Université Gustave Eiffel

ENSG Géomatique
ÉCOLE NATIONALE DES SCIENCES GÉOGRAPHIQUES

IGN
INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

Creating digital twins of cities: from data acquisition to 3D modeling

Bruno Vallet
Senior Researcher, IGN/UGE

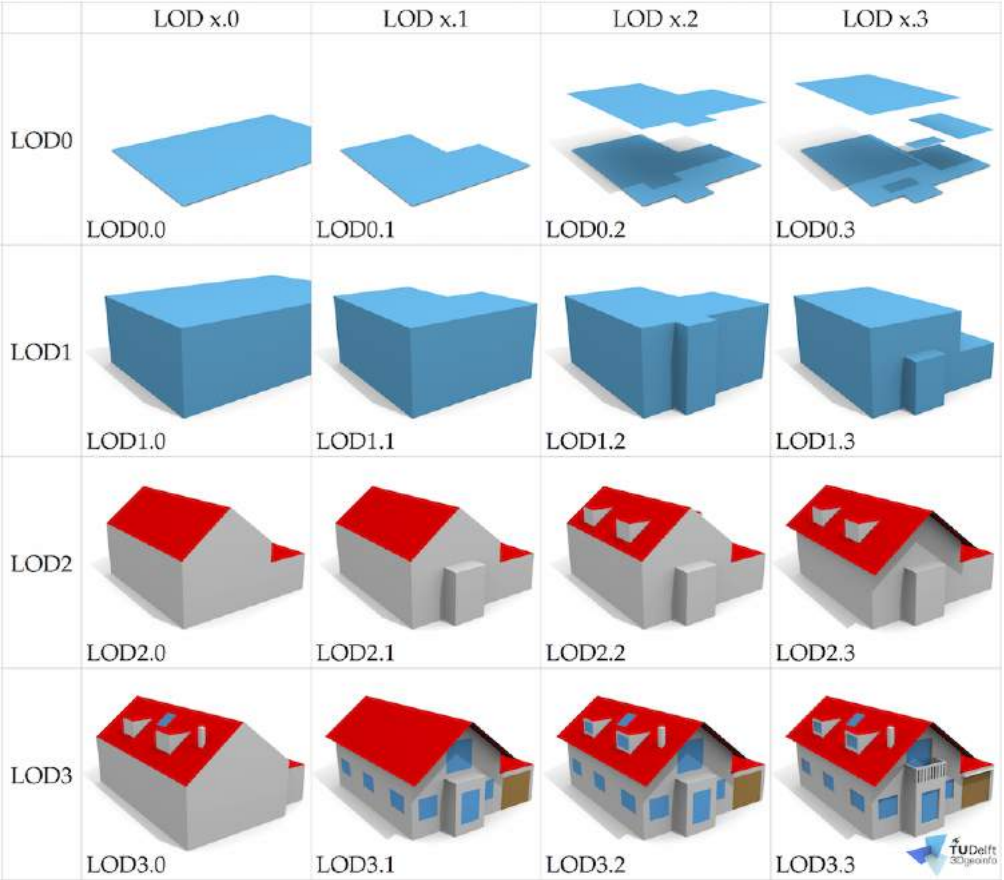
Introduction

Introduction

- What is 3D city modeling ?
  - Creating a faithful digital twin of the city :
    - Accurate : low error between model and reality
      - Relative : accurates sizes and slopes
      - Absolute : georeferencing
    - Semantized : types of the objects are known
    - Generalized :
      - contains only the required details
      - highly structured
    - Actual / up to date

Introduction

- CityGML : 3D city model standard
  - **Defines a data model for 3D city models**
  - **Defines Levels of Details (LoD)**



Introduction : How to create digital twins

- Data acquisition :
  - Image
  - Lidar
  - Radar
- Data registration/georeferencing
  - Allows to combine various sources
  - Ensures correct georeferencing

Introduction : How to create digital twins

- Dense matching (for images) :
  - **create a point cloud from oriented images**
- Data fusion :
  - **create a single representation from heterogeneous sources**
- Modeling :
  - **create a structured model from merged data**
- Updating
  - **Detect, classify and apply changes**

Introduction : Stakes and trends

- Increase quality :
  - Accuracy (geometric and semantic)
  - Level(s) of detail
  - Precision/recall
- Decrease costs
  - Data acquisition
  - Automatization (registration and modeling)
    - Requires scene analysis/understanding (computer vision)

Introduction : Applications

- Urban planning
- Inventory
- Itinerary computation for all mobilities
- Accessibility diagnostics
- HD mapping for autonomous driving
- Simulation : trafic, noise, lighting, pollution, ...
- Communication

Introduction : Challenges

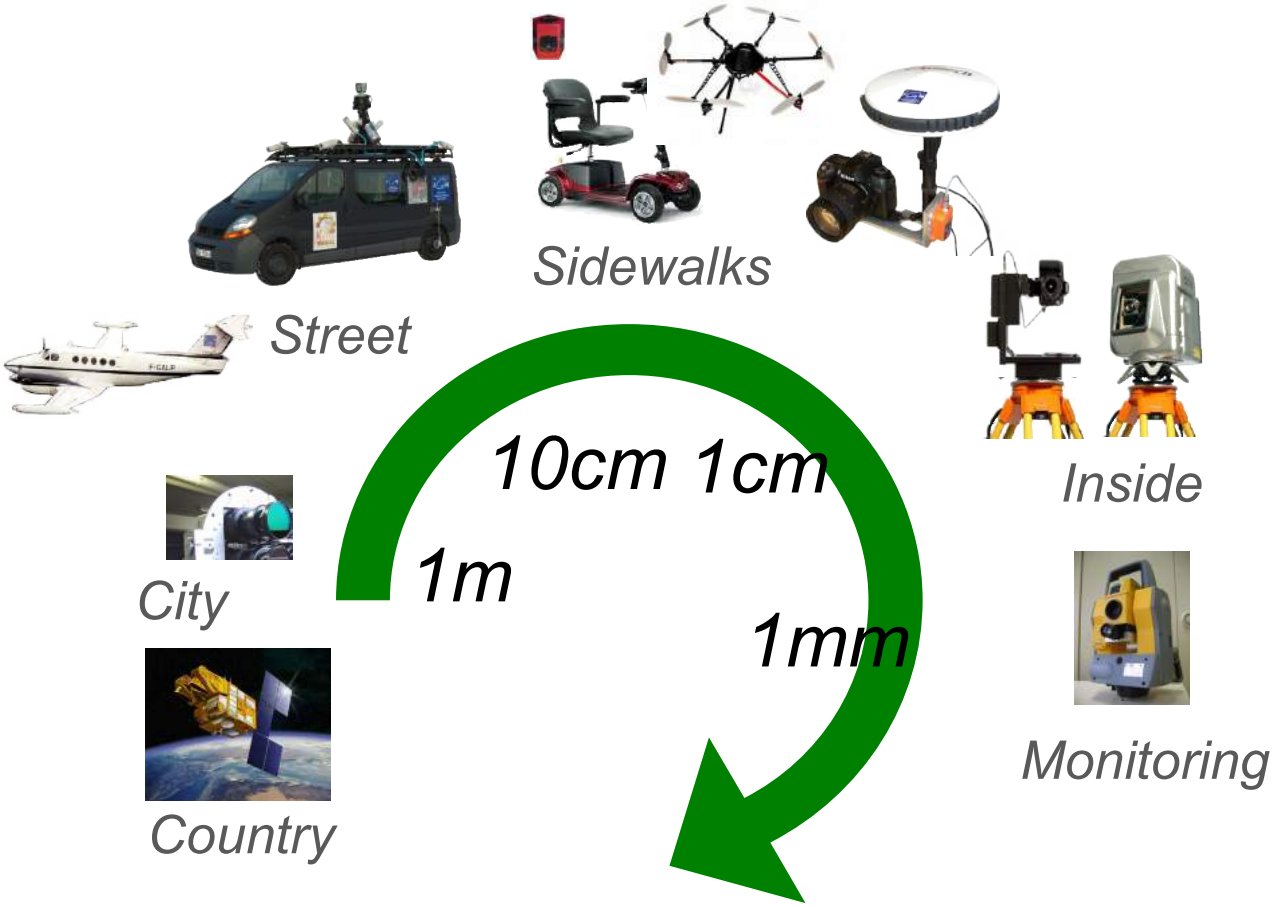
- Big data : Terabytes per km²
- Complexity :
  - **Possibly complexe 3D shapes with occultations**
  - **Mobile and non sustainable objets (detection and filtering)**
  - **Radiometry (images) : correcting shadows and refletions**
- Geolocalisation
  - **GPS/GNSS highly unreliable in urban areas:**
    - **Few visibles satellites**
    - **Multi echoes**

Introduction : overview

- Data acquisition
- Georeferencing and dense matching
- Scene analysis and reconstruction
- Applications

Data Acquisition

Acquisition platforms



Acquisition platforms

Sensors

- An acquisition platform combines 3 type of sensors :
  - **Georeferencing**
  - **Image**
  - **Lidar**

Georeferencing sensors

- 3 types of sensors:
  - **Inertial Measurement Unit (IMU)**
  - **GPS** : mesures a position
  - **Odometre** : mesures a distance
- Combined into a platform trajectory

Lidar sensors

- 2 types :
  - Planar Lidar
  - Rotating Lidar

Lidar sensors

Lidar sensors

Lidar sensors

- Rotating angular sector (~10Hz)

Lidar sensors

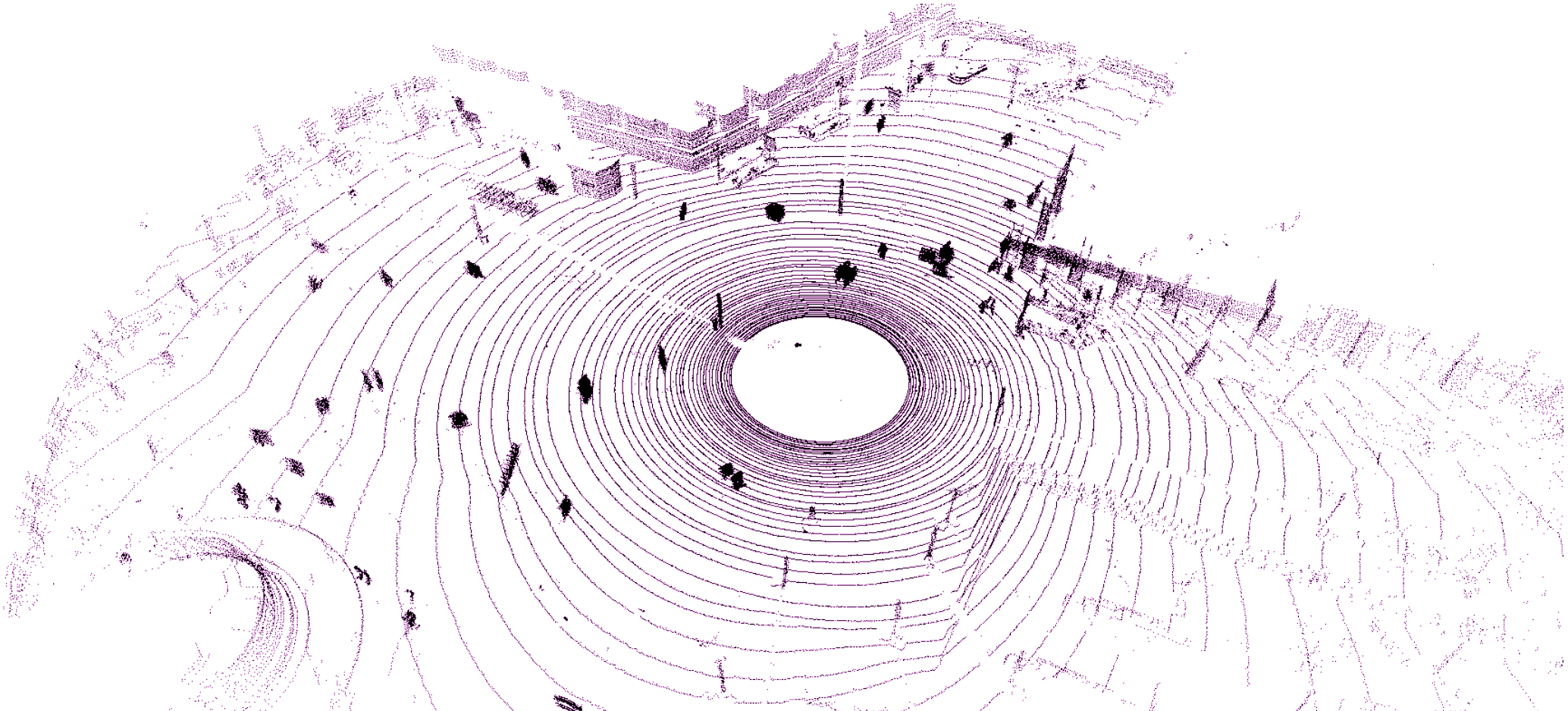


Image sensors

- **Panoramic** and stereo (**front** and **rear**)

