

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

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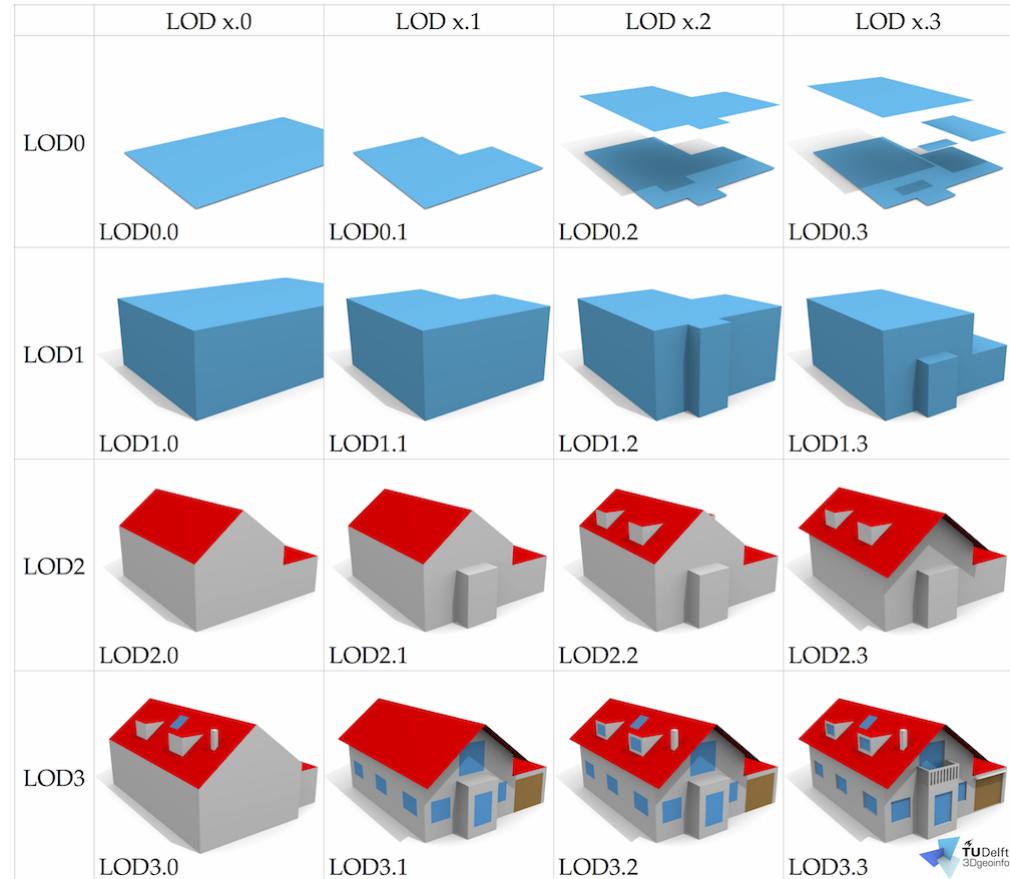
Introduction

Introduction

- What is 3D city modeling ?
 - Creating a faithful digital twin of the city :
 - Accurate : low error between model and reality
 - Relative : accurate 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 : traffic, noise, lighting, pollution, ...
- Communication

Introduction : Challenges

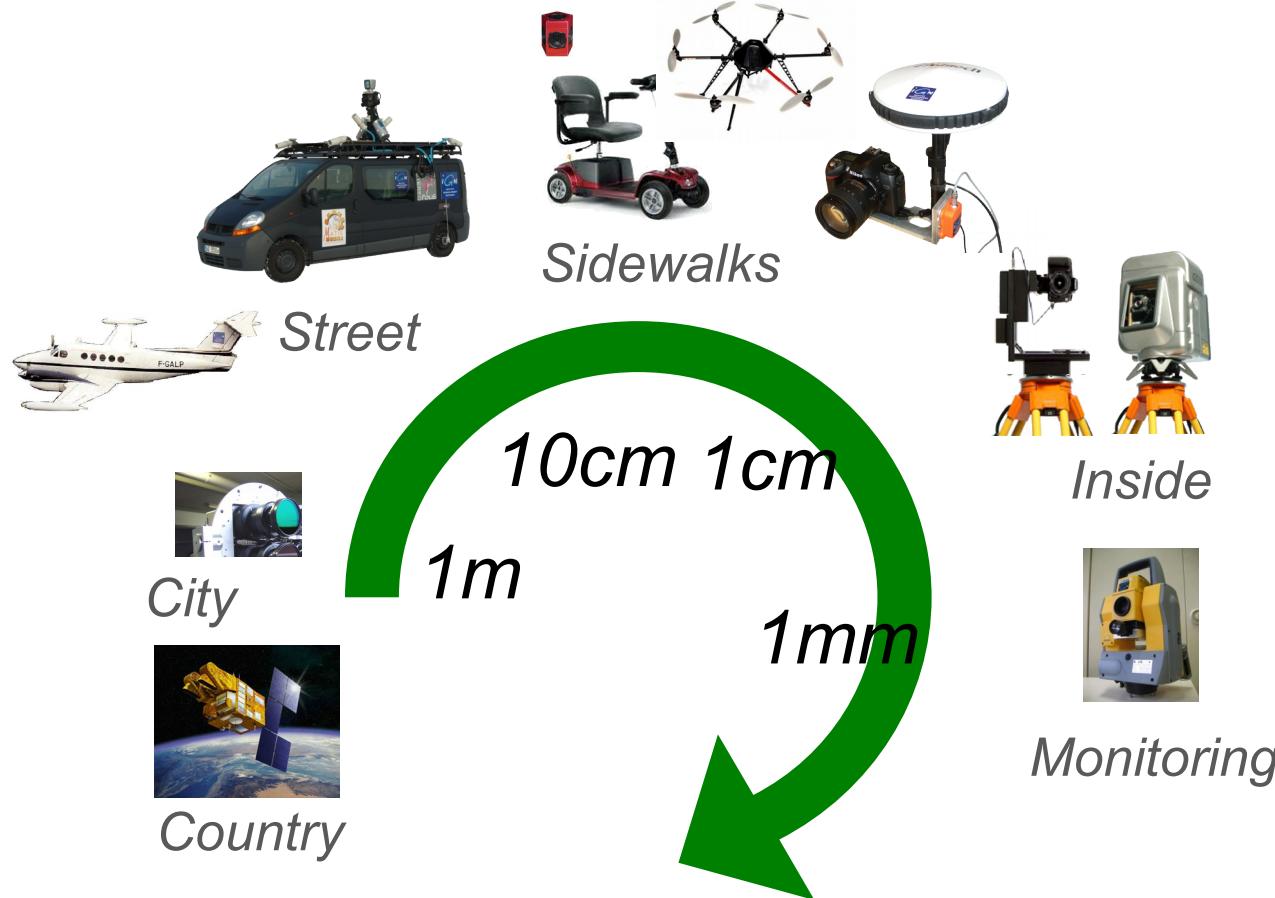
- Big data : Terabytes per km²
- Complexity :
 - Possibly complexe 3D shapes with occultations
 - Mobile and non sustainable objets (detection and filtering)
 - Radiometry (images) : correcting shadows and refletions
- Geolocalisation
 - GPS/GNSS highly unreliable in urban areas:
 - Few visibles satellites
 - 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** : measures a position
 - **Odometre** : measures a distance
- Combined into a platform trajectory



Lidar sensors

- 2 types :
 - Planar Lidar
 - Rotating Lidar



Lidar sensors



Lidar sensors



0dB

-20dB

Lidar sensors

- Rotating angular sector (~10Hz)



Lidar sensors

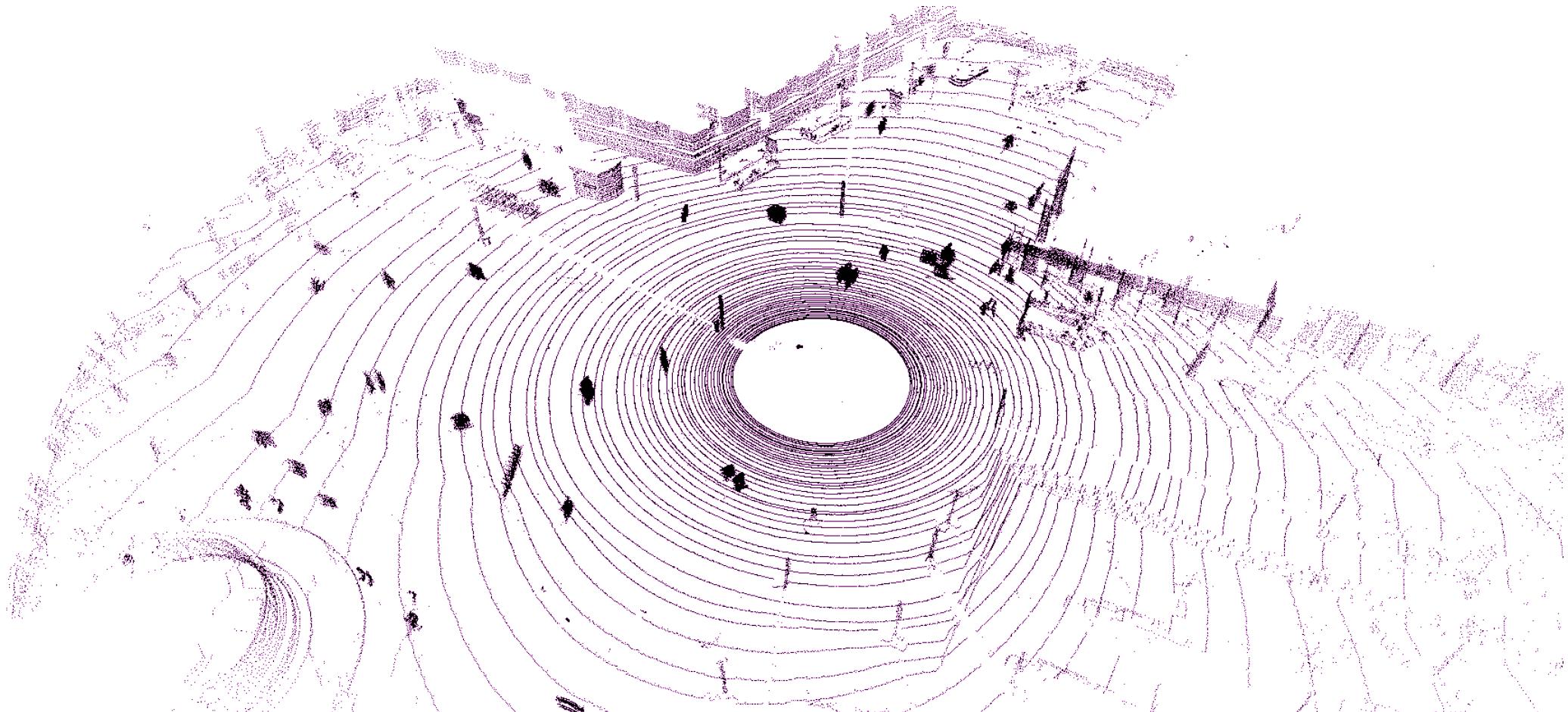


Image sensors

- Panoramic and stereo (front and rear)



