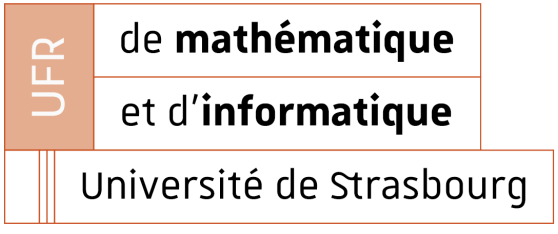

IRMA


Inria

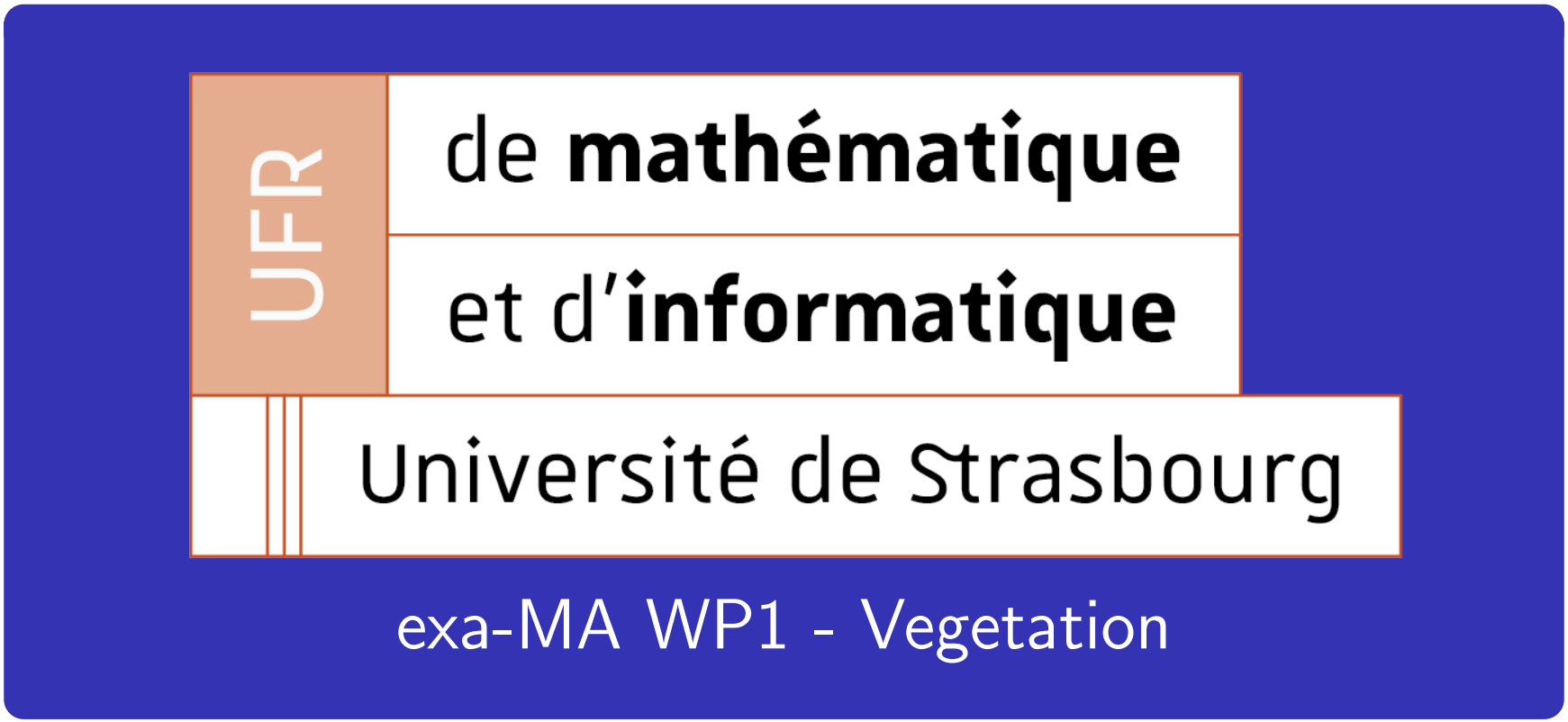

HiDALGO2
CENTRE OF EXCELLENCE


NumPEx


UFR
de mathématique
et d'informatique
Université de Strasbourg


cemosis
Centre de modélisation et de simulation de Strasbourg

Introduction



Pierre-Antoine SENGER

August 22, 2024

Introduction

This project is part of a series conducted within the **exa-MA** project, which is a segment of the **Numpex** project section.

- Exa-MA WP1 - Vegetation
- Exa-MA WP1 - Terrain
- Exa-MA WP1 - Urban Building LOD-1
- Exa-MA WP1 - Urban Building LOD-2 and Kinetic
- Exa-MA WP3 - Performance and Scalability

Introduction

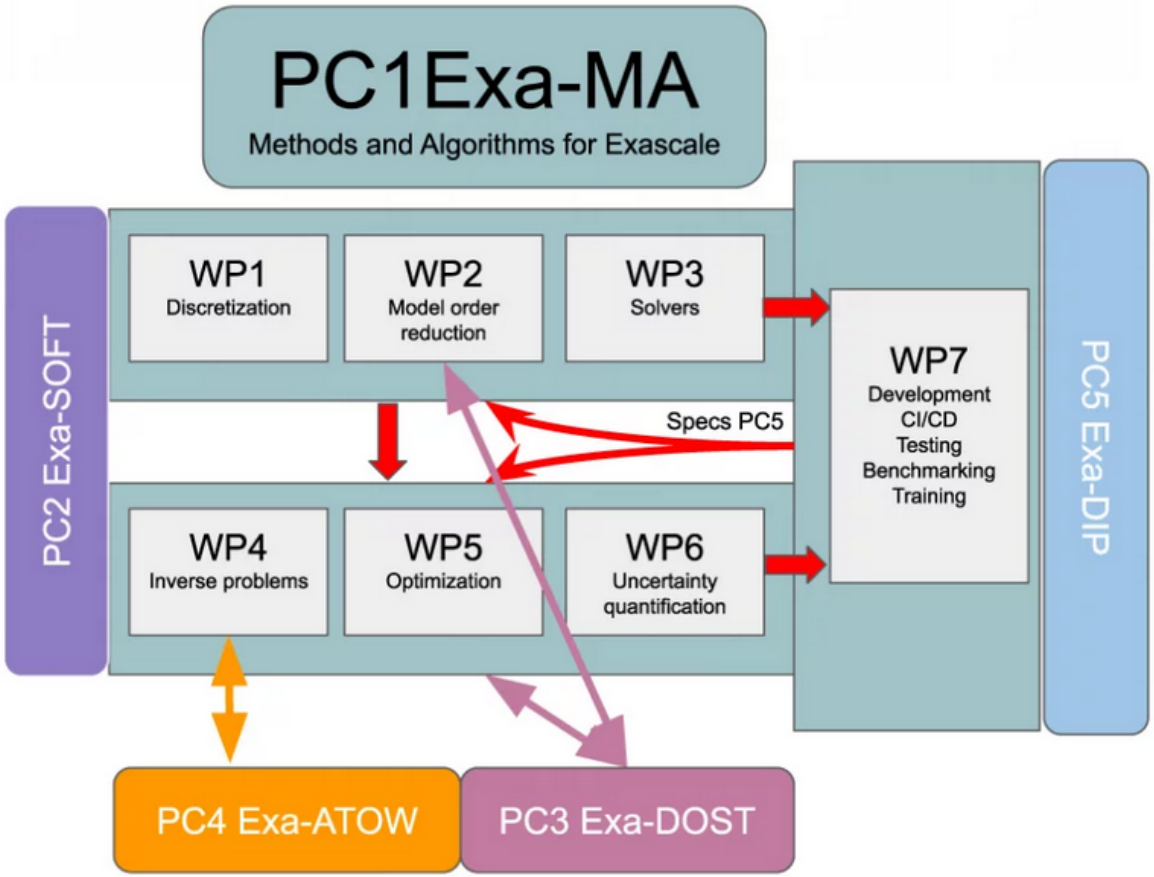


Figure: Exa-MA project overview [1]

Context

Figure: Hidalgo2 UBM poster [2]

- $\sim$ 75% of the EU buildings stocks is energy inefficient
- $\sim$ 40% of the EU energy consumption is due to buildings
- Buildings are responsible for $\sim$ 36% of the EU CO2 emissions

Context: Ktirio

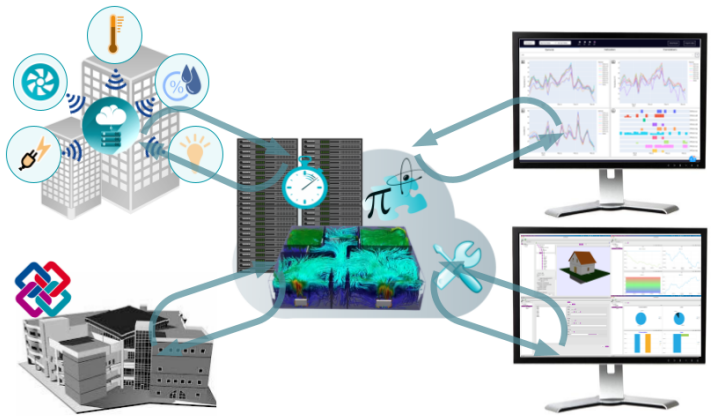


Figure: Ktirio project [3]

- Online platform for building energy simulation
- Provides tools for generating and simulating energy models
- Offers comfort and energy performance indicators
- Real-time monitoring of energy consumption/comfort
- Uses data assimilation to improve model reliability
- Incorporates model order reduction methods to speed up simulations
- Deployed on a cloud platform for access to computing resources

Context: Primiray focus

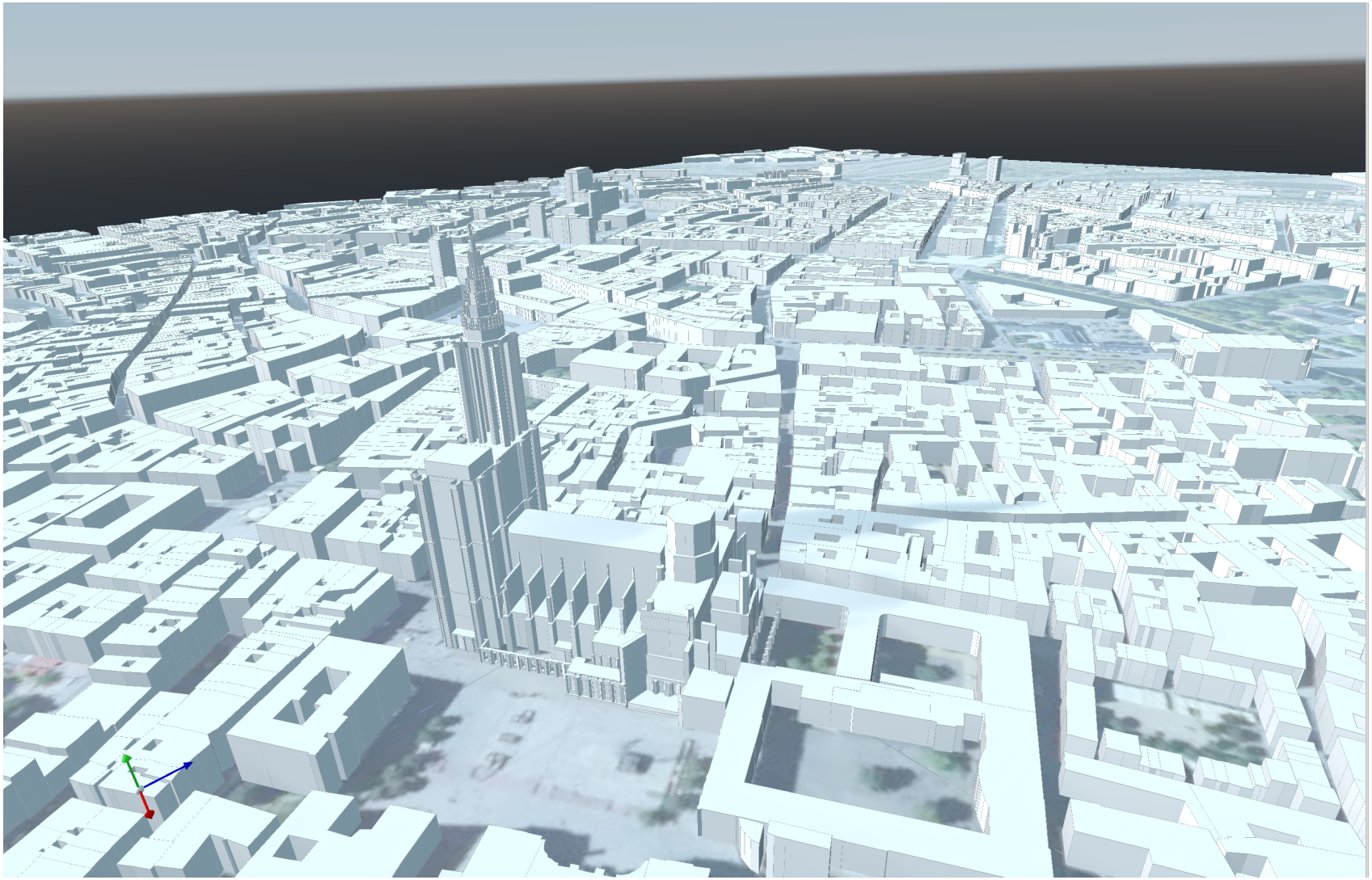


Figure: 3D Model of Strasbourg, France

Context: Adaptibility

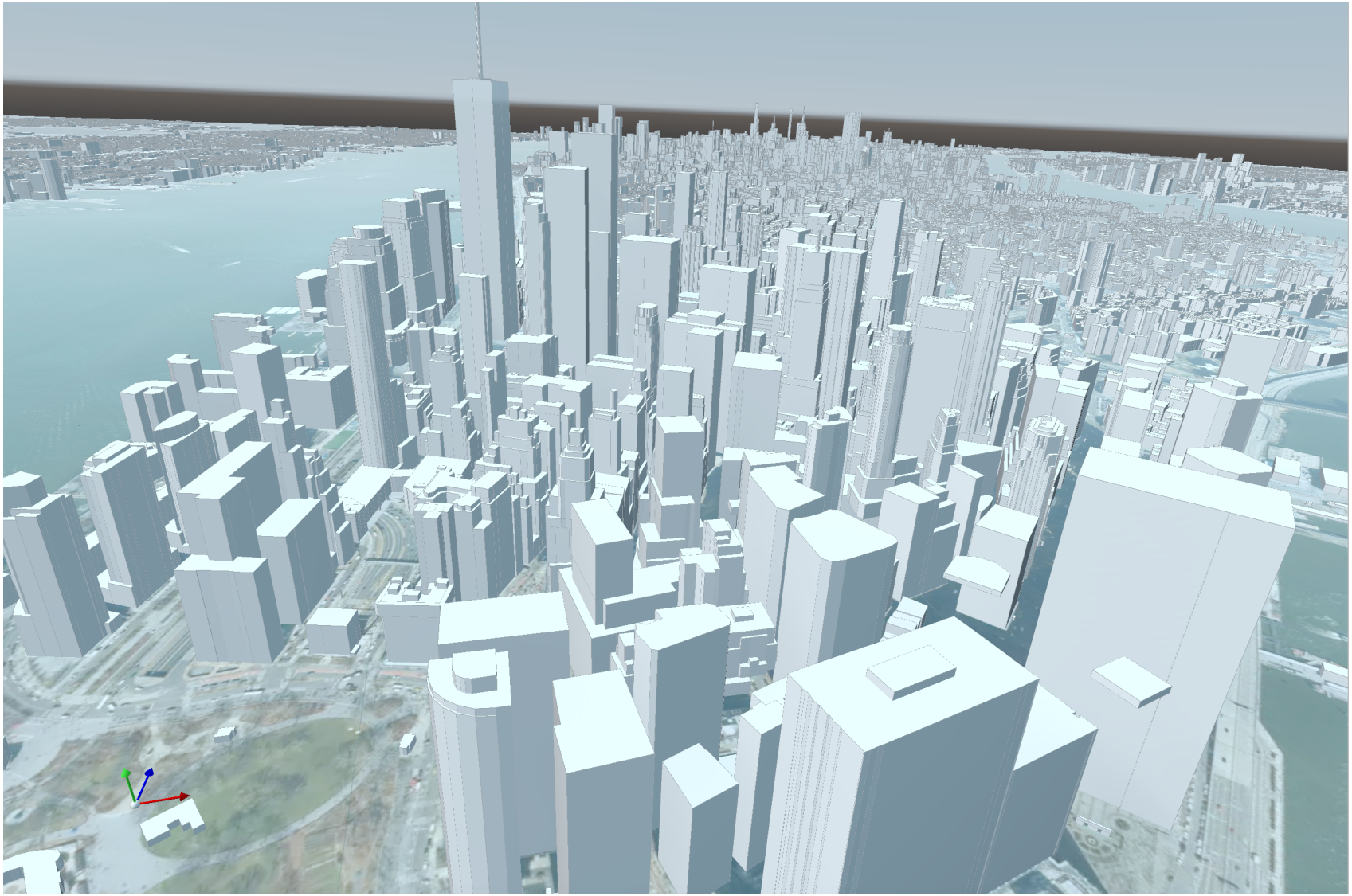


Figure: 3D Model of Manhattan, New York [4]

Objectives

- **Extracting tree data** from **OpenStreetMap**
- **Generating 3D tree models**
- **Integrating tree models** in the **terrain mesh**
- **Optimizing computational efficiency**

Methodology Steps

- Data Acquisition
- Generating Tree Library
- Scaling Trees
- Placing Trees
- Merging Meshes
- Parallelization

Data Acquisition

Figure: OpenStreetMap Logo

Figure: Curl Logo

Data Acquisition: Query Class

```
1  void perform_query(std::string bbox, bool verbose) {
2      std::string query =
3          "[out:json]; (node(" + bbox + ")[\"natural\"=\"tree
       \"];); out;";
4      cpr::Response r = cpr::Post(
5          cpr::Url{"http://overpass-api.de/api/interpreter"},
       cpr::Body{query},
6          cpr::Header{{"Content-Type", "application/x-www-form
       -urlencoded"}},
7          cpr::Timeout{10000} // Set a timeout of 10 seconds
8      );
9  }
10
```

