

UFR

de **mathématique**
et d'**informatique**



Université de Strasbourg

exa-MA WP1 - Vegetation

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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 WP1 - Performance and Scalability

Introduction

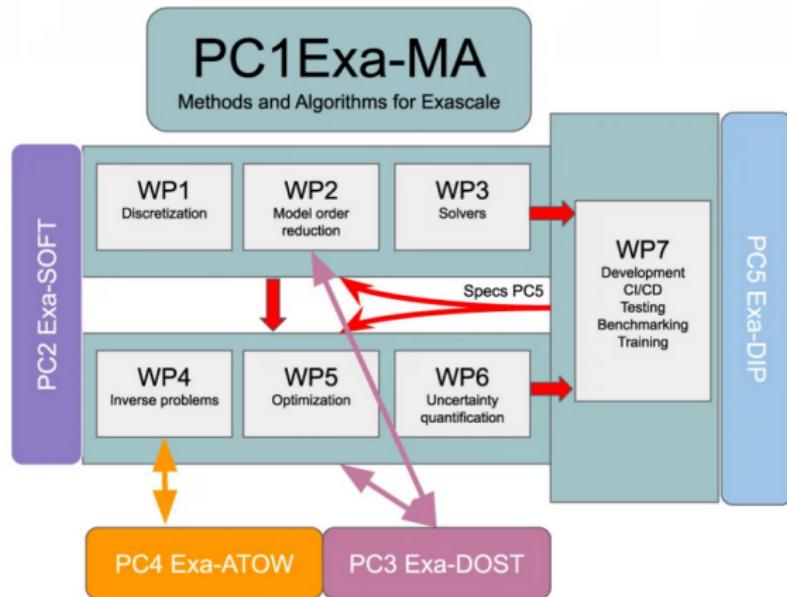


Figure: Exa-MA project overview [1]

Context



Figure: Hidalgo2 UBM poster [2]

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

Context

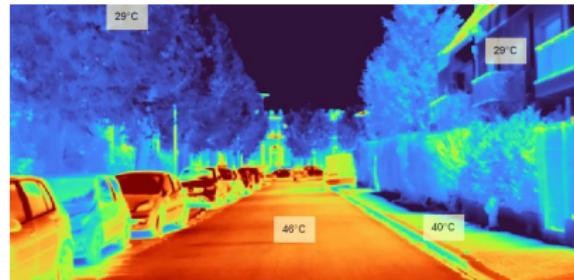


Figure: Thermal image of a street depicting heat distribution [3]

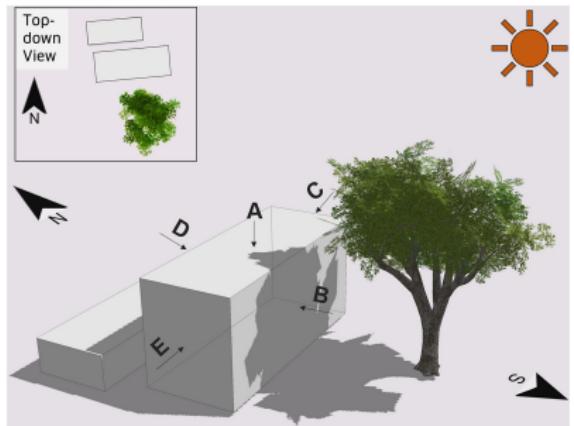


Figure: Tree providing shade to a building [4]

Context: Ktirio

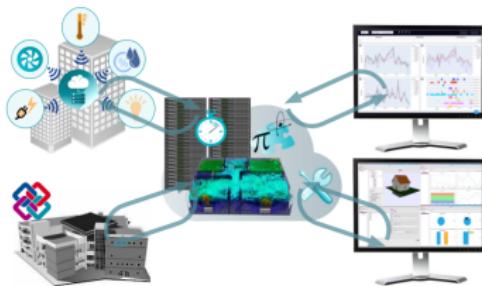


Figure: Ktirio project [5]

- 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

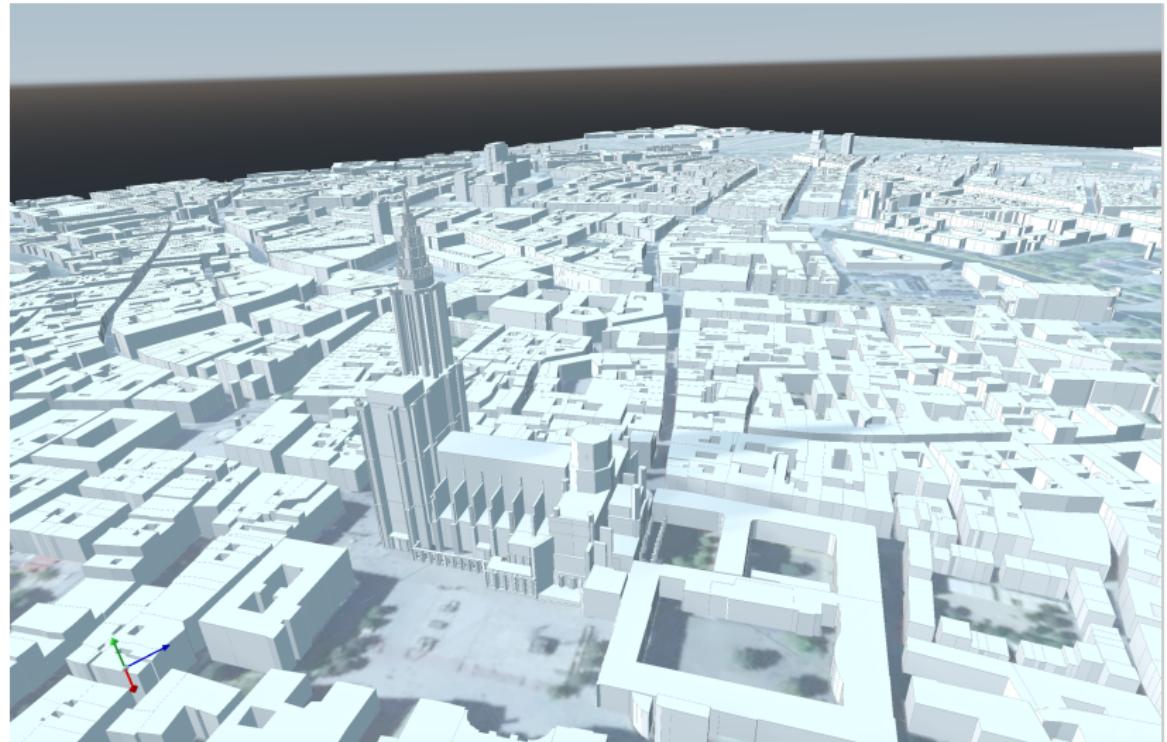


Figure: 3D Model of Strasbourg, France

Context: Adaptability

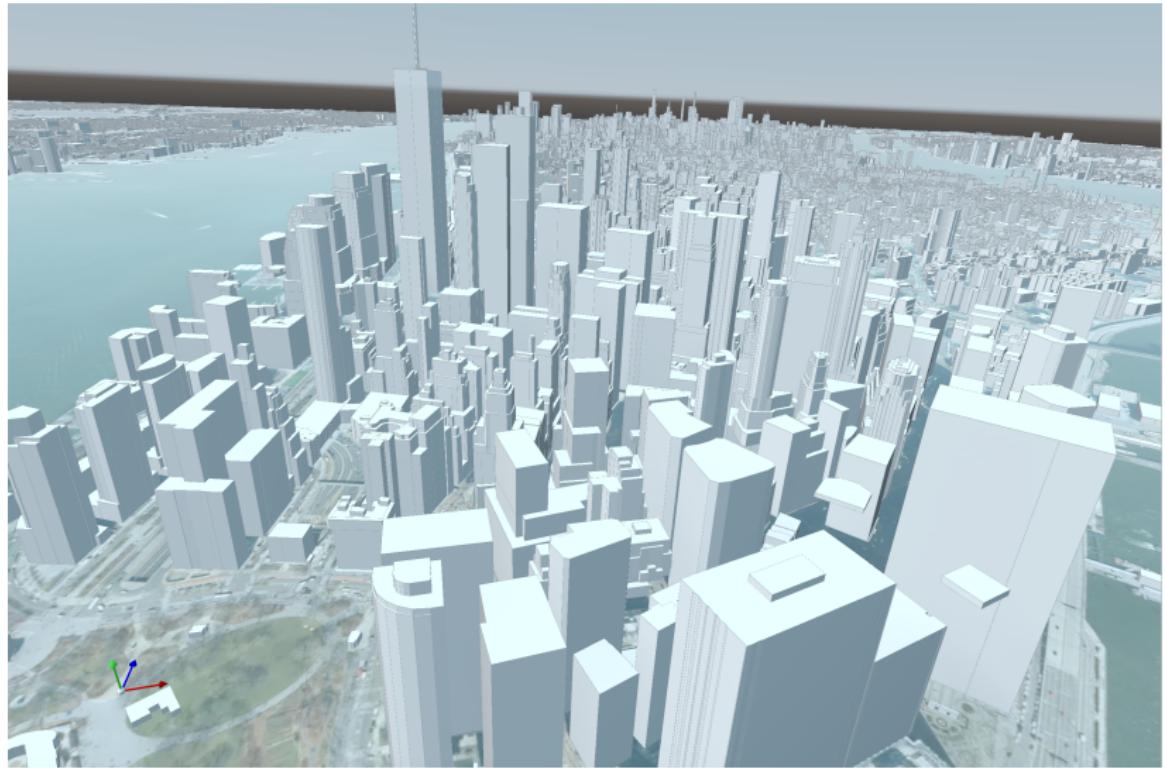


Figure: 3D Model of Manhattan, New York [6]

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
4         \"]); out;";
5     cpr::Response r = cpr::Post(
6         cpr::Url{"http://overpass-api.de/api/interpreter"},
7         cpr::Body{query},
8         cpr::Header{{"Content-Type", "application/x-www-form
9         -urlencoded"}},
10        cpr::Timeout{10000} // Set a timeout of 10 seconds
11    );
12 }
```

Data acquisition: .json output

