Geospatial
Research
Innovation +
Development

LOW CARBON LIVING CRC

# Progressing precinct modelling on the UNSW campus and beyond: BIM/PIM and 3DGIS

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Innovation and Development
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Paul Kiefer

**TODAY**

**2:00-3:40pm** **GRID Presentations**

3:45-4:00pm Augmented reality demo

**4:00-4:15pm** **Break**

**4:15-5:00pm** **Workshopping**

4:15-4:30pm Who you are, what organisation are you from, how might 3D integrated BIM/GIS assist you in your role?

4:30-4:45pm

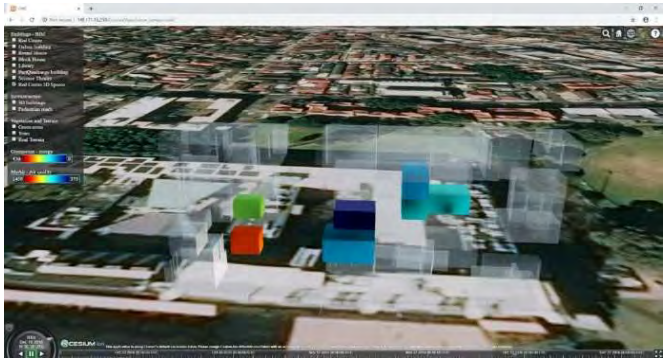
1. How often do you update your data (daily, monthly, yearly)?
2. If you have 3D data, what is it used for?
3. If you have sensor data and what they use them for?
4. What kind of problems need 3D data and 3D solutions?

4:45-5:00pm Presentation of results and discussion

**5:00-6:00pm** **Mingling with canapés and drinks**

# Content

- **Introduction**
  - Goal of the project
  - Existing systems and data
  - BIM-3DGIS-Sensor model and System Architecture
- Data processing
  - 3D reconstruction
  - BIM georeferencing
  - myair sensors
- Data management
- Query and visualisation



Sisi Zlatanova

# The project

**Investigate approaches for 3D Precinct Information Modelling (PIM)**

**Integration of:**

- BIM and 3D GIS
- sensor data

**Requirements:**

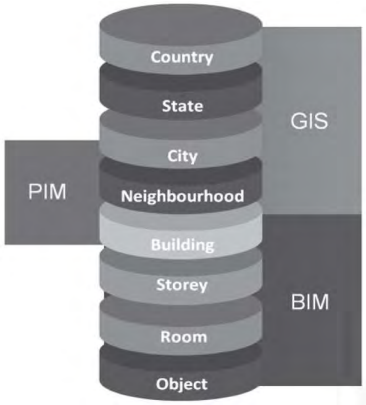
- Compliant with international standards
- Object-oriented and semantically-rich data structure
- Open source solutions

**Focus on:**

Workflow for 3D reconstruction

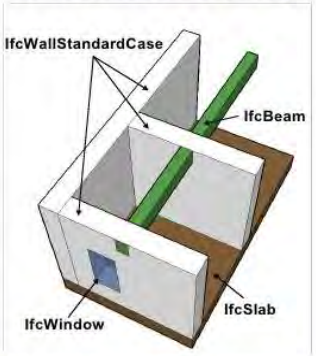
3D spatial structuring

System architecture



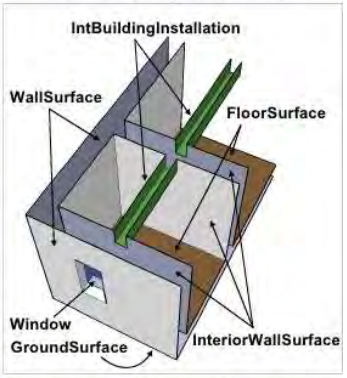

Precinct IM: a new digital platform for integrated design, assessment and management of the built environment, 2017, Newton, plume, Marchant, Mitchell and Ngo

**BIM (e.g., IFC)**
Constructive Solid Geometry




Volumetric, parametric primitives representing the structural components of buildings

**3D GIS (e.g., CityGML)**
Boundary Representation




Accumulation of observable surfaces of topographic features

# Existing systems and data at EM UNSW

**Very complex:**

- **7 Departments of Estate Management UNSW:**

Asset Management, Development, Facilities Management, Strategy and Business Systems, Security and Traffic, Environmental Sustainability and Property Management.

