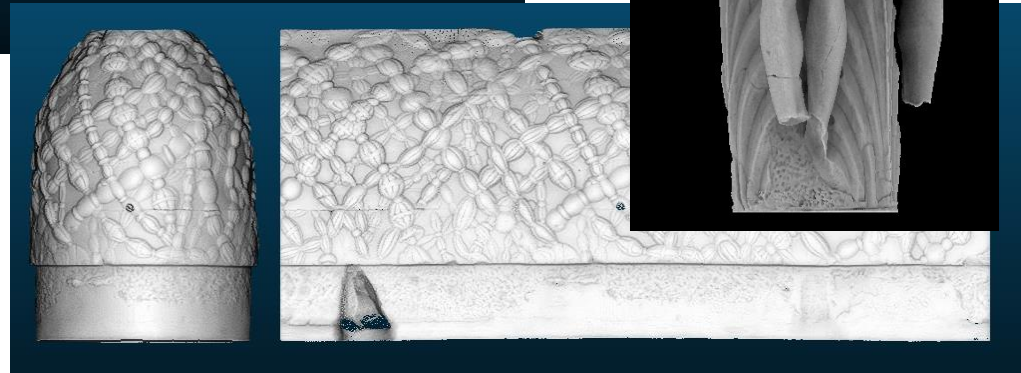
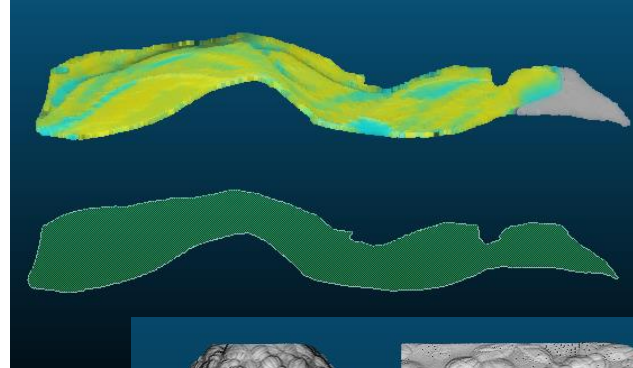
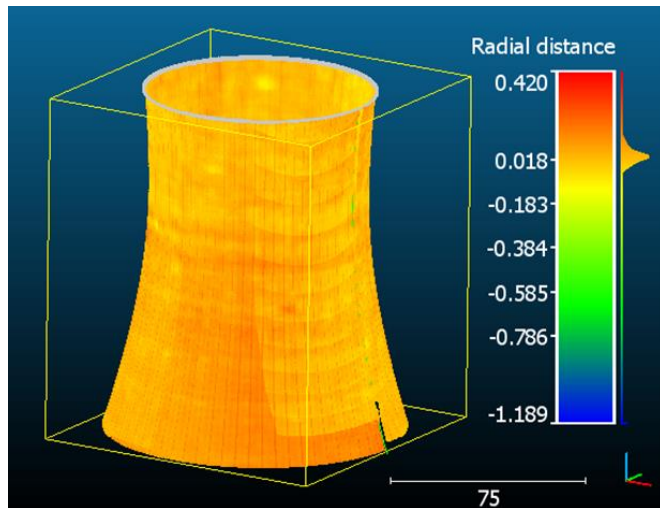
Scanning a single nuclear reactor building

- 2002: 3 days, 50 M. points
- 2014: 1.5 days, **50 Bn** points (+ high res. photos)



# EDF and Laser Scanning

- Other scanning activities:
  - Building monitoring (dams, cooling towers, etc.)
  - Landslide monitoring
  - Hydrology
  - Historical preservation (EDF Foundation)





# PhD



- *Change detection on 3D geometric data*
  - Application to Emergency Mapping
- Inspired by 9/11 post-attacks recovery efforts  
(see “Mapping Ground Zero” by J. Kern, Optech, Nov. 2001)



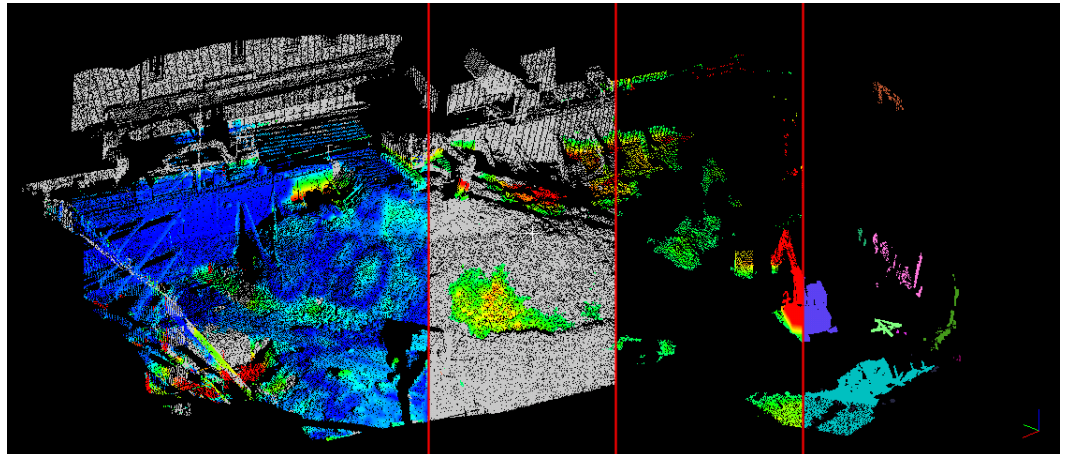
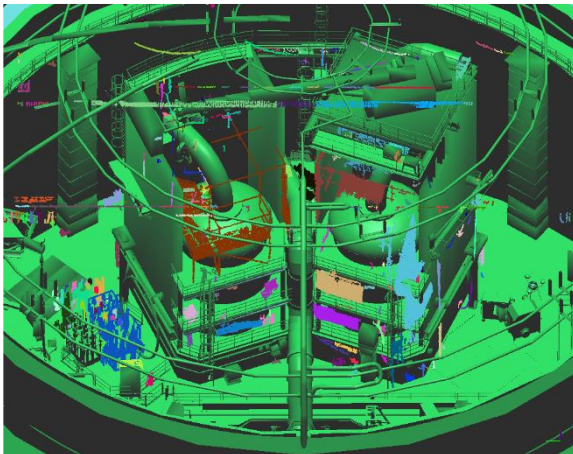
*TLS was used for: visualization, optimal crane placement, measurements, monitoring the subsidence of the wreckage pile, slurry wall monitoring, etc.*



# CloudCompare V1



- 2004-2006
- Aim: quickly detecting changes by comparing TLS point clouds...
  - with a CAD mesh
  - or with another (high density) cloud





# CloudCompare V2

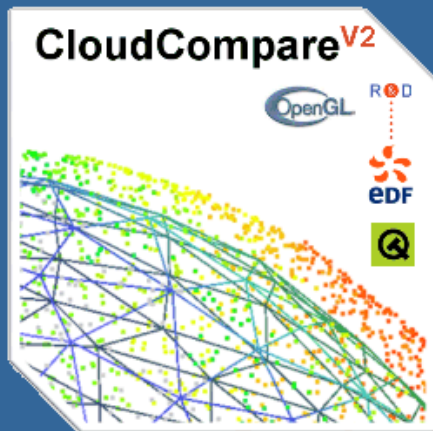
- 2007: “Industrialization” of CloudCompare  
... for internal use only!
- Rationale:
  - *idle reactor = 6 M€ / day*
  - acquired data can be checked on-site → less missing or erroneous data → no need to come back later
  - checking the work of sub-contractors in charge of modeling became fast and accurate
  - the algorithms are also used for clash detection during virtual simulation of tricky maintenance operations → highly reduces the risk of issues or *bad surprises* during the actual maintenance operation

+ *EDF is not a software company*



# The *open-source* path

- 2009/2010: CloudCompare **V2.1**
  - Already a multi-purpose point cloud editing and processing software
- 2017: CloudCompare **V2.8**
- 2019: CloudCompare **V2.11**



Runs on:

Windows (XP / 7 / 8 / 10)

Mac OS (*Andy Maloney*)

Linux (*Romain Janvier*)

Support for 3D mouse & stereo displays



# Open Source!

- Evolves quickly...
- ... in the direction users want (*faster if users actively participate to the developments* 😊)
- Remains under close supervision of its administrator
- Manufacturer independent
- Supported by various companies and public institutions (EDF, BRGM, CNRS, etc.)



# Open Source!

- o Free...