```
1  {
2      "type": "node",
3      "id": 10162018740,
4      "lat": 48.5850910,
5      "lon": 7.7502624,
6      "tags": {
7          "circumference": "1.47655",
8          "diameter_crown": "5",
9          "genus": "Platanus",
10         "height": "6",
11         "leaf_cycle": "deciduous",
12         "leaf_type": "broadleaved",
13         "natural": "tree",
14         "ref": "16401",
15         "source": "data.strasbourg.eu - patrimoine_arbore",
16         "source:date": "2022-01-02",
17         "species": "Platanus acerifolia x",
18         "species:wikidata": "Q24853030"
19     }
20 }
21 }
```

Generating Tree Library

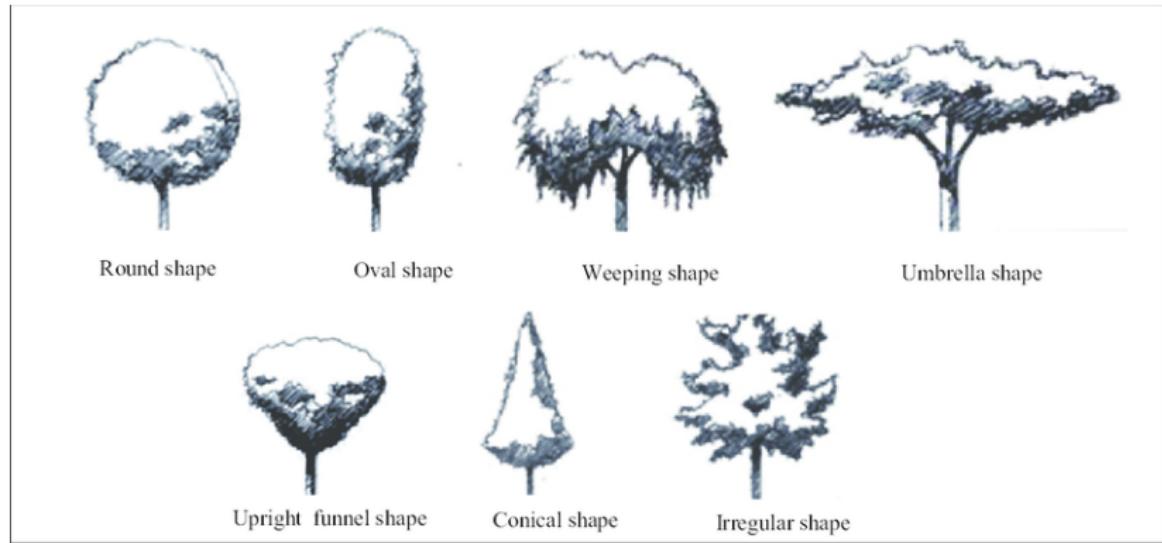


Figure: Different tree shapes

Tree Modeling: lod 0

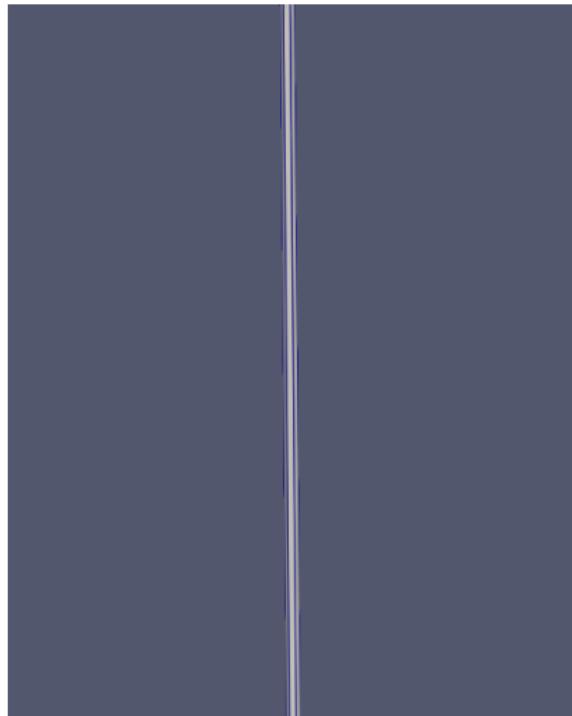


Figure: Tree Trunk model

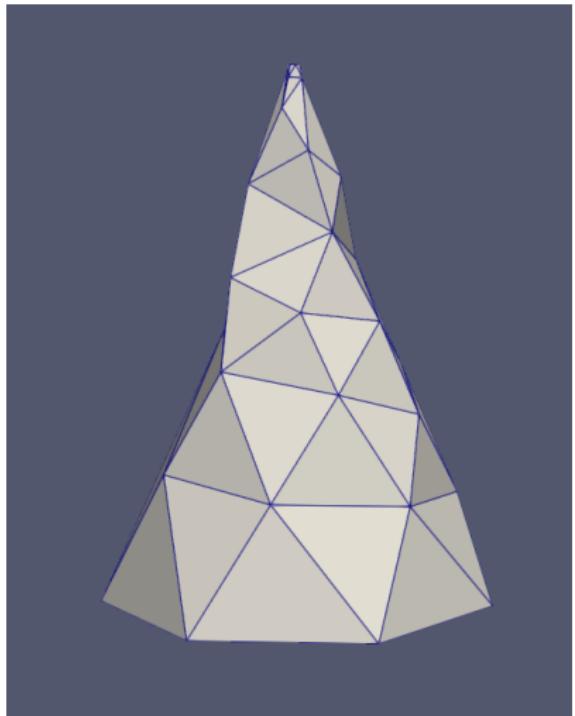


Figure: Cone shaped Tree model

Tree Modeling: lod 0

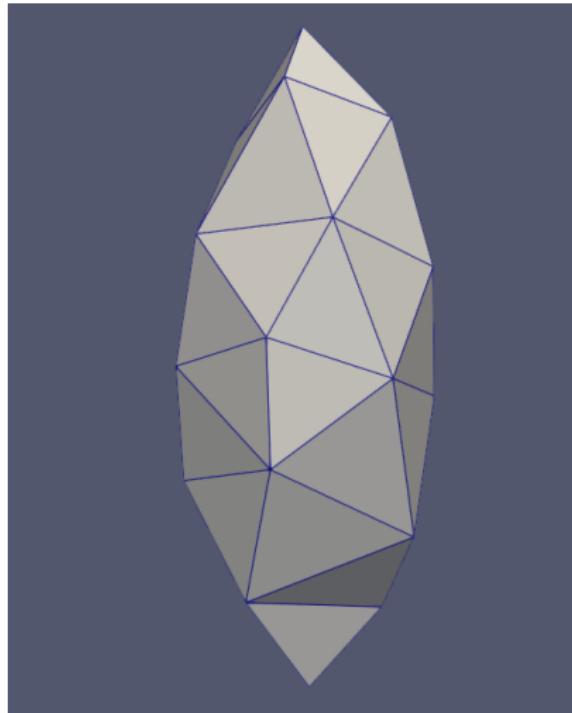


Figure: Oval shaped Tree model

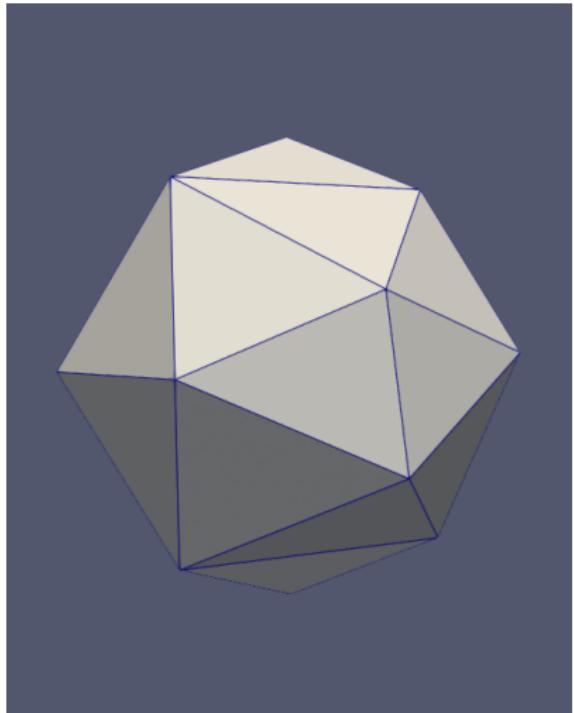


Figure: Round shaped Tree model

Tree Modeling: lod 1,2 and 3

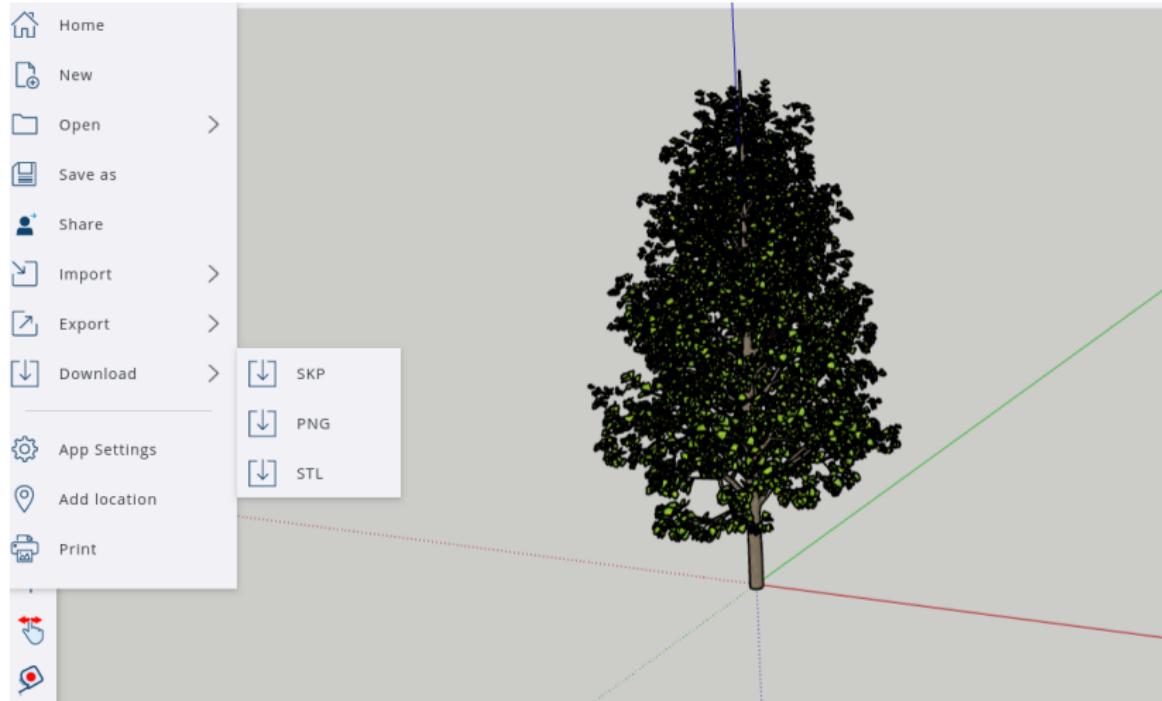


