ExaMA WP1 - Vegetation

Giulio CARPI LAPI, Pierre-Antoine SENGER

June 3, 2024

Introduction

- Part of the **HiDALGO2** project
- Specifically **Urban Building Model** use case
- Project conducted within **Cemosis - IRMA**
- Supervised by **Pierre Alliez** and **Vincent Chabannes**

HiDALGO Centre of Excellence

cemosis Centre de modélisation et de simulation de Strasbourg

IRMA

Context

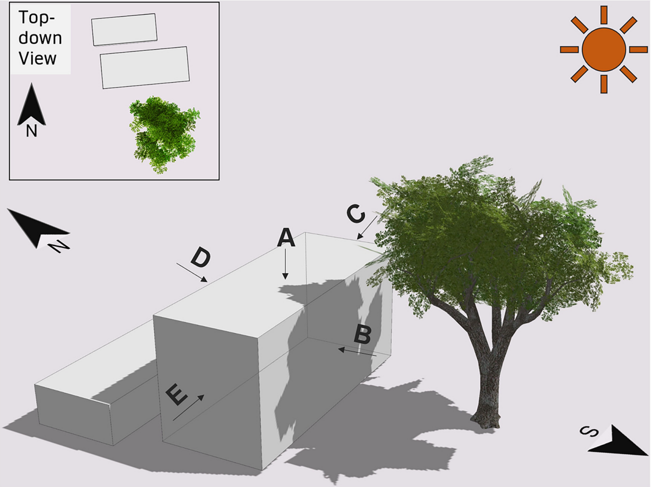


Figure: Tree providing shade to a building[1]

Context

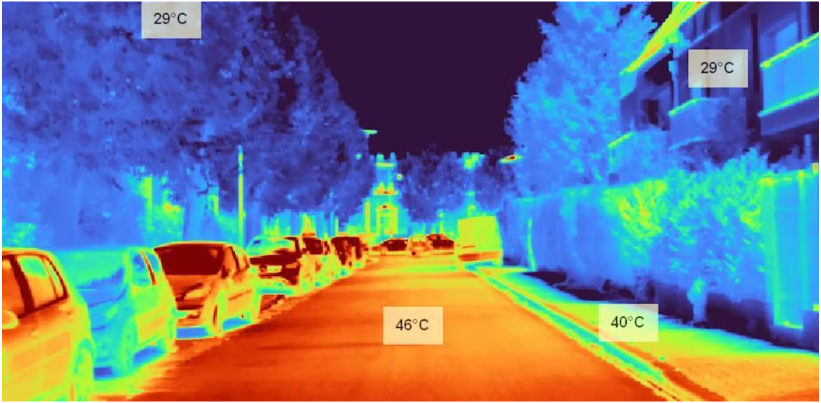


Figure: Thermal image of a street depicting heat distribution[2]

Context

Main goals:

- Integrate **trees** into **3D geometric models** of **urban environments**
- Improve the **accuracy** of **thermal** and **energy simulations**

Context: Primiray focus

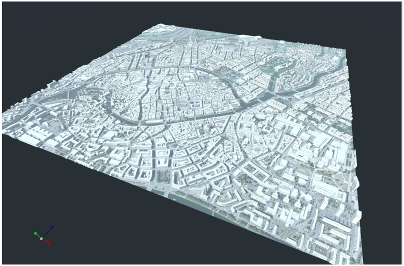


Figure: Strasbourg 3D model (1)

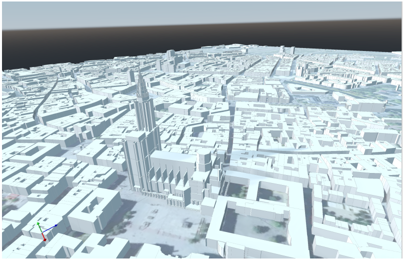


Figure: Strasbourg 3D model (2)

Context: Adaptability

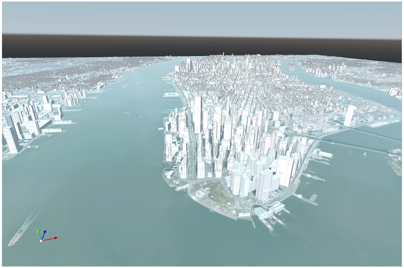


Figure: Manhattan 3D model (1)

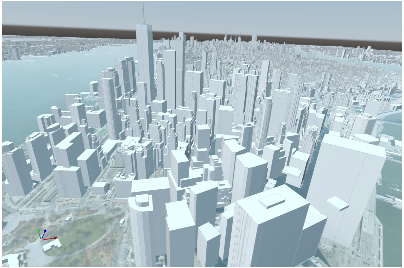


Figure: Manhattan 3D model (2)