- o ...however, someone still needs to pay ;)
  - either by developing new fonctionnalités
  - or by paying someone else to do it
- o Plugins are not necessarily open source or free



# Users

## ○ Too many 😊

- Academics:
  - remote sensing
  - geology
  - archeology
  - etc.

● Surveyors →

● Forensic experts →

● Architects →

● MDs, dentists →

● 3D designers →

● Artist?! →

# Developers

## ○ Barely enough 😞

- a few PhD students and research engineers

● none

● 1

● none

● none

● none

● none



# CloudCompare Event 2020



**CloudCompare**  
3D point cloud and mesh processing software  
Open Source Project

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## CloudCompare Event 2020

**edf**

Event Timing: March 11-13, 2020

~~Developers training course: March 11-12 (20 )~~ **FULL!**  
Users workshop: March 13 (100 )

Event information and registration

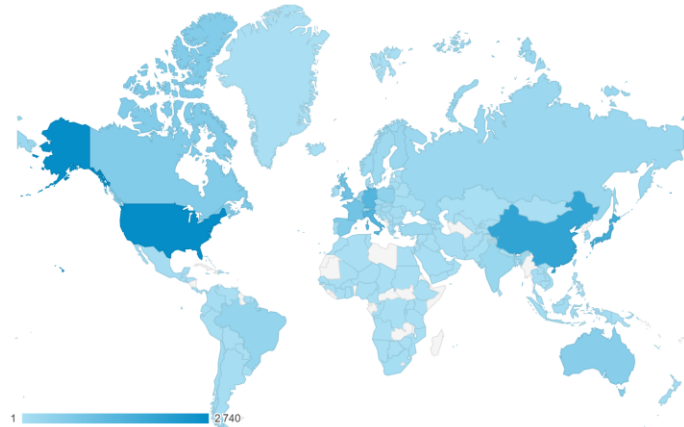
[REGISTER NOW](#) 

**FREE**



# Worldwide

Sessions  
(November)



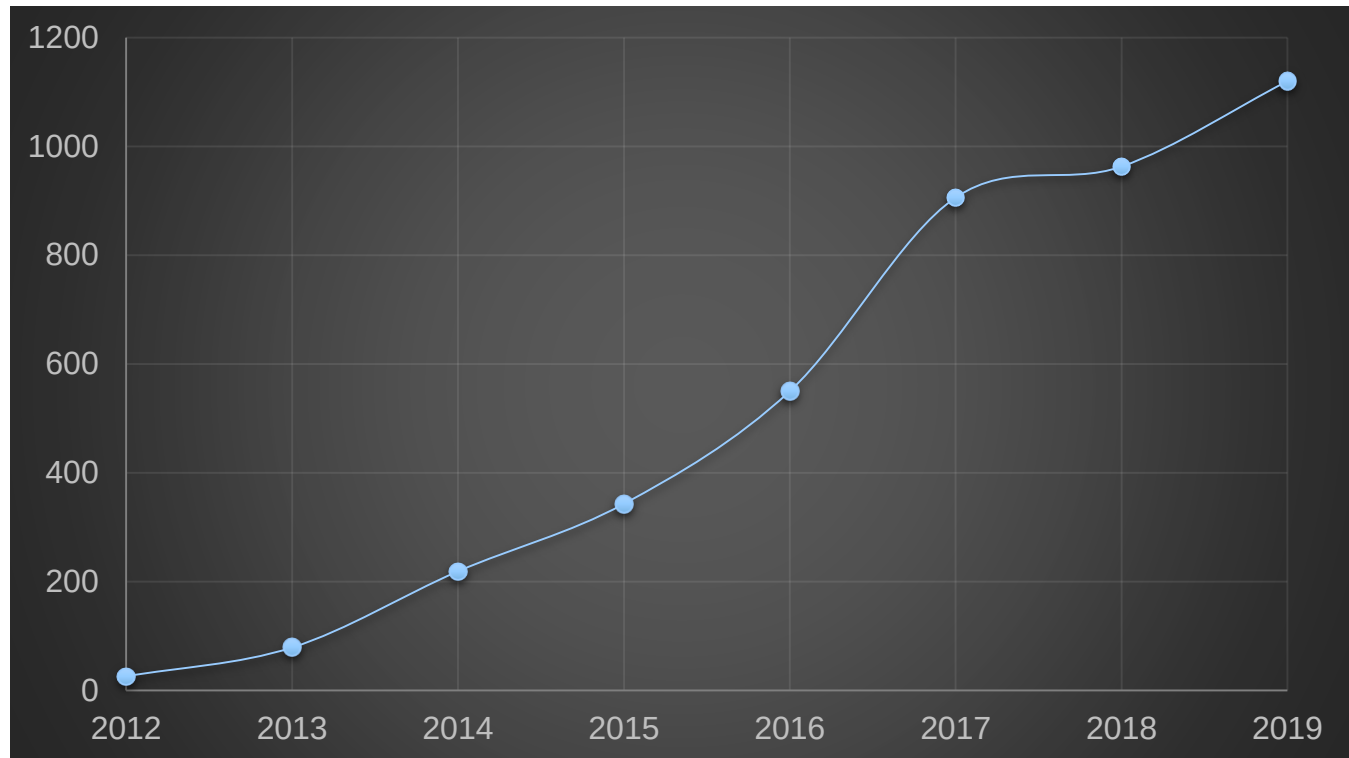
Dimension principale : Pays Ville Continent Sous-continent

| Dimension secondaire ▾ |                                       |                                       |                                       |                                                      |                                                |                                                        |                                                    |                             |                                             |  |
|------------------------|---------------------------------------|---------------------------------------|---------------------------------------|------------------------------------------------------|------------------------------------------------|--------------------------------------------------------|----------------------------------------------------|-----------------------------|---------------------------------------------|--|
| Pays ▾                 | Acquisition                           |                                       |                                       | Comportement                                         |                                                |                                                        | Conversions                                        |                             |                                             |  |
|                        | Utilisateurs ▾<br>↓                   | Nouveaux utilisateurs ▾               | Sessions ▾                            | Taux de rebond ▾                                     | Pages/session ▾                                | Durée moyenne des sessions ▾                           | Taux de conversion par objectif ▾                  | Objectifs réalisés ▾        | Valeur de l'objectif ▾                      |  |
|                        | 19873<br>% du total: 100,00 % (19873) | 18057<br>% du total: 100,00 % (18043) | 25668<br>% du total: 100,00 % (25668) | 41,39 %<br>Valeur moy. pour la vue: 41,39 % (0,00 %) | 1,87<br>Valeur moy. pour la vue: 1,87 (0,00 %) | 00:02:01<br>Valeur moy. pour la vue: 00:02:01 (0,00 %) | 0,00 %<br>Valeur moy. pour la vue: 0,00 % (0,00 %) | 0<br>% du total: 0,00 % (0) | 0,00 \$US<br>% du total: 0,00 % (0,00 \$US) |  |
| 1. 🇺🇸 United States    | 2740 (13,71 %)                        | 2526 (13,99 %)                        | 3327 (12,96 %)                        | 47,07 %                                              | 1,79                                           | 00:01:38                                               | 0,00 %                                             | 0 (0,00 %)                  | 0,00 \$US (0,00 %)                          |  |
| 2. 🇨🇳 China            | 1985 (9,93 %)                         | 1740 (9,64 %)                         | 2671 (10,41 %)                        | 40,96 %                                              | 1,91                                           | 00:02:20                                               | 0,00 %                                             | 0 (0,00 %)                  | 0,00 \$US (0,00 %)                          |  |
| 3. 🇯🇵 Japan            | 1714 (8,57 %)                         | 1524 (8,44 %)                         | 2202 (8,58 %)                         | 38,47 %                                              | 2,08                                           | 00:02:19                                               | 0,00 %                                             | 0 (0,00 %)                  | 0,00 \$US (0,00 %)                          |  |
| 4. 🇮🇹 Italy            | 1450 (7,25 %)                         | 1338 (7,41 %)                         | 1840 (7,17 %)                         | 34,08 %                                              | 1,92                                           | 00:02:17                                               | 0,00 %                                             | 0 (0,00 %)                  | 0,00 \$US (0,00 %)                          |  |
| 5. 🇩🇪 Germany          | 1388 (6,94 %)                         | 1269 (7,03 %)                         | 1854 (7,22 %)                         | 44,01 %                                              | 1,90                                           | 00:02:00                                               | 0,00 %                                             | 0 (0,00 %)                  | 0,00 \$US (0,00 %)                          |  |
| 6. 🇬🇧 United Kingdom   | 965 (4,83 %)                          | 872 (4,83 %)                          | 1179 (4,59 %)                         | 41,56 %                                              | 1,85                                           | 00:02:05                                               | 0,00 %                                             | 0 (0,00 %)                  | 0,00 \$US (0,00 %)                          |  |
| 7. 🇫🇷 France           | 908 (4,54 %)                          | 841 (4,66 %)                          | 1099 (4,28 %)                         | 40,95 %                                              | 1,85                                           | 00:01:52                                               | 0,00 %                                             | 0 (0,00 %)                  | 0,00 \$US (0,00 %)                          |  |
| 8. 🇪🇸 Spain            | 714 (3,57 %)                          | 656 (3,63 %)                          | 914 (3,56 %)                          | 36,76 %                                              | 1,99                                           | 00:02:14                                               | 0,00 %                                             | 0 (0,00 %)                  | 0,00 \$US (0,00 %)                          |  |
| 9. 🇨🇦 Canada           | 648 (3,24 %)                          | 563 (3,12 %)                          | 814 (3,17 %)                          | 40,66 %                                              | 1,75                                           | 00:01:37                                               | 0,00 %                                             | 0 (0,00 %)                  | 0,00 \$US (0,00 %)                          |  |
| 10. 🇦🇺 Australia       | 562 (2,81 %)                          | 500 (2,77 %)                          | 688 (2,68 %)                          | 39,68 %                                              | 1,80                                           | 00:01:47                                               | 0,00 %                                             | 0 (0,00 %)                  | 0,00 \$US (0,00 %)                          |  |