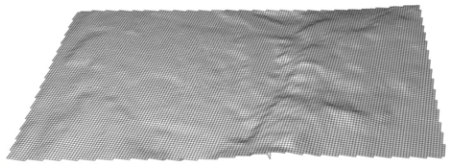
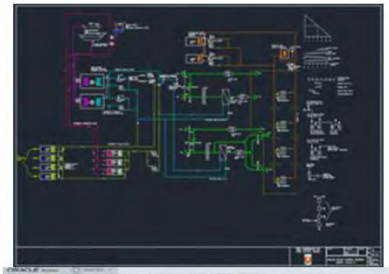
- **5 Software packages:**

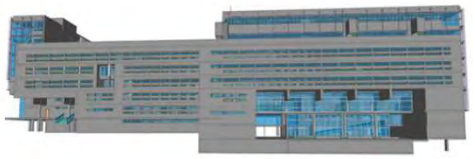
Archibus, ArcGIS, AutoCAD, Revit, Greensense

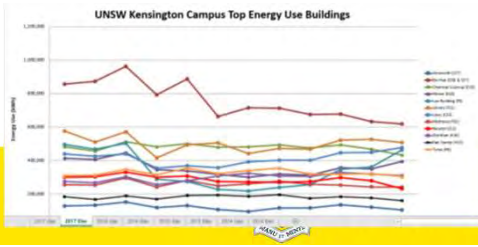
- **Many data formats in 2D and 3D**

DXF/DWG, Shape, IFC

- **Various geometries**
- **Little semantics**

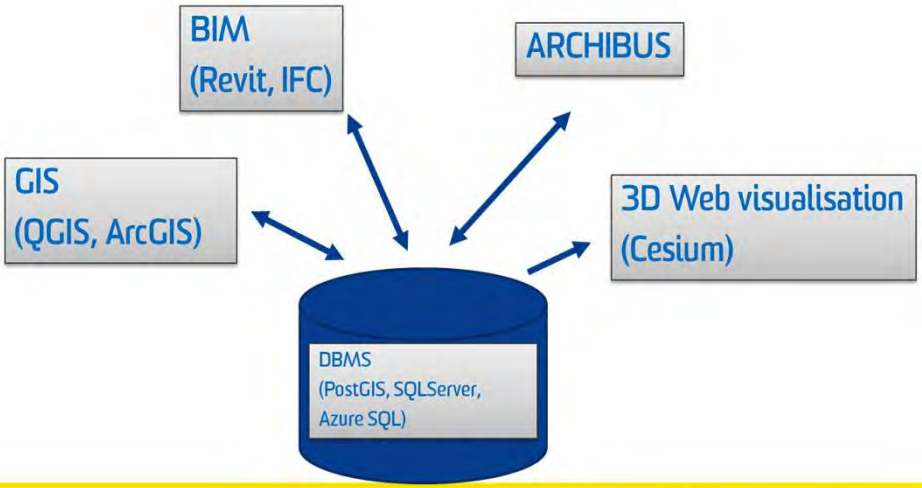




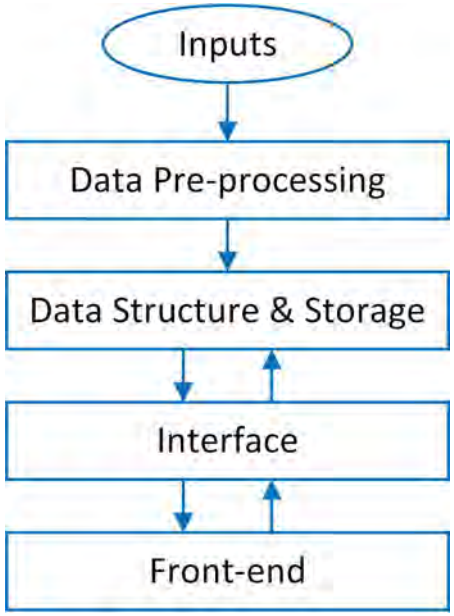
# The data

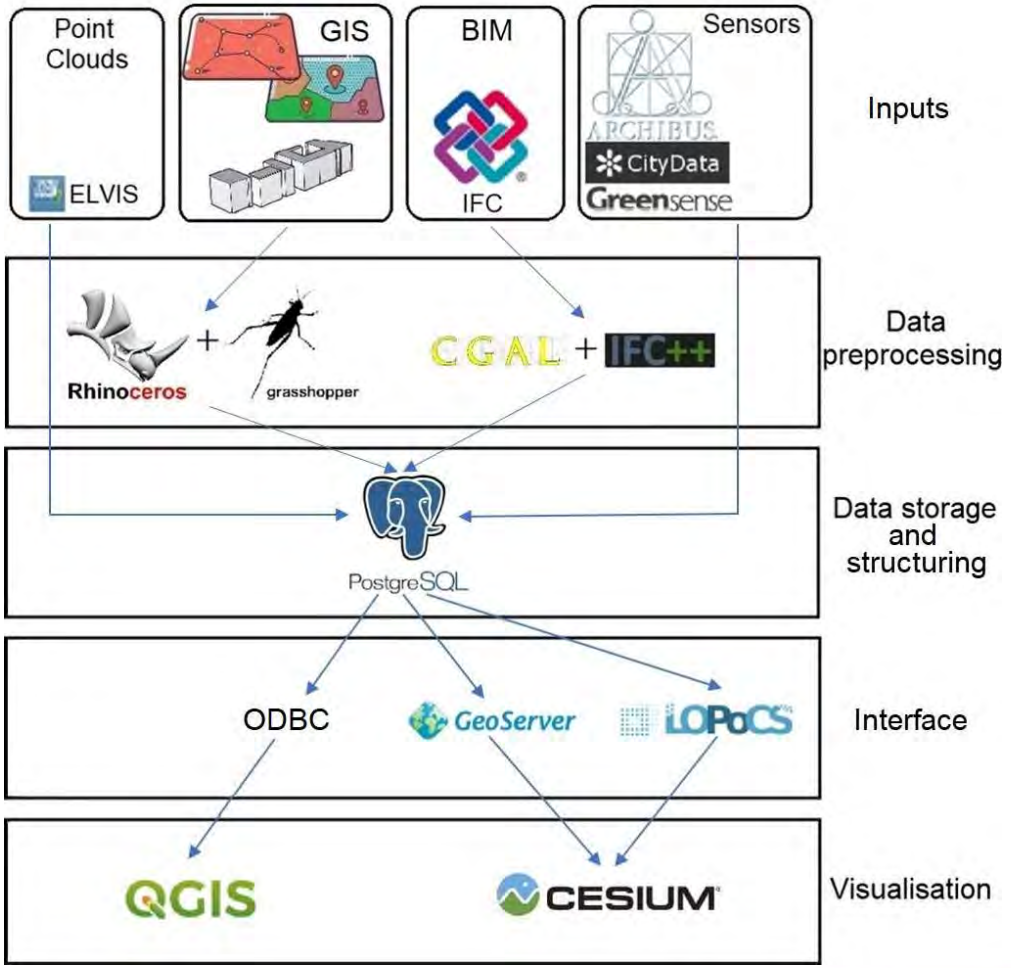
| Category | Object | Attributes | Geometry | Relationships |
|---|---|---|---|---|
| Building | Building footprint | Name, number, area, perimeter, height | Polygon | |
| | Buildings above footprint | | Line | Part of building |
| | Floor/ Storey | | Polygon | |
| | Roof | roof material, slabs, slab material | Solid/Mesh | Building storey |
| | Wall | wall type, wall material | Solid/Mesh | Building storey, building |
| | Slab | material | Solid/Mesh | Building storey, building |
| | Window | Window style | Polygon<br>Solid/Mesh | Room, building storey, building |
| | Door | Door style and material | Polygon<br>Solid/Mesh | Room, Building storey |
| | Stair | Type, Stair material | Solid/Mesh | Building storey |
| | Ramp | Flight | Solid/Mesh | Stairs, building storey, building |
| | Column | Type, column material | Solid/Mesh | Building storey |
| | Curtain walls | Type and material | Solid/Mesh | Building storey, building |