Objectives

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

Sofware and libraries: Overpass API

Read-only API to query data from **OpenStreetMap**

Sofware and libraries: OpenStreetMap

Collaborative free **geographic database**

Sofware and libraries: Overpass turbo

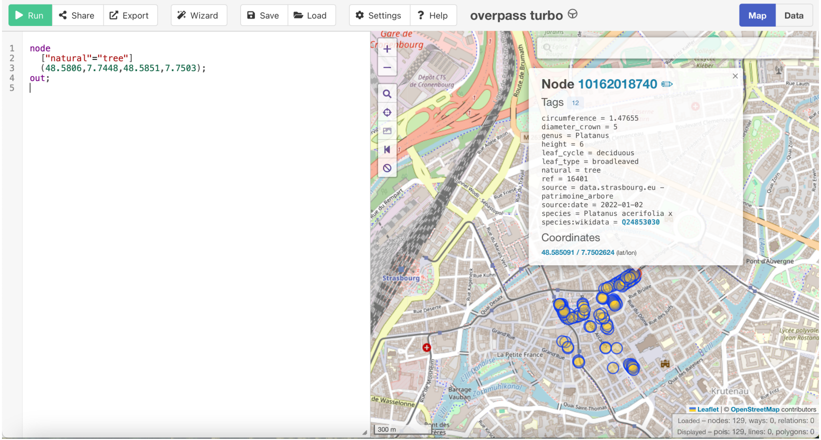


Figure: Query in Overpass turbo interface

Sofware and libraries: Overpass turbo

Sofware and libraries: cURL

URL transfer library

Data acquisition: The query

```cpp
#include <curl/curl.h>

curl_easy_setopt(curl, CURLOPT_URL,
                 "http://overpass-api.de/api/interpreter");

// Set the Overpass query with the bounding box
std::string query =
"[out:json]; (node(" + bbox + ")[\"natural\"=\"tree\"];);
    out;";

std::cout << "Query: " << query << std::endl;

```

Data acquisition: .json output


```json
{
  "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"
  }
}
```

Data acquisition: Base tree models

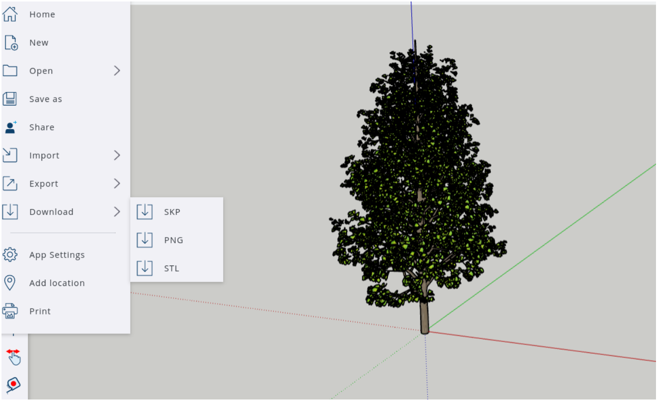


Figure: Mesh of a Ginkgo tree on Sketchup 3D Warehouse

Data acquisition: Base tree models

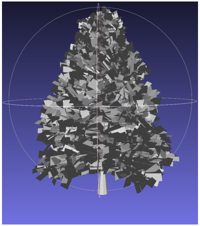


Figure: Abies

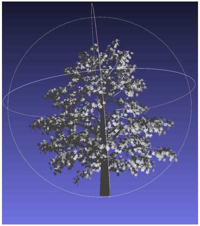


Figure: Acer

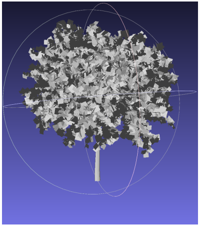


Figure: Aesculus

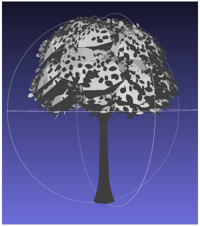


Figure: Catalpa

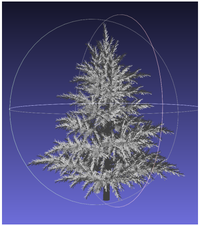


Figure: Cedrus

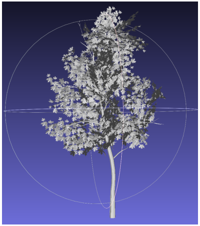


Figure: Liquidanbar

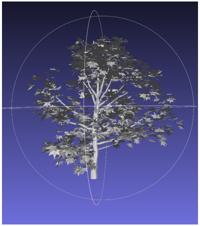


Figure: Platanus

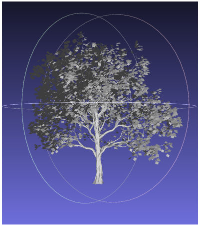


Figure: Quercus

Data acquisition: Tree library

```
{
    "known_genus": ["Abies",
                    "Acer",
                    "Aesculus",
                        ... ],
    "cedrus_like": [ "Chaemacyparis",
                    "Cupressus",
                        ... ],
    "acer_like": ["Fadus",
                "Metasequoia",
                "Sequoiadendron",
                ... ],
    "liquidambar_like": ["Liriodendron",
                        "Pyrus",
                        "Alnus",
                        ... ],
    "quercus_like": ["Corylus",
                    "Carya",
                    "Fagus",
                    ... ]
}
```

Sofware and libraries: CGAL

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

Reminder: Delaunay triangulation

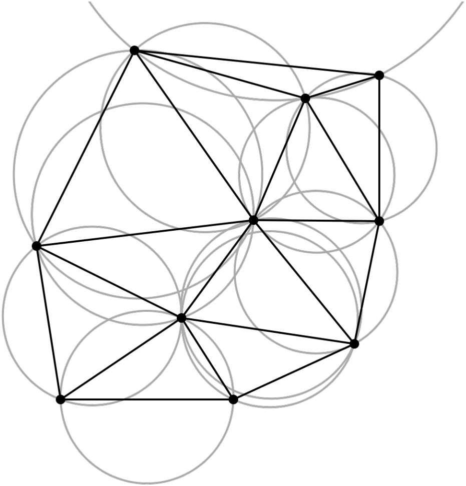


Figure: Delaunay triangulation. The circumcircle of each triangle contains no other point[3]

Reminder: Delaunay and Voronoi

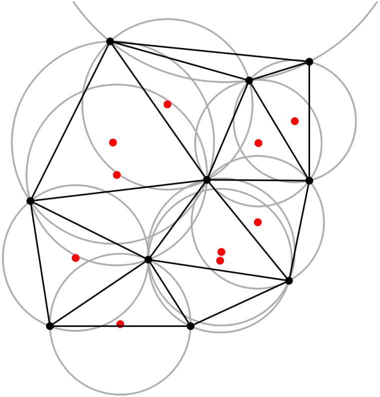


Figure: Delaunay triangulation with the centers of the circumcircles[3]

