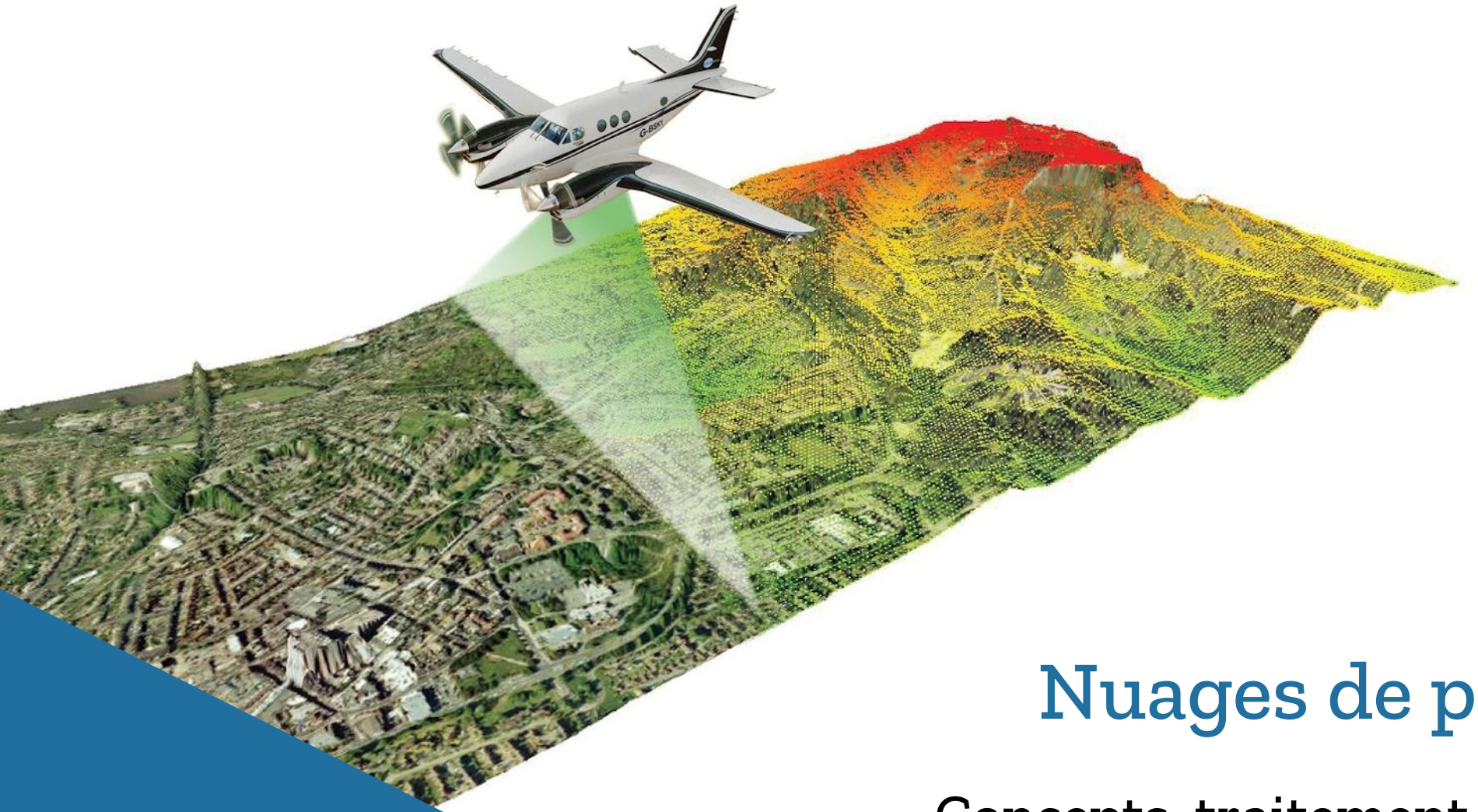


LIÈGE université
Geomatics

Nuages de points & SIG

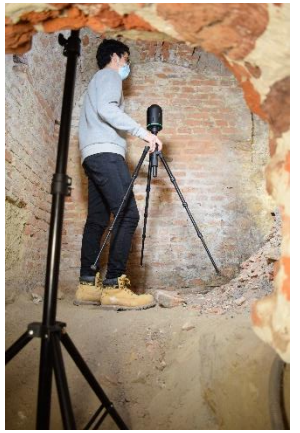
Concepts, traitement et manipulation

Abderrazzaq Kharroubi

19 Novembre 2021

Présentation

- Abderrazzaq kharroubi, akharroubi@uliege.be
- Ingénieur d'Etat en topographie
- Doctorant à l'unité de géomatique 2020
- Aspirant FNRS 2021
- Thématique de recherche:
  - Analyse et traitement des nuages de points



Contenu

1. Notions
2. Applications et cas d'usages
3. Nuage de point et SIG
   - QGIS
   - PostGIS/pgpointcloud
   - Polyfit
   - CityGML et CityJSON
4. Mon sujet de recherche

LIÈGE université
Geomatics

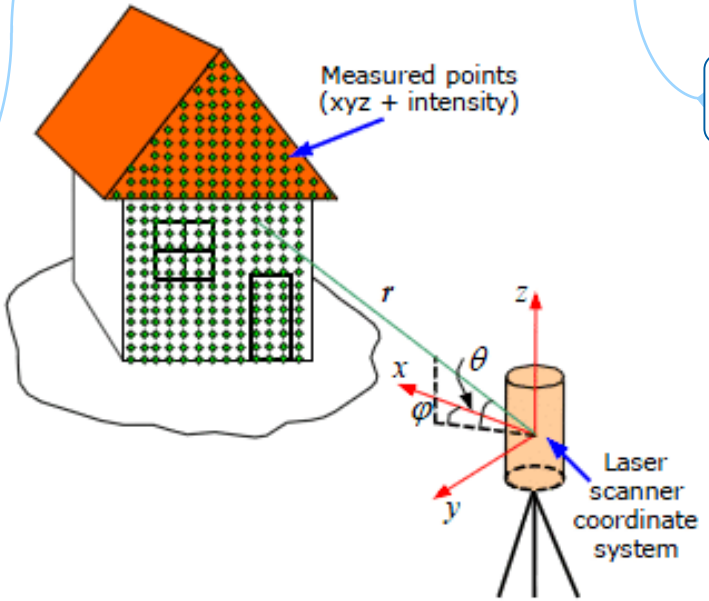
Nuage de points 3D

Notions & rappels

Un nuage de points ?

- Satellite
  - spatial
- Plane
- Helicopter
- UAV
  - aerial
- Vehicle
- Handheld
- Tripod
  - terrestrial

Point cloud
$P = \{pi \in R3+d , i = 1, 2, ..., N\}$



- **3 + d** : xyz-dimension and additional properties
  - xyz
  - RGB
  - Intensity
  - Classification
  - ...etc.
- **N** is the number of points
  - Few points
  - Billions and trillions

Lasergrammétrie

Photogrammétrie

© Leica

Scanner Laser

Au sol, embarqué ou aéroporté

Principe

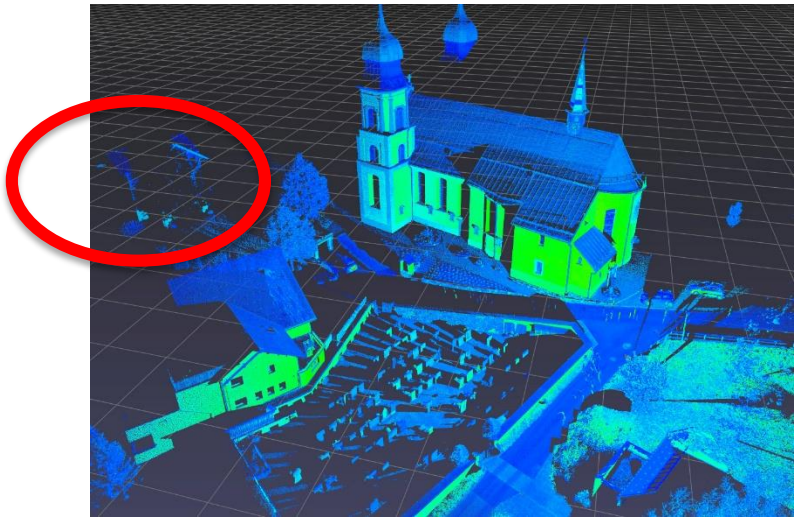
Balayage haute fréquence (2M de points/s)

Le laser émet des impulsions

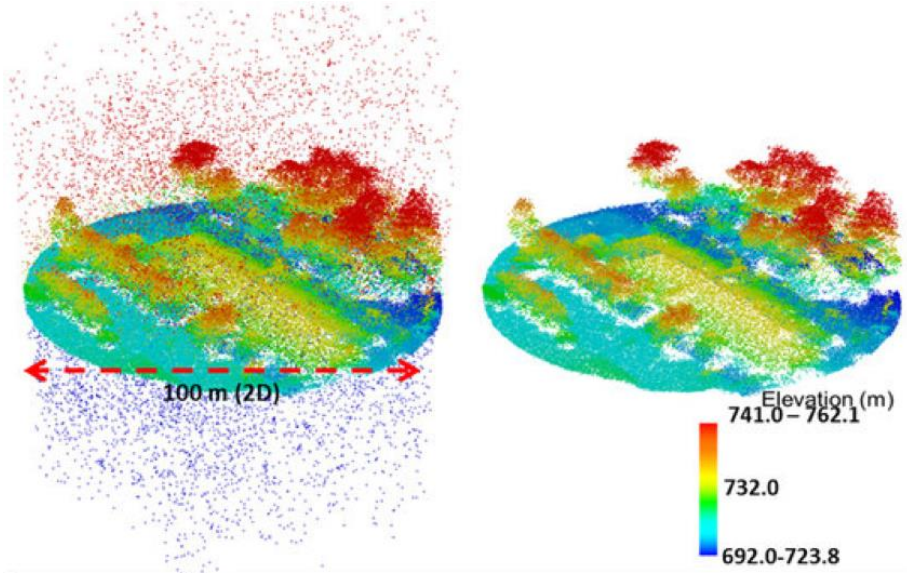
Le scanner récupère les signaux réfléchis par le sol,

végétation, les bâtiments....

- Filtre statistique
- Double scan
- …



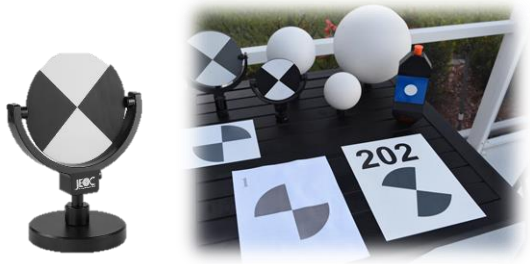
© Semantic3D



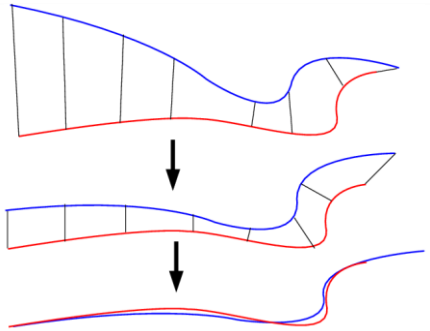
© Hacarus

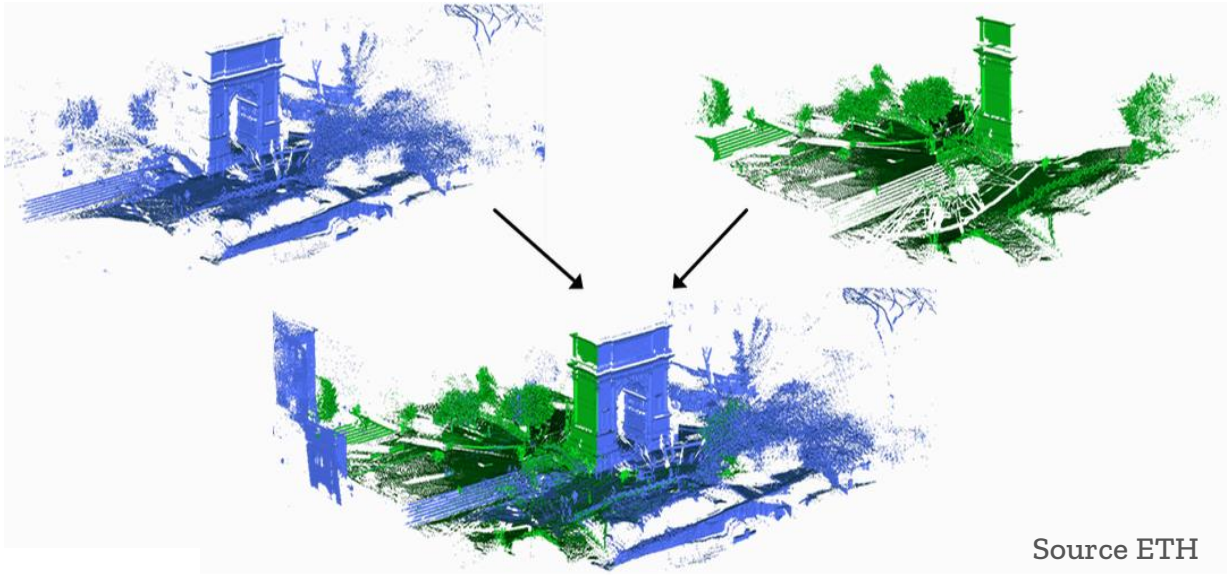
Nettoyage, filtrage, échantillonnage…etc.