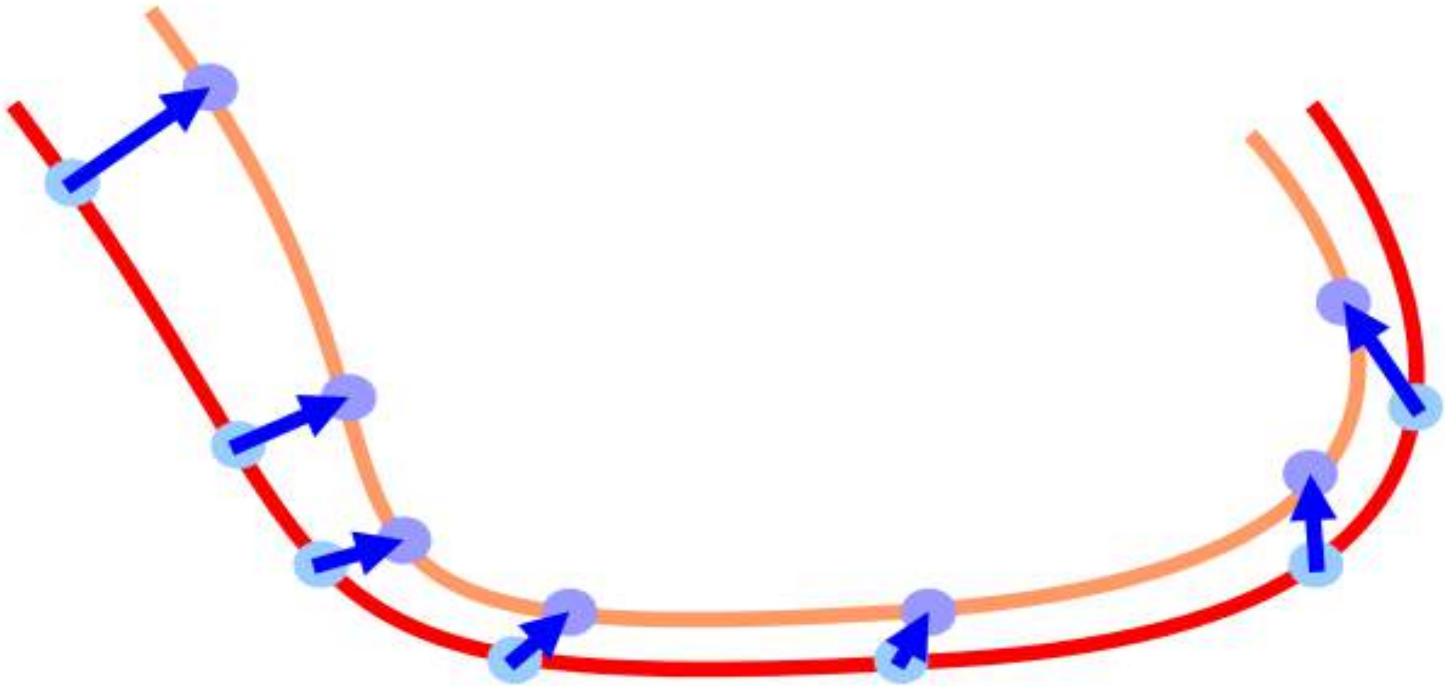
Image sensors

Image sensors

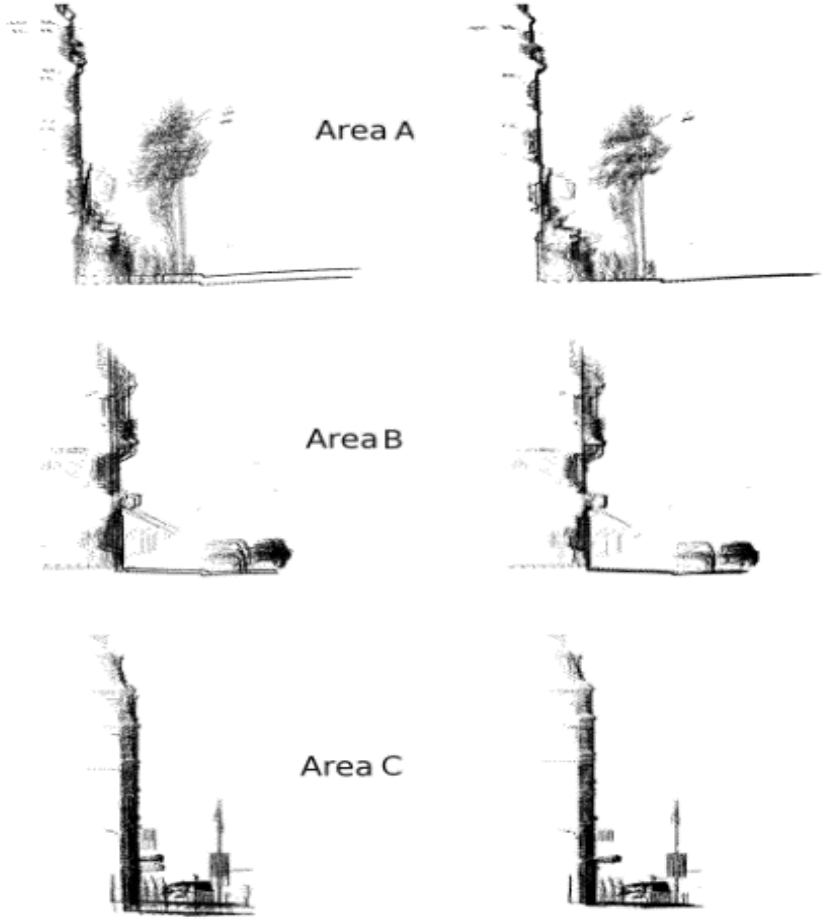
Georeferencing/registration

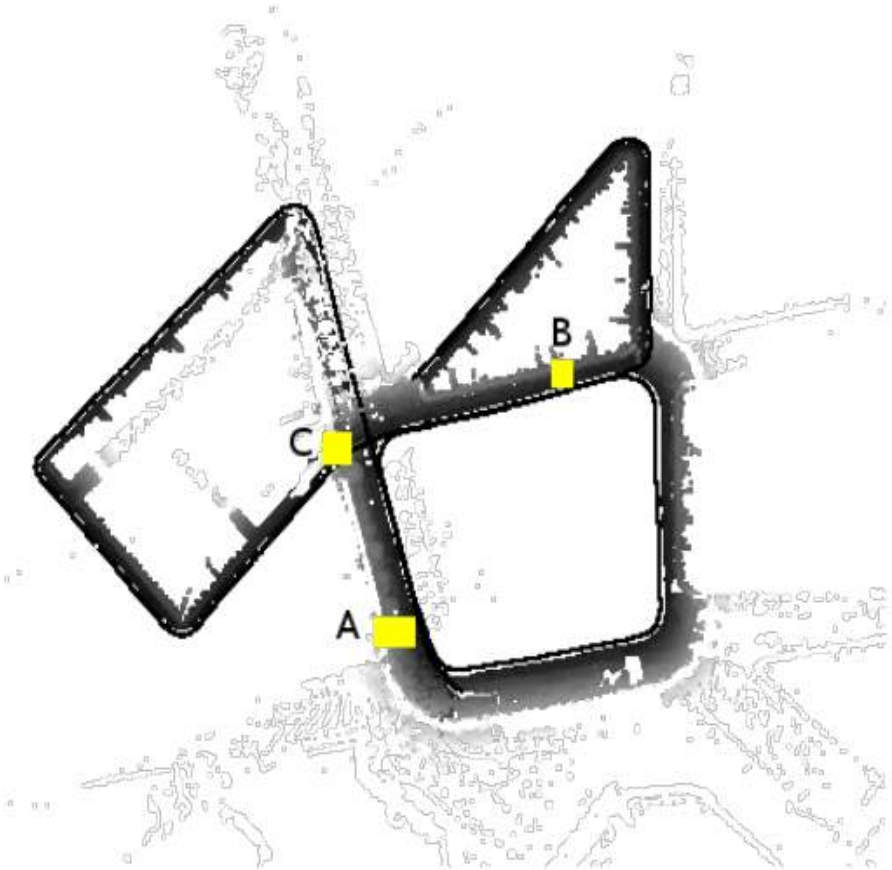
Introduction

- Data registration = platform trajectory estimation



Lidar self registration





Lidar registration on 3D city model

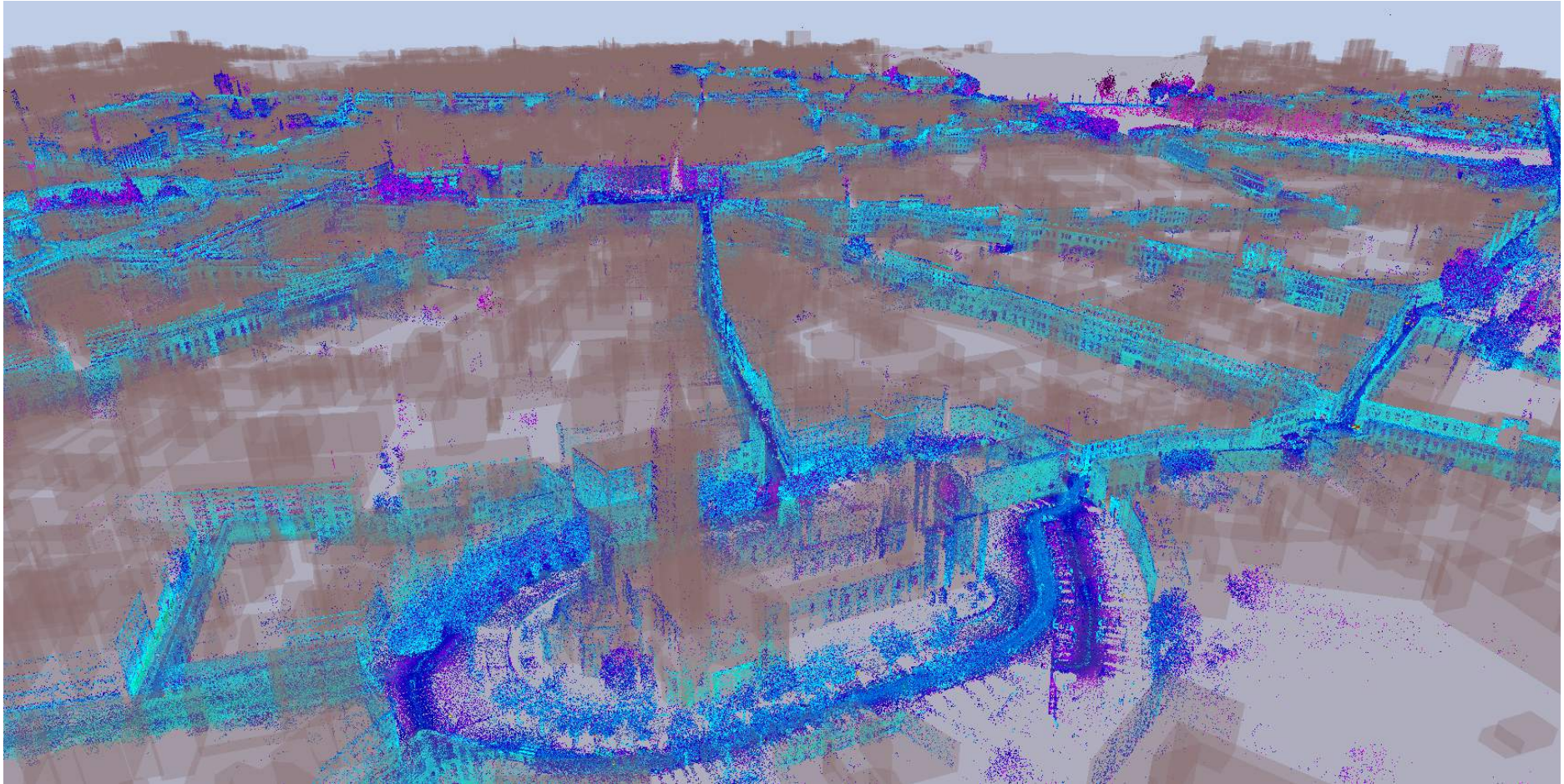


Image pose estimation

- Find common points between images
- Minimize reprojection error
- For geolocalization, we need :
  - **Ground control points**
  - **GPS/GNSS data**

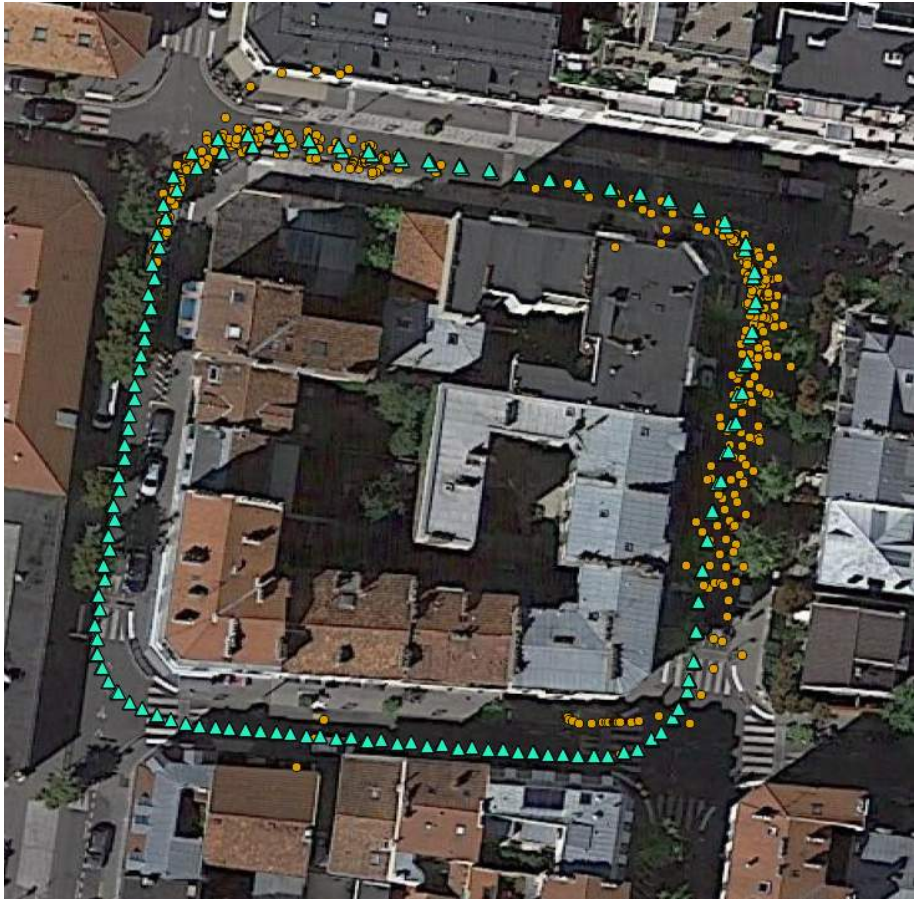
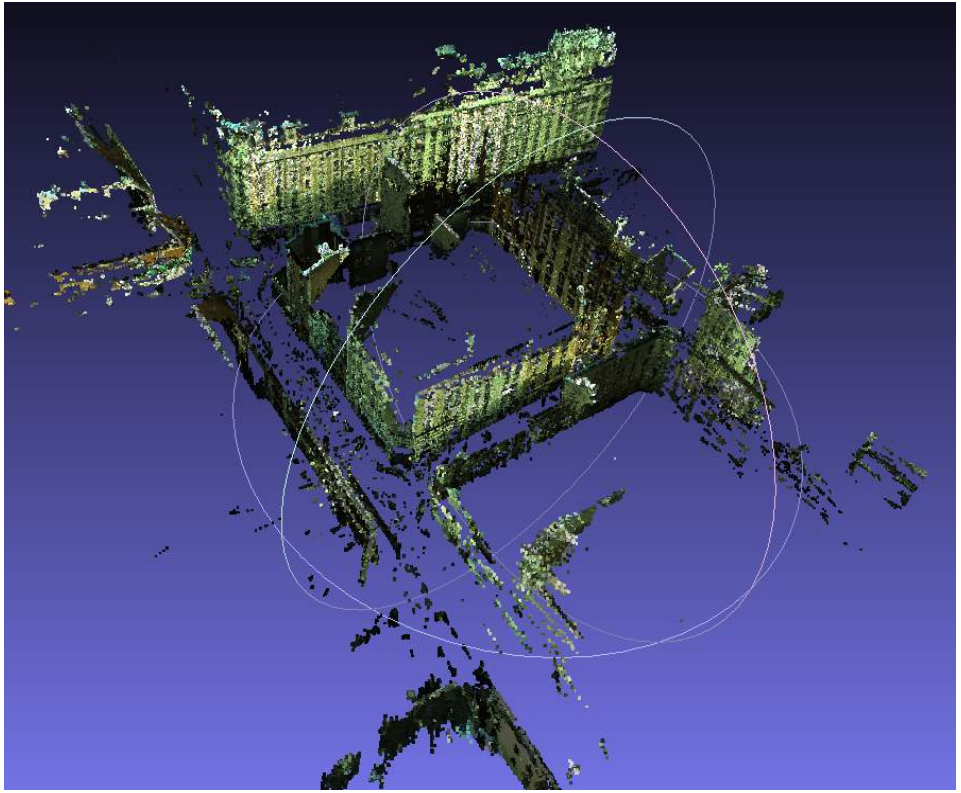