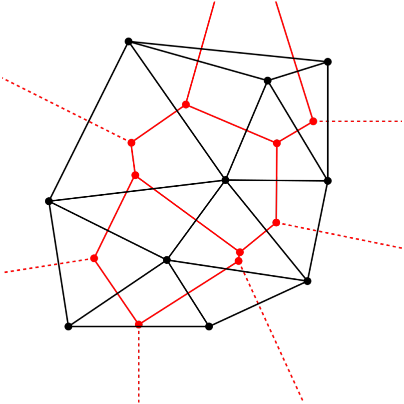


Figure: The dual of the Delaunay triangulation, the Voronoi diagram[3]

Tree modeling: Alpha Wrapping

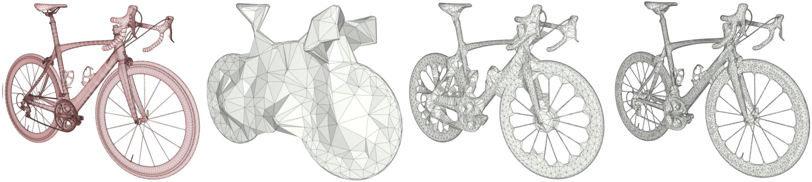


Figure: Different LOD of the Alpha Wrapping of a bike[4]

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

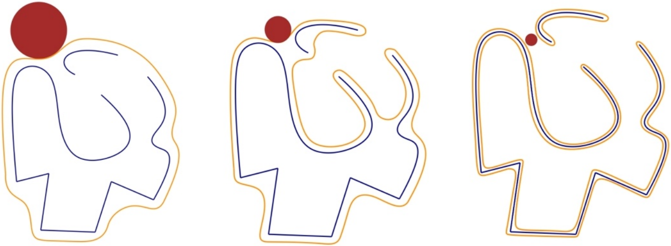


Figure: Alpha Wrapping in 2D with Offset and different Alpha parameters

Tree modeling: Alpha Wrapping

video link

Tree modeling: wrapping base tree

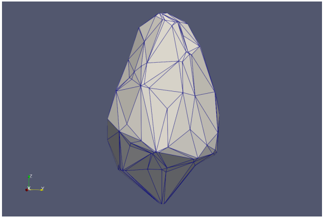


Figure: Ginkgo lod0

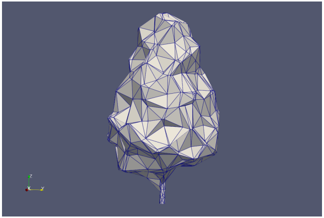


Figure: Ginkgo lod1

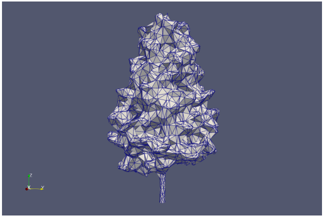


Figure: Ginkgo lod2

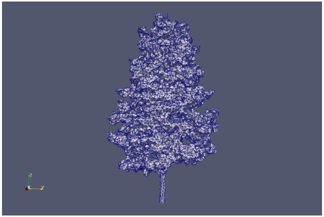


Figure: Ginkgo lod3

Tree modeling: Mercator's projection

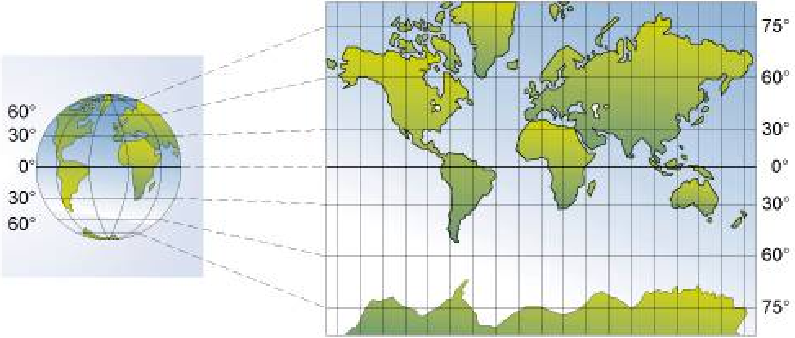


Figure: Mercator's projection[5]

Tree modeling: Mercator's projection

A(latitude, longitude) $=$ A(ϕ, λ),

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

,where λ_0 is the center of the map

Tree modeling: Mercator's projection

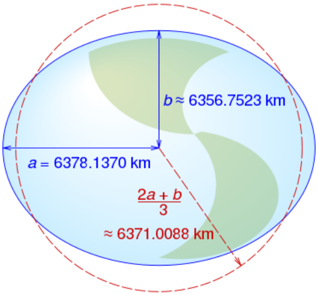


Figure: Earth as an ellipsoid[6]

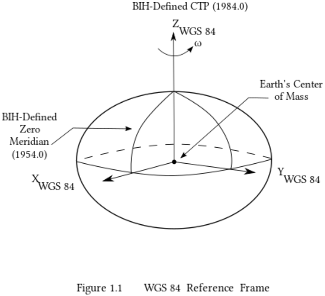


Figure: WGS 84 reference frame[6]