Data acquisition: .json output


```
{
  "type": "node",
  "id": 10162018740,
  "lat": 48.5850910,
  "lon": 7.7502624,
  "tags": {
    "circumference": "1.47655",
    "diameter_crown": "5",
    "genus": "Platanus",
    "height": "6",
    "leaf_cycle": "deciduous",
    "leaf_type": "broadleaved",
    "natural": "tree",
    "ref": "16401",
    "source": "data.strasbourg.eu - patrimoine_arbore",
    "source:date": "2022-01-02",
    "species": "Platanus acerifolia x",
    "species:wikidata": "Q24853030"
  }
}
```

Generating Tree Library

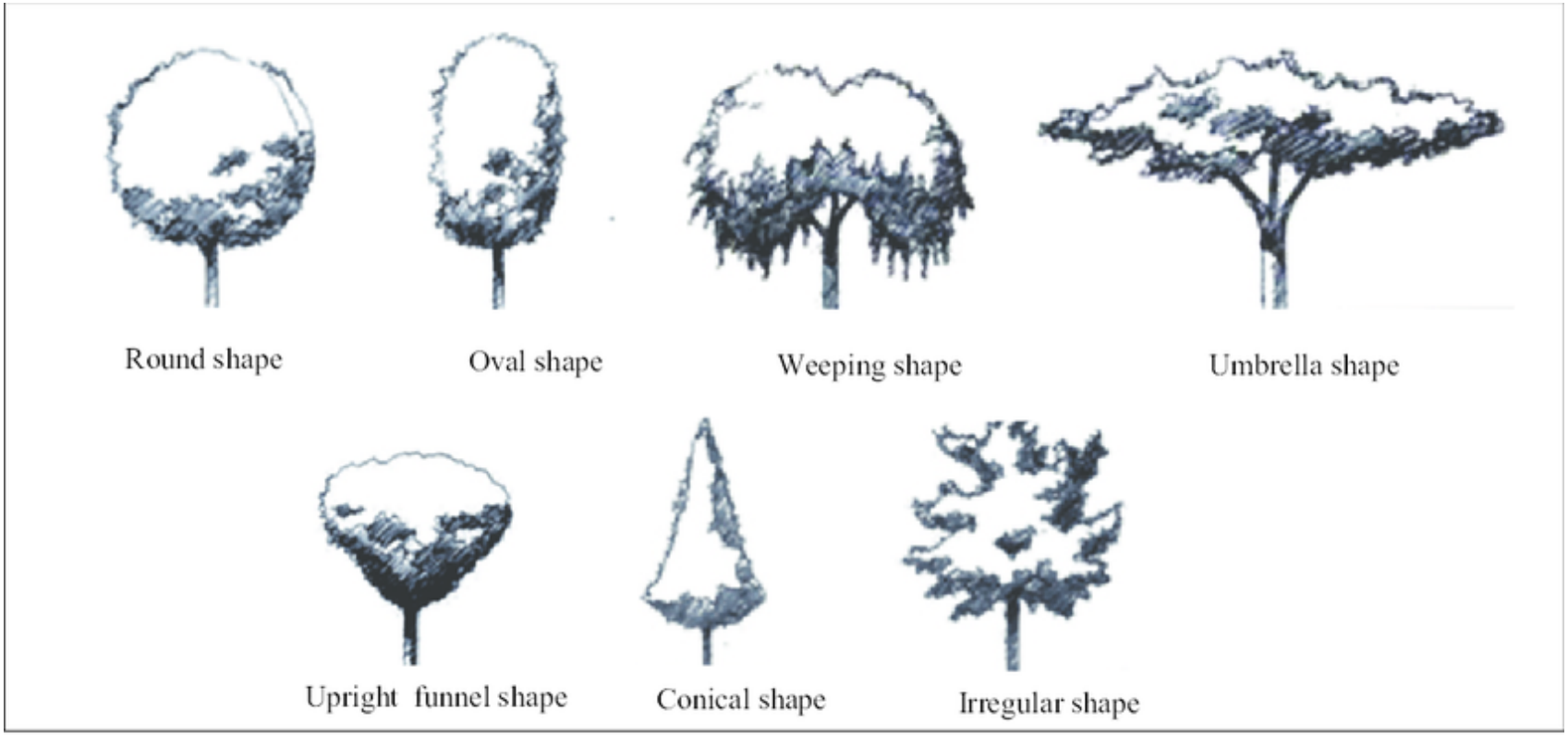


Figure: Different tree shapes

Tree Modeling: lod 0

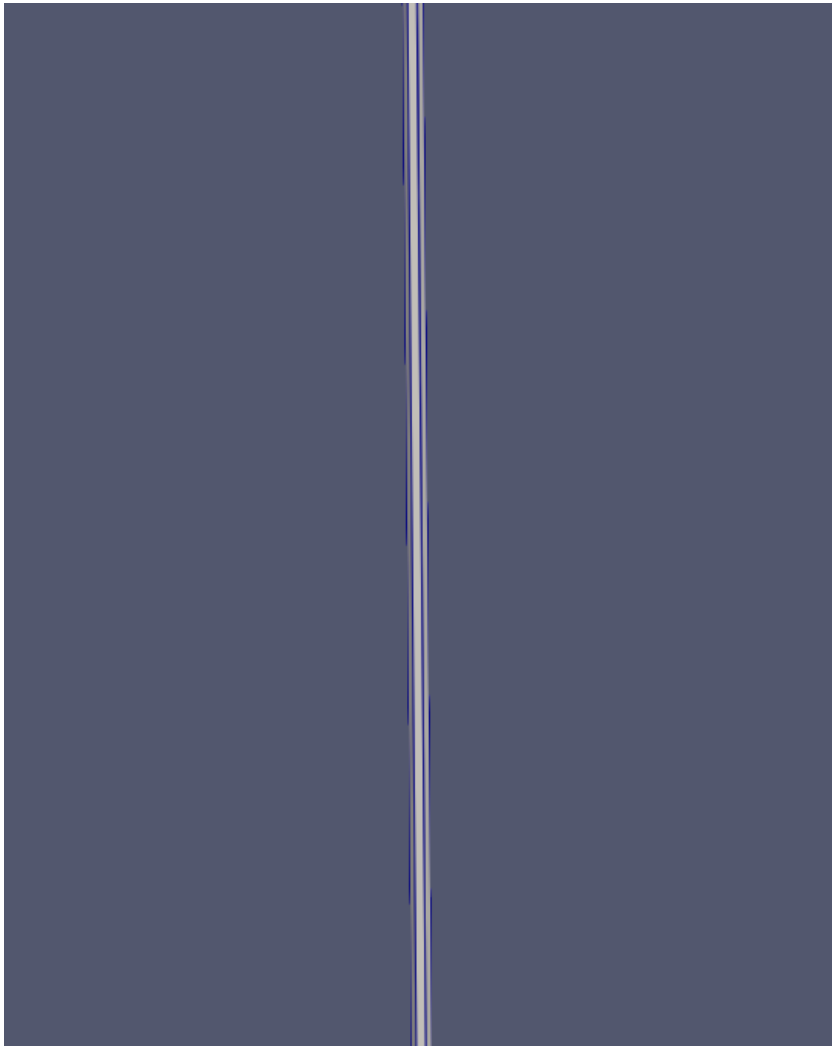


Figure: Tree Trunk model

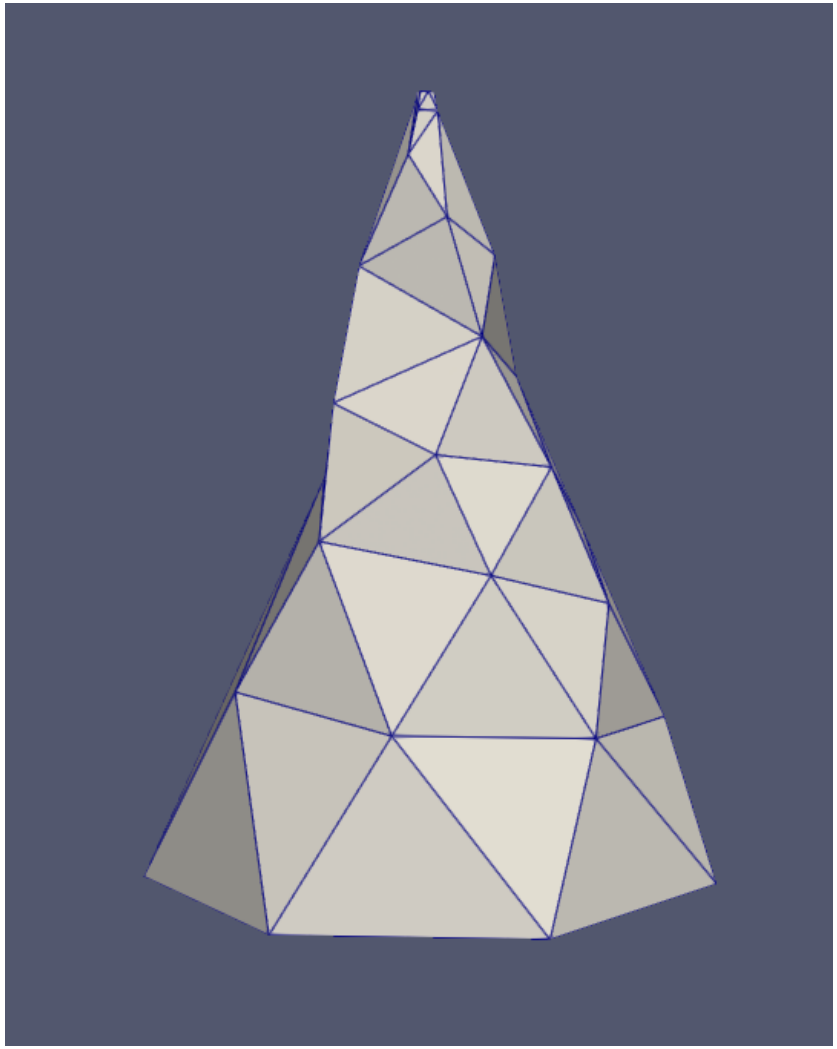


Figure: Cone shaped Tree model

Tree Modeling: lod 0

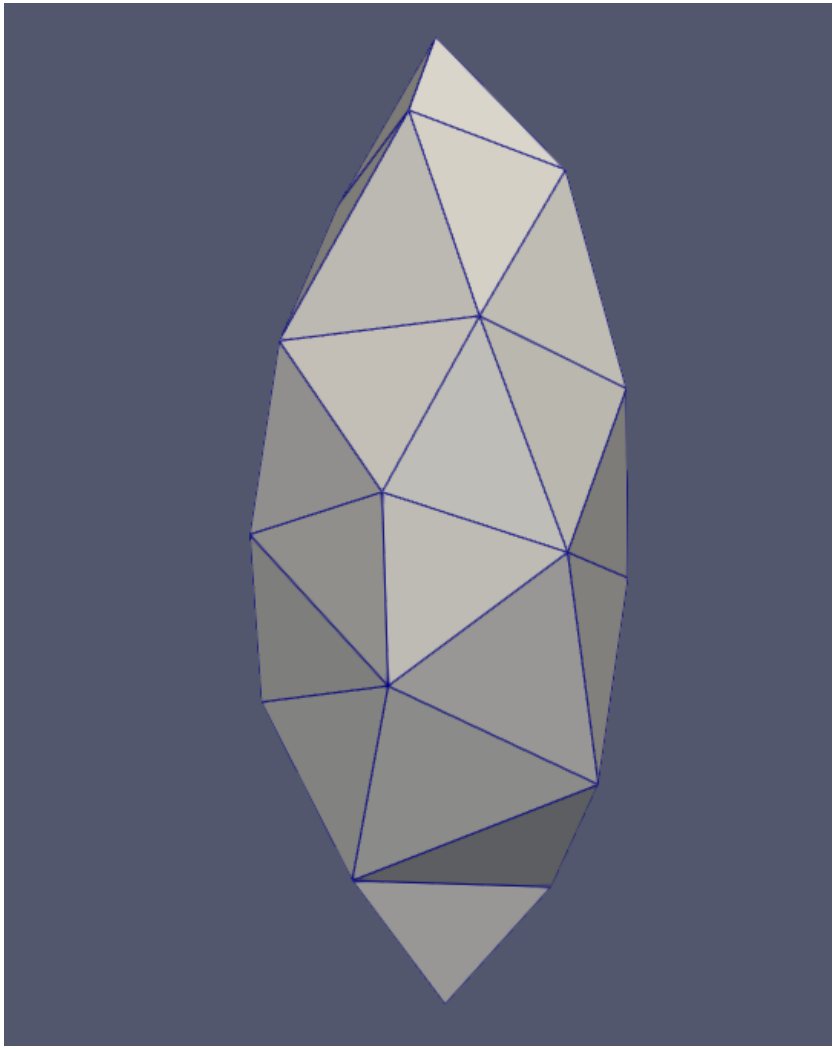


Figure: Oval shaped Tree model

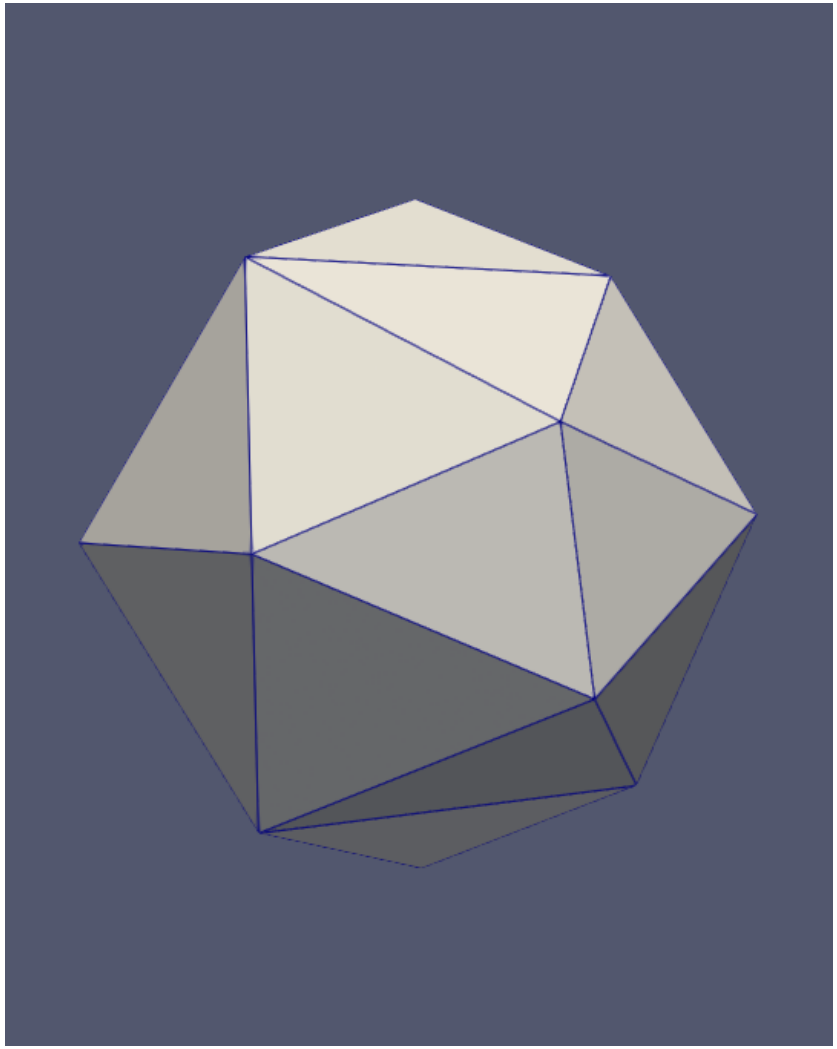