Image dense matching

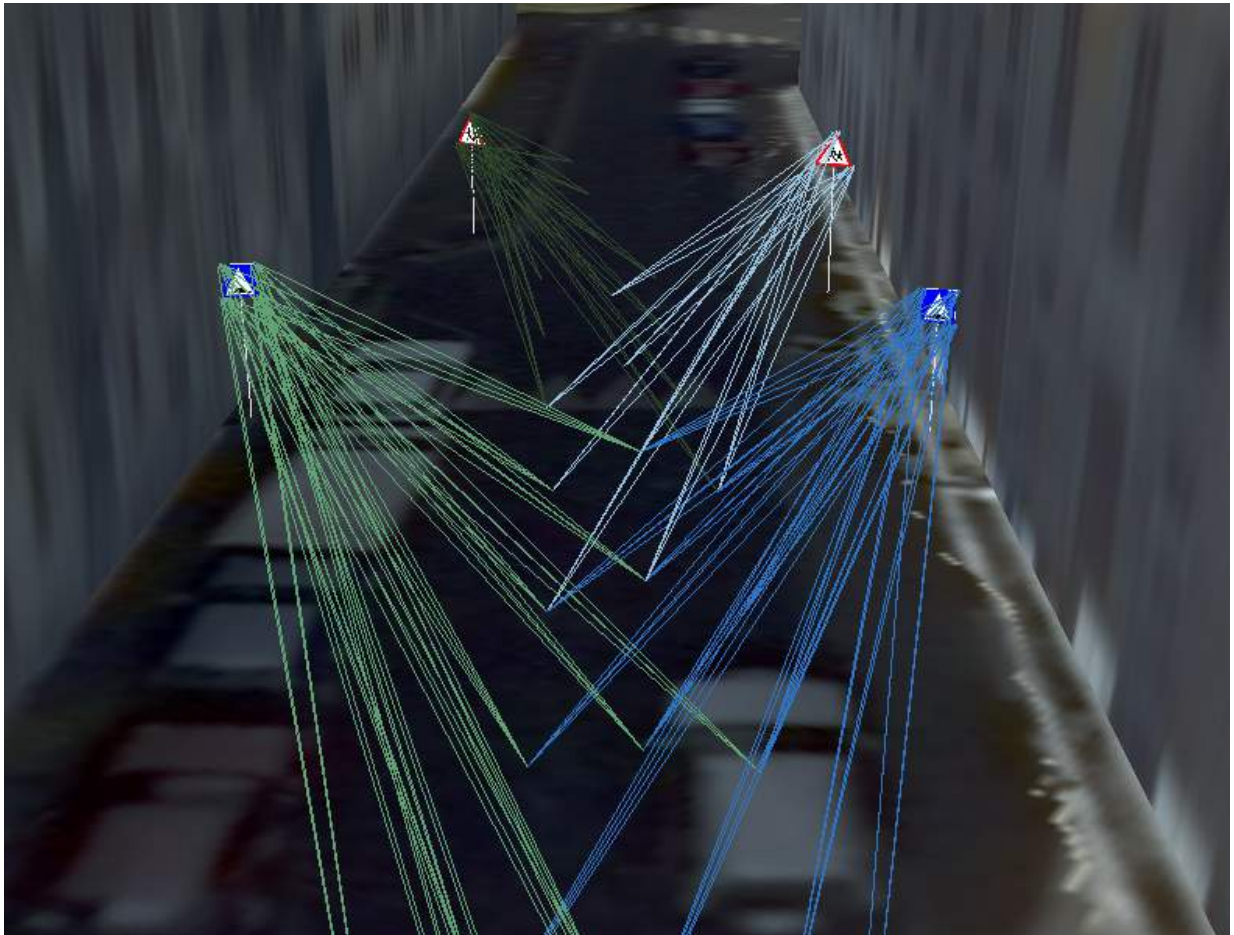
- Compute correlation scores on a voxel grid
- Find a smooth surface that passes through maximum correlation voxels



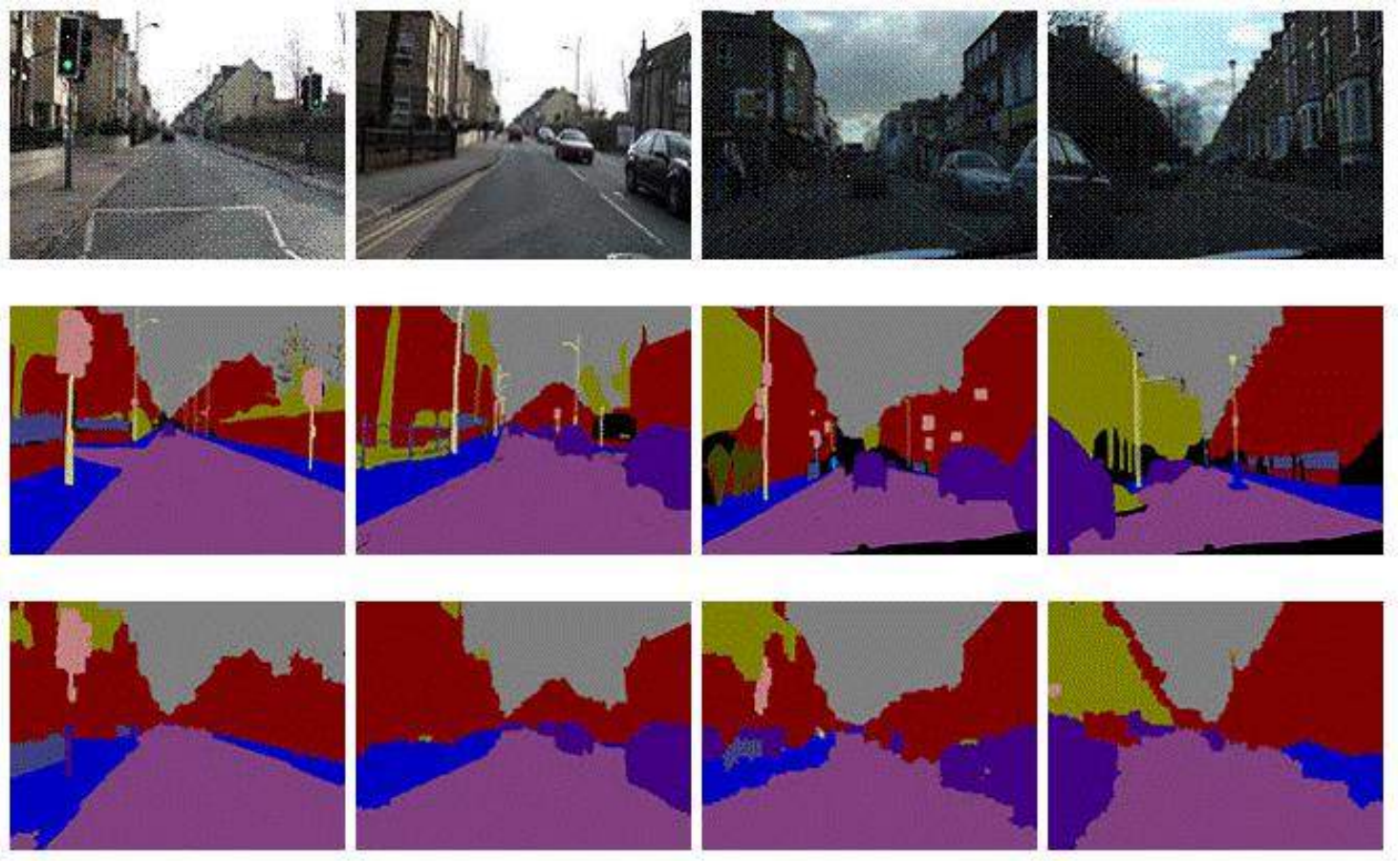
Scene analysis and reconstruction

Object detection

3D objects reconstruction

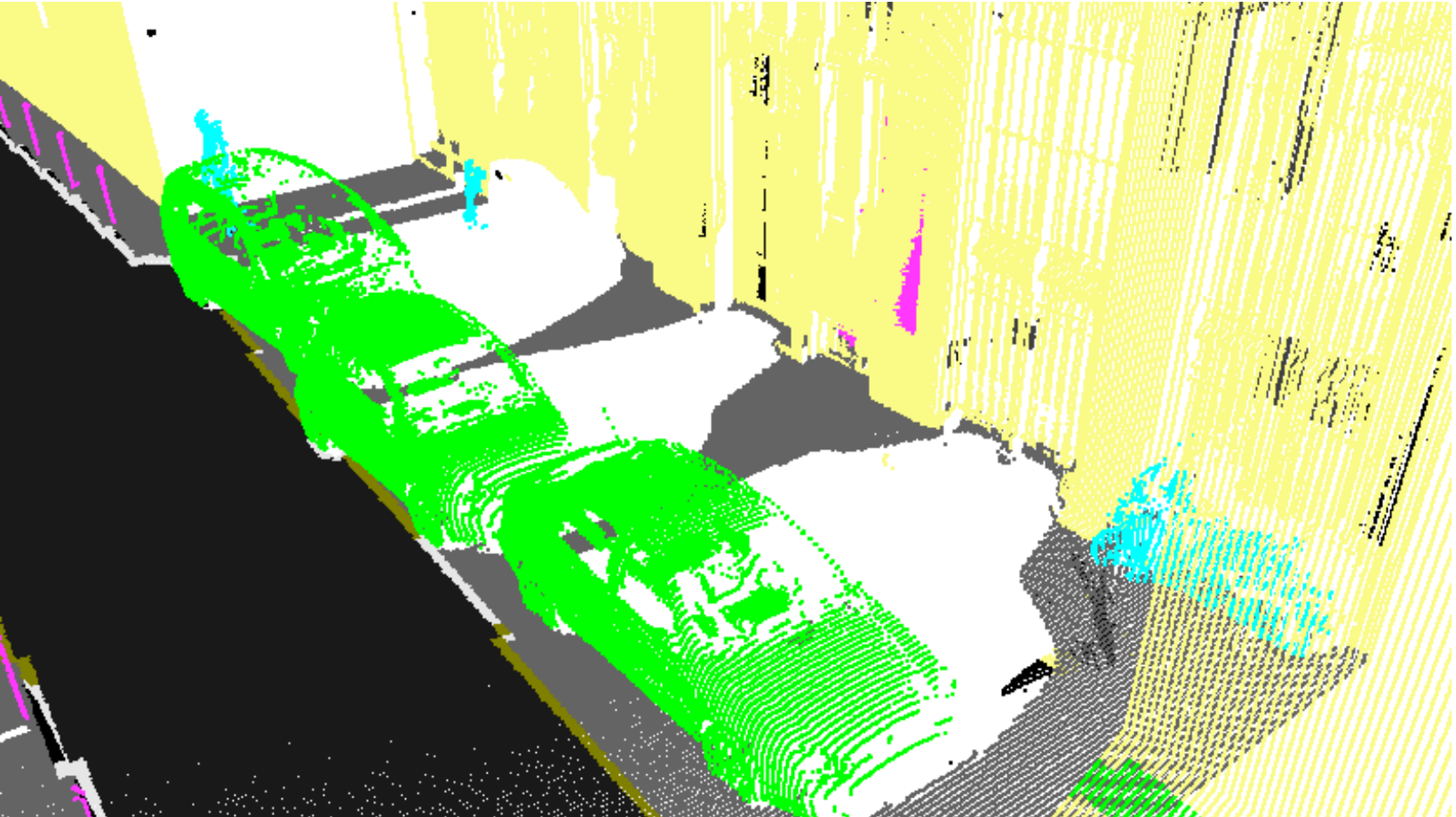


Semantic analysis of images



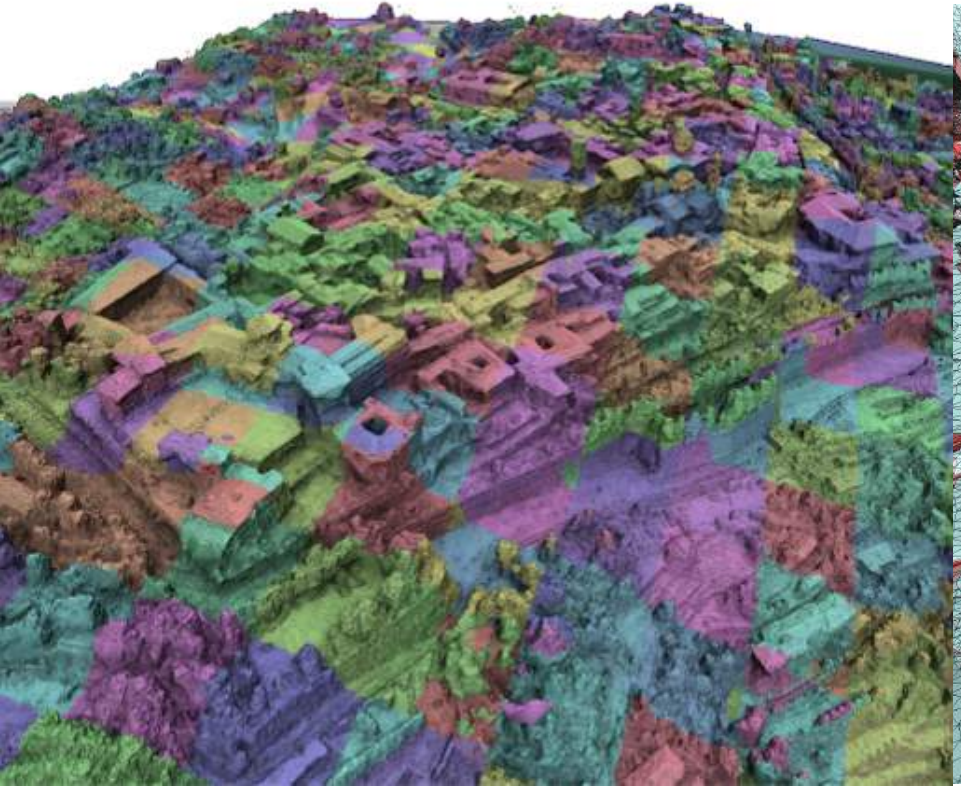
- Road
- Sky
- Tree
- Sidewalk
- Car
- Pole