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

Tree modeling: affine transformation

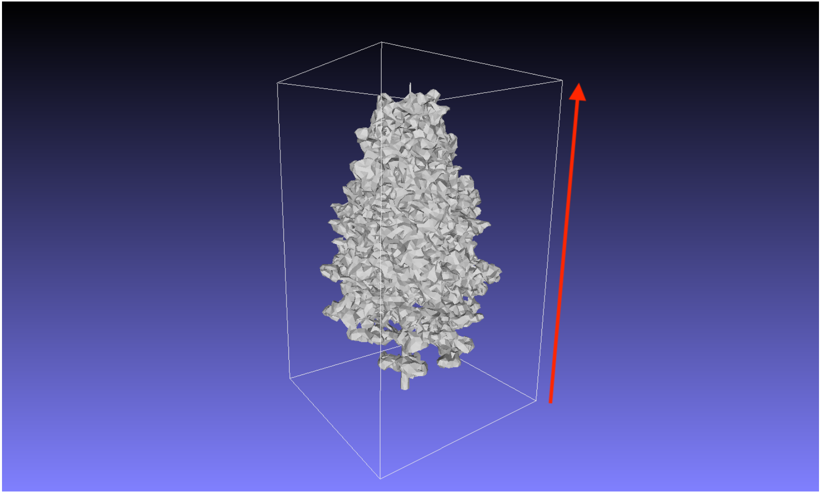


Figure: Ginkgo tree bounding box

Tree modeling: affine transformation

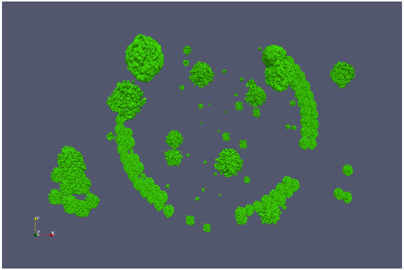


Figure: Republic square with LOD 3 trees.

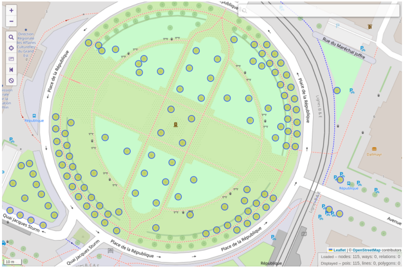


Figure: Republic square trees from Overpass turbo[7]