| | Room/ Space | Name, description | Polygon<br>Solid/Mesh | Building storey, building<br>(Room) |
| | Beams | beam type and material | Solid/Mesh | Building storey, building |
| | Indoor furniture | Type | Polygon<br>Solid/Mesh | Building storey, building |
| | Ventilation (riser) | IFC entity, name, material | Solid/Mesh | Building storey, building |
| Indoor electricity | Smoke Detector | Type | Point, (Symbol) | |
| | Warning speakers | Type | Point (Symbol) | |
| | Emergency exit lighting | Type | Point (Symbol) | |
| | Light Switch | Type | Point (Symbol) | |
| City furniture | Bollards, survey marks, fences, walls, seats, bins and ACs | Height, width | Point, line | |
| Transportation | Roads, walkways, car park lot | Use, function | Line | |
| Vegetation | Garden and tree | Tree attributes: diameter, id, code, species | Point, Line | |
| Land use | Cadastre Parcels | owner | Polygon | |
| Sewer utility network | Sewer pipe | Type | Line | |
| | Sewer pit | Width, length | Point | |
| | Sewer manhole | Width, length | Point | |
| | Sewer inspection opening | Type | Point | |

1. Buildings LOD1
2. Surface objects LOD1 (grass, roads, trees)
3. Terrain
4. BIM
5. Energy data per building
6. Air quality data per room



# System Architecture (SA)



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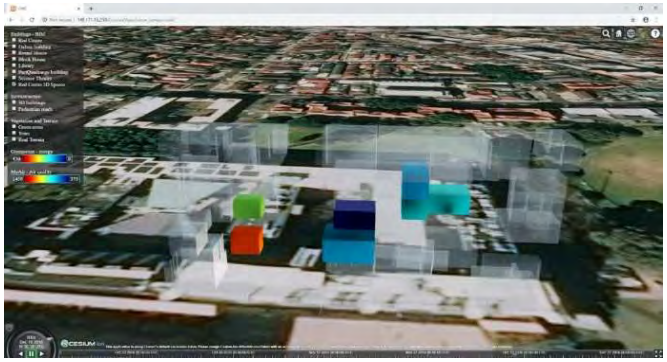
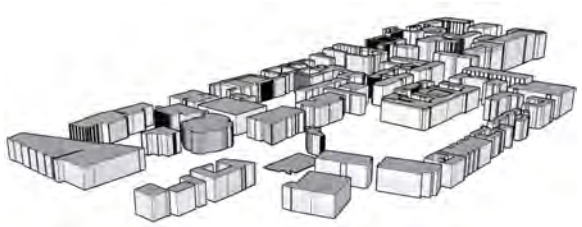
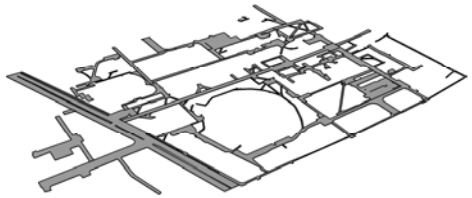