Figure: 3D model of a Ginkgo tree on Sketchup

Tree preprocessing

Remove trunk/branches, normalize and center

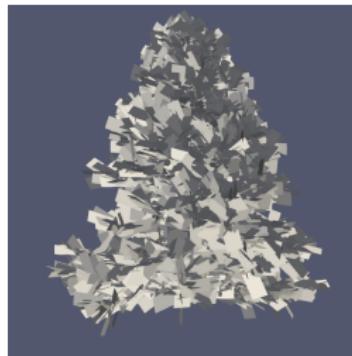


Figure: A preprocessed
conifer tree



Figure: A preprocessed
Ginkgo tree

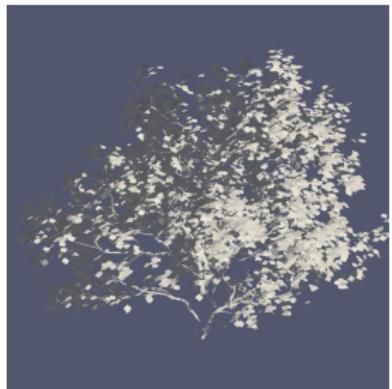
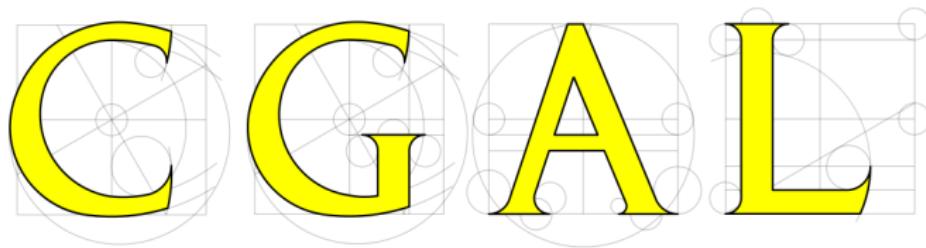


Figure: A preprocessed
Quercus tree

Software 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[7]

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: Alpha Wrapping

video link

Tree Modeling: lod 1,2 and 3

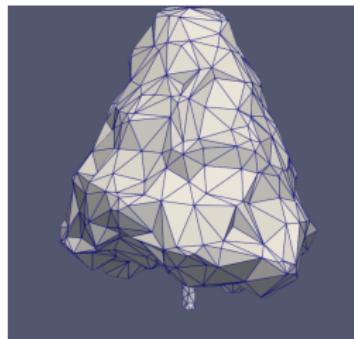


Figure: A wrapped conifer tree for LOD 1

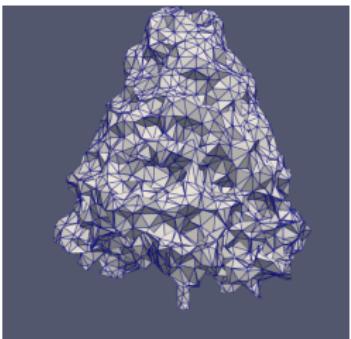


Figure: A wrapped conifer tree for LOD 2

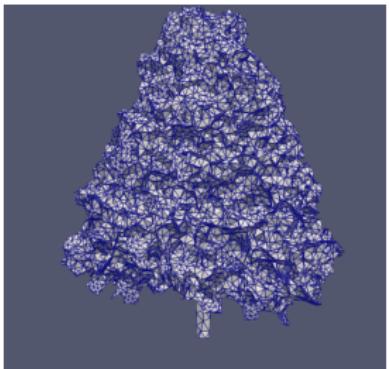


Figure: A wrapped conifer tree for LOD 3

Tree Modeling: lod 1,2 and 3

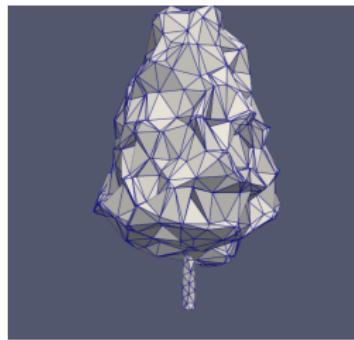


Figure: A wrapped Ginkgo tree for LOD 1

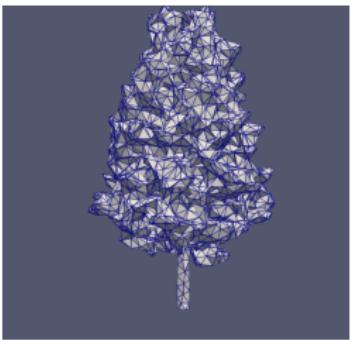


Figure: A wrapped Ginkgo tree for LOD 2

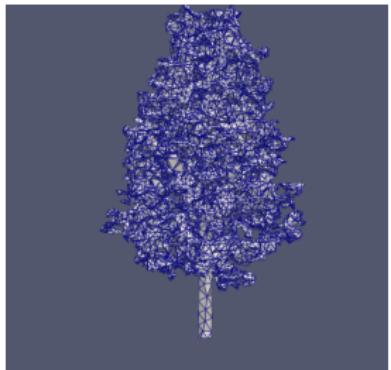


Figure: A wrapped Ginkgo tree for LOD 3

Tree Modeling: lod 1,2 and 3

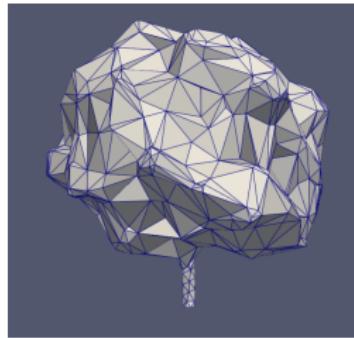


