CloudCompare
Journée d'étude Big Data et données spatialisées

www.cloudcompare.org

@CloudCompareGPL

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29 Juin 2023, Saint Mandé, France

The CloudCompare project

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

- **EDF**
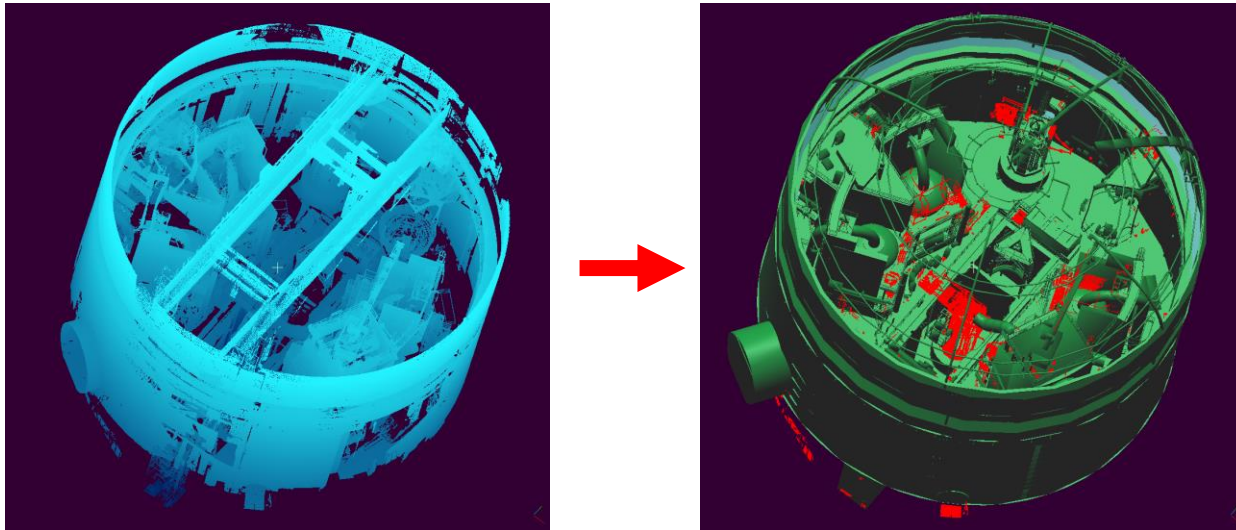 - Main French power utility
  - More than 165 000 employees worldwide
    - 2 000 @ R&D (< 2%)
      - 200 know about CloudCompare (< 0.2%)
  - Sales >69 B€
  - > 400 dams + 56 nuclear reactors (19 plants)

EDF and Laser Scanning

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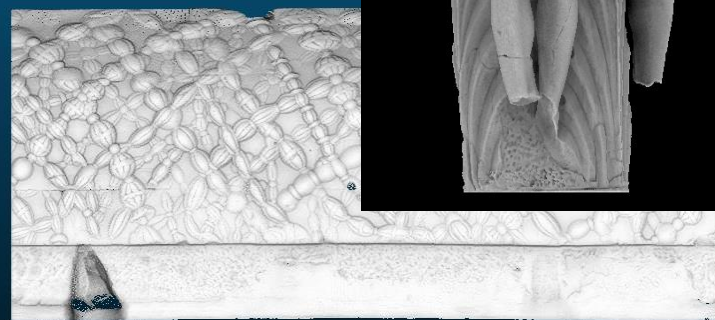
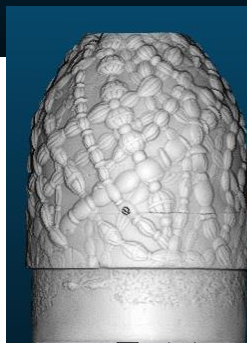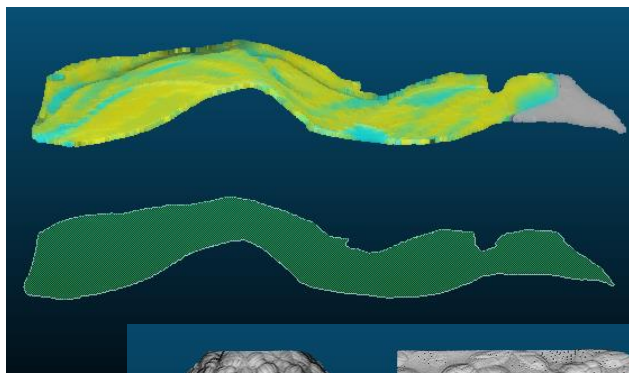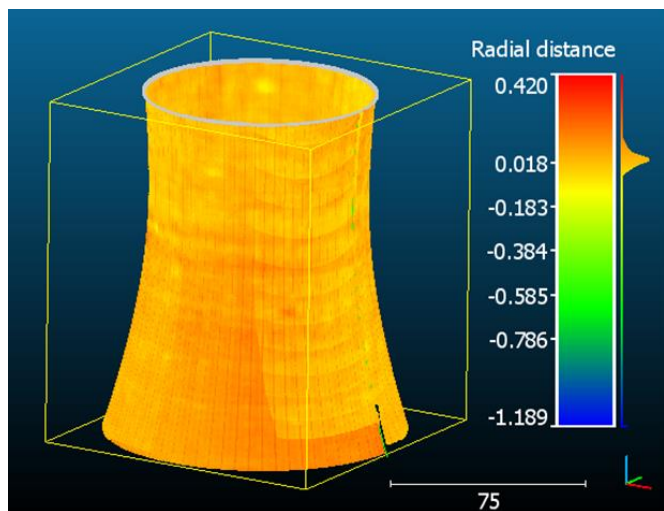○ Main scanning activity: *as-built* documentation

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
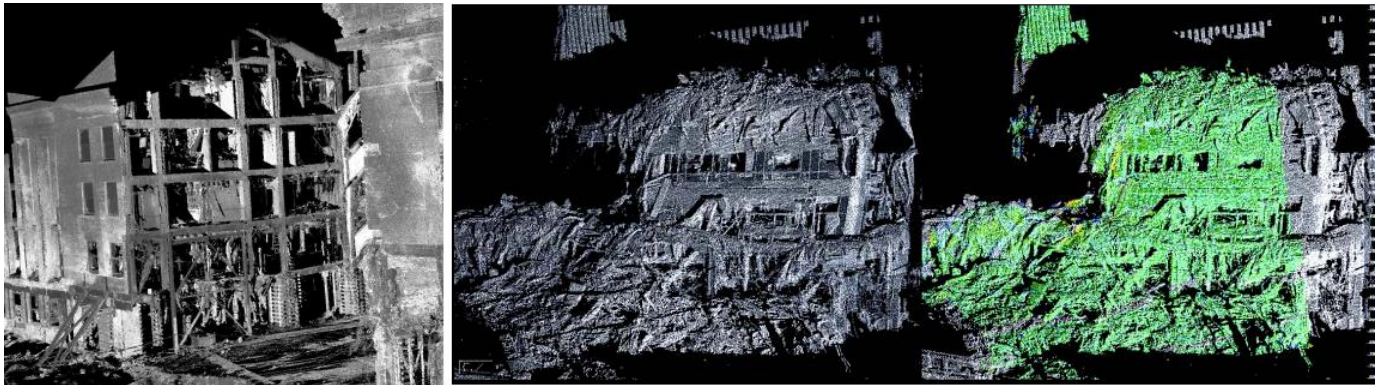 - Historical preservation (EDF Foundation)