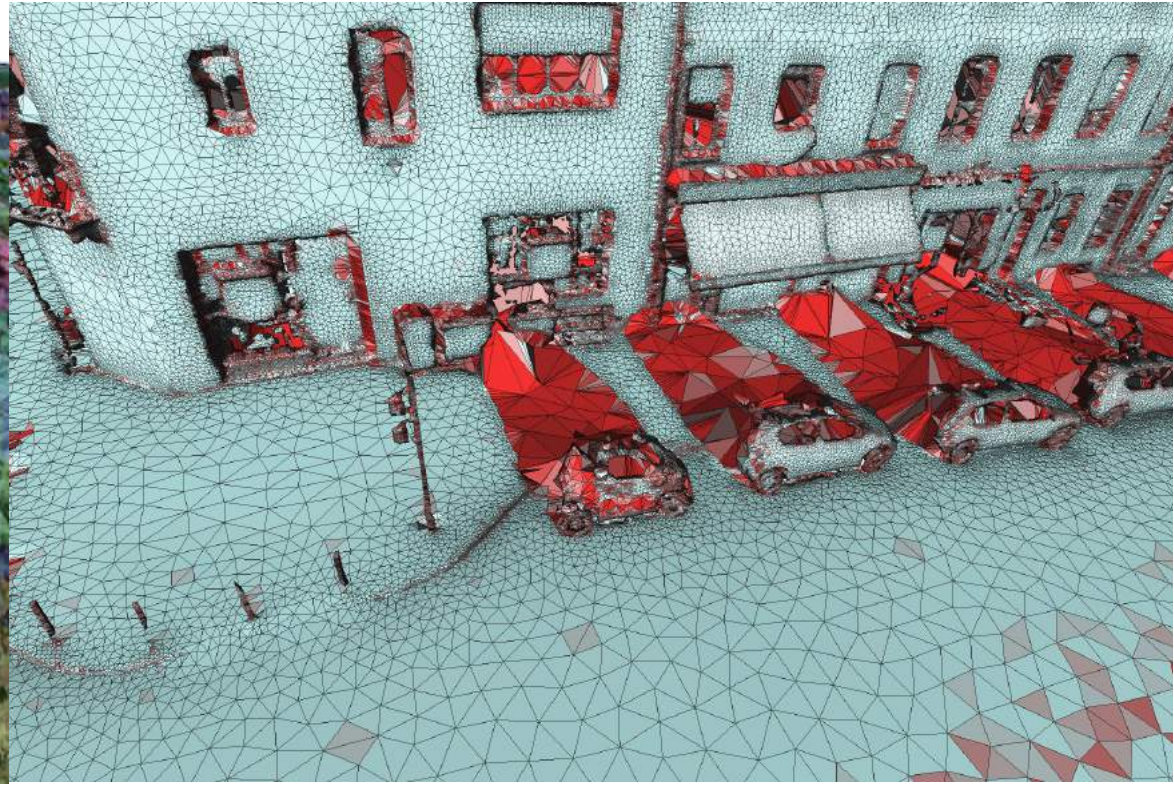
Semantic analysis of Lidar



- Road
- Sidewalk
- Building
- Pole
- Car
- 2 wheeler

Surface reconstruction



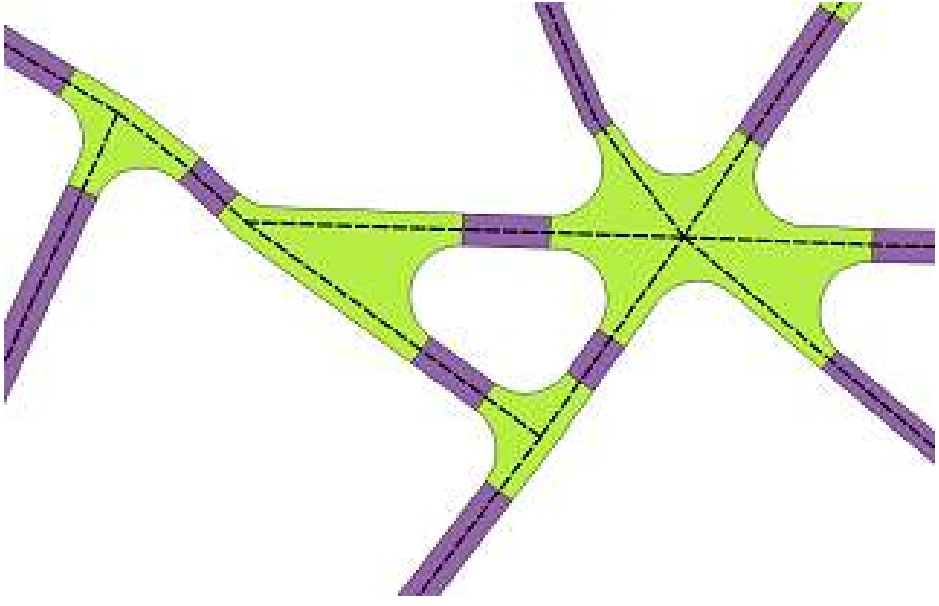


Structured reconstruction

- Navigability arrangement

Structured reconstruction

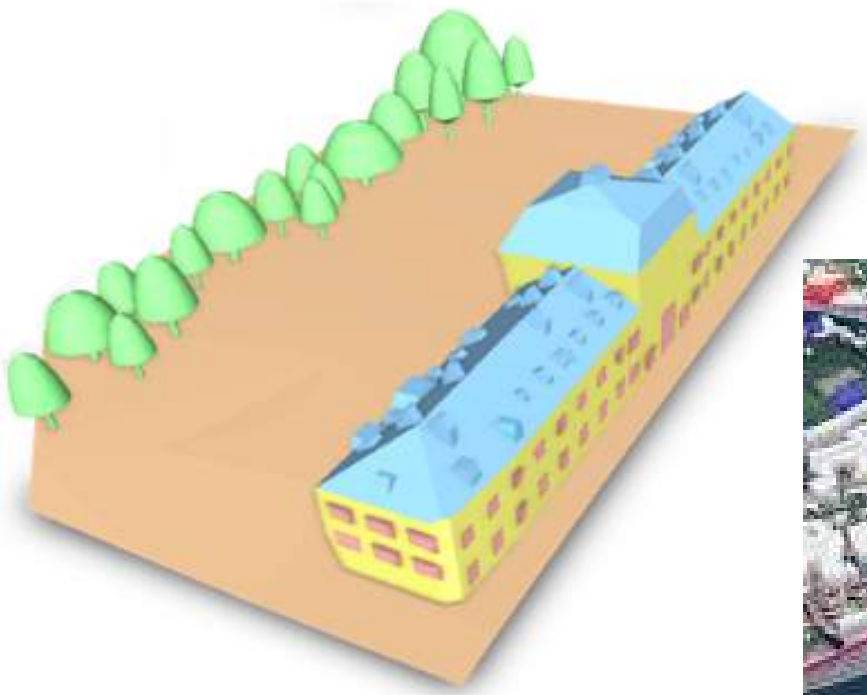
- Navigability arrangement



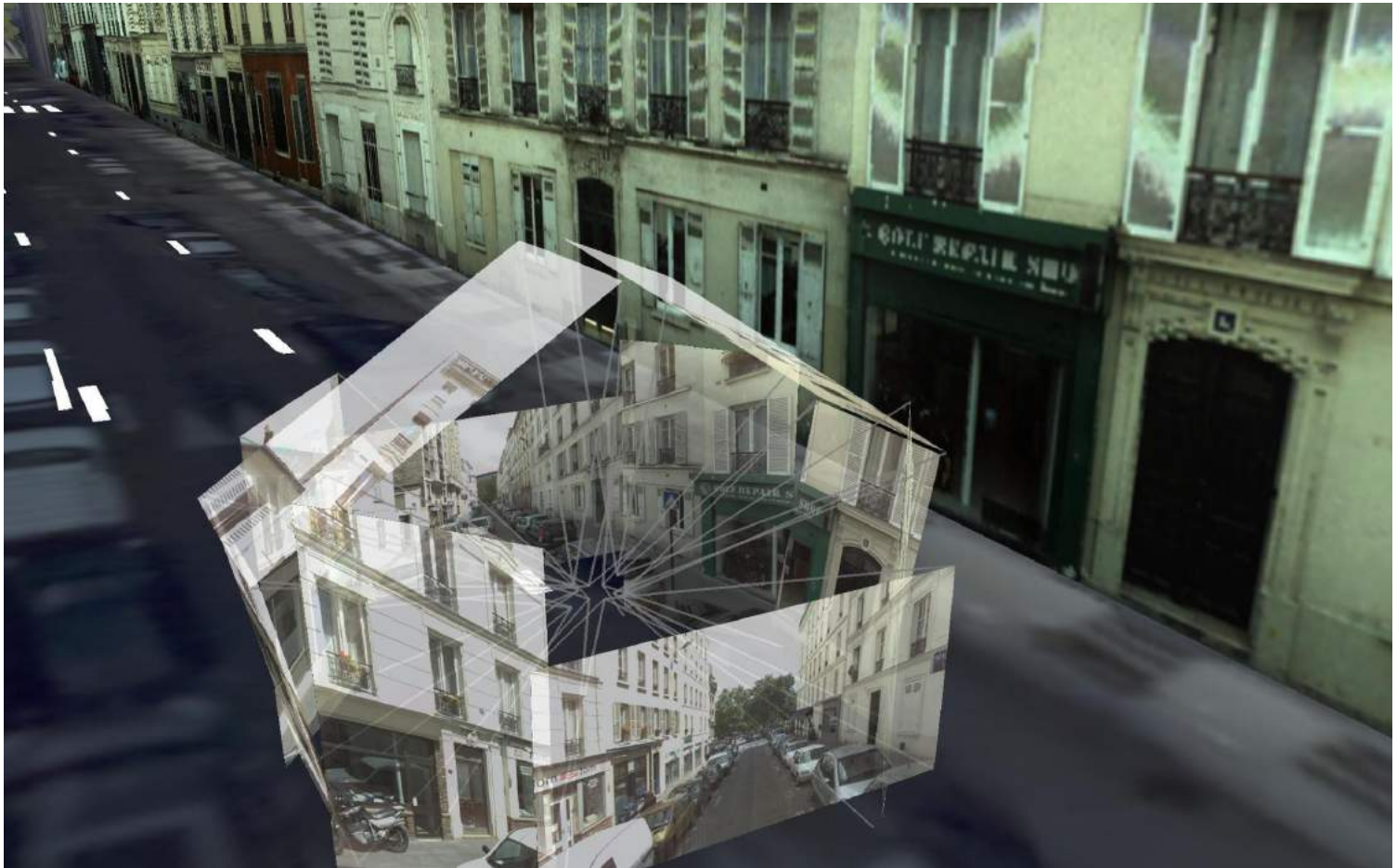
Structured reconstruction : buildings

2 approaches :

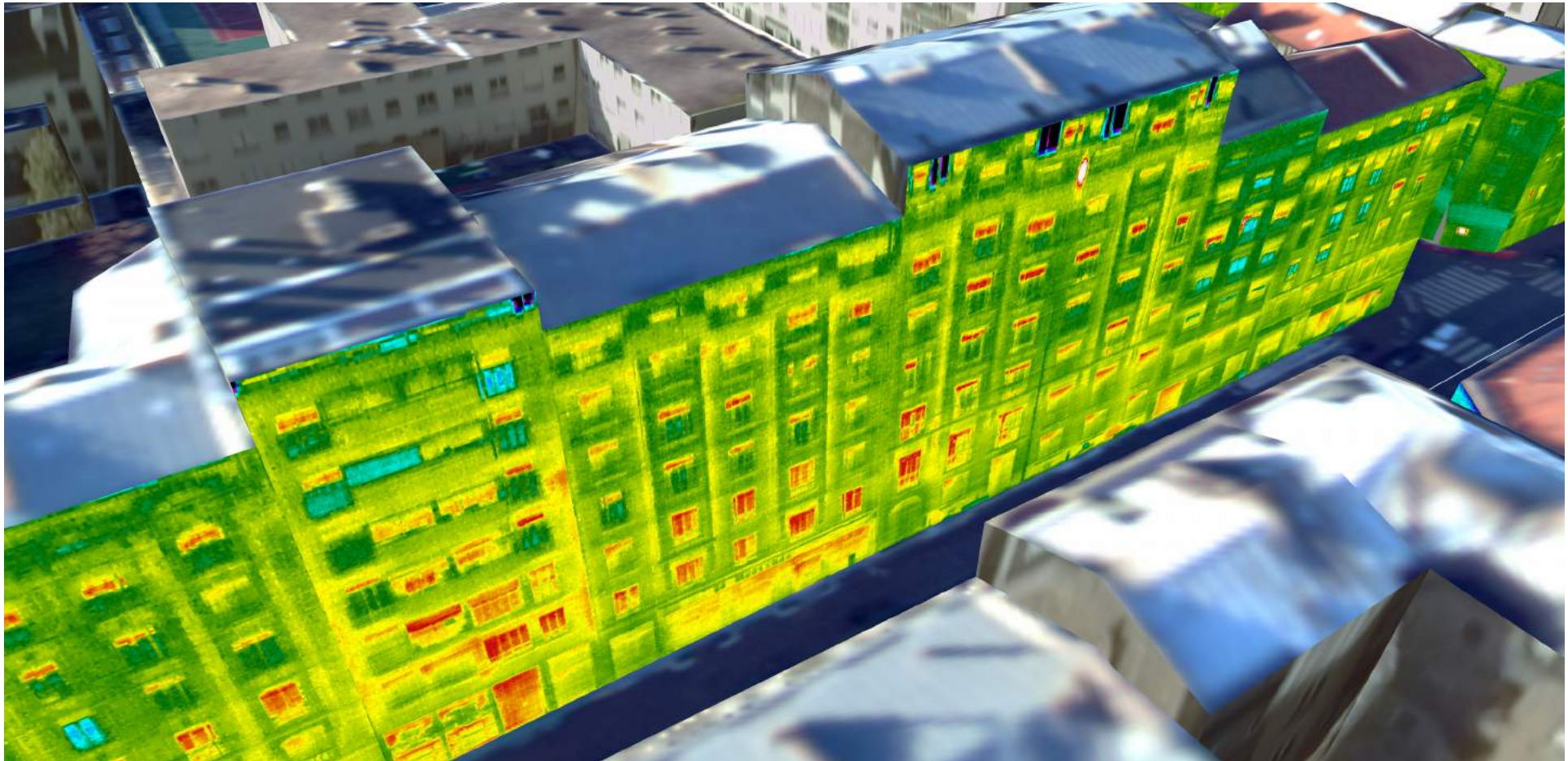
- Bottom up :
  - Find parts
  - Aggregate them
- Top down :
  - Fit models from a library