Tree modeling: affine transformation

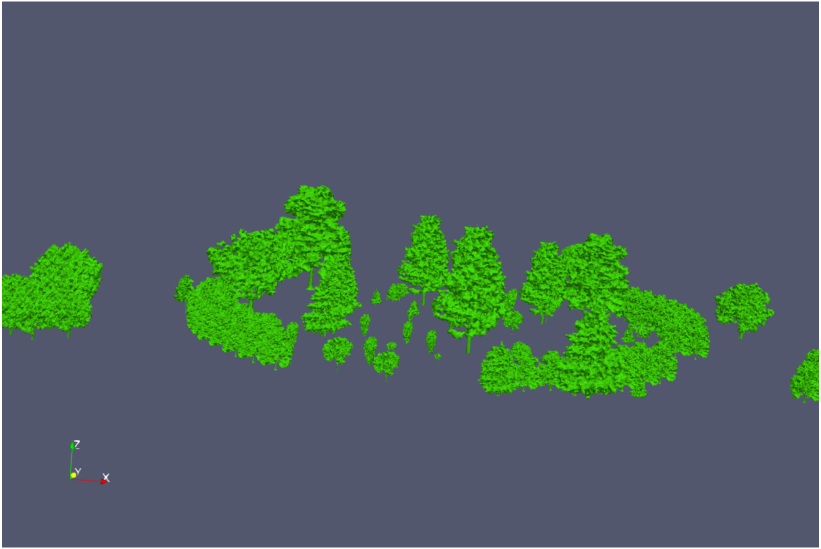


Figure: Side view of Republic square with LOD 3 trees

Tree modeling: model integration

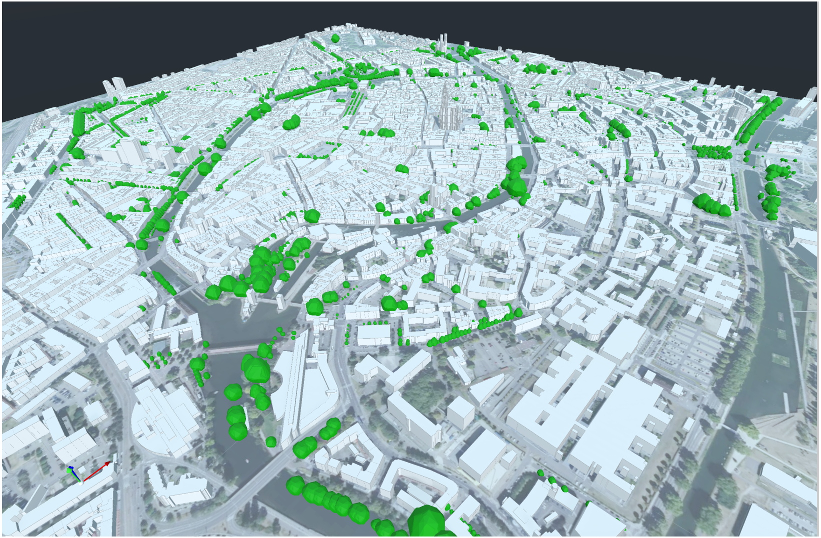


Figure: Strasbourg 3D model with LOD 0 trees

Tree modeling: model integration

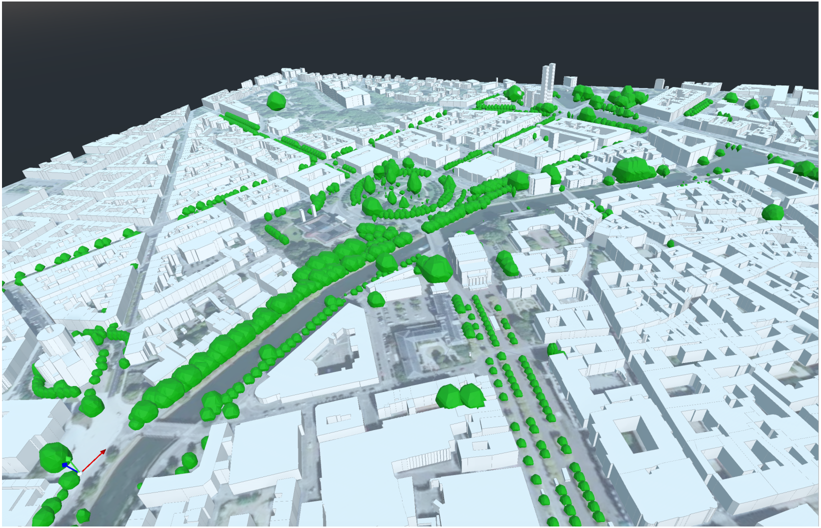


Figure: Strasbourg 3D model with LOD 0 trees

Benchmark

Figure: Bounding Box 1: 153.7 m², 12 trees

Benchmark

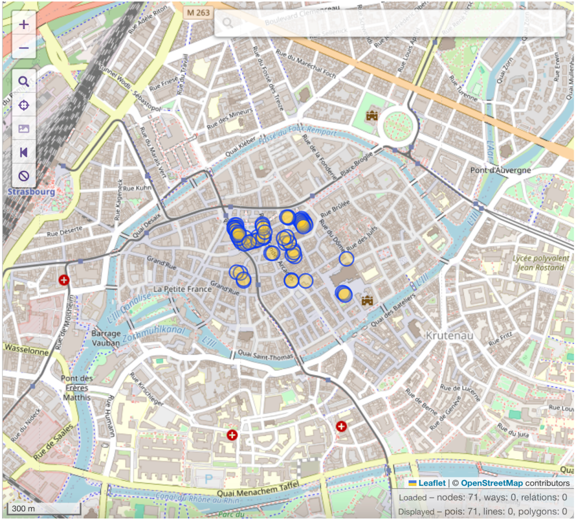


Figure: Bounding Box 2: 384.0 m², 71 trees

Benchmark

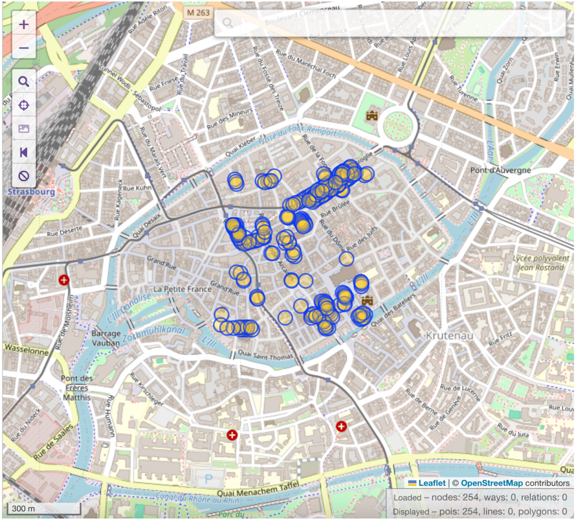


Figure: Bounding Box 3: 626.1 m², 254 trees

Benchmark

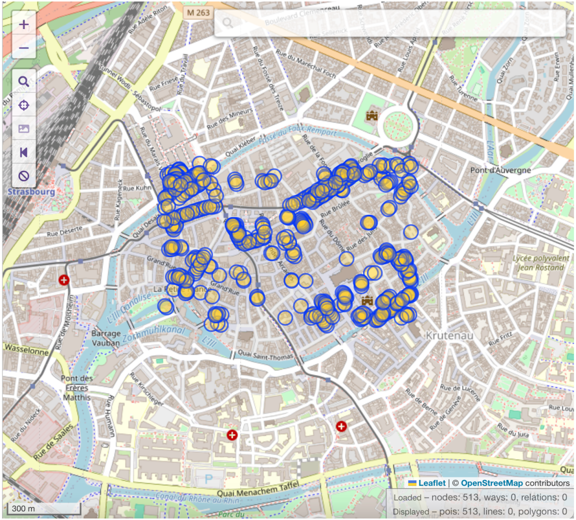
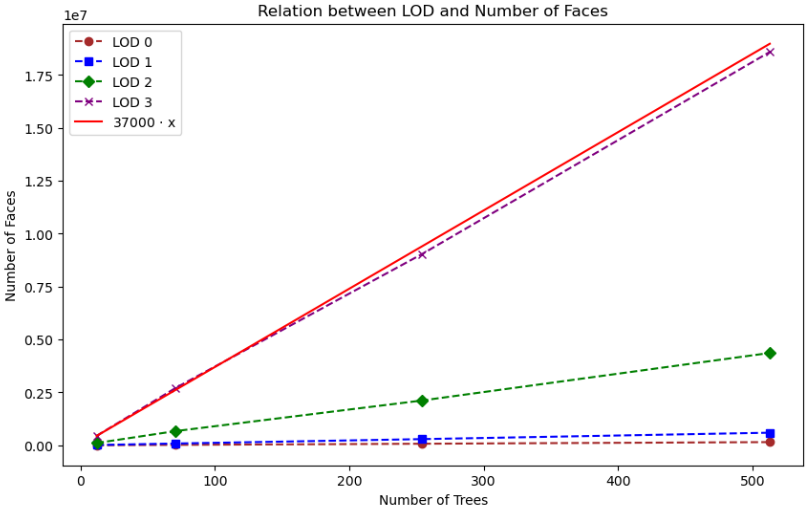


Figure: Bounding Box 4: 808.4 m², 513 trees

Benchmark: relation LOD-number of faces



Benchmark: execution time (Part 1)