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*)
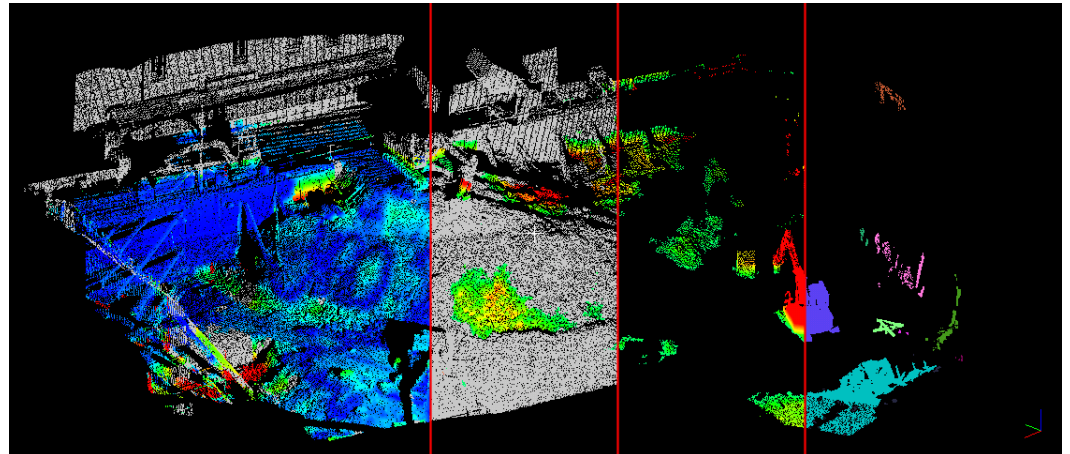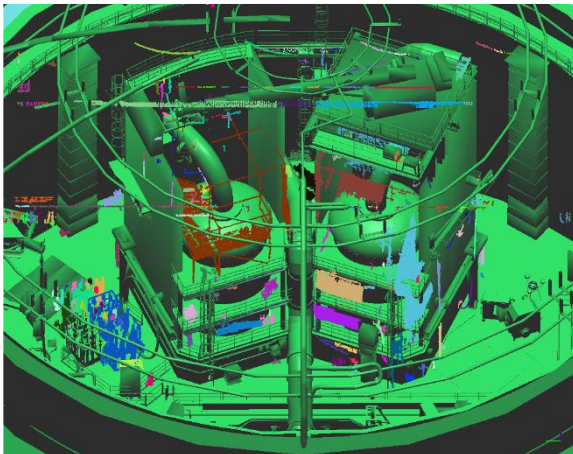

TLS was used for: visualization, optimal crane placement, measurements, monitoring the subsidence of the wreckage pile, slurry wall monitoring, etc.

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**

- **2023: CloudCompare V2.13**

CloudCompare^{V2}
OpenGL R&D
eDF
Q
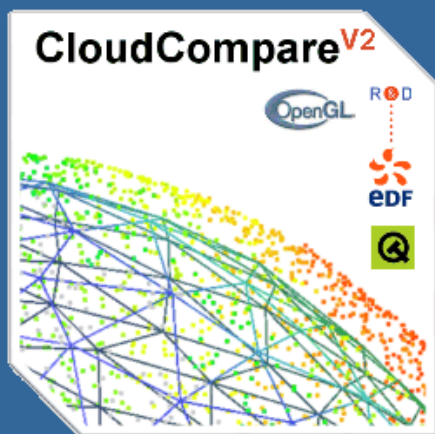
Runs on:
  Windows
  Linux
  macOS (*sometimes*)

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 developping new functionnalities
  - or by paying someone else to do it

o Plugins are not necessarily open source or free

Users

Developers

- Too many 😋
  - Academics: ————————→
    - remote sensing
    - geology
    - archeology
    - etc.
  - Surveyors ————————→
  - Forensic experts ——————→
  - Architects ————————→
  - MDs, dentists ——————→
  - 3D designers ——————→
  - Artist?! ————————→

- Barely enough 😅
  - a few PhD students and research engineers

  - none
  - 1
  - none
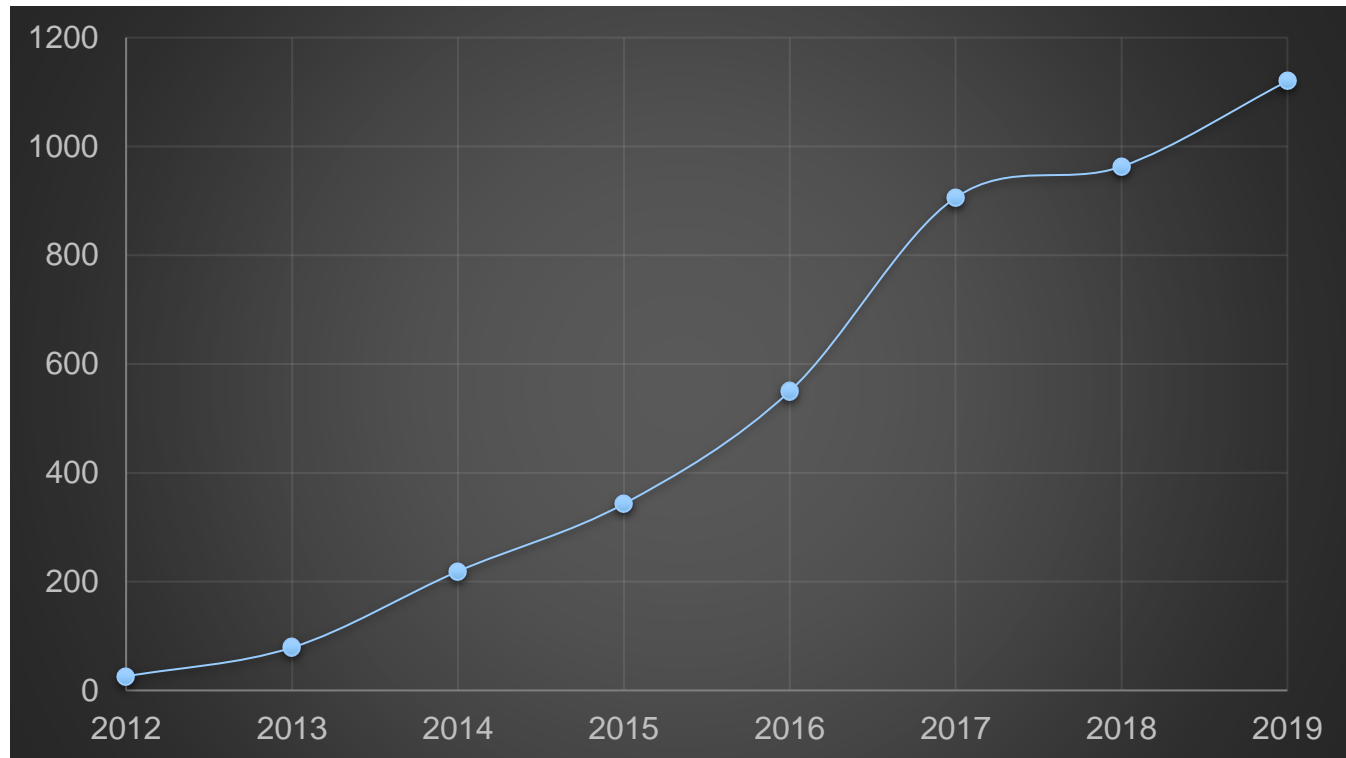 - none
  - none
  - none

SW development cycle

Specs → algorithm → "packaging" (GUI, details, etc.) → ~~tests~~

- simple forum message
- the best part
- less funny
- developer's hell
- user's hell

stability

users feedback!