Figure: Round shaped Tree model

Tree Modeling: lod 1,2 and 3

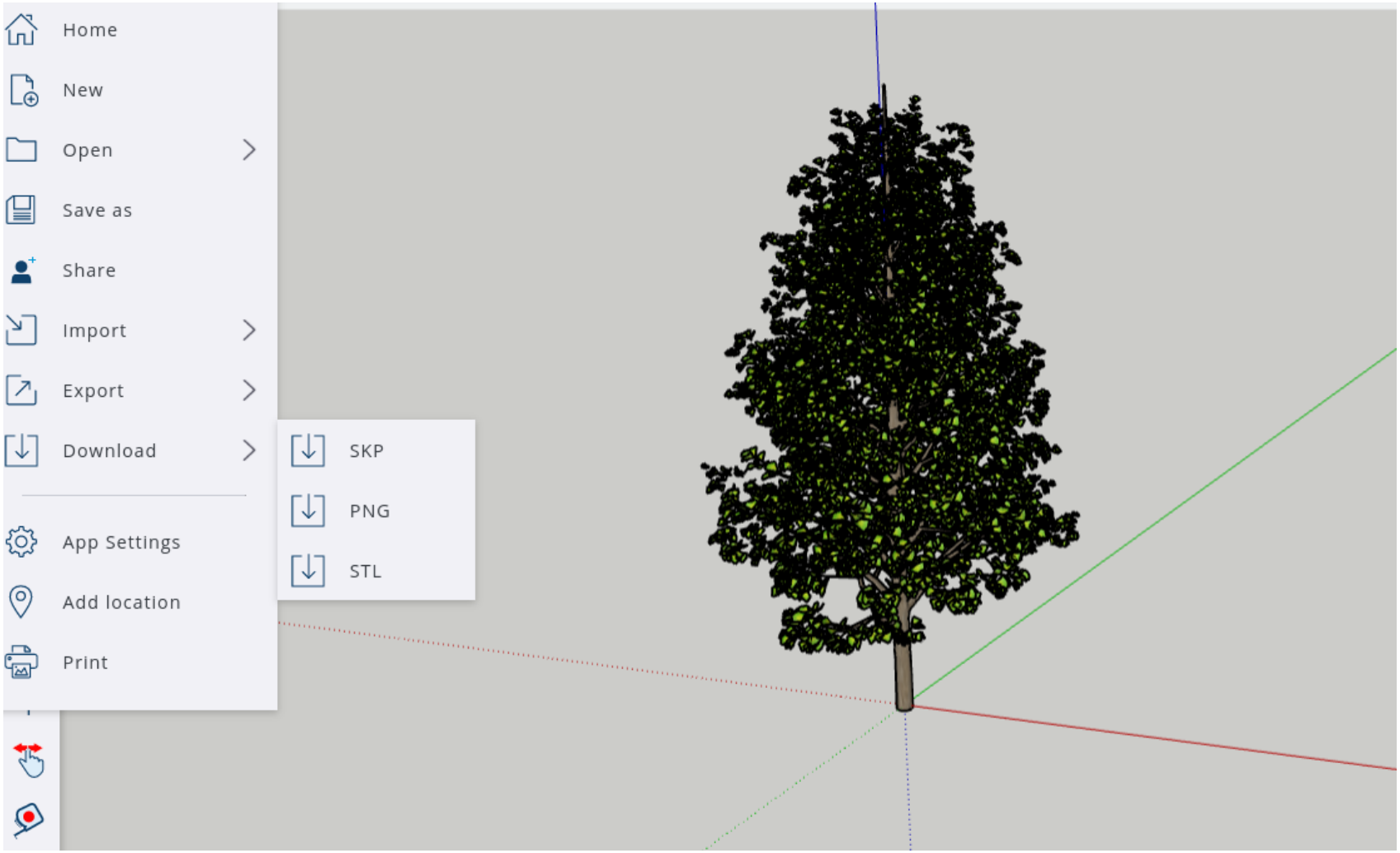


Figure: 3D model of a Ginkgo tree on Sketchup

Tree preprocessing

Remove trunk/branches, normalize and center

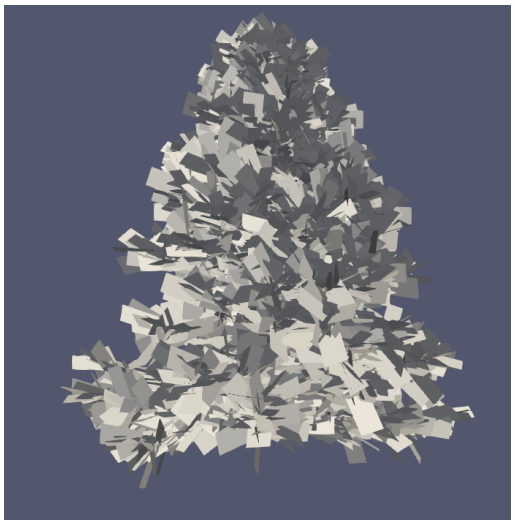


Figure: A preprocessed conifer tree

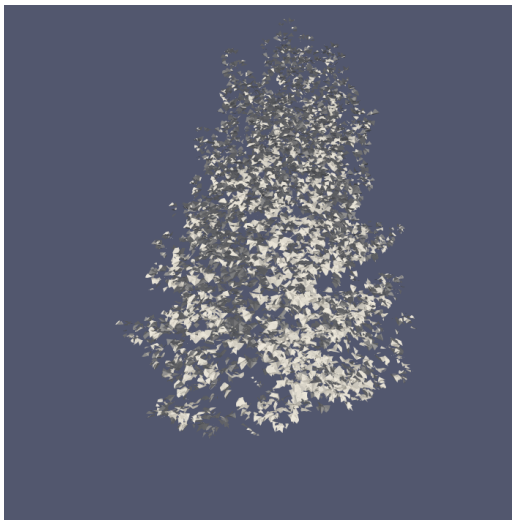


Figure: A preprocessed Ginkgo tree

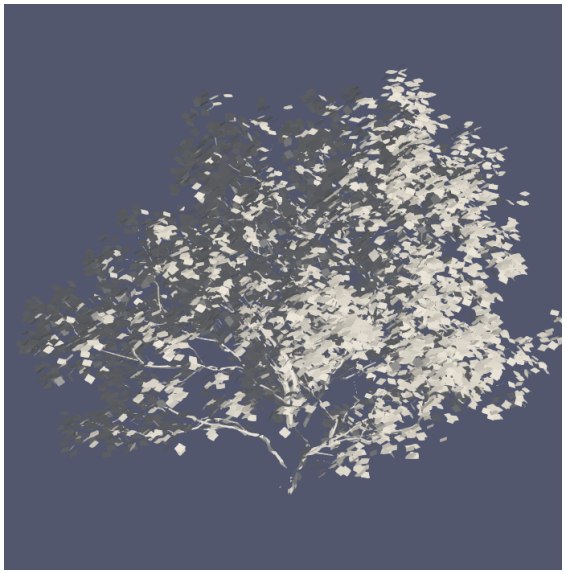
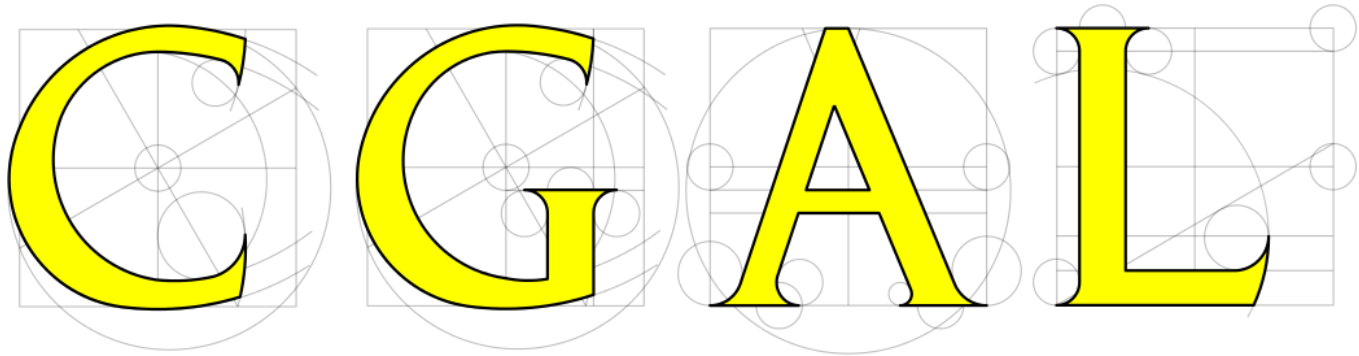


Figure: A preprocessed Quercus tree

Sofware and libraries: CGAL



Open source software library for **computational geometry algorithms**

Tree modeling: Alpha Wrapping

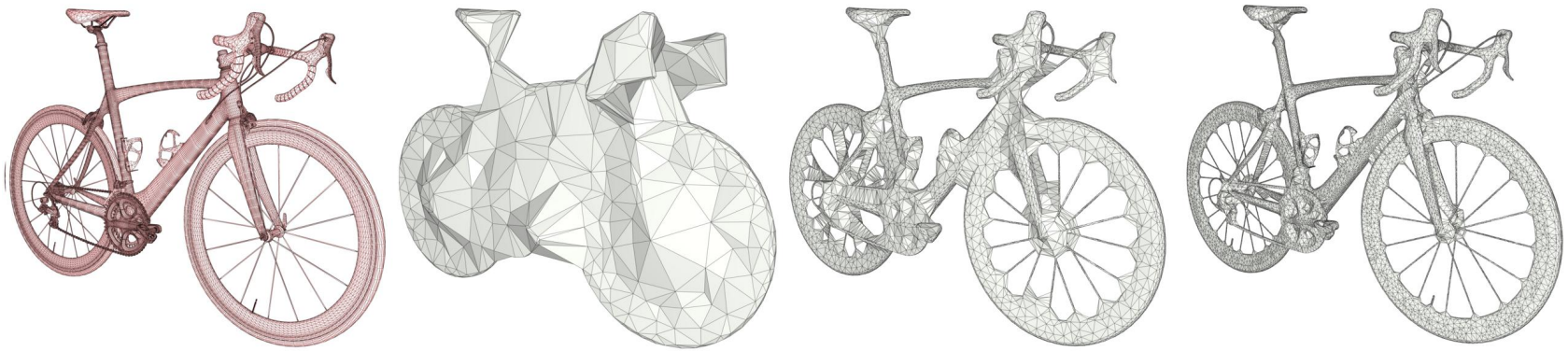


Figure: Different LOD of the Alpha Wrapping of a bike[5]

Tree modeling: Alpha Wrapping

Input:

- 3D model with possible defects

Output:

- Water-tight mesh
- No self-intersections
- Strictly enclosing the input
- Well shaped triangles