Jinjin Yan

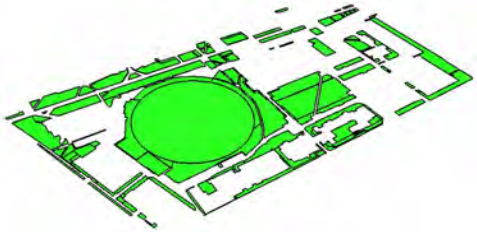
# 3D model reconstruction



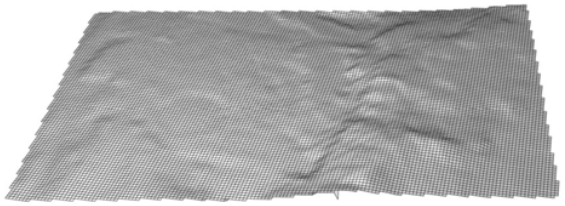
LOD1 Buildings



Roads



Green areas

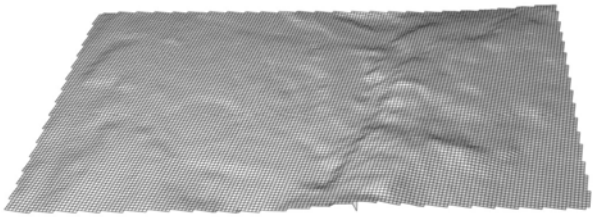


Terrain

Trees

# Buildings LOD1 and terrain integration

Footprints



Terrain

- ❑ Footprints + Height + Terrain
- ❑ Footprints + Point cloud
- ❑ 3D objects + Terrain
- ❑ 3D objects + 3D point clouds
- ❑ Point cloud only

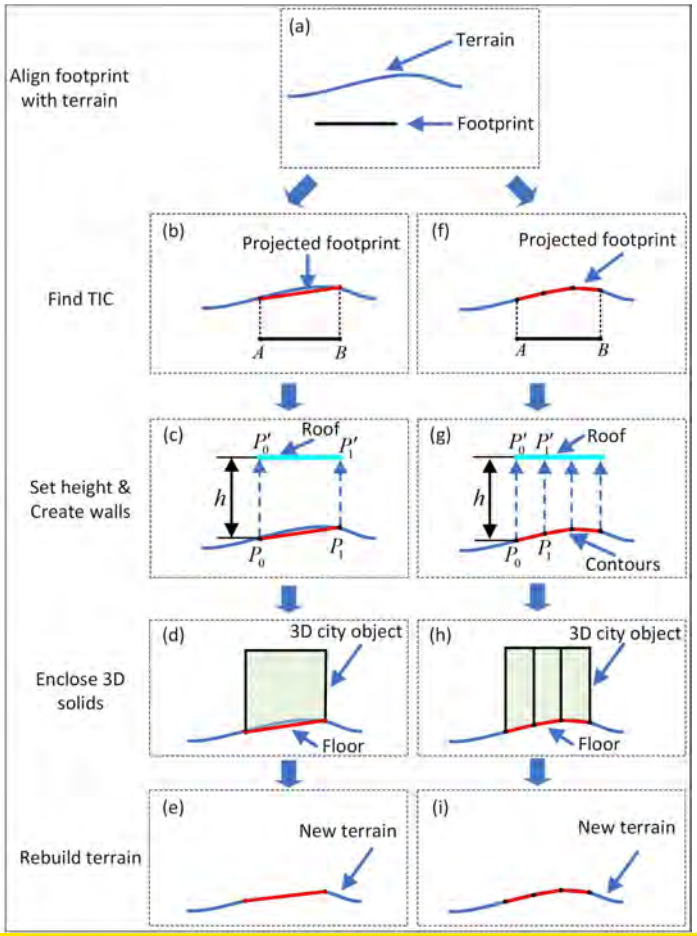
# Terrain Intersection Curves (TIC)

Terrain Intersection Curves (TIC)