Figure: A wrapped Quercus tree for LOD 1

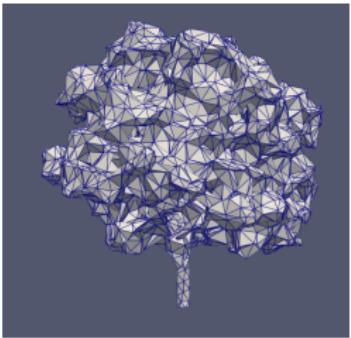


Figure: A wrapped Quercus tree for LOD 2

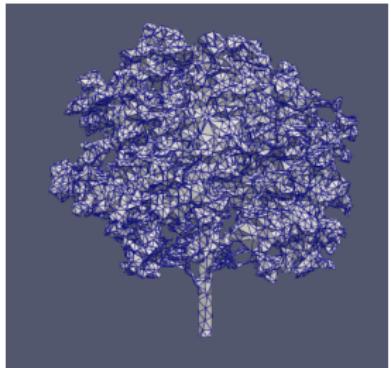


Figure: A wrapped Quercus tree for LOD 3

Tree Modelings

Used Alpha Values for Each LOD

Tree	LOD 0	LOD 1	LOD 2	LOD 3
Alpha	Nan	20	50	100

Number of Faces for Each LOD

Tree	LOD 0	LOD 1	LOD 2	LOD 3
Trunk	28	28	28	28
Cone	72	894	6038	34260
Oval	52	1260	9254	44942
Round	30	1198	10152	45164

Tree Modeling: tagging leaves

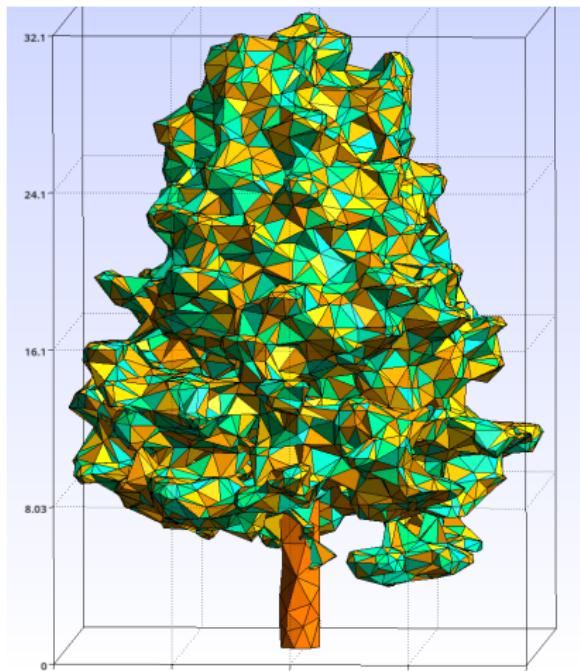


Figure: A tree with 4 different markers on the leaves

Tree Modeling: tree's scaling

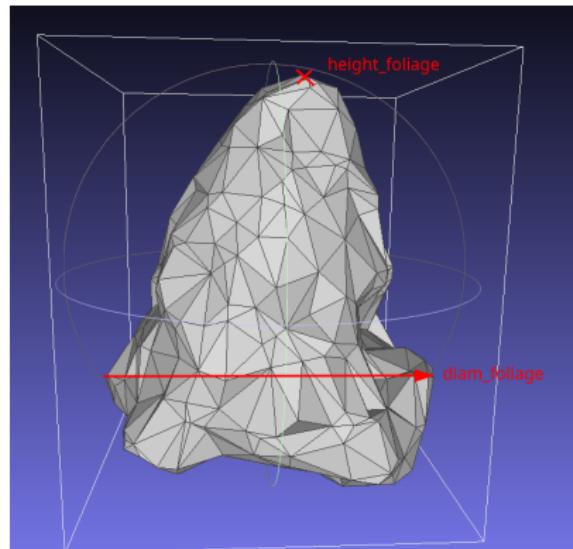


Figure: Foliage mesh

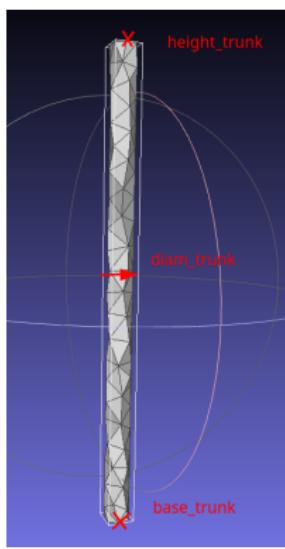


Figure: Trunk mesh

Tree Modeling: Mercator's projection

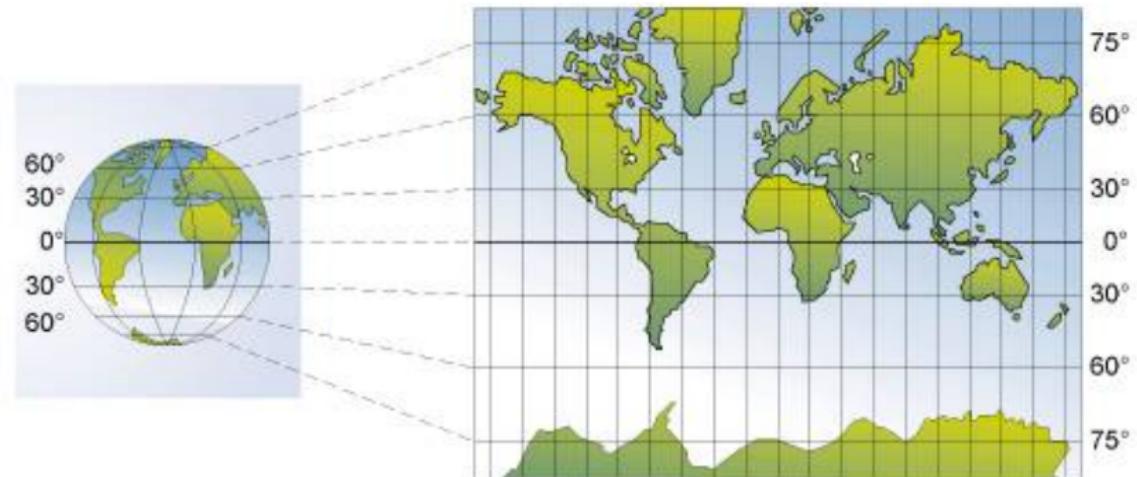


Figure: Mercator's projection[8]

Tree Modeling: Mercator's projection

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

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

, where λ_0 is the center of the map

Tree Modeling: Mercator's projection

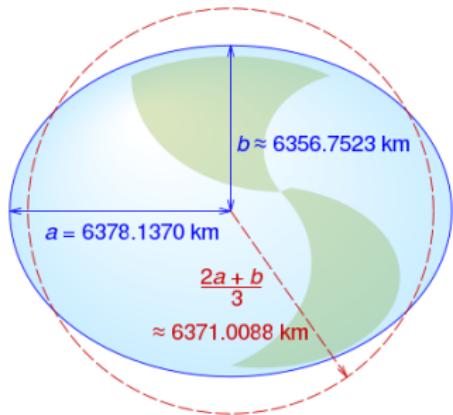