Image sensors



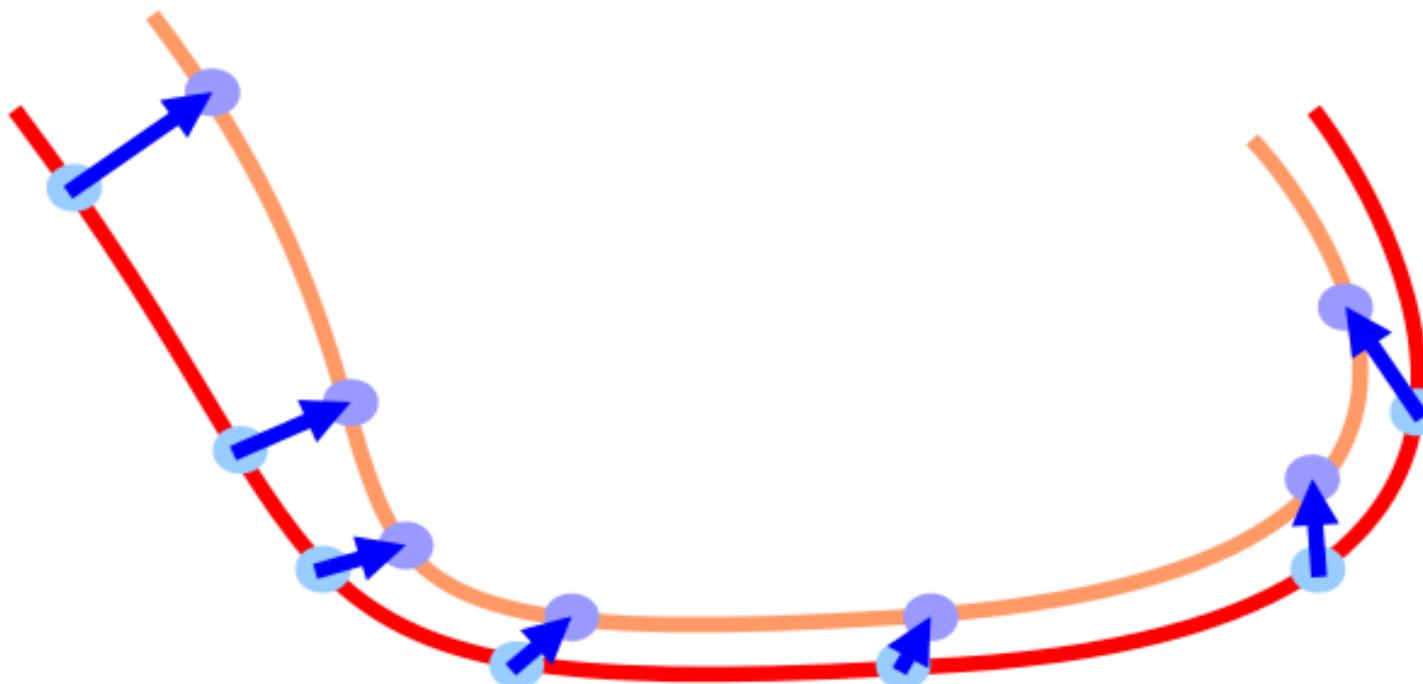
Image sensors



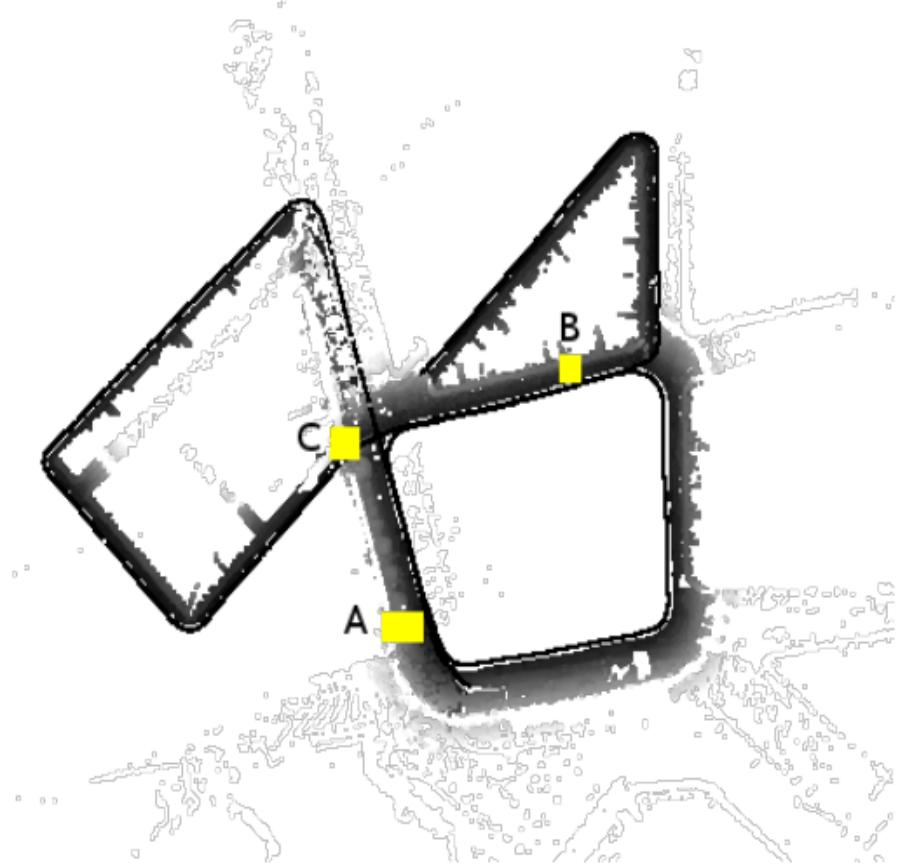
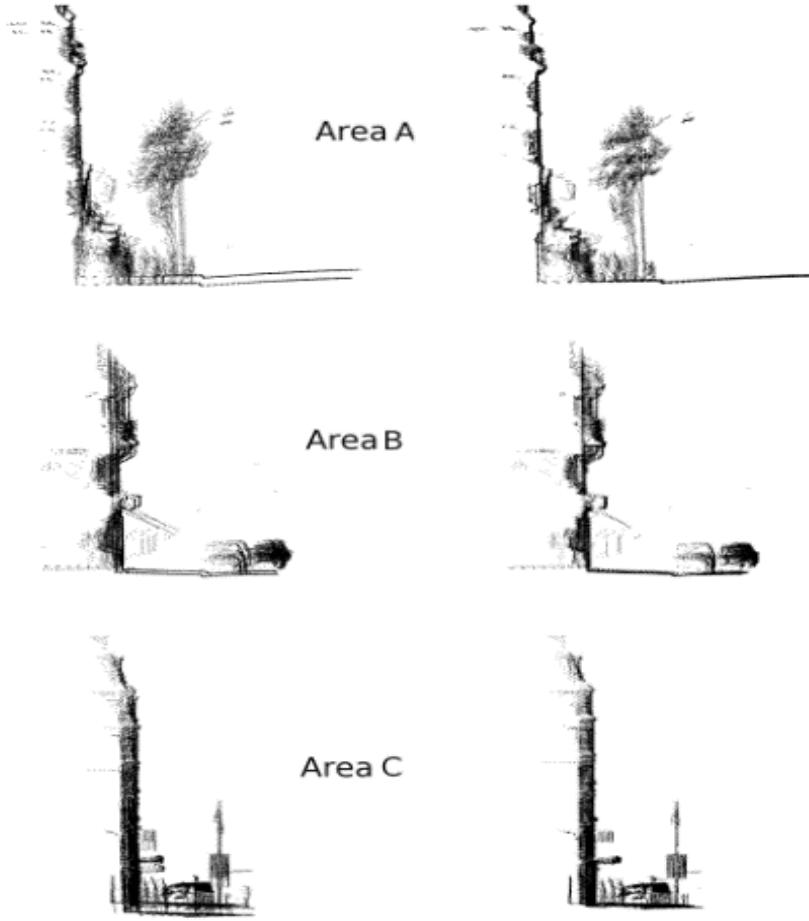
Georeferencing/registration

Introduction

- Data registration = platform trajectory estimation



Lidar self registration



Lidar registration on 3D city model

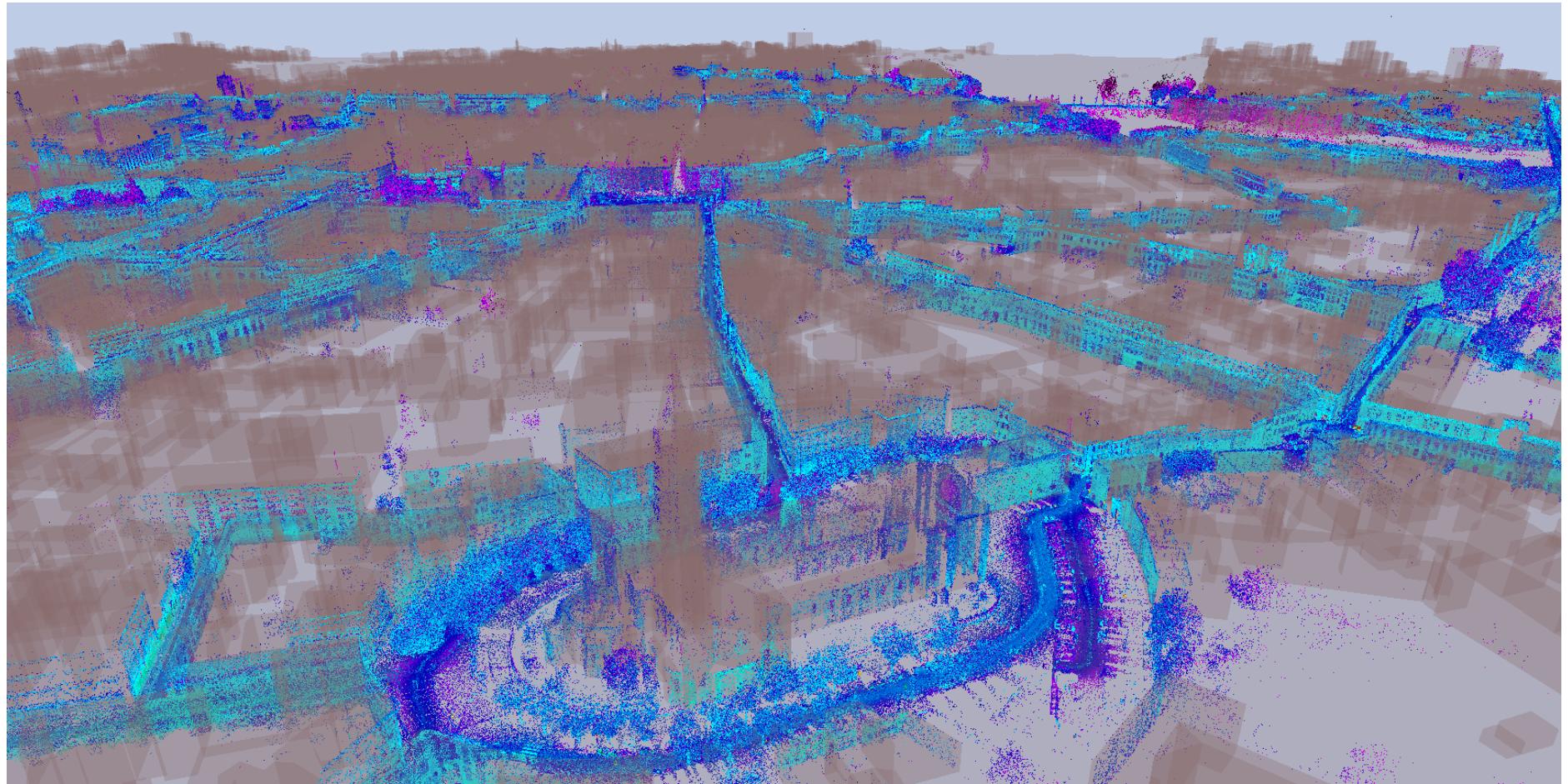


Image pose estimation

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

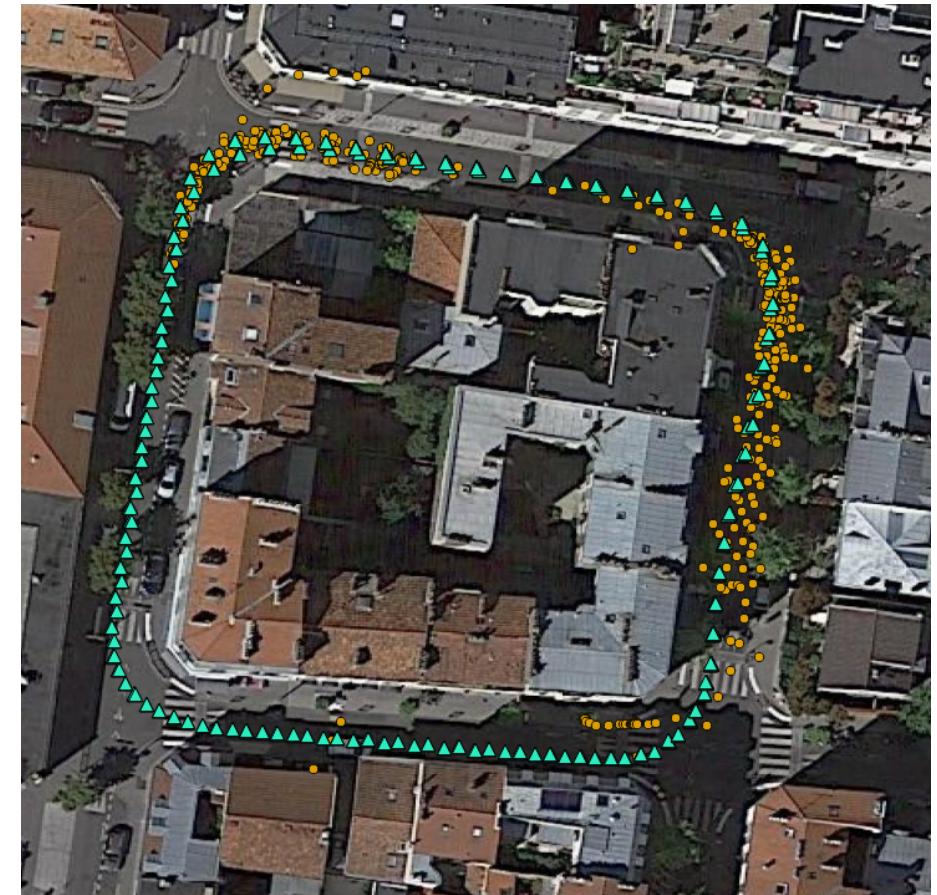
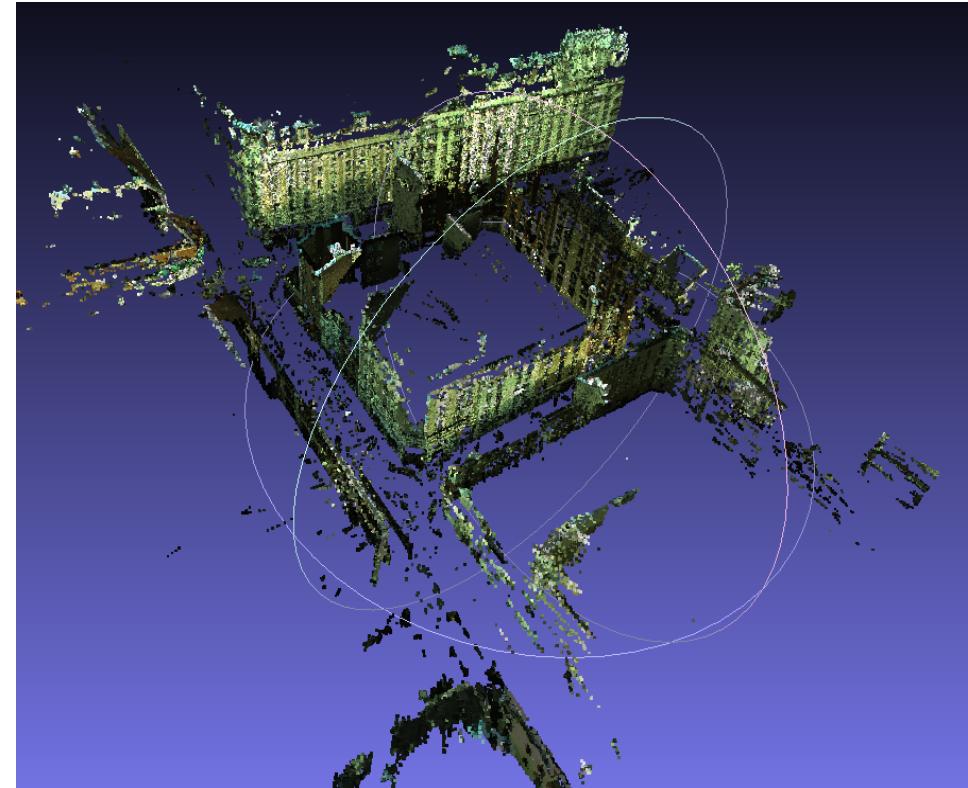