> 3300 users registered to the newsletter



# Citations in scientific articles

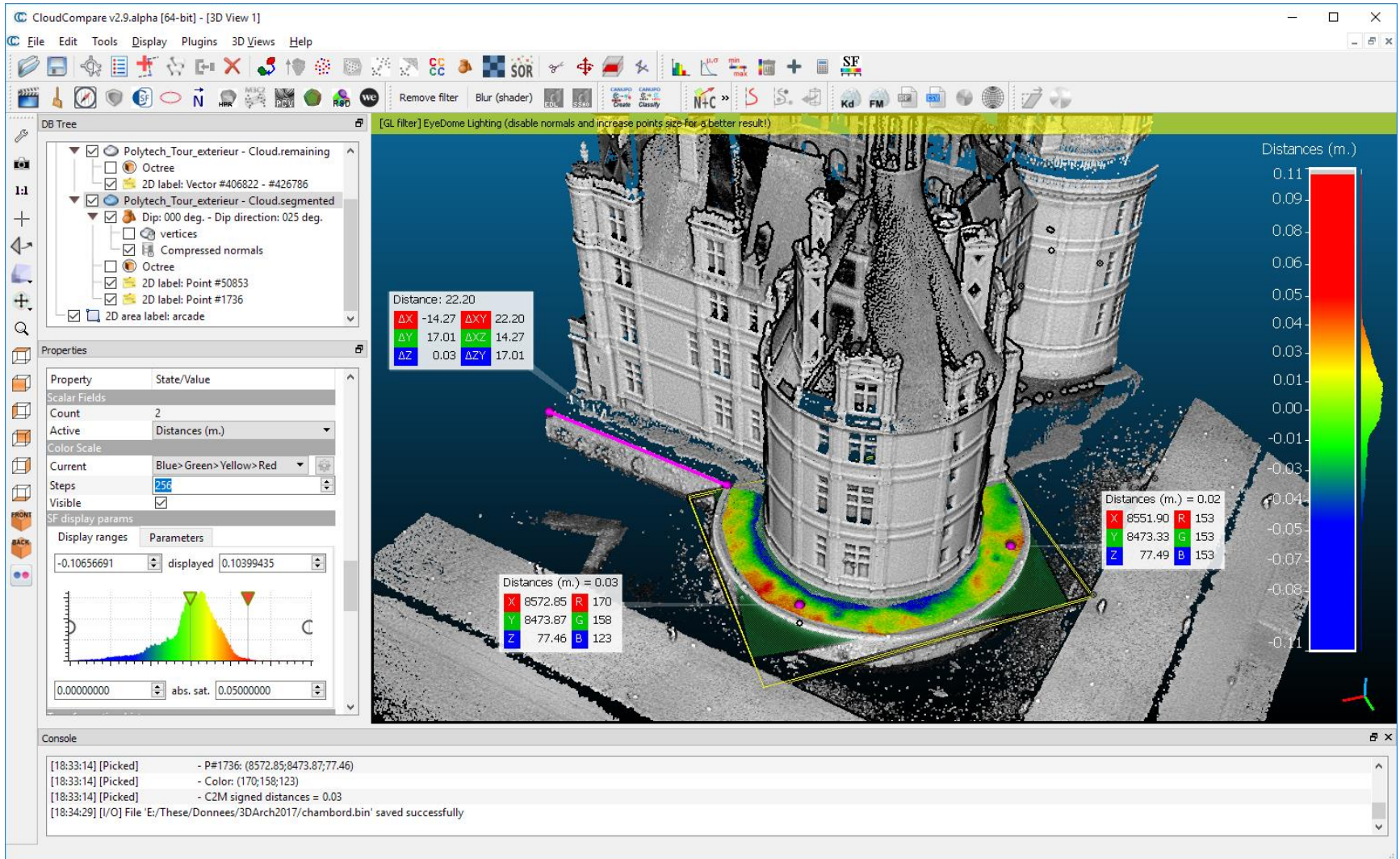


*source: Google scholar*

● ● ● Quick overview



# Interface





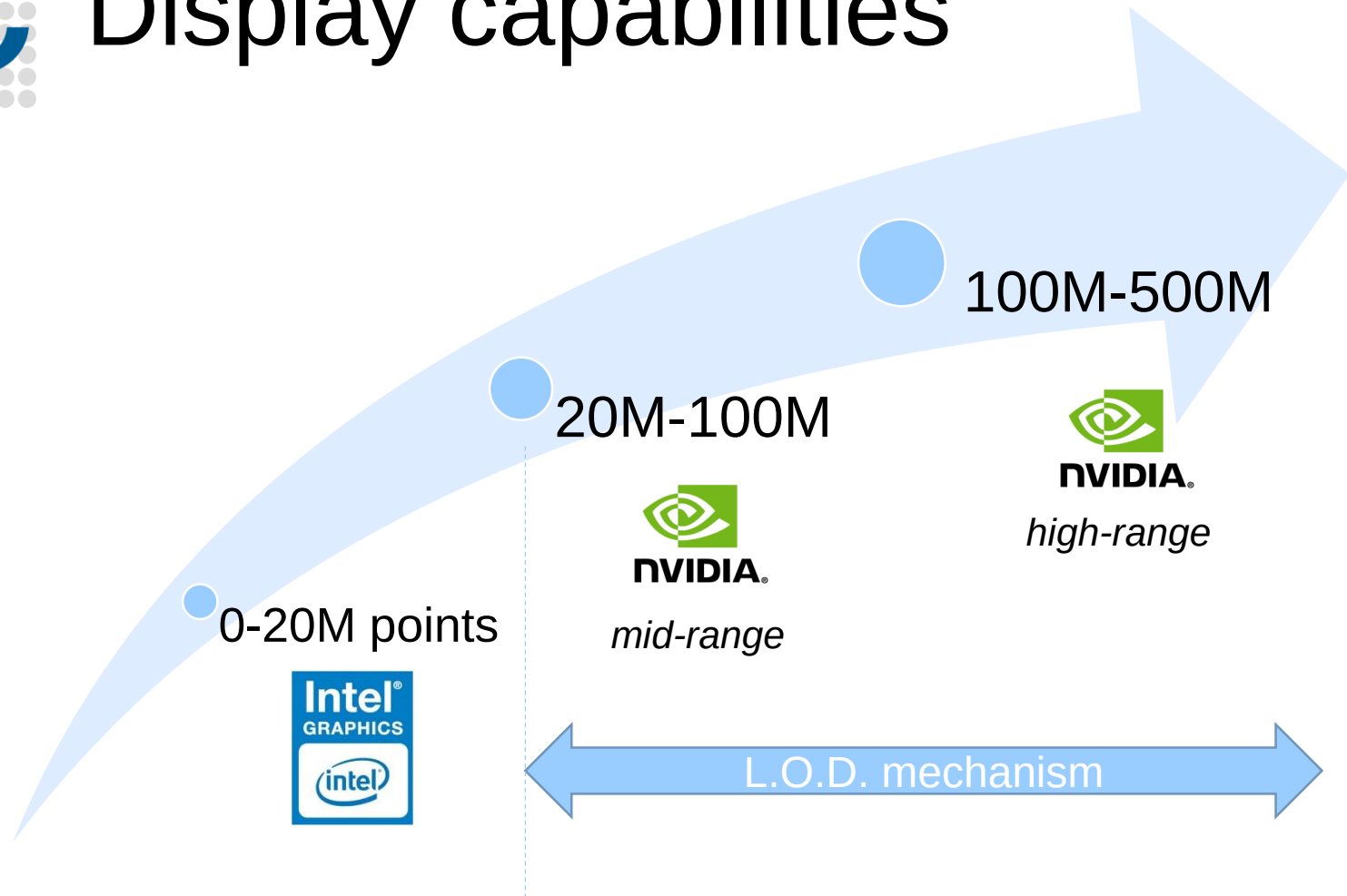
# Inputs / outputs

- point clouds 
  - ASCII, PLY, LAS, E57, PTX, PCD... + Faro, **Riegl**, DotProduct
- triangular meshes 
  - OBJ, PLY, STL, OFF, FBX
- polylines 
  - SHP, DXF, etc.
- rasters 
  - geotiff, etc. (*thanks to GDAL*)
- calibrated pictures 
  - Bundler OUT, Photoscan PSZ
- sensors
  - TLS  or projective cameras 

+ dedicated format: **BIN** (for projects)



# Display capabilities



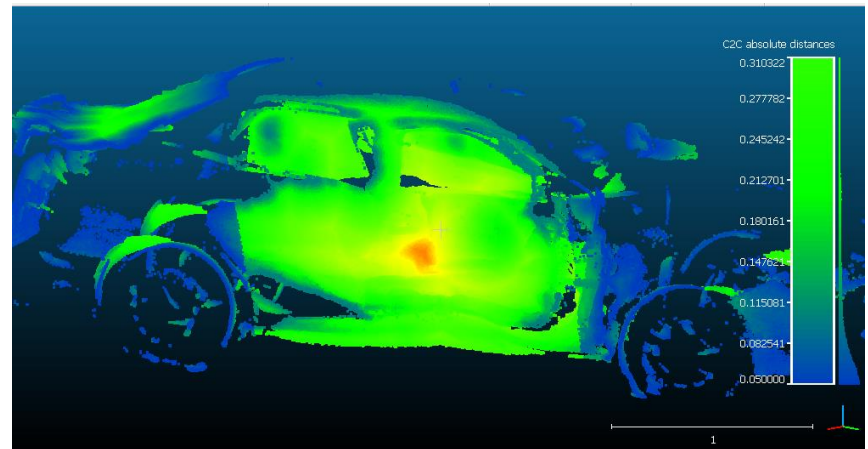
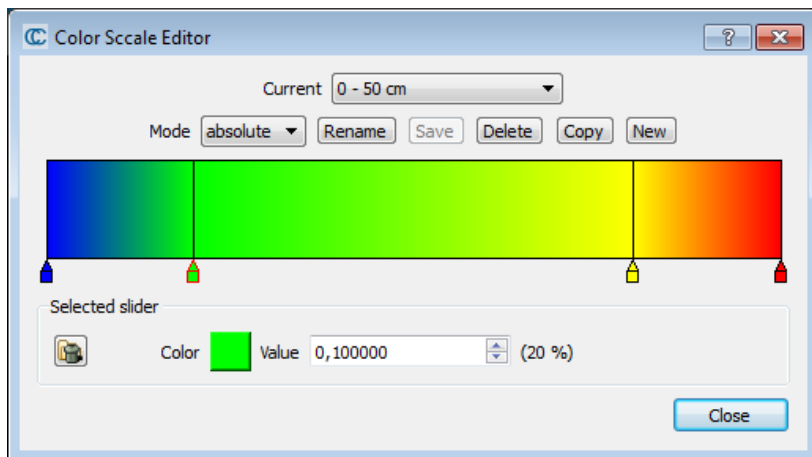
> 500 M. points?

- for now, use the command line mode 😊
- later: *out-of-core* support?



# Scalar fields

- One value per point