Figure: Earth as an ellipsoid[9]

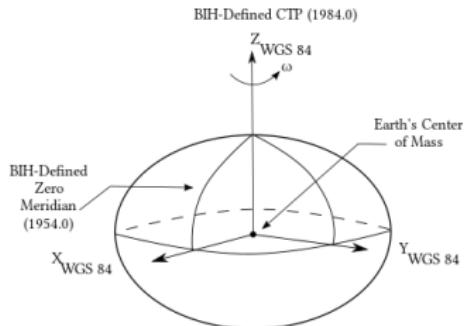


Figure 1.1 WGS 84 Reference Frame

Figure: WGS 84 reference frame[9]

WGS84toCartesian.hpp \implies **GPS to Cartesian**

Tree Modeling: foliage and trunk placement

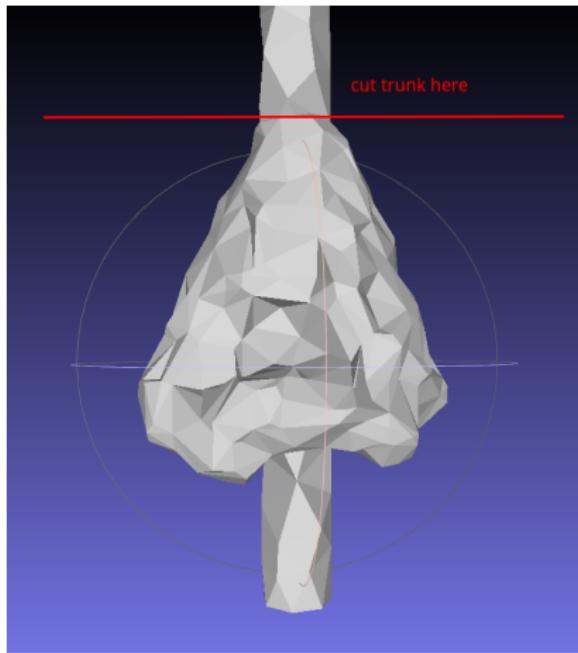


Figure: .3D model of a tree with a trunk that is too long

Tree Modeling: tree's placement

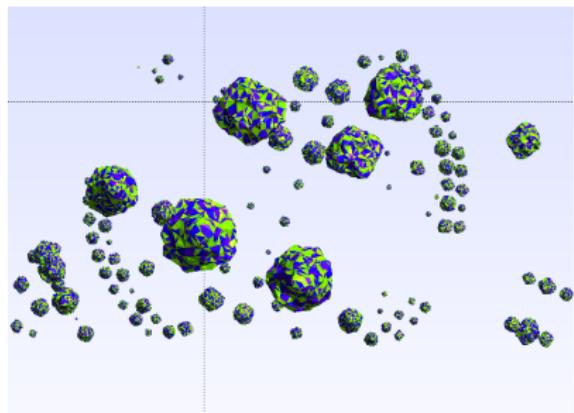


Figure: Republic square with LOD 1 trees

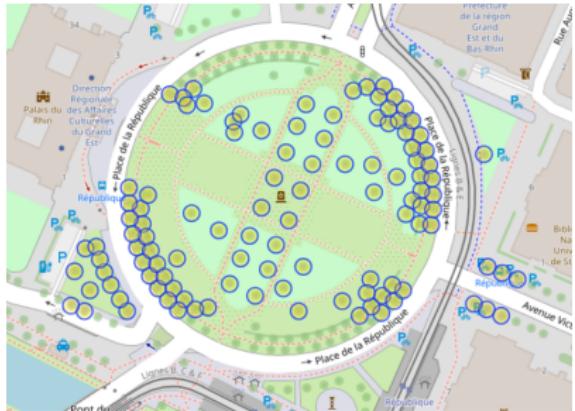


Figure: Republic square trees from Overpass turbo[10]

Tree Modeling: tree's placement

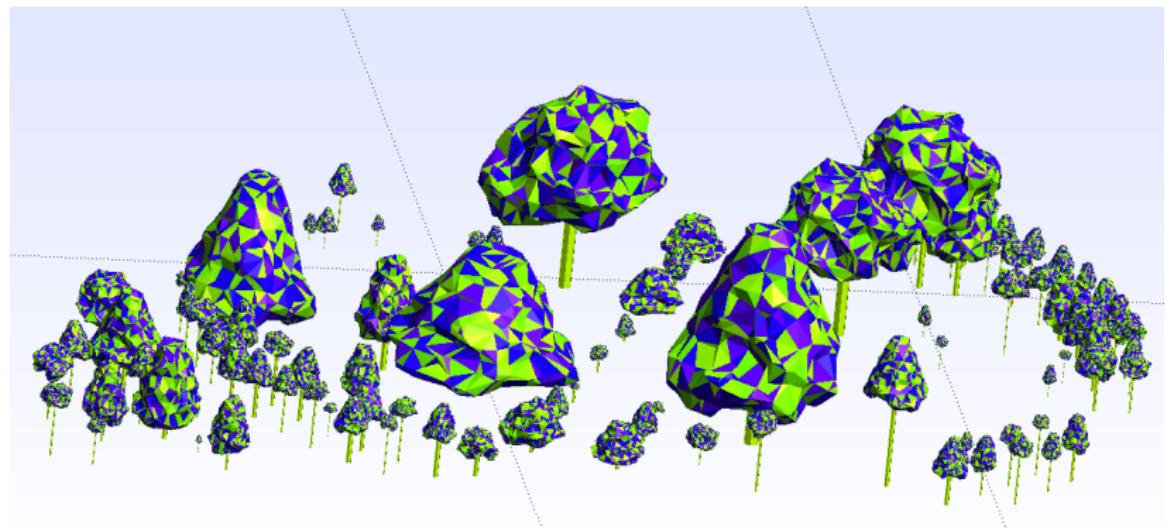


Figure: Republic square with LOD 1 trees

Tree Modeling: tree's altitude

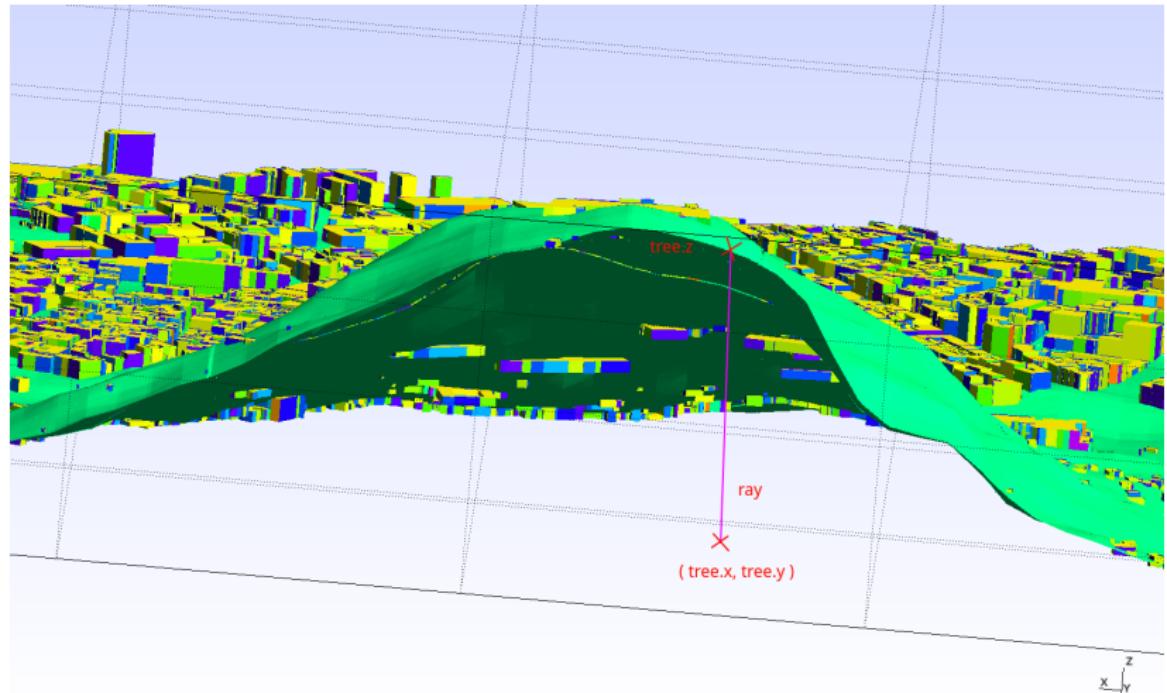


Figure: Raycasting of a tree in Grenoble, France

Raycasting: BVH

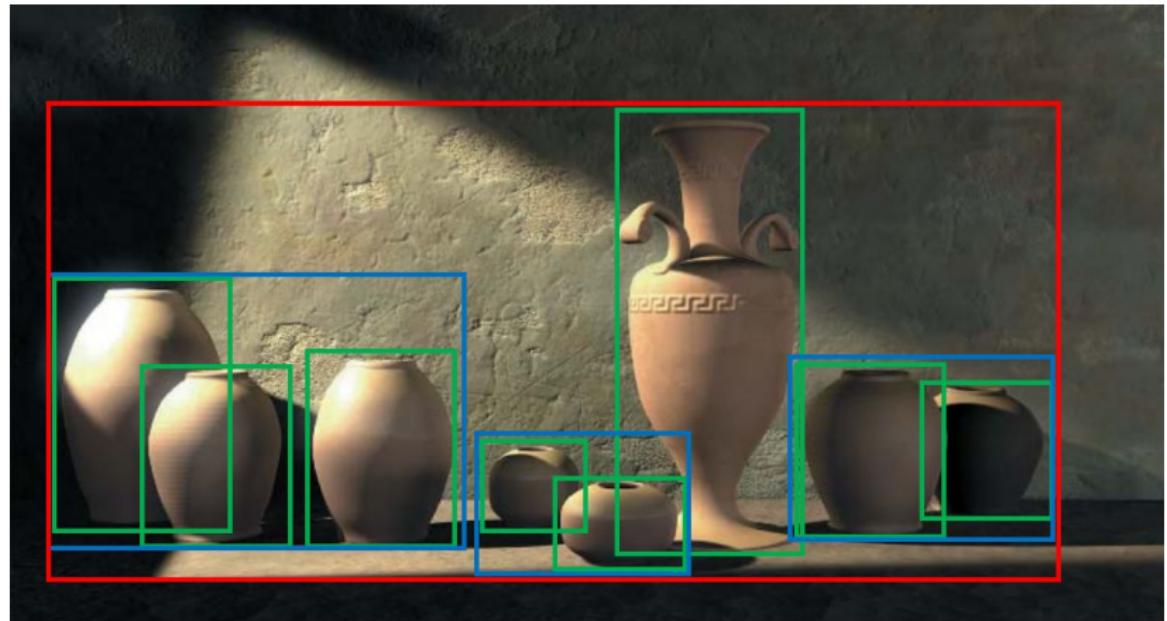


Figure: Image based on A 3-Dimensional Representation for Fast Rendering of Complex Scenes, by Rubin and Whitted. [11]

Tree Modeling: mesh merging



Figure: A plant going through a wall

Tree Modeling: mesh merging

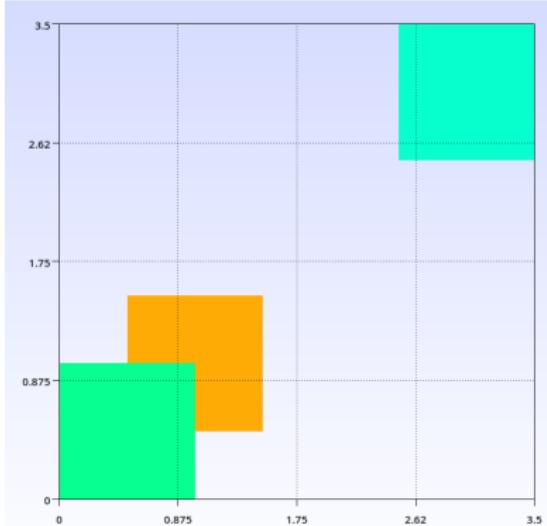