Image dense matching

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

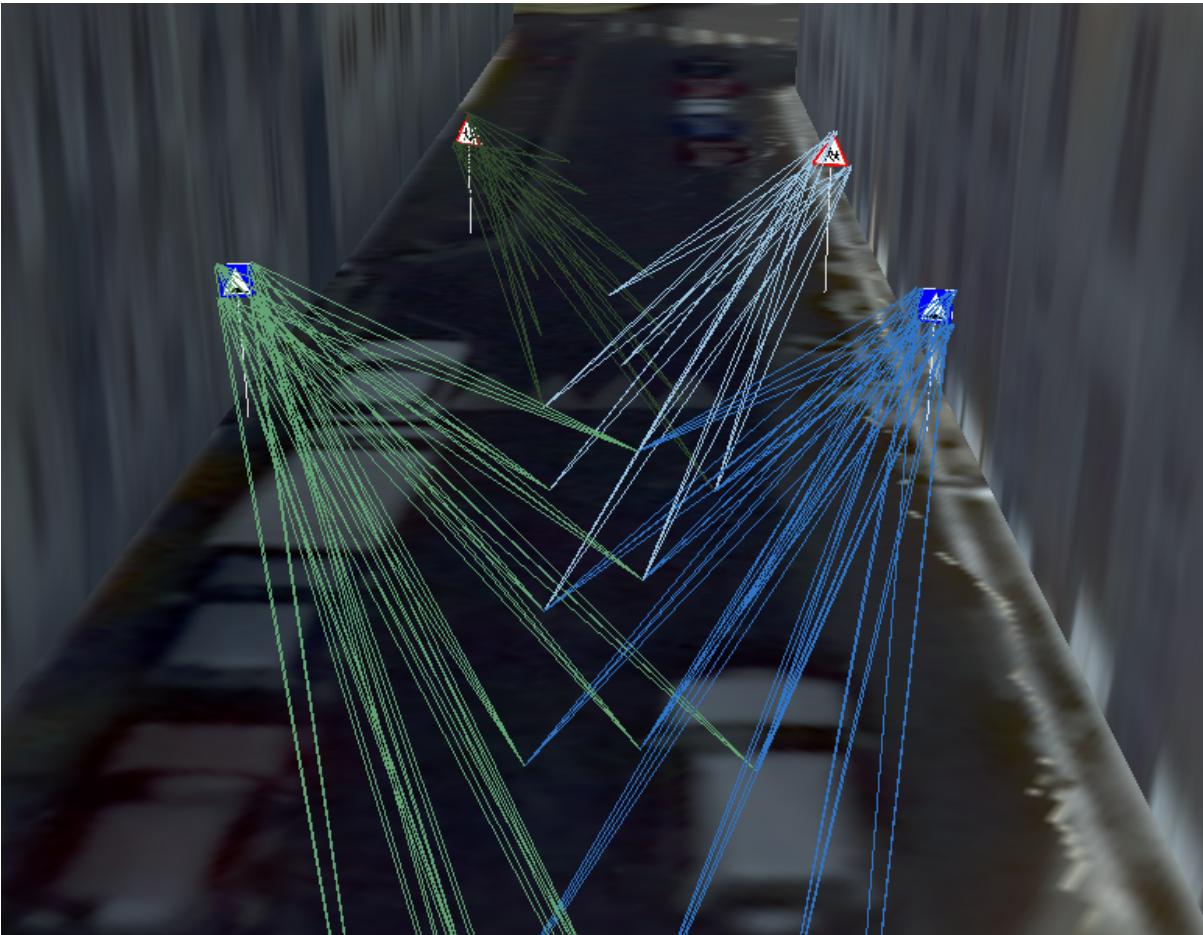


Scene analysis and reconstruction

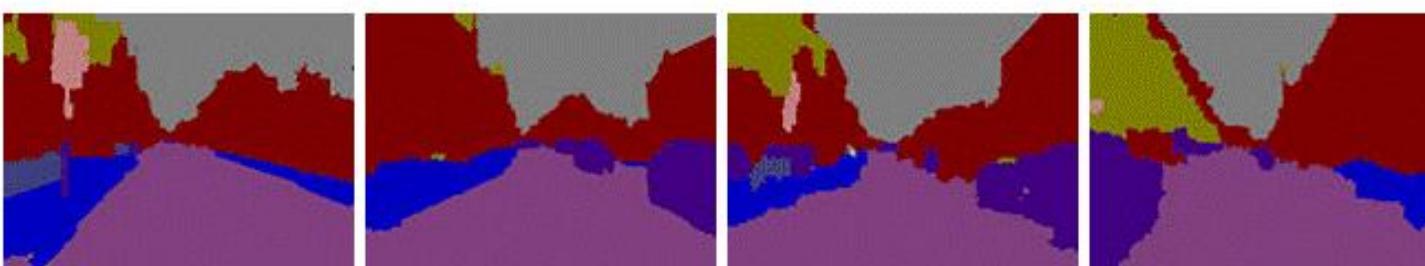
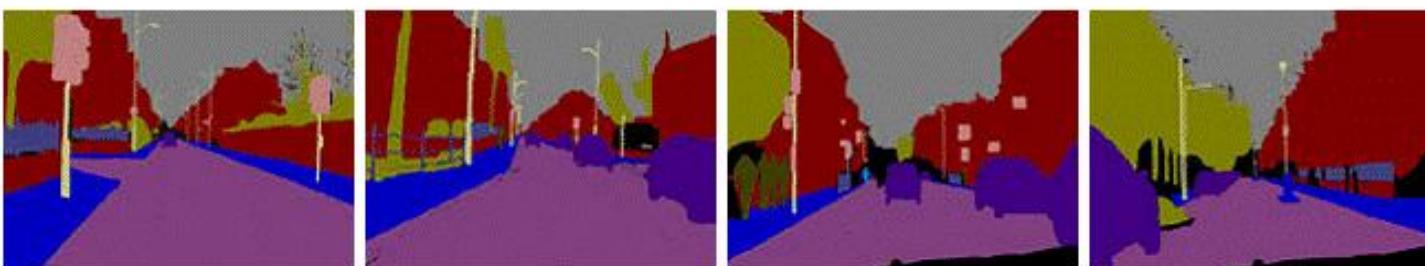
Object detection



3D objects reconstruction

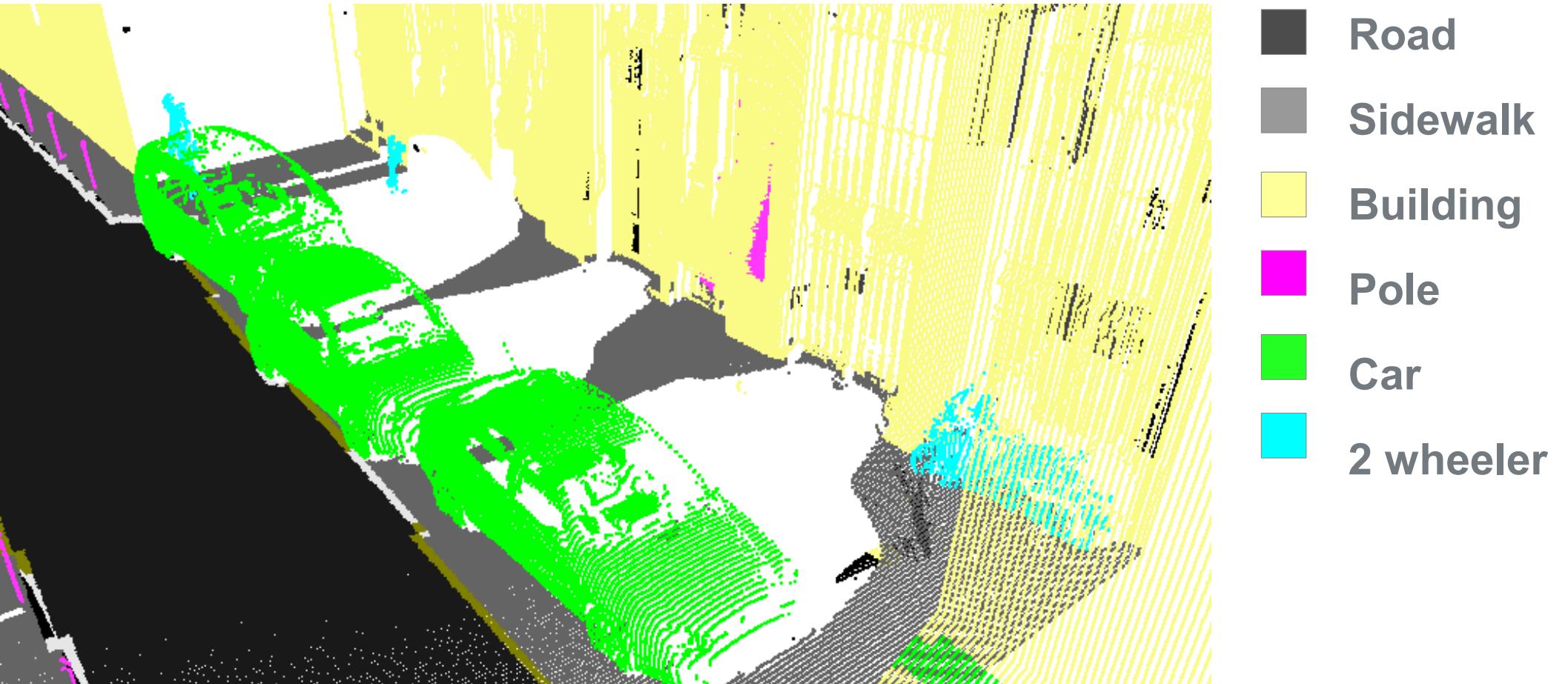


Semantic analysis of images

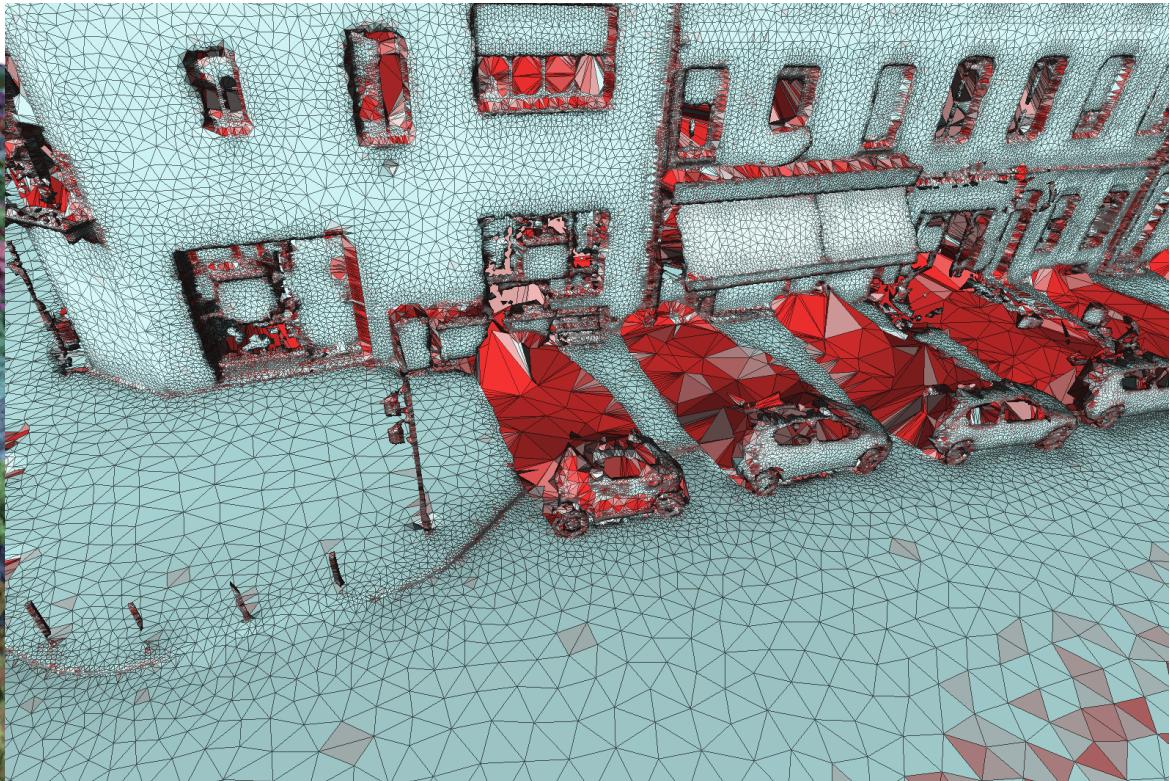
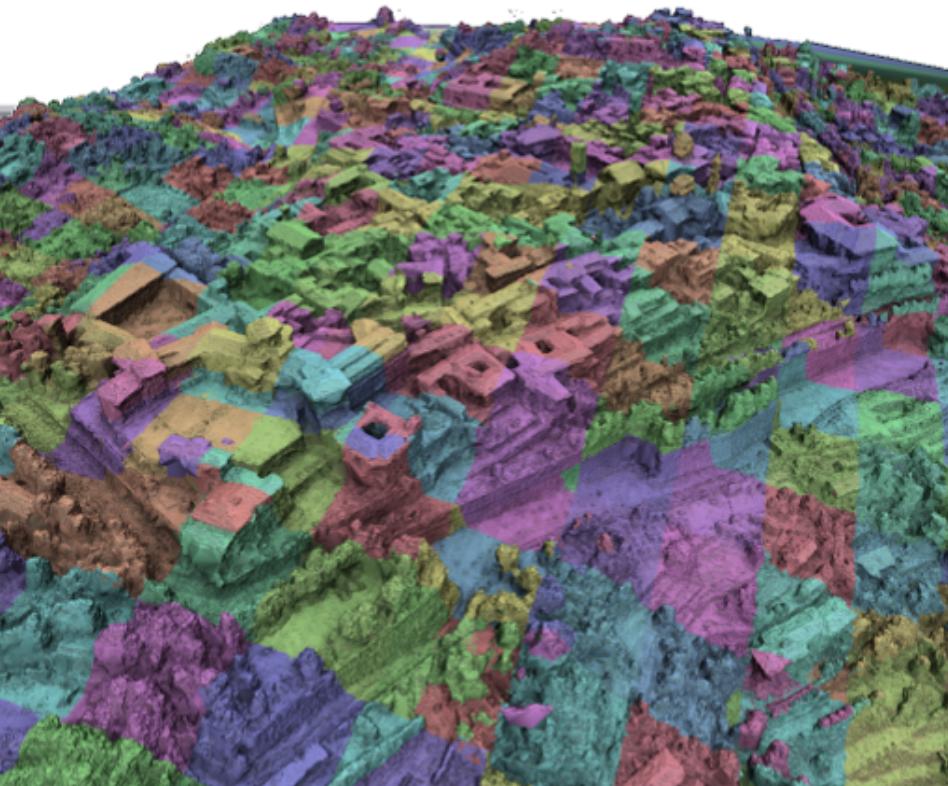