- Par cible

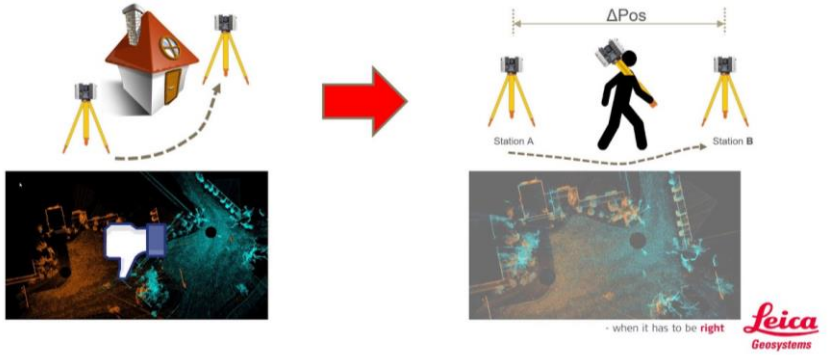


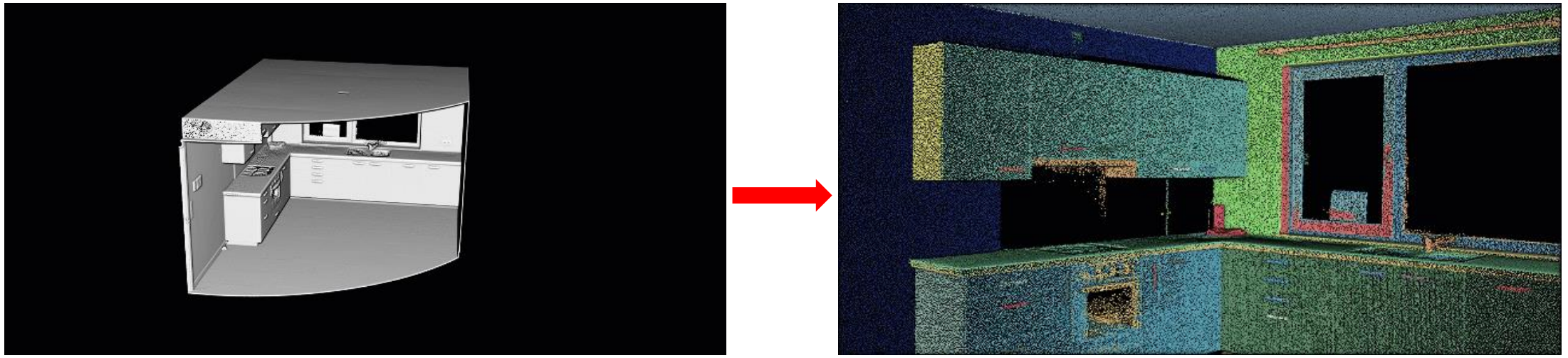
- Cloud to cloud (ICP…etc)



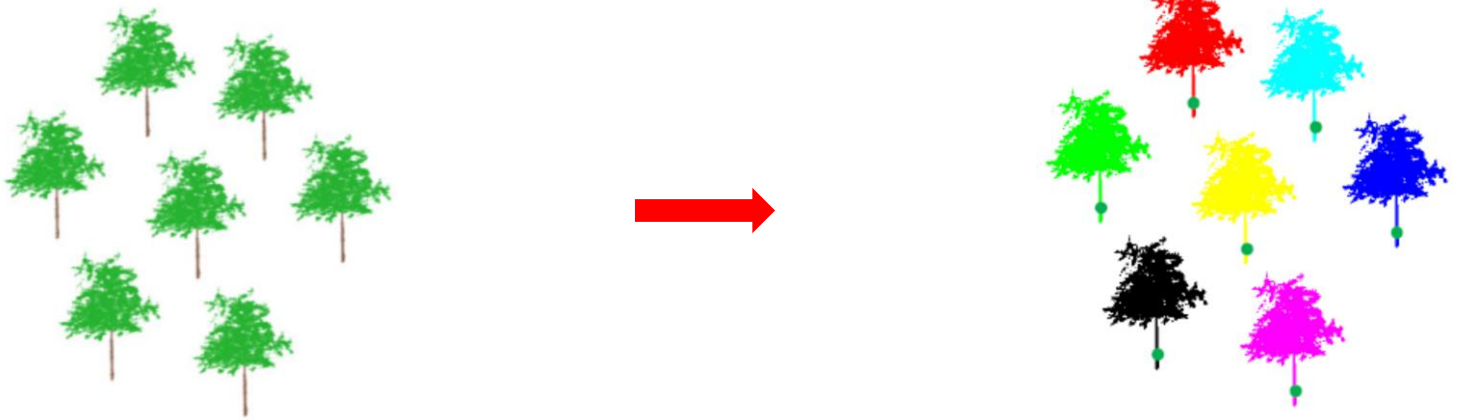


- SLAM
- Grand SLAM (INS+VIS)

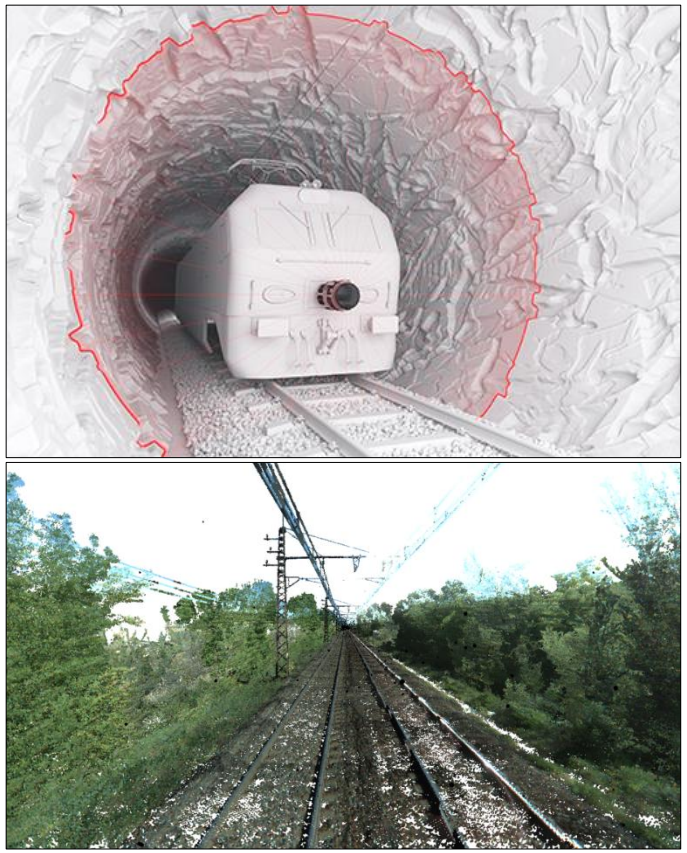




© F. Poux

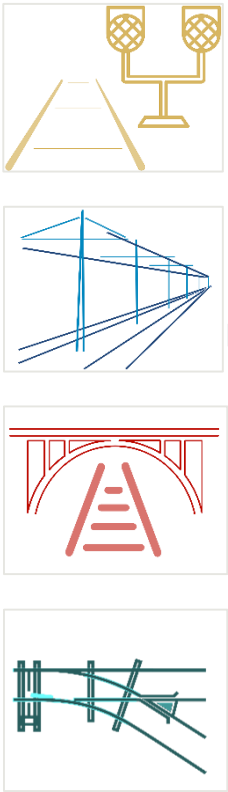


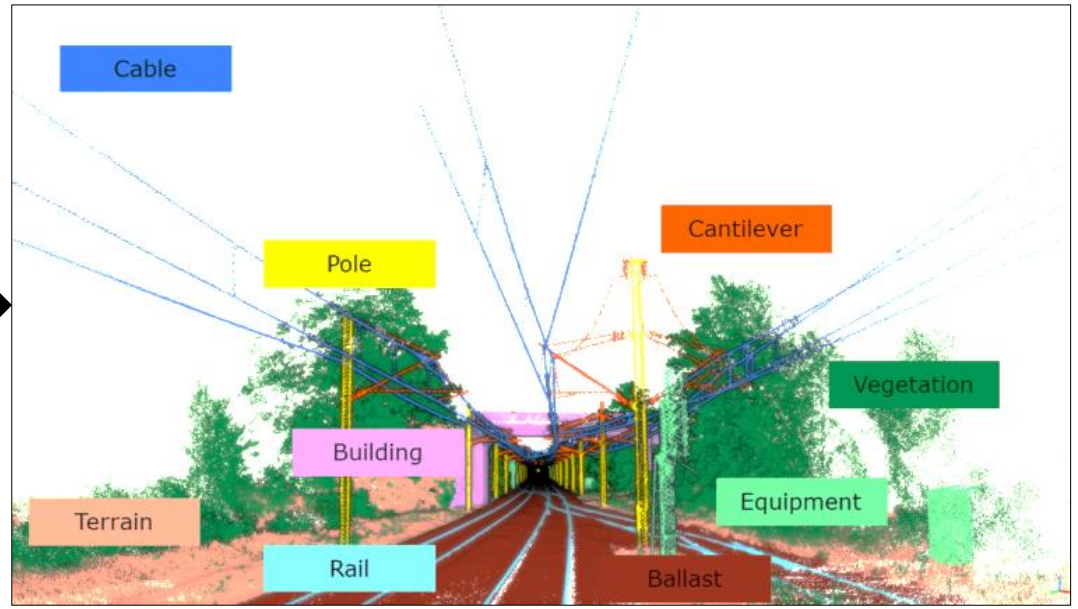
- RANSAC, Croissance de région, DBSCAN, HDBSCAN...etc



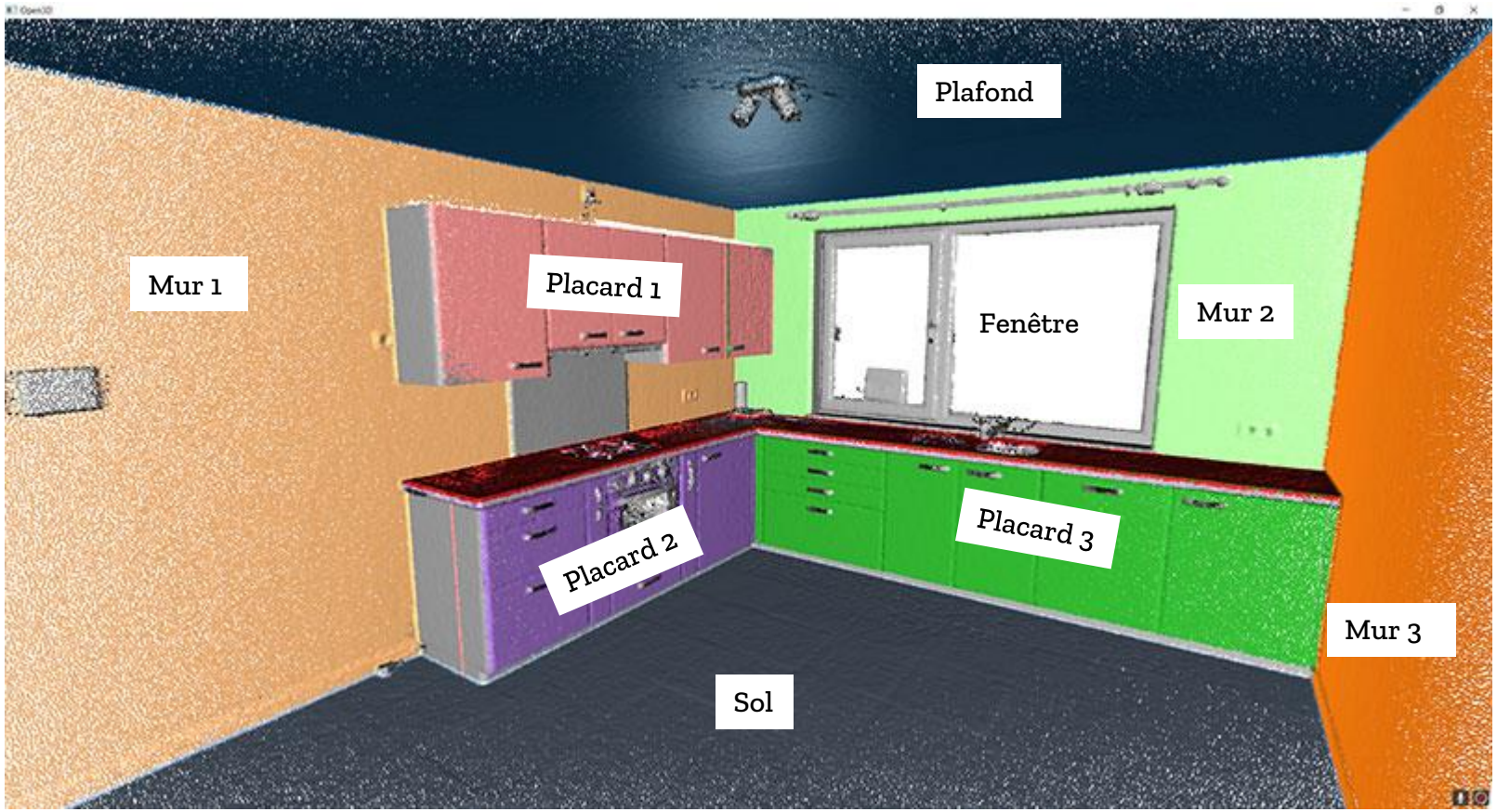
Raw 3D data (1),(2)

Semantics

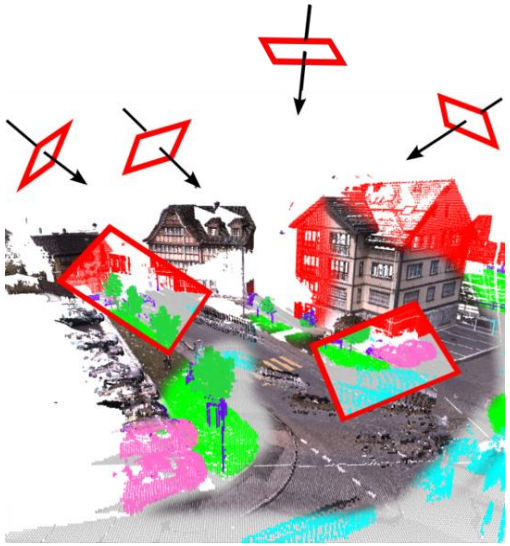




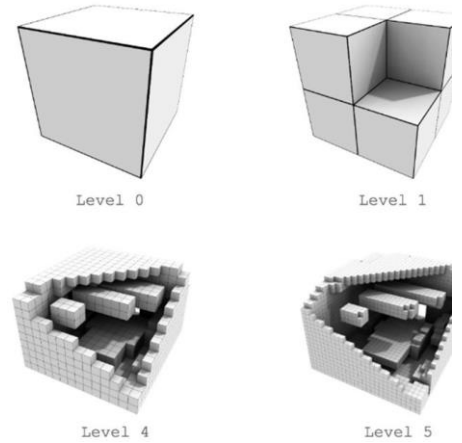
Turning data into information (3)