Figure: Autorefine before

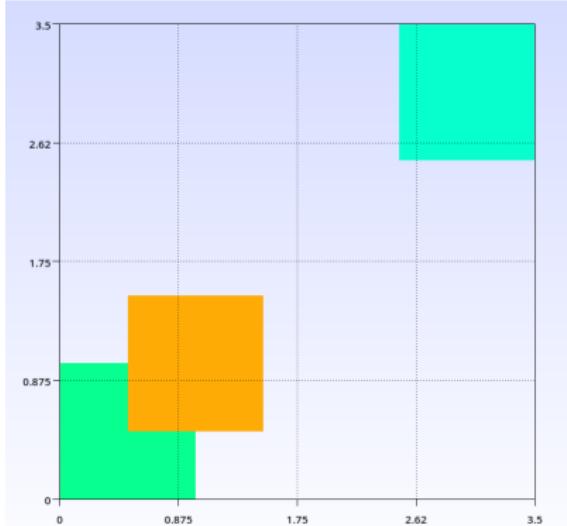


Figure: Autorefine after

Tree Modeling: thread parallelization

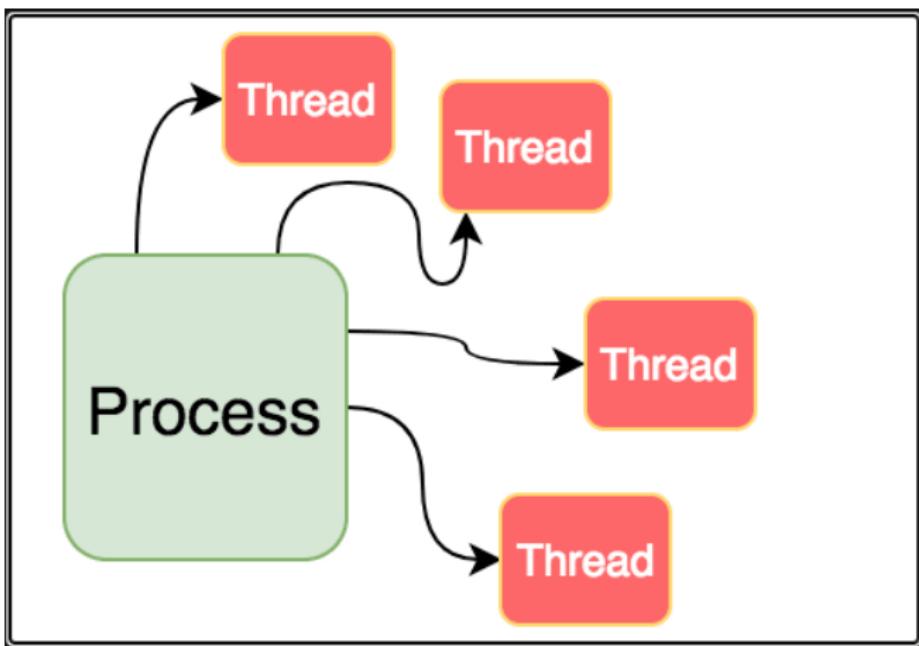


Figure: Parallelization of the tree generation process

Tree Modeling: thread parallelization autorefine

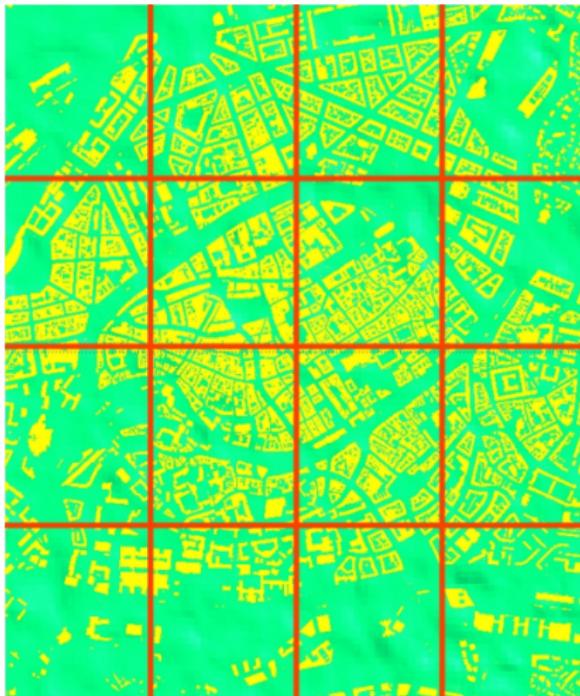


Figure: Parallelization of the mesh refinement process

Results: Model Integration

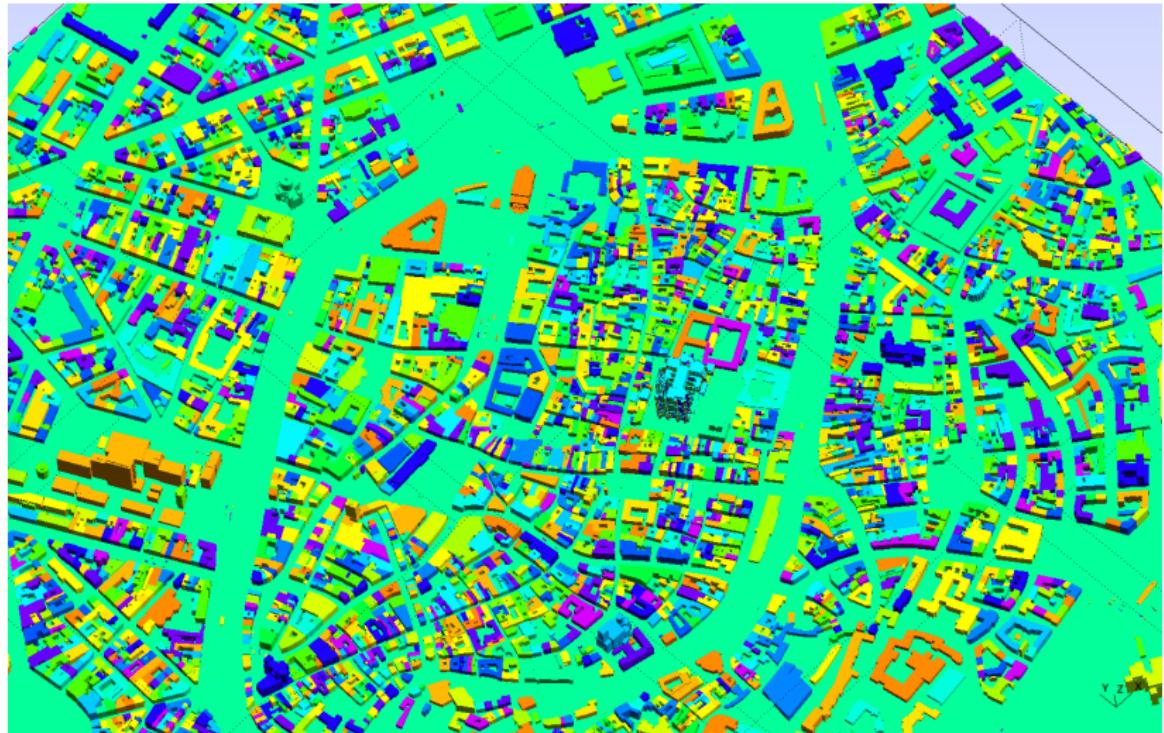


Figure: 3D Model of Strasbourg city center, buildings only

Results: Model Integration

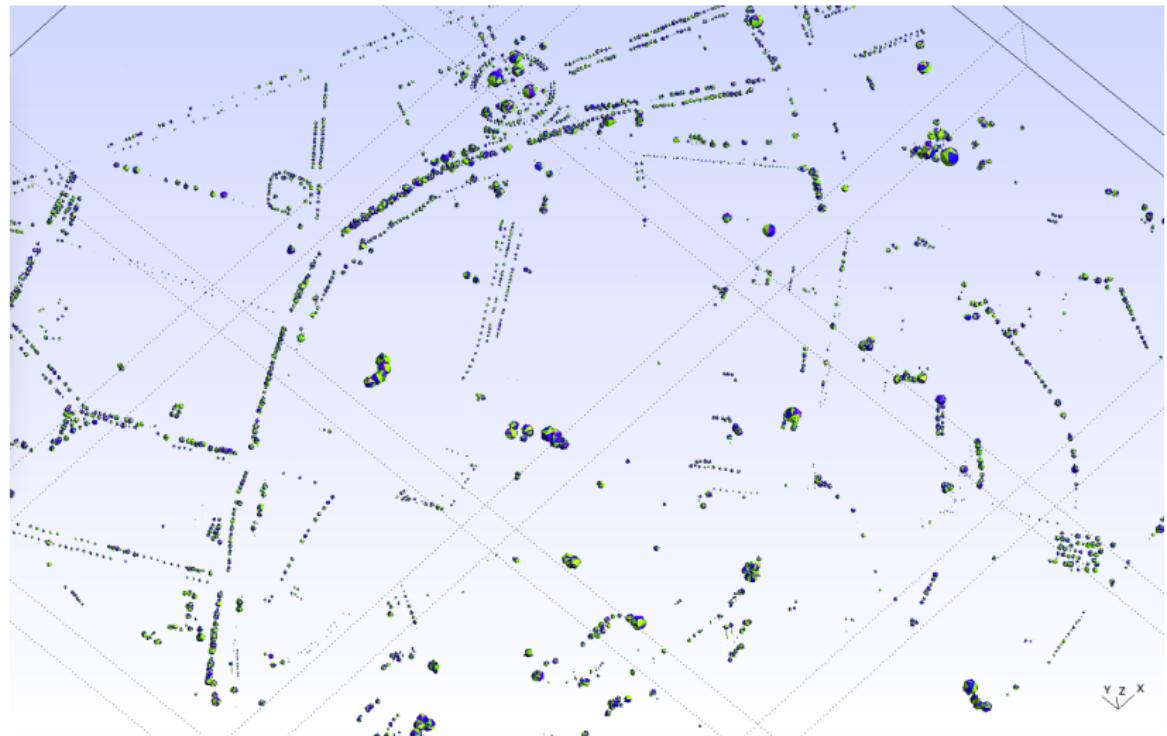


Figure: 3D Model of Strasbourg city center, trees only

Results: Model Integration

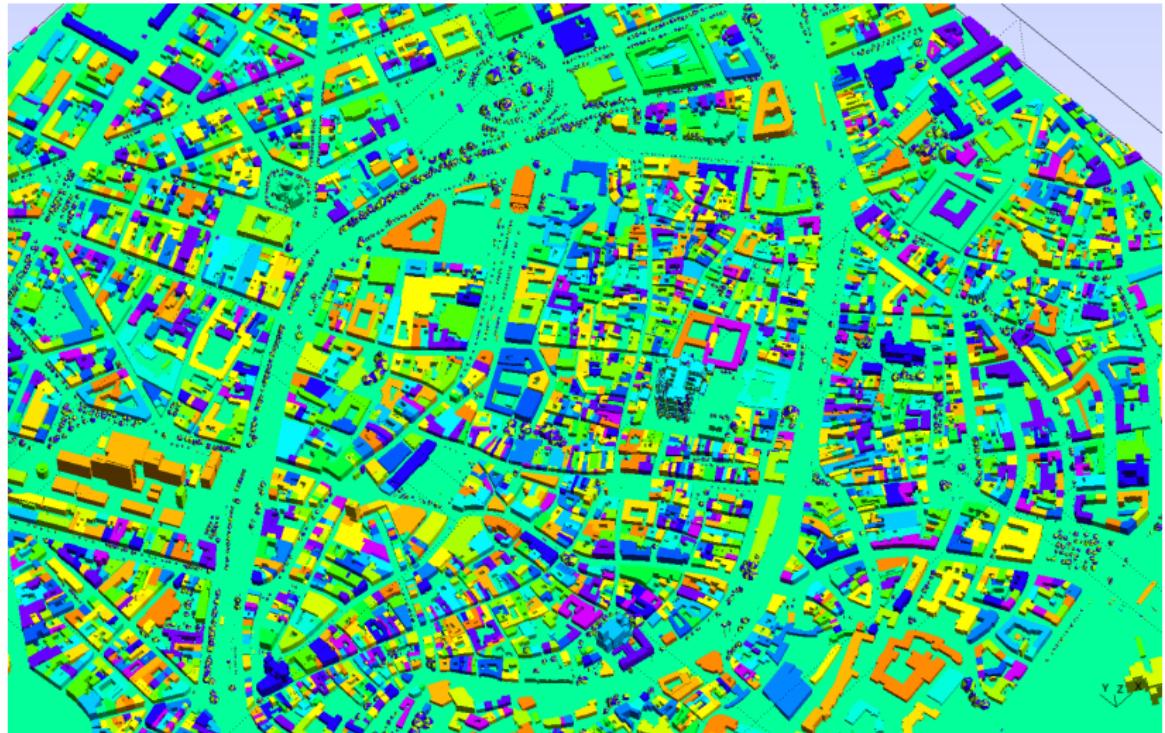


Figure: 3D Model of Strasbourg city center, buildings and trees

Results: Model Integration

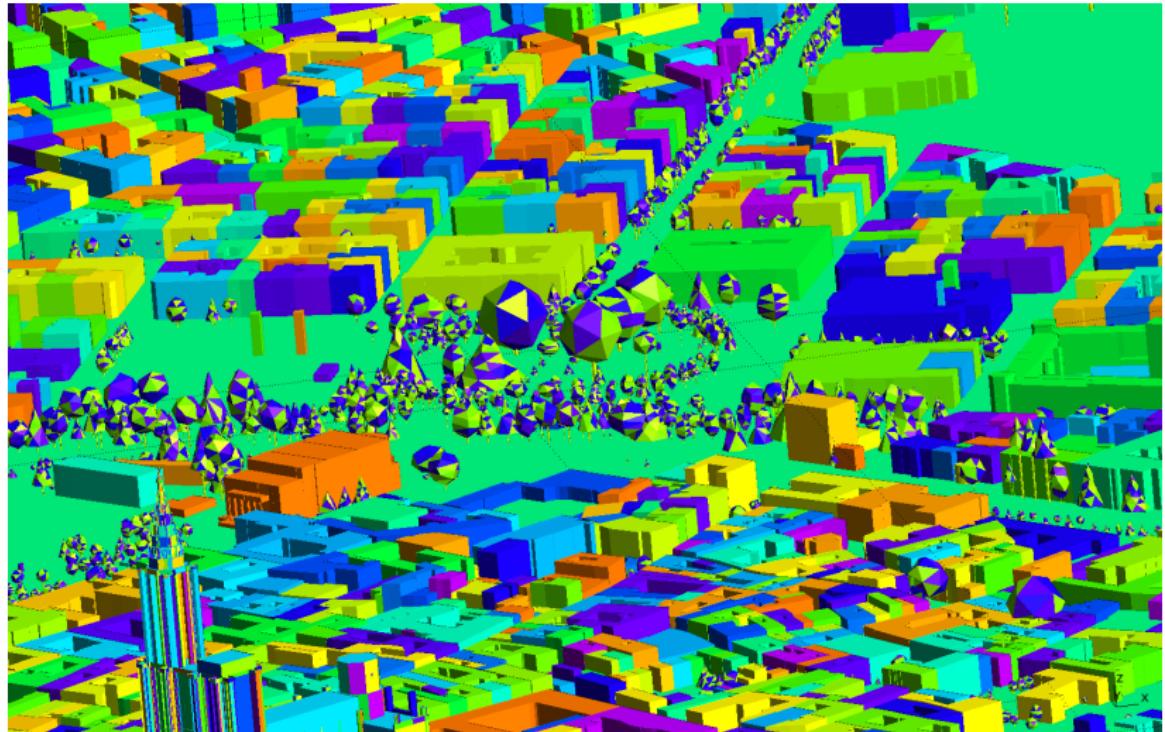


Figure: 3D Model of Strasbourg city center, buildings and vegetation, with a focus on Republic Square, LOD 0

Results: Model Integration

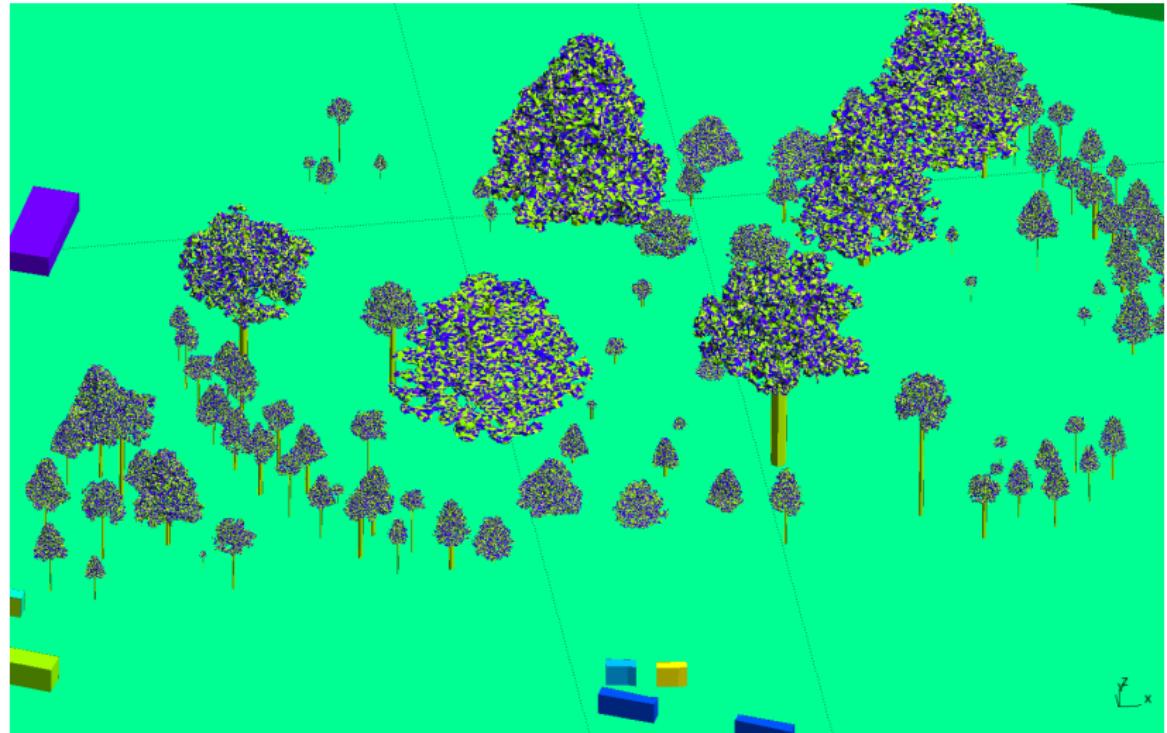


Figure: 3D Model of Strasbourg city center, buildings and vegetation, with a focus on Republic Square, LOD 3

