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OBSERVATION



LIÈGE université  
GeoScITY

# From semantic segmentation of LiDAR point clouds to 3D objects for digital twins

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# Who are we?

## Geospatial Data Science and City Information Modeling

### GeoScITY

The “Geospatial Data Science and City Information Modeling” Lab is a research group specialising in spatial information modelling. Its activities cover both theoretical aspects (qualitative spatial reasoning, spatial ontologies, etc.) and operational developments (use of AI methods in geospatial data processing, development of spatial data infrastructures, etc.). Research focuses mainly on urban applications, from the territorial to the building scale, without excluding other themes such as digital heritage.

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*Acquisition, processing and display of geographical data "from territory to building scale"*

[www.geoscience.uliege.be](http://www.geoscience.uliege.be)



# City Digital Twin

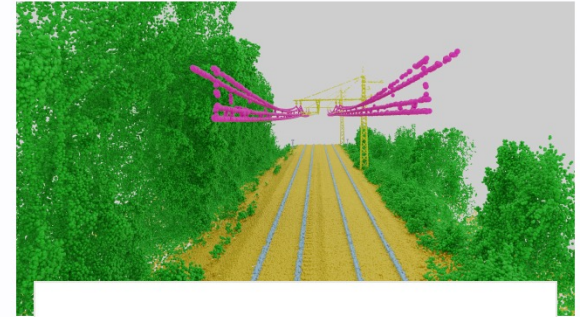
## Some recent projects



**SEM 3D**



**Cerbere**



**TrackGen**

## Some on-going or recent PhD Thesis

*Semantic segmentation of aerial LiDAR data using deep learning*

*Towards a 3D property valuation with BIM-CIM based data*

*City digital twins: levels of data integration*

*Change detection using mobile LiDAR point's cloud*

*From consistency to flexibility: shifting the structure*



# 3D semantic objects for urban applications (SEM 3D)



SEM 3D



Research  
Innovation  
award  
BeGEO 24

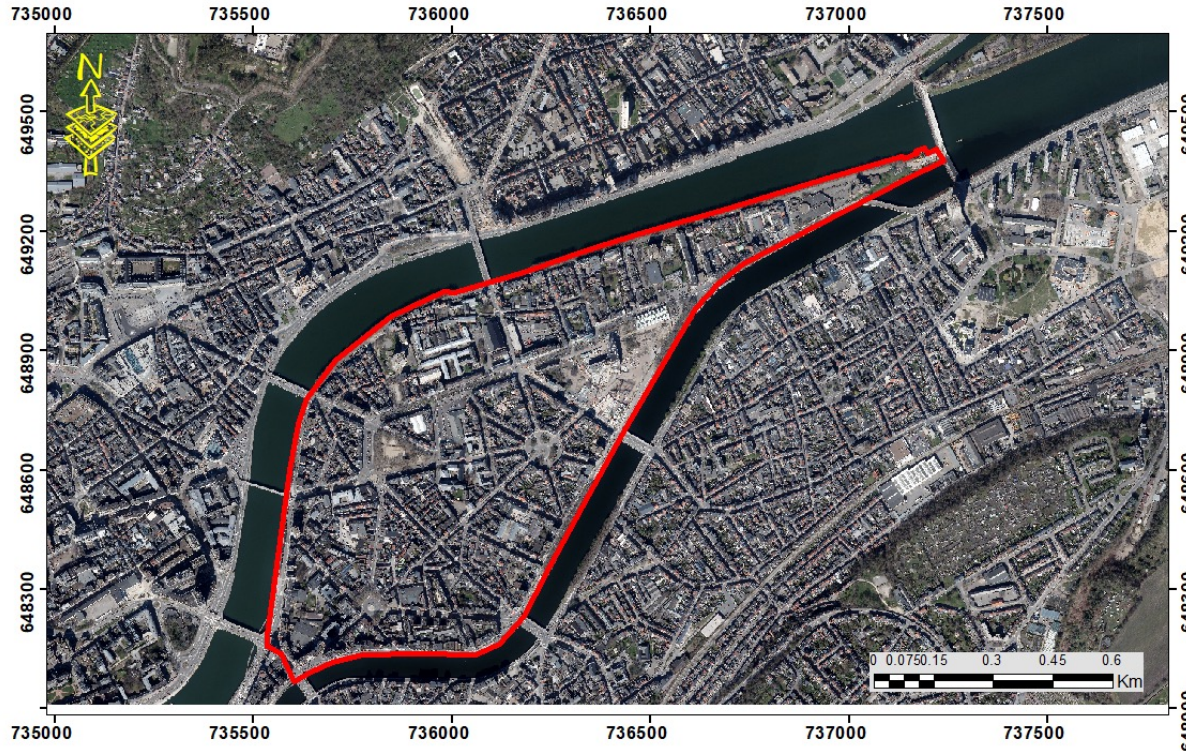
## Scientific objectives

- Implementation of procedures for extracting semantically enriched urban 3D objects based on data from airborne or ground-based sensors (LiDAR and spectral) using Deep Learning (DL) type artificial intelligence (AI) techniques.

## In practice...

- *Enabling the City of Liège to improve urban management using 3D objects (buildings, trees, roads, etc.) obtained from data made available by the Walloon Region.*