- █ Road
- █ Sky
- █ Tree
- █ Sidewalk
- █ Car
- █ Pole

Semantic analysis of Lidar



Surface reconstruction



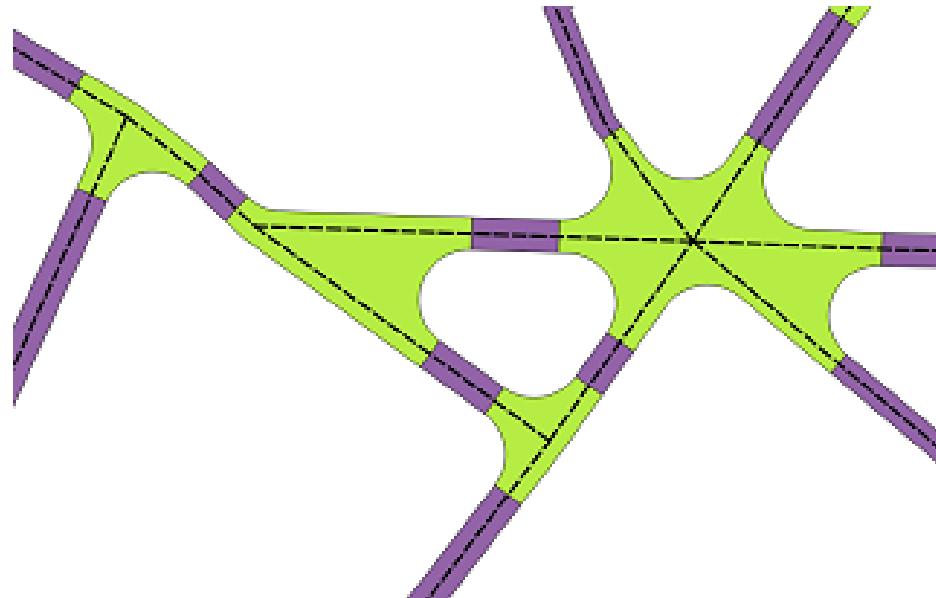
Structured reconstruction

- Navigability arrangement



Structured reconstruction

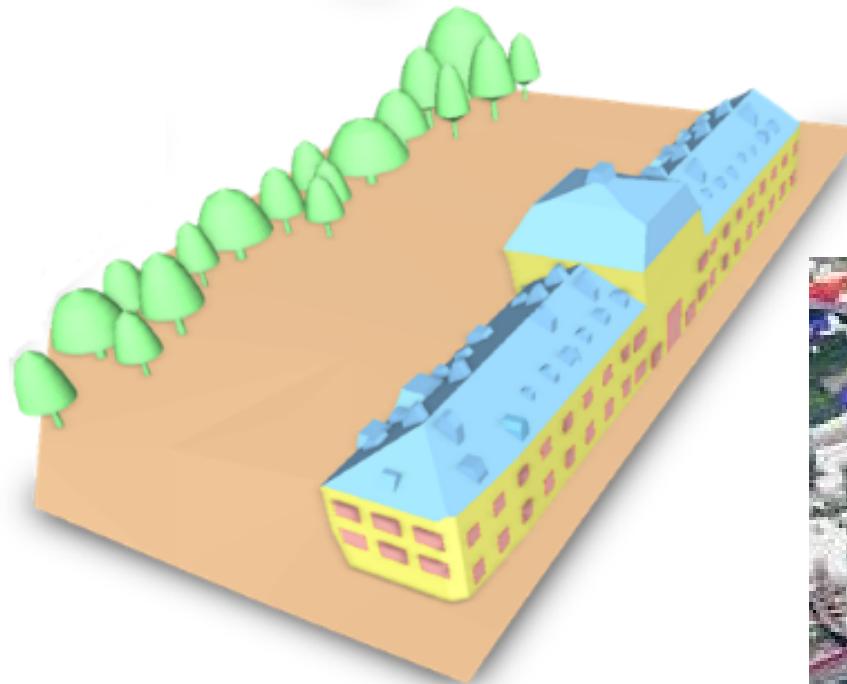
- Navigability arrangement



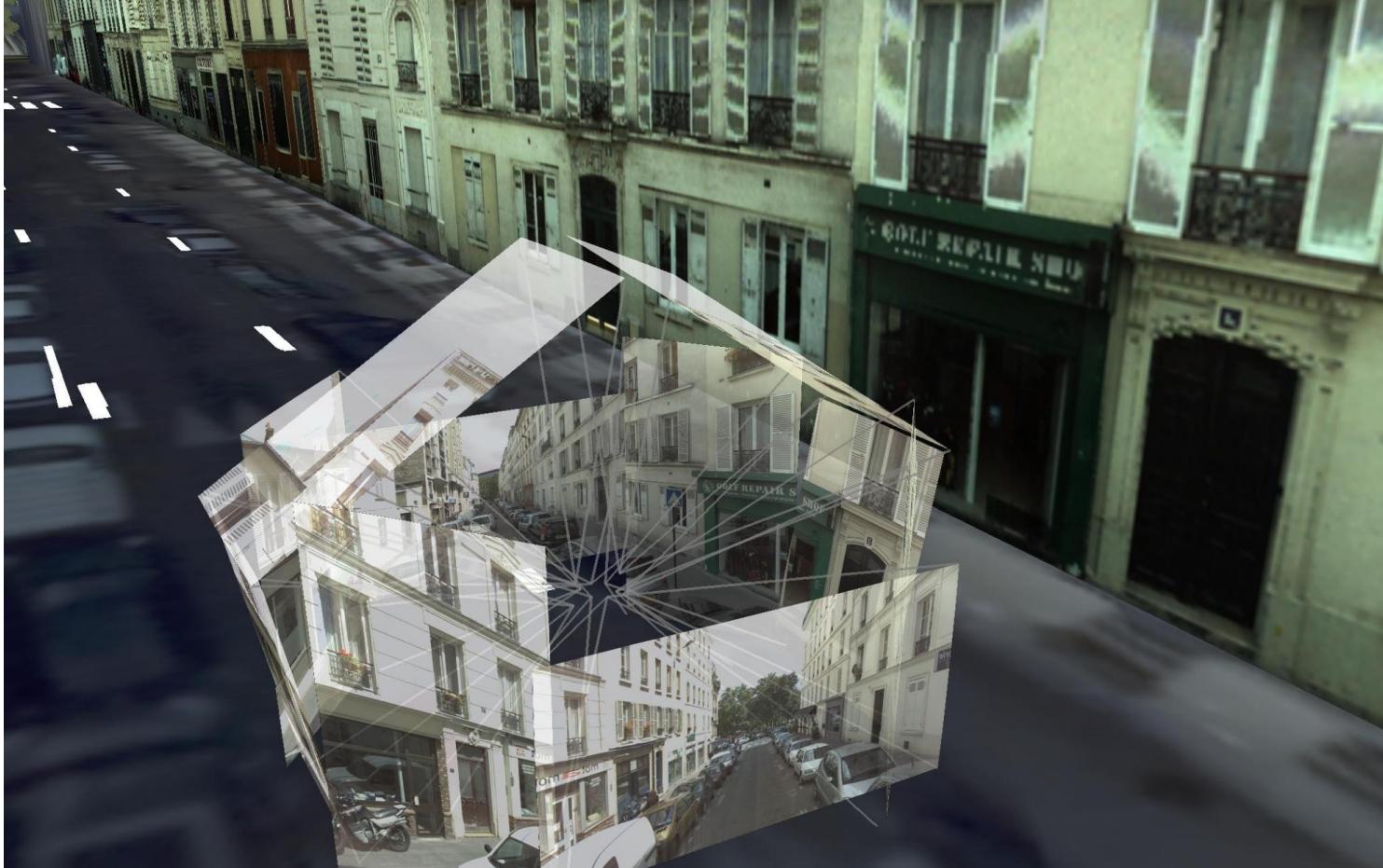
Structured reconstruction : buildings

2 approaches :

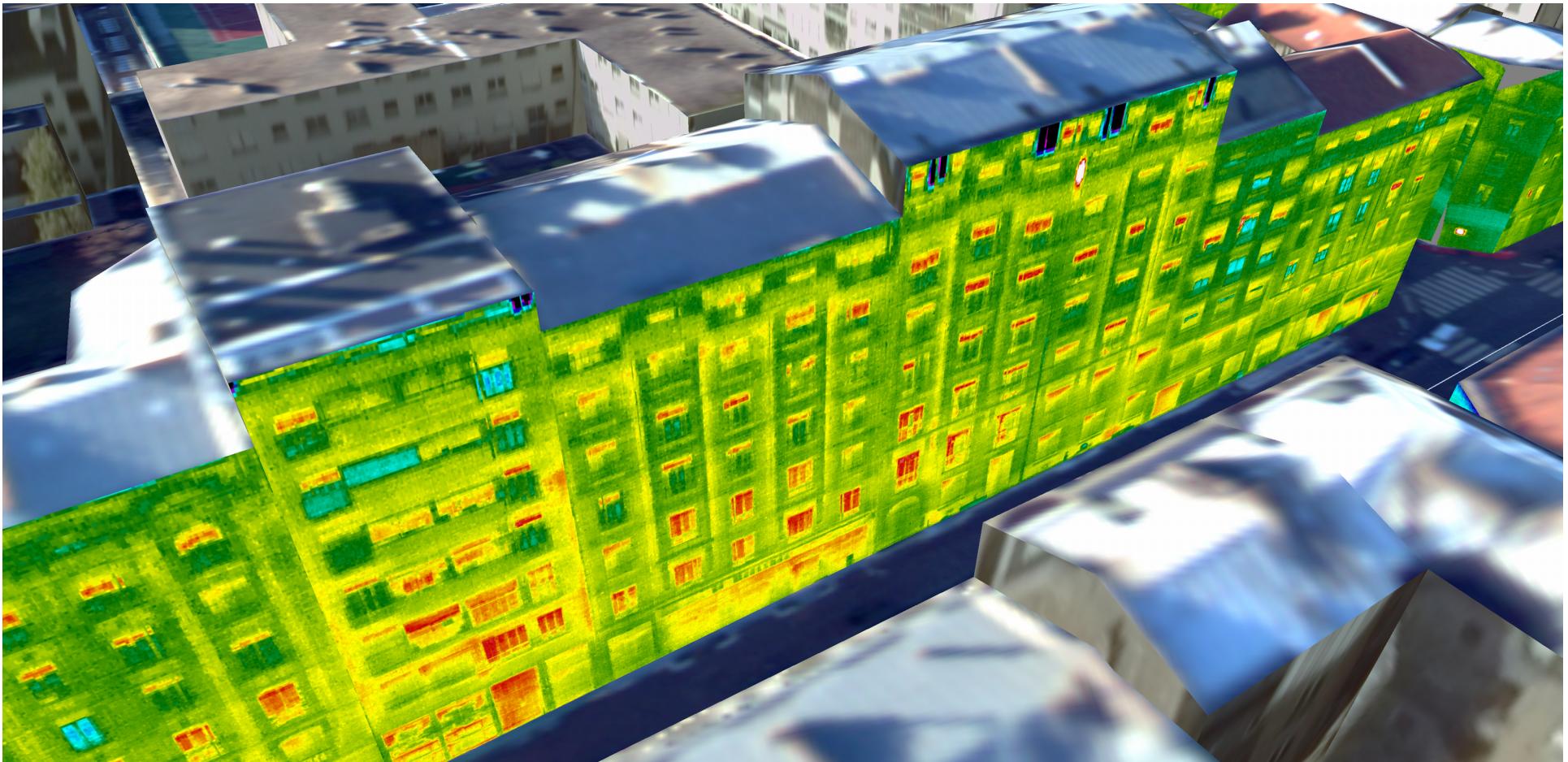
- Bottom up :
 - Find parts
 - Aggregate them
- Top down :
 - Fit models from a library



