

Transforming Semantic Point Clouds into Functional 3D Objects: Exploring City Digital Twin Technology

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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"

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City Digital Twin

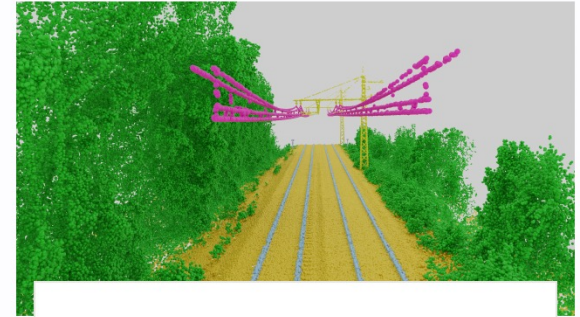
Some recent projects



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

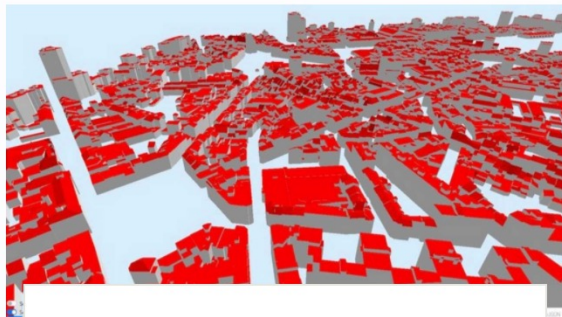
City digital twins: levels of data integration