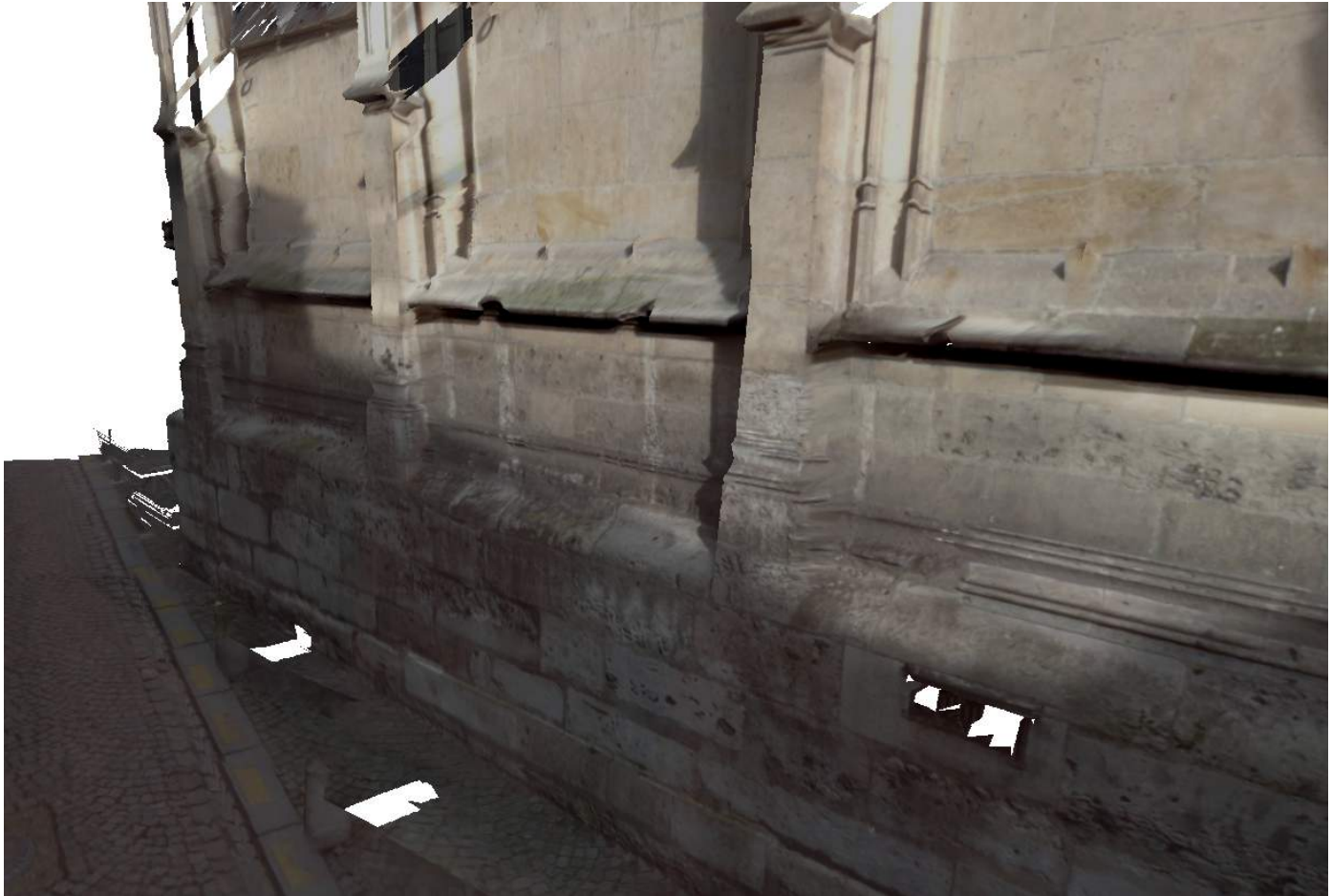
Texturing



Texturing

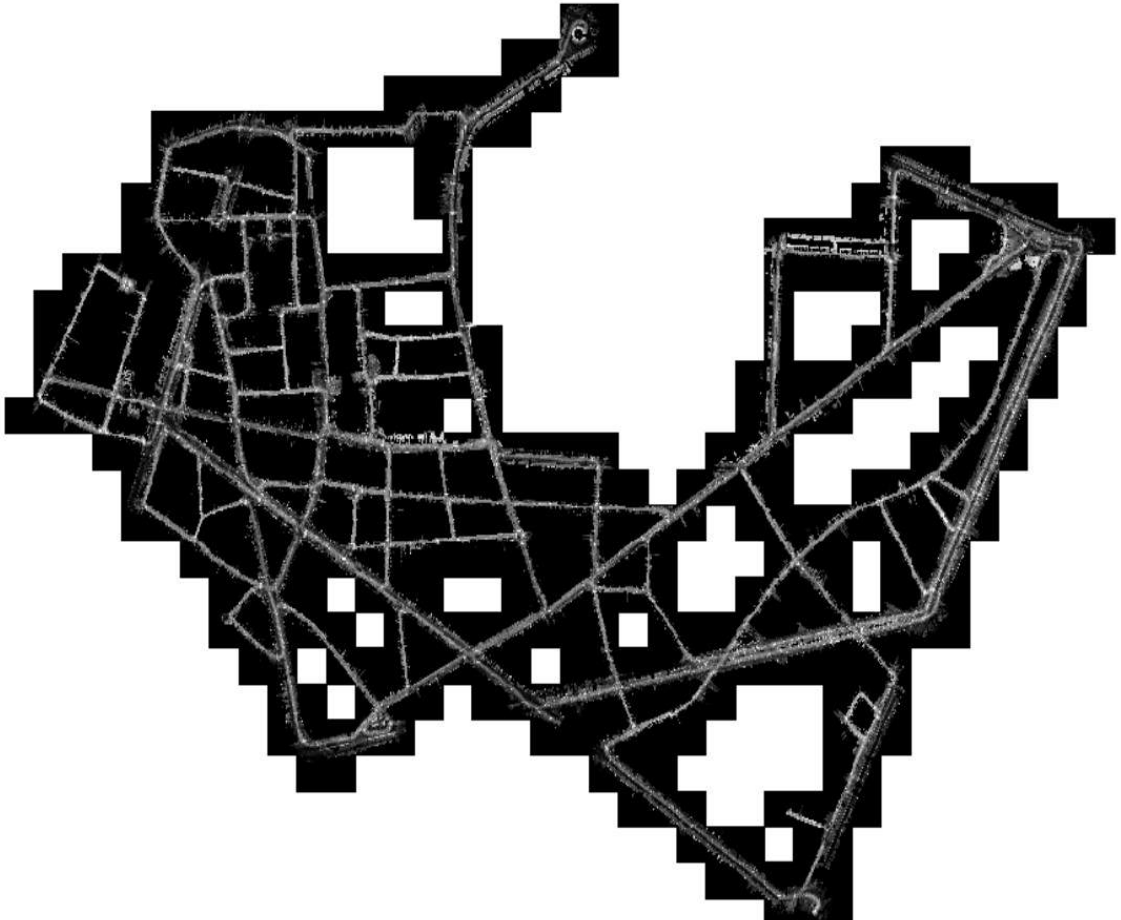


Texturing



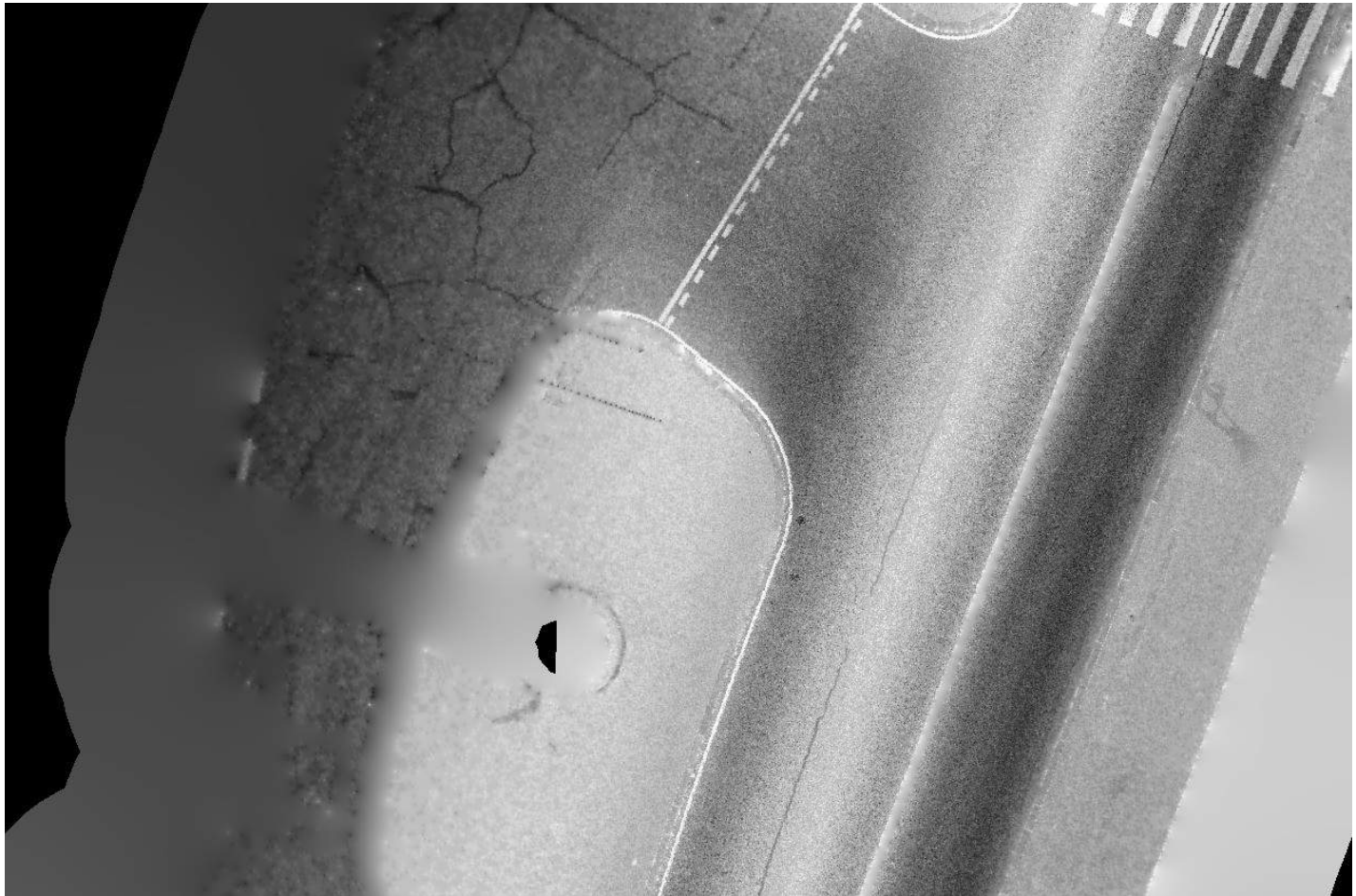
Texturing

Lidar Ortho/DEM

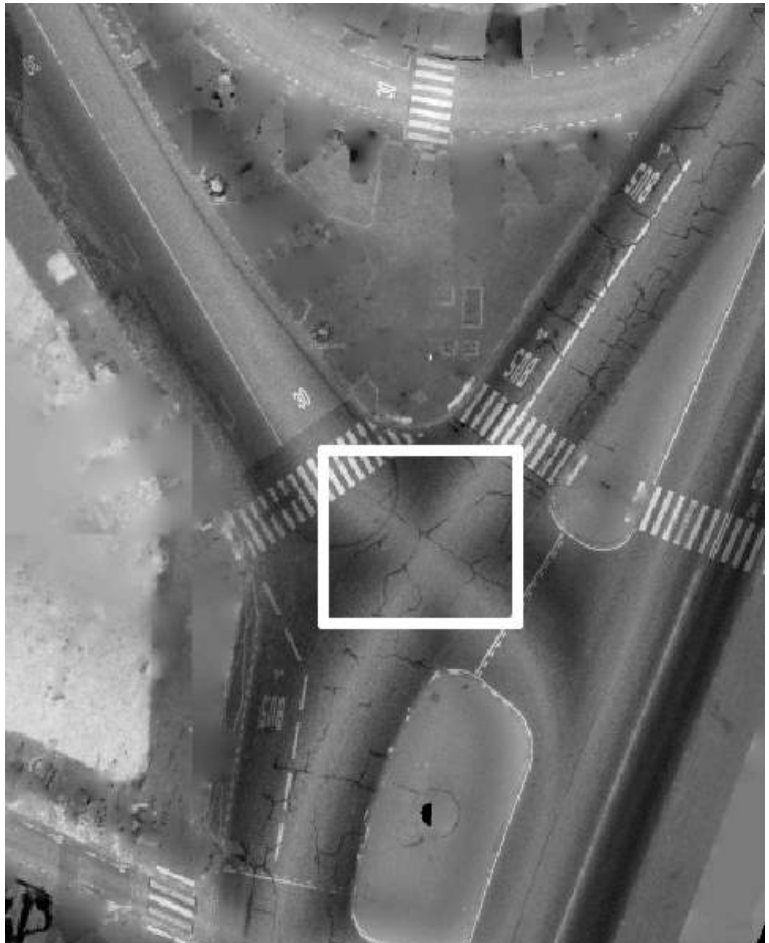


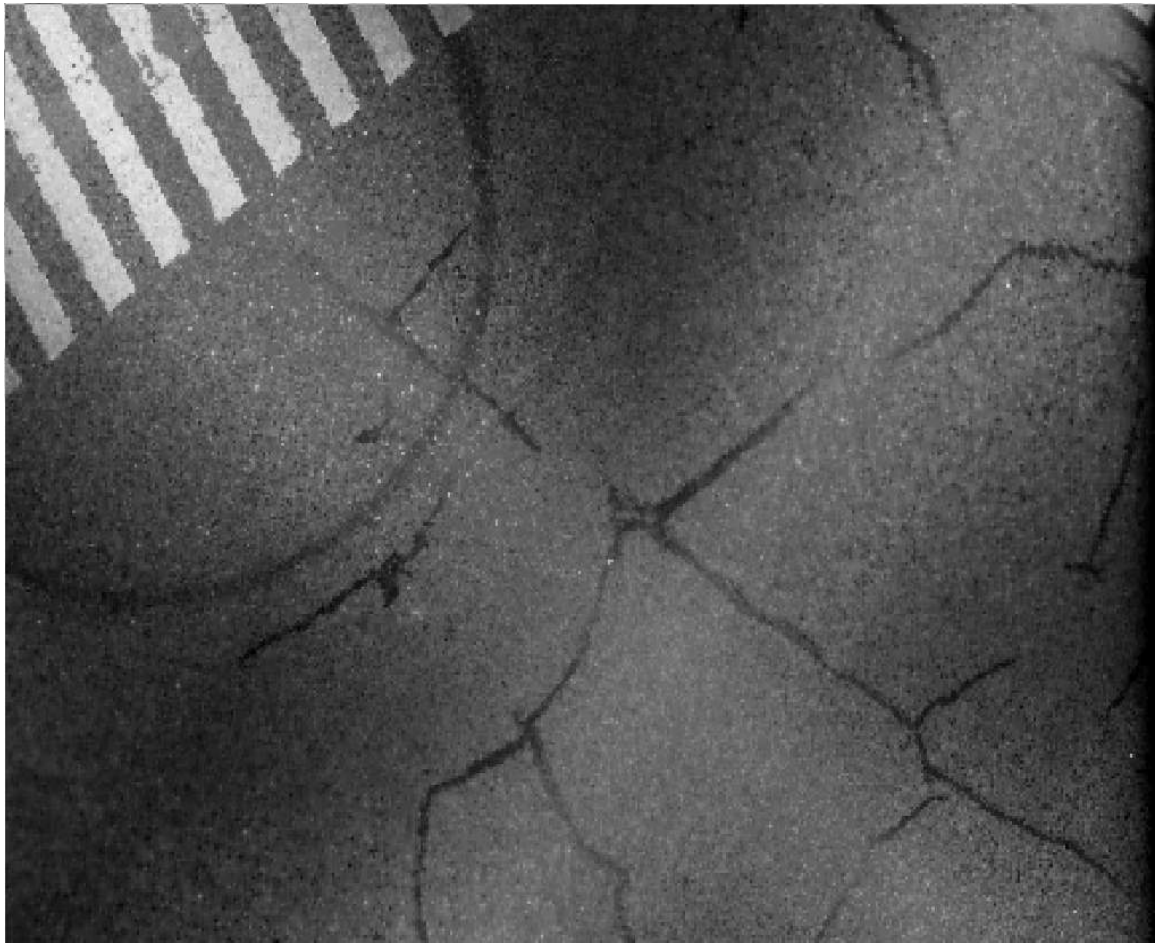
Lidar Ortho/DEM : projection

Lidar Ortho/MNE : interpolation



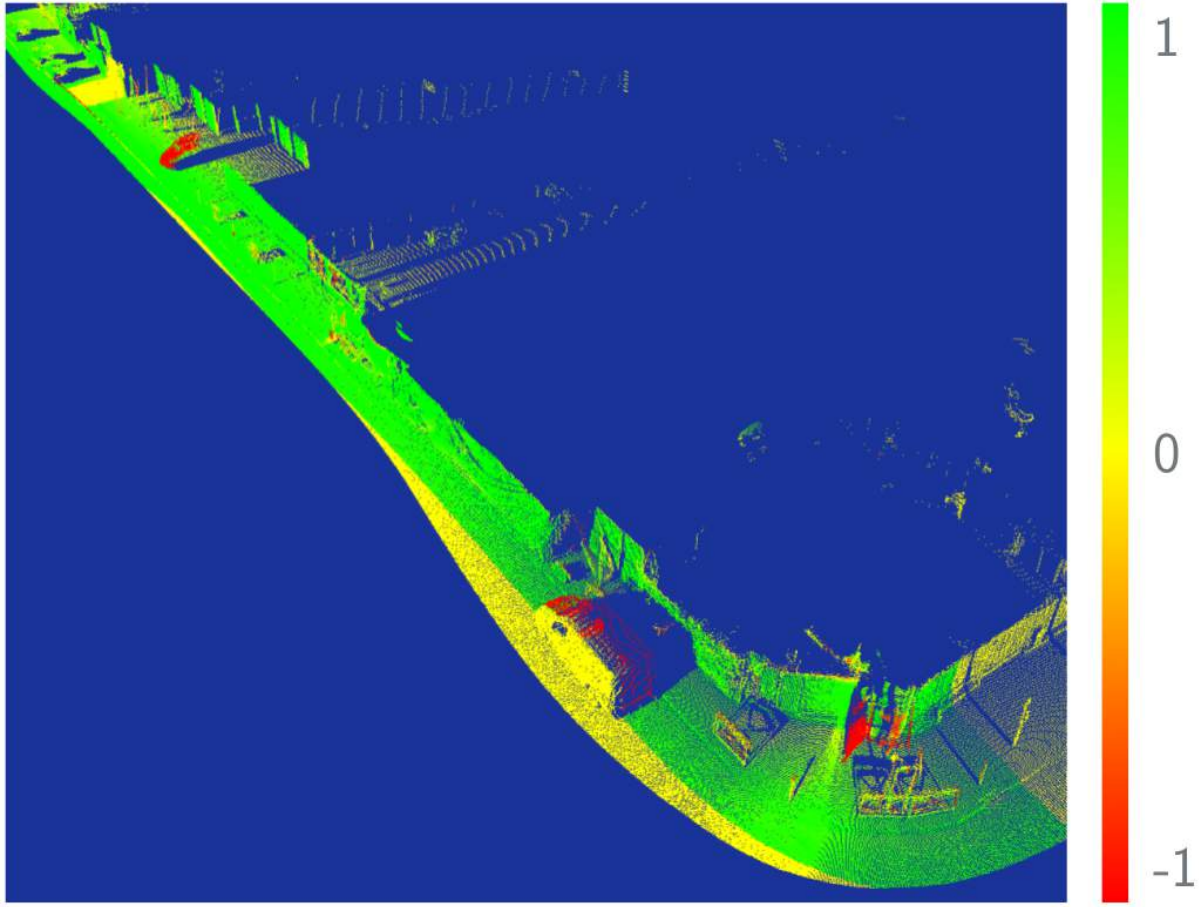