First release

time
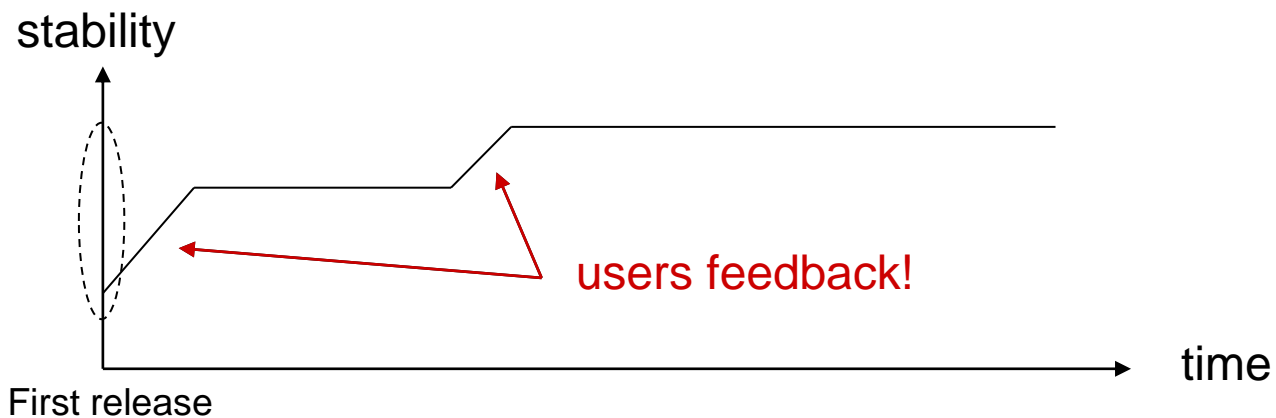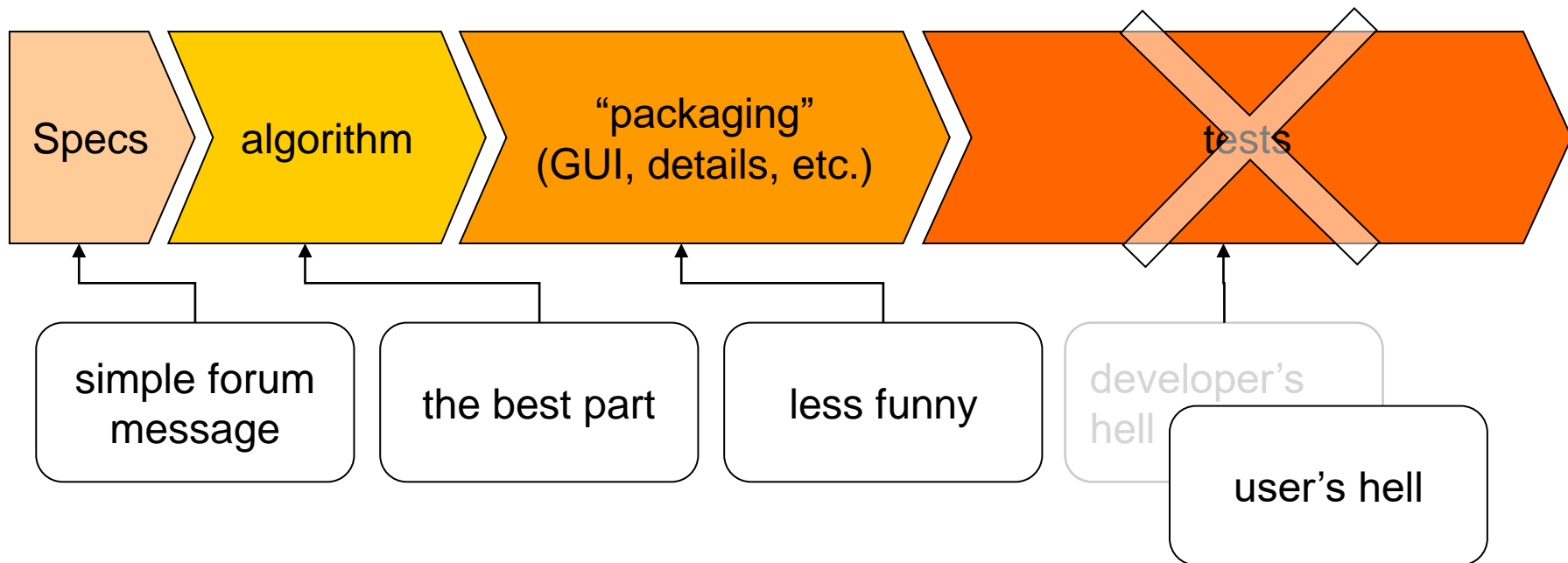
Worldwide
(6 months view)
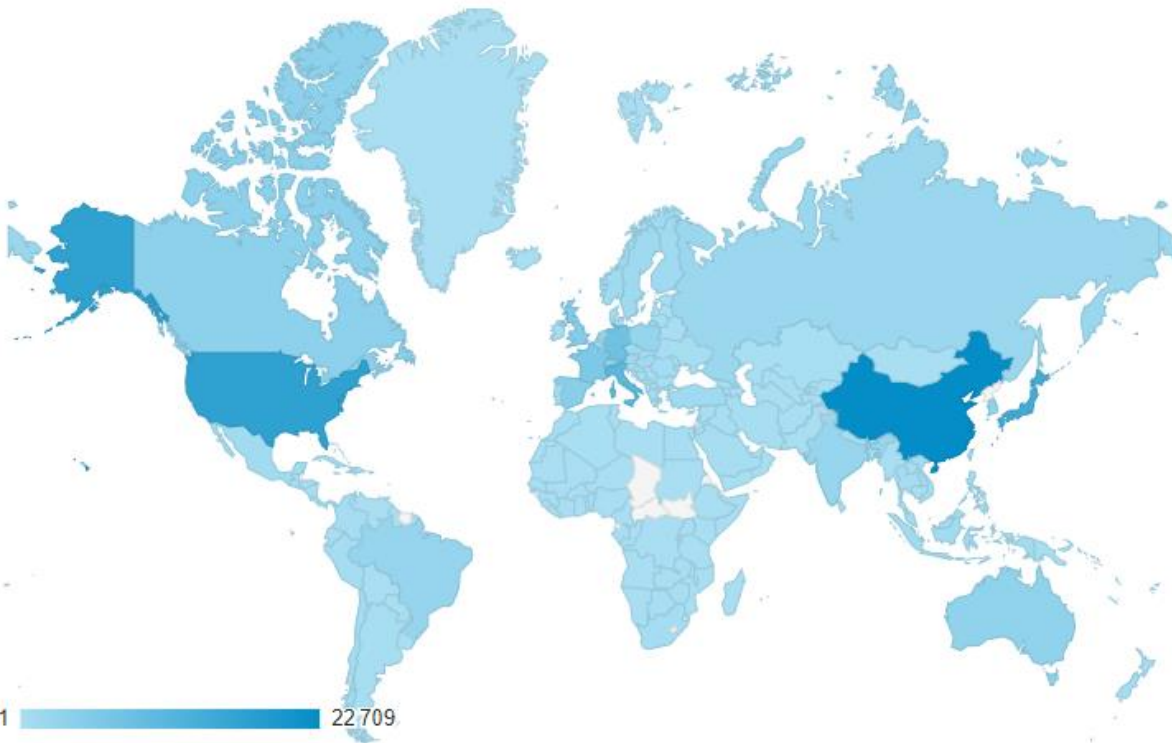
Pays	Acquisition	
	Utilisateurs ⬇	
	145 957 % du total: 100,00 % (145 957)	
1. 🇨🇳 China	**22 709**	(15,42 %)
2. 🇺🇸 United States	**16 792**	(11,40 %)
3. 🇯🇵 Japan	**14 101**	(9,58 %)
4. 🇮🇹 Italy	**10 790**	(7,33 %)
5. 🇩🇪 Germany	**8 019**	(5,45 %)
6. 🇫🇷 France	**6 142**	(4,17 %)
7. 🇬🇧 United Kingdom	**5 056**	(3,43 %)
8. 🇪🇸 Spain	**4 444**	(3,02 %)
9. 🇨🇦 Canada	**3 827**	(2,60 %)
10. 🇰🇷 South Korea	**3 474**	(2,36 %)