- The value can be anything (distance, intensity, density, roughness, confidence, curvature, temperature, time, etc.)
- Values can be (dynamically) color-coded





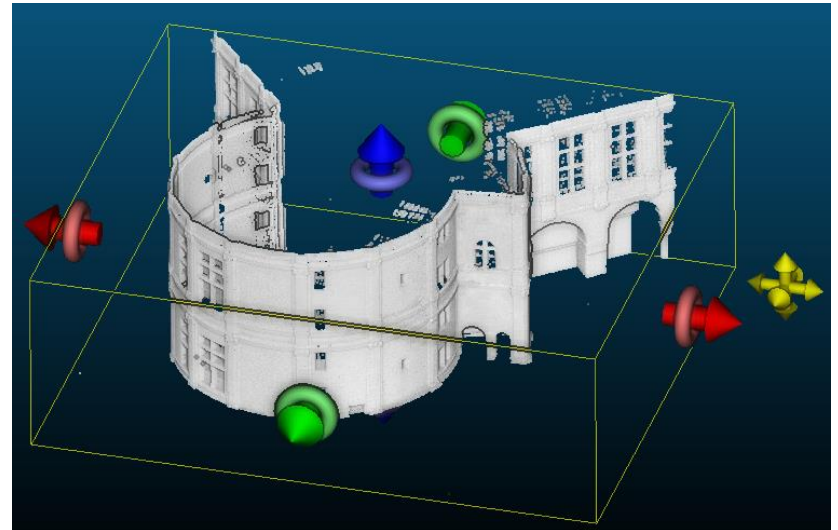
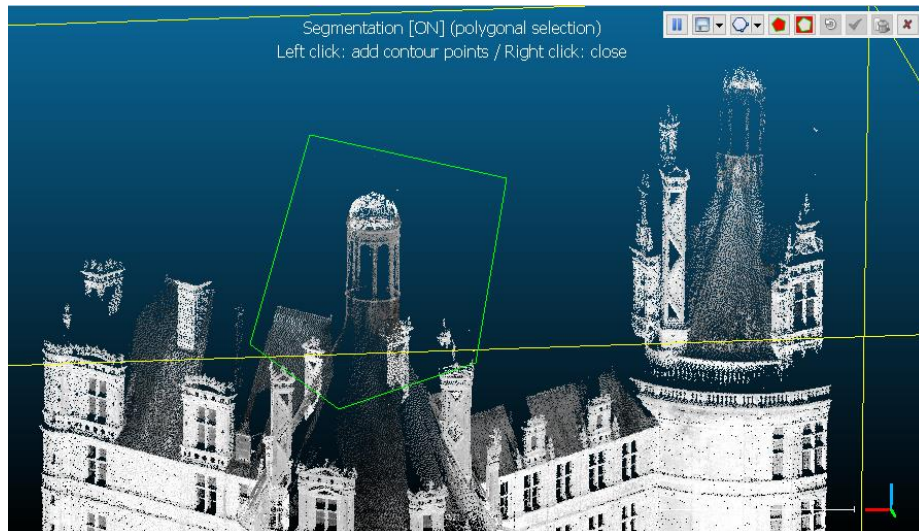
# Scalar fields

- Values can be
  - mixed (+,-,/x)
  - transformed (cos, log, etc.)
  - filtered (spatial smoothing, spatial gradient, etc.)
  - imported or exported as a coordinate dimension
  - merged with colors
  - transferred to another entity (+ interpolated)
- Statistics can be computed
- Clouds can be processed based on those values
  - Segmentation (*“Filter by value”*)
  - Subsampling



# Main features

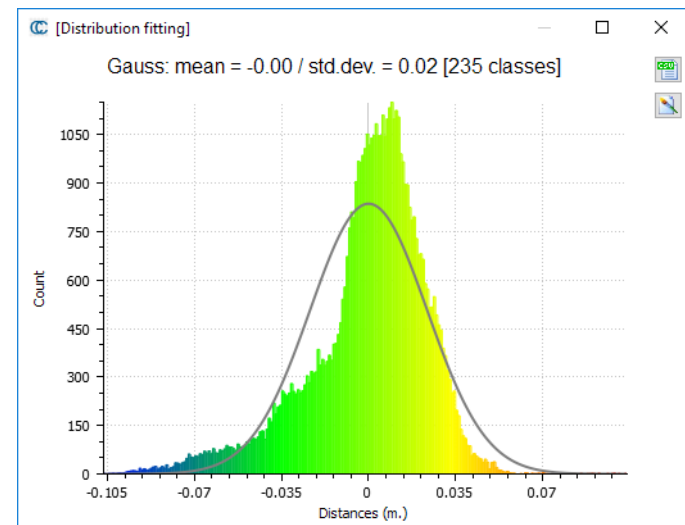
- Interactive tools
  - transformation, segmentation, cross section
- Colors
  - create, convert, level, etc.
- Normals
  - create, convert, orient