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

Liège

Tremplin. IA
by DigitalWalleronia



Research
Innovation
award
BeGEO 24

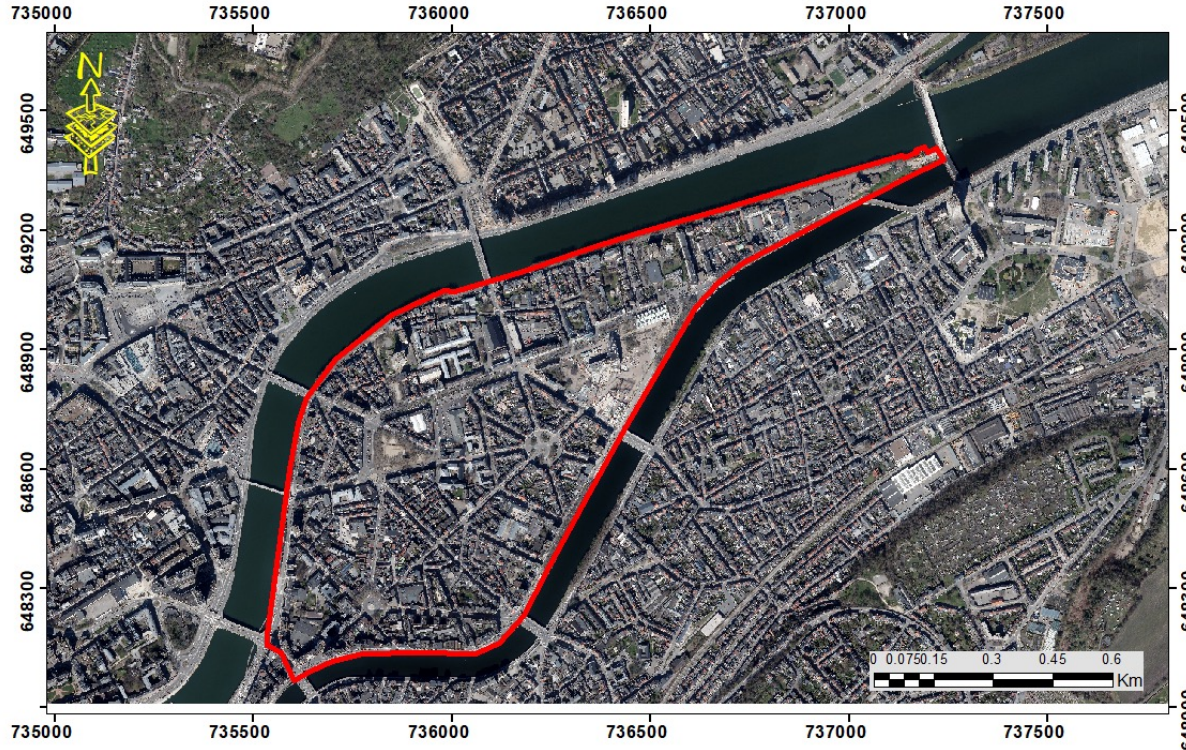
Scientific objectives

- 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.*

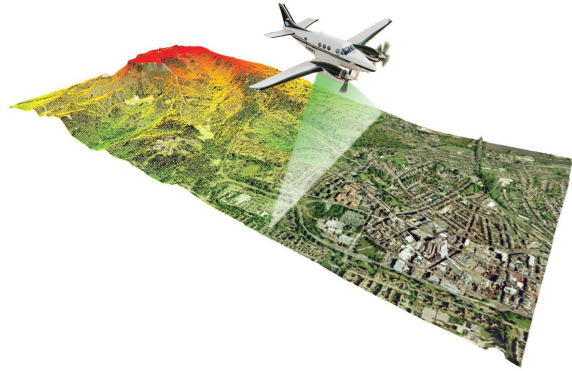
SEM 3D – case study



Outremeuse island – City of Liege, Belgium

SEM 3D - Data

► LiDAR



► Images



► 2D vector data



SEM 3D – colored point cloud

- ▶ **Cleaning the point cloud and colouring from images**



SEM 3D – Point classification

- Classification of points into several categories using deep learning techniques (AI)

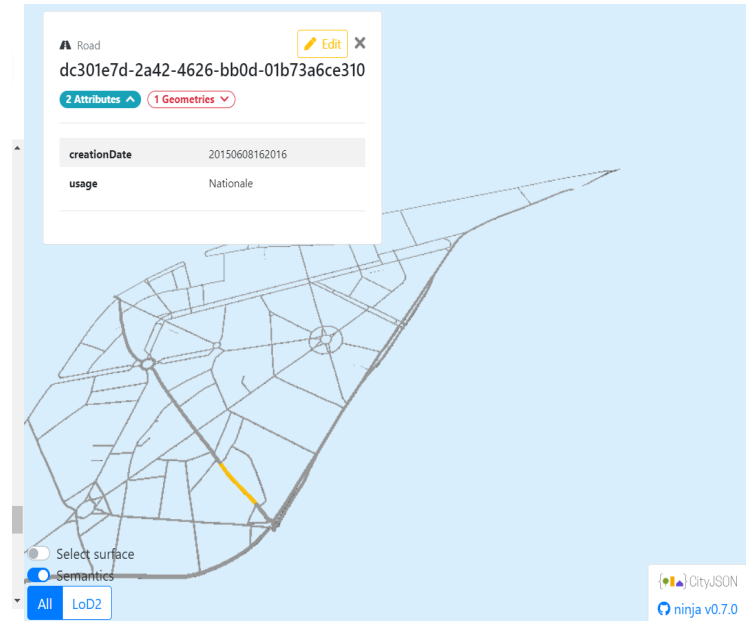
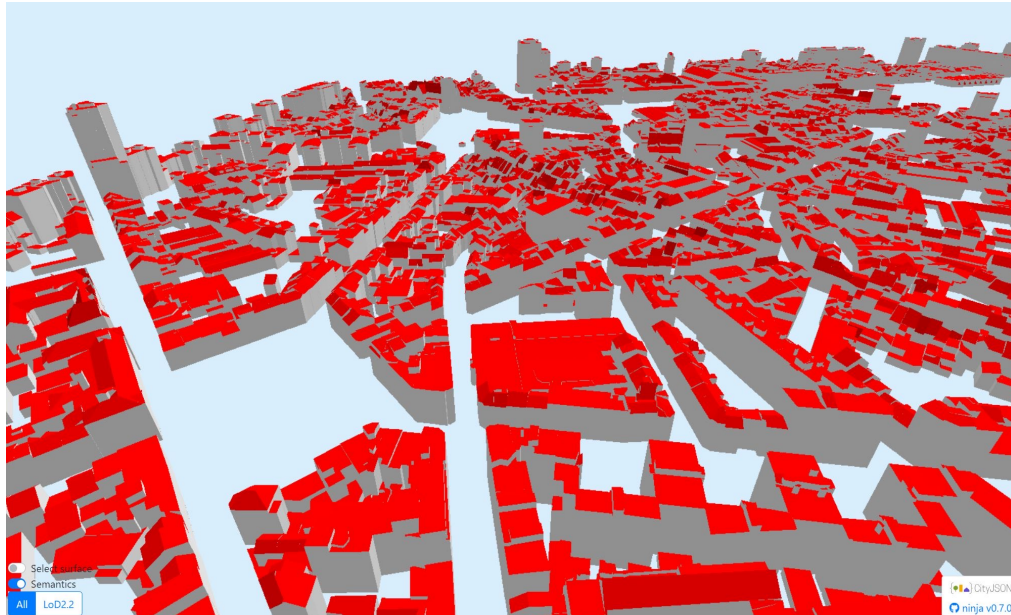
High technical expertise