> 108k downloads in 6 months (Windows version)
> 5000 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
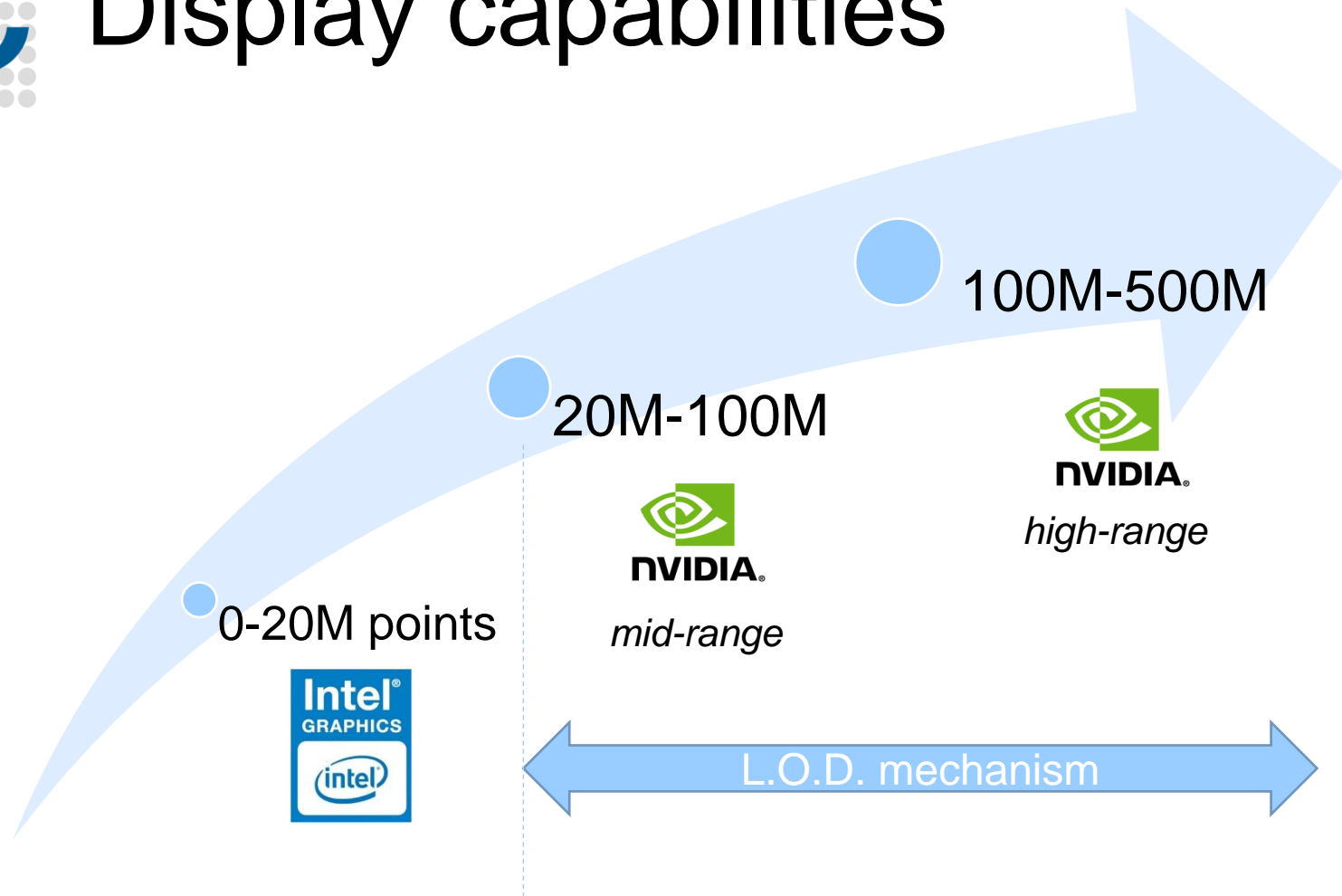 - SHP, DXF, etc.
- rasters
  - geotiff, etc. (*thanks to GDAL*)
- calibrated pictures
  - Bundler OUT, Photoscan PSZ
- sensors
  - TLS or projective cameras

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

Display capabilities

100M-500M

20M-100M

high-range

0-20M points

Intel® GRAPHICS intel
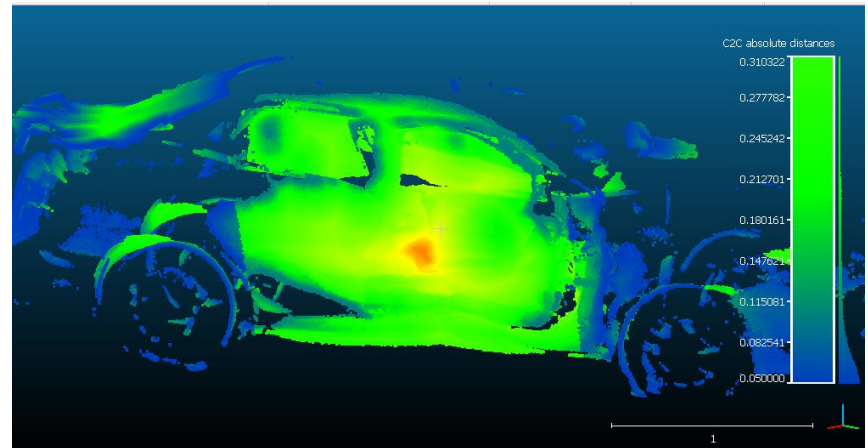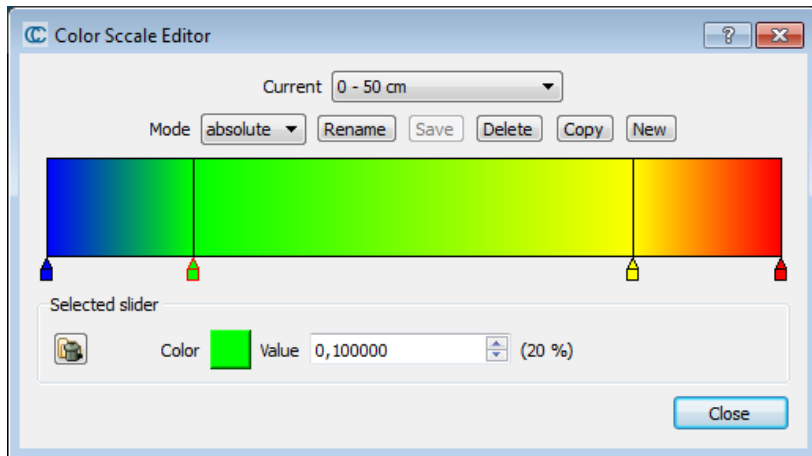
mid-range

L.O.D. mechanism

> 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
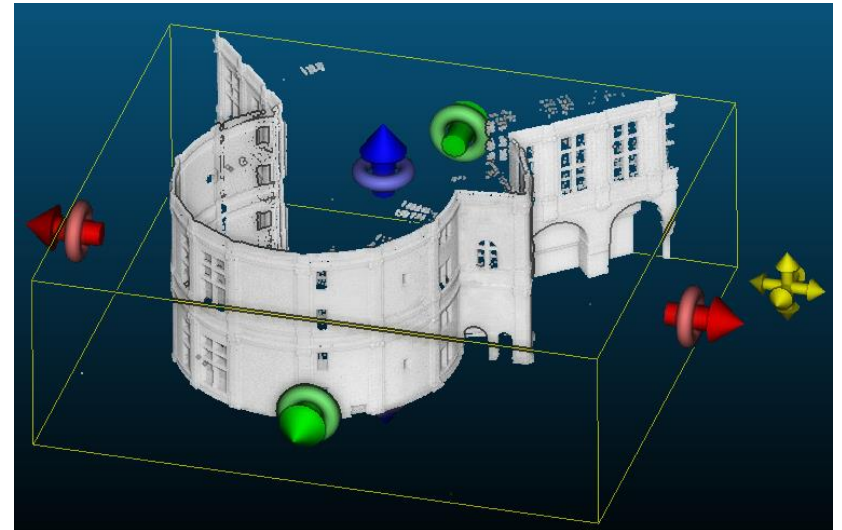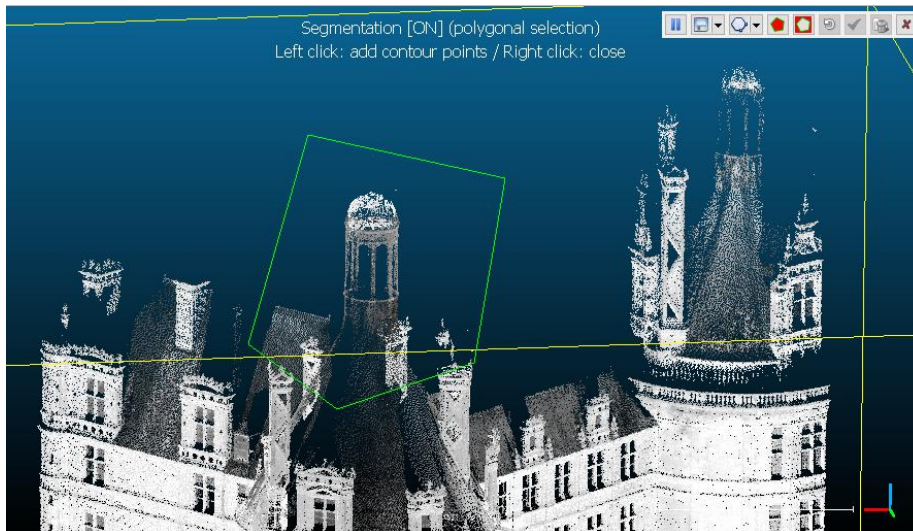
Main features