# Main features

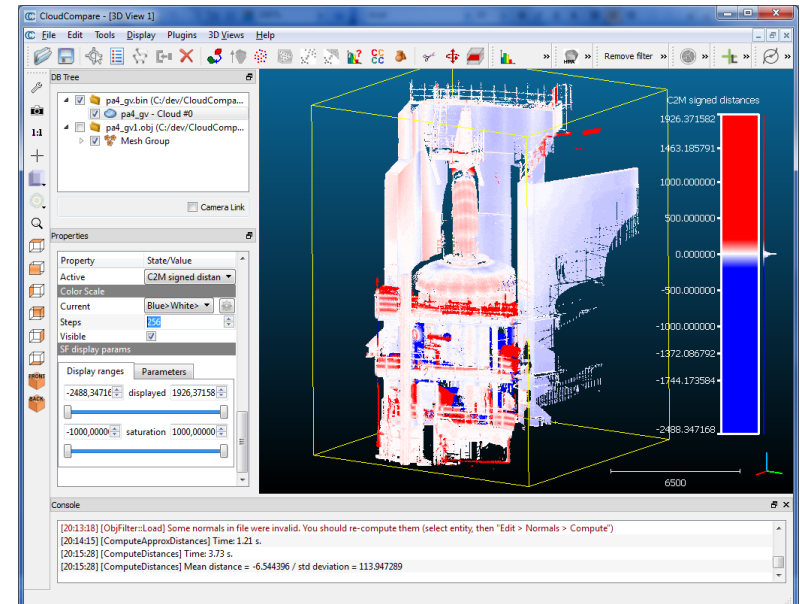
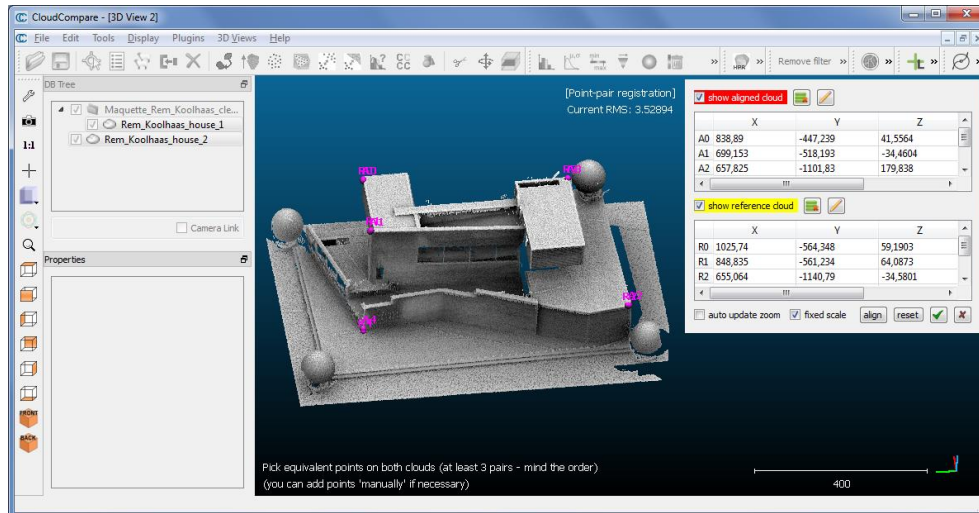
- Mesh operations
  - create (2.5D Delaunay), sample points, smooth, etc.
  - → *see Meshlab for more*
- Scalar fields operations
  - filter points by value, convert, smooth, gradient, etc.
- Point picking,  
Distance / angle measurements
- Others
  - Subsample, merge, scale, etc.





# Main tools

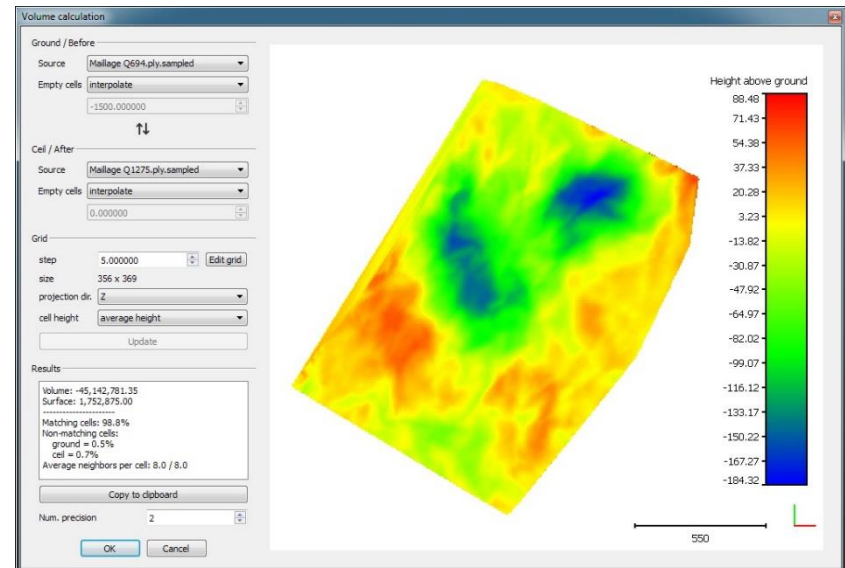
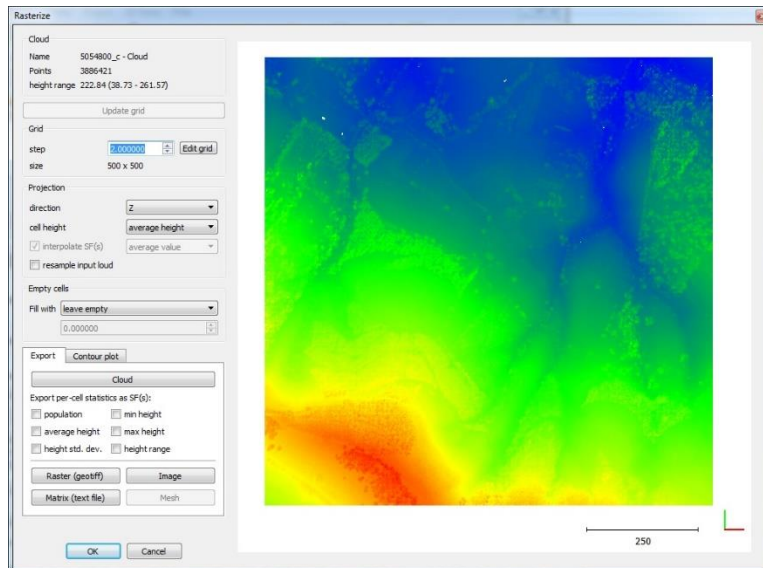
- Registration
  - point-pair-based alignment, ICP
- Distances
  - Cloud-to-cloud (C2C), Cloud-to-mesh (C2M), Cloud-to-primitive (C2P), Robust cloud-to-cloud (M3C2)