- Buildings
- High Vegetation
- Traffic Roads
- Cars
- Bridge
- Walls
- Ground
- Unclassified

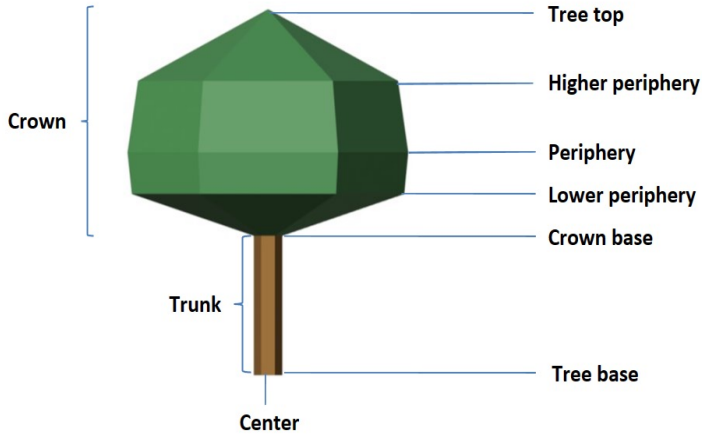
SEM 3D – Extracting 3D objects

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



SEM 3D – Extracting 3D objects

► Vegetation



LOD0



LOD1



LOD2

Software interface showing a 3D visualization of a tree object. The interface includes a settings panel on the left and a 3D view on the right.

Object Name: SolitaryVegetationObject
Value: 351.0

Attributes: 9 Attributes (expanded)
Geometries: 1 Geometries (expanded)

Point Count	1377
Height Crown Base	34.167
Periphery Height	44.3175
Periphery Radius	7.563690203610289
Lower Periphery Height	39.24225
Lower Periphery Radius	8.903198885483391
Higher Periphery Height	46.08865
Higher Periphery Radius	8.553577670411979
Tree Top	47.8598

Interface controls: Settings, Help, Select surface, Semantics, All, LoD2, CityJSON, ninja v0.7.0