- 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
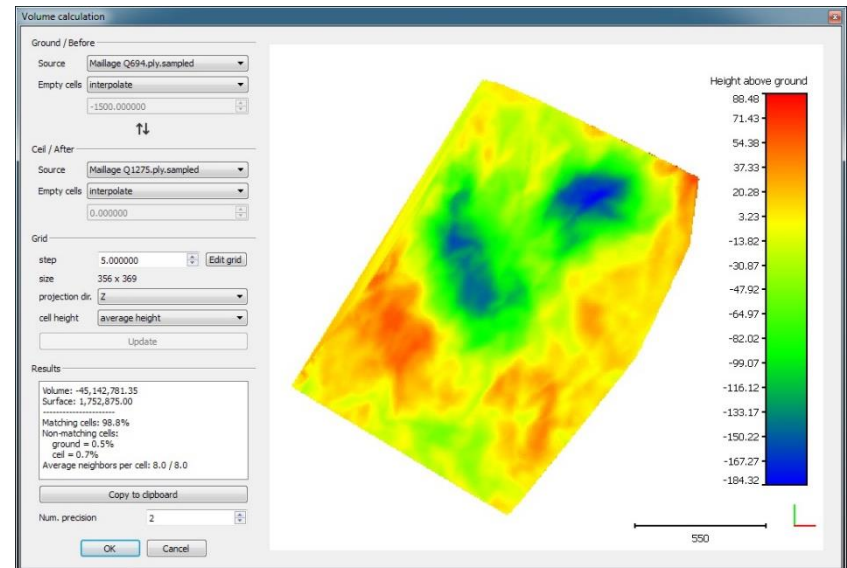 - Subsample, merge, scale, etc.
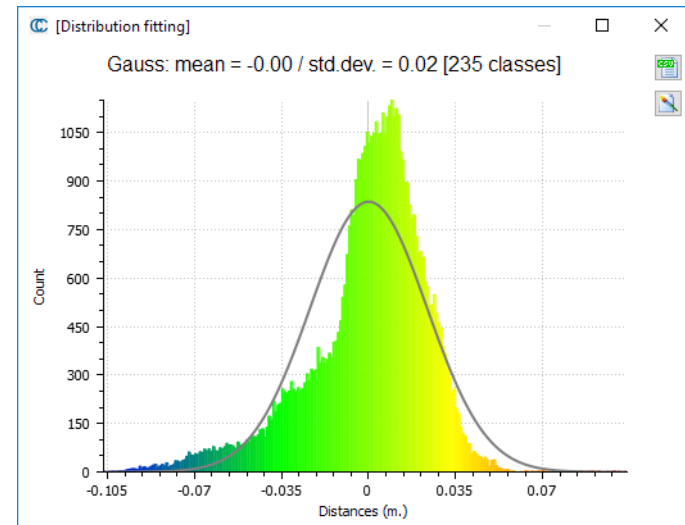
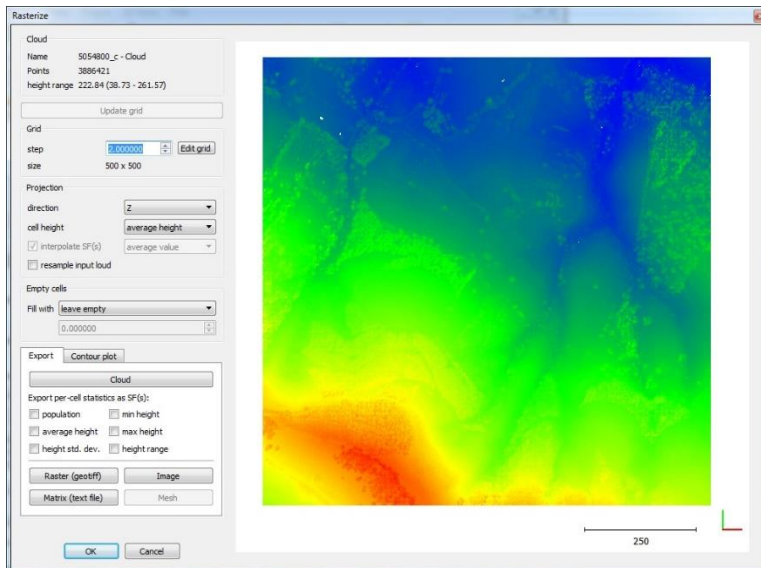# Main tools

- Registration
  - point-pair-based alignment, ICP

- Distances
  - Cloud-to-cloud (C2C), Cloud-to-mesh (C2M), Cloud-to-primitive (C2P), Robust cloud-to-cloud (M3C2)
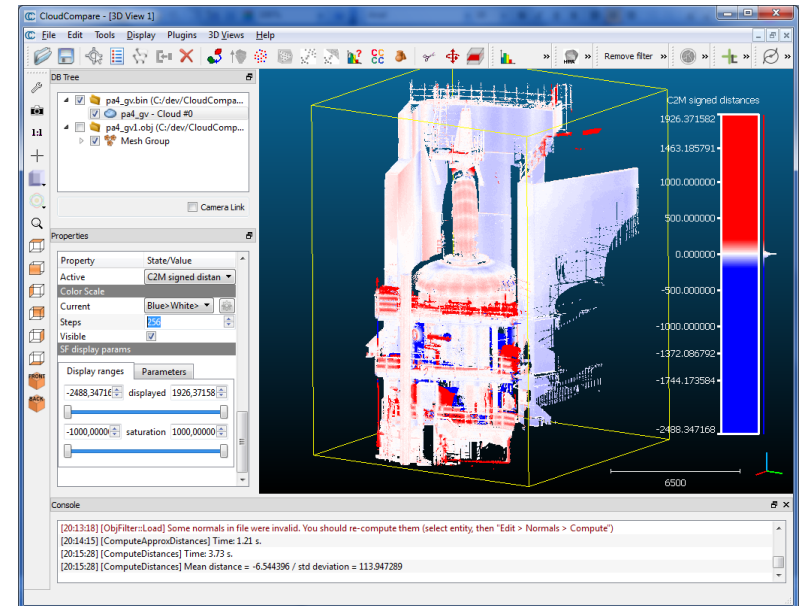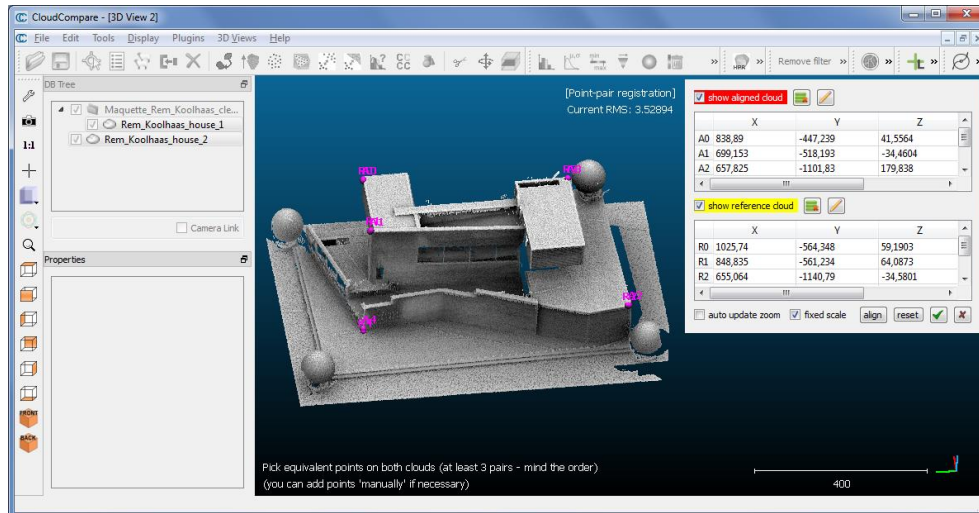
Main tools