**3D objects may partially float over or sink into the terrain**

**when integrating 3D objects with flat bottoms on uneven terrain**

# Approach for integrating 3D objects and terrain

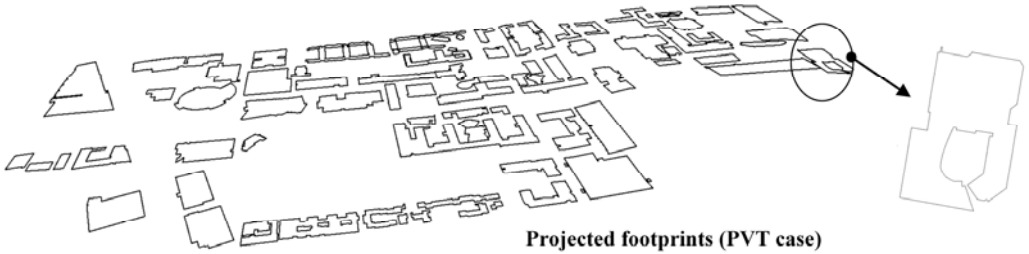



## Footprints + Height + Terrain

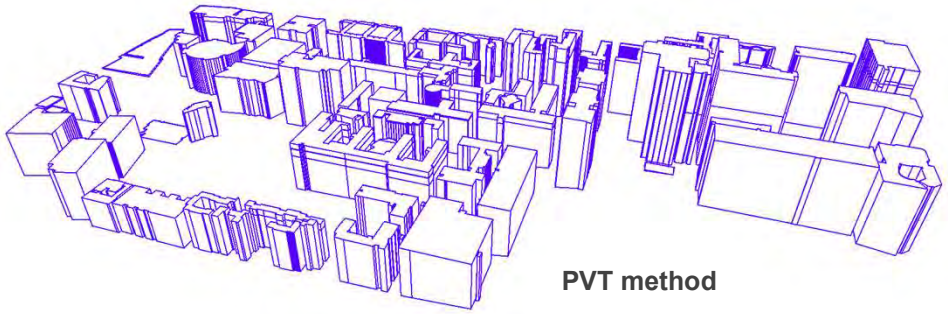
- **Find TIC by projecting footprints onto the terrain;**
- **Set height and create walls surfaces of the 3D buildings;**
- **Generate roof and ground surface to create 3D building (solids);**
- **Rebuild terrain considering TIC as constraints.**

Left. **P**rojecting **V**ertices of footprints on the **T**errain **(PVT)**

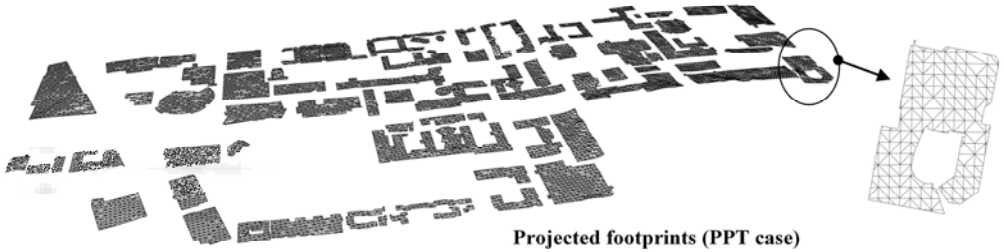
Right. **P**rojecting the whole footprint **P**olyline on the **T**errain **(PPT)**



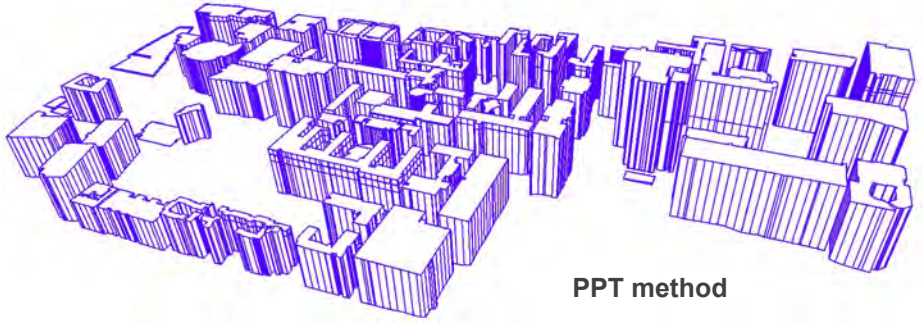
Projected footprints (PVT case)