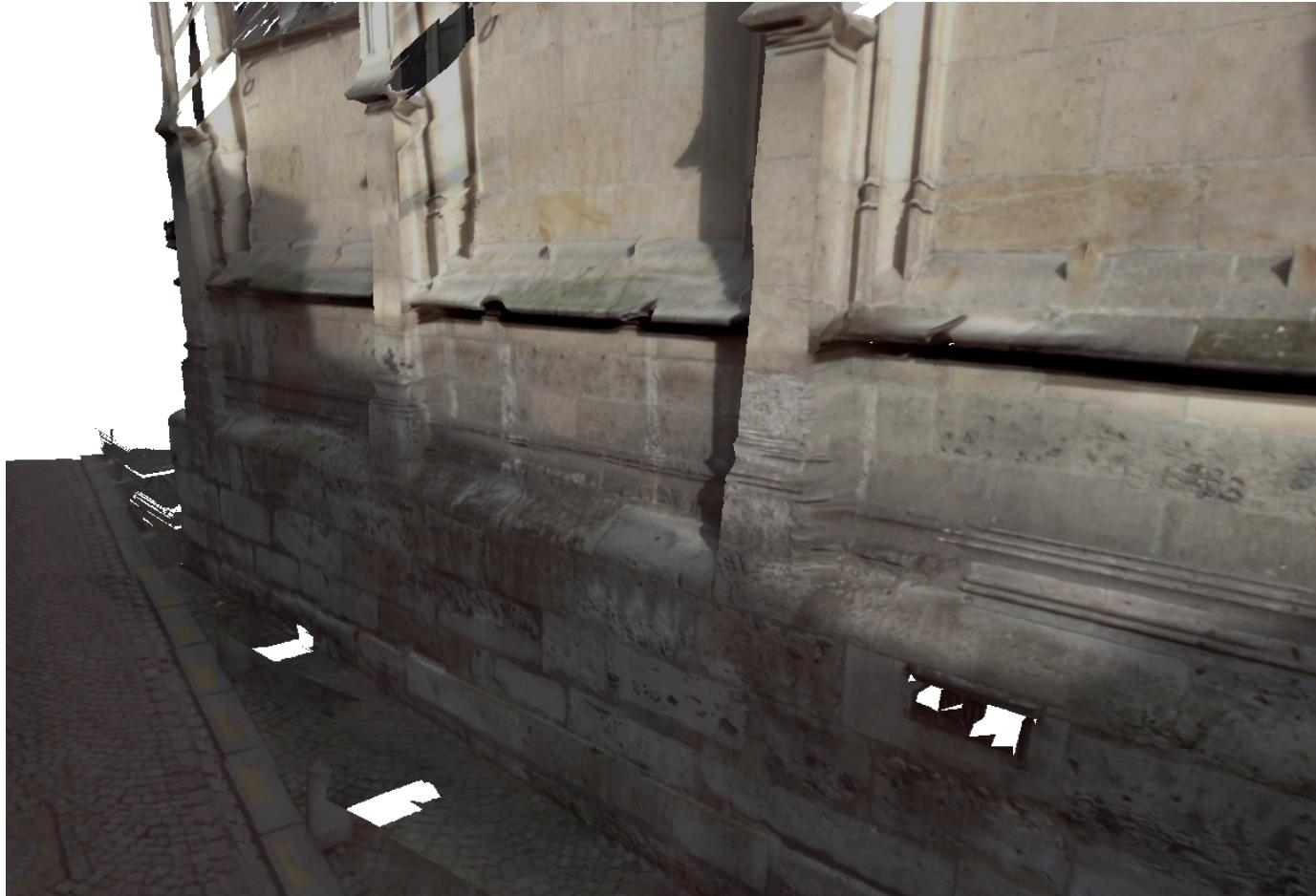
Texturing



Texturing



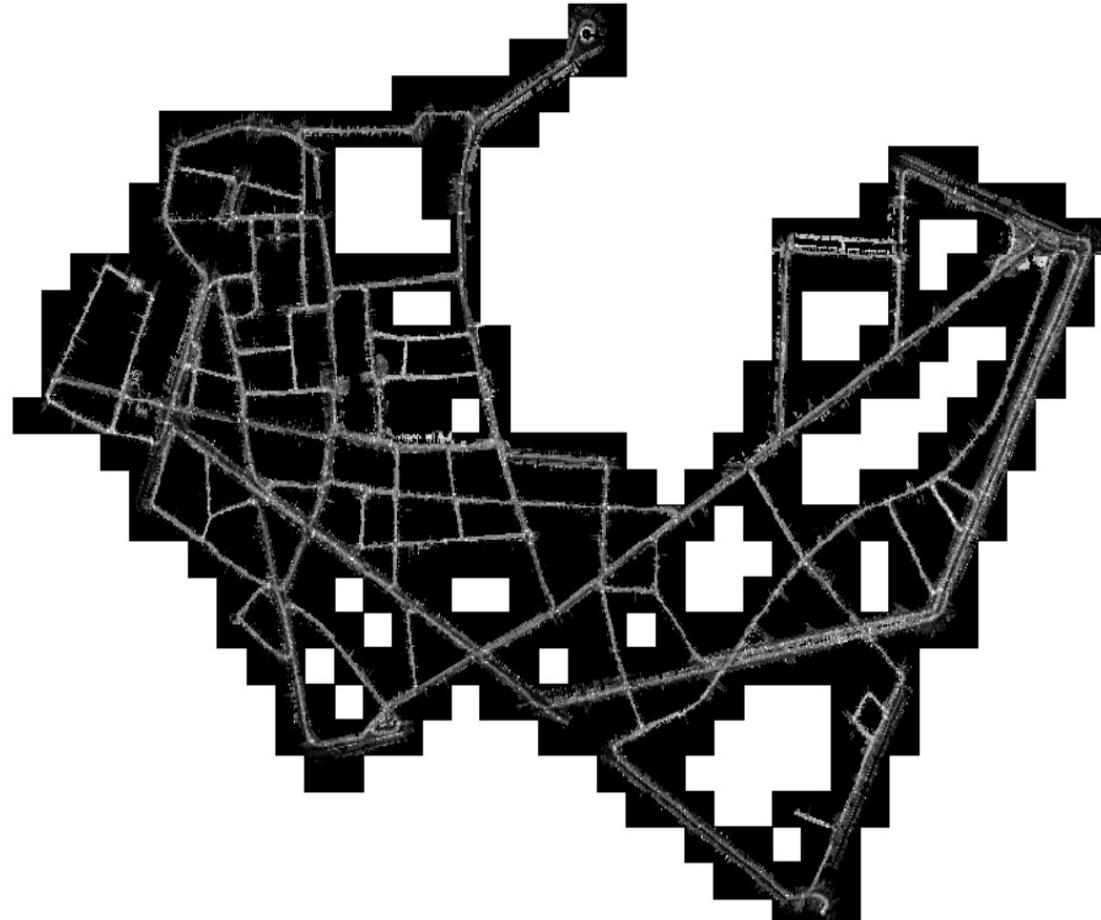
Texturing



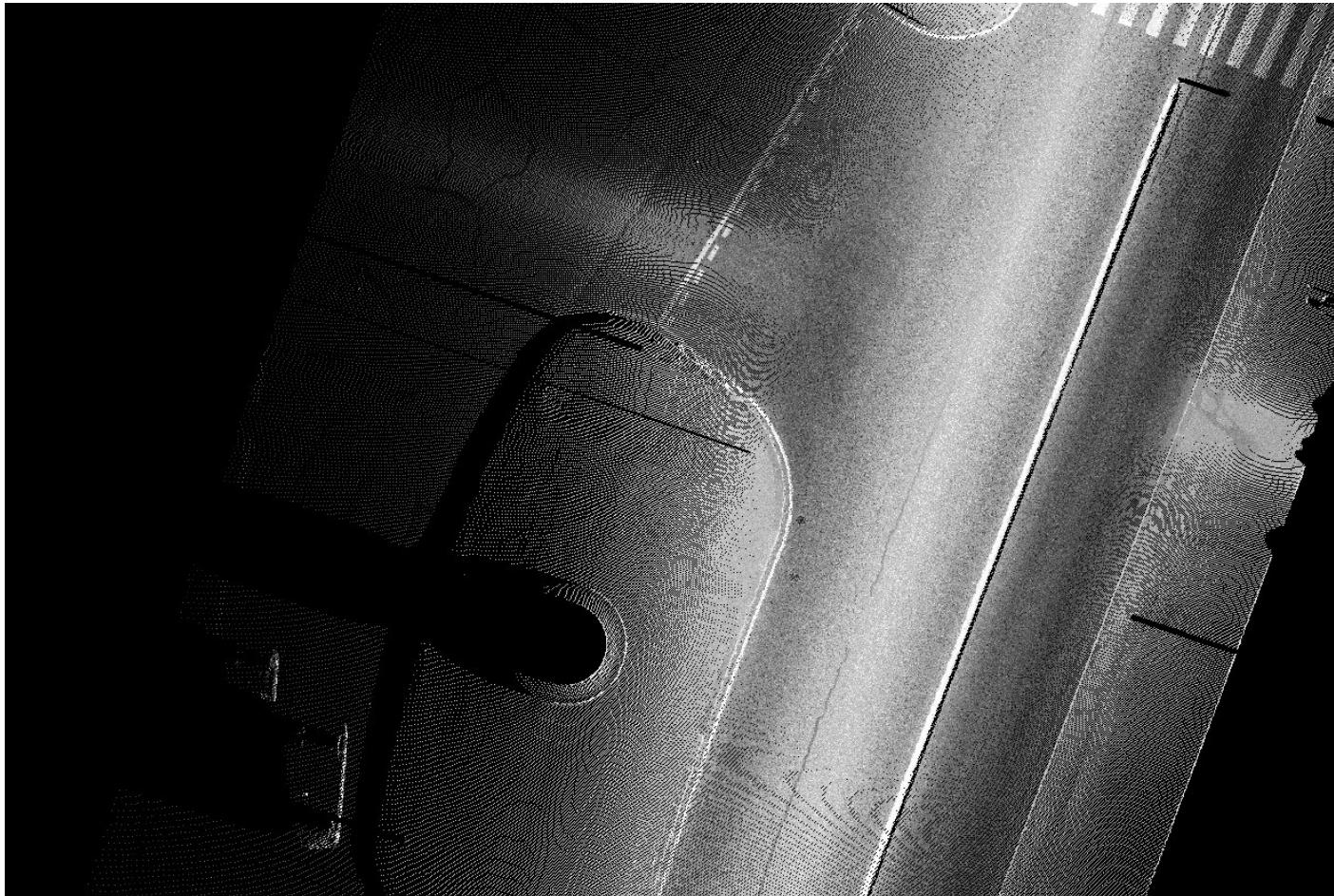
Texturing



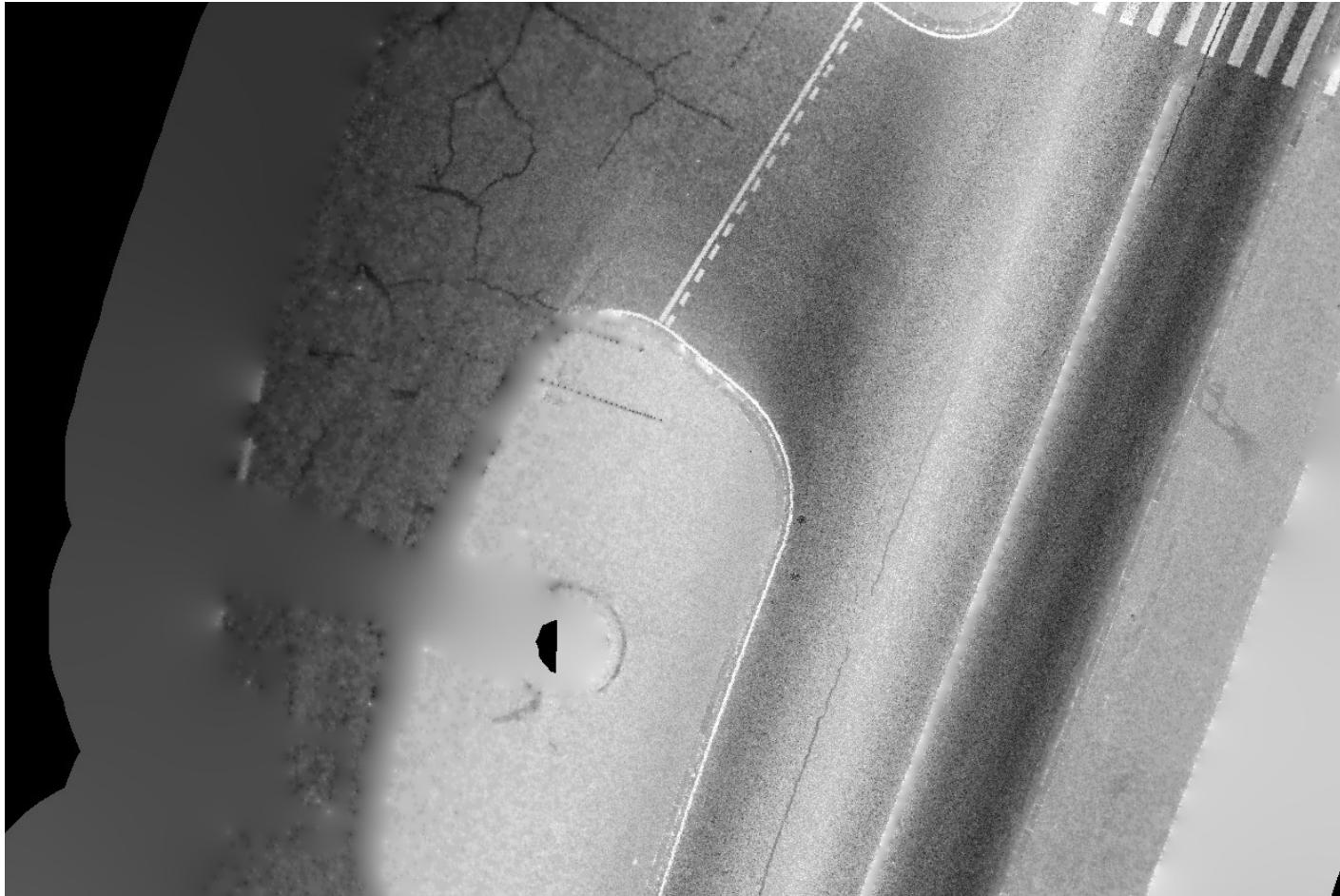
Lidar Ortho/DEM



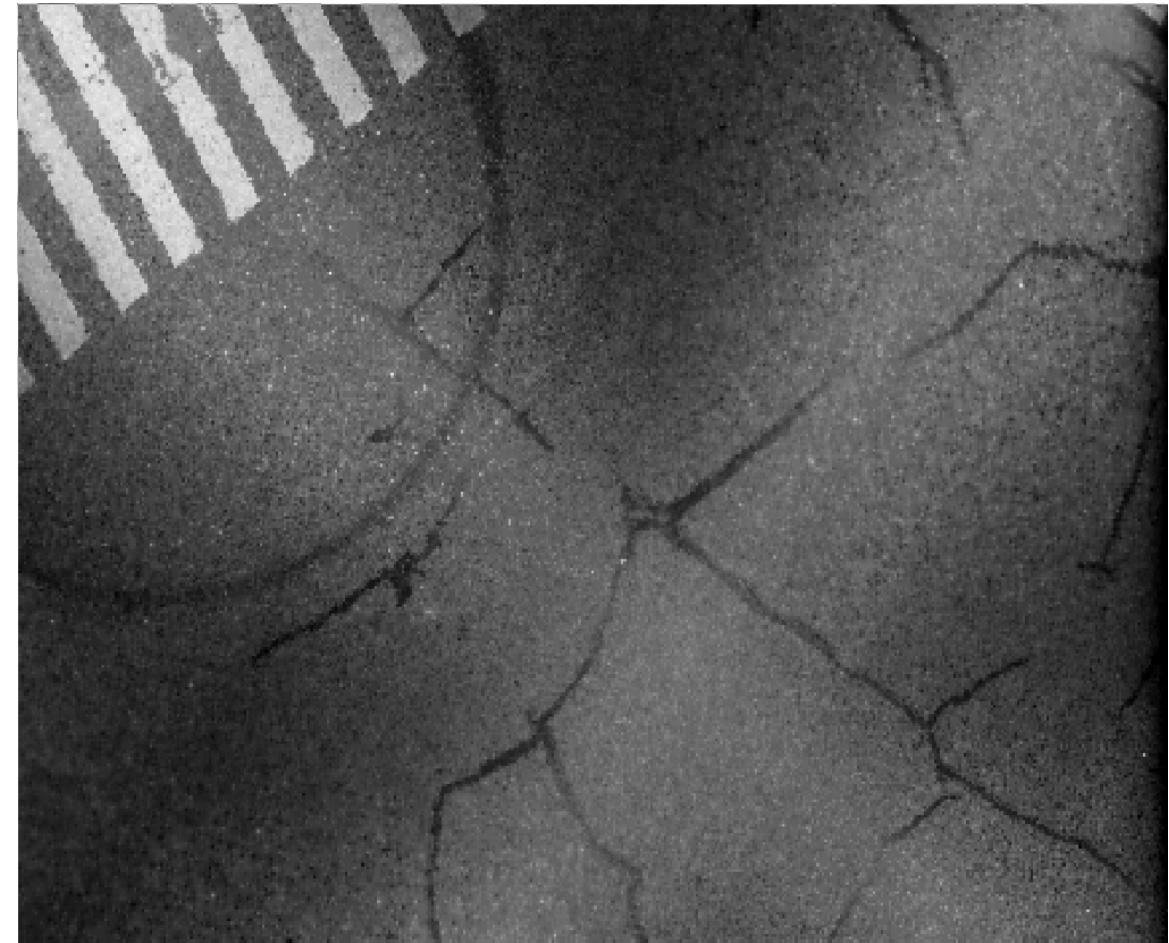
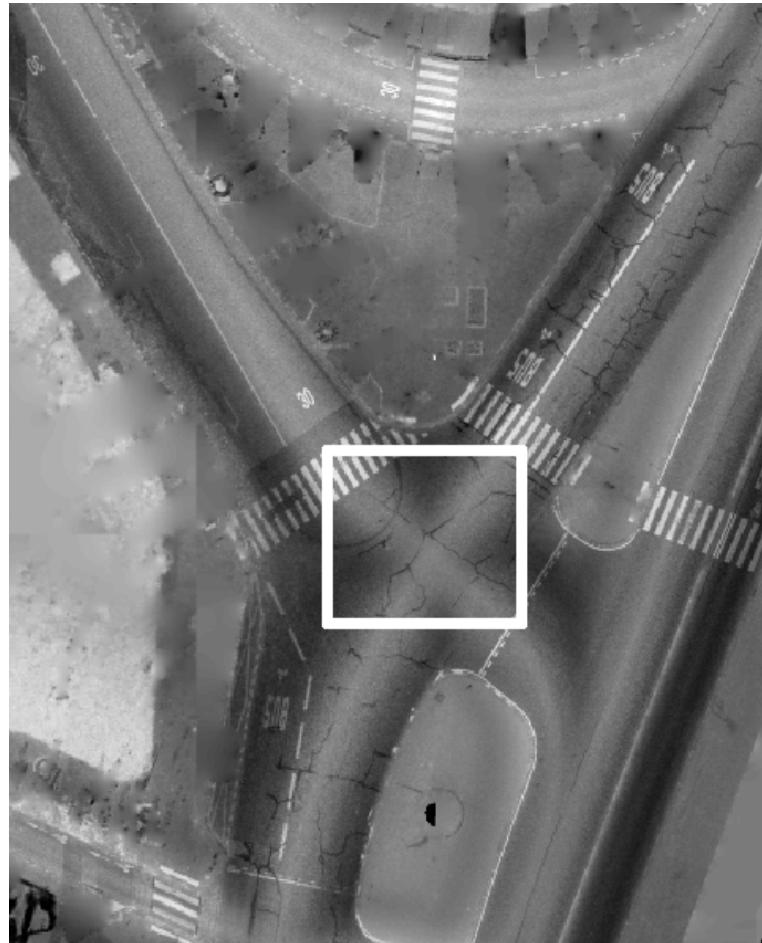
Lidar Ortho/DEM : projection