# Main tools

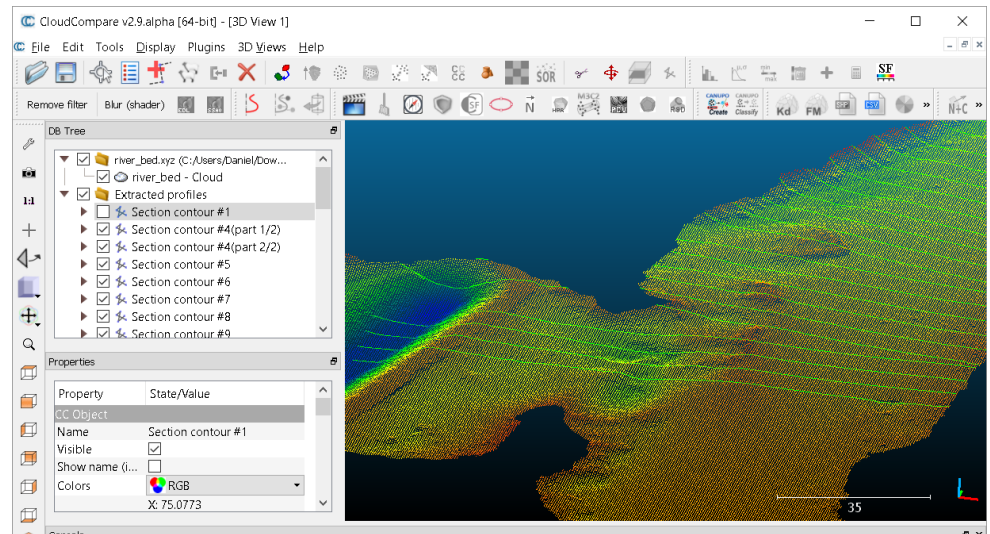
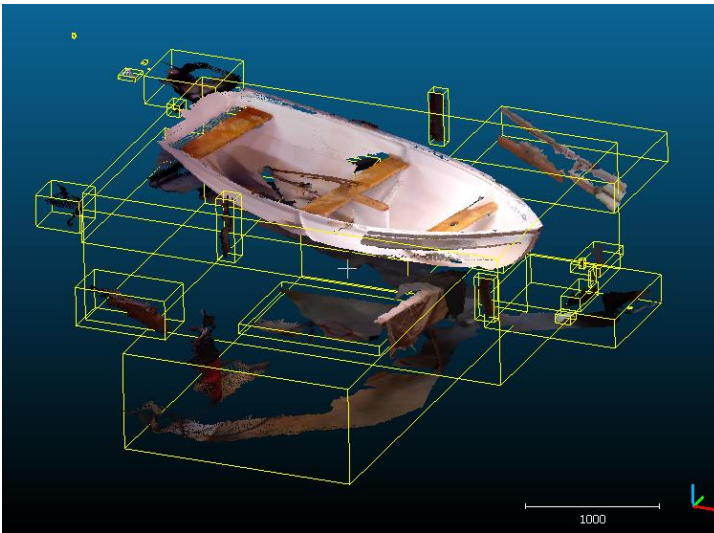
- Cleaning
  - SOR, etc.
- Rasterize
  - + contour plot
- 2.5D volume estimation





# Main tools

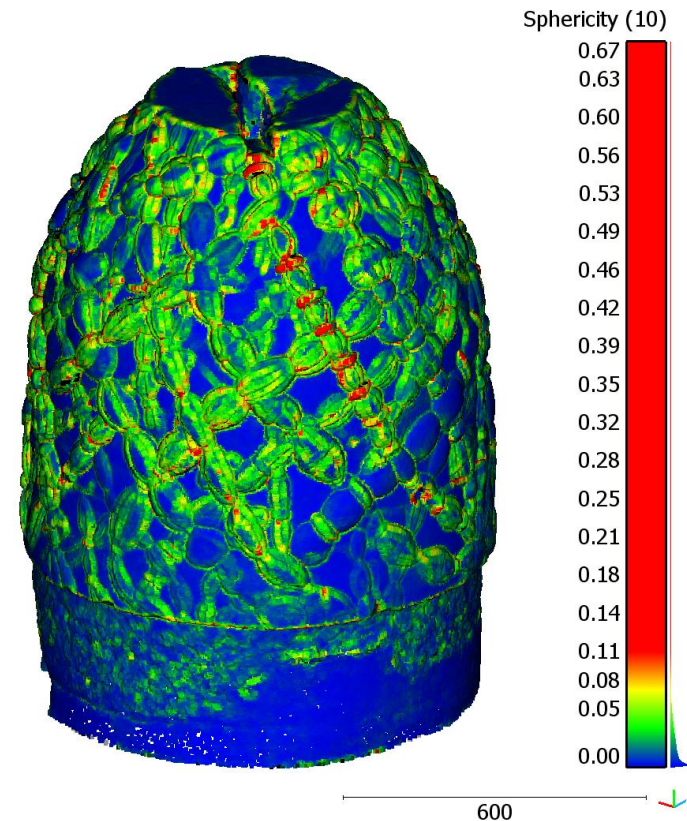
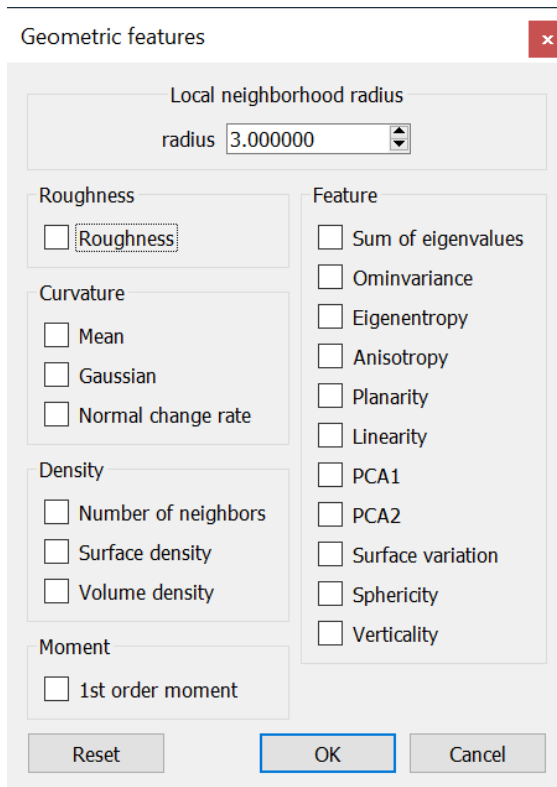
- Segmentation
  - connected components, profile extraction, etc.
- Fitting
  - plane, sphere, quadric, etc.





# Main tools

- Roughness, curvature, density and other geometric features computation



Features: "Contour detection in unstructured 3D point clouds", Hackel et al, 2016

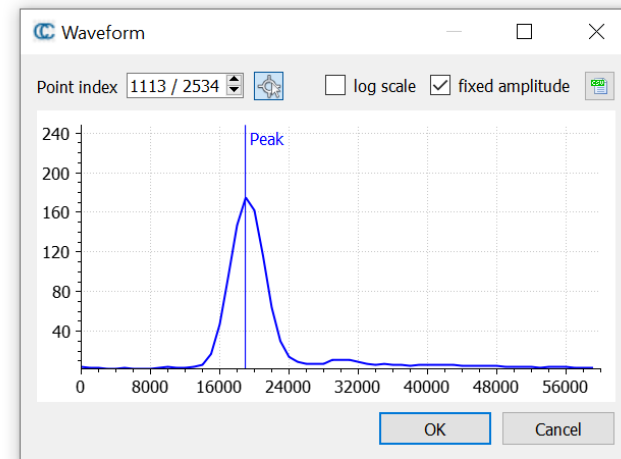
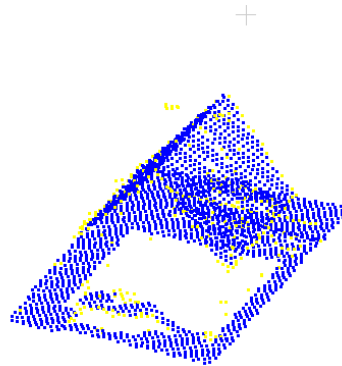


# Advanced point cloud processing



# Built-in support

- Octree structure (fast construction, fast kNN)
- Sensors (TLS or Camera)
- Scan grids (structured point clouds)
- Full waveform