Lidar Ortho/DEM : blending



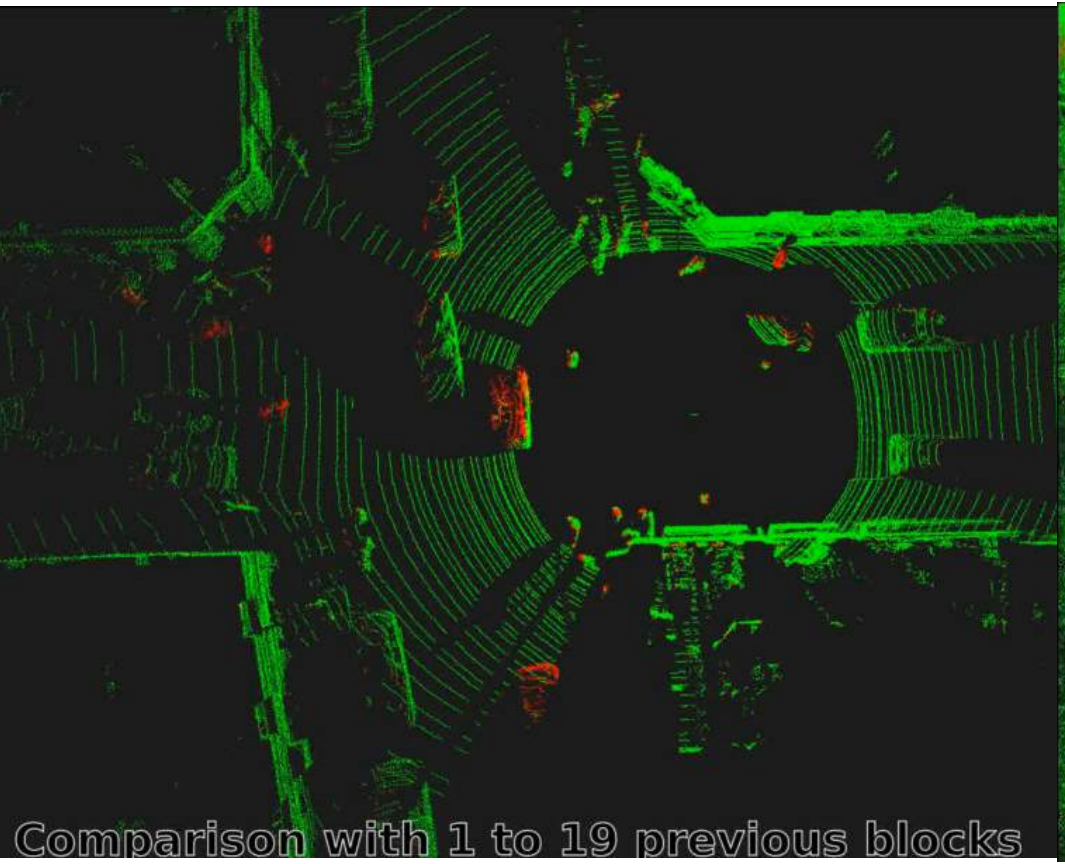


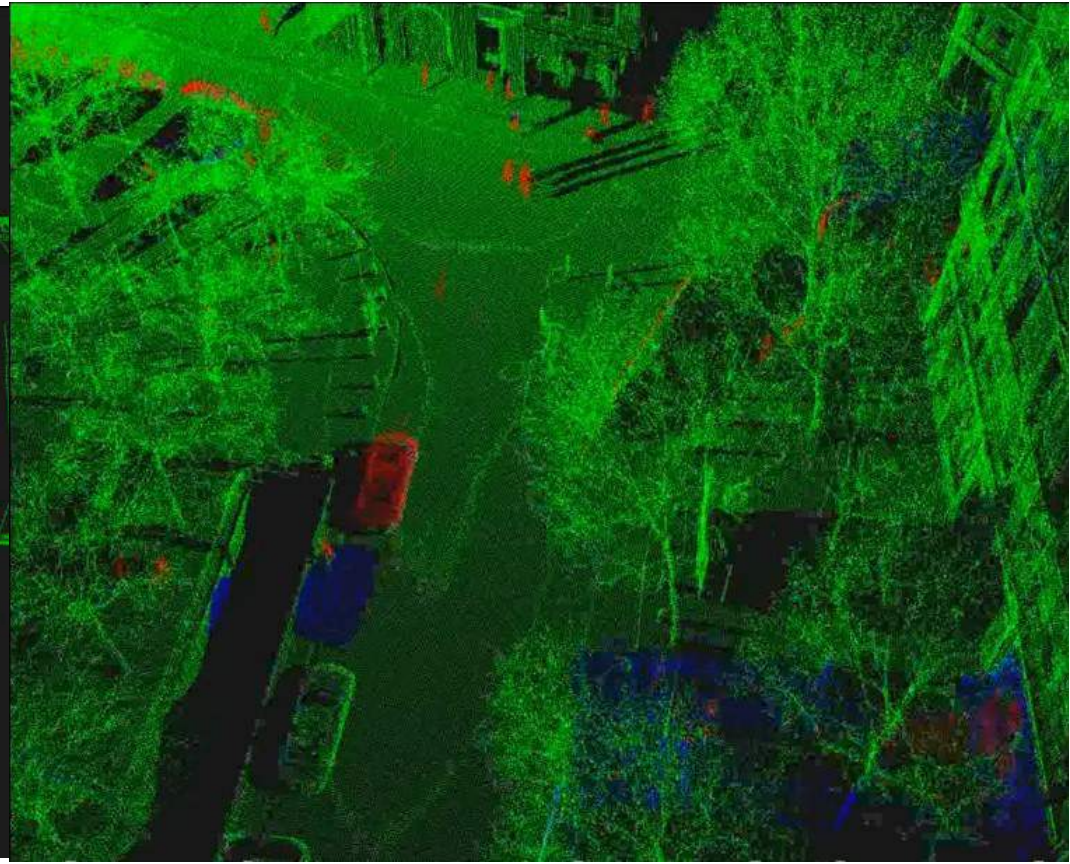
Lidar Ortho/DEM : result

Change detection

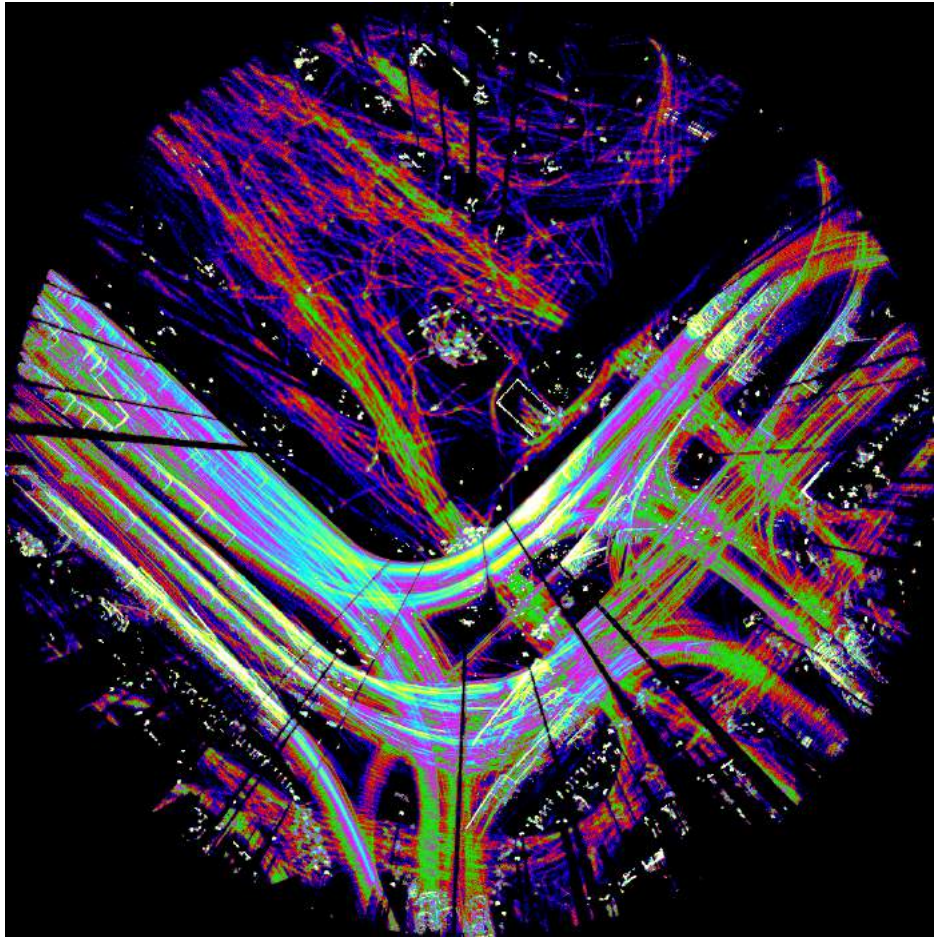


Change detection





Flow mapping

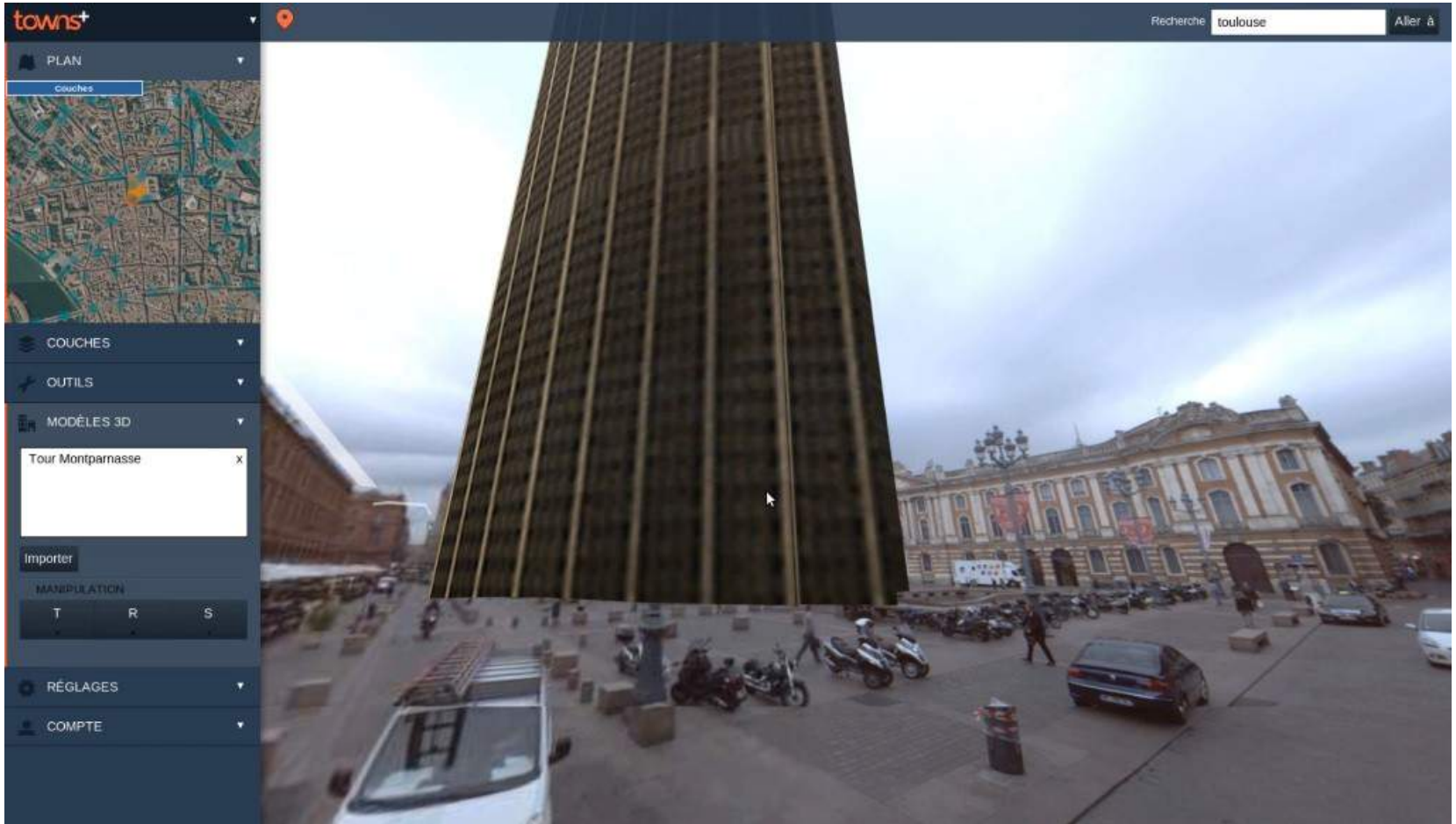


Applications

Urban planning

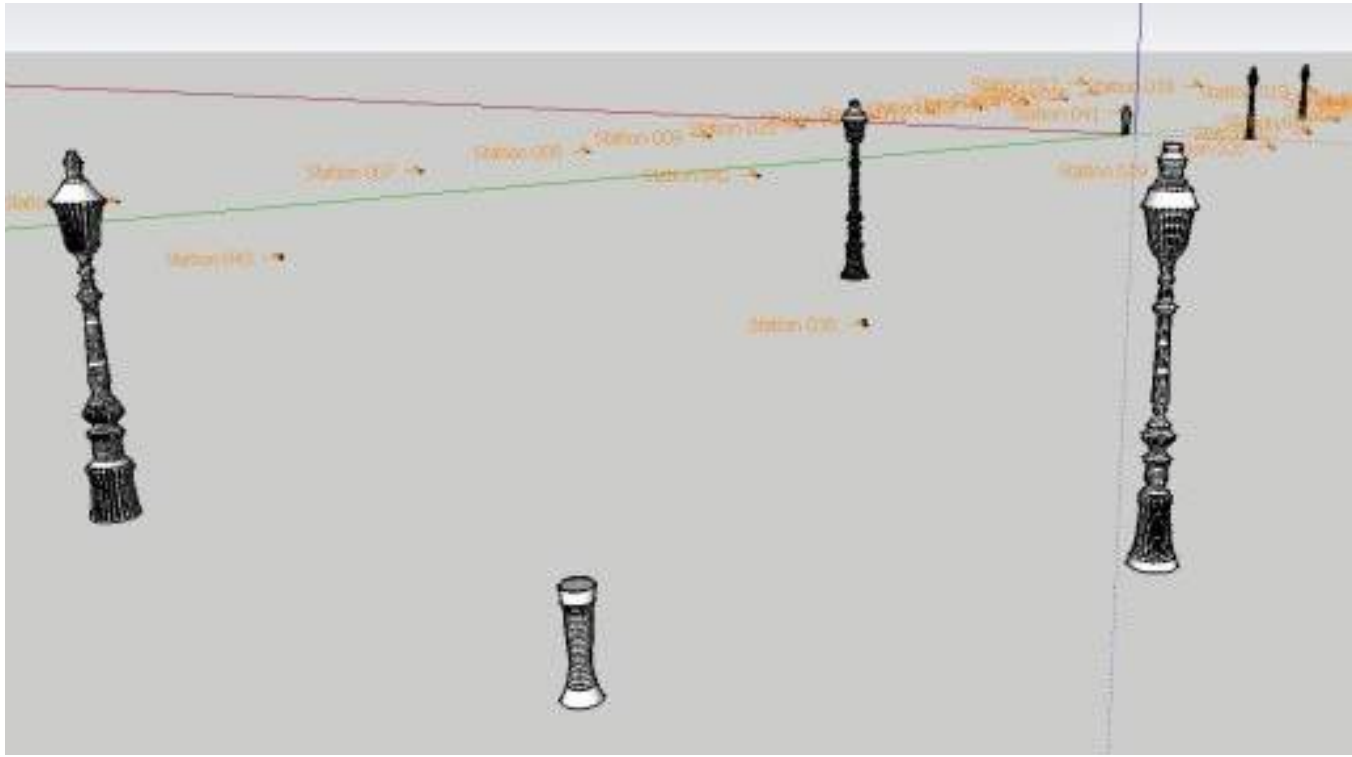
- Urban planning requires
  - **Precise knowledge of a territory**