Plafond
Mur 1
Placard 1
Fenêtre
Mur 2
Placard 3
Placard 2
Mur 3
Sol

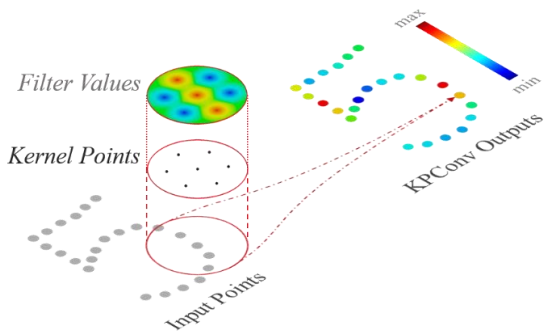
- Multi-View images [2]
- 3D regular voxel grid [3]
- Graph-based structure [1]
- Convolutional-based structure [5]
- Unordered ensemble of point [4]



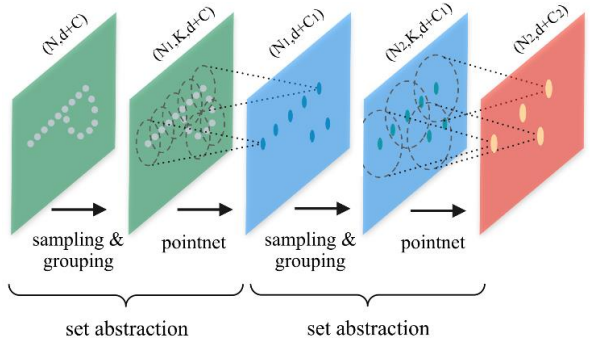
Credit: Boulch et al. 2017



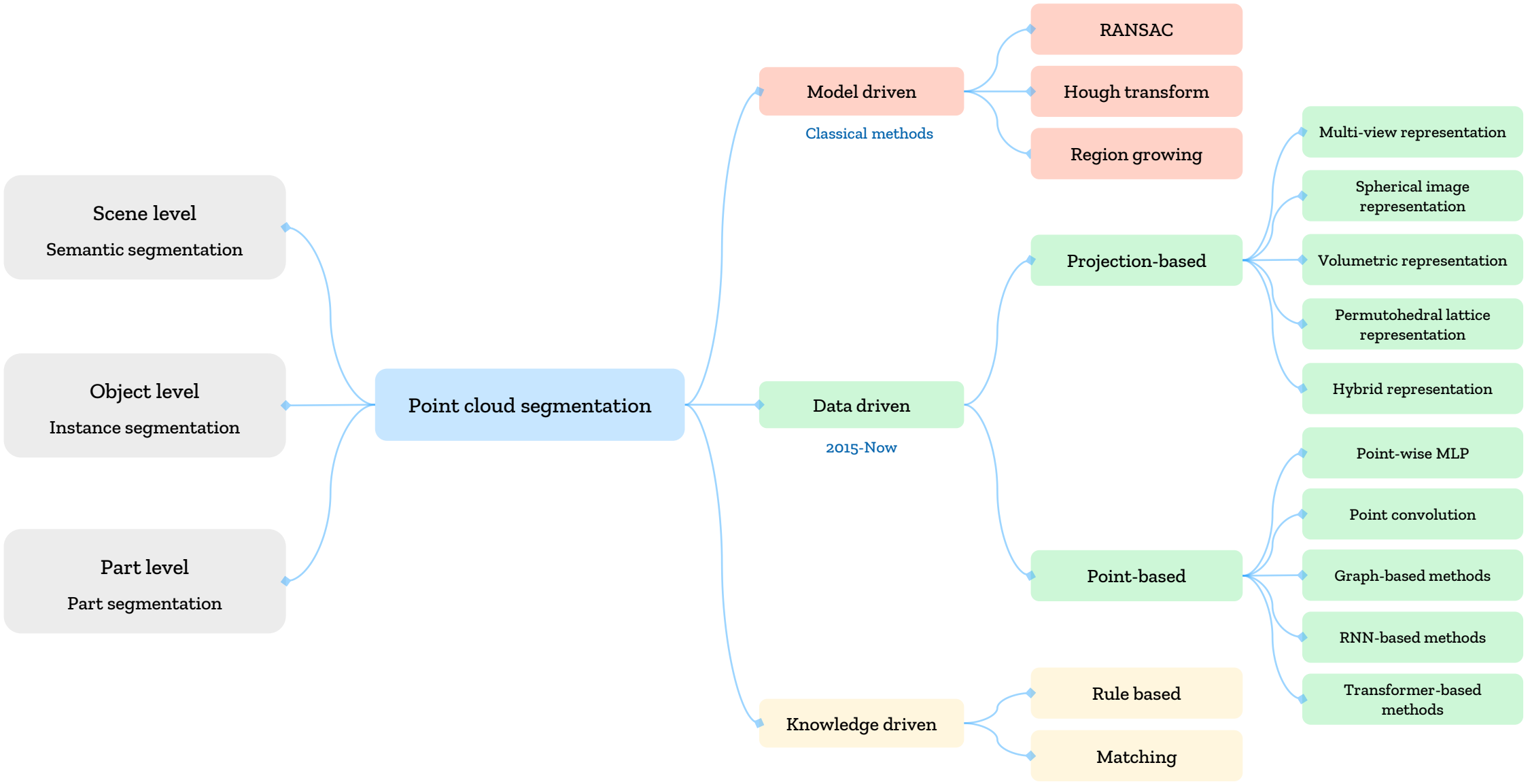
Credit: Poux et al. 2019



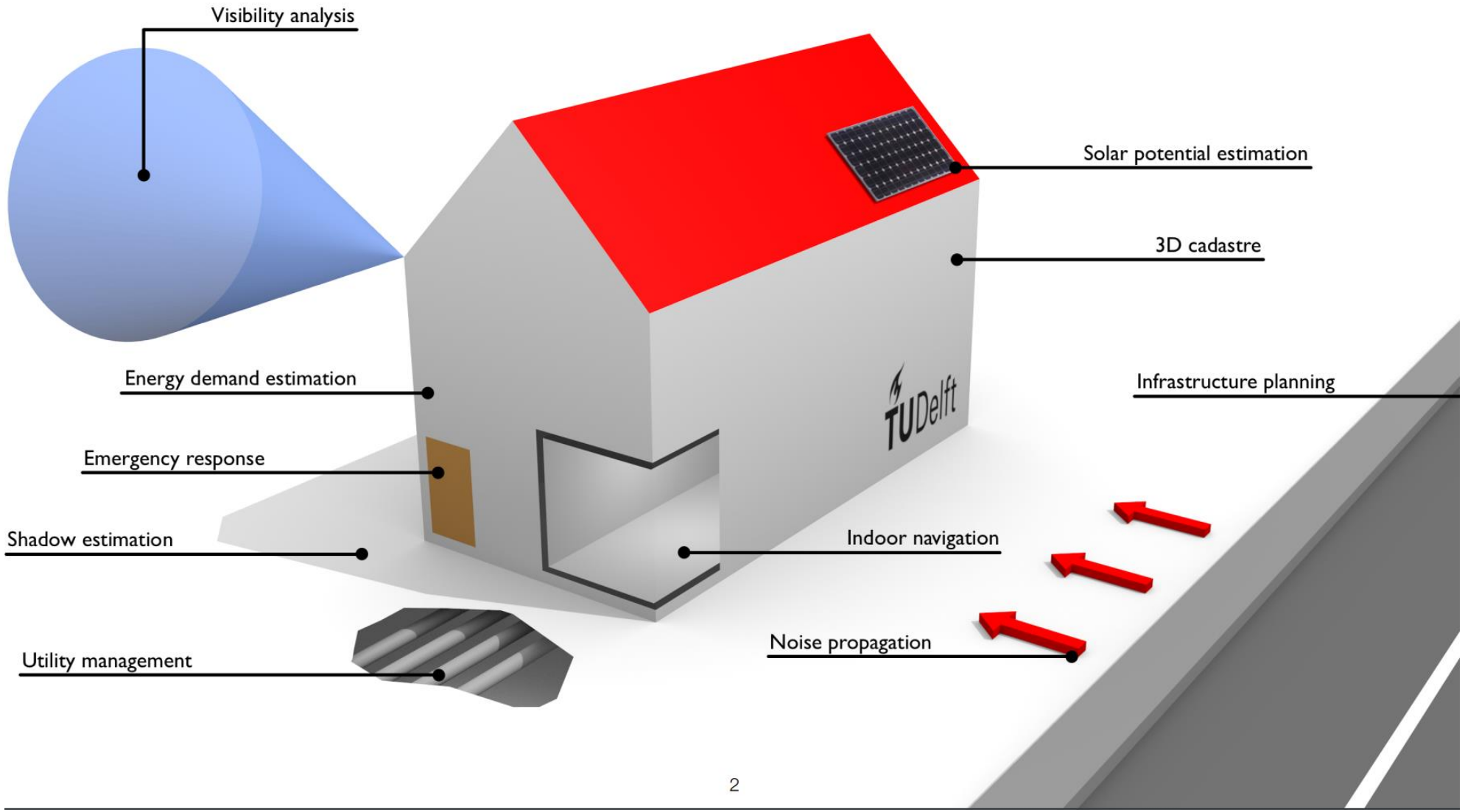
Credit: Hugues et al. 2019



Credit: Charles et al. 2019

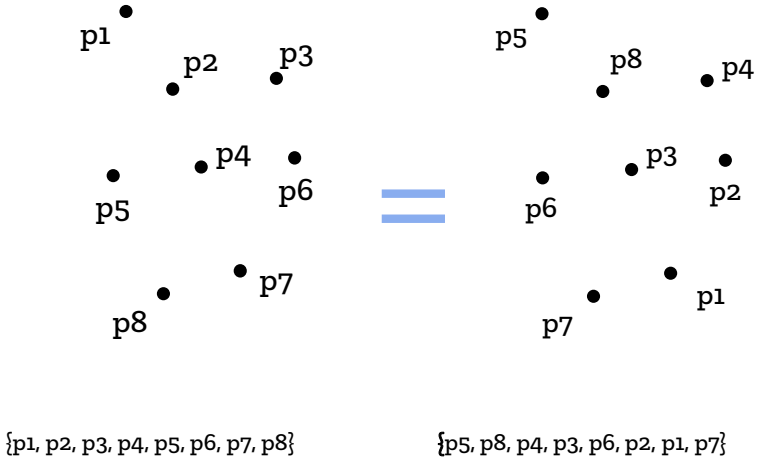

Scene level
Semantic segmentation
Object level
Instance segmentation
Part level
Part segmentation
Point cloud segmentation
Model driven
Classical methods
RANSAC
Hough transform
Region growing
Data driven
2015-Now
Projection-based
Multi-view representation
Spherical image representation
Volumetric representation
Permutohedral lattice representation
Hybrid representation
Point-based
Point-wise MLP
Point convolution
Graph-based methods
RNN-based methods
Transformer-based methods
Knowledge driven
Rule based
Matching

https://nasa-ammos.github.io/3DTilesRendererJS/example/bundle/index.html


Visibility analysis
Solar potential estimation
3D cadastre
Energy demand estimation
Infrastructure planning
Emergency response
Shadow estimation
Indoor navigation
Noise propagation
Utility management
TUDelft
2

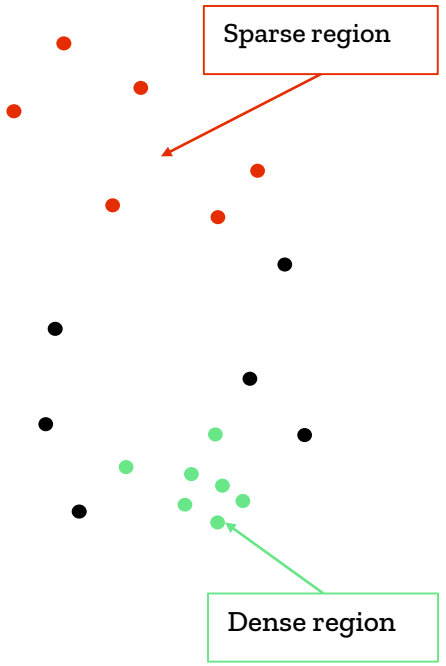
Les specifities des nuages de points

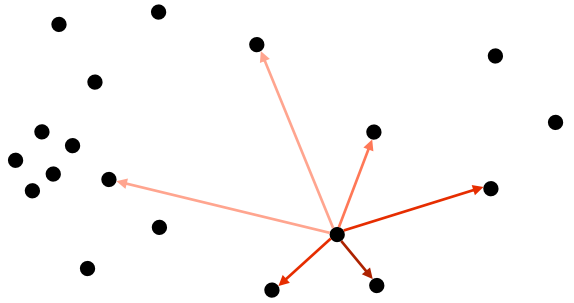
- Data volume 2M pts/s
- 1h acquisition → 7 B points
- Lack of regular grid
- Invariance by permutation
- Variable density
- Acquisition artefacts
- Occlusions