PVT method



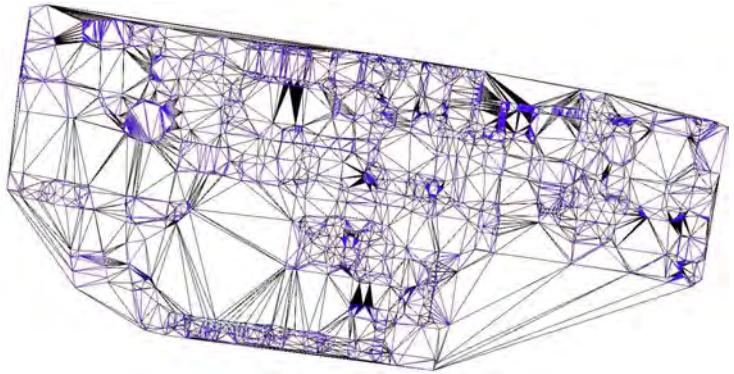
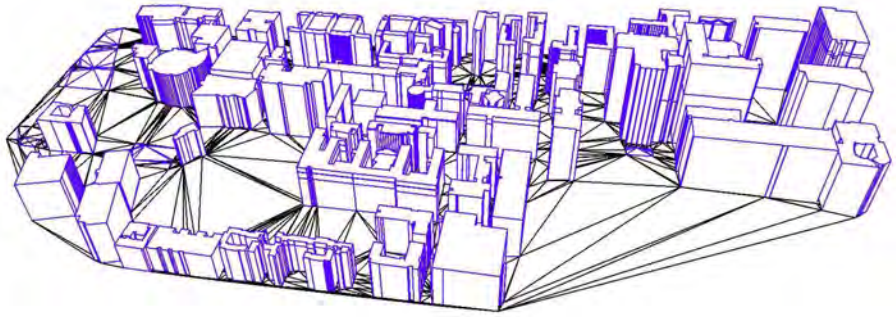
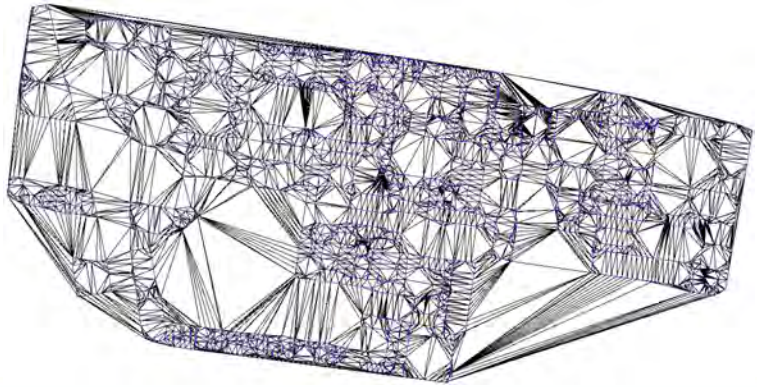
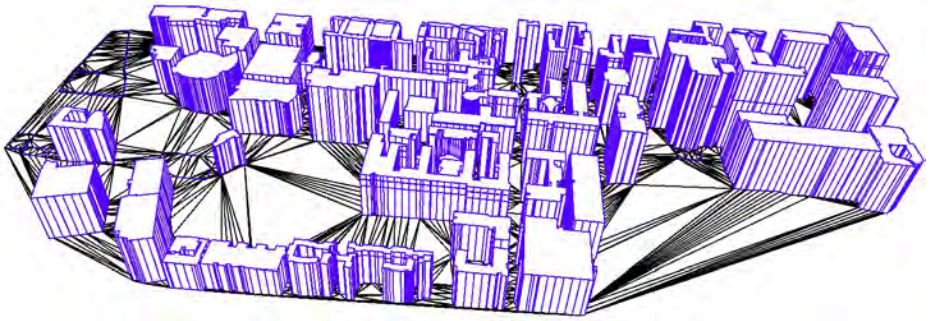
Projected footprints (PPT case)



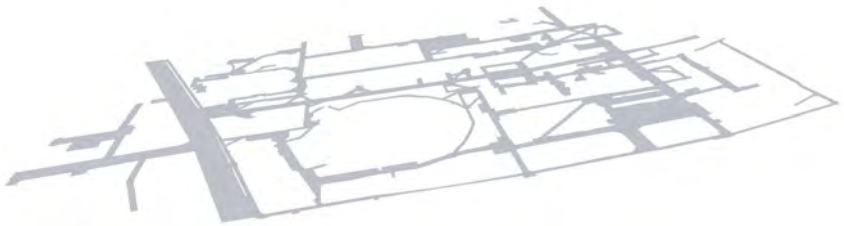
PPT method

The projected footprints on the terrain.

Reconstructed LOD1 buildings.

| | Top view | Perspective view |
|---|---|---|
| PVT method |  |  |
| PPT method |  |  |

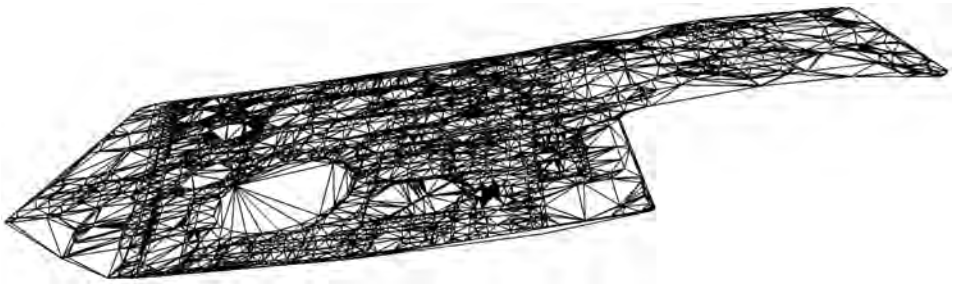
# Roads, green areas, trees, and terrain