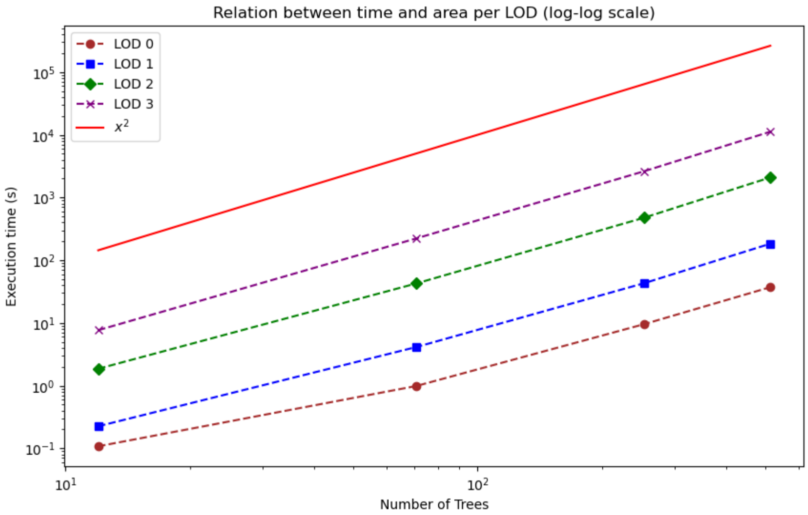


Figure: `corefine_and_compute_union`

Benchmark: execution time (Part 2)

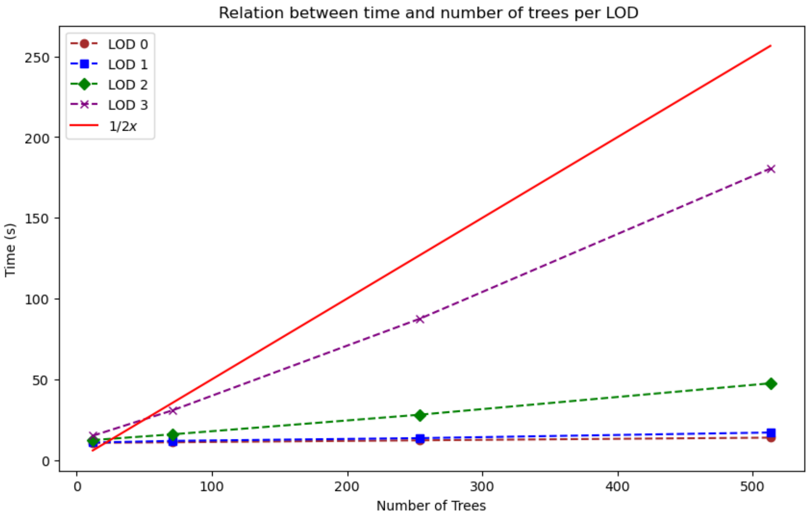


Figure: `autorefine_triangle_soup`

Prospects

- Account for **seasonal changes** and **leaf fall**
- **Solar masks** and **shading calculations**

Prospects: Leaf fall

- Seasonal leaf changes
- **More** leaves in **spring**/**summer** and **fewer** in **fall**/**winter**

Prospects: Shading calculations

- Ray tracing and shading simulations with **Feel++**
- **Impact** of **trees** in urban **microclimates**

Prospects: Shading calculations

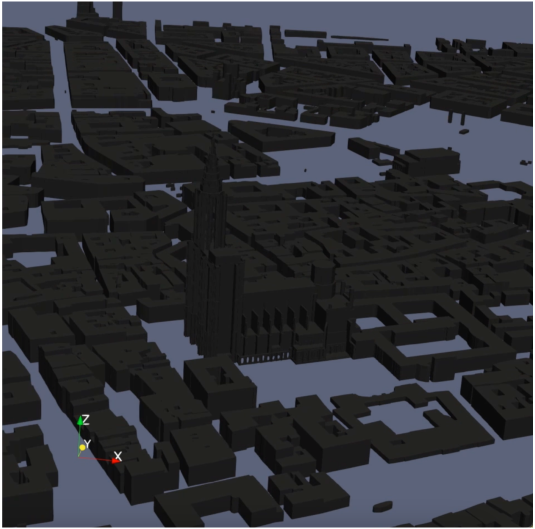


Figure: Shading calculations in urban environments (1)

Prospects: Shading calculations

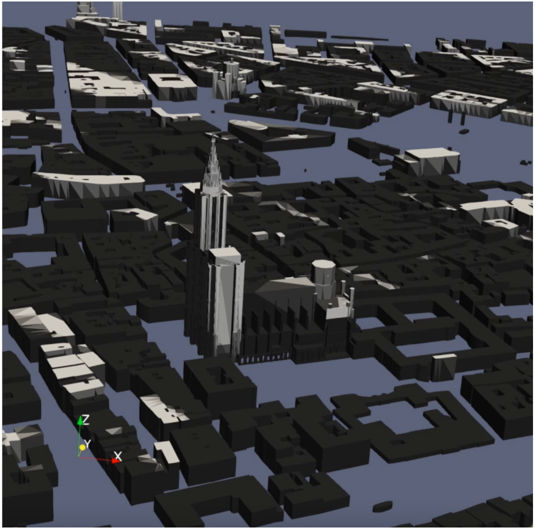


Figure: Shading calculations in urban environments (2)