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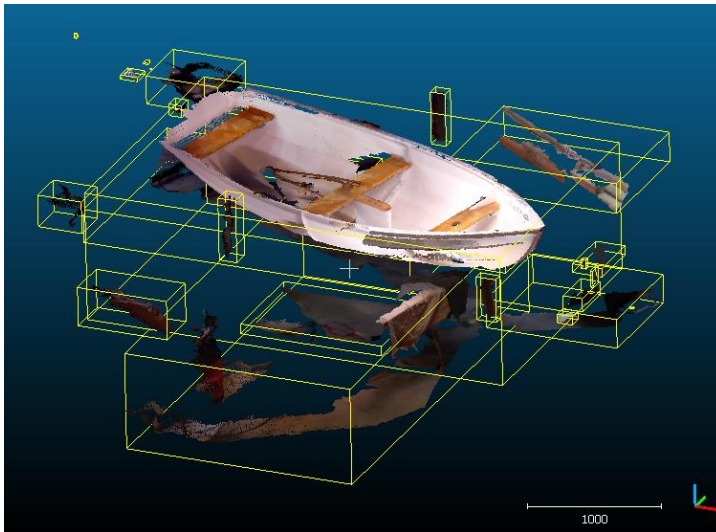- Rasterize
  - + contour plot
- 2.5D volume estimation

Main tools

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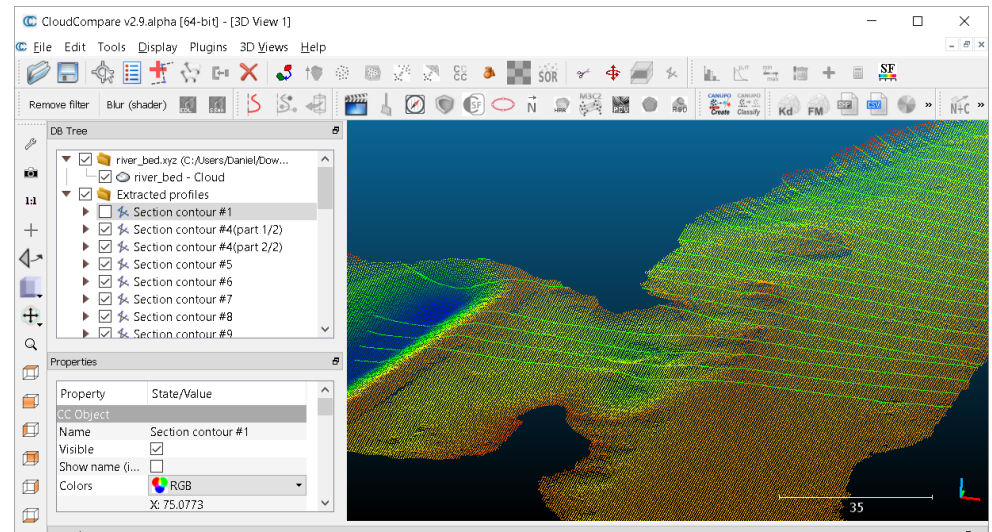
Main tools

○ Roughness, curvature, density and other geometric features computation

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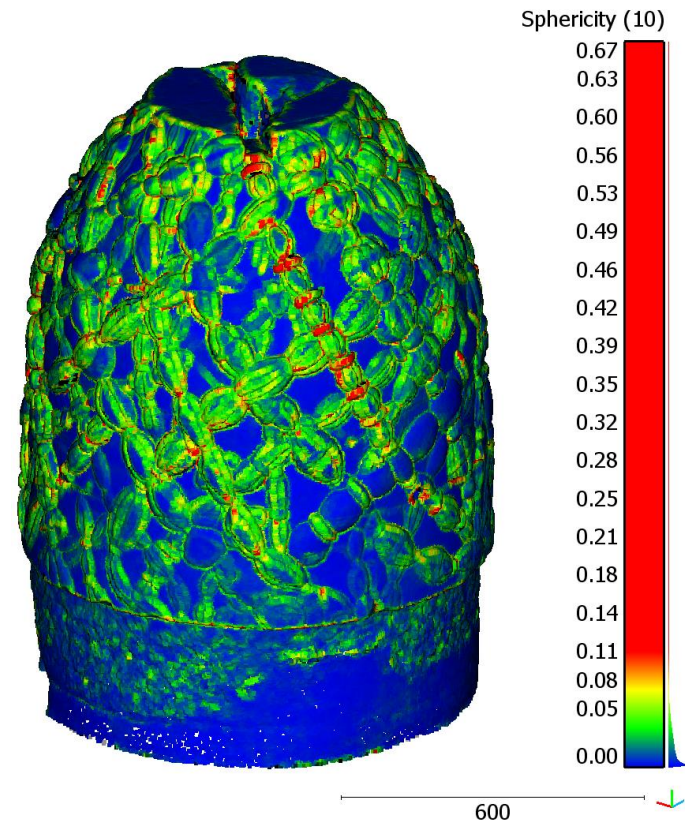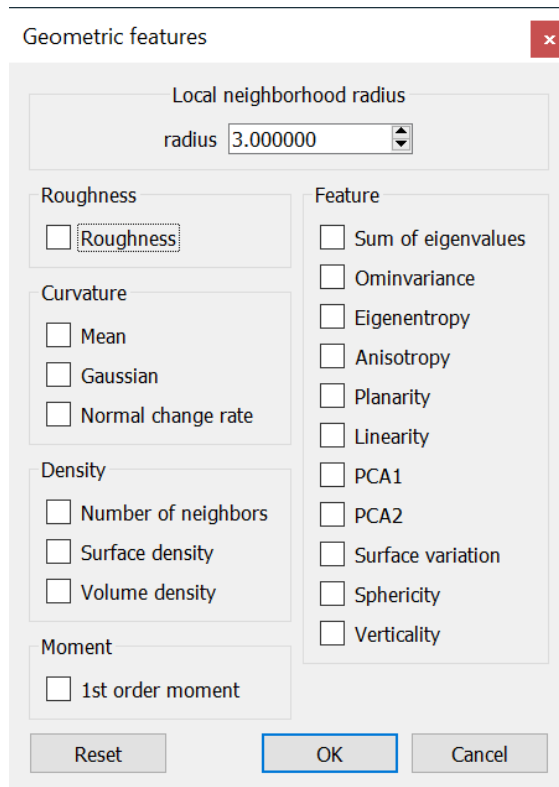
Advanced LIDAR point cloud processing