Roads

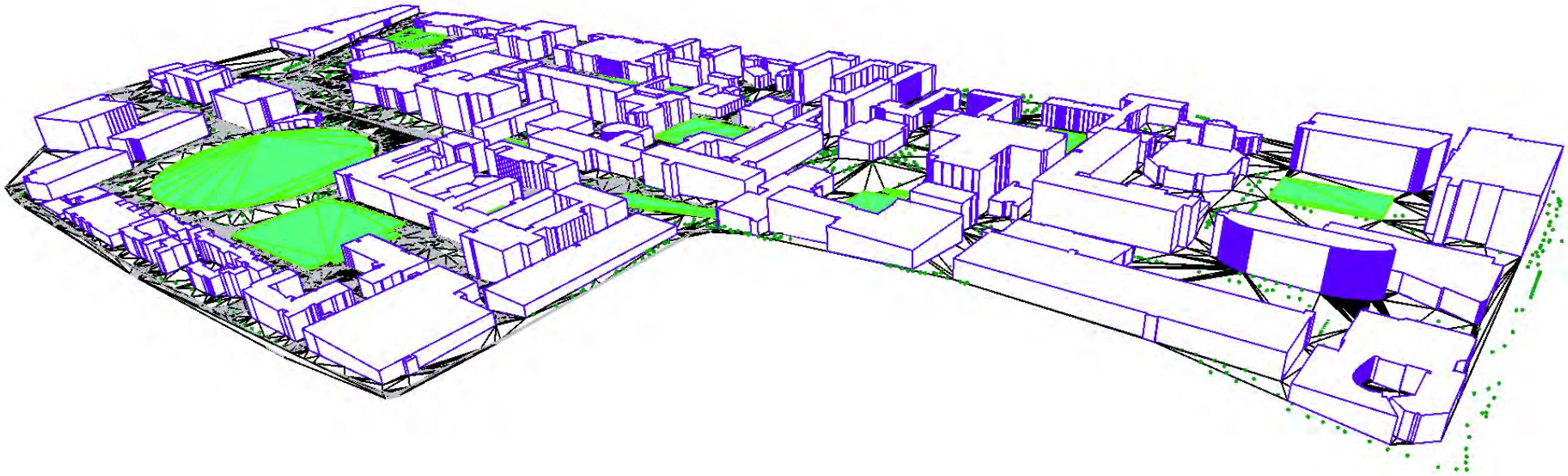
Green areas

Trees



Terrain

# Integration of all objects



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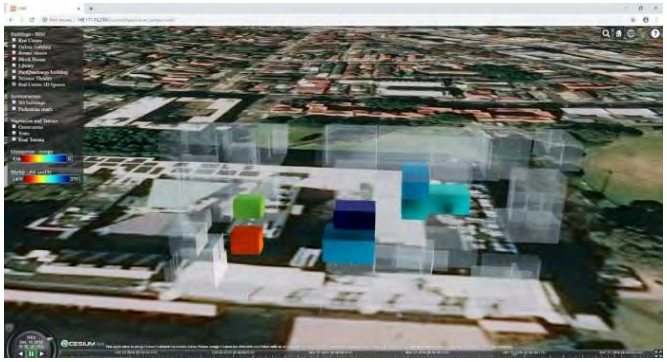


Abdoulaye Diakité

# BIM/GIS Integration

- Building Information Model (BIM) / Geographic Information System (GIS)
- BIM → local coordinate systems
- GIS → global coordinate systems

# BIM Geo-Referencing: Manual approach

- Current most common practice
- Subjective/error prone
- Limited software support

(a) (b)

# BIM Geo-Referencing: Automatic approach

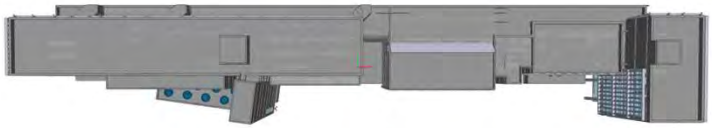
- Solution: 3 basic steps
  - Use 2D map polygons
  - Compute transformation matrix of alignment with 2D BIM
  - Apply the transformation to the 3D BIM

# BIM Geo-Referencing

- Use 2D map polygons

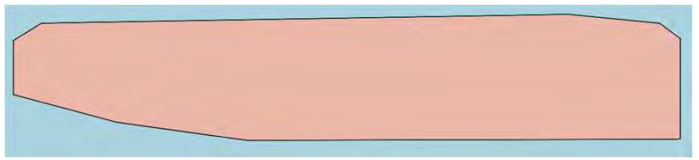
Footprints (EM)

Footprint (OSM)