Results: Performance



Figure: Bounding Box 1: 153.7 m^2 , 12 trees

Results: Performance

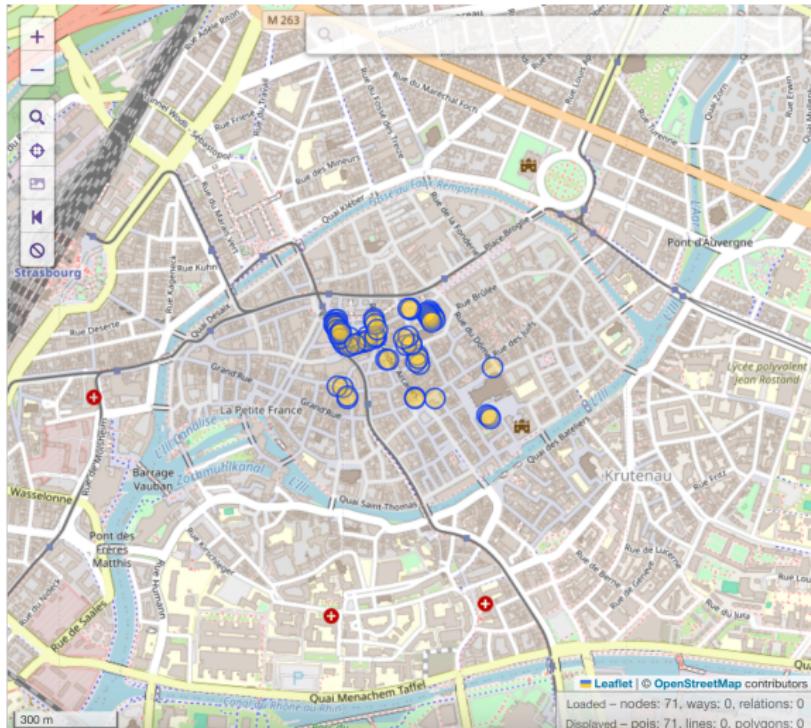


Figure: Bounding Box 2: 384.0 m², 71 trees

Results: Performance

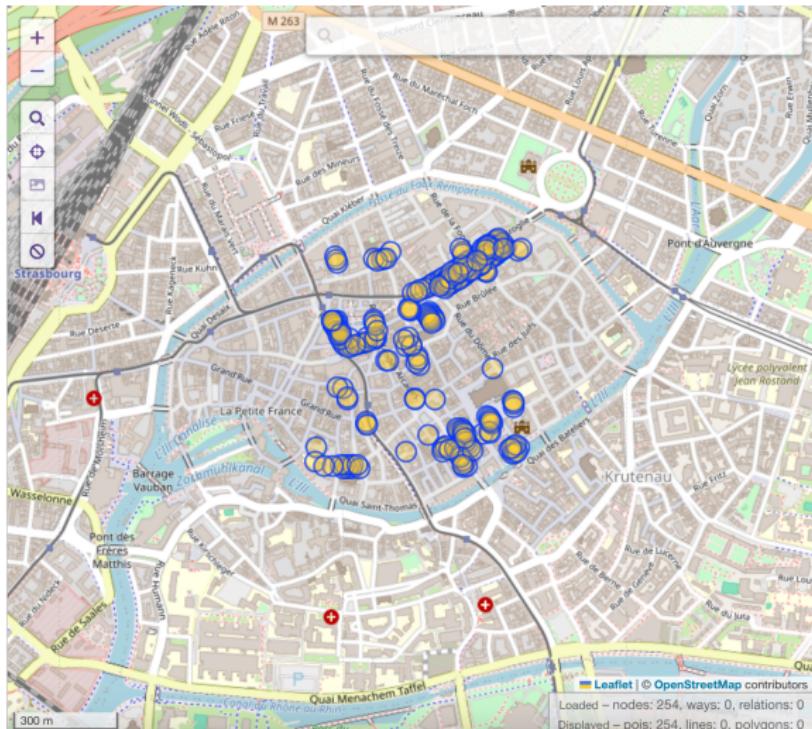


Figure: Bounding Box 3: 626.1 m², 254 trees

Results: Performance

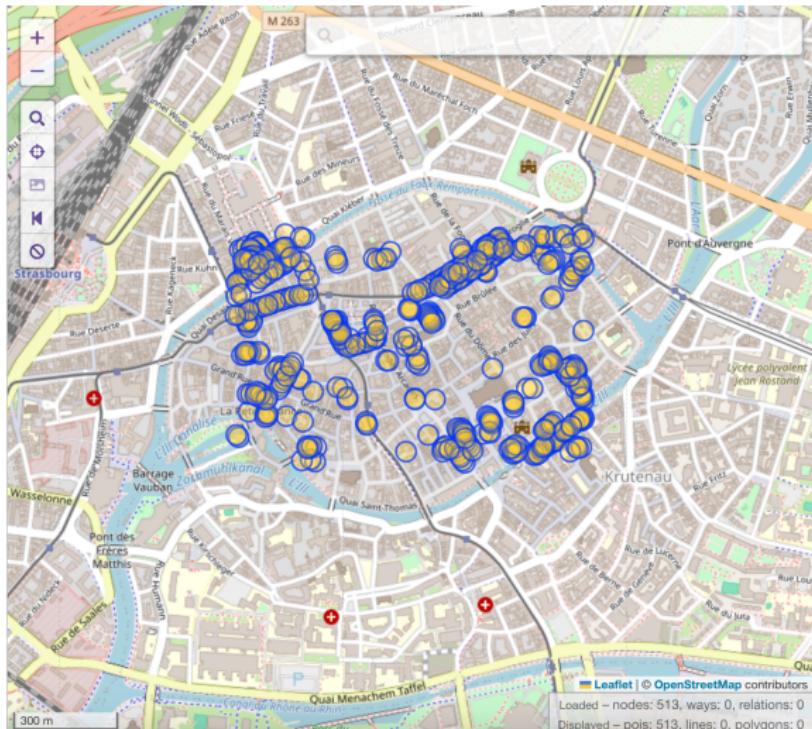


Figure: Bounding Box 4: 808.4 m², 513 trees

Results: Performance

Without LOD 3

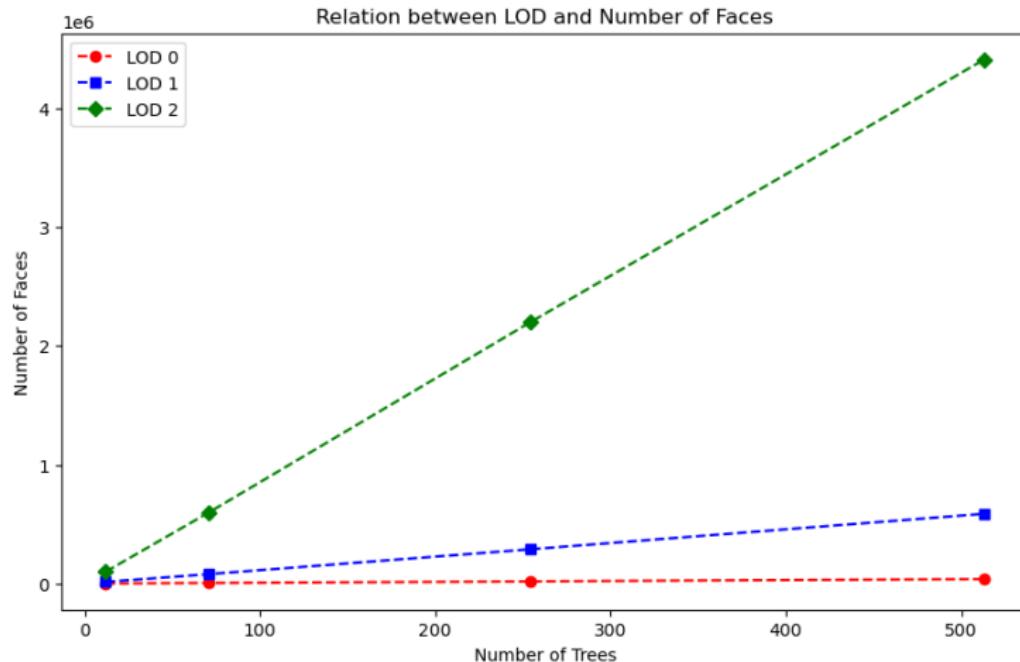


Figure: Relationship between the number of faces and the number of trees

Results: Performance

With LOD 3

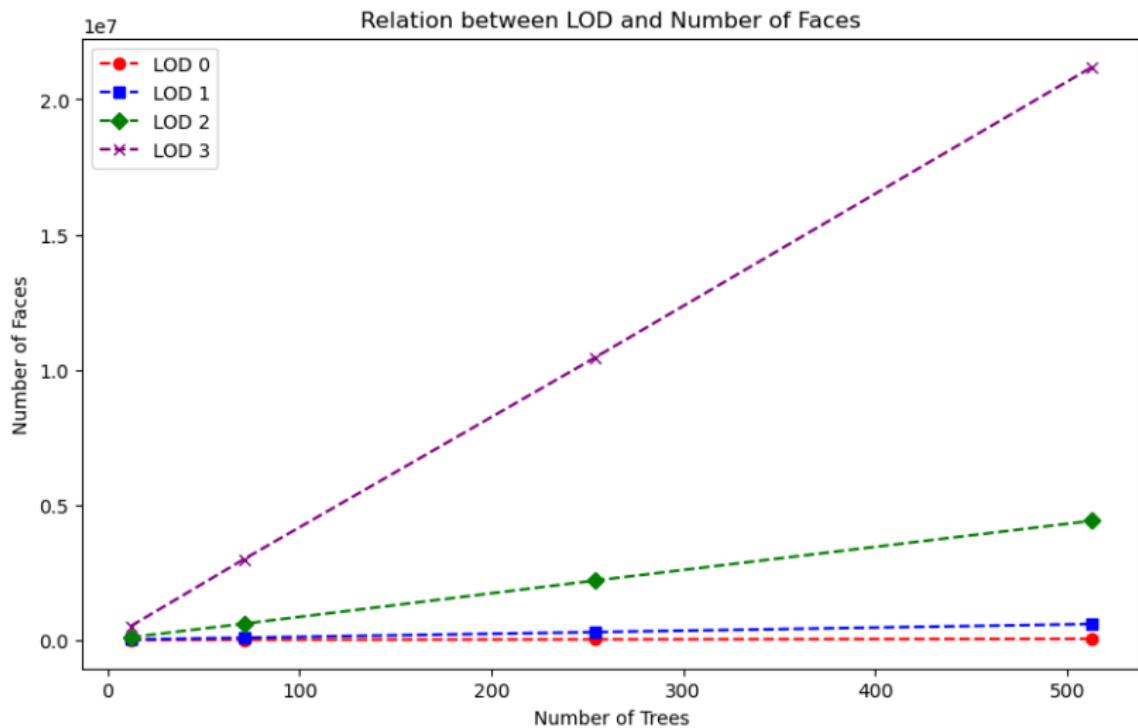


Figure: Relationship between the number of faces and the number of trees

Results: Performance

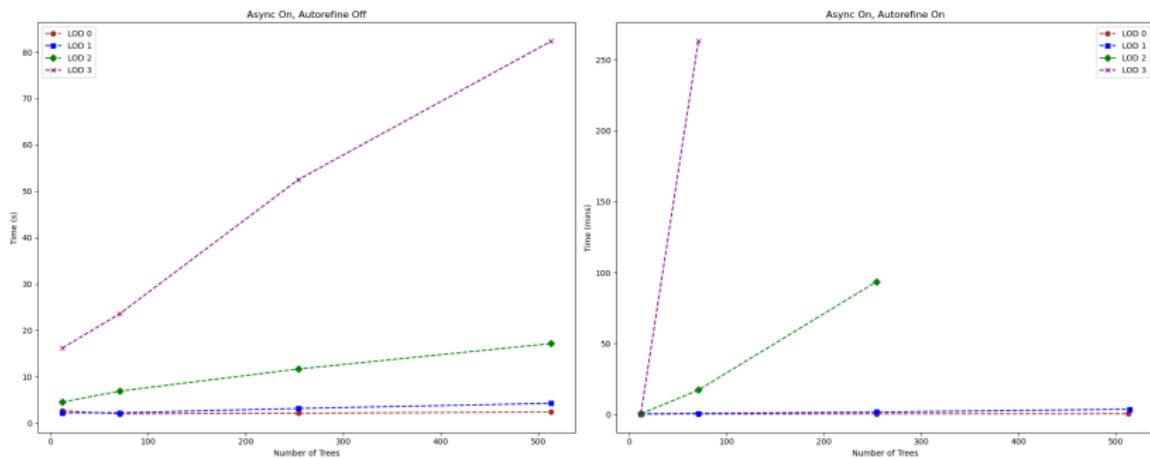


Figure: Comparison of the execution time with and without the autorefine method

Results: Performance

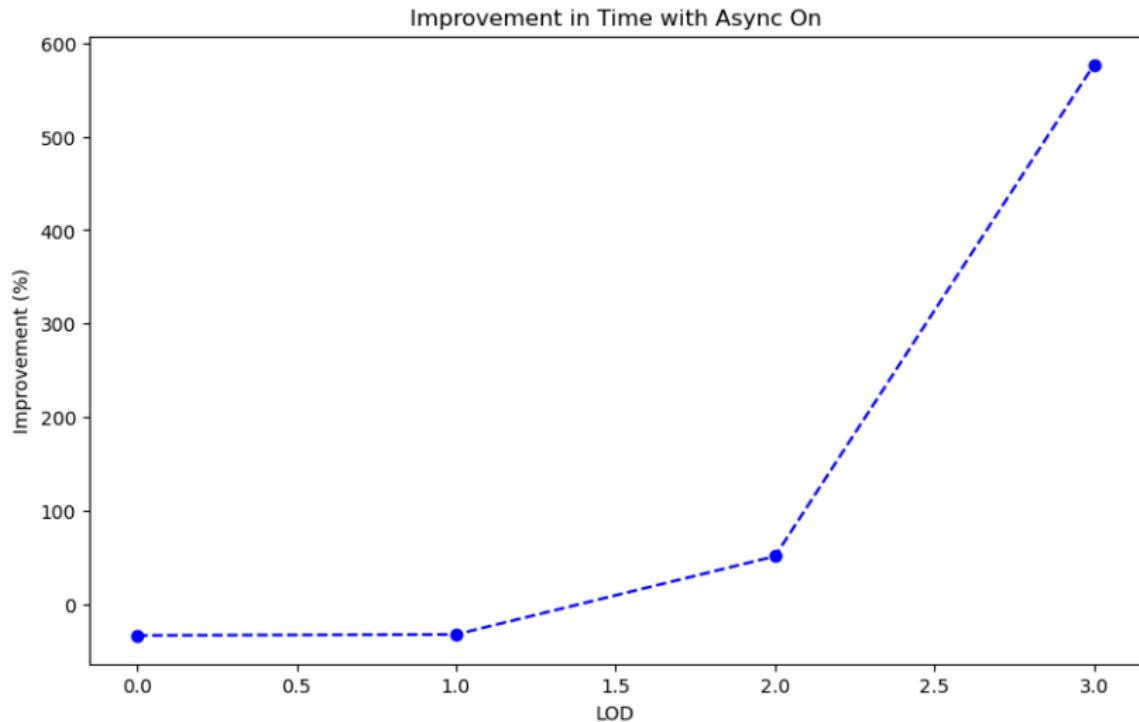


Figure: Thread parallelization improvement

Prospects

- Fixing the tree's altitude

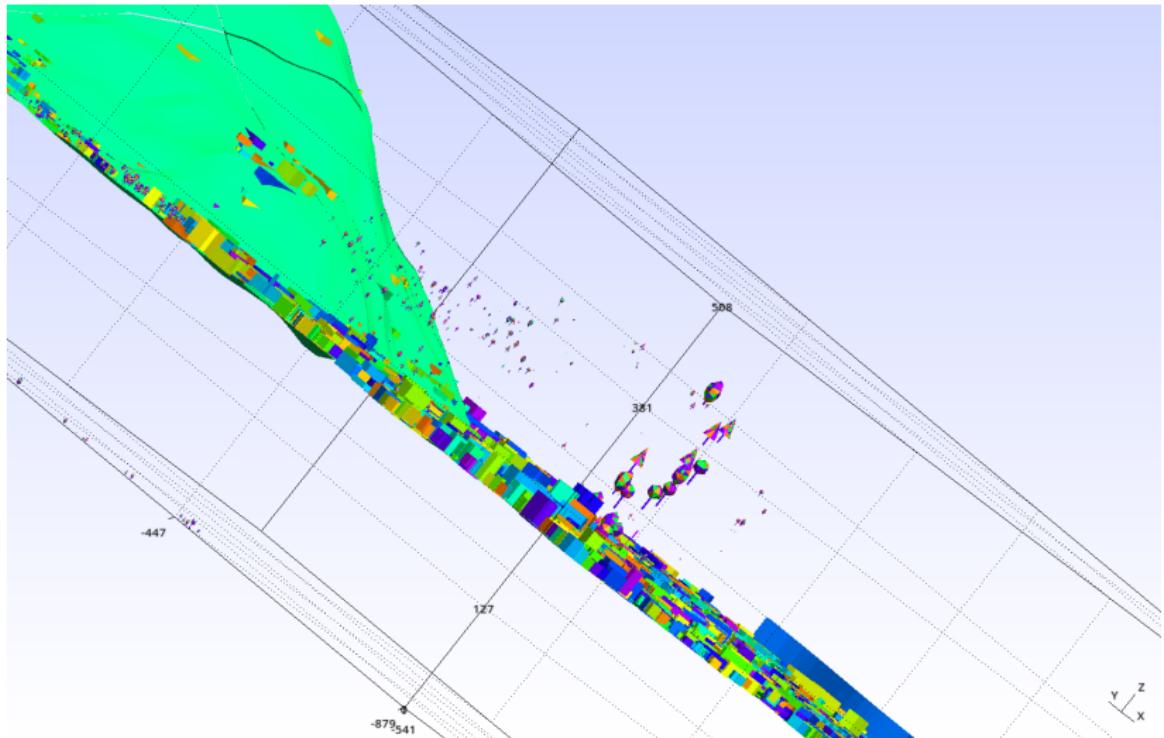


Figure: Grenoble elevation fail

Prospects

- Parallelize the computation of the ‘autorefine’ method