  - **Visualizing the impact of a project on the territory**

Urban planning



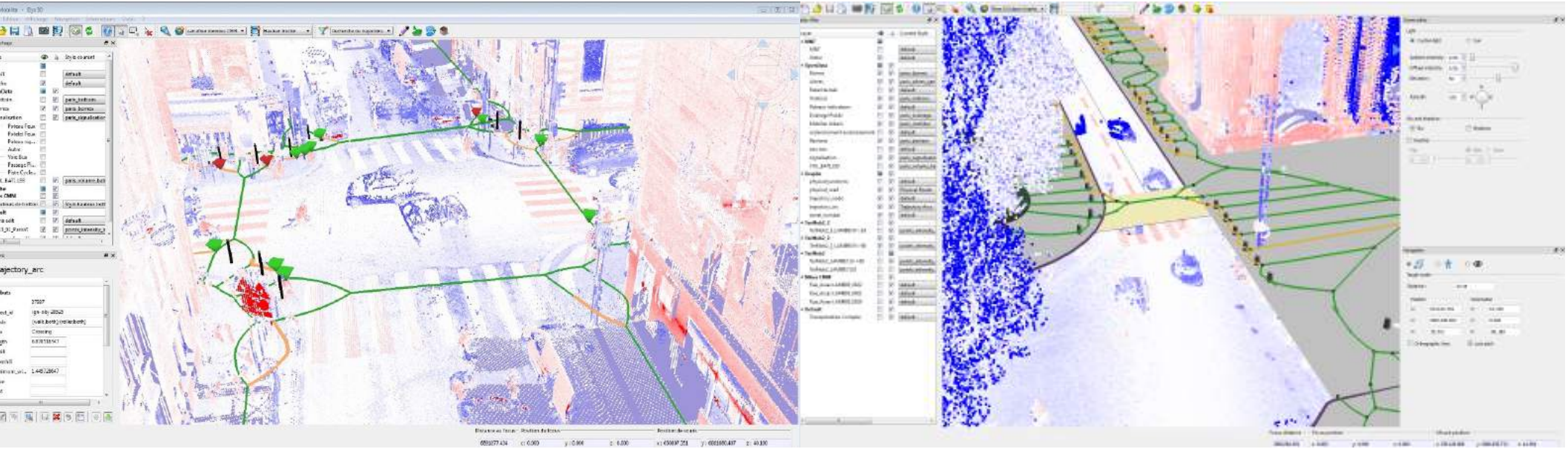
Inventory

- City management requires an inventory of many types of urban objects :
  - **Road and sidewalk : surface degradation**
  - **Urban furniture : diagnostic for replacement/reparation**
  - **Road signs/marks for renovation and modification**