{p1, p2, p3, p4, p5, p6, p7, p8}

{p5, p8, p4, p3, p6, p2, p1, p7}





Démonstration

Open3D + CloudCompare

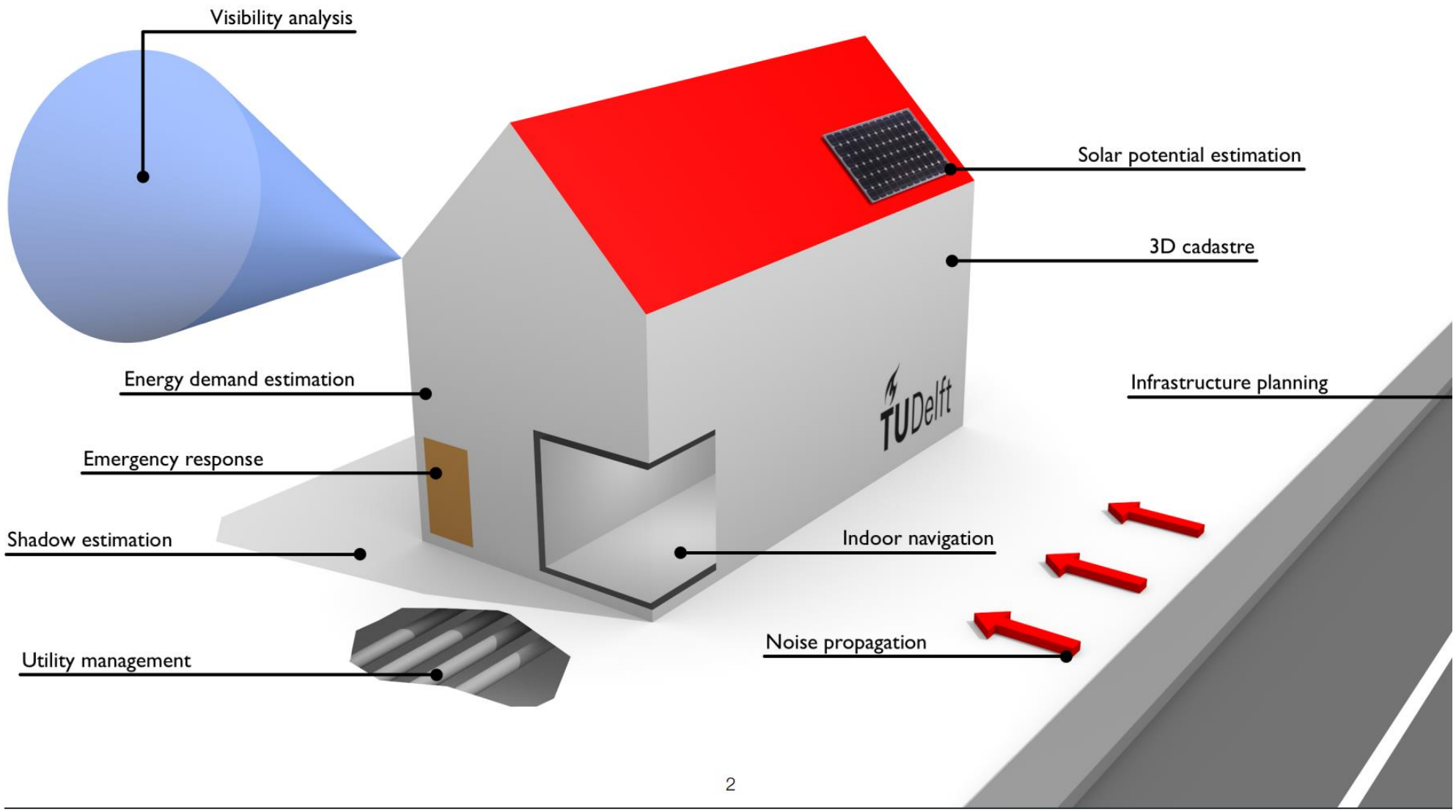
Étapes installation et traitement

- Installer CloudCompare
- Télécharger nuage de points à partir de PDOK-AHN3 ou OpenTopography
- Import du nuage de point
- Filtrage
- Segmentation
- Classification
- Export

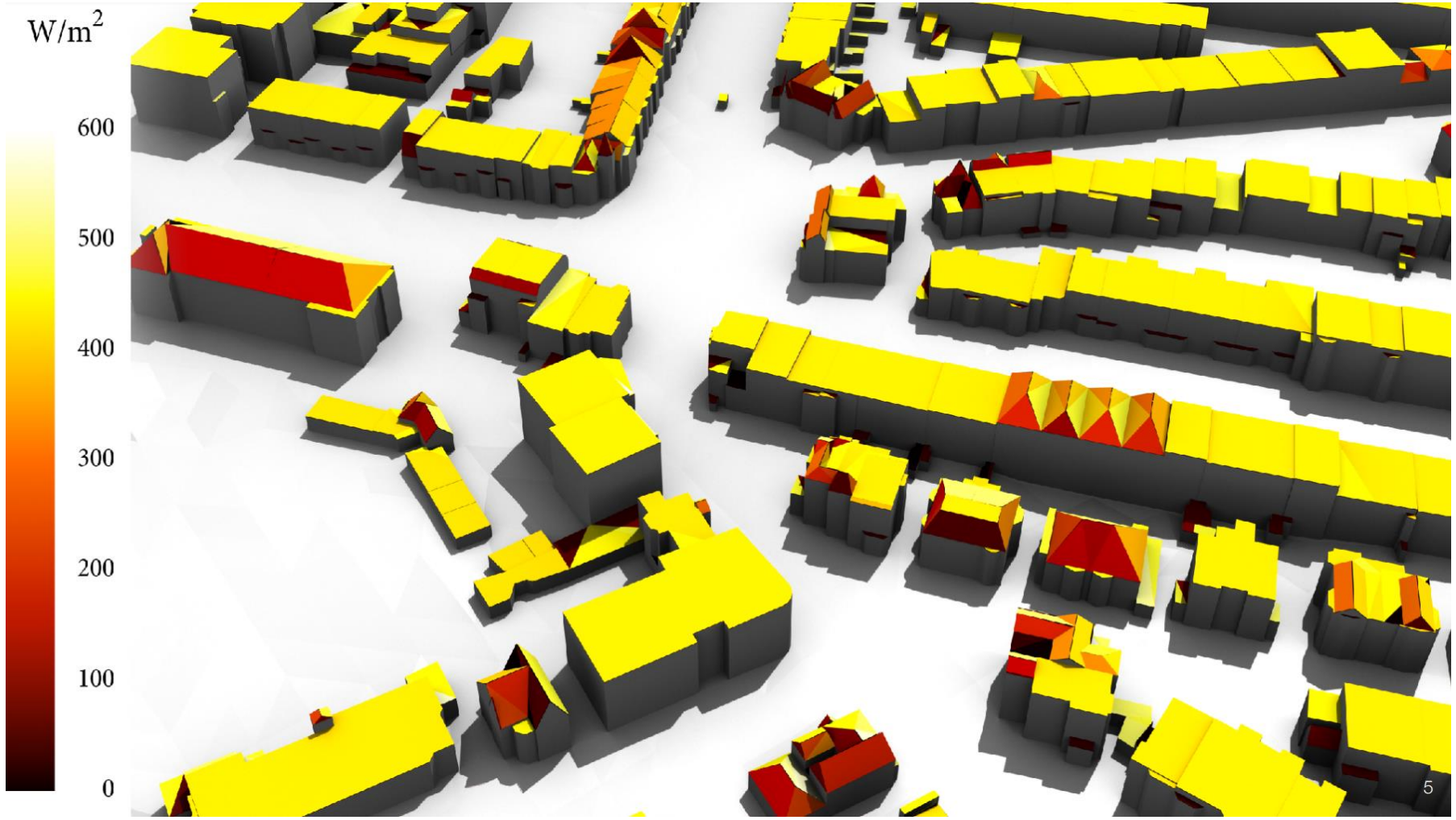
LIÈGE université
Geomatics

Nuage de points et SIG

Applications et cas d'usages

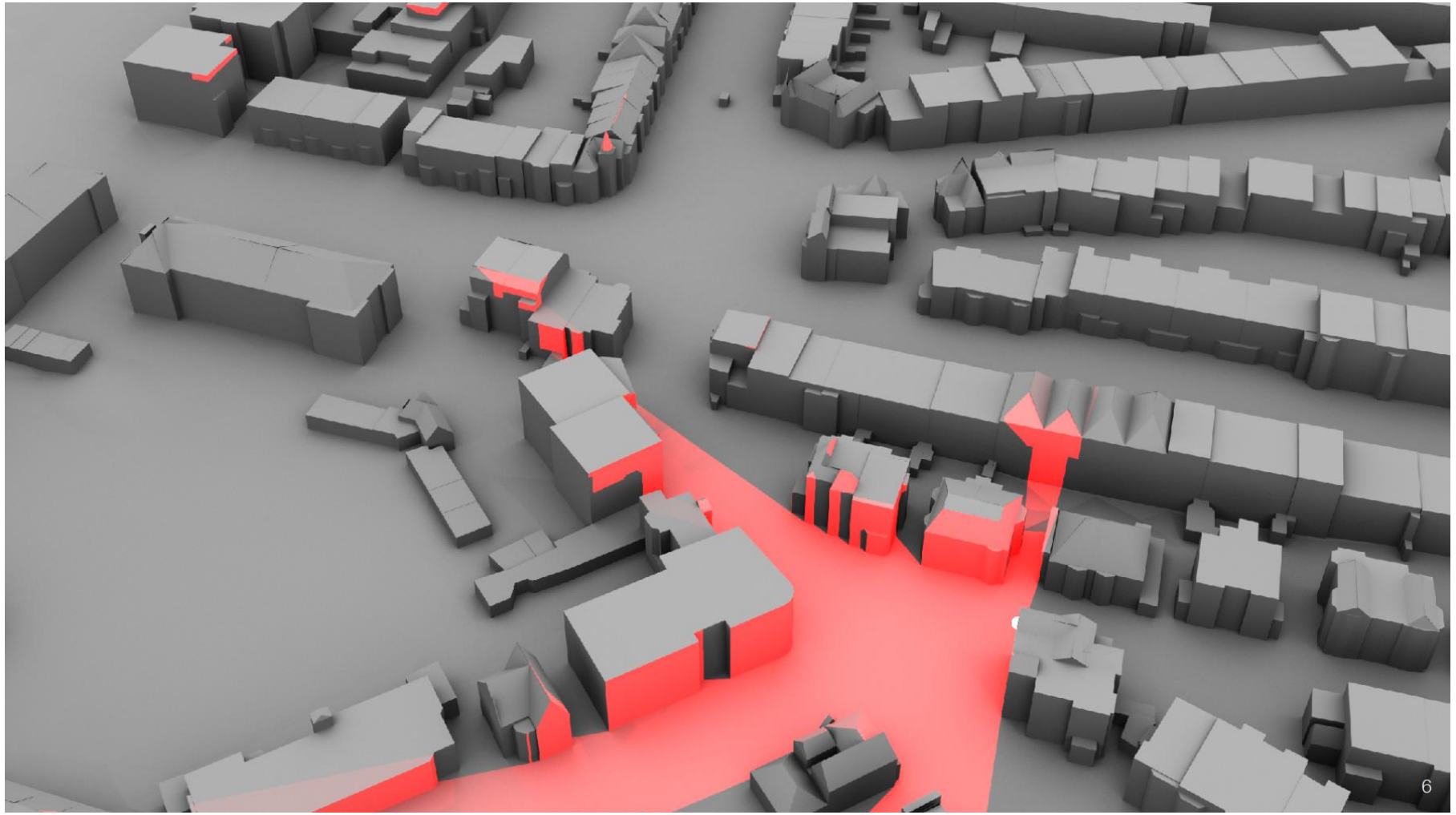


Source: TUDelft



Solar potentiel estimation

Source: TUDelft

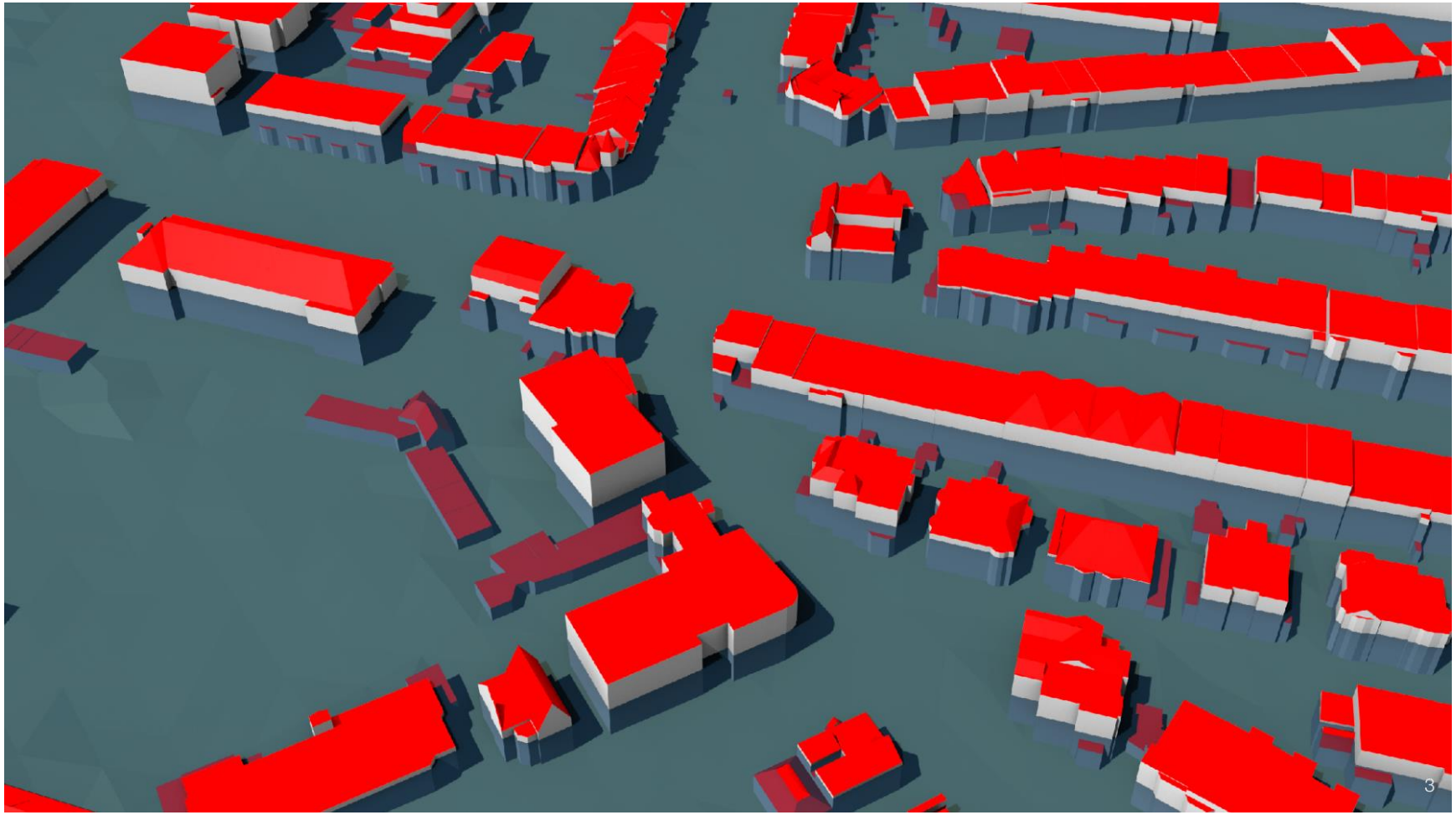


Visibility analysis

Source: TUDelft

Noise propagation

Source: TUDelft



Inondation

Source: TUDelft

LIÈGE université
Geomatics

Nuage de points et SIG

Démonstration sur QGIS

Étapes d'installation

- **Installer QGIS version > 3.18** (with native support for point cloud data)
- **Télécharger WhiteboxTools plugin**
  - From the **Plugins** menu, select **Manage and Install Plugins**....
  - Select the **Settings** tab and press the Add button.
  - In the **Repository details** dialog box, enter something logical, such as LiDAR Plugins in the **Name** textbox.
  - In the **URL** textbox, enter https://plugins.bruy.me/plugins/plugins.xml and press OK.
  - Select the All tab and enter the word 'whitebox' in the search box. Whitebox for Processing should appear the search listing. Select and check this toolbox and press the Install button.
  - …etc
- **Le reste des étapes disponible:** https://www.whiteboxgeo.com/manual/wbt_book/qgis_plugin.html