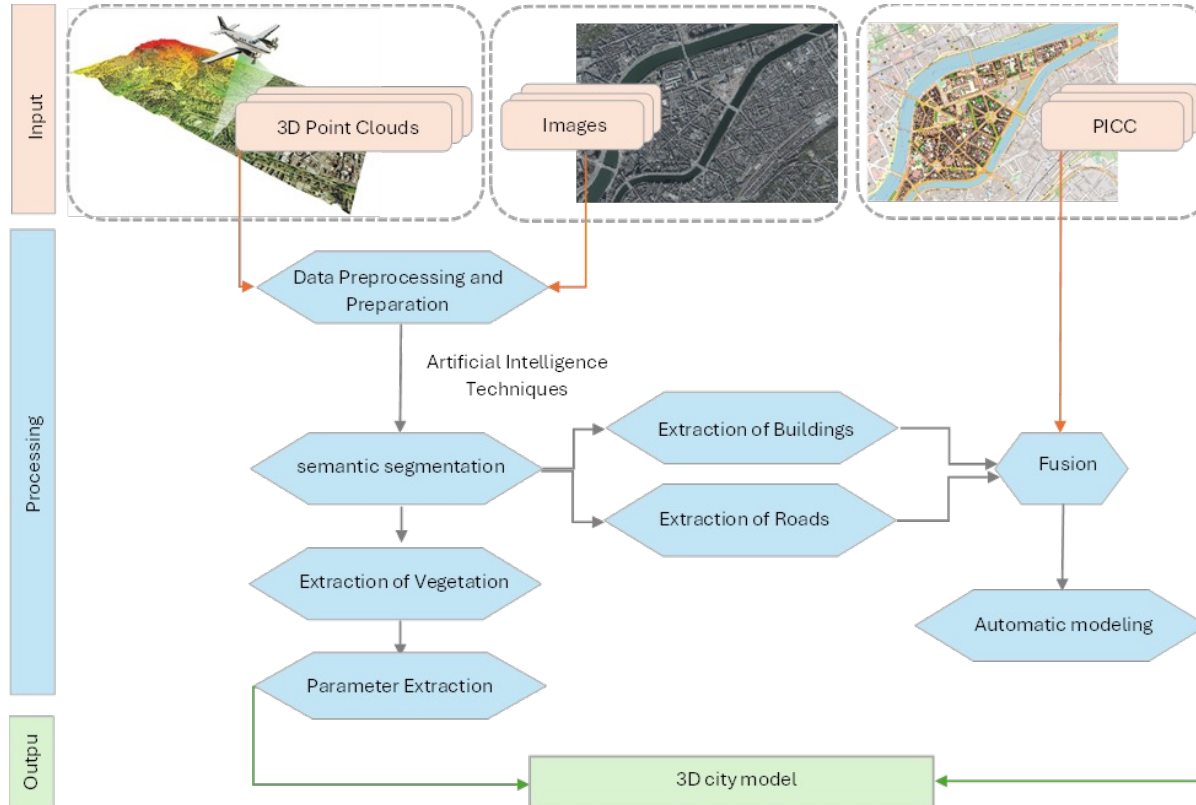
# SEM 3D – case study



Outremeuse island – City of Liege, Belgium



# SEM 3D - The general workflow

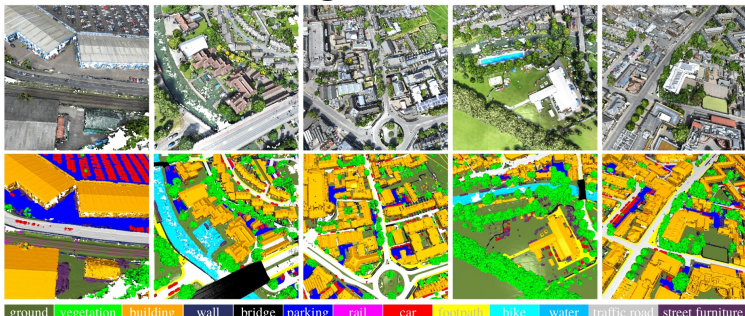


## NOTATION

- Data
- ⬡ Processing
- ▭ Output