Tree modeling: Alpha Wrapping

Figure: Alpha Wrapping in 2D with Offset and different Alpha parameters

Tree Modeling: lod 1,2 and 3

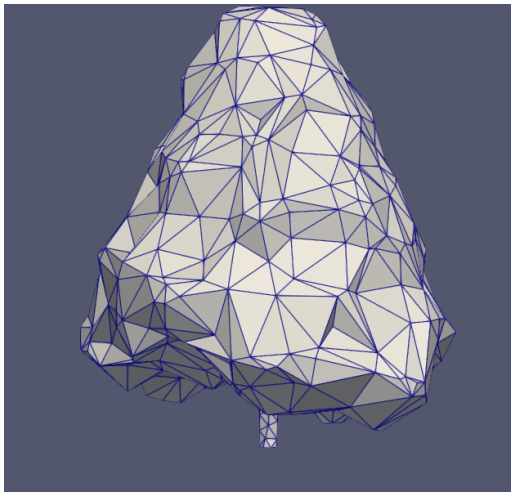


Figure: A wrapped conifer tree for LOD 1

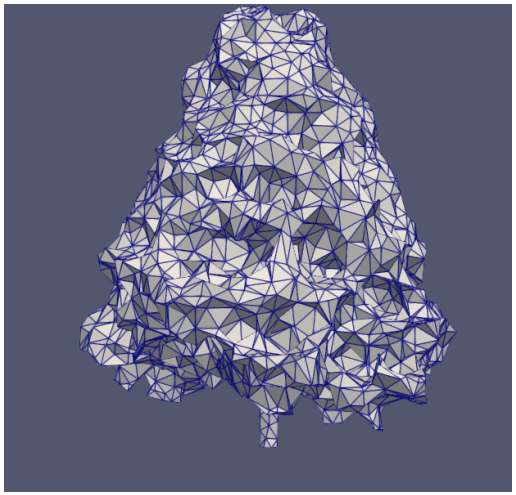


Figure: A wrapped conifer tree for LOD 2

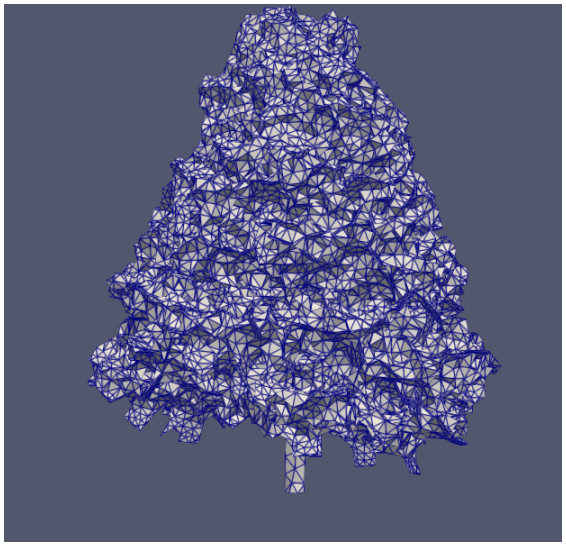


Figure: A wrapped conifer tree for LOD 3

Tree Modeling: lod 1,2 and 3

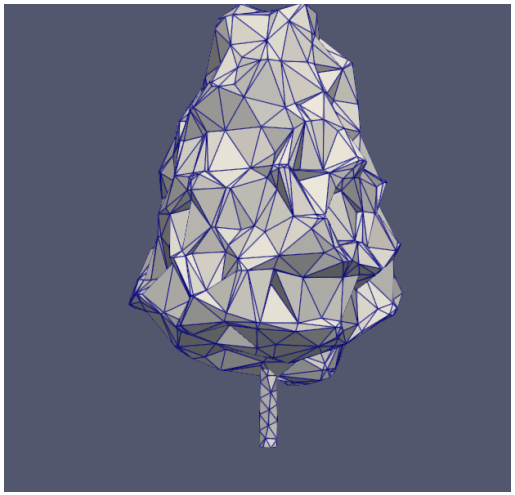


Figure: A wrapped Ginkgo tree for LOD 1

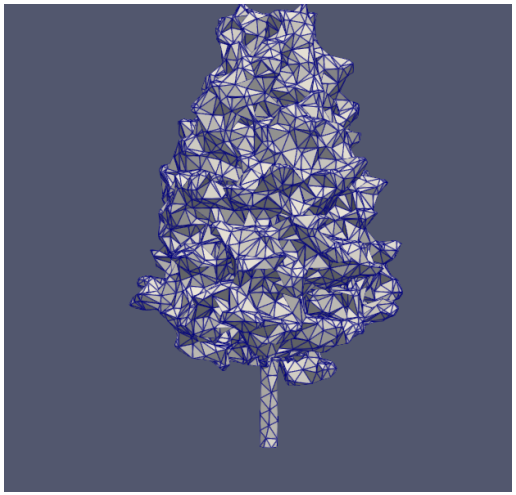


Figure: A wrapped Ginkgo tree for LOD 2

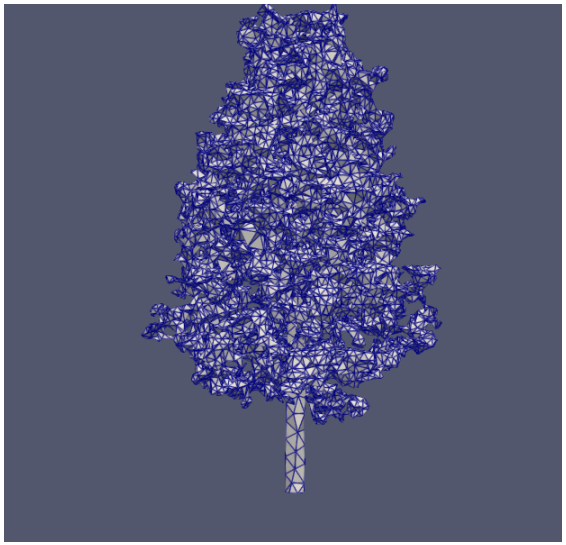


Figure: A wrapped Ginkgo tree for LOD 3

Tree Modeling: lod 1,2 and 3

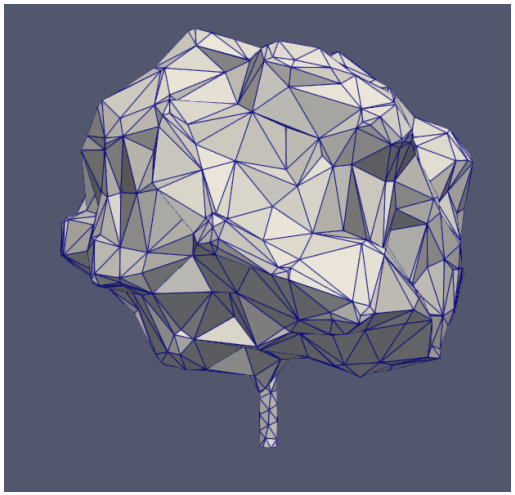


Figure: A wrapped Quercus tree for LOD 1

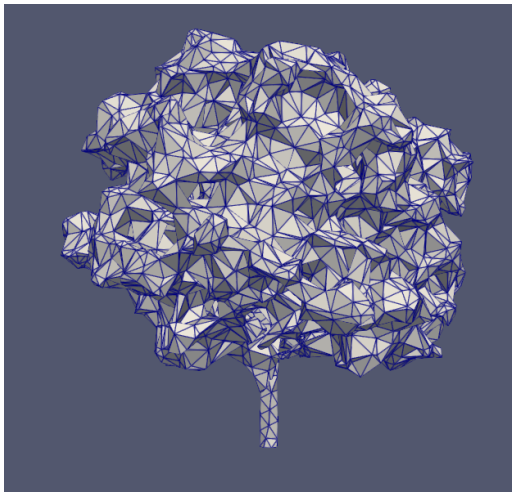


Figure: A wrapped Quercus tree for LOD 2

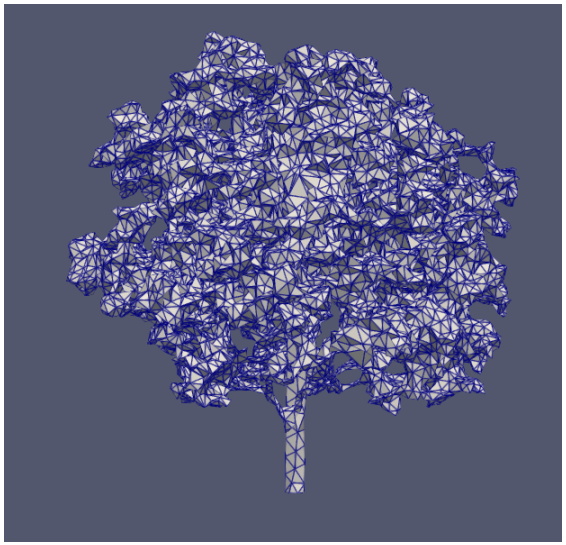


Figure: A wrapped Quercus tree for LOD 3

Tree Modeling: tagging leaves

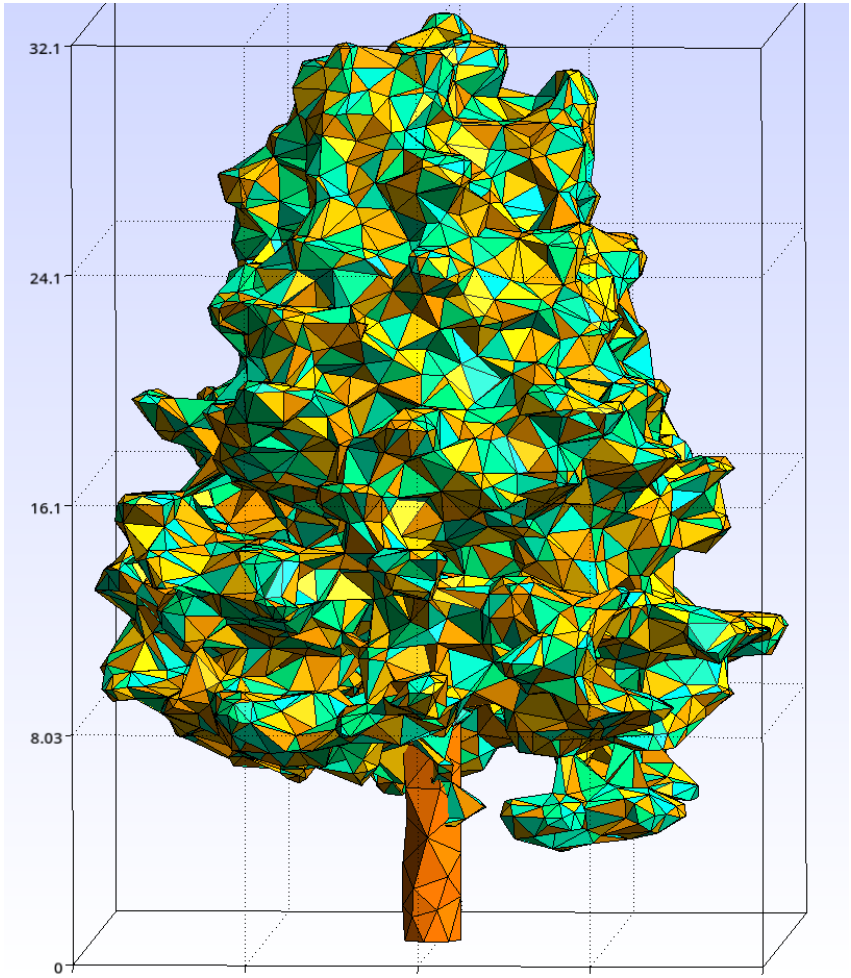


Figure: A tree with 4 different markers on the leaves

Tree Modeling: tree's scaling

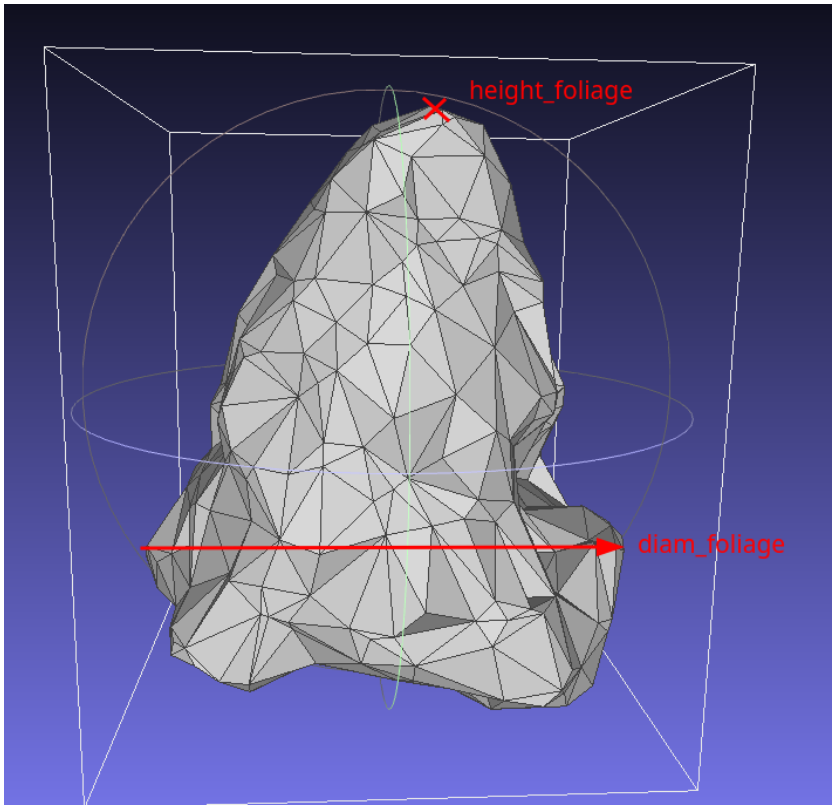


Figure: Foliage mesh

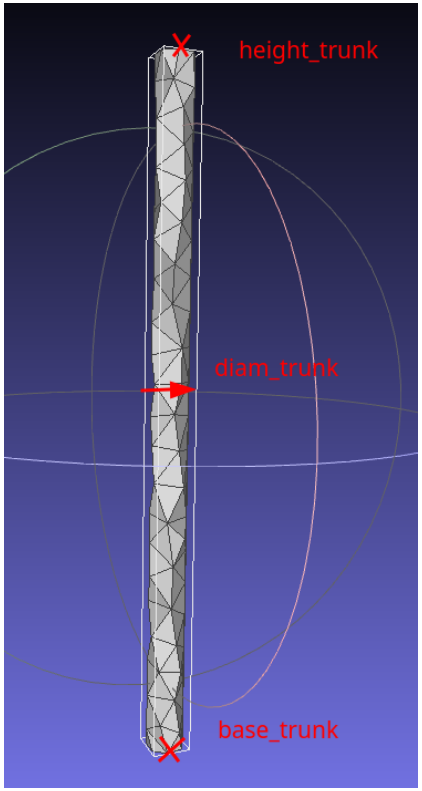


Figure: Trunk mesh

Tree Modeling: Mercator's projection

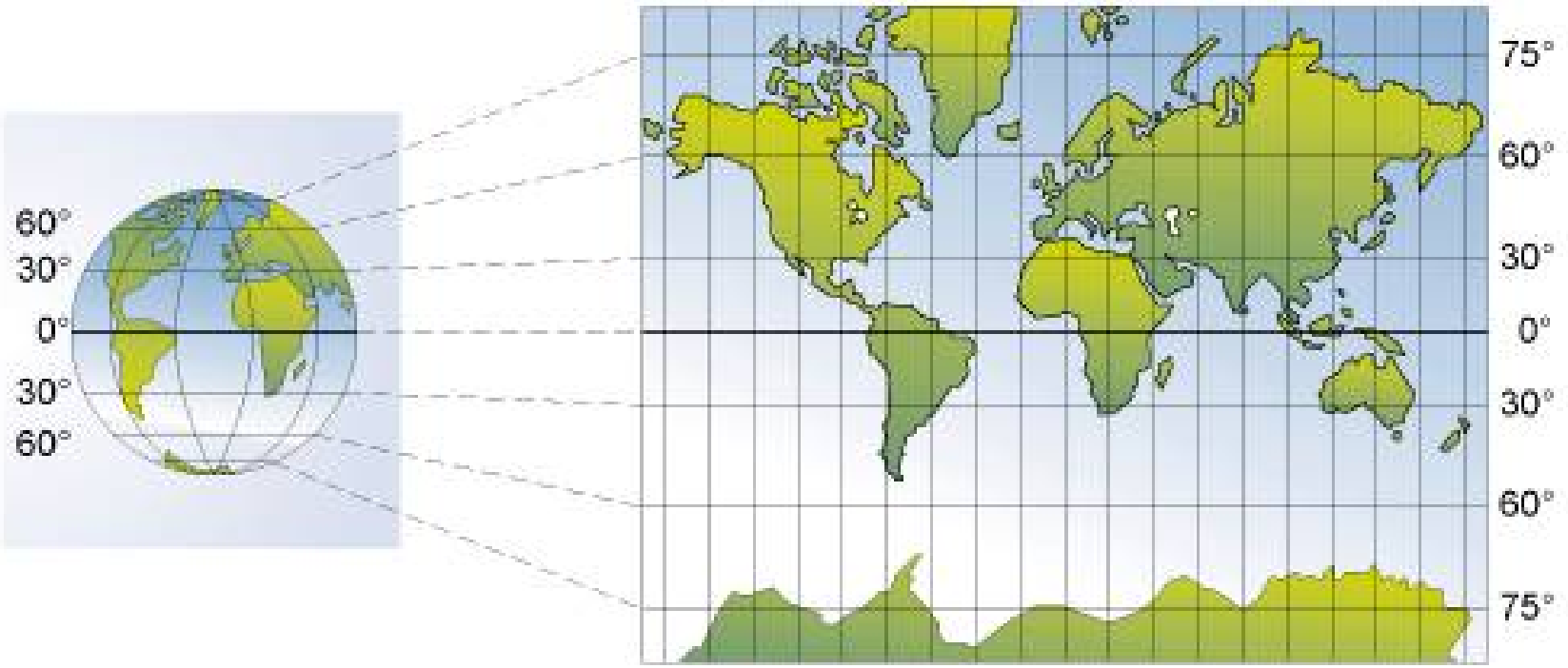


Figure: Mercator's projection[6]

Tree Modeling: Mercator's projection

$$\mathrm{A}(\text{latitude, longitude}) = \mathrm{A}(\phi, \lambda),$$

$$\text{projection} \Longrightarrow \quad \begin{cases} x = \lambda - \lambda_0 \\ y = \ln(\tan(\frac{\pi}{4} + \frac{\phi}{2})) \end{cases} \tag{1}$$

,where λ_0 is the center of the map

Tree Modeling: Mercator's projection

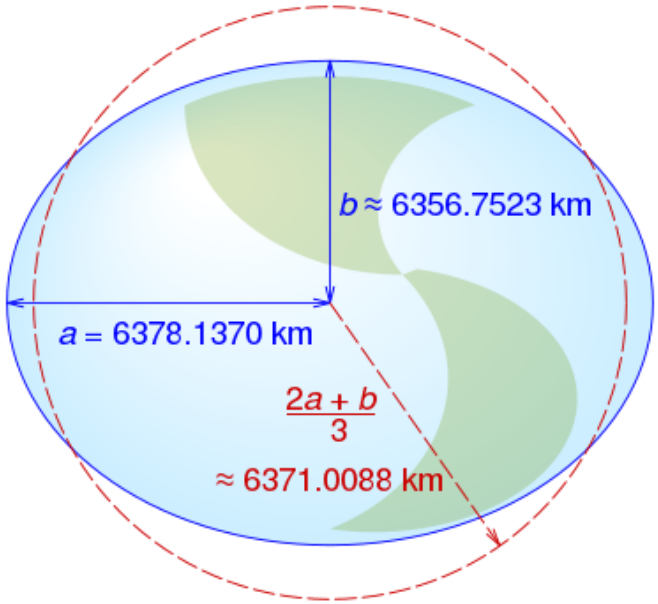


Figure: Earth as an ellipsoid[7]

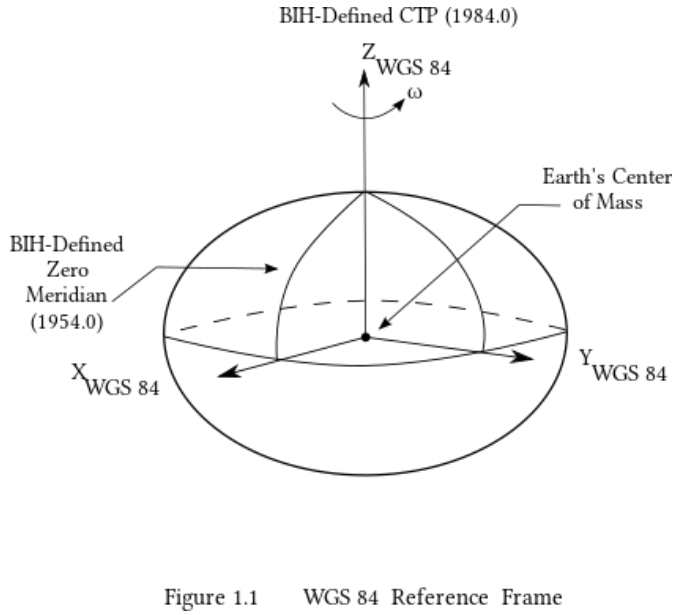


Figure: WGS 84 reference frame[7]

WGS84toCartesian.hpp $\Longrightarrow$ **GPS** to **Cartesian**

Tree Modeling: tree's placement

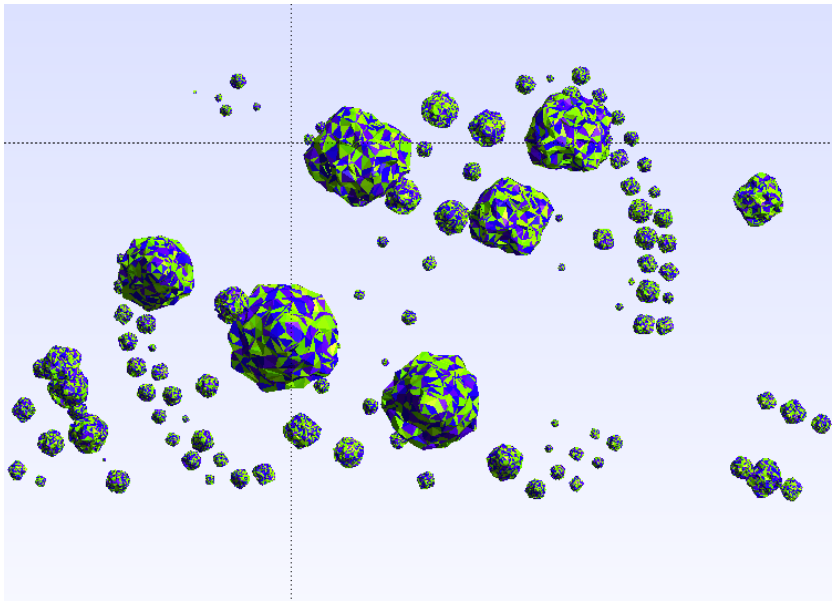


Figure: Republic square with LOD 1 trees

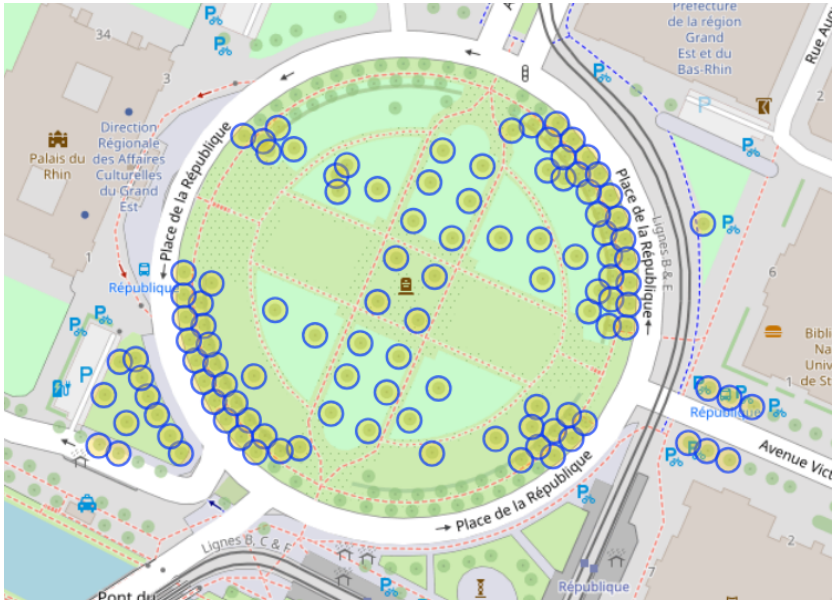


Figure: Republic square trees from Overpass turbo[8]