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

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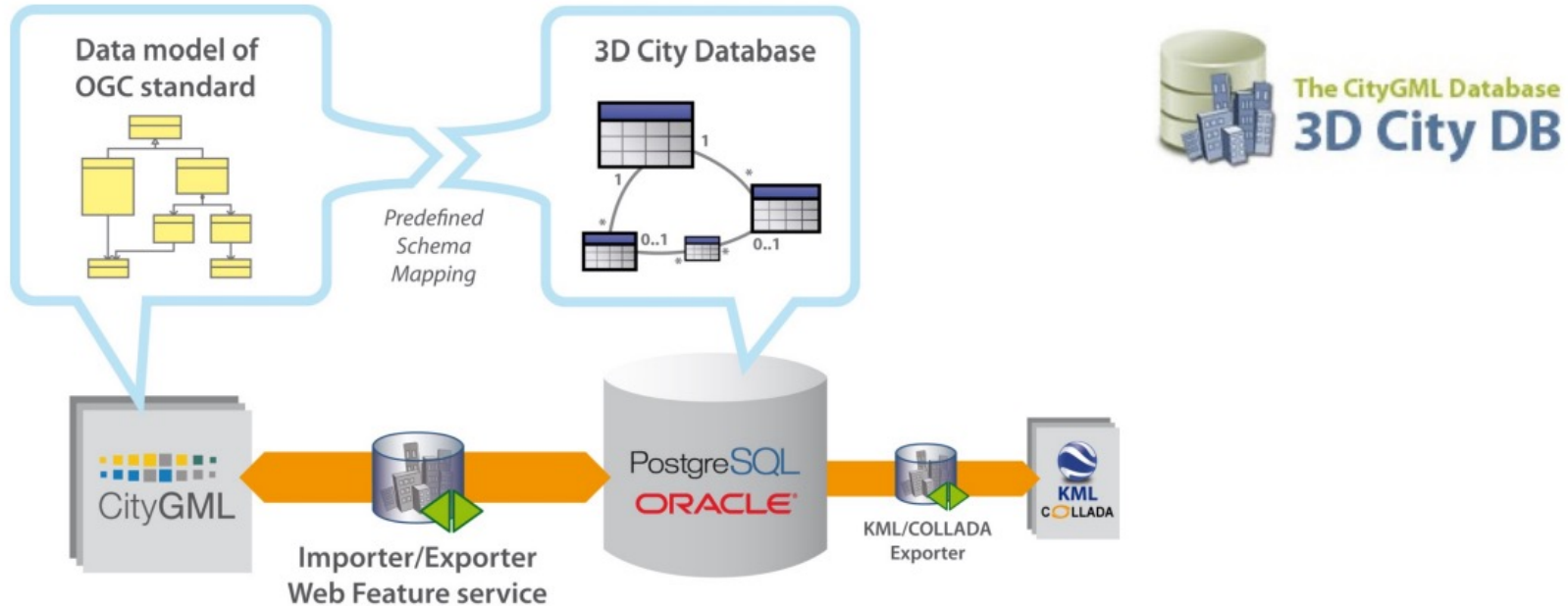
References

- ▶ 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
- ▶ Ballouch, Z., Hajji, R., Kharroubi, A., Poux, F., & Billen, R. (2024). **Investigating Prior-Level Fusion Approaches for Enriched Semantic Segmentation of Urban LiDAR Point Clouds.** Remote Sensing, 16 (2), 329.
- ▶ 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
- ▶ Ballouch, Z., Hajji, R., Poux, F., Kharroubi, A., & Billen, R. (16 July 2022). **A Prior Level Fusion Approach for the Semantic Segmentation of 3D Point Clouds Using Deep Learning.** Remote Sensing, 14 (14), 3415.