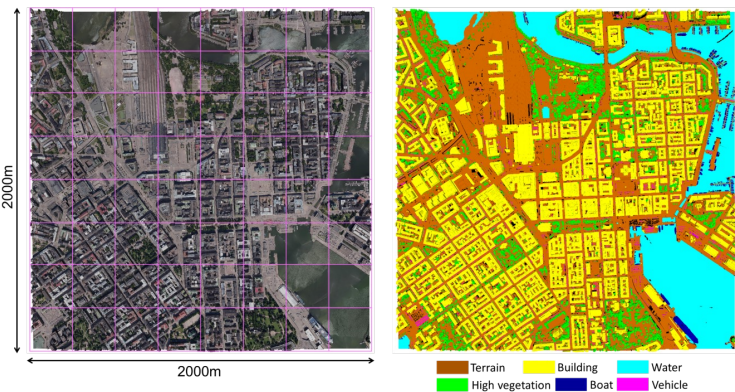
# SEM 3D - Point classification

## Training sets 1

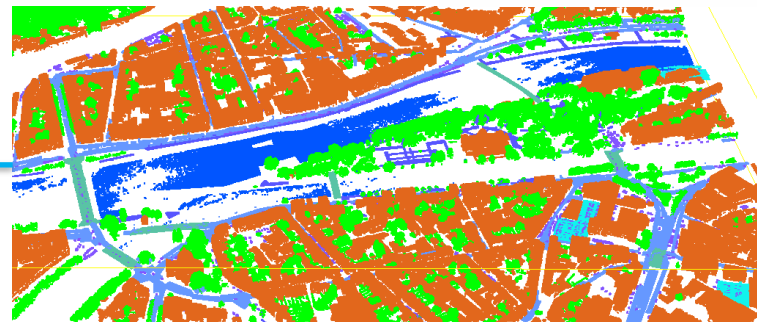


### SensatUrban dataset

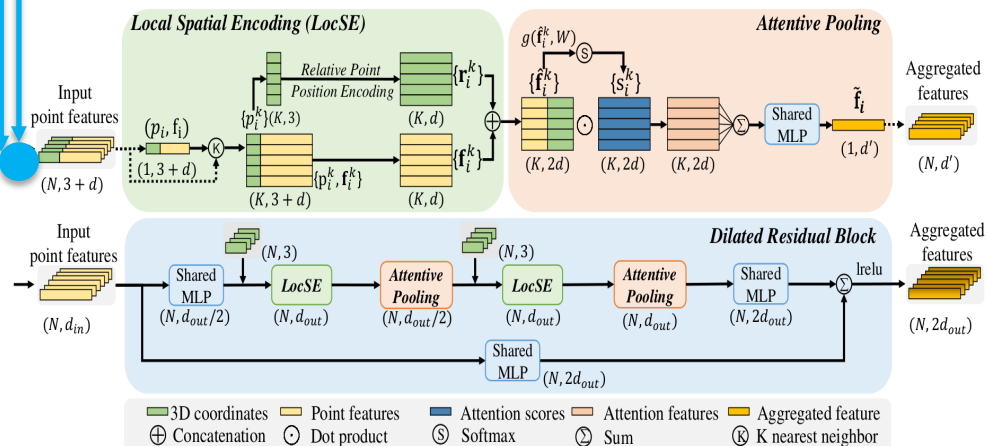
## Training sets 3



## Training sets 2



### Liège