Étapes de traitement

- Télécharger un nuage de point à parti de PDOK-AHN3, ou OpenTopography
- Importer le nuage de point sur QGIS
- Découvrir les propriétés du nuage de points
- Hillshading (*LidarHillshade*)
- Importer l'orthophoto associée
- Installer OSMQuick
- Coloriser le nuage de point à partir de l'ortho (*Lidarcolourize*)
- Intersection polygone et lidar (*Erase polygon from lidar*)
- Classification (*ClassifyBuildingInLidar*)
- *Lidar to digital surface model*
- *Install terrain shading->*

Démonstration

QGIS

LIÈGE université
Geomatics

Nuage de points et SIG

Démonstration sur Pgpointcloud

Stockage fichier

- Standard (de facto) pour échanger et stocker les données LiDAR

  LAS

  LAZ (version compressée du LAS)

- Problèmes du stockage fichier

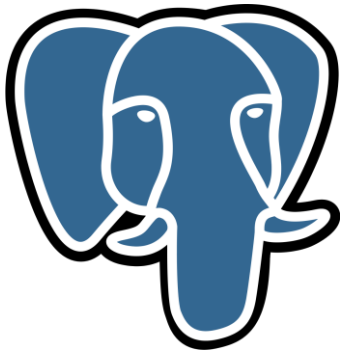
  Beaucoup de petits fichiers

  Gestion arborescente compliquée

  Nécessité des scripts parallélisés pour traiter ces gros volume de données…

Utiliser un SGBD

- Requêtes
  - Spatiales
  - Temporelles
  - Attributaires
- Croiser les données
- Mettre à jour
- Centraliser la gestion de la donnée



ORACLE

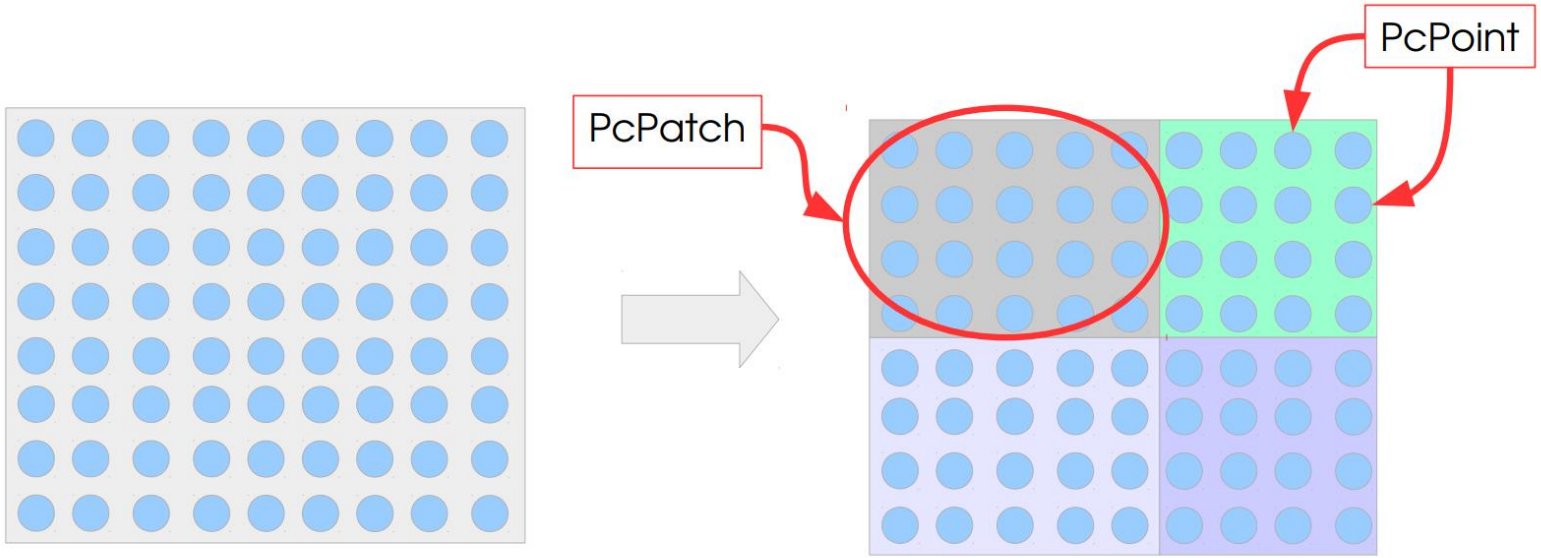
SGBD

- Chaque point est géoréférencé→ PostGIS ?
  - Difficile de stocker un point par ligne avec une telle volumétrie

- Besoin de regrouper les points pour optimiser le stockage

pgPointCloud

- Lien: pgpointcloud https://github.com/pgpointcloud/pointcloud
- Extension PostgreSQL pour stocker les nuages de points.
- Organiser les points en Patch pour réduire la taille de la table!



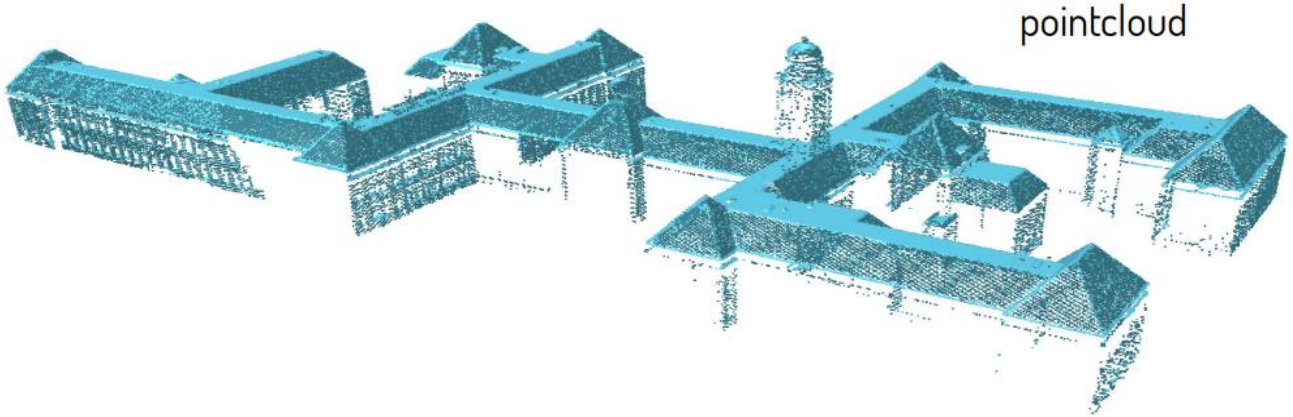
Démonstration

PostGIS/Pgpointcloud

LIÈGE université
Geomatics

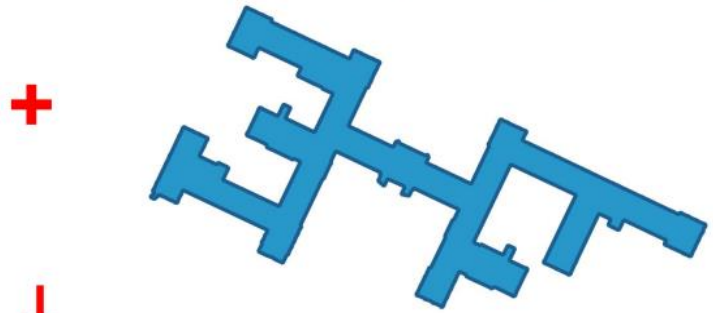
Nuage de points et SIG

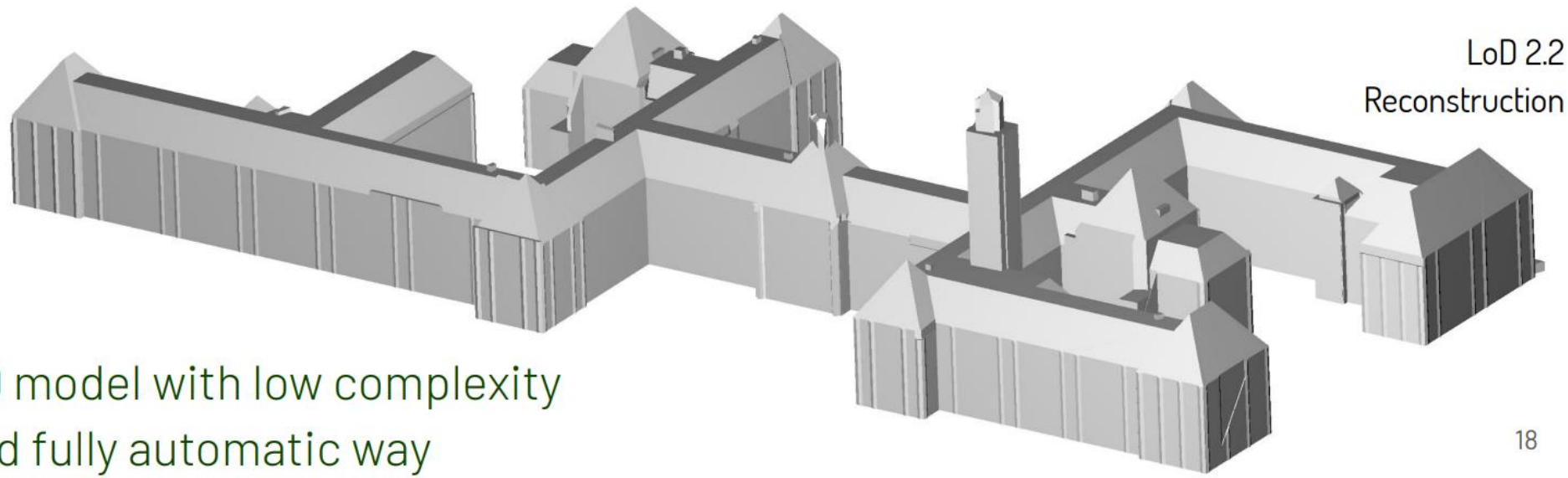
Démonstration sur Polyfit



pointcloud

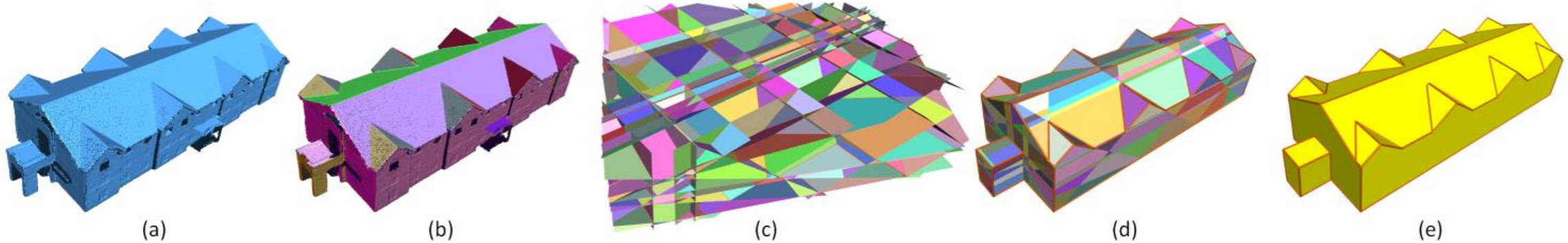
footprint polygon





LoD 2.2
Reconstruction

- Accurate 3D model with low complexity
- In robust and fully automatic way



(a) Input point cloud.

(b) Planar segments.