Lidar Ortho/MNE : interpolation



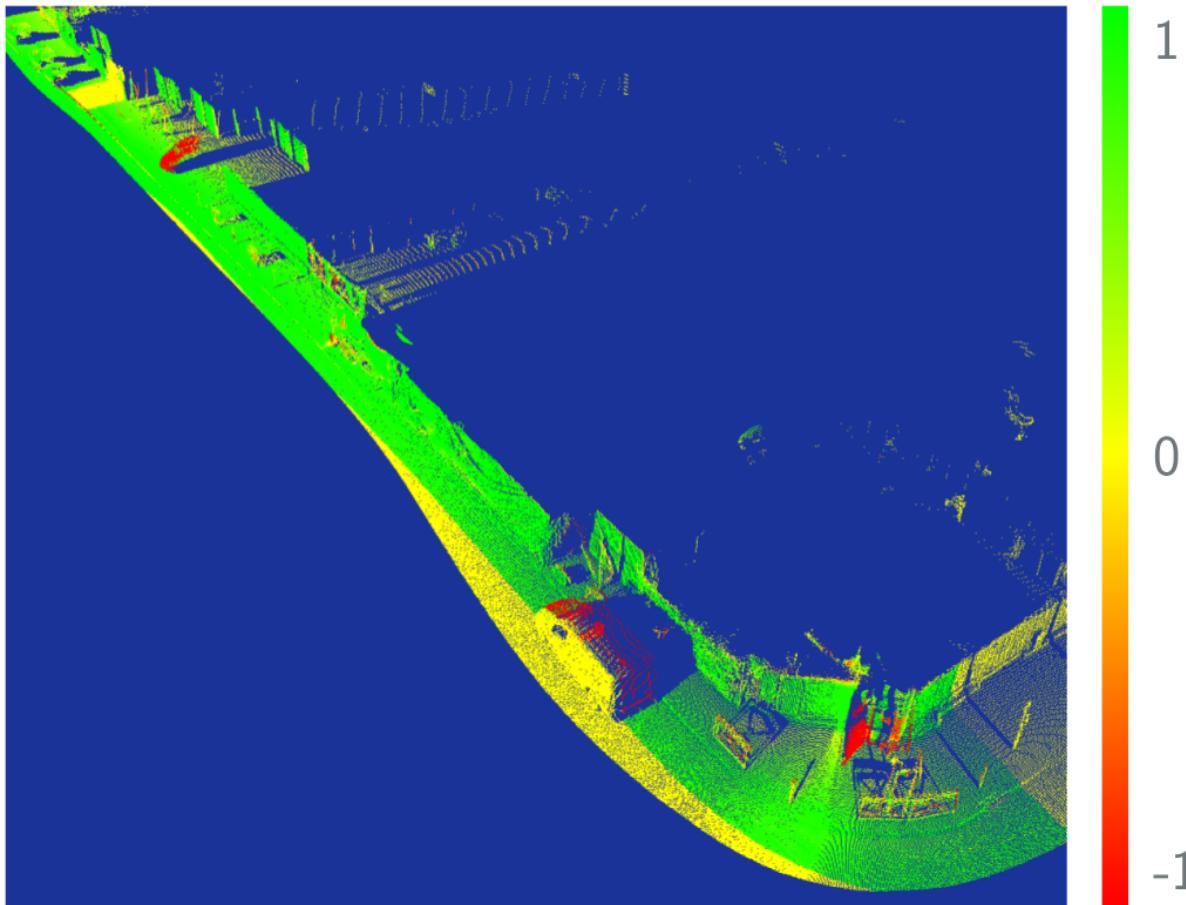
Lidar Ortho/DEM : blending



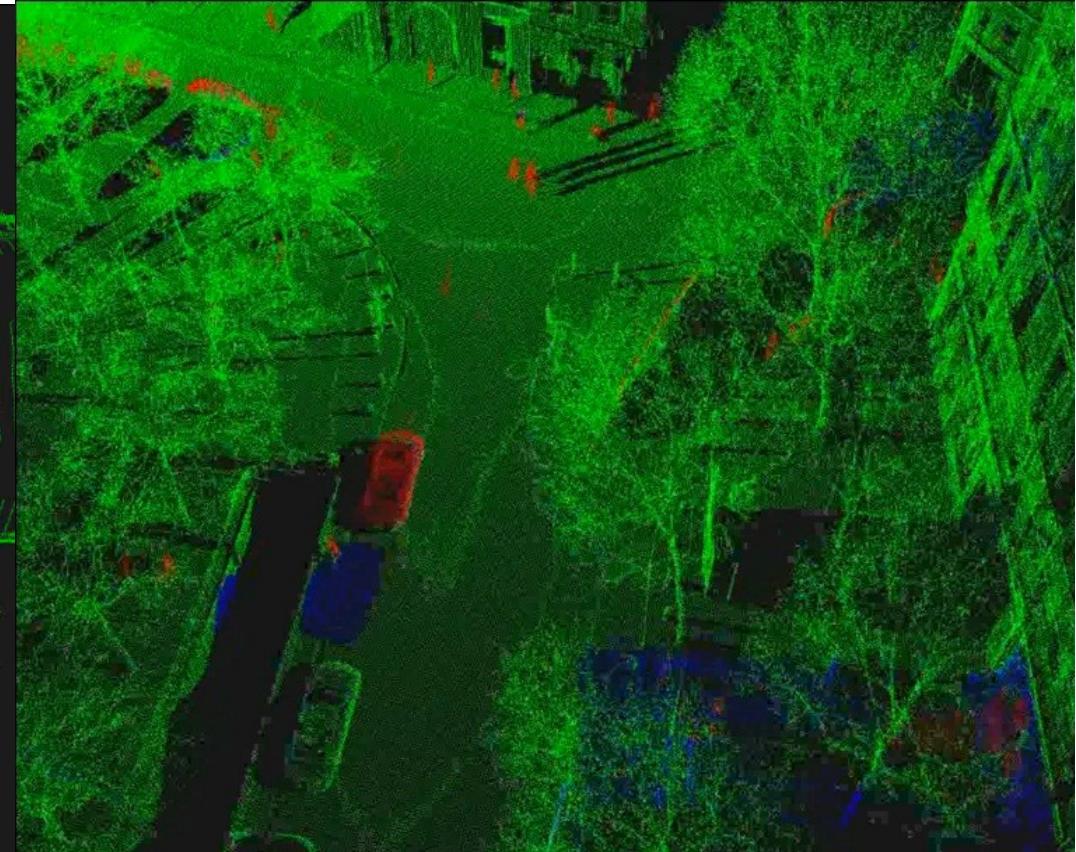
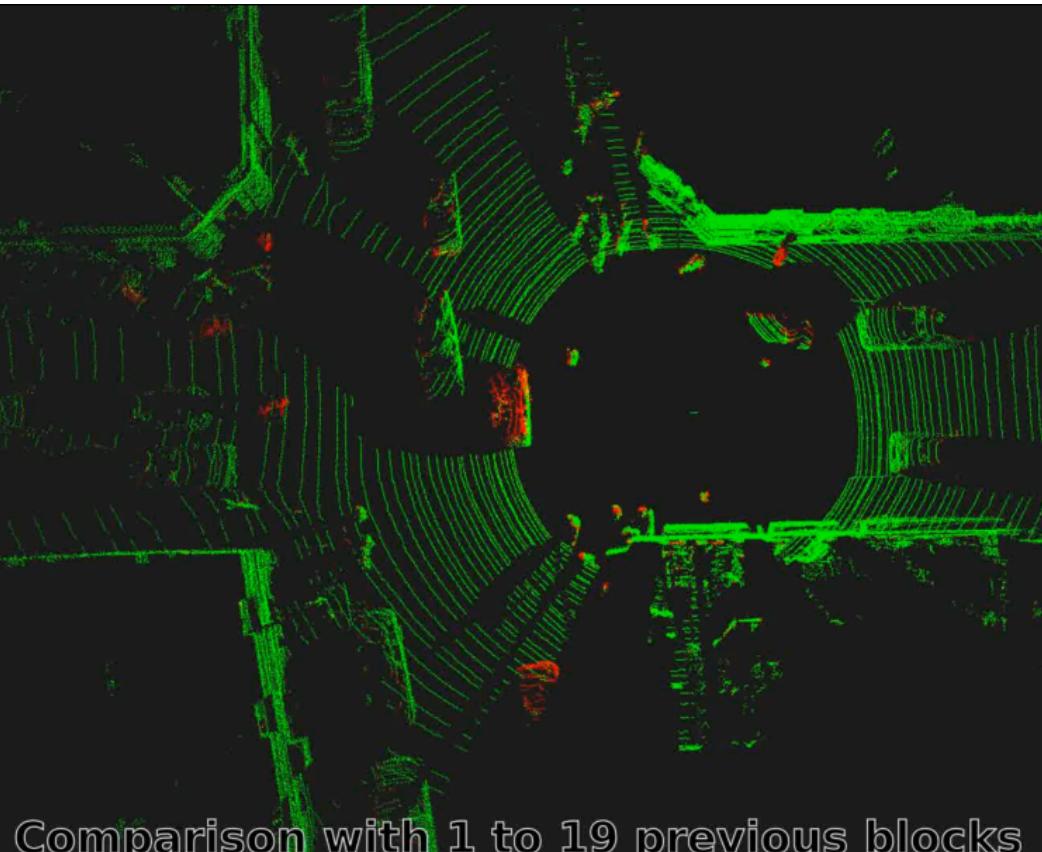
Lidar Ortho/DEM : result