dataset



## Deep learning model

# SEM 3D – Point classification

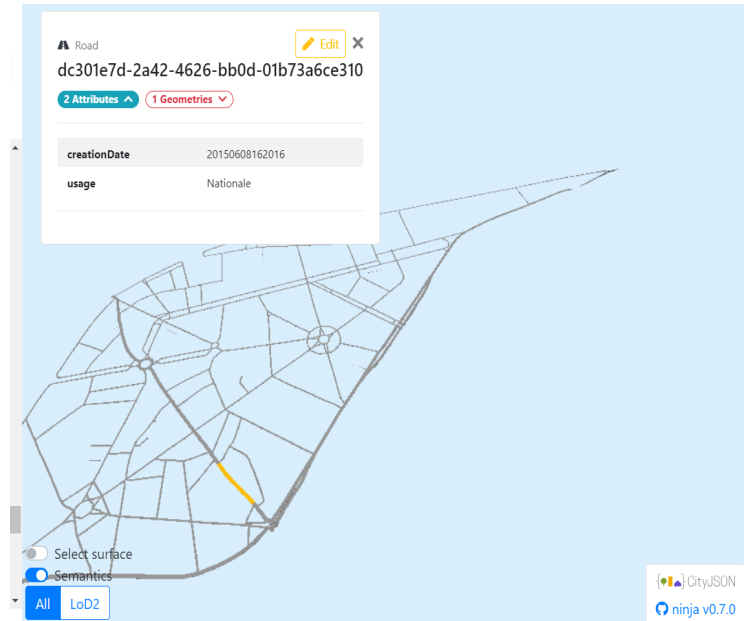
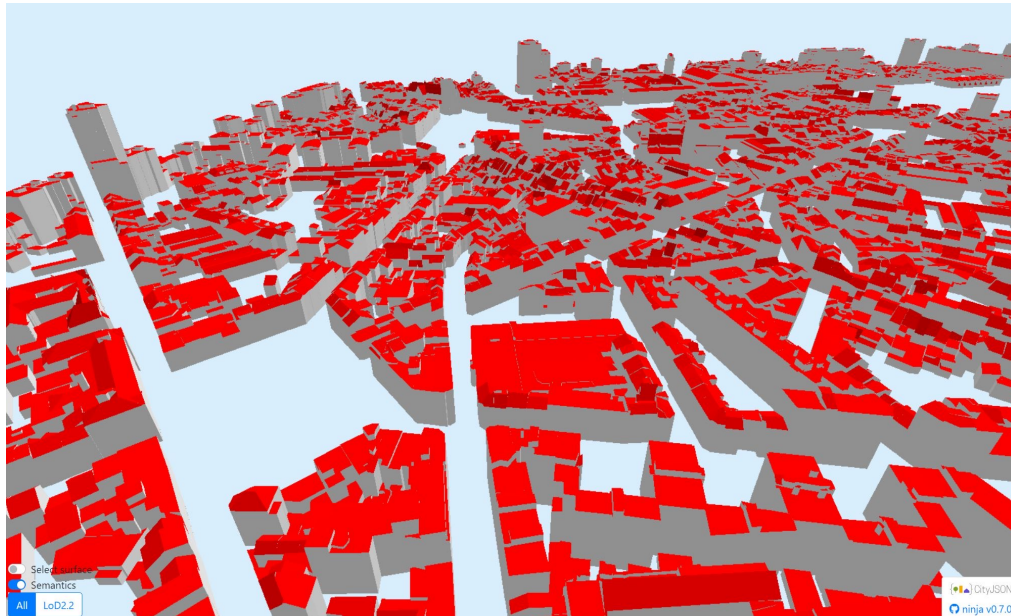
- ▶ 3D classification of points into several categories using deep learning techniques (AI)