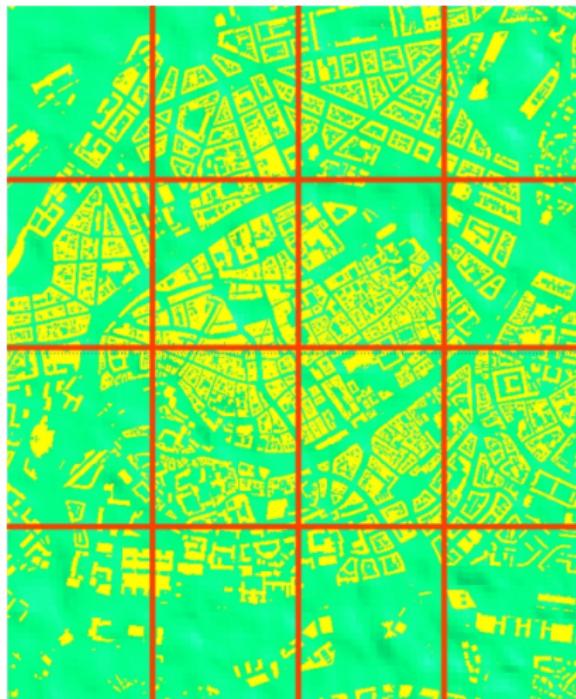


Figure: Terrain mesh splitted into smaller parts, the red lines represent the boundaries of the parts and should not be parallelized

Prospects

- Improve the handling of missing tree data

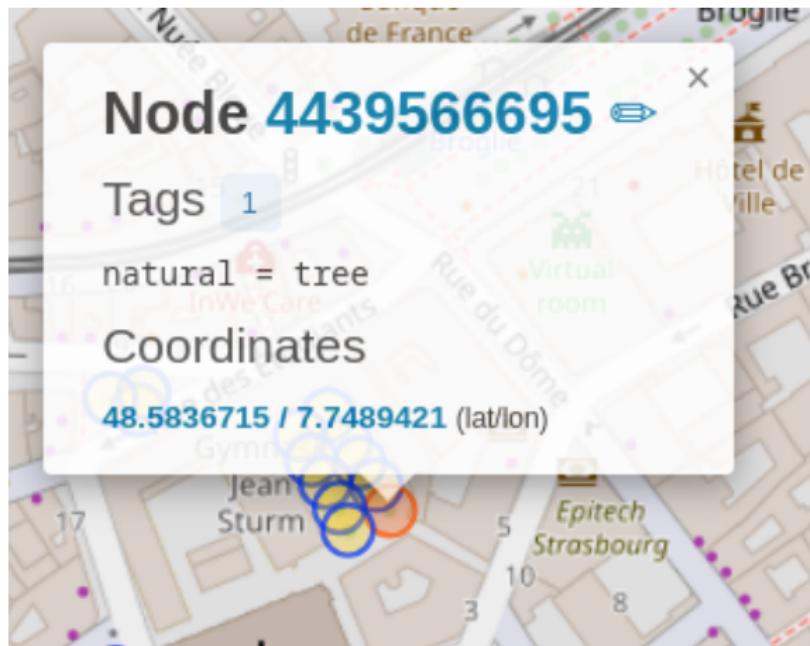


Figure: An Overpass Turbo Node with missing metadata

Prospects

- Shading calculation

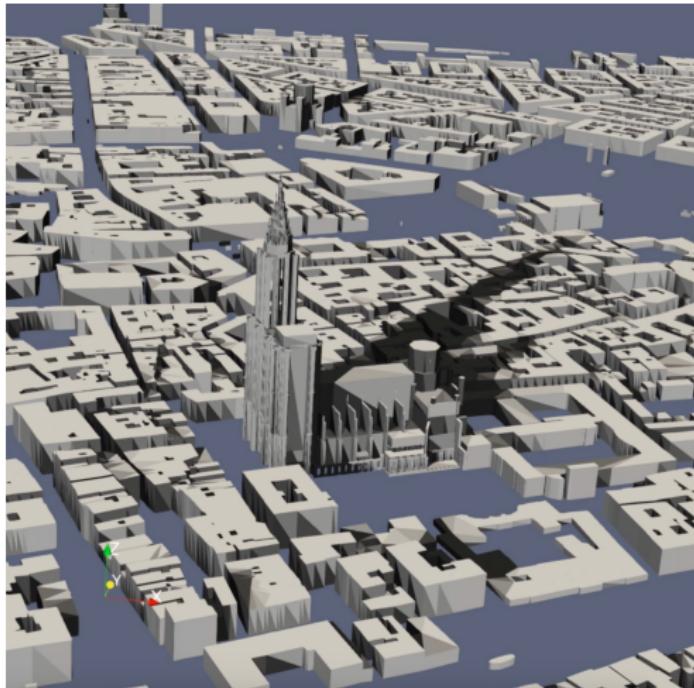


Figure: The shadow cast by the Cathedral of Strasbourg

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?

Contact Information:

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github.com/PA-Senger

-  **Numpex.**
Exa-MA.
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-  **HiDALGO2.**
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-  **P. Verchere.**
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-  **Cemosis.**
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-  **Christophe Prud'homme.**
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Shenzhen Institute of Advanced Technology, China; Purdue

University, USA.

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