Change detection

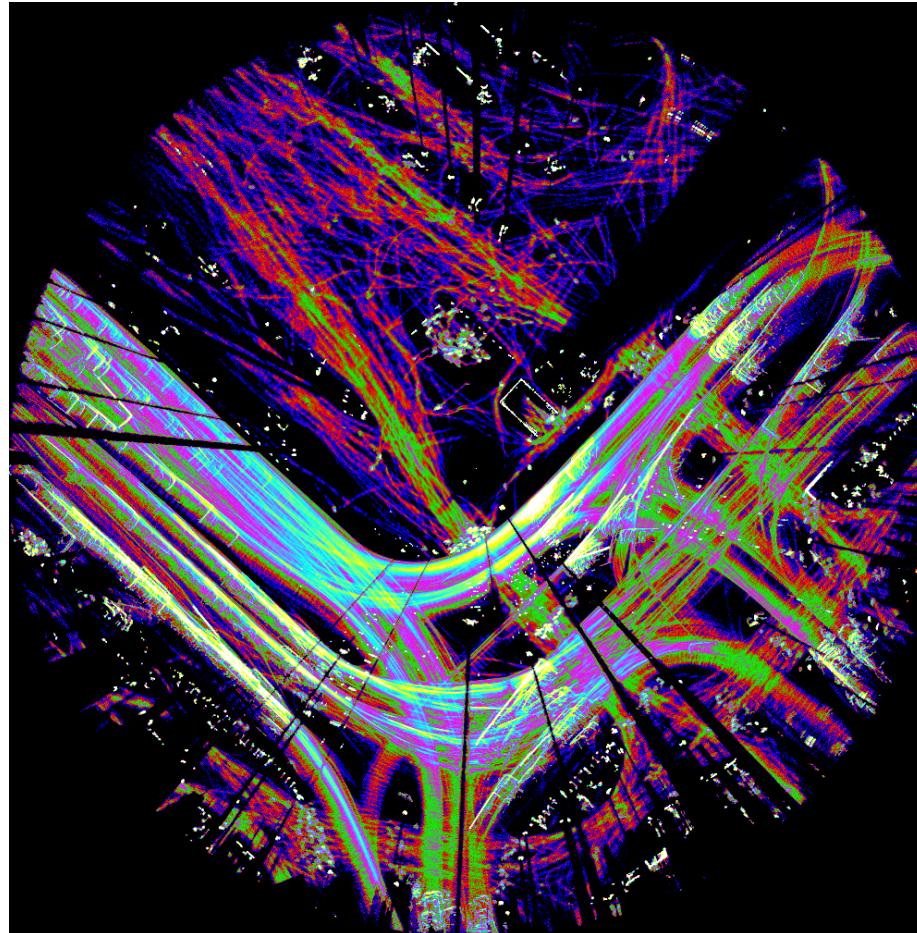


Change detection



Comparison with 1 to 19 previous blocks

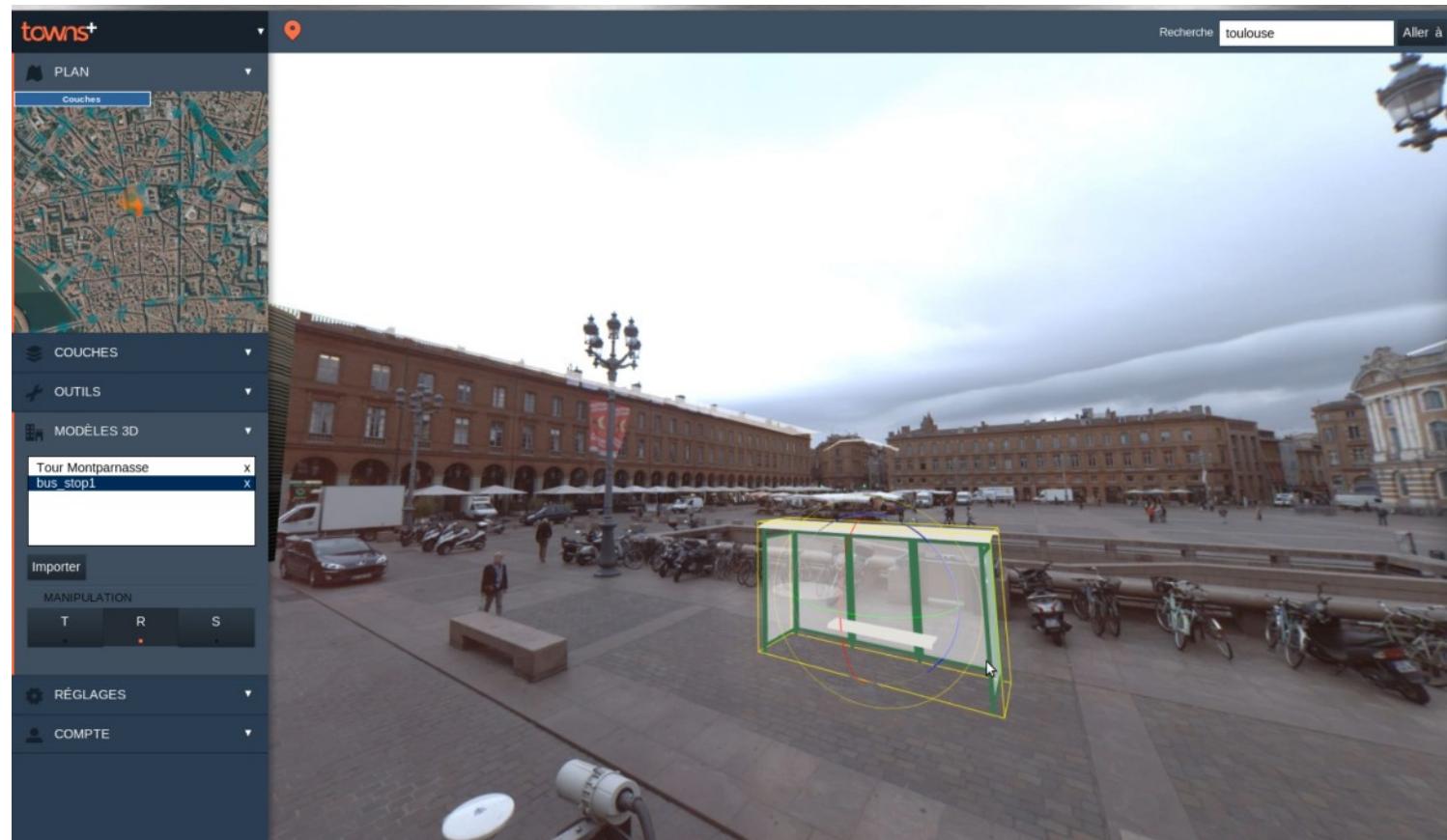
Flow mapping



Applications

Urban planning

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

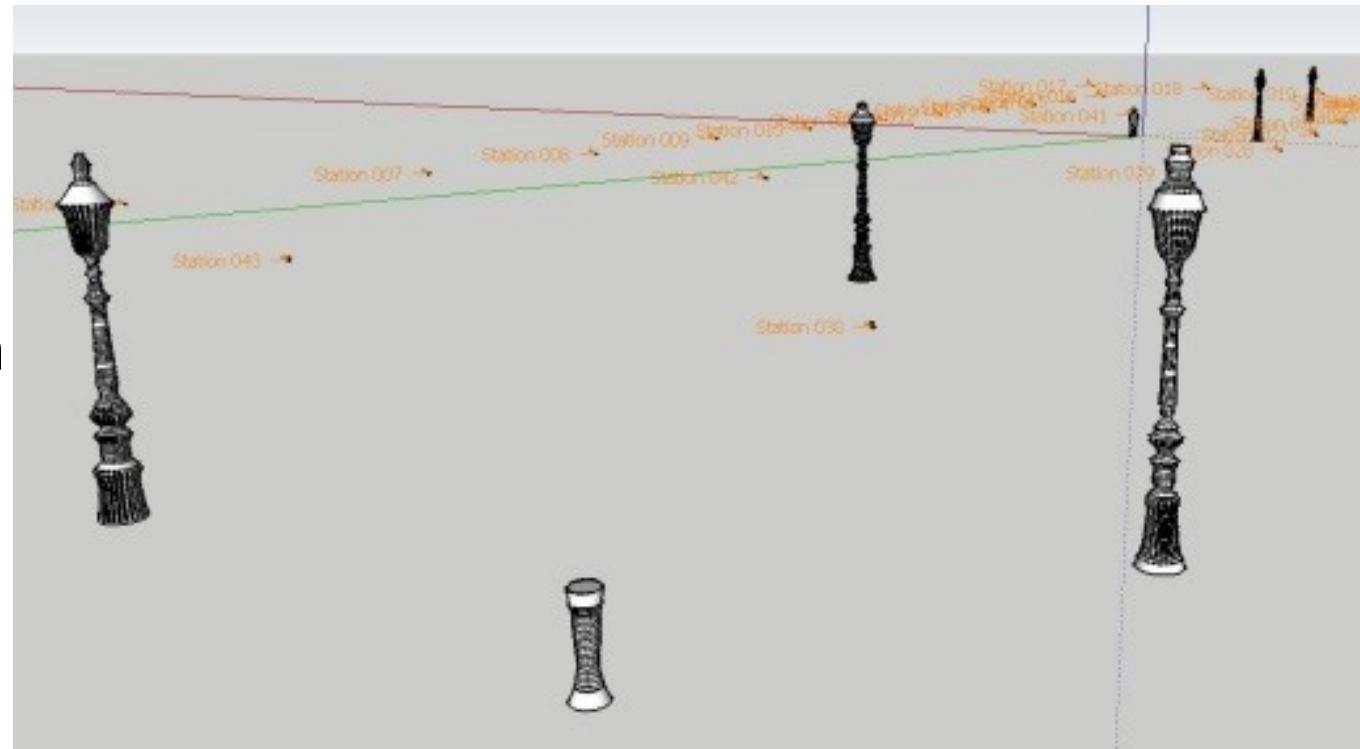


Urban planning



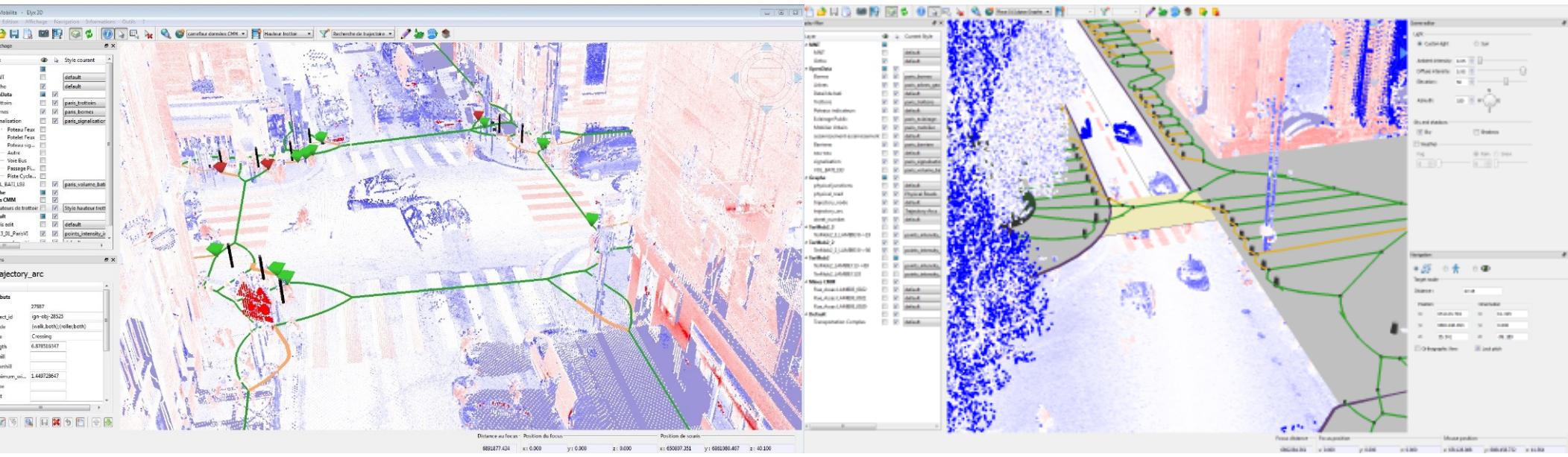
Inventory

- 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**



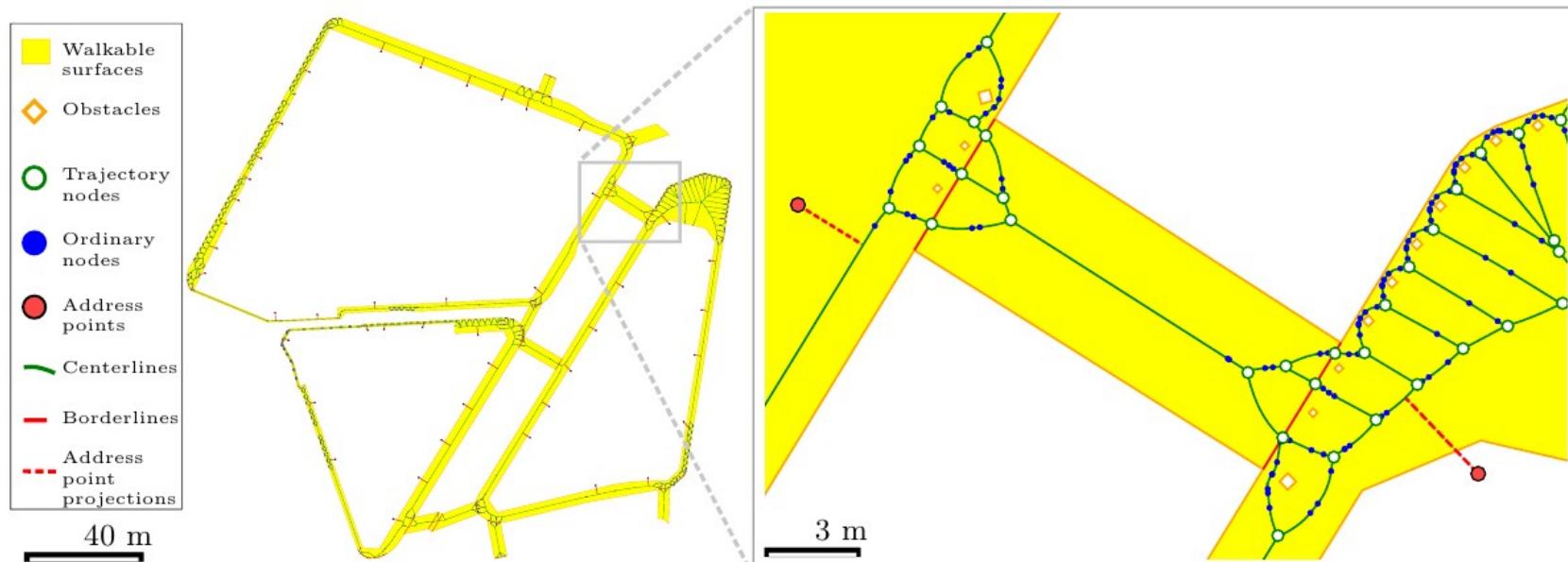
Itinerary computation

- Itinerary computation requires a navigability graph



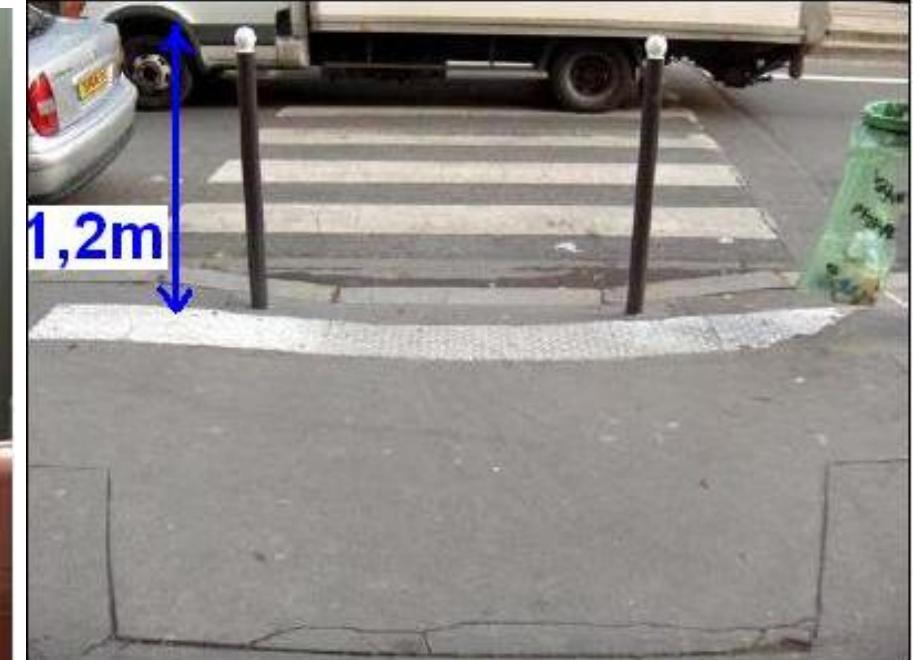
Itinerary computation

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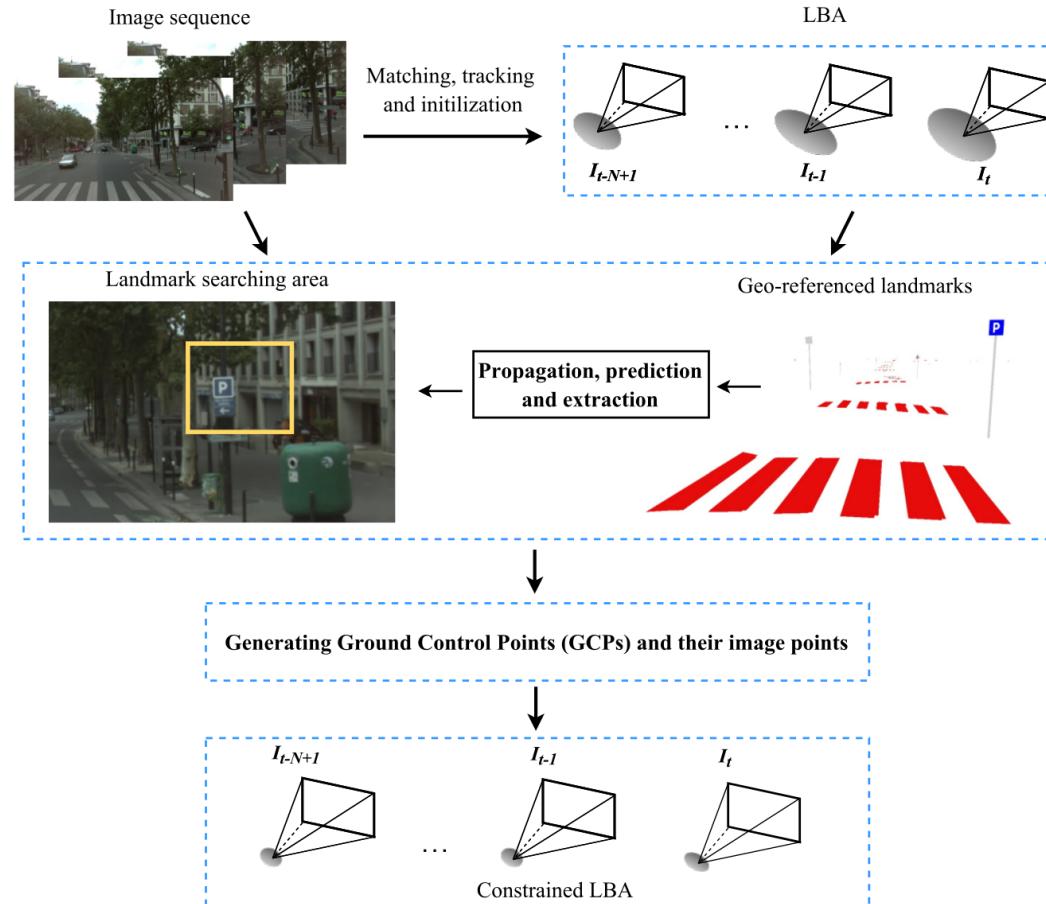