Prospects: Shading calculations

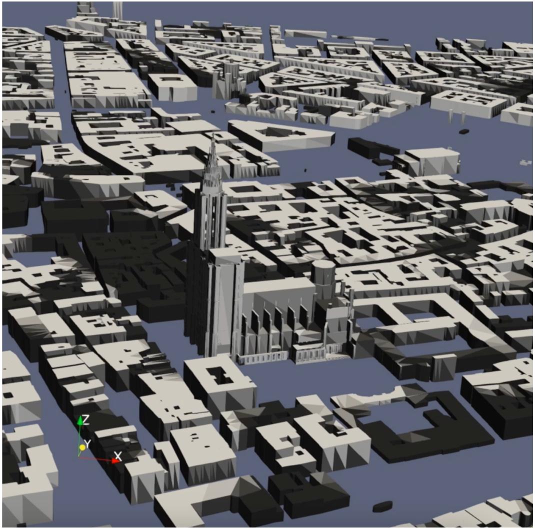


Figure: Shading calculations in urban environments (3)

Prospects: Shading calculations

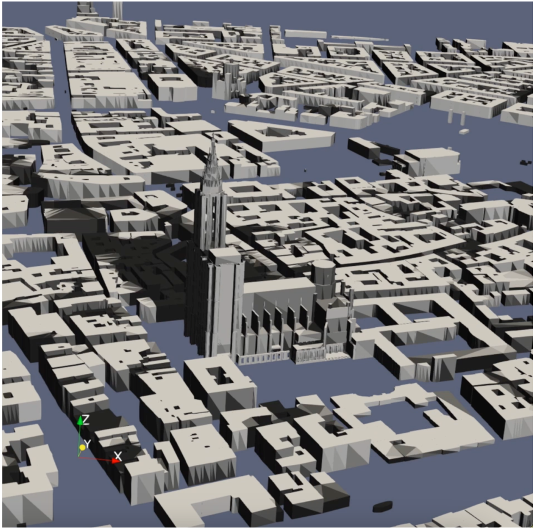


Figure: Shading calculations in urban environments (4)

Prospects: Shading calculations

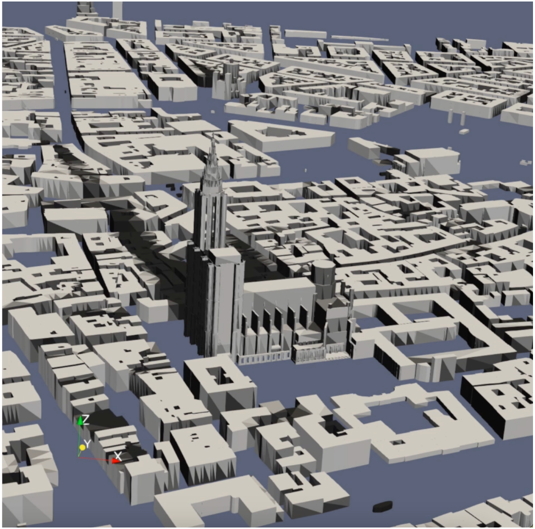


Figure: Shading calculations in urban environments (5)

Prospects: Shading calculations

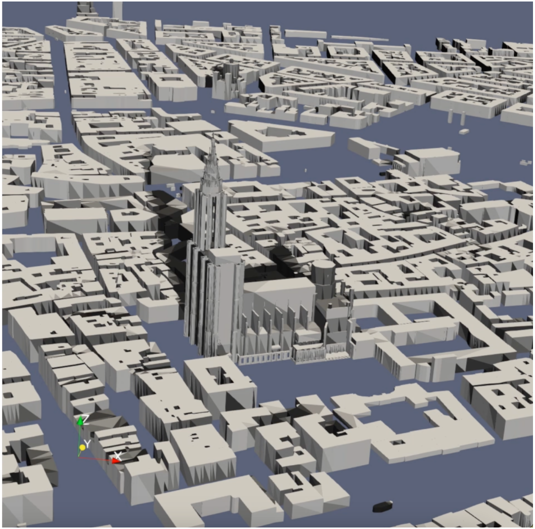


Figure: Shading calculations in urban environments (6)

Prospects: Shading calculations

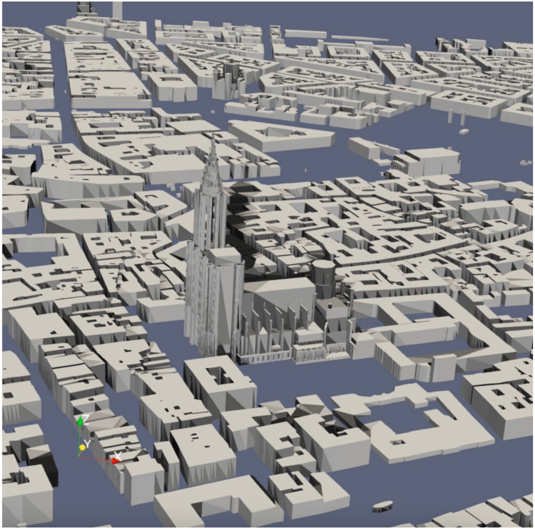


Figure: Shading calculations in urban environments (7)

Prospects: Shading calculations

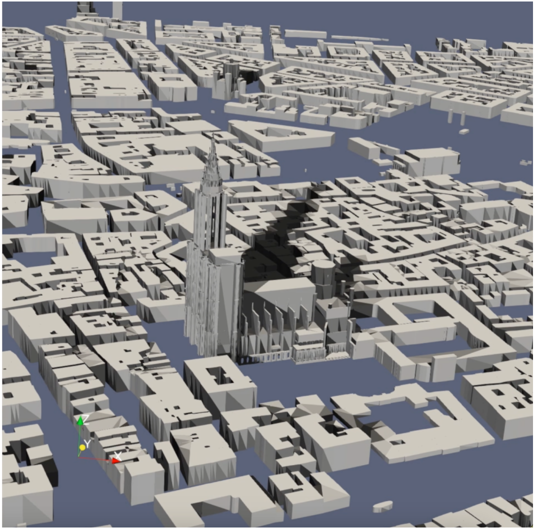


Figure: Shading calculations in urban environments (8)