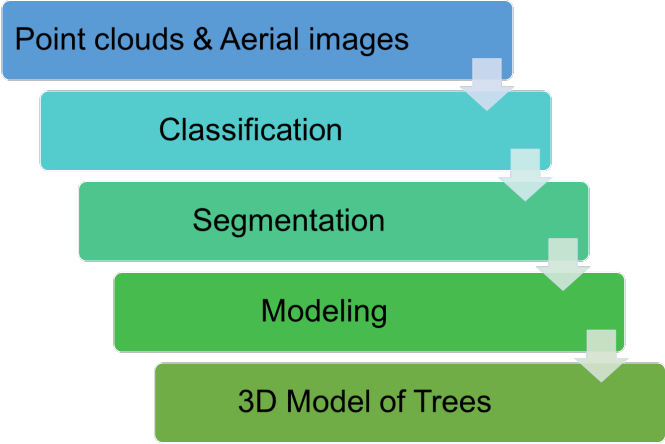
# SEM 3D – Creation of 3D city models

- ▶ Based on classified points and 2D vector data
- ▶ Building and road

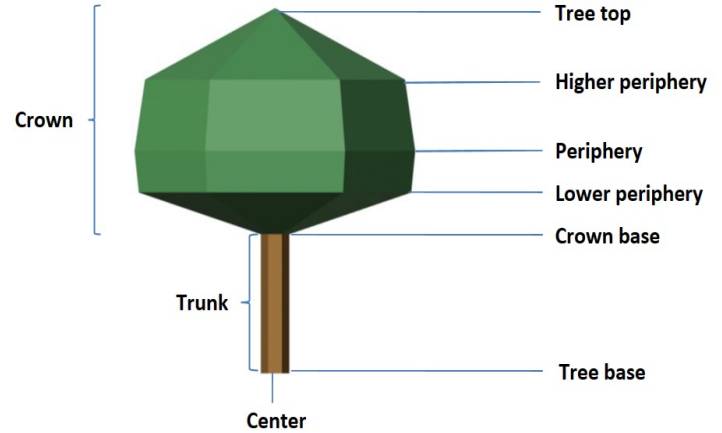


# SEM 3D – Creation of 3D city models

## ► Vegetation



General Workflow for Tree Modeling



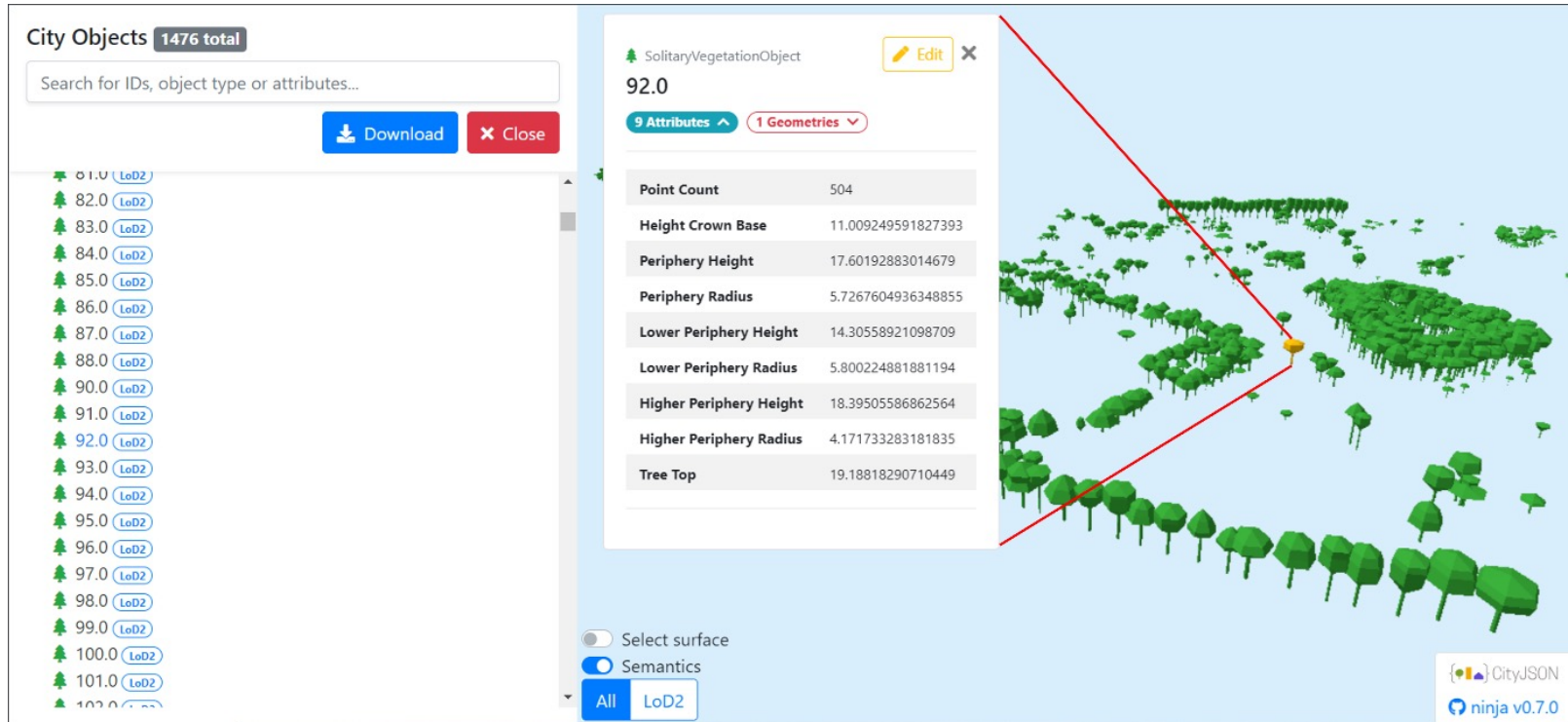
Tree construction parameters

### Detail levels



# SEM 3D – Creation of 3D city models

## ► Vegetation



The screenshot displays a 3D city model interface with a focus on vegetation. On the left, a 'City Objects' panel shows a list of 1476 total objects, with a search bar and 'Download' and 'Close' buttons. The list includes various LOD levels (81.0 to 102.0) for 'SolitaryVegetationObject'. A detailed view of a selected object (ID 92.0) is shown on the right, listing 9 attributes and 1 geometry. The attributes table is as follows:

Attribute	Value
Point Count	504
Height Crown Base	11.009249591827393
Periphery Height	17.60192883014679
Periphery Radius	5.7267604936348855
Lower Periphery Height	14.30558921098709
Lower Periphery Radius	5.800224881881194
Higher Periphery Height	18.39505586862564
Higher Periphery Radius	4.171733283181835
Tree Top	19.18818290710449

Below the table, there are controls for 'Select surface' (disabled), 'Semantics' (checked), and a dropdown menu set to 'All' with 'LoD2' selected. The 3D view shows a cluster of green trees on a light blue surface, with a red bounding box highlighting a specific tree. In the bottom right corner, there is a 'CityJSON' logo and the version 'ninja v0.7.0'.



# SEM 3D – Creation of 3D city models

## ➤ 3D city model of Outremeuse district



## ➤ Validation results of all city objects

File	Validation of geometry	Validation of the schema
<b>Buildings.json</b>	93,2% valid	100% valid
<b>Roads.json</b>	87% valid	100% valid
<b>Vegetation.json</b>	100% valid	100% valid