Region growing
RANSAC

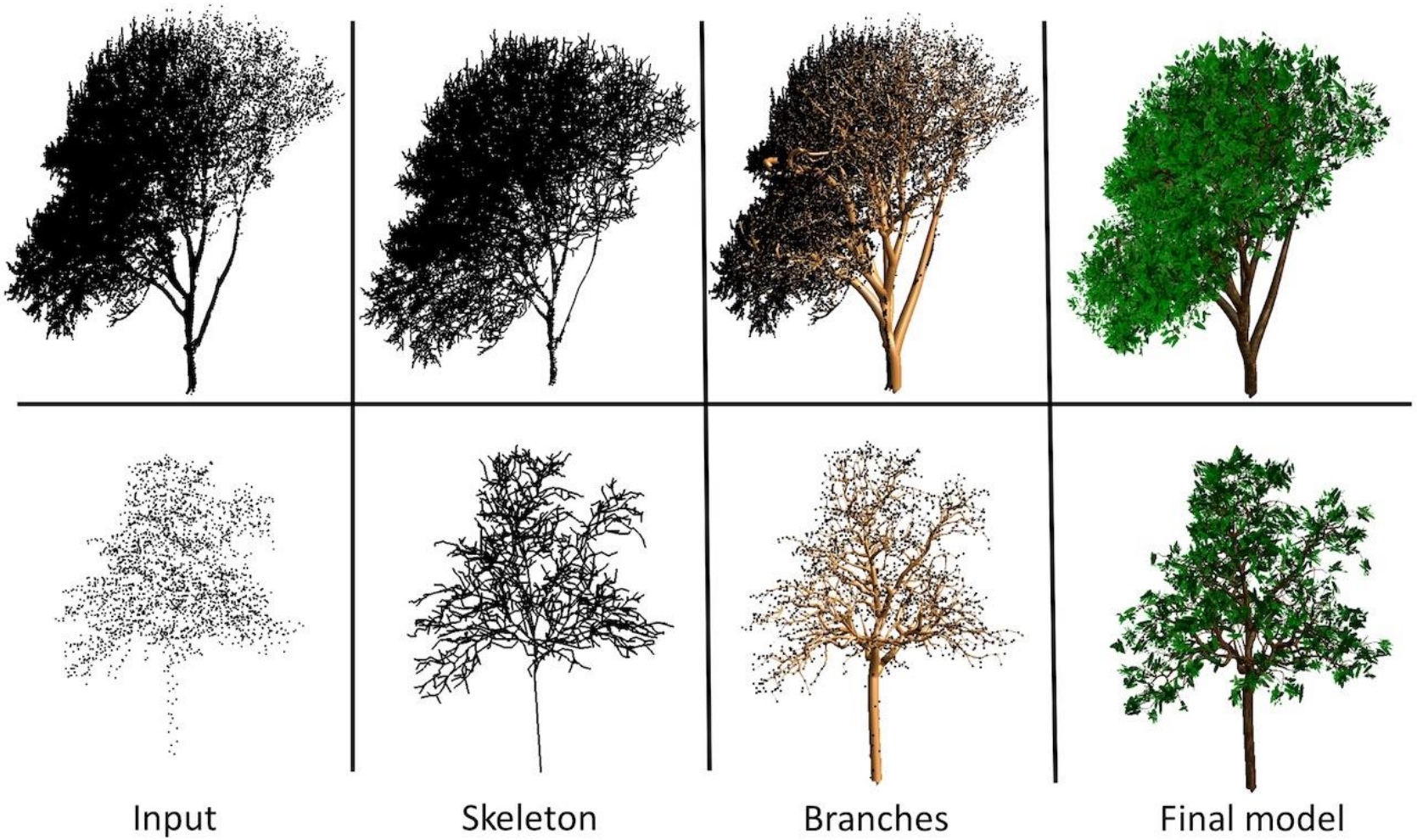
(c) Candidate faces generated using pairwise intersection.

(d) Selected faces.

(e) Reconstructed model

Download and install

https://3d.bk.tudelft.nl/liangliang/publications/2017/polyfit/polyfit.html



AdTree: 3D Trees reconstructed from point clouds

Démonstration

PolyFit

LIÈGE université
Geomatics

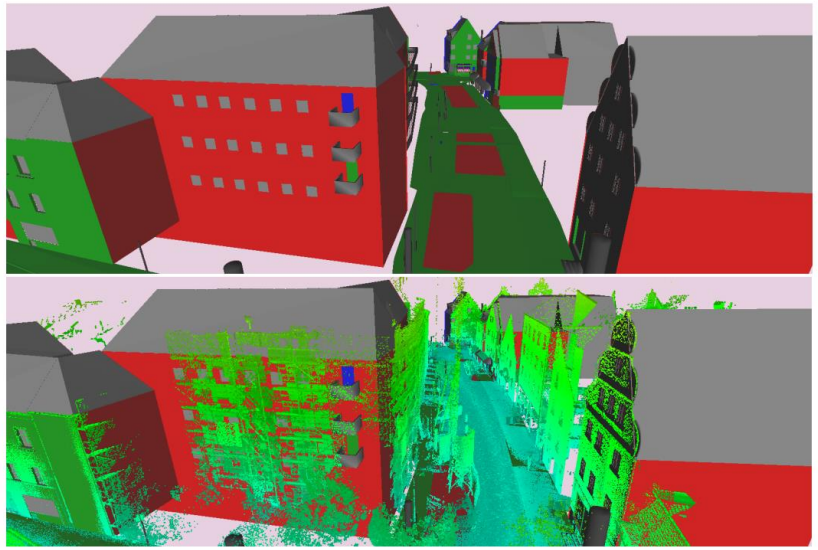
Nuage de points et SIG 3D

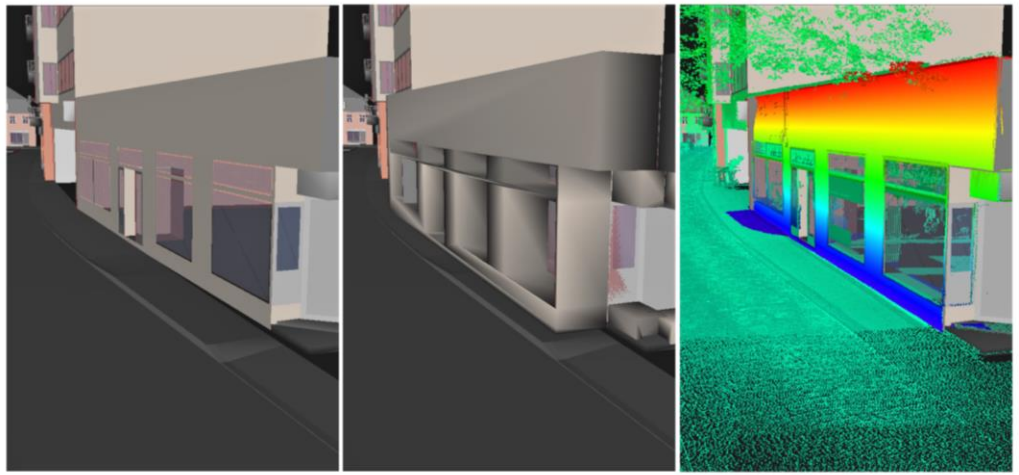
CityGML and CityJSON

CityGML is an open data model and XML-based format for the storage and exchange of virtual 3D city models.

CityJSON is an open data format for distributing 3D city models (also known as digital twins), and a JSON-encoding of the CityGML data model.

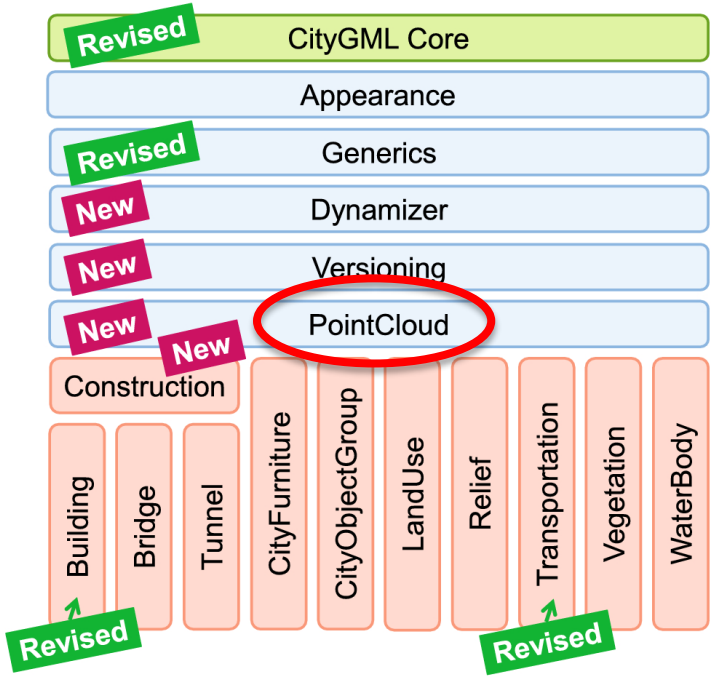
Point cloud integration in CityGML 3.0





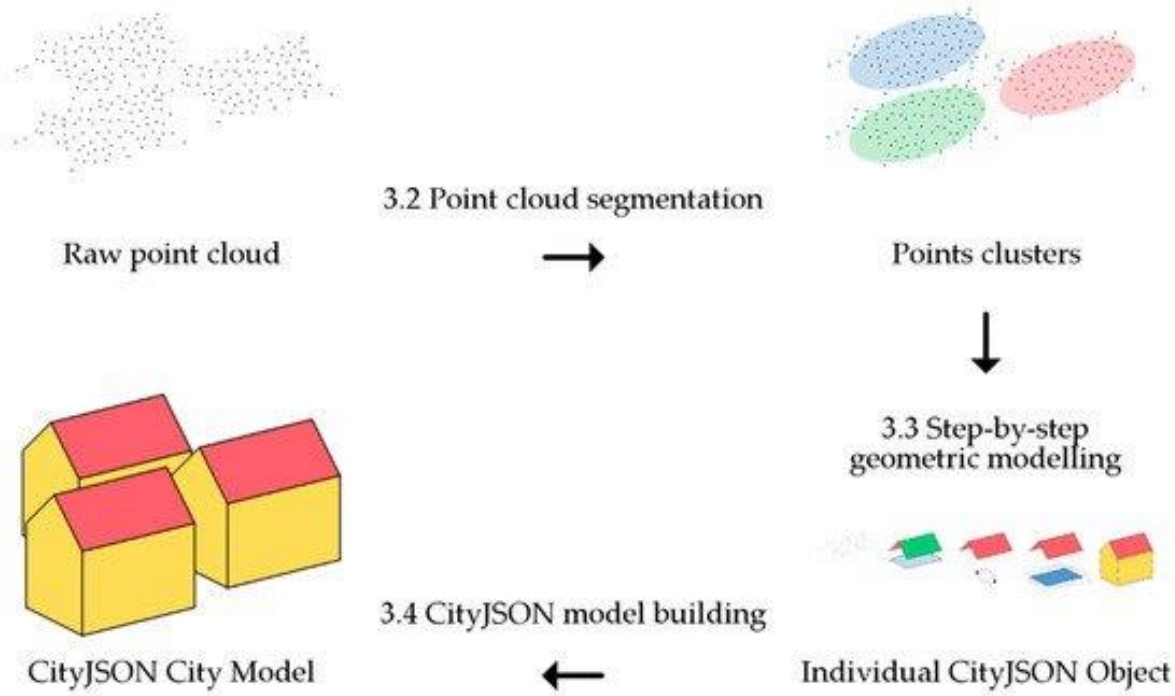
(i) Semantic model (ii) 3D Buffering (iii) Subset (colorful)

CityGML

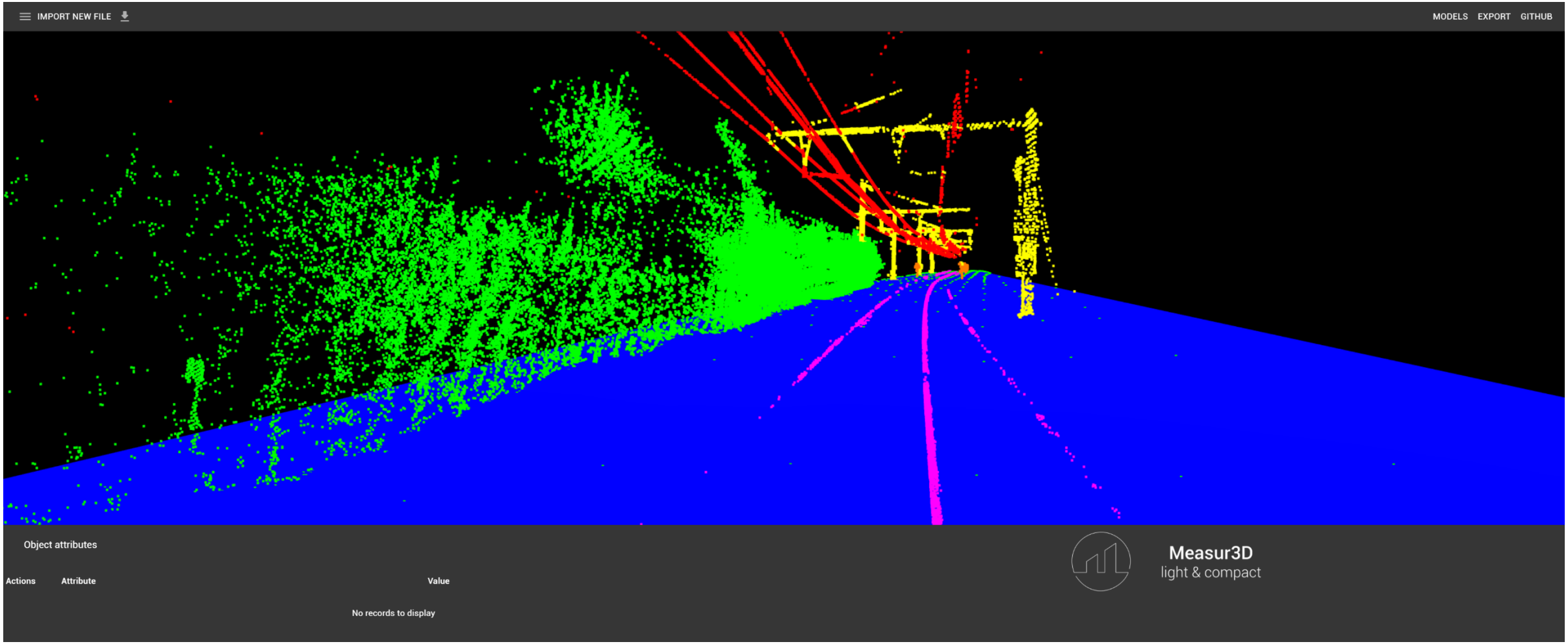


CityJSON

- Based on the CityGML conceptual model
  - JSON encoding
- Lightweight and developers-friendly alternative to CityGML.
  - 6-7x more compact
- Measur3D - Web application
  - First management in database
  - Viewer
  - Attribute management
  - 0.2.1 Version: Concurrent models
  - OGC API – Features