Prospects: Shading calculations

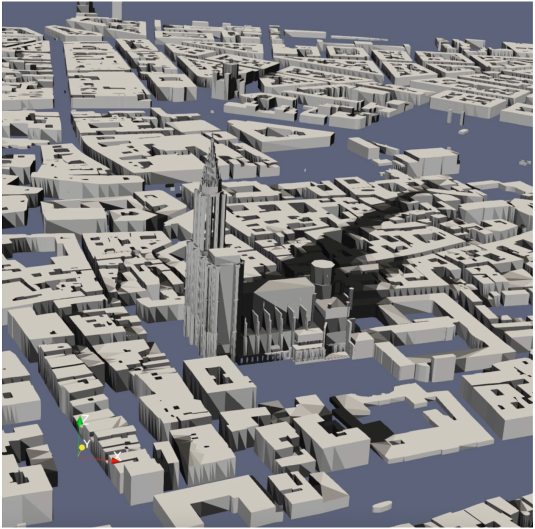


Figure: Shading calculations in urban environments (9)

Prospects: Shading calculations

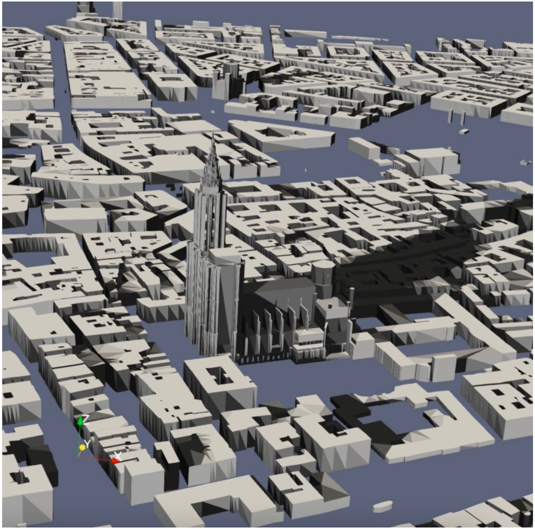


Figure: Shading calculations in urban environments (10)

Prospects: Shading calculations

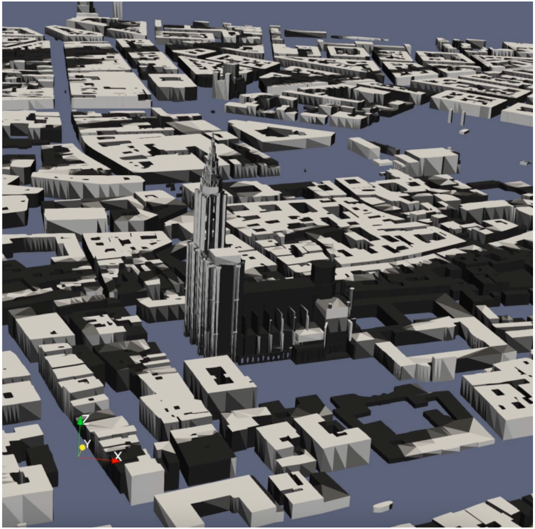


Figure: Shading calculations in urban environments (11)

Prospects: Shading calculations

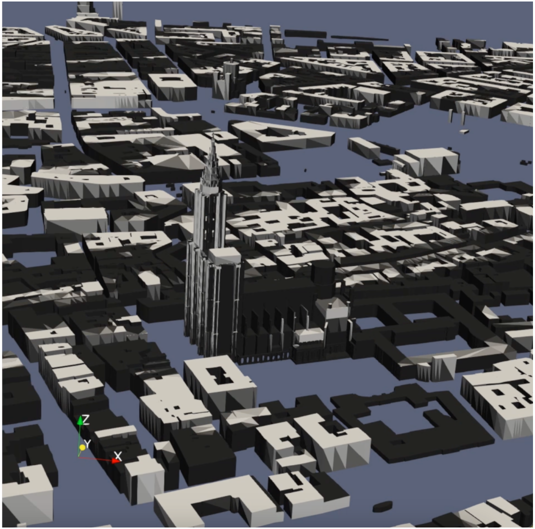


Figure: Shading calculations in urban environments (12)

Prospects: Shading calculations

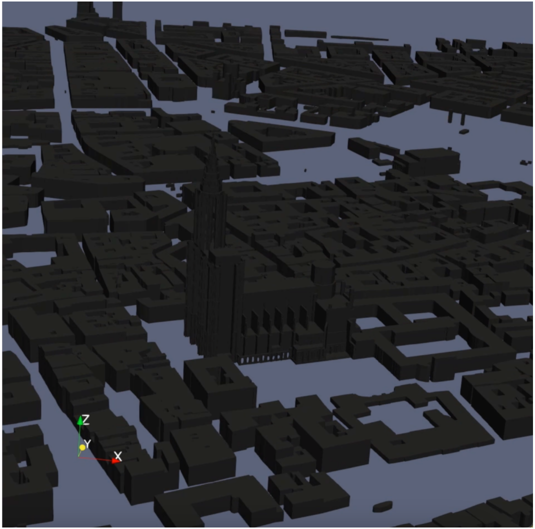


Figure: Shading calculations in urban environments (13)

Conclusion

- **Tree data** extraction from **OpenStreetMap**
- **3D tree models** generation with **CGAL**
- **Integration** of tree models in the **terrain mesh**
- **Optimization** of **computational efficiency**

Conclusion

ExaMA WP1 - Vegetation:

- Foundation for future urban energy simulations integrating vegetation into the models

The end

Thank you for your attention!

Yujin Park, Jean-Michel Guldmann, Desheng Liu.
Impacts of tree and building shades on the urban heat island: Combining remote sensing, 3D digital city and spatial regression approaches.
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Mercator projection.
Wikipedia, 2024.

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