# Obtention d'objets sémantiques 3D pour les applications urbaines (SEM3D)

Financé par : Tremplin IA Digital Wallonia



# Our R&D agenda en CDTs

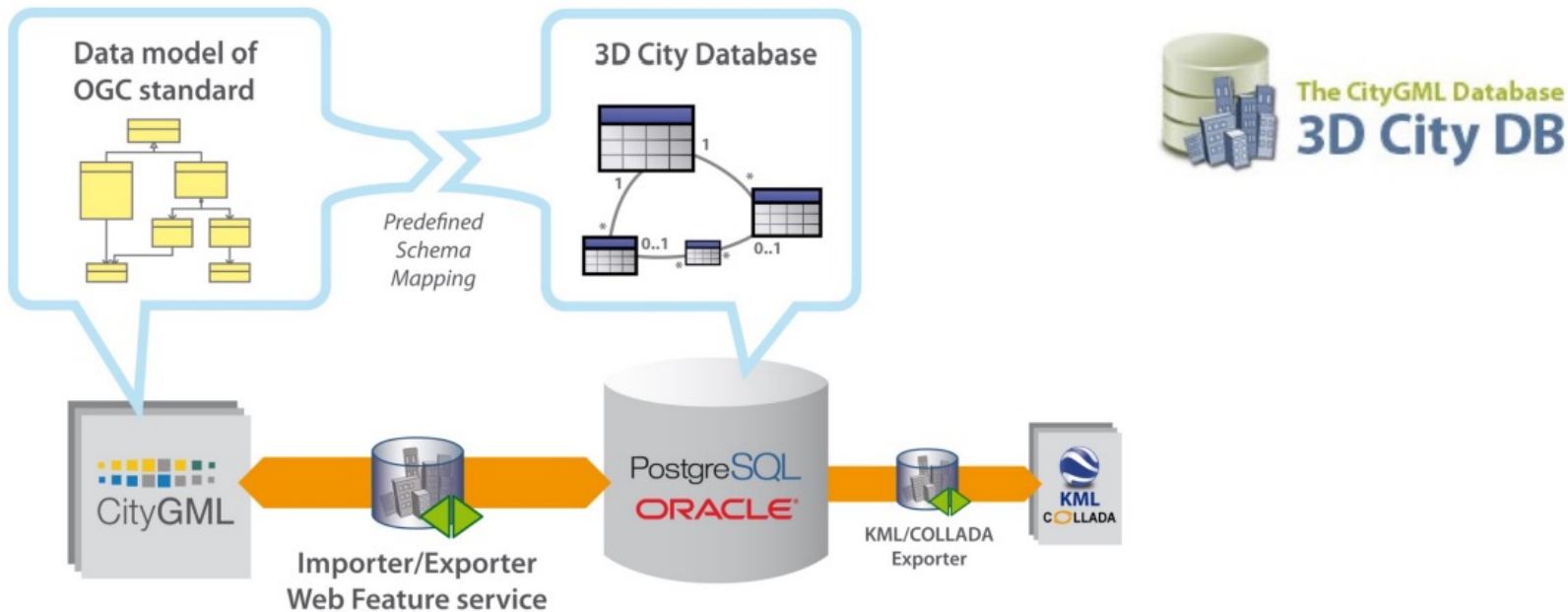
- ▶ Optimize 3D urban object extraction procedures
  - More classes ... more objects ... more automation ... quality control
- ▶ Develop / improve DT data platform (static and dynamic data integration)
  - E.g. CERBERE Project