Tree Modeling: tree's placement

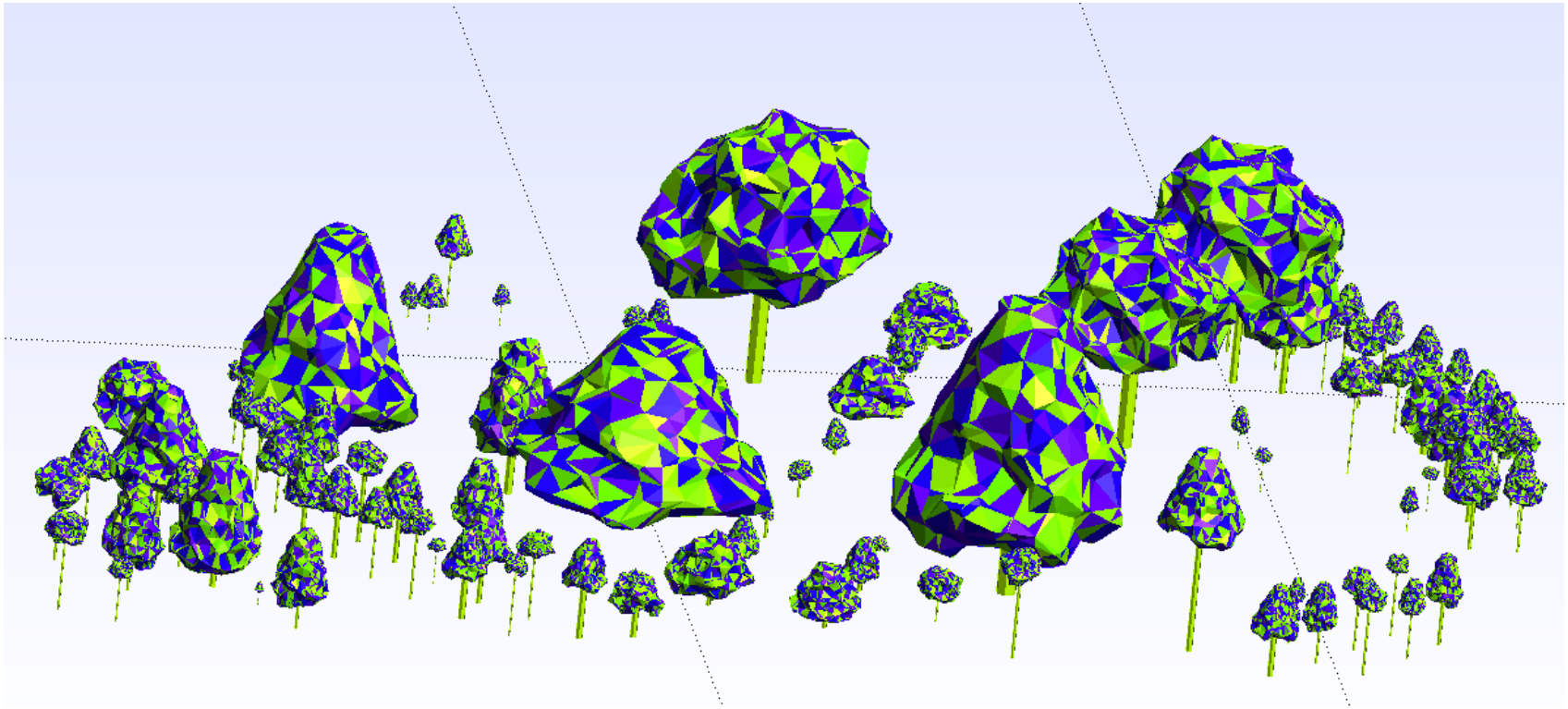


Figure: Republic square with LOD 1 trees

Tree Modeling: tree's altitude

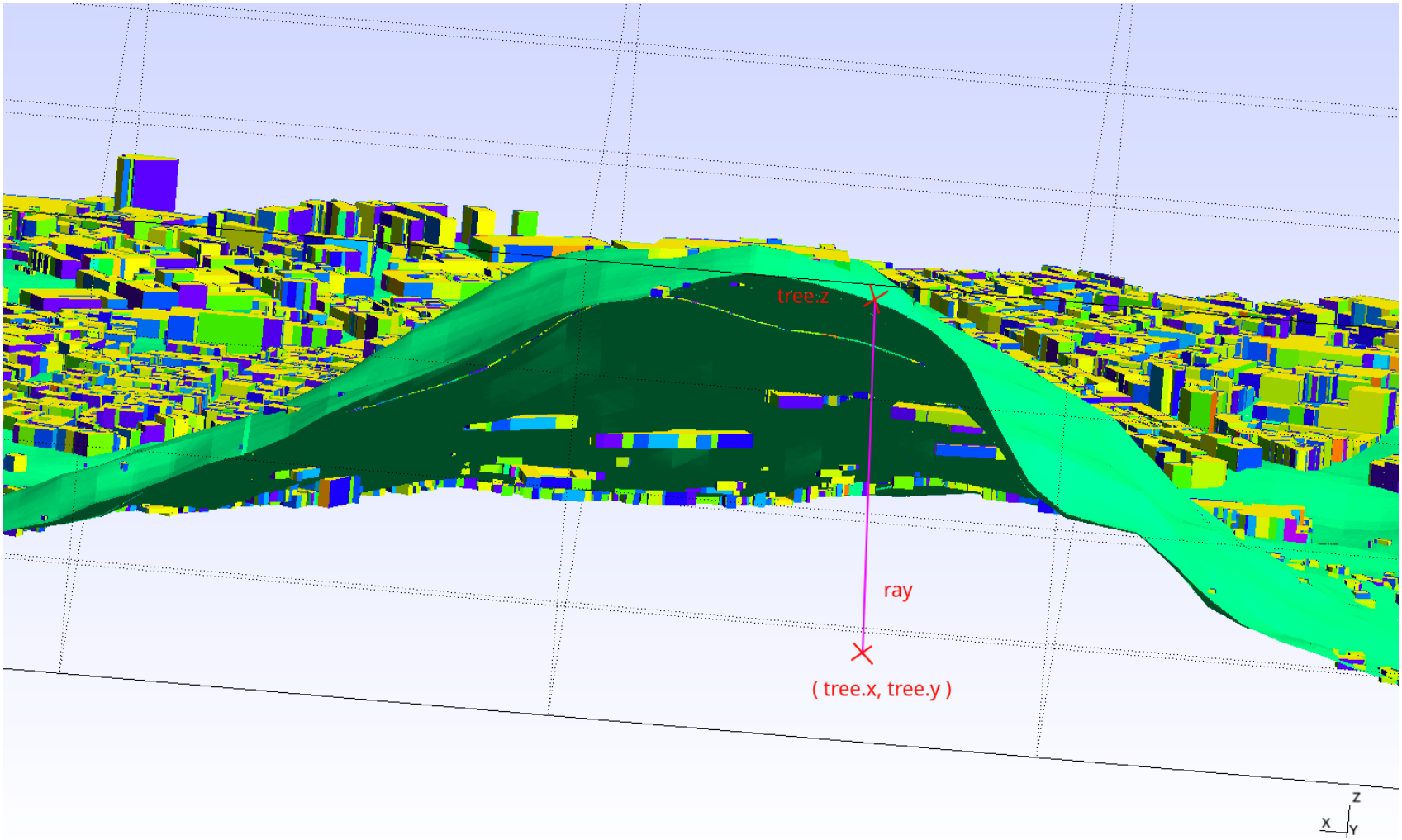


Figure: Raycasting of a tree in Grenoble, France

Tree Modeling: mesh merging

Figure: A plant going through a wall

Tree Modeling: mesh merging

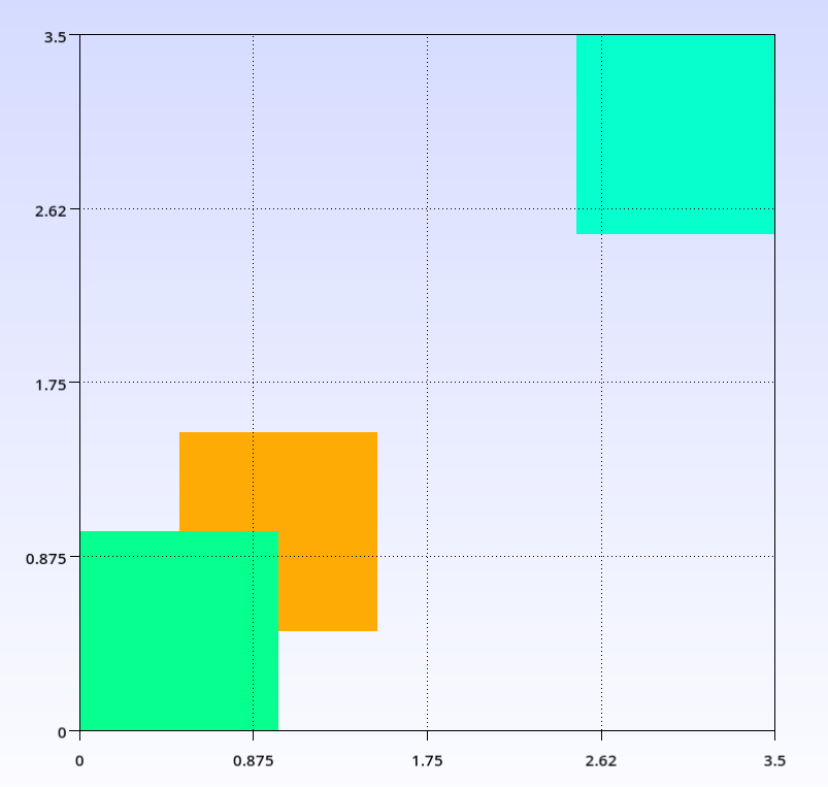


Figure: Autorefine before

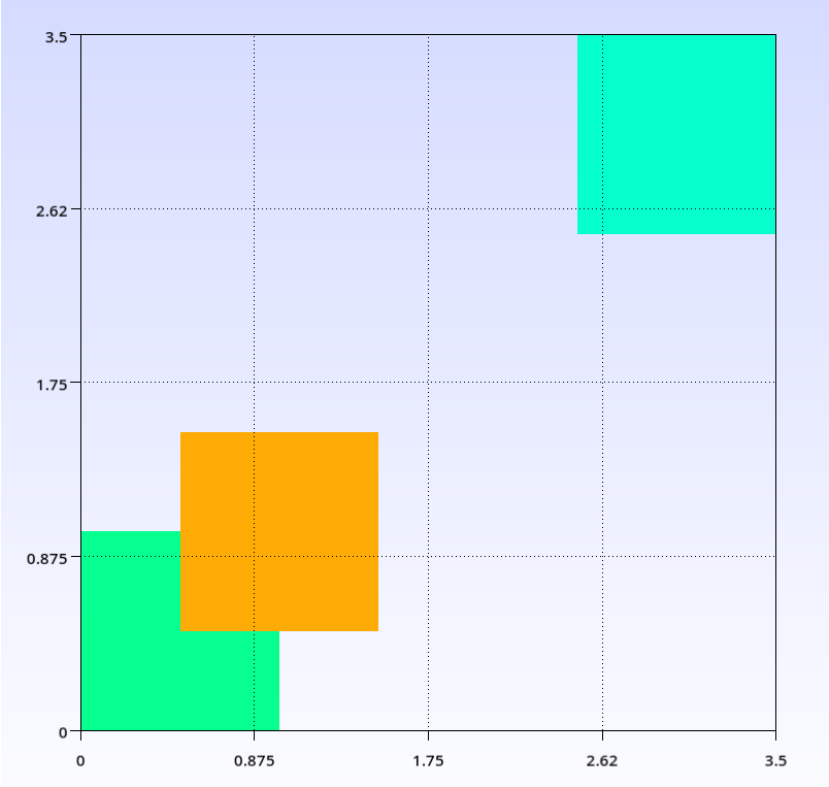


Figure: Autorefine after

Tree Modeling: thread parallelization

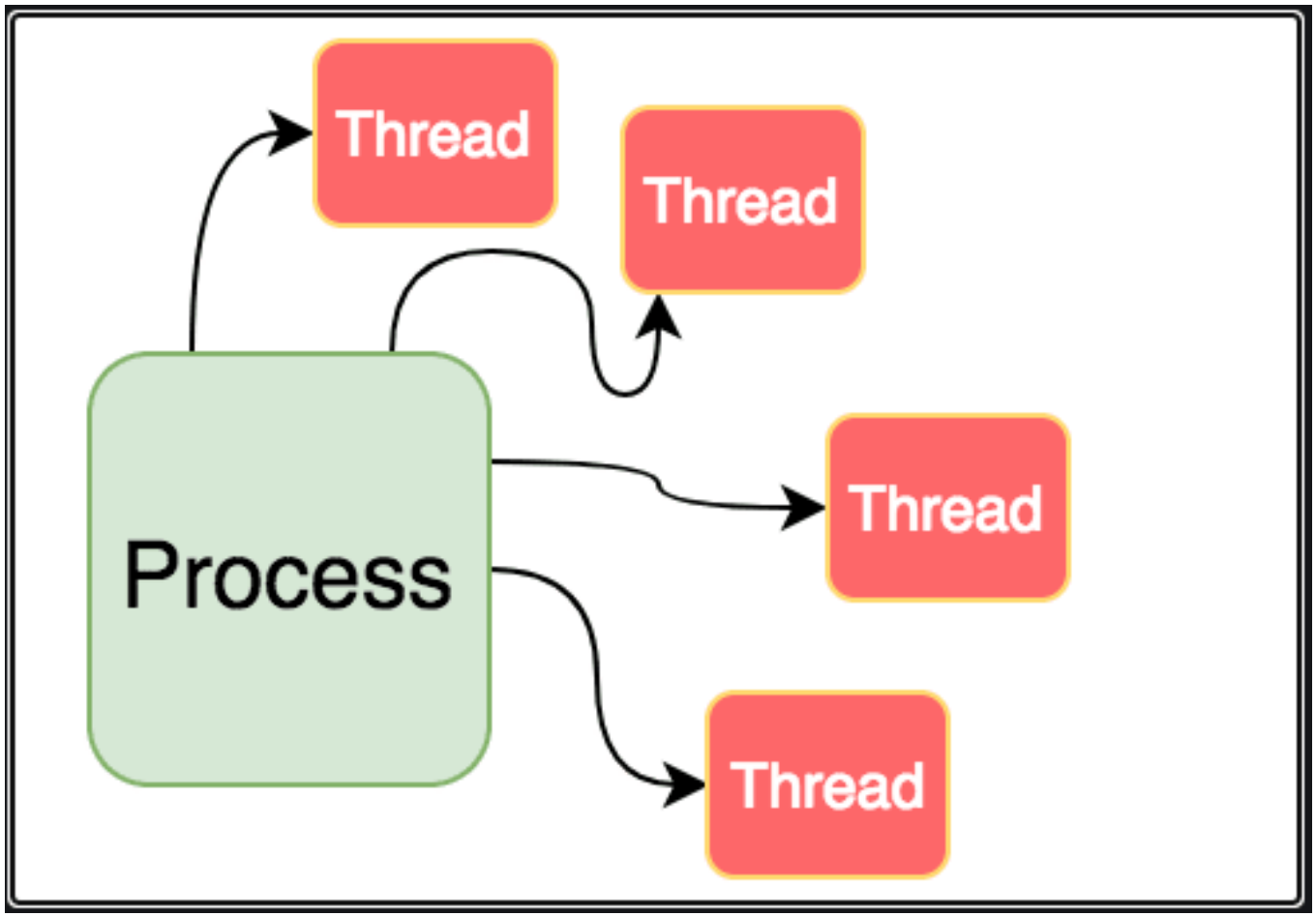


Figure: Parallelization of the tree generation process

Results: Model Integration

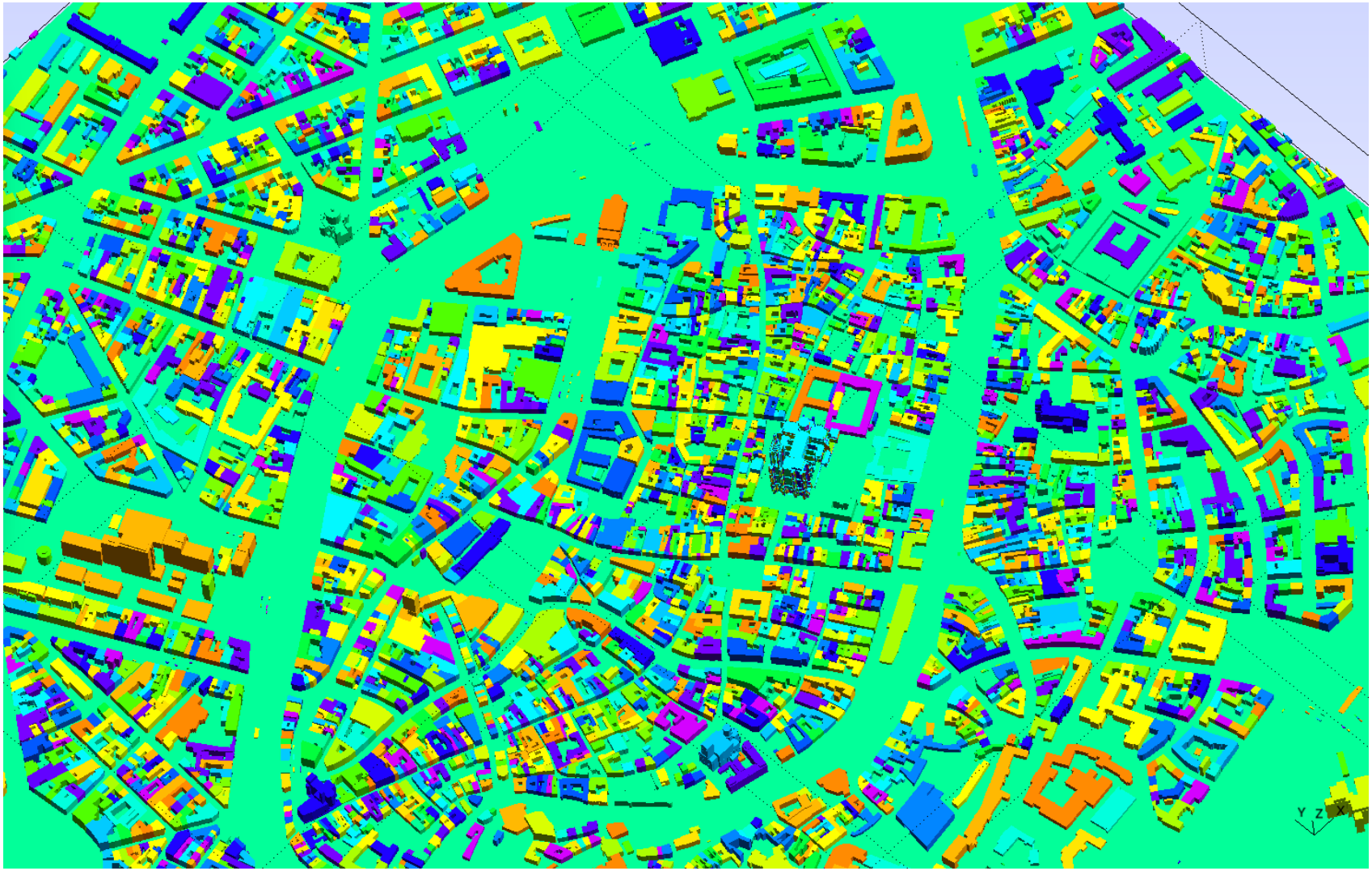