Point cloud integration in CityJSON



Gilles Antoine Nys: https://ganys.github.io/Measur3D/

LIÈGE université
Geomatics

Ma recherche

Cartographie du changement 3D

3D Change detection

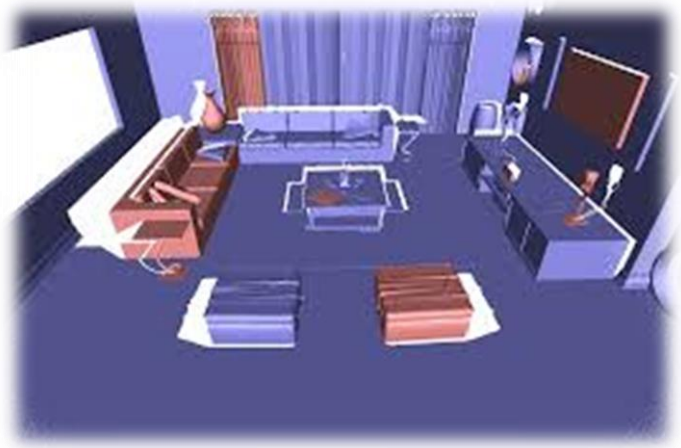
From a time-serie, detect locations where changes occurred over time, e.g:

- Man-made changes: appearance/disappearance of building,…
- Natural changes: vegetation growth, deforestation, flooding, fires,…
- Variations of terrain: glacier displacements, land subsidence,…

Change types

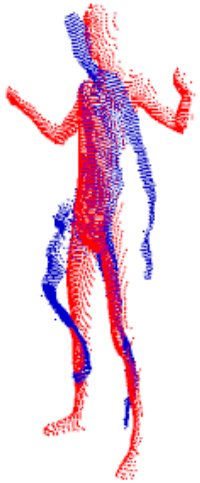
Seasonal changes

Credit: Matheus B. Vicari, al (2019)



Furniture moved in between scans

Credit: Gianpaolo Palma, al (2015)



Walking person

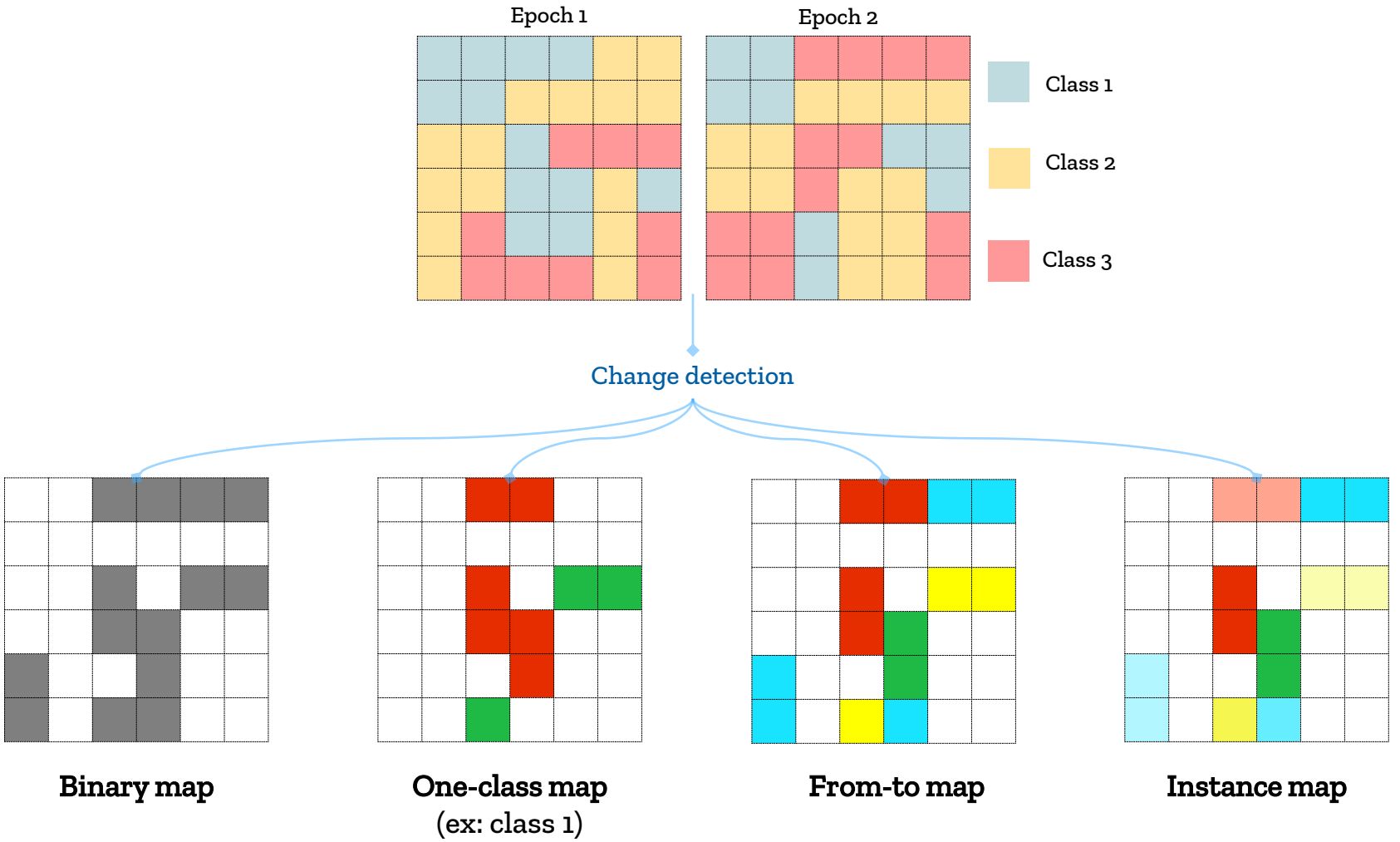
Credit: Mao Ye, al (2011)

Slow
long-term changes

Rigid and/or non-rigid

Fast
Short-term changes

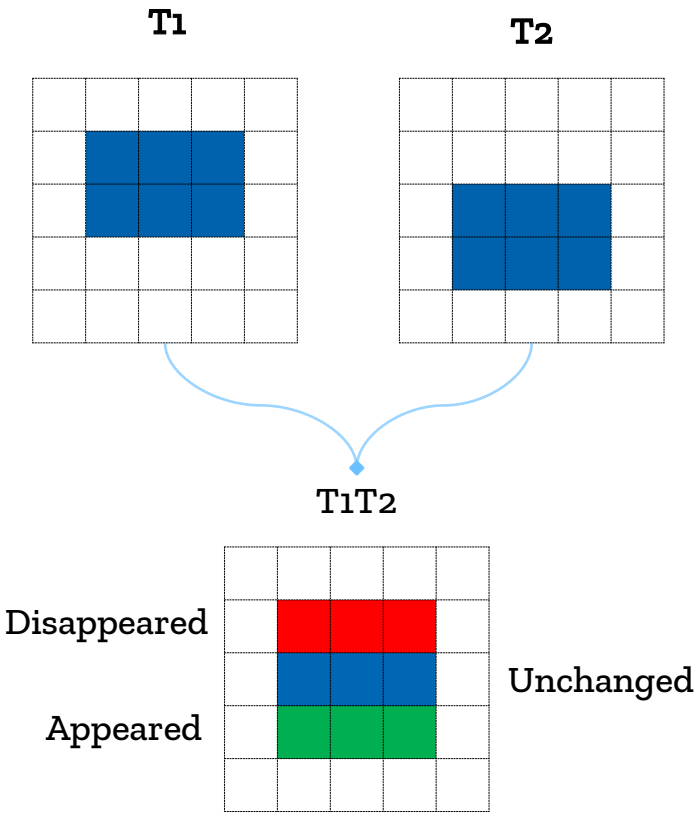
3D Change detection type



Standard approaches problems

Case 1: moving objects

Same object but change detected



Case 2: Similar objects

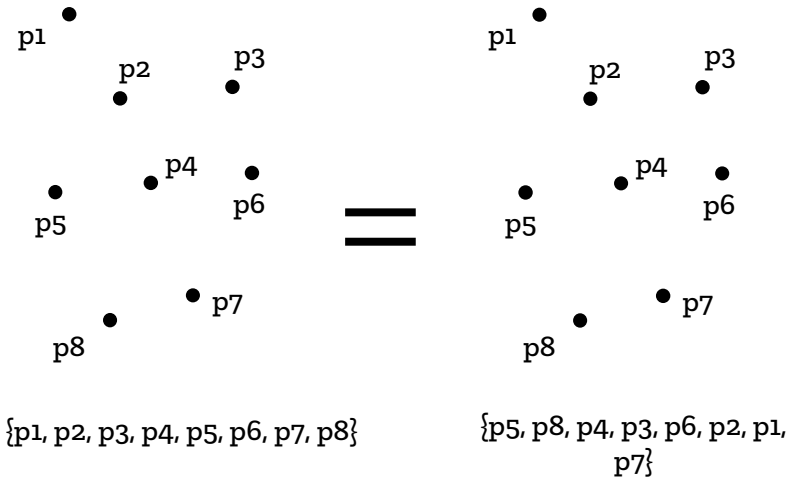
Different object but no change detected

Credit : Evan Herbst, al (2011)

How to achieve object-level change detection with uncertainty evaluation ?

Related challenges

Sensitive to: Noise, Occlusion, Registration error

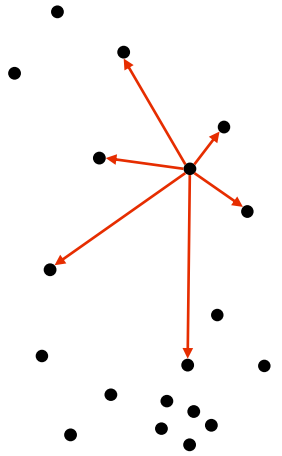


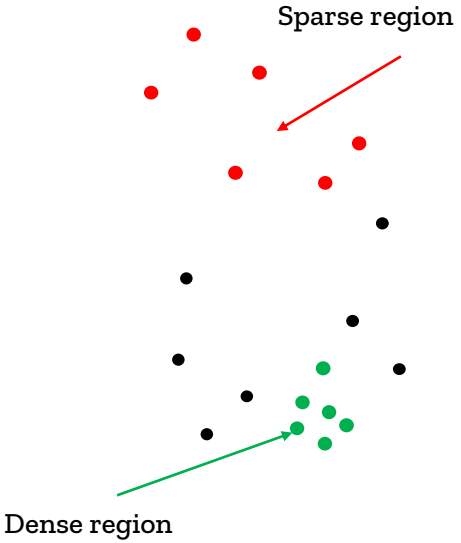
{p1, p2, p3, p4, p5, p6, p7, p8}

{p5, p8, p4, p3, p6, p2, p1, p7}

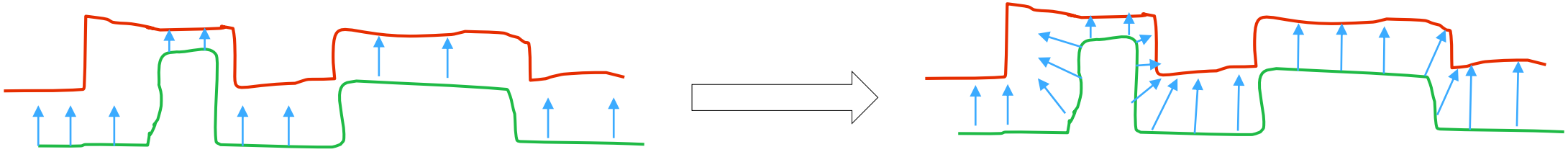
Unordered

Unstructured





Irregular



One direction

Multiple direction

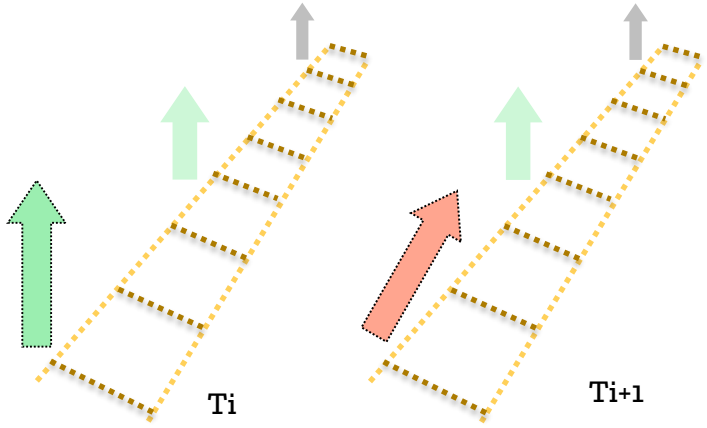
Essentially you must MINIMIZE changes due to characteristics you are NOT interested in, in order to IDENTIFY changes you ARE interested in.