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 correspondances along surface normal
  - Multi-scale approach
  - Uncertainty estimation based on local surface roughness
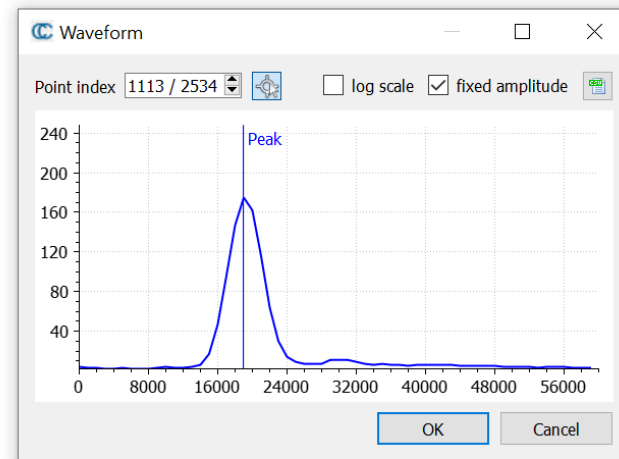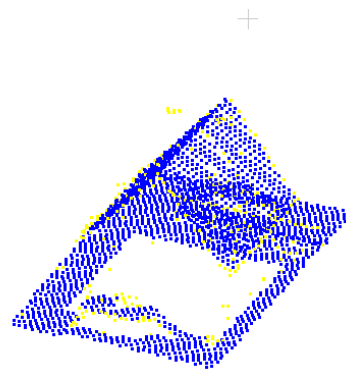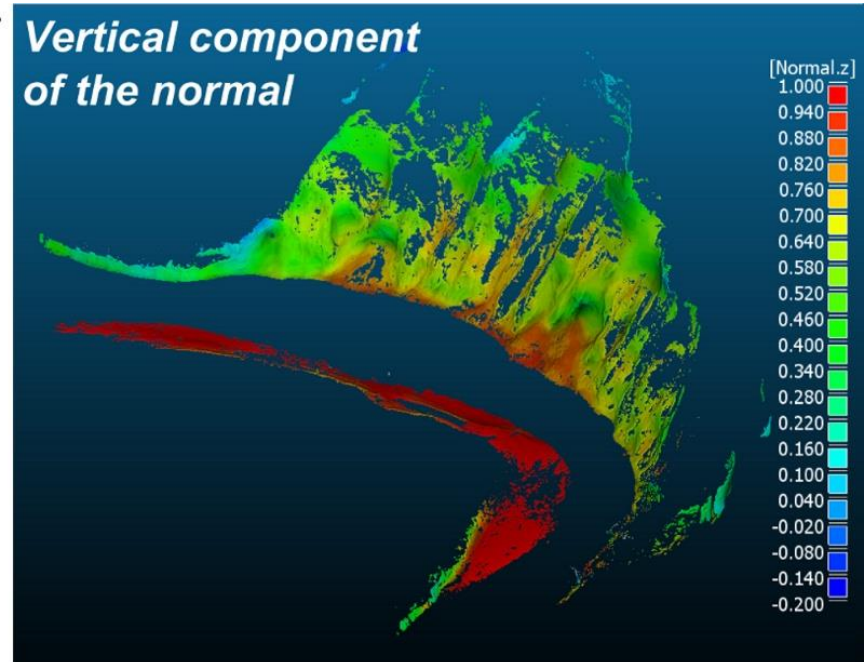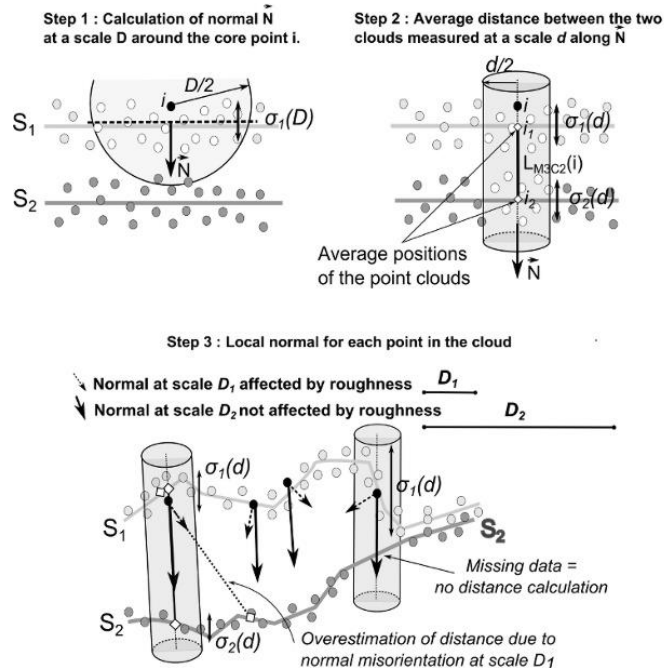

Step 1 : Calculation of normal $\vec{N}$ at a scale D around the core point i.

Step 2 : Average distance between the two clouds measured at a scale d along $\vec{N}$

Average positions of the point clouds

Step 3 : Local normal for each point in the cloud

Normal at scale D_1 affected by roughness
Normal at scale D_2 not affected by roughness

Missing data = no distance calculation

Overestimation of distance due to normal misorientation at scale D_1

Vertical component of the normal

[Normal.z]
1.000
0.940
0.880
0.820
0.760
0.700
0.640
0.580
0.520
0.460
0.400
0.340
0.280
0.220
0.160
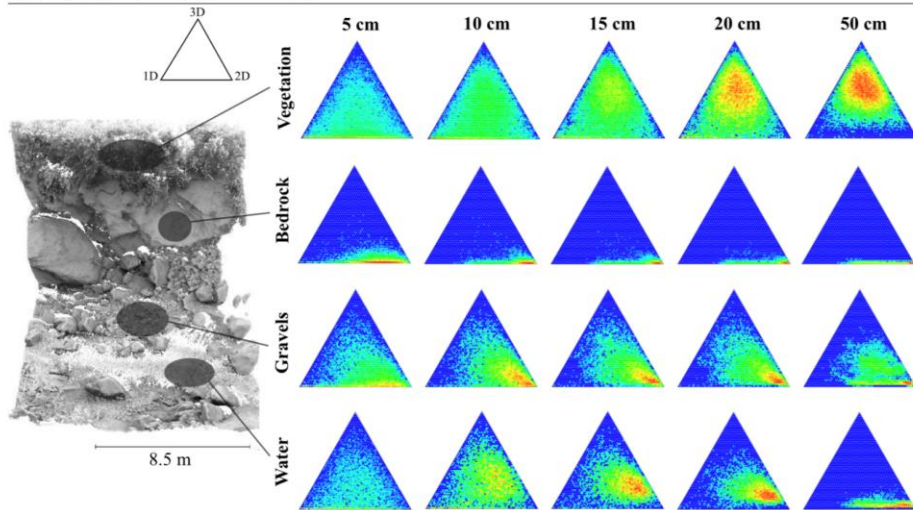0.100
0.040
-0.020
-0.080
-0.140
-0.200

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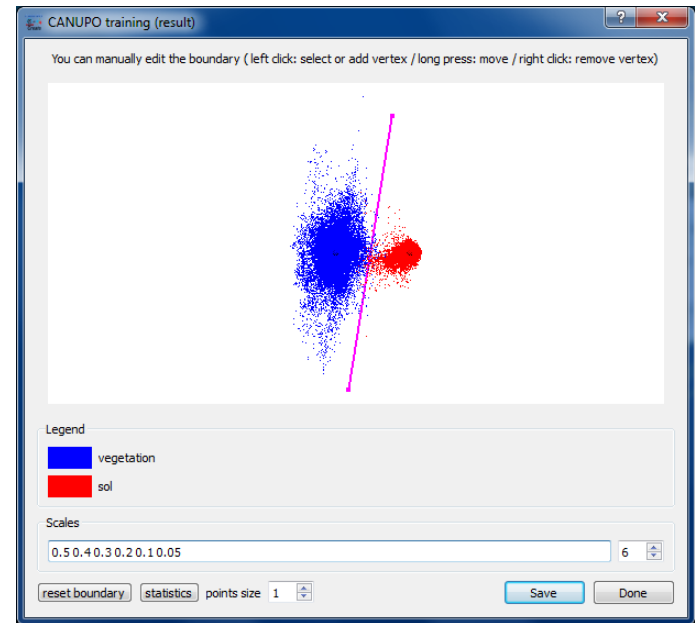
"3D Terrestrial lidar data classification of complex natural scenes using a multi-scale dimensionality criterion: applications in geomorphology", N. Brodu, D. Lague, 2012

3DMASC

- Advanced point cloud classification
  - https://lidar.univ-rennes.fr/en/3dmasc
  - **M**ultiple **A**ttributes, **S**cales and **C**louds
  - Designed to classify bi-temporal or bi-spectral surveys
  - Fully configurable (*mix any number of scalar fields, geometric features, colors, etc.*)