Figure: 3D Model of Strasbourg city center, buildings only

Results: Model Integration

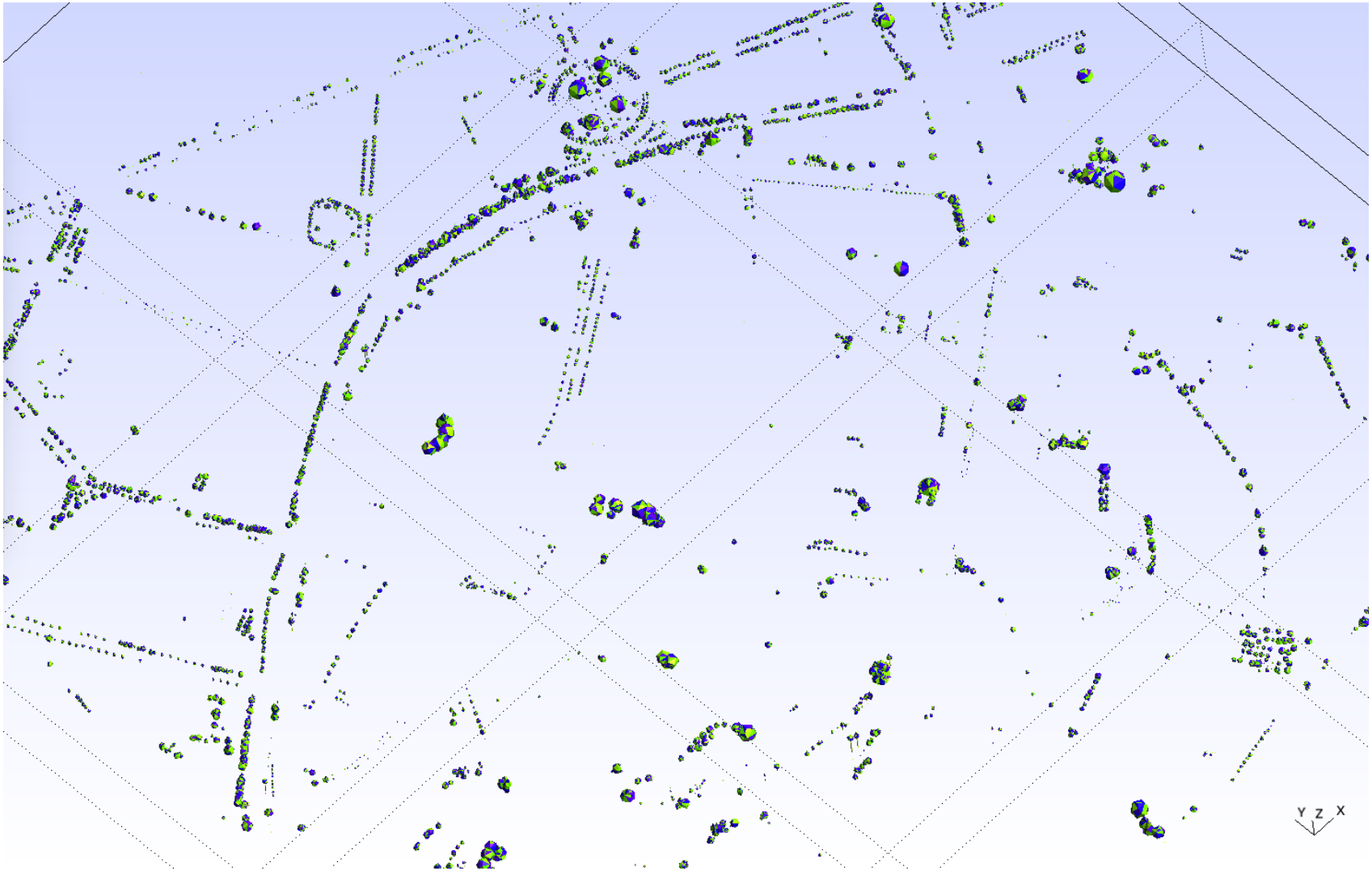


Figure: 3D Model of Strasbourg city center, trees only

Results: Model Integration

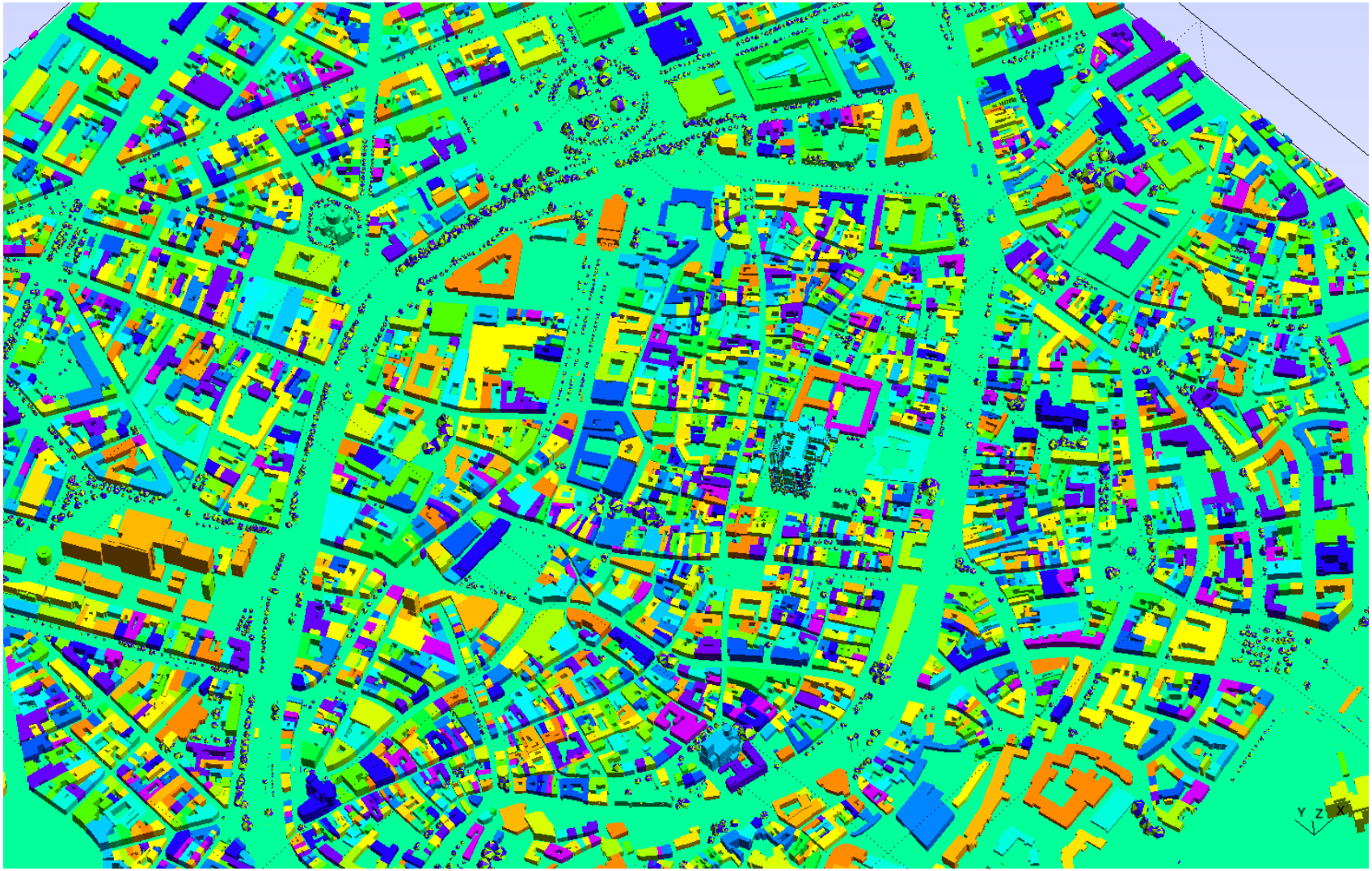


Figure: 3D Model of Strasbourg city center, buildings and trees

Results: Model Integration

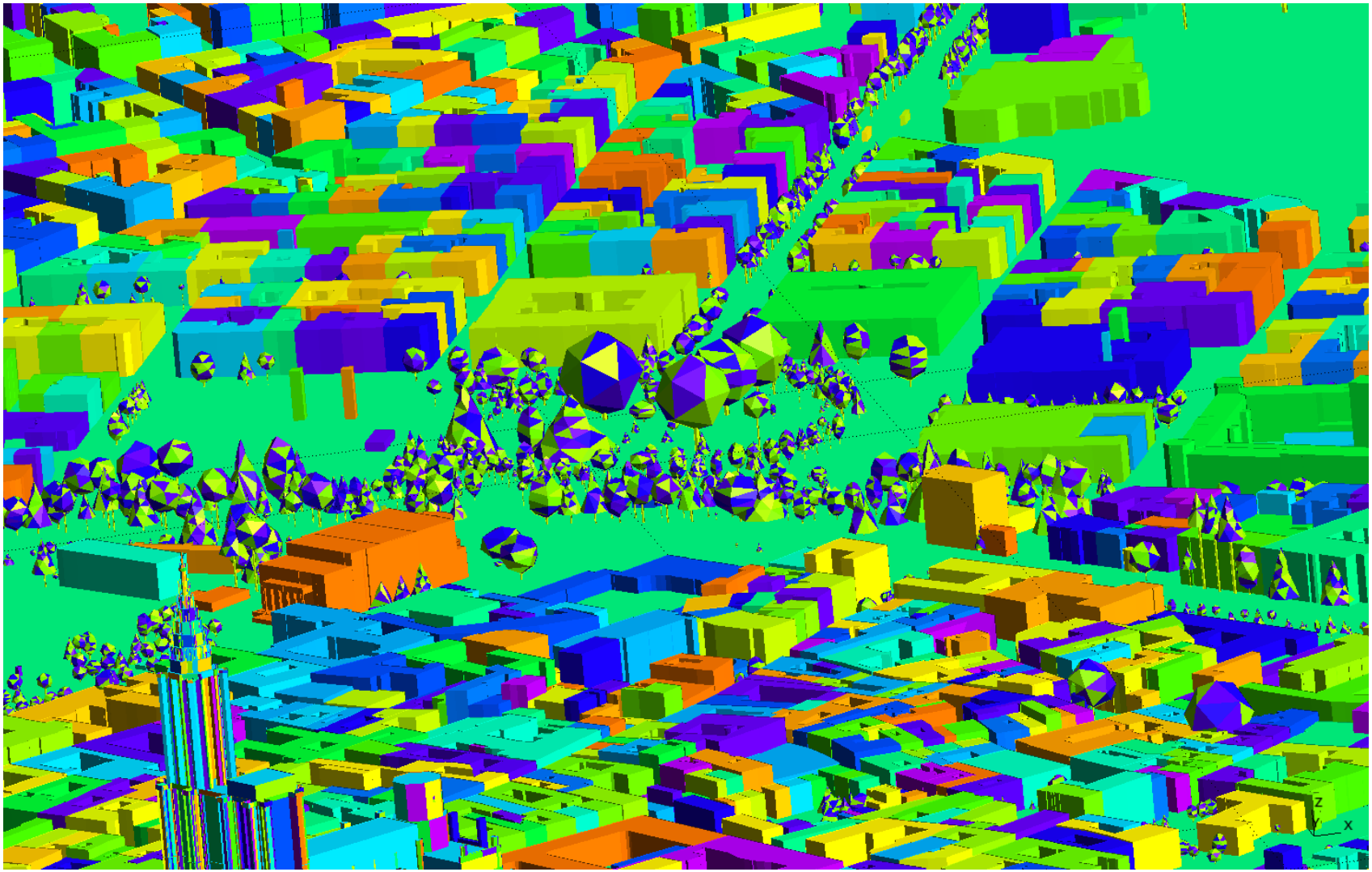


Figure: 3D Model of Strasbourg city center, buildings and vegetation, with a focus on Republic Square, LOD 0

Results: Model Integration

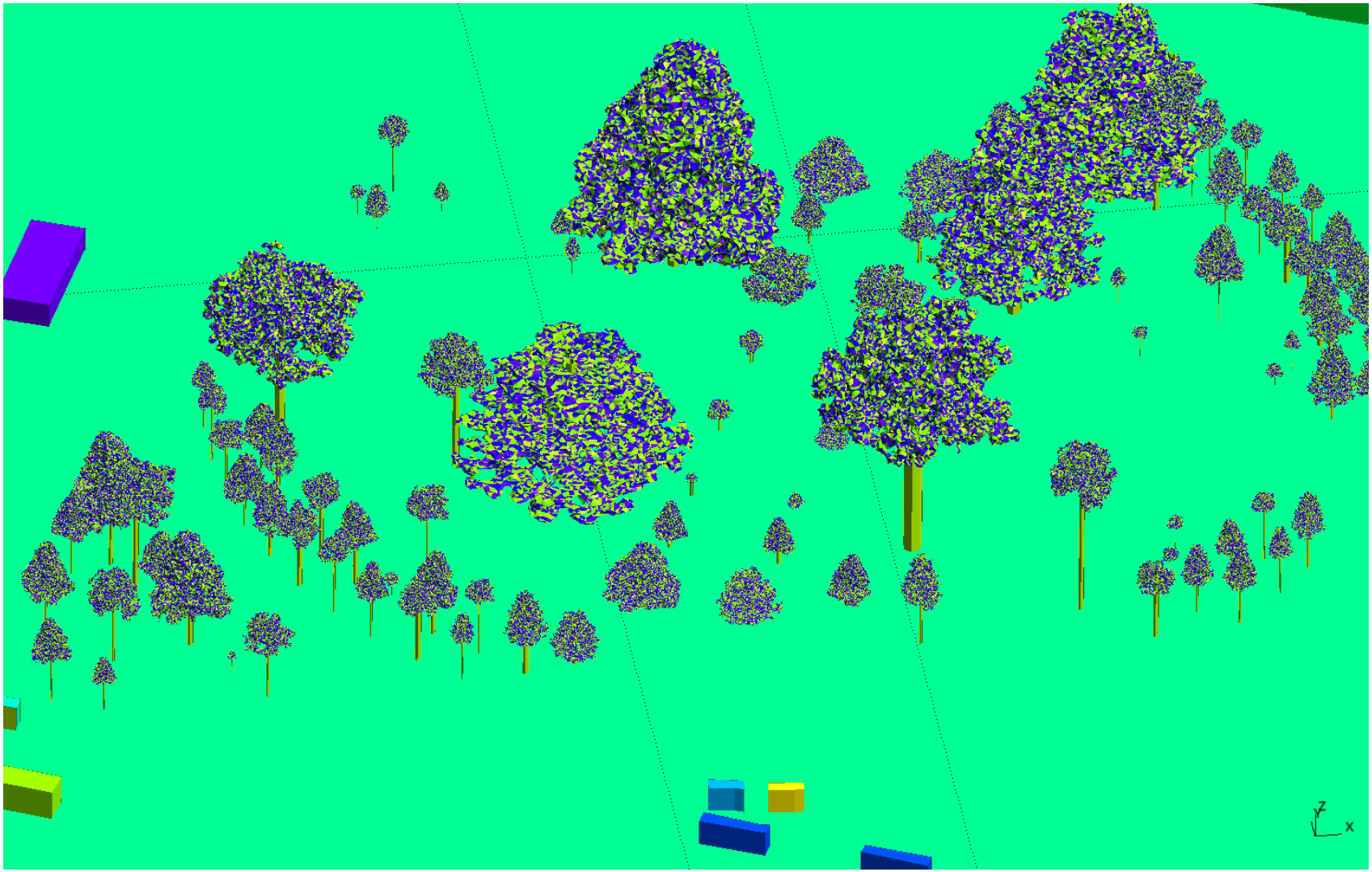


Figure: 3D Model of Strasbourg city center, buildings and vegetation, with a focus on Republic Square, LOD 3