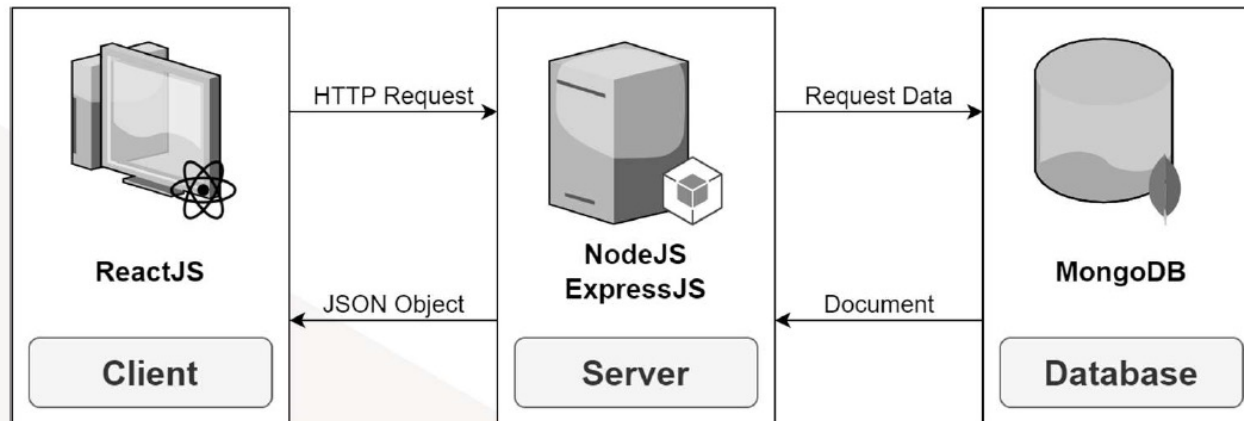
CERBERE – 3D platform

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



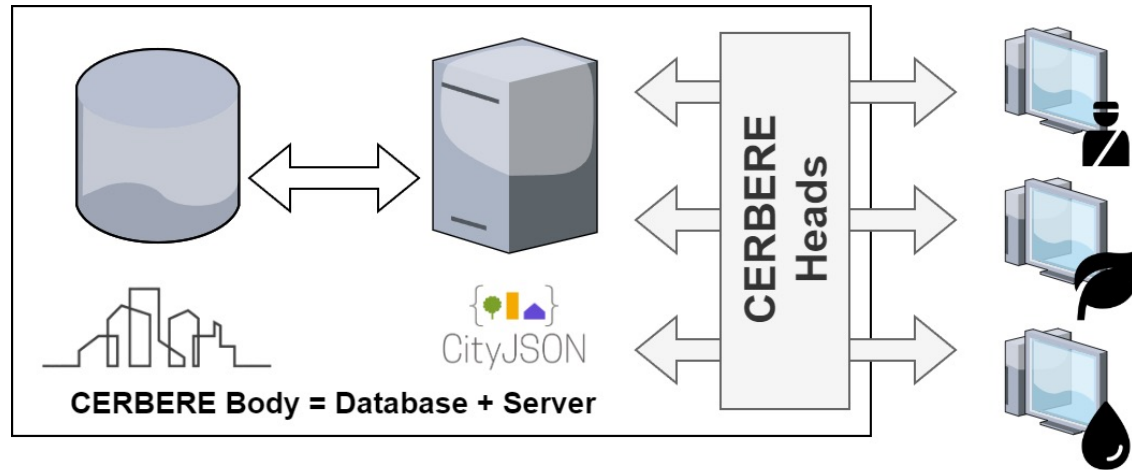
CERBERE – 3D platform

- ▶ 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.



References

- ▶ 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
- ▶ Nys, G.-A., & Billen, R. (2022). **From consistency to flexibility: Handling spatial information schema thanks to a middleware in a 3D city modeling context.** Transactions in GIS.
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Perspectives

- ▶ Optimize 3D urban object extraction procedures – *our core business*
- ▶ Expand Digital Twin to other Liège Districts
- ▶ Scale to Other Cities: Wa-LOD2 project – full territory of Wallonia.

- ▶ Demonstrate Digital Twin Benefits: Explore applications in energy, transport, etc., to showcase relevance.
- ▶ Integrate Smart Cities dynamics...
- ▶ Explore Diverse Urban Contexts: engage with cities in Morocco, Rwanda, etc.

References

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