- intermediate vegetation (Ain)
- (high) vegetation
- vegetated ground
- surf zone (Fréhel)
- water
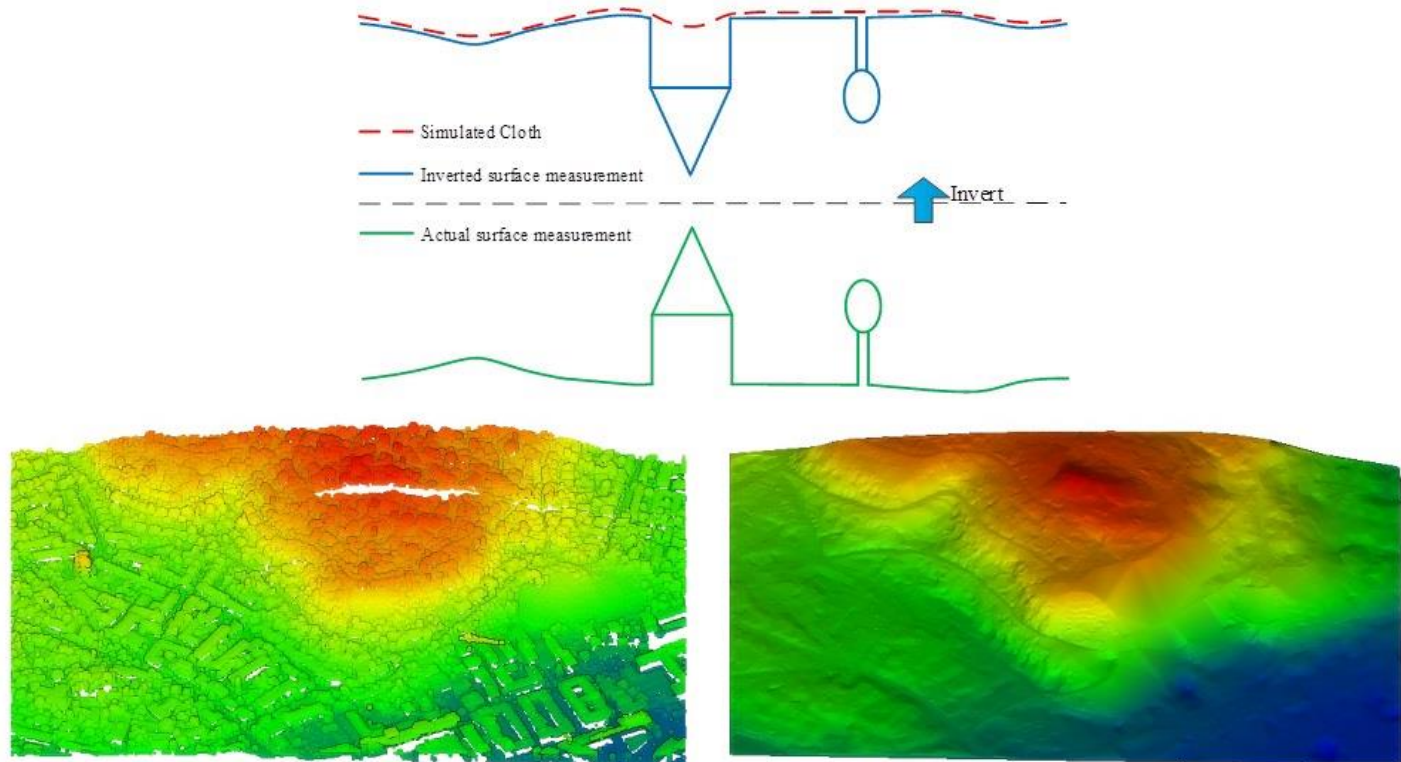- underwater sand
- underwater rock (Fréhel)
- ground
- rock (Fréhel)
- pebble (Fréhel)
- buildings
- artificial ground
- power lines
- vehicles

3DMASC: Accessible, explainable 3D point clouds classification. Application to Bi-Spectral Topo-Bathymetric lidar data, M. Letard et al, 2023

Cloth Simulation Filter (CSF)

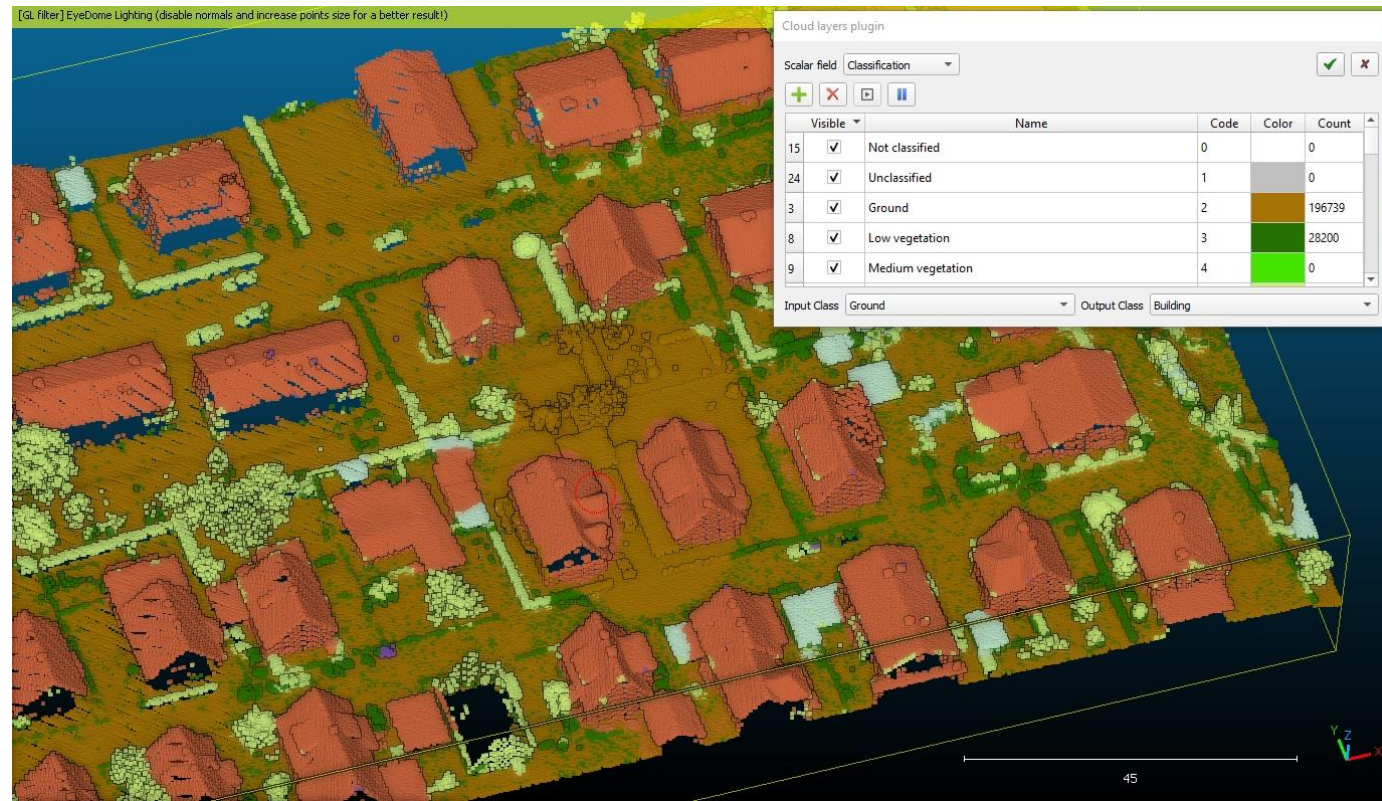○ Ground points extraction from LiDAR point clouds

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

Cloud Layers

- Manual (re)labelling of point clouds
- Works with any scalar field
- (developed in Ukraine 🇺🇦)

Other plugins

- Automatic shape detection (Ransac Shape Detection)
- Structural geology toolbox for the interpretation and analysis of virtual outcrop models (Compass)
- 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)
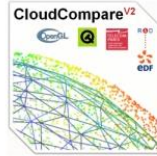- Hidden Points Removal (HPR)
- etc.

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**

Next steps

○ CloudCompare V2.13 (*about to be released*)

○ Long term
  ● Out-of-core support?

○ And always the ever-growing TODO list…

Thanks for your attention!

www.cloudcompare.org