Accessibility diagnostic

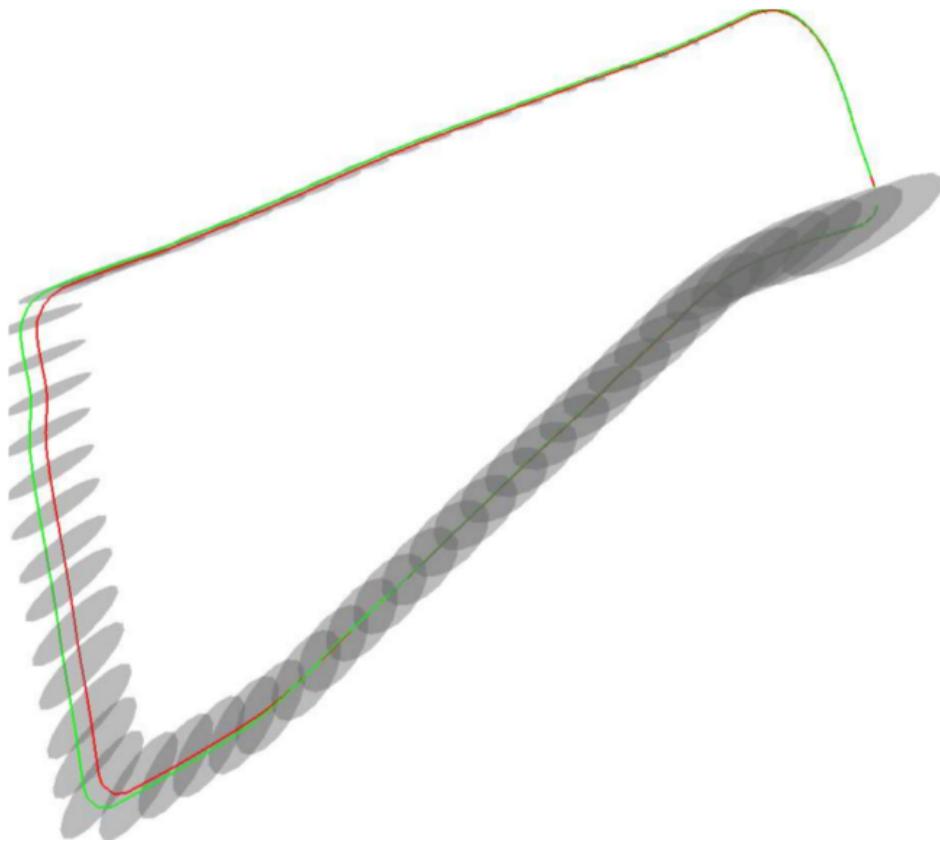
- Accessibility for wheelchairs can be assessed based on
 - Minimum width along a path / Curb heights / Slopes



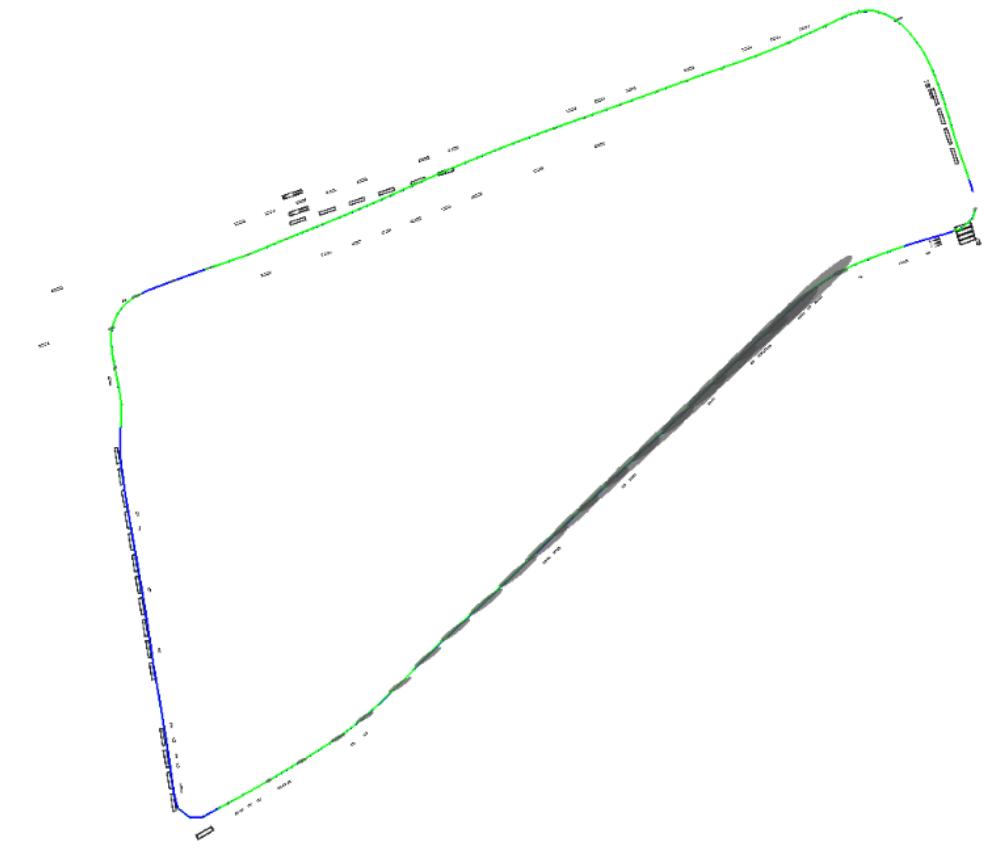
Landmarks based localization



Landmarks based localization



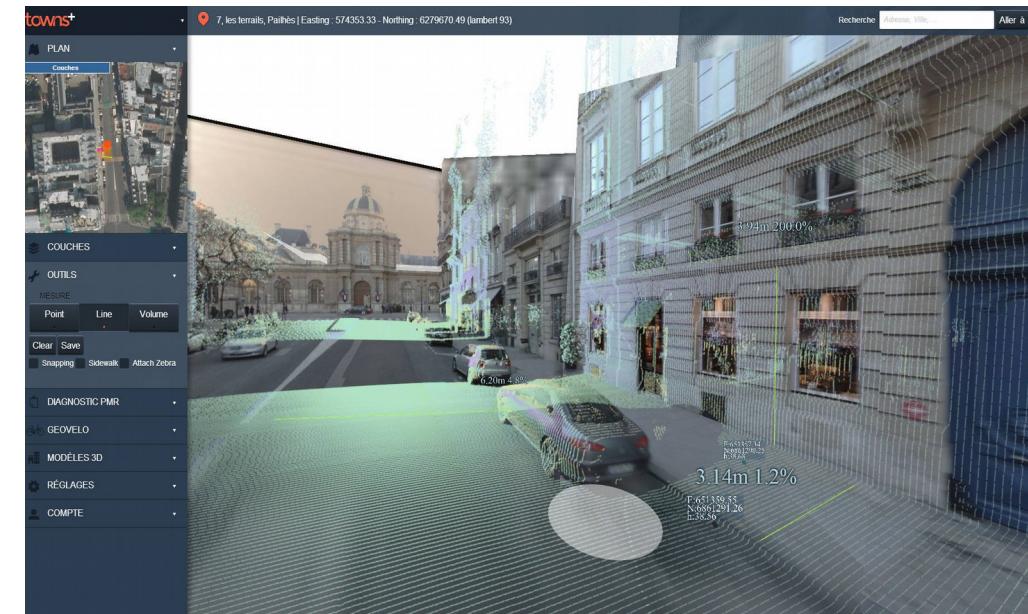
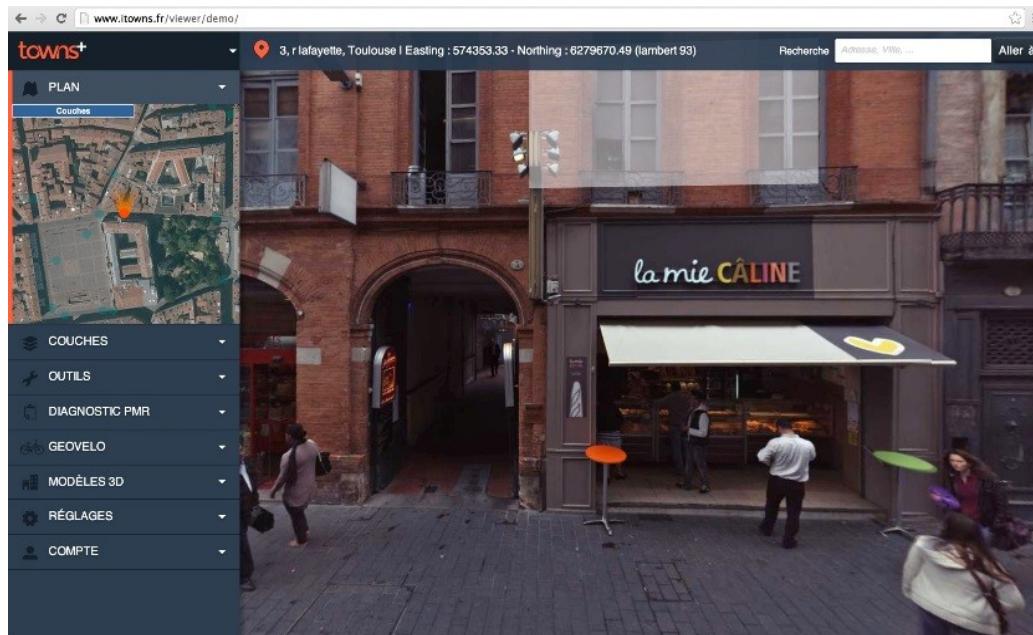
Mono camera + LBA



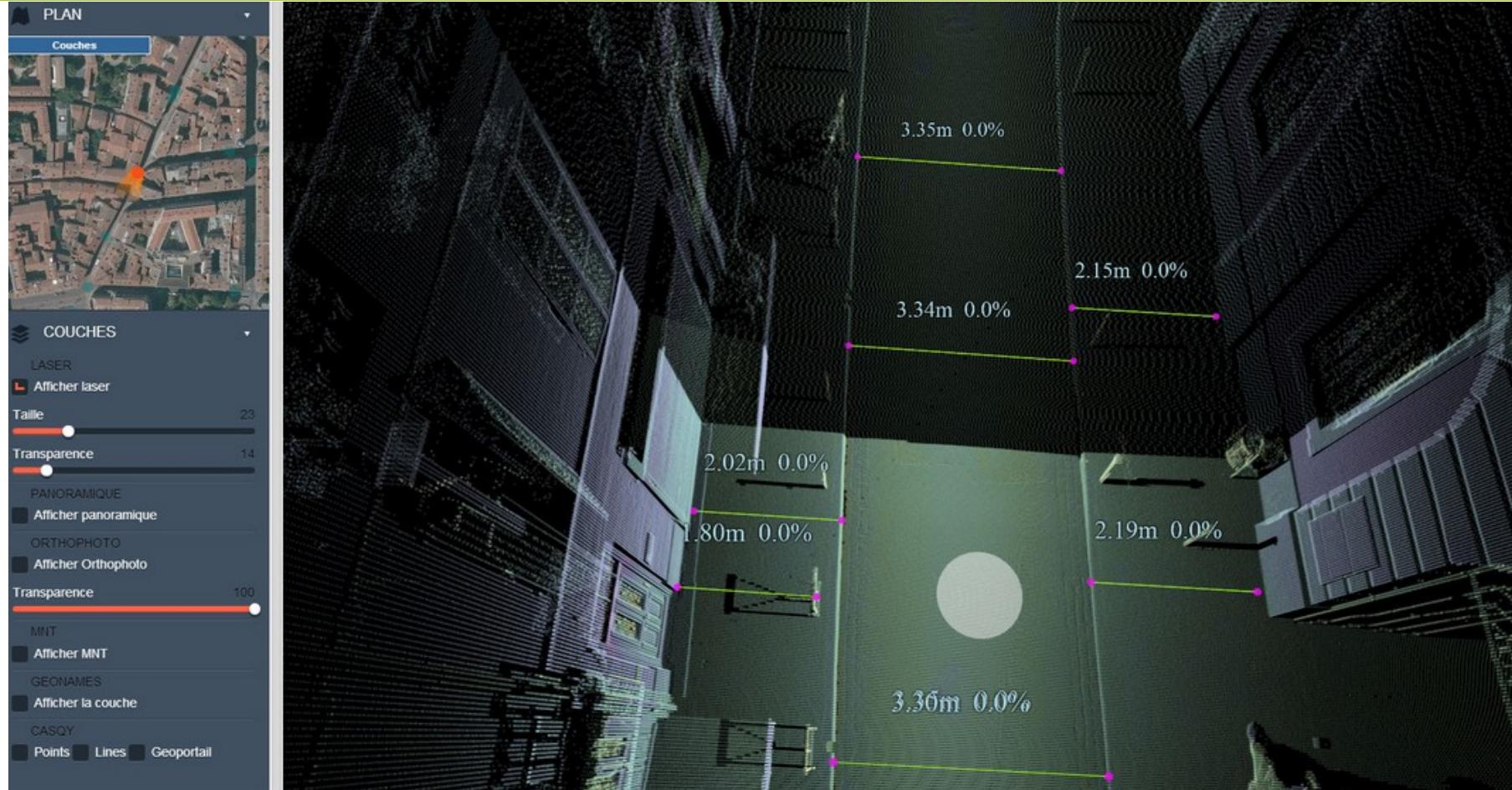
Mono camera + LBA + landmarks

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 »

towns⁺

7, les terrails, Pailhès | Easting : 574400.73 - Northing : 6279667.65 (lambert 93)

Recherche Aller à

PLAN

Couches



COUCHES

Outils

MESURE

Point Line Volume

Clear Save

Snapping Sidewalk Attach Zebra

DIAGNOSTIC PMR

Annotations < >

GEOVELO



pas de rampe

E:574404.82
N:6279673.13
h:142.04

Simulation

- Simulation results quality depends on model quality:
 - **Traffic** : 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**

Thank you for your attention

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