Results: Performance

Figure: Bounding Box 1: 153.7 m², 12 trees

Results: Performance

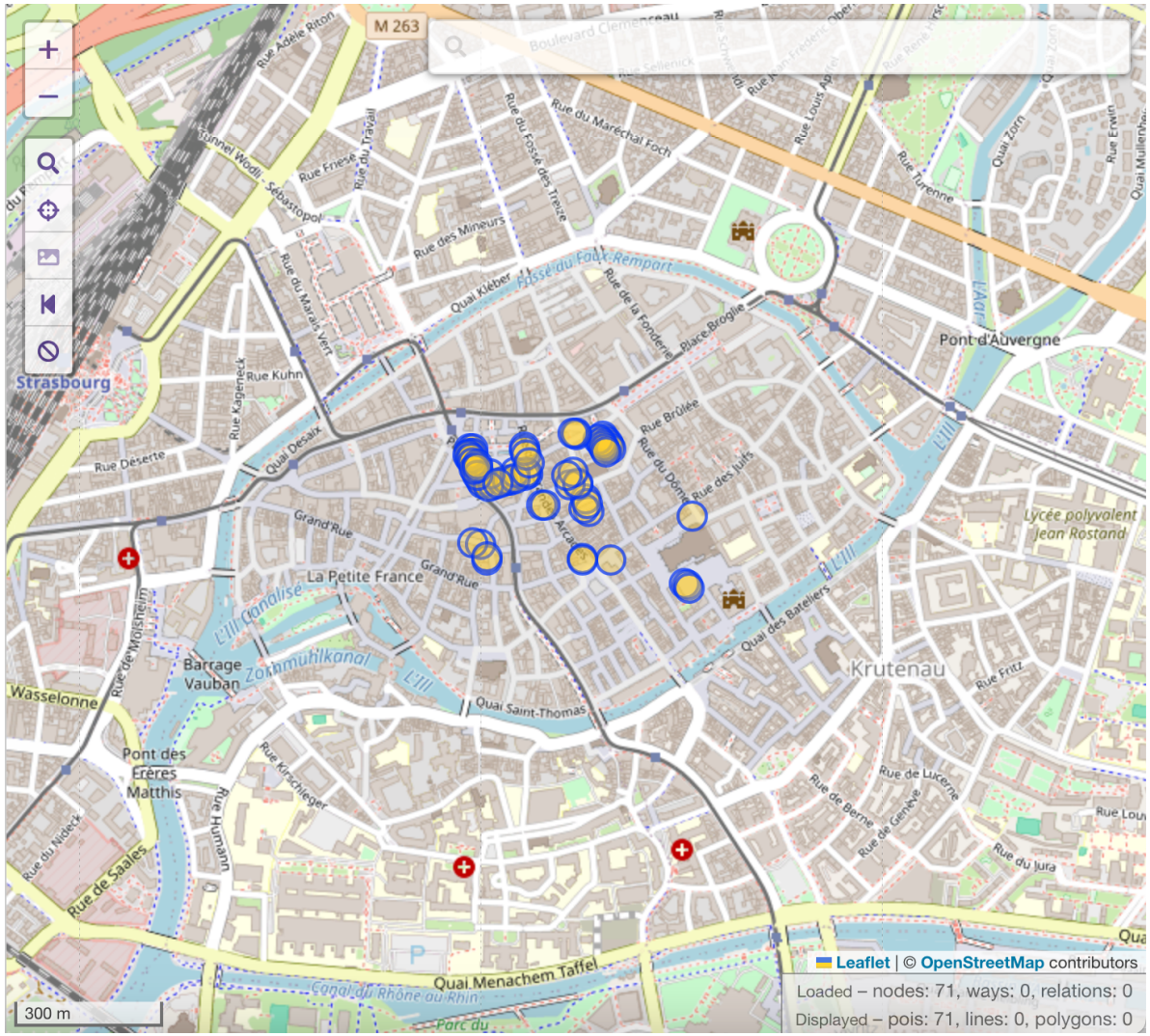


Figure: Bounding Box 2: 384.0 m², 71 trees

Results: Performance

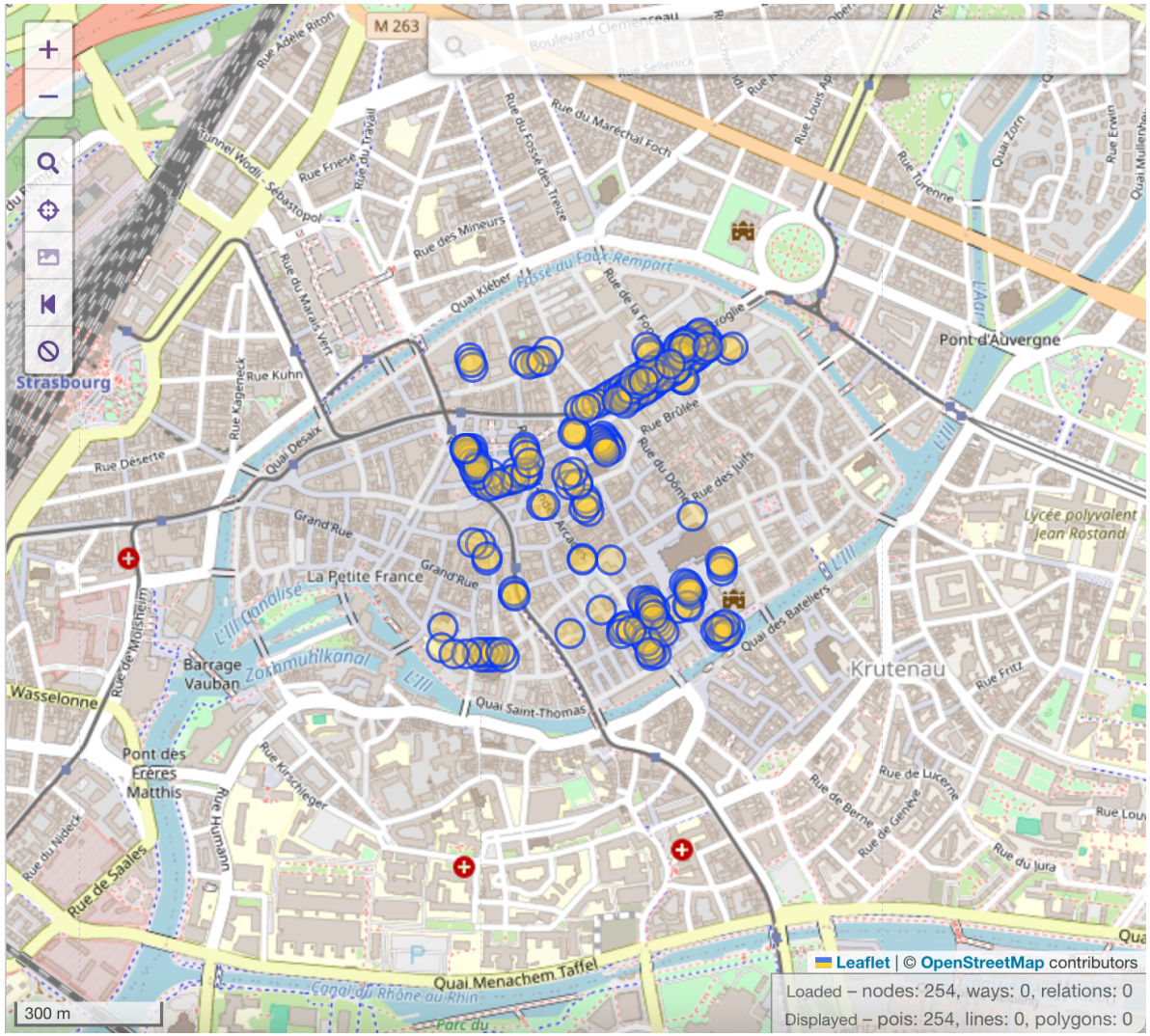


Figure: Bounding Box 3: 626.1 m², 254 trees

Results: Performance

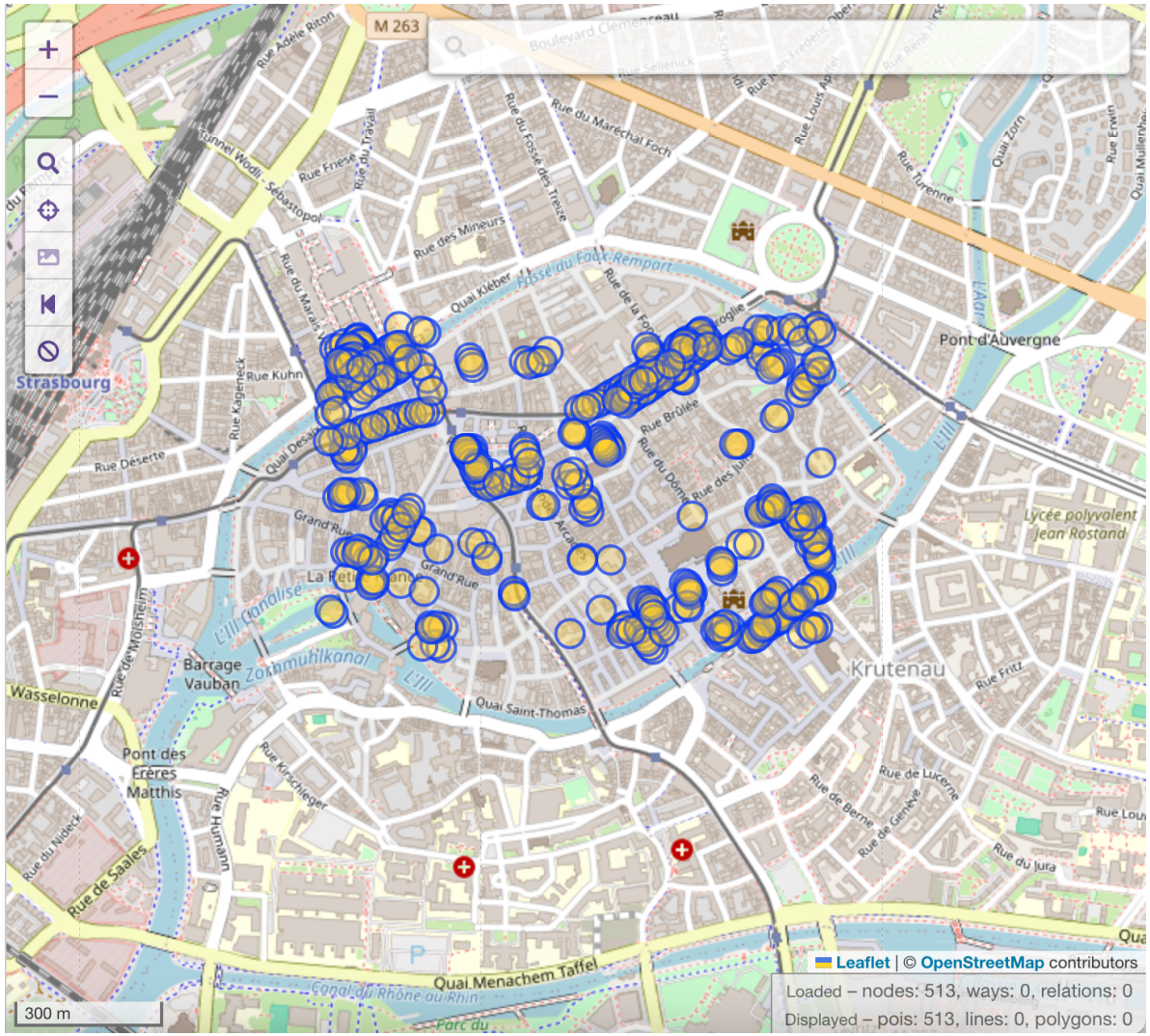


Figure: Bounding Box 4: 808.4 m², 513 trees

Results: Performance

Without LOD 3

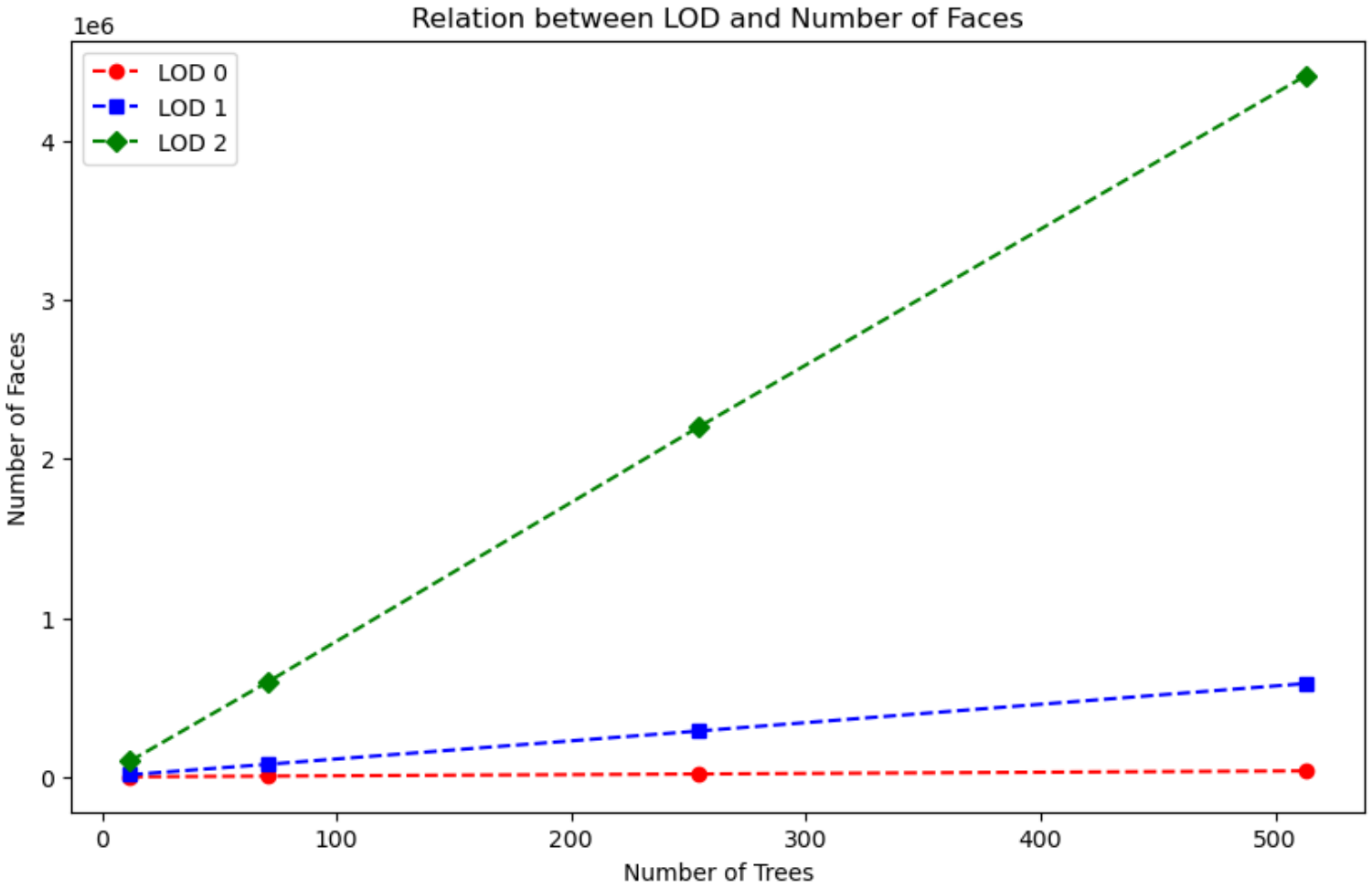


Figure: Relationship between the number of faces and the number of trees

Results: Performance

With LOD 3

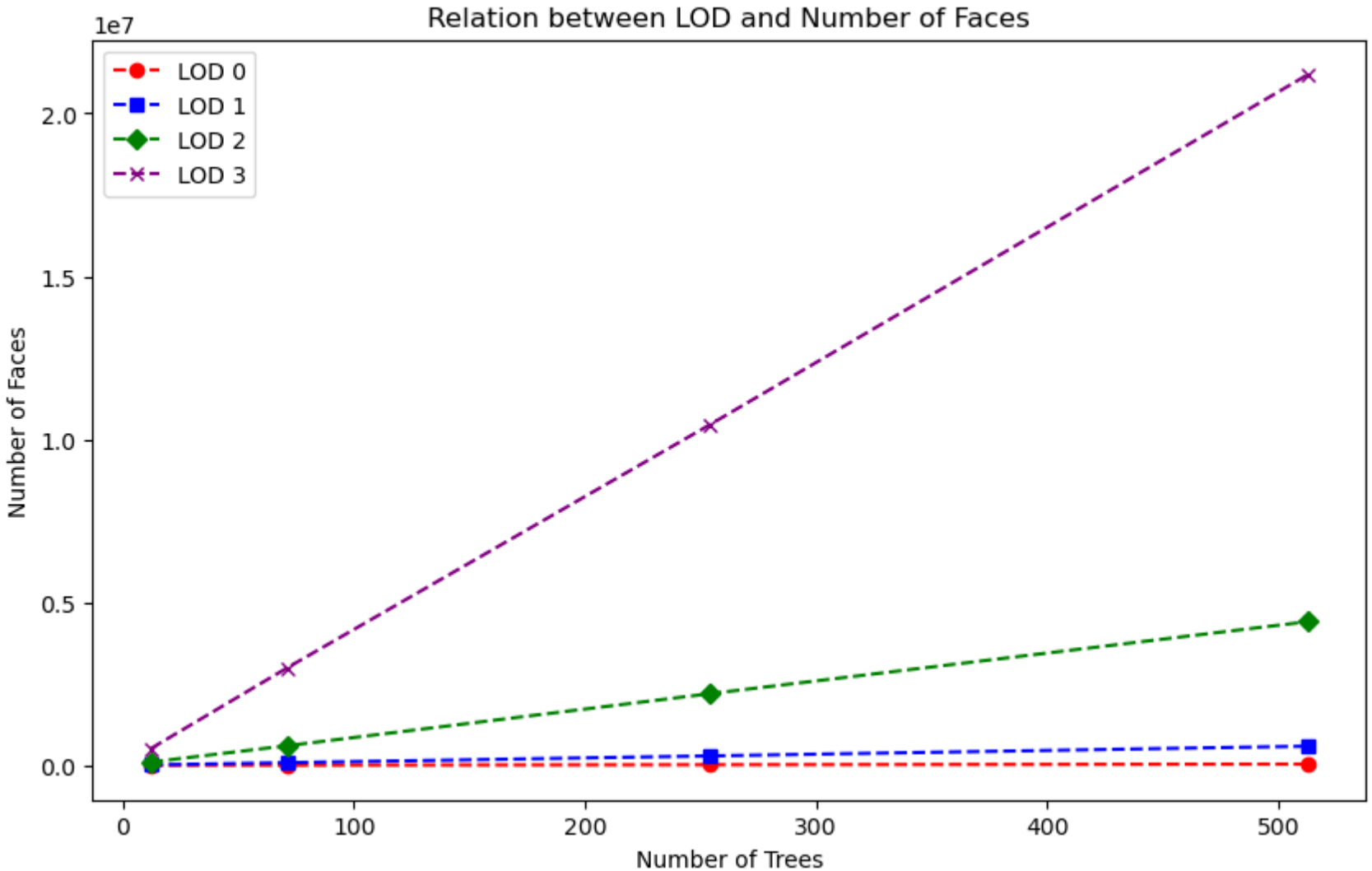


Figure: Relationship between the number of faces and the number of trees

Results: Performance

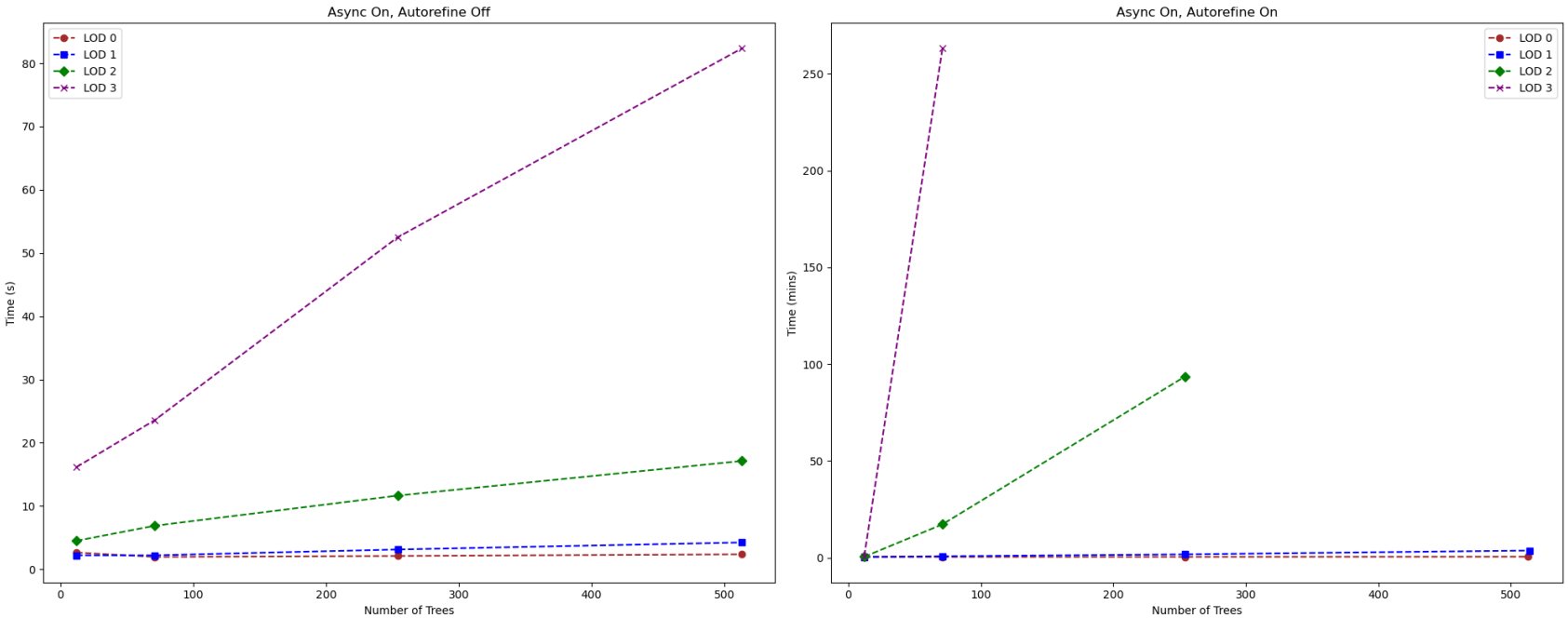


Figure: Comparison of the execution time with and without the autorefine method

Results: Performance

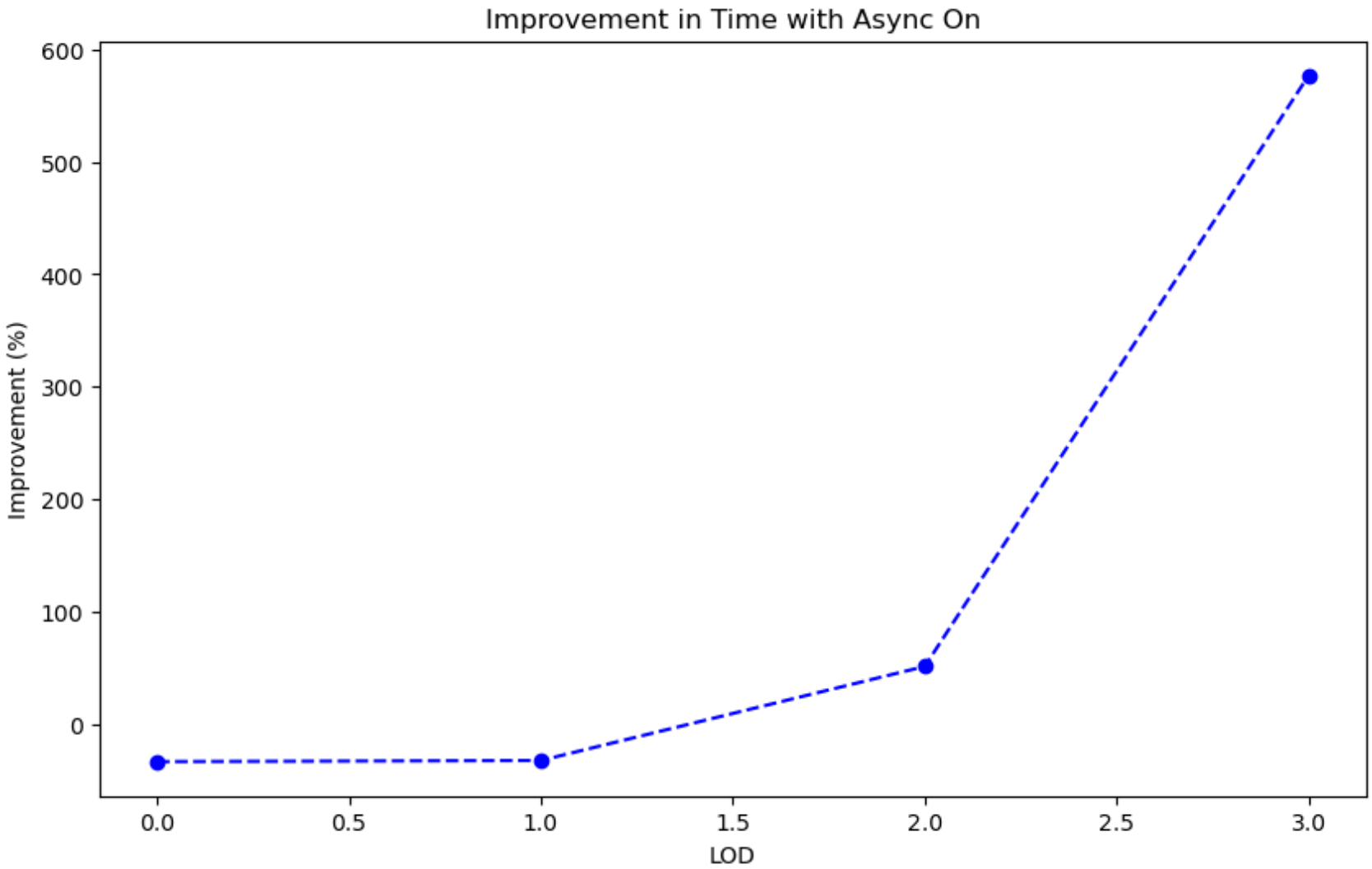


Figure: Thread parallelization improvement

Prospects

- Fixing the tree's altitude

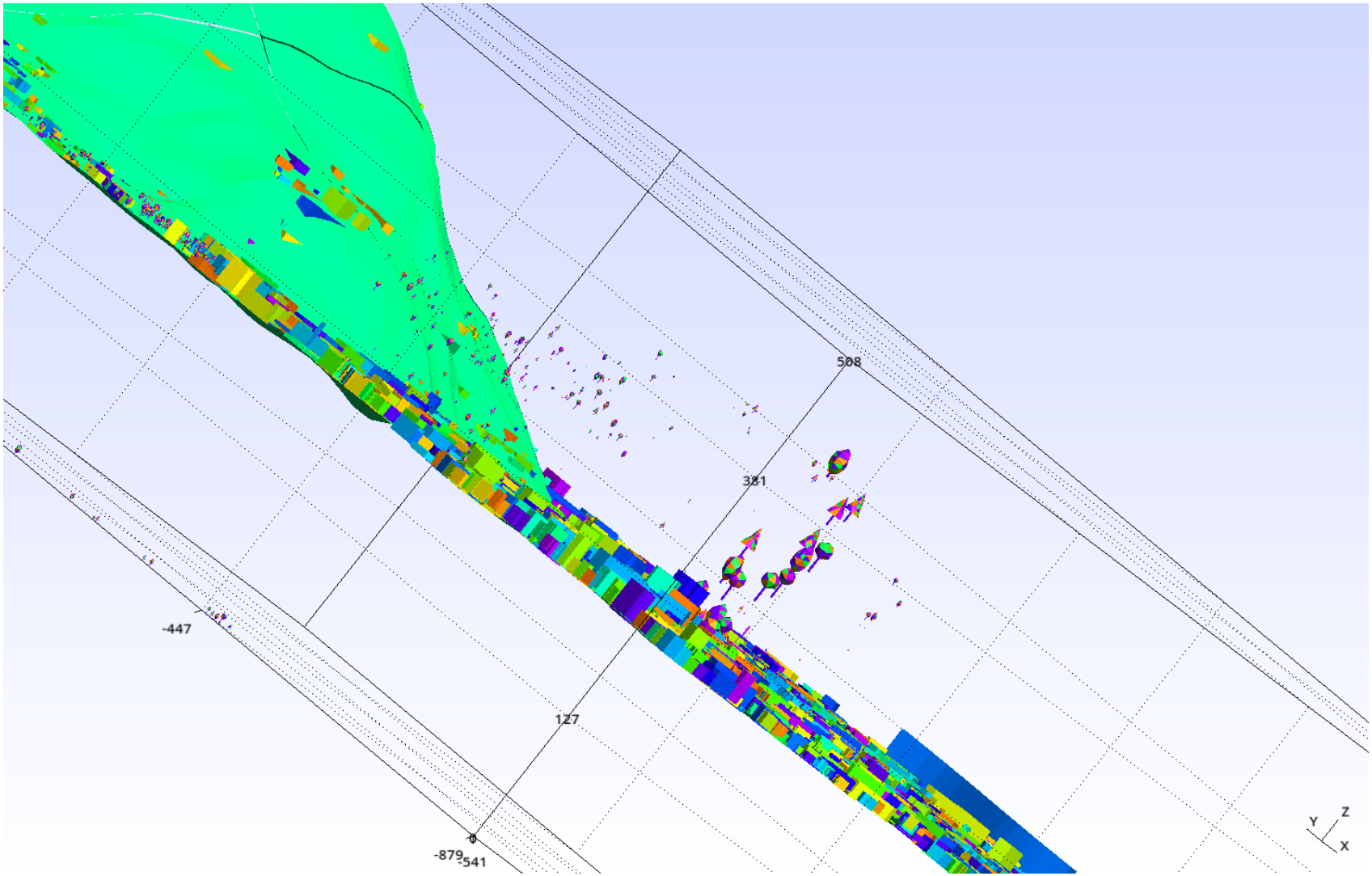


Figure: Grenoble elevation fail

Prospects

- Parallelize the computation of the ‘autorefine‘ method

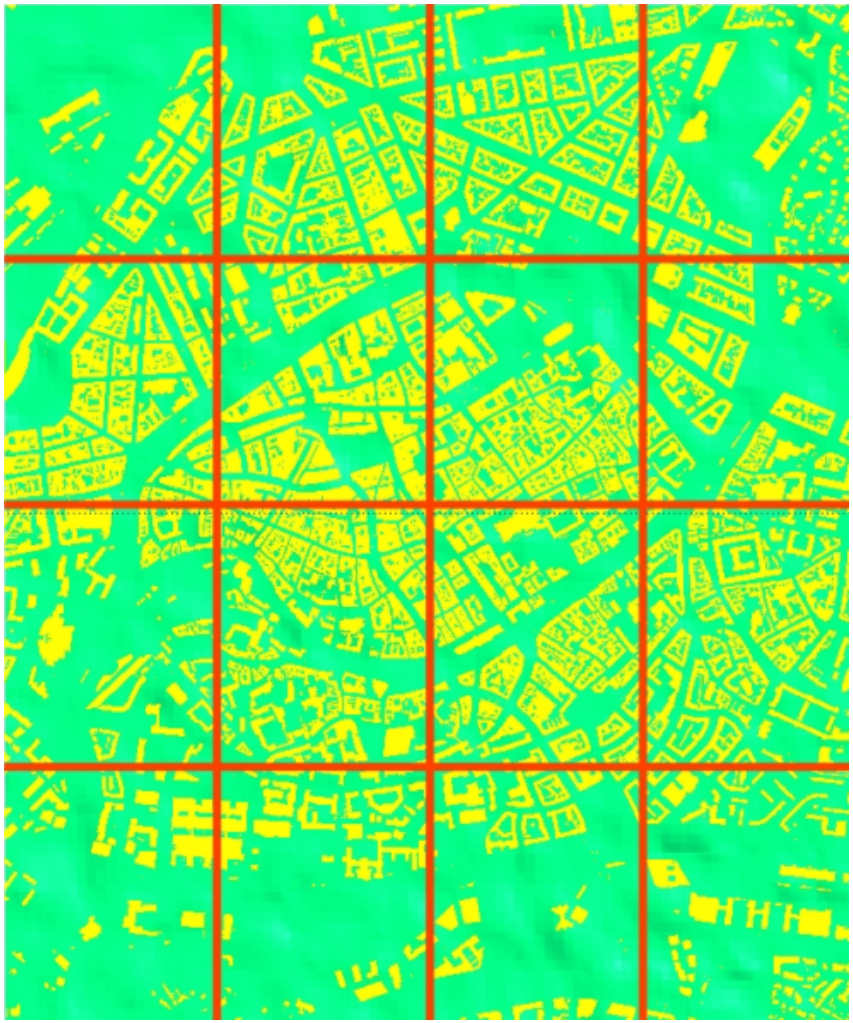