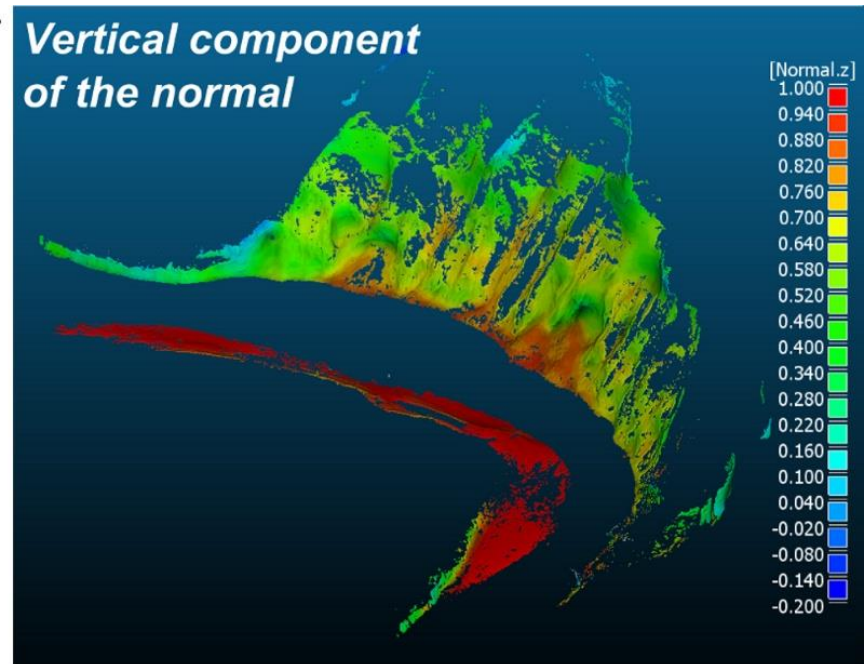
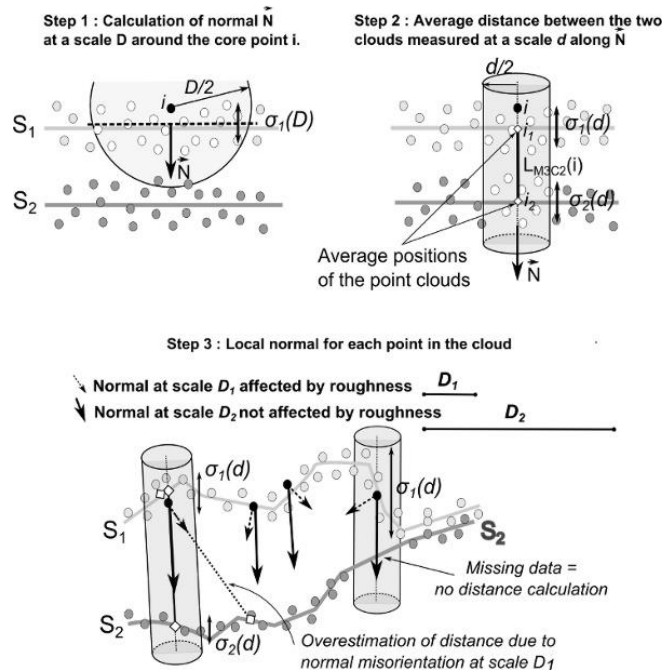


- Plugins
- Command line mode



# M3C2

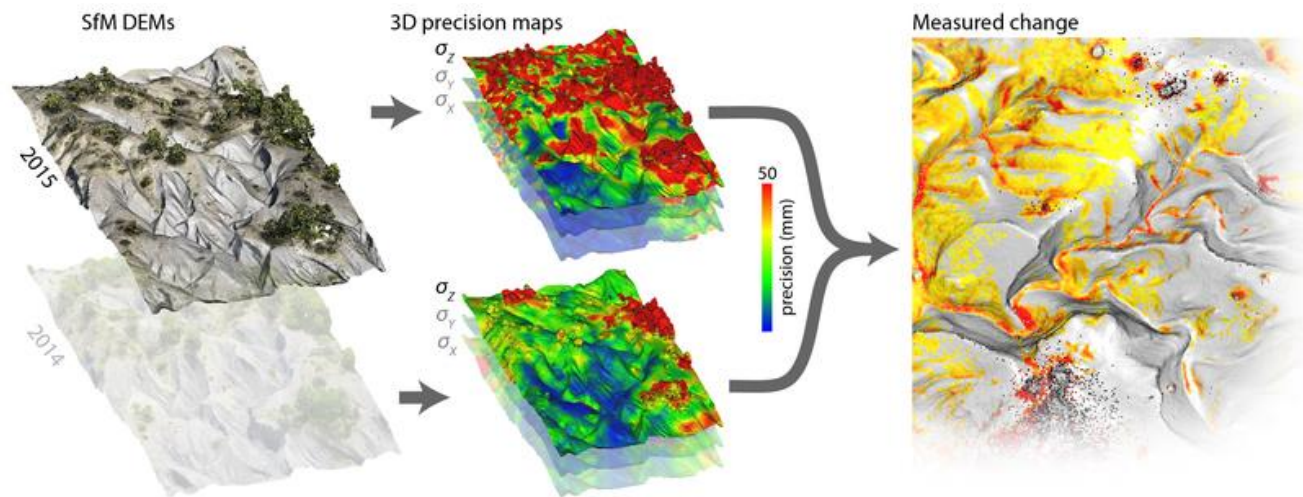
- Robust + signed C2C distances
  - Search correspondences along surface normal
  - Multi-scale approach
  - Uncertainty estimation based on local surface roughness





# M3C2

- 'Precision maps' (M3C2-PM) variant



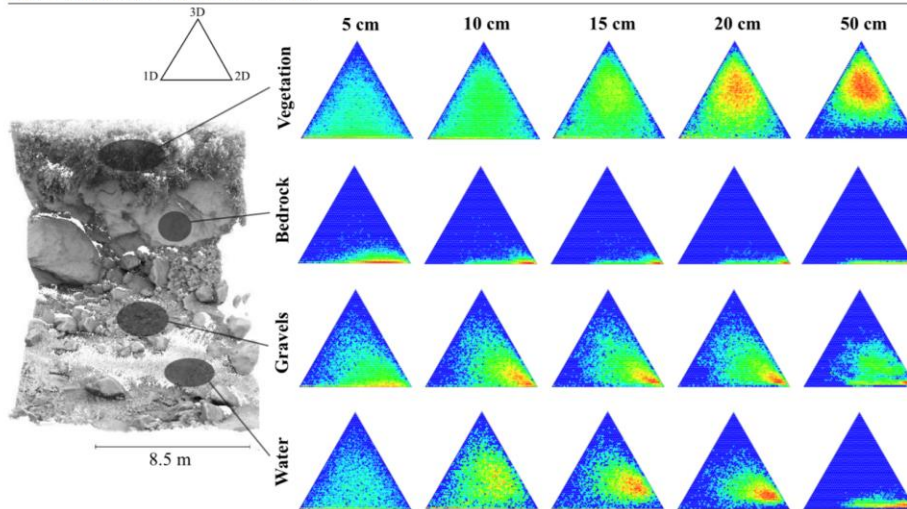
*"3D uncertainty-based topographic change detection with SfM photogrammetry: precision maps for ground control and directly georeferenced surveys" by M. James et al.*



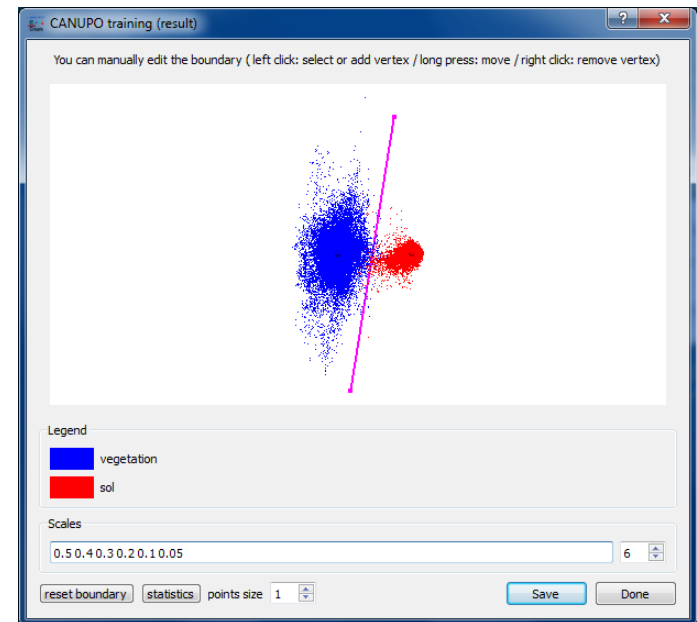
# Canupo

- Point cloud classification
  - Multi-scale local dimensionality feature
  - SVM based training

Fig. 7 Multiscale, multi-class scenario



Left : excerpt from the point cloud of fig. 1. Right: dimensionality diagrams for the four main classes of a mountain river environment at scales ranging from 5 to 50 cm. Colors from blue to red correspond to the density of points from the training dataset and characterize the degree of clustering around a given dimensionality.