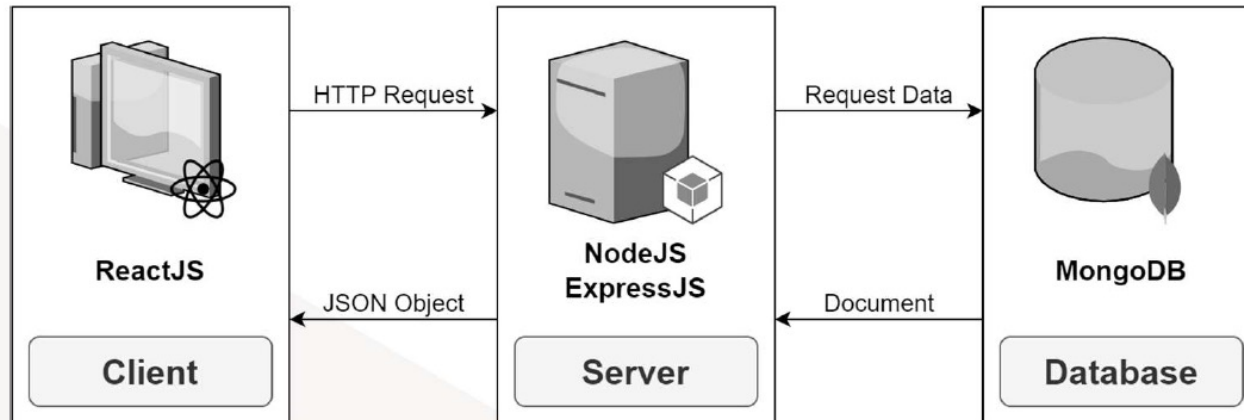
# CERBERE – 3D platform

- ▶ An alternative (or a complement) to the 3D CityDB solution



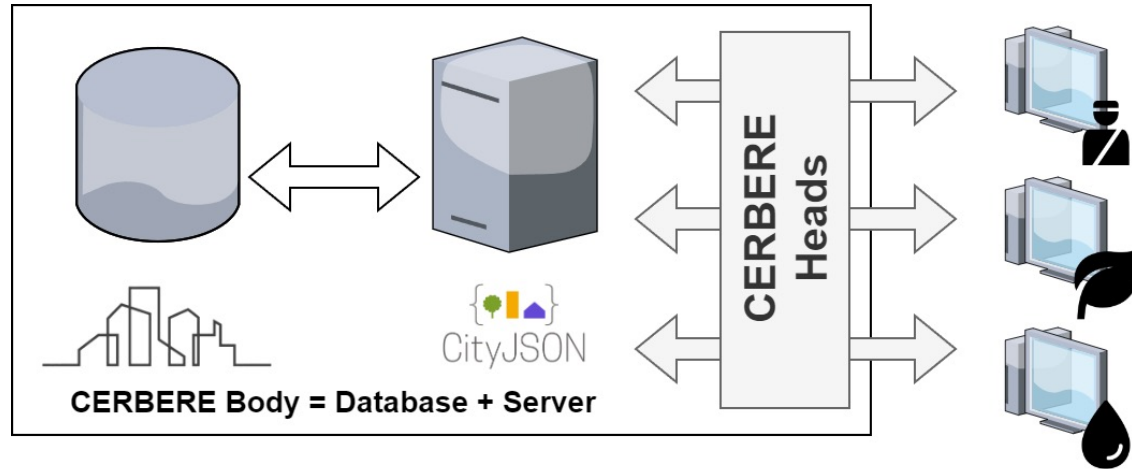
# CERBERE – 3D platform

- ▶ A MERN application (MongoDB, ReactJS, ExpressJS and NodeJS) to manage CityJSON files
- ▶ Guarantee of the logic and quality of the model passed from the database to the middleware



# CERBERE – 3D platform

- ▶ The middleware acts as an input and output filter, making it possible to handle all kinds of data from heterogeneous sources.







# Our R&D agenda en CDTs

- ▶ Optimize 3D urban object extraction procedures
  - More classes ... more objects ... more automation ... quality control
- ▶ Develop / improve DT data platform (static and dynamic data integration)
  - E.g. CERBERE Project
- ▶ Explore applications in energy, transport, urban greening, etc.
- ▶ Integrate Digital Twinning and Smart Cities programs.
- ▶ Explore Diverse Urban Contexts: engage with cities in Morocco, Rwanda, etc.

# References

- ▶ Ballouch Z., Jeddoub I., Hajji R., Kasprzyk J-P & Billen R. (forthcoming). **Towards a Digital Twin of Liege: The Core 3D Model based on Semantic Segmentation and Automated Modeling of LiDAR Point Clouds.** SDSC2024 conference, ISPRS Annals
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- ▶ Yarroudh, A., Kharroubi, A., & Billen, R. (2024). **Optim3D: Efficient and Scalable Generation of Large-Scale 3D Building Models.** In Lecture Notes in Geoinformation and Cartography
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- ▶ Kasprzyk J-P & Billen R. (forthcoming). **Towards a multi-database CityGML environment adapted to big geodata issues of city digital twins.** SDSC2024 conference, ISPRS Archives
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# Thanks for your attention



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