Figure: .Terrain mesh splitted into smaller parts, the red lines represent the boundaries of the parts and should not be parallelized

Prospects

- Improve the handling of missing tree data

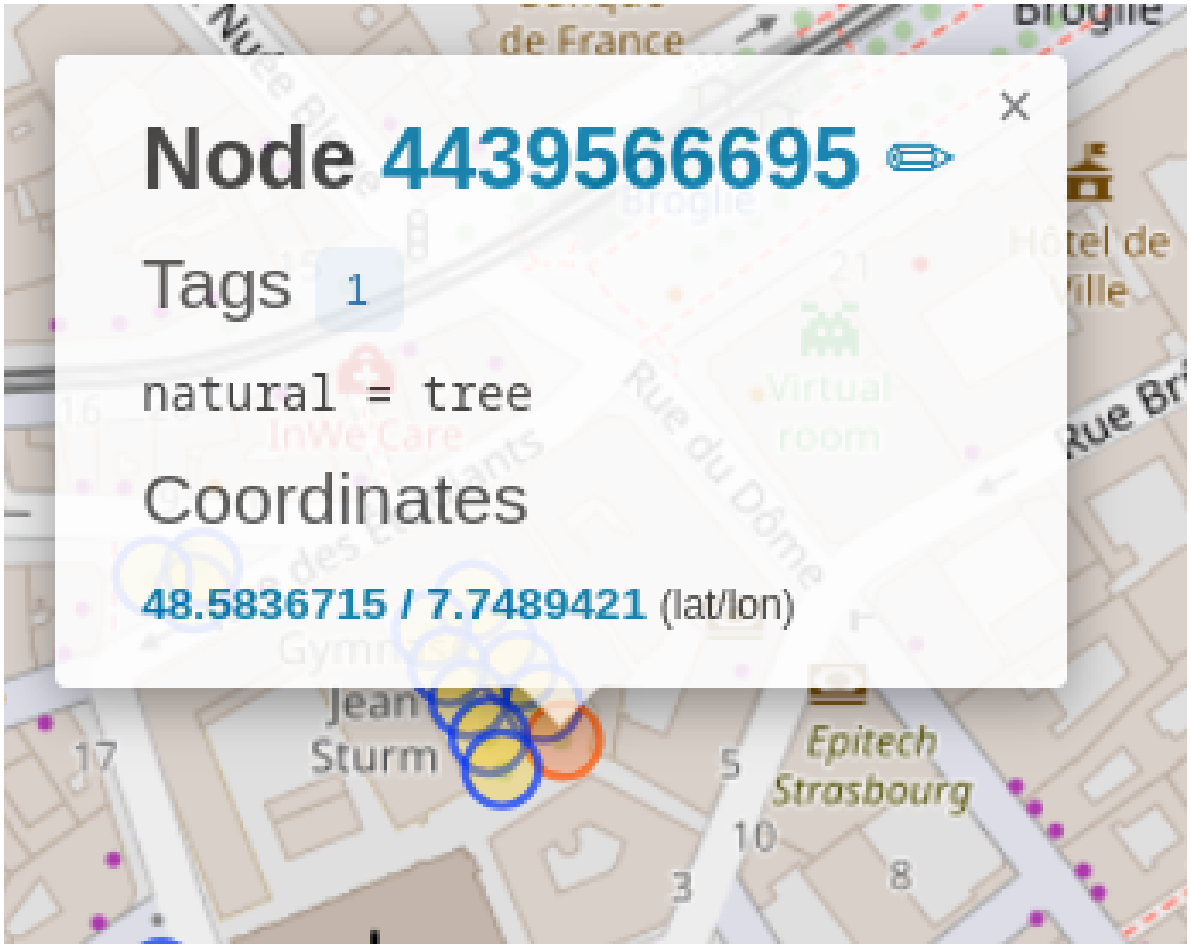


Figure: An Overpass Turbo Node with missing metadata

Prospects

- Shading calculation

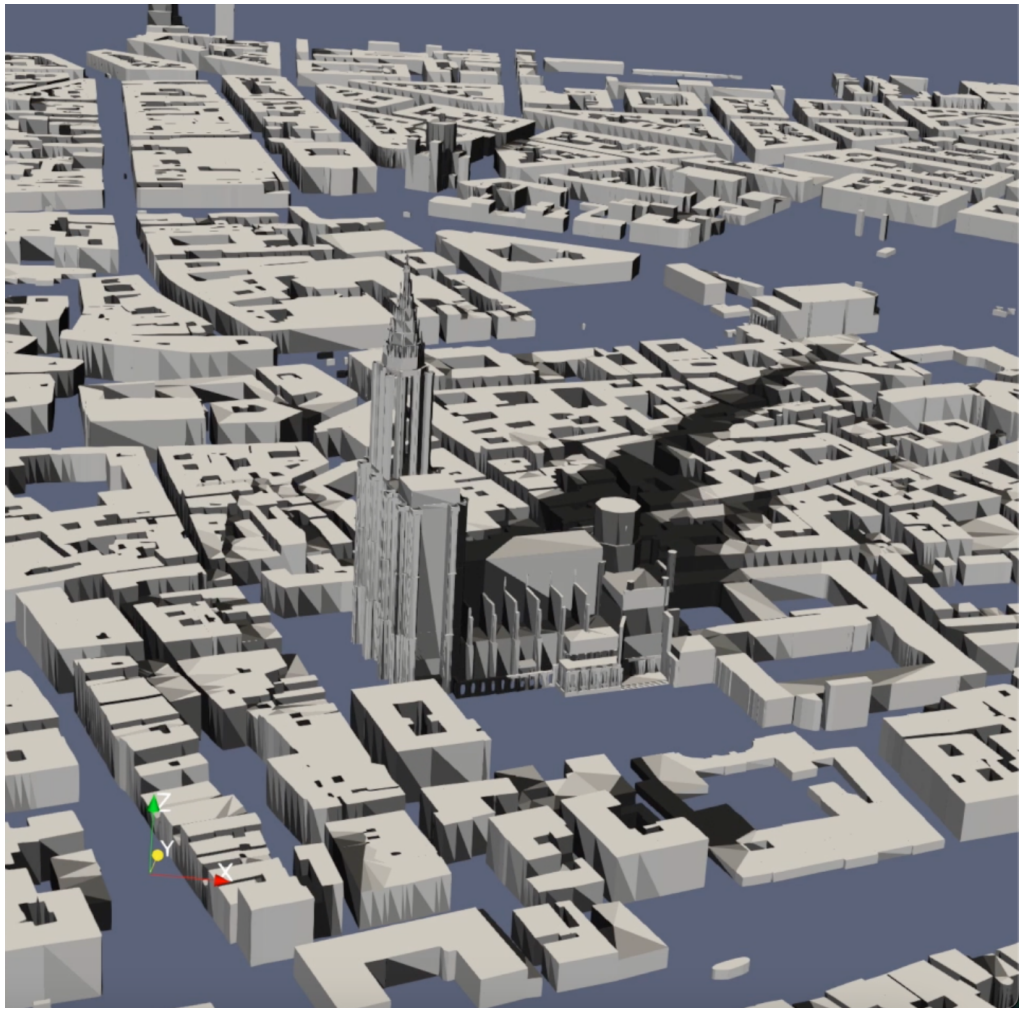


Figure: The shadow cast by the Cathedral of Strasbourg

Conclusion

- **Project Goal:** Enhanced urban modeling by integrating 3D tree models into urban environments.
- **Key Achievements:**
  - Extracted tree data from OpenStreetMap.
  - Generated 3D tree models using CGAL and Gmsh.
  - Integrated models into existing terrain meshes.
  - Utilized different Levels of Detail (LOD) for flexible modeling.
- **Technical Highlights:**
  - Robust data acquisition and model generation techniques.
  - Successful scalability and performance benchmarks.
  - Addressed missing data with default tree height values.
- **Future Directions:**
  - Incorporate tree elevations, parallelization, and advanced shading for improved modeling.

The end

Thank you for your attention!

Any questions?

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