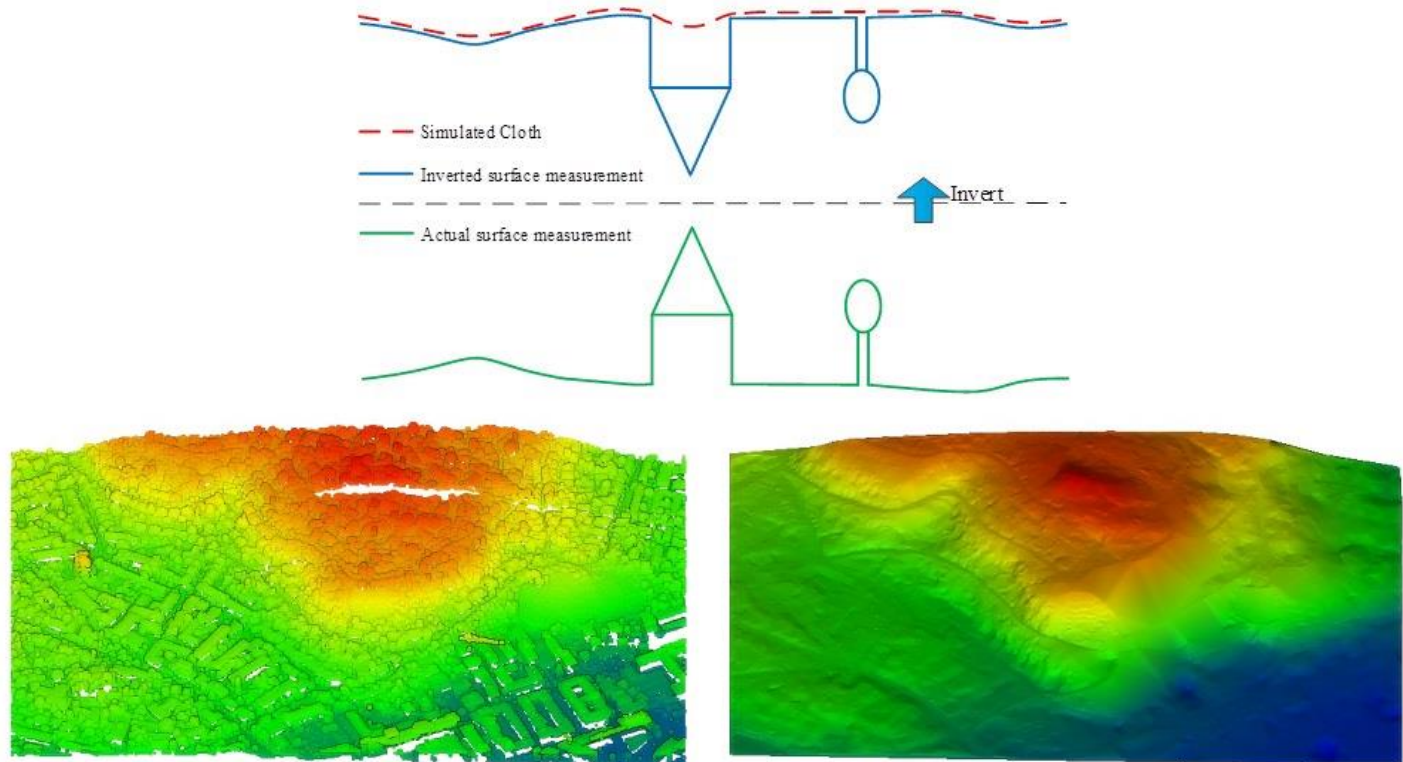


*"3D Terrestrial lidar data classification of complex natural scenes using a multi-scale dimensionality criterion: applications in geomorphology", N. Brodu, D. Lague, 2012*



# Cloth Simulation Filter (CSF)

- Ground points extraction from LiDAR point clouds

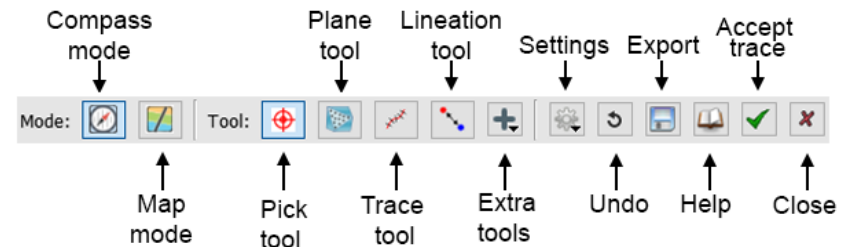


"An Easy-to-Use Airborne LiDAR Data Filtering Method Based on Cloth Simulation", W. Zhang et al., 2016

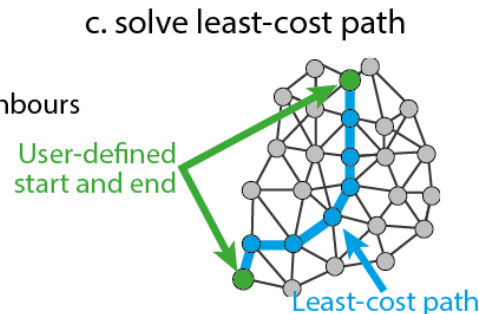
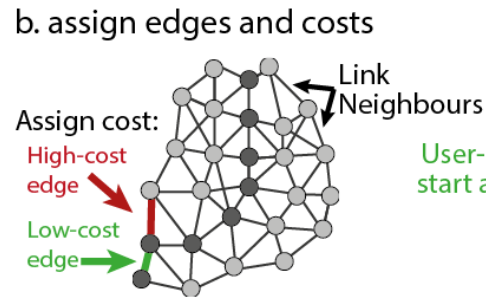
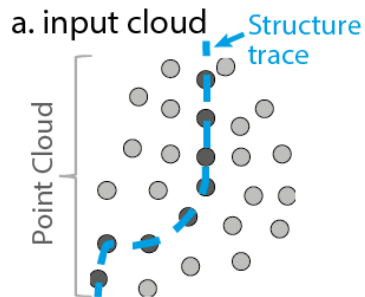


# Compass

- Structural geology toolbox for the interpretation and analysis of virtual outcrop models
  - Delineation of geological units
  - Measurement of orientations and thicknesses



- Tracing and automated path 'following'



*"Rapid, semi-automatic fracture and contact mapping for point clouds, images and geophysical data", S. Thiele et al., 2017*



# Other plugins



- Automatic shape detection (Ransac Shape Detection)
- Geological facet extraction (Facets)
- Global illumination of clouds and meshes (PCV)
- 3D surface reconstruction (PoissonRecon)
- Animation rendering (Animation)
- Surface of Revolution Analysis (SRA)
- Planar surfaces cleaning (Virtual Broom)
- Hidden Points Removal (HPR)
- etc.

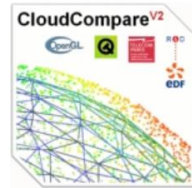


# Creating your own plugin...

- ... is easy:
  - copy the 'dummy' plugin folder
  - replace the word 'dummy' in all files by your plugin name
  - and add the code for your plugin 'action' at the right place
- Plenty of examples
  - simply mimic another plugin that has the same workflow
- Ask questions on the forum (*or send me an email*)
- **Development in C++ with Qt**



# Thanks for your attention!



**CloudCompare**

**3D point cloud and mesh processing software  
Open Source Project**

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Welcome to the official website of the **CloudCompare** project.

**Want to know when a new release comes out?** Subscribe to the newsletter

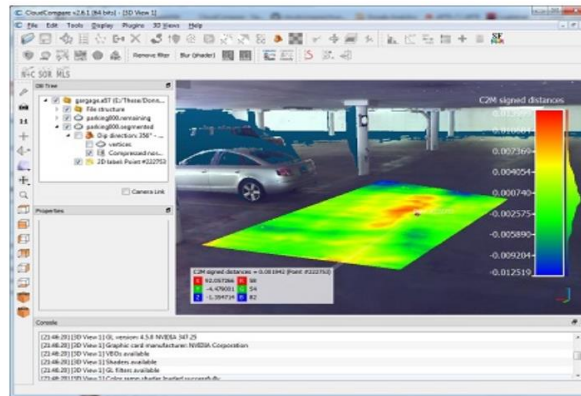
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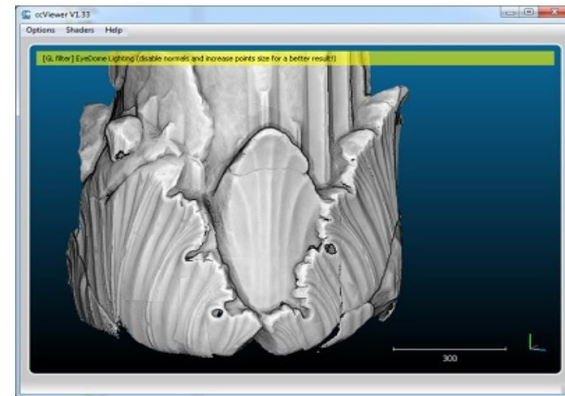


**CloudCompare 2020 Developers training & Workshop: March 11-13 2020**

[Visit the event page](#)



**CloudCompare** (*view, edit and process*)



**ccViewer** (*light viewer only*)

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# [www.cloudcompare.org](http://www.cloudcompare.org)