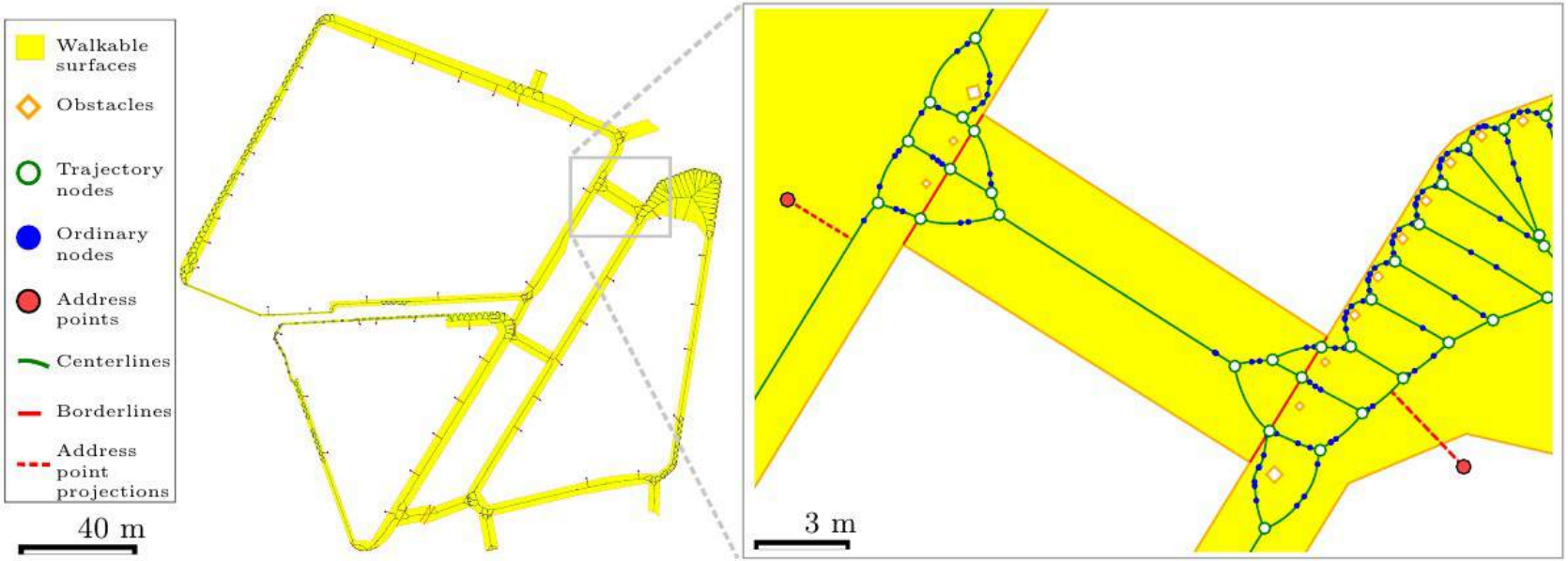
Itinerary computation

- Itinerary computation requires a navigability graph



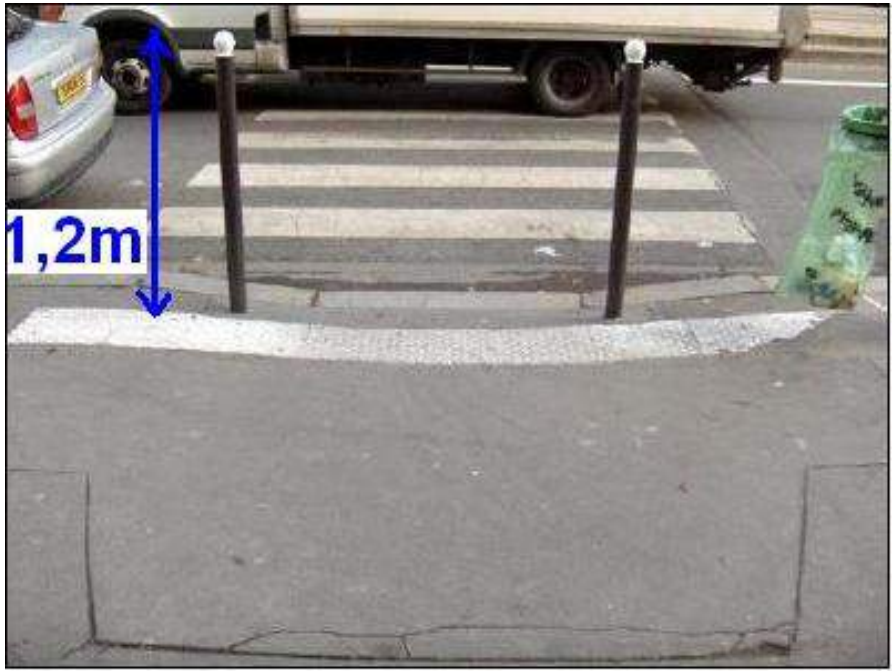
Itinerary computation

- Itinerary computation requires a navigability graph

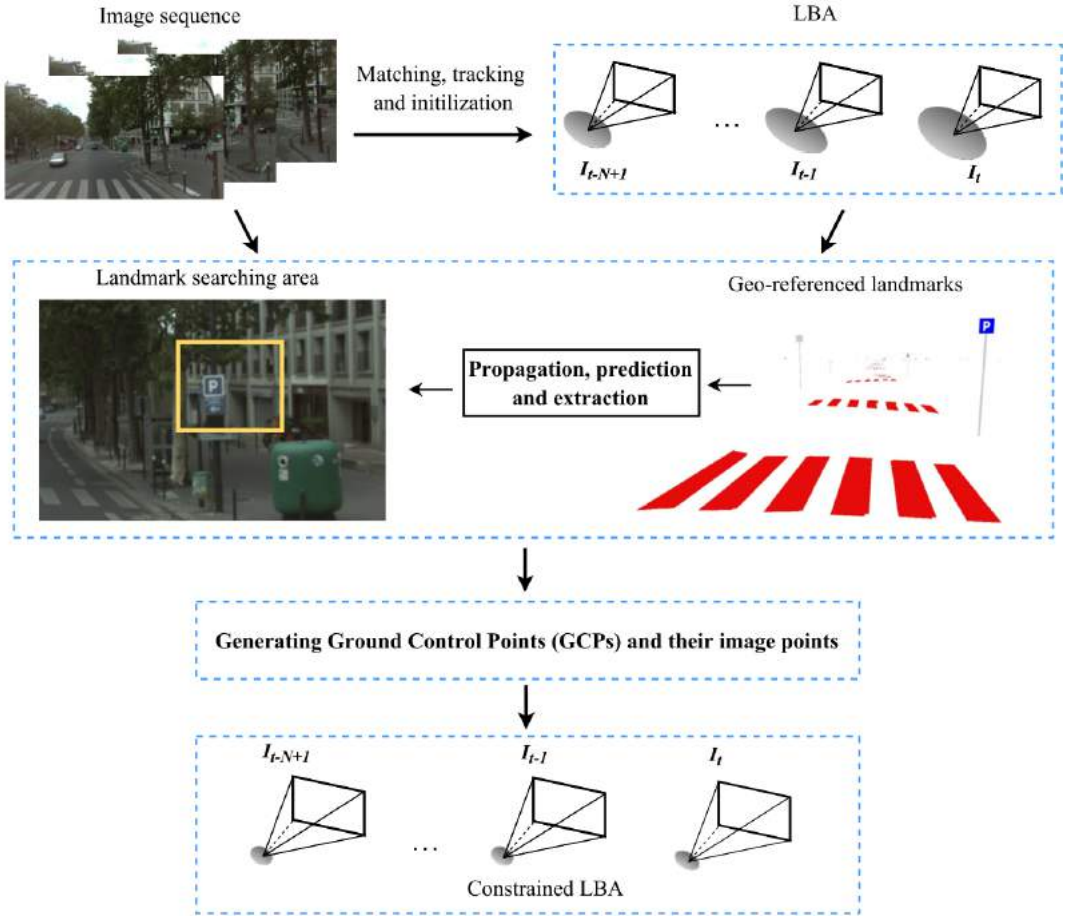


Accessibility diagnostic

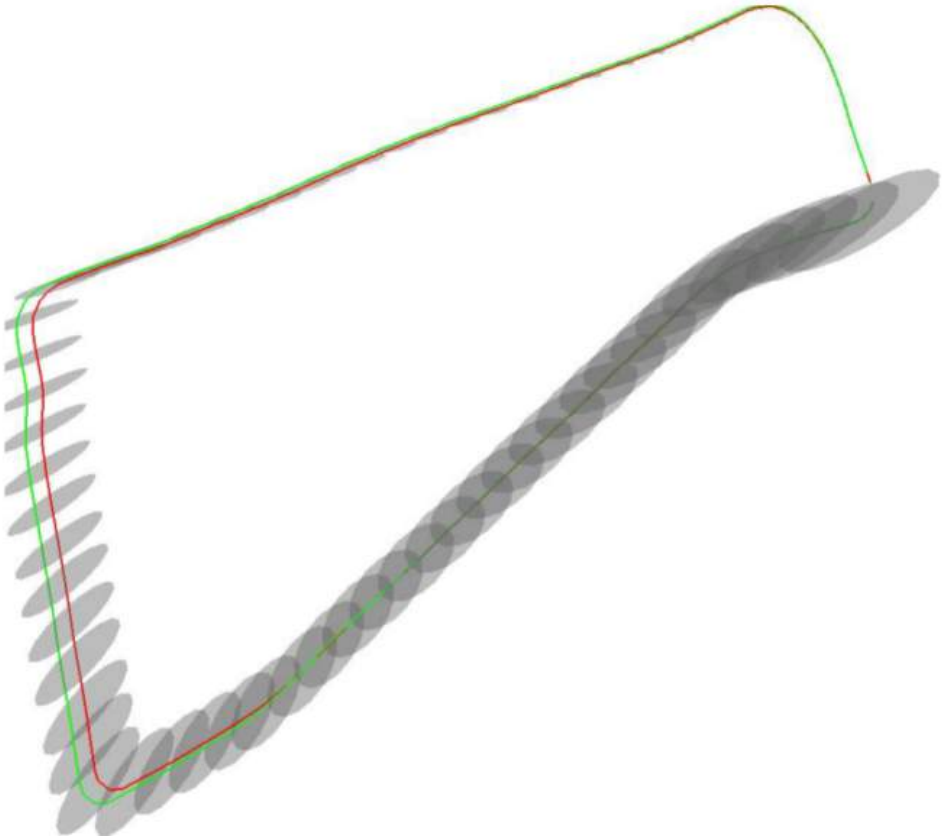
- Accessibility for wheelchairs can be assessed based on
  - **Minimum width along a path / Curb heights / Slopes**



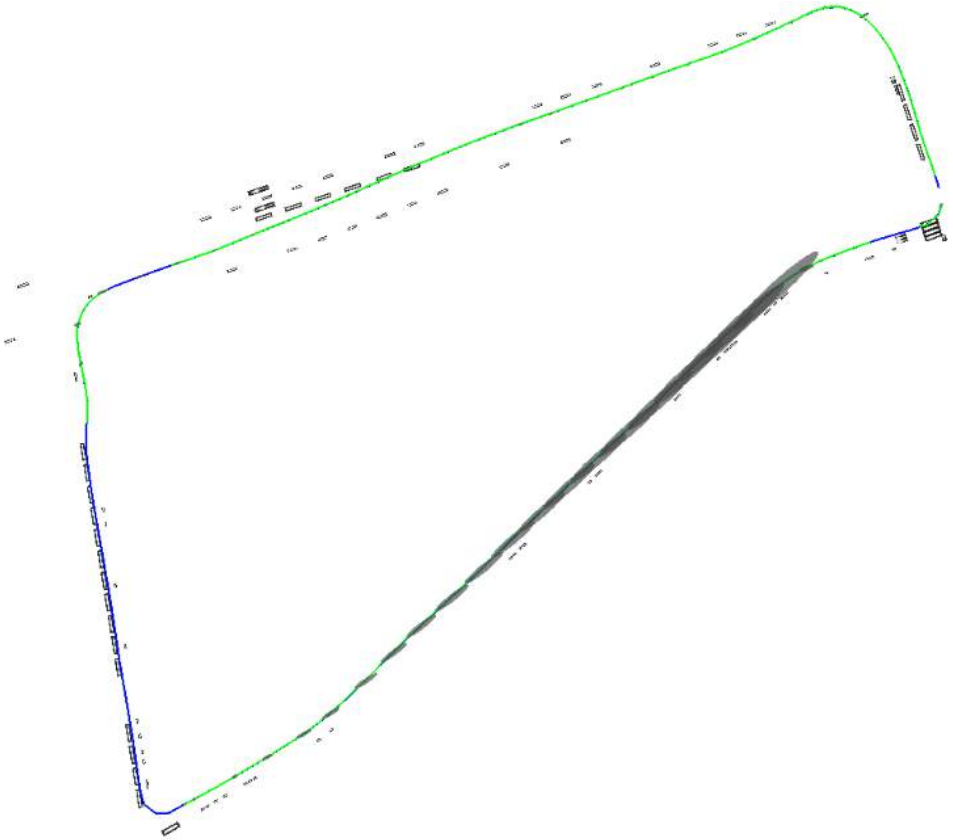
Landmarks based localization



Landmarks based localization



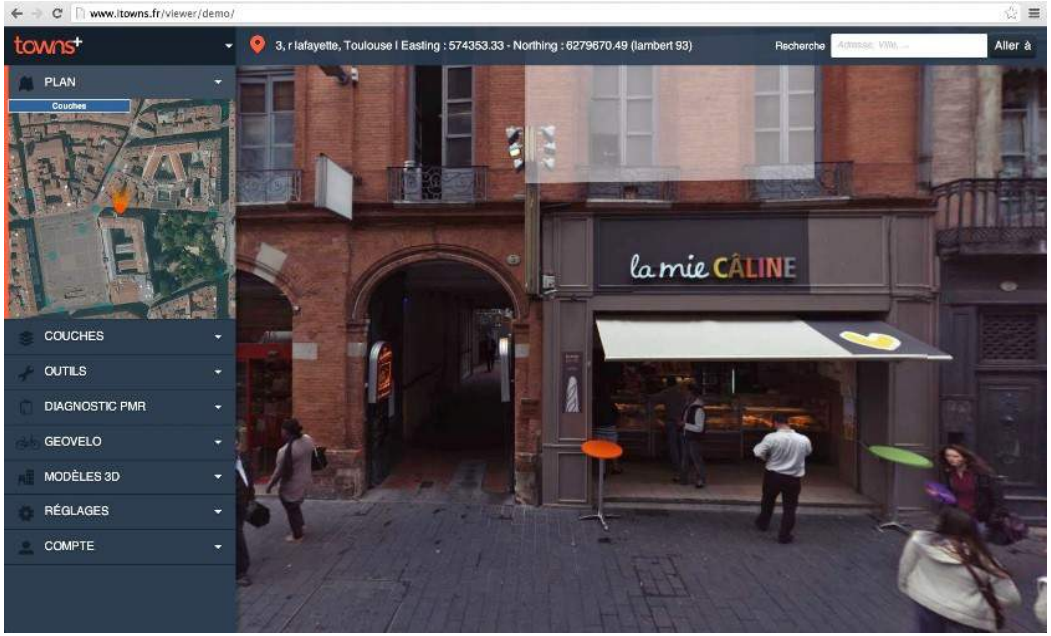
Mono camera + LBA



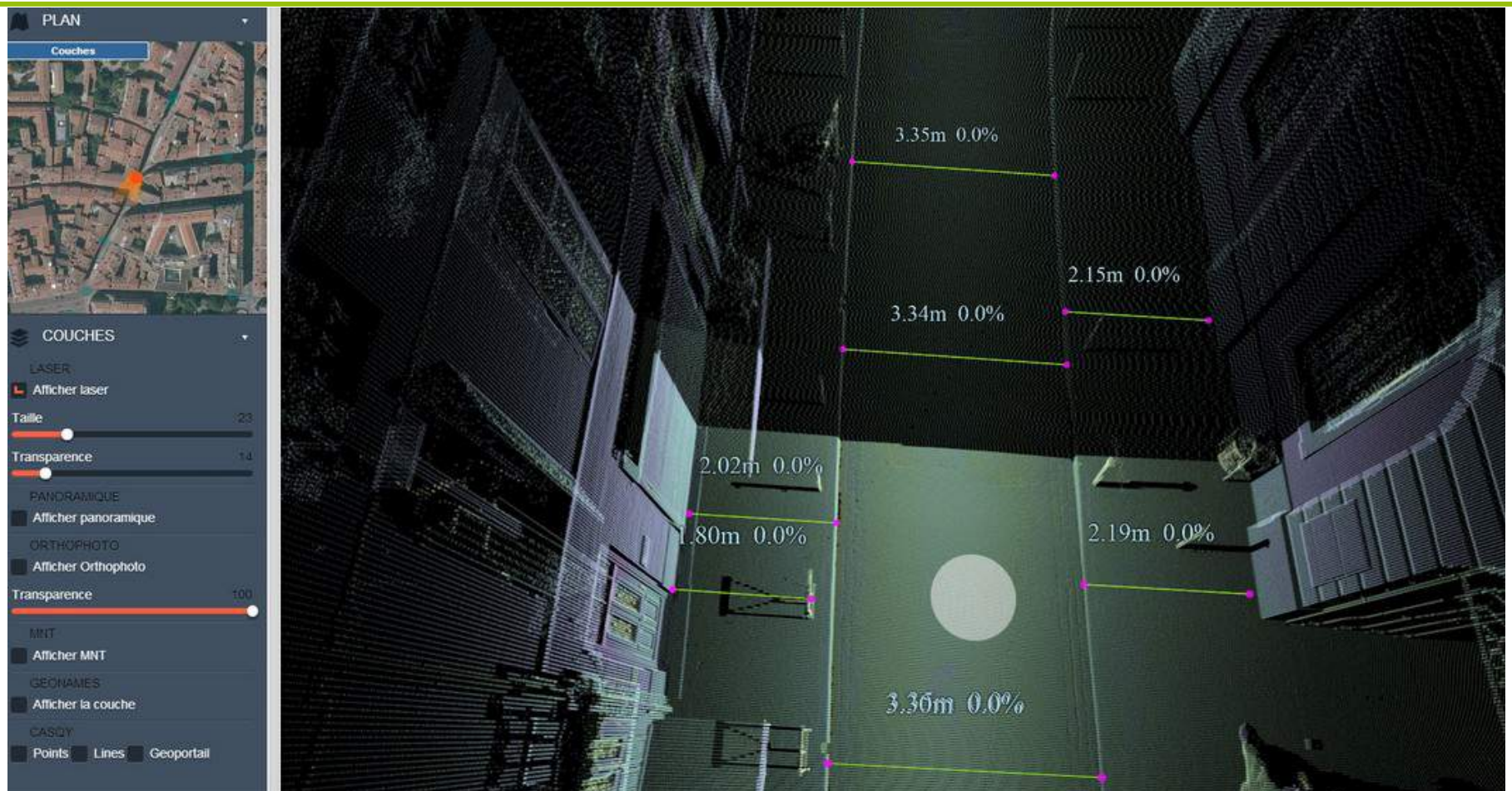
Mono camera + LBA + landmarks

Surveying « in the office »

- Accurate georeferenced data allows for field surveying without leaving the office : Productivity increase / Cost decrease



Surveying « in the office »



Surveying « in the office »

Simulation

- Simulation resluts quality depends on model quality:
  - Trafic : lanes separation, directions and widths, connexions at cross roads, ...
  - Noise: Geometric model of the scene and materials
  - Flood: Currently geometric model in 2.5D (Digital Elevation Models) but ideally in 3D to allow modeling bridges and tunnels
  - Wave propagation for mobile phone antennas placement
  - Intervisibility for real estate and security

Communication

Conclusion

Conclusion

- Maturity level :
  - Acquisition is mature but dynamic (new sensors and platforms)
  - Georeferencing : more and more mature but georeferencing accuracy still not well controlled
  - Analysis : Deep Learning allowed for a major improvement making automation possible.
  - Scaling up : Big Data and Cloud technology getting more mature

Conclusion

- Perspectives :
  - Crowdsourcing
  - Map updating from low cost data
  - Uncertainties handling
  - Image/Lidar coupling
  - Semantisation/reconstruction coupling
  - Aerial/terrestrial coupling

Université Gustave Eiffel

ENSG Géomatique
ÉCOLE NATIONALE DES SCIENCES GÉOGRAPHIQUES

IGN
INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

Thank you for your attention

Contact : bruno.vallet@ign.fr