Existing approaches

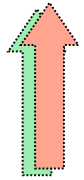
- Image differencing methods
  - Subtract High value of one date from another
  - Select a threshold to identify change
  - Results in positive and negative values areas of change and zero (in theory) in areas of no change
- C2C (Cloud to cloud)
- M3C2 (Multiscale Model to Model Cloud Comparison)
- Machine learning with handcrafted features
- Deep learning

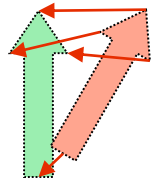
Semantics-aided change detection

$P = \{P_k \in R^{3*N_k}\}_K$ $Q = \{Q_l \in R^{3*M_l}\}_L$



T(p) = R*p + t
where t ∈ R3 is the translation and
R ∈ SO(3) is the rotation



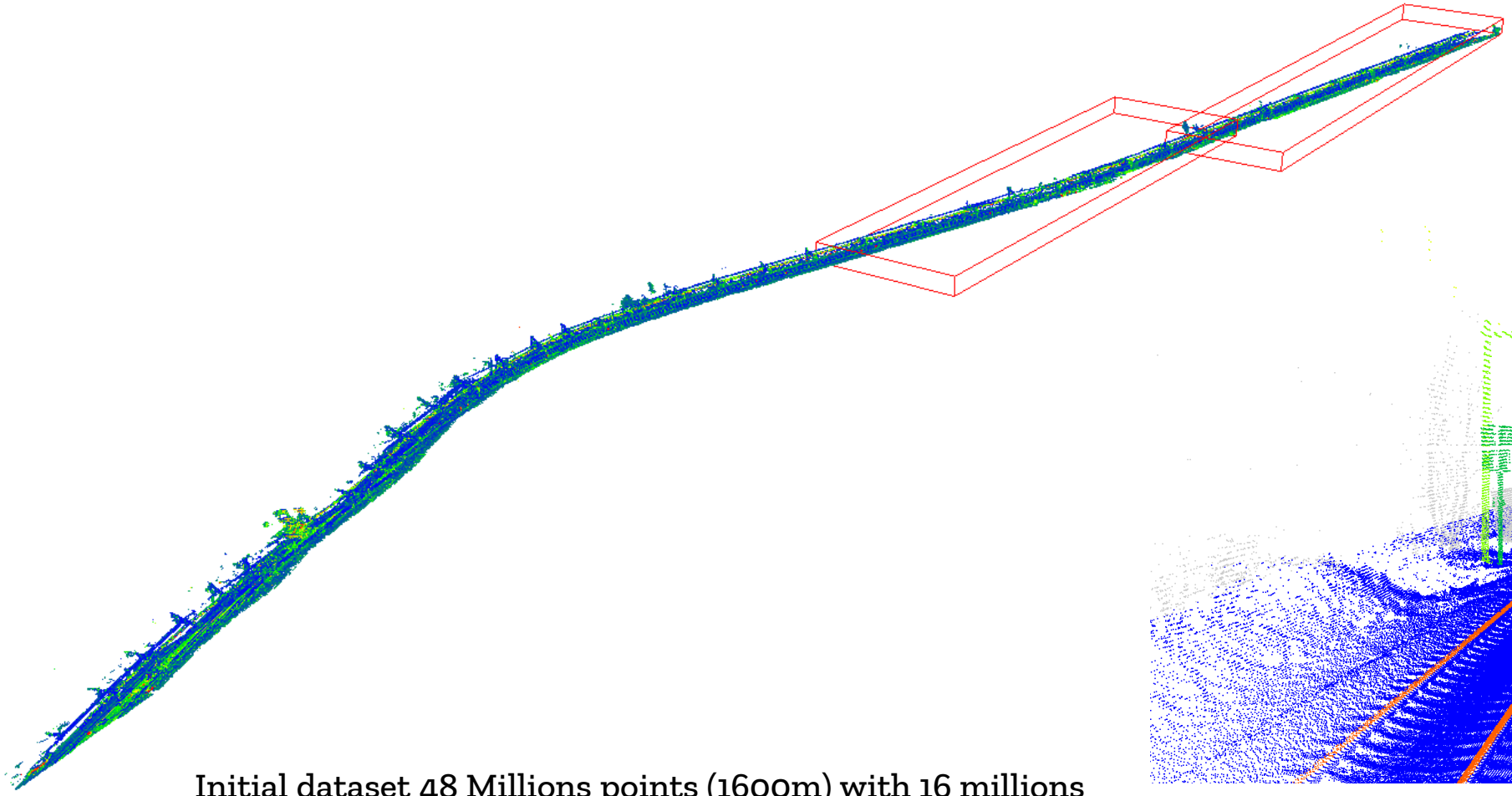


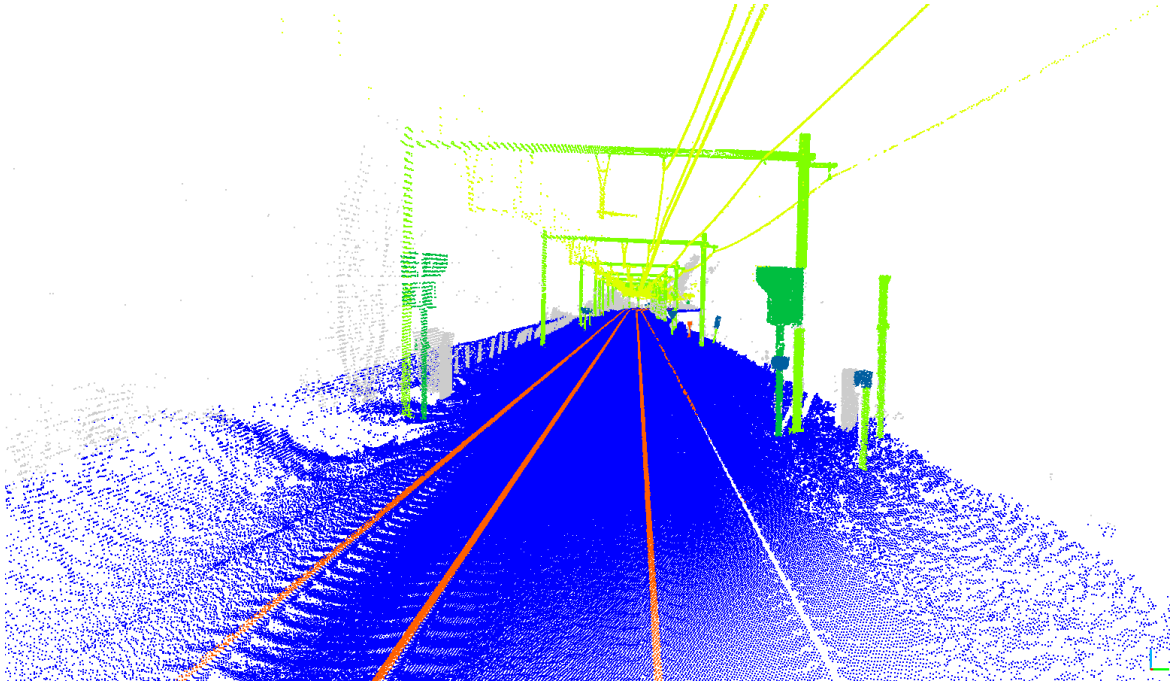
1. Enriched point clouds (object level)

2. Object registration

3. Correspondence

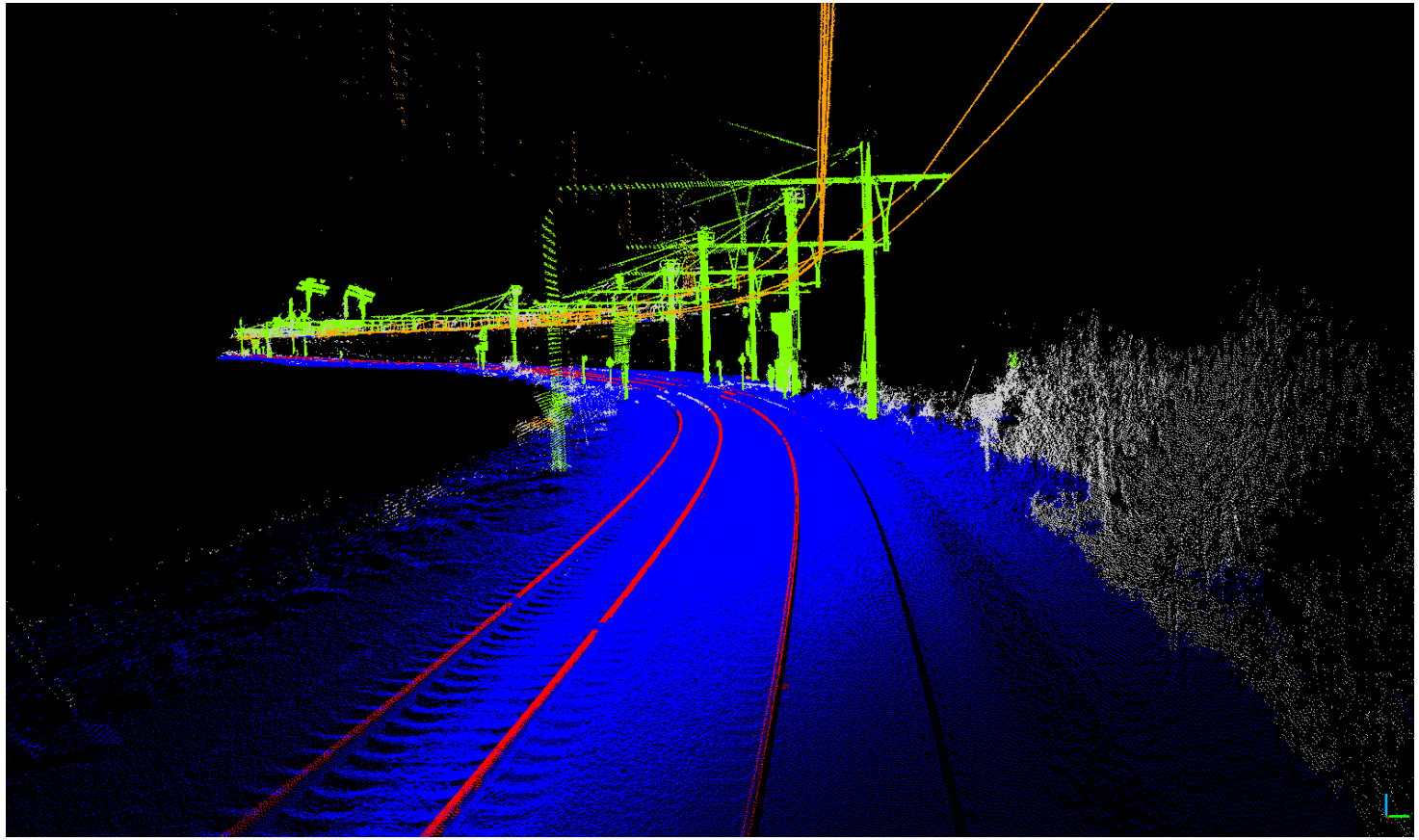
Semantics-aided change detection





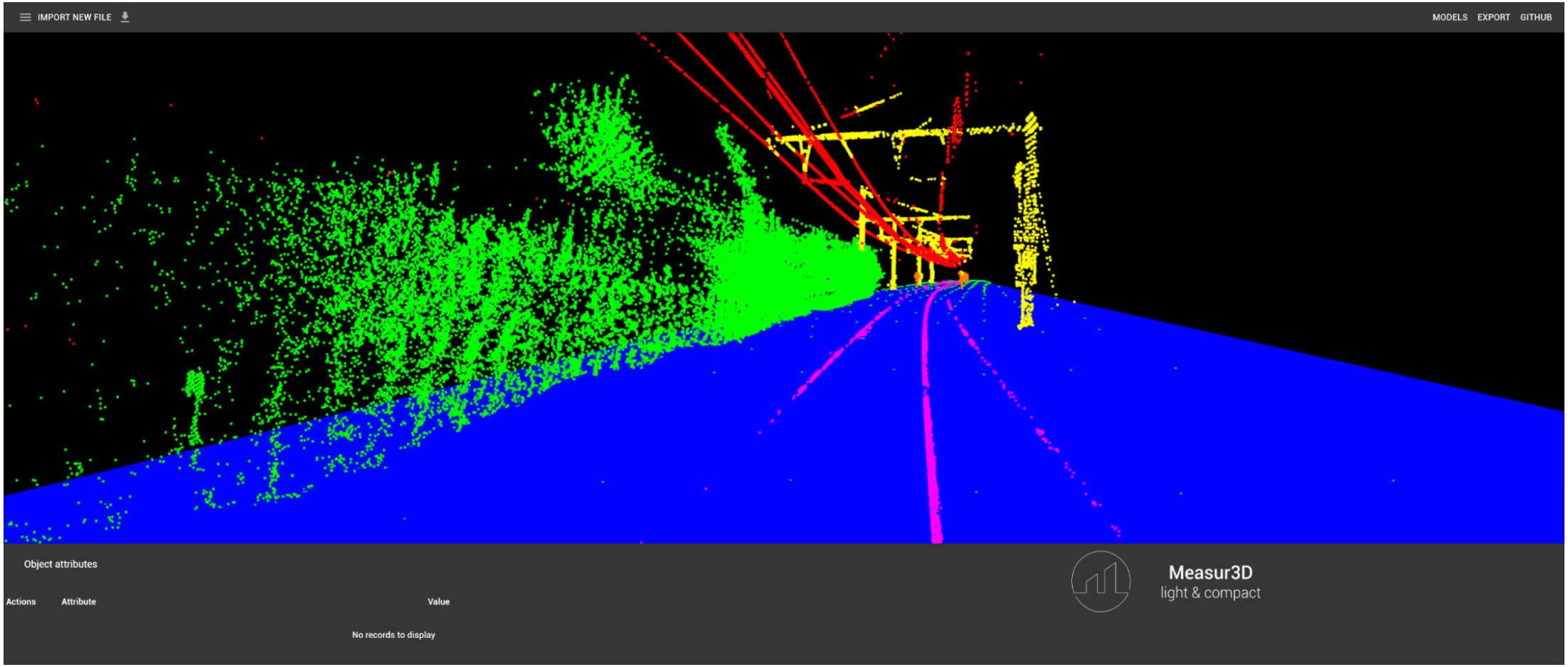
Initial dataset 48 Millions points (1600m) with 16 millions labelled points

Semantics-aided change detection



Semantic segmentation for railways using RandLA-Net

Point Cloud and 3D GIS for web



Gilles Antoine Nys:
https://ganys.github.io/Measur3D/

Do not hesitate to ask me !

LIÈGE université
Geomatics

Geomatics Unit | geomatics.ulg.ac.be

Allée du Six Août 19 (B5A) | 4000 Liège

akharroubi@uliege.be

My Publications

1. Abderrazzaq Kharroubi, Rafika Hajji, Roland Billen, Florent Poux. Classification and integration of massive 3d points clouds in a virtual reality VR environment. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. (2019).
2. Abderrazzaq Kharroubi, Roland Billen, Florent Poux. Marker-less mobile augmented reality application for massive 3d point clouds and semantics. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. (2020).
3. Abderrazzaq Kharroubi, Line Van wersh, Roland Billen, Florent Poux. Tesserae3d: a benchmark for tesserae semantic segmentation in 3D point clouds. ISPRS - International Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences. (2021).
4. Gilles-Antoine Nys, Abderrazzaq Kharroubi, Florent Poux, Roland Billen. An extension of CityJSON for the support of 3D point clouds. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. (2021).
5. Rafika Hajji, Abderrazzaq Kharroubi, Youssef Benbrahim, Zidane Bahhane and Adil El Ghazouani. Integration of BIM and Mobile Augmented Reality in the AECO Domain. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. (2021).