BIM Top view

Convex hulls of the 2D polygons



2D Convex hulls of the BIM

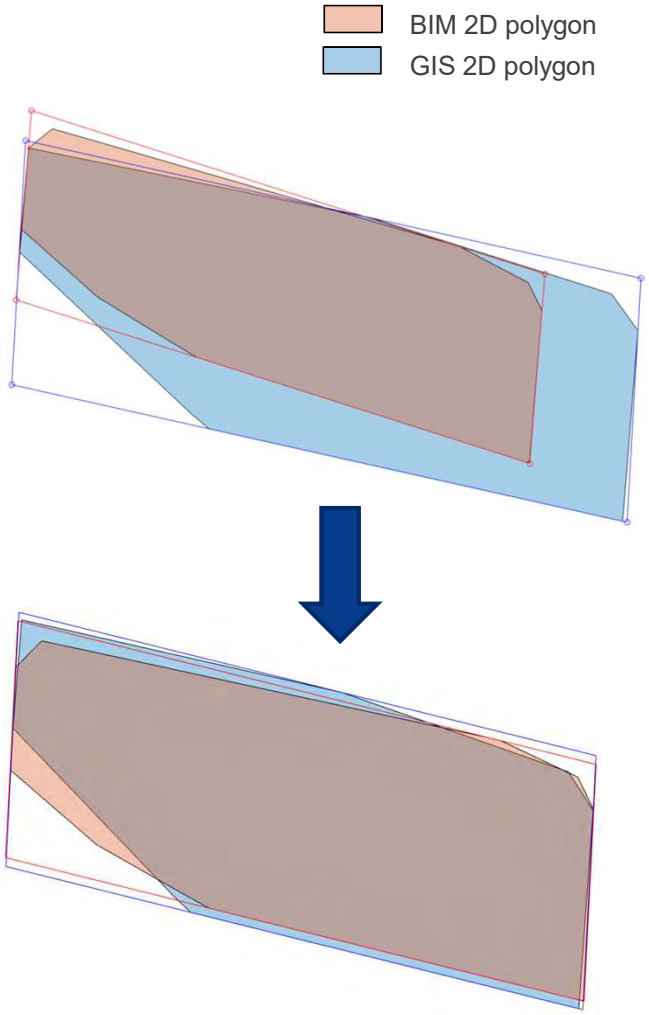
# BIM Geo-Referencing

- Aligning 2D map and 2D BIM polygons
  - Approximative rigid matching (Euclidean transformation)
  - Adapted from [Goodrich et al., 1999]

✓ Input shapes of different size
✓ No corresponding points needed
✗ Coarse approximation
✗ No scaling

- Aligning 2D map and 2D BIM features
  - Absolute Orientation (affine transformation) [Horn, 1987]

✓ Closed form solution: the best-fit possible in one single step
✗ Input shapes of same size
✗ Corresponding points required (≥ 3)



# BIM Geo-Referencing

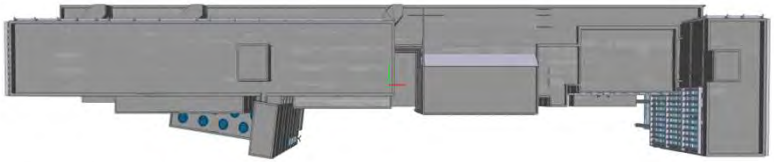
- Apply transformation to 3D BIM
  - ➢ 4x4 Transformation matrix is applied to the 3D coordinates of the BIM geometry data.

2D view

3D view

# BIM Geo-Referencing

- How good (accurate) is our method?
  - Mostly depends on the map polygon
  - Precise footprint → Precise georeferencing!



Max error: 1.24 m

Max error: 0.29 m

# Open-Source Implementation

- Reading BIM data
  - IFC++ (C++ library)
- Geometric operations
  - CGAL (C++ library)
- Alignment
  - Matlab
- Transformation
- Export to database
  - Libpqxx (C++ library)
  - PostGIS (POLYHEDRALSURFACE)

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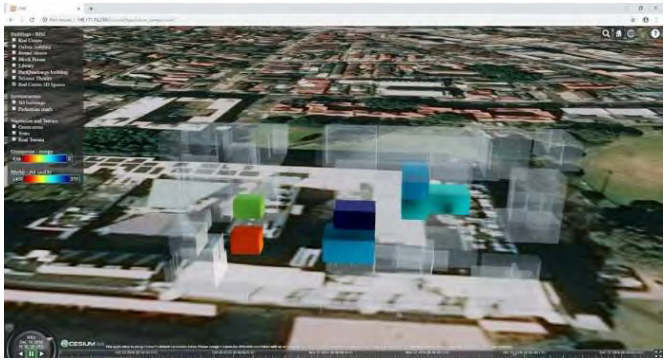
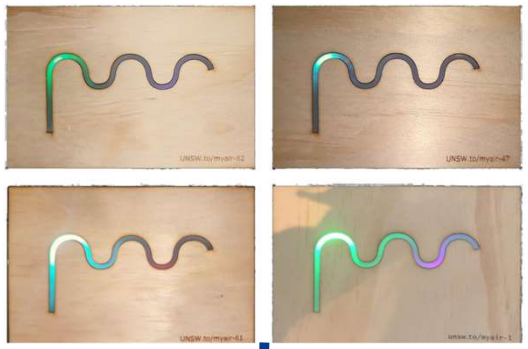
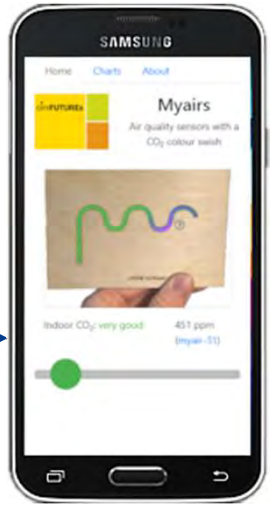


# myair

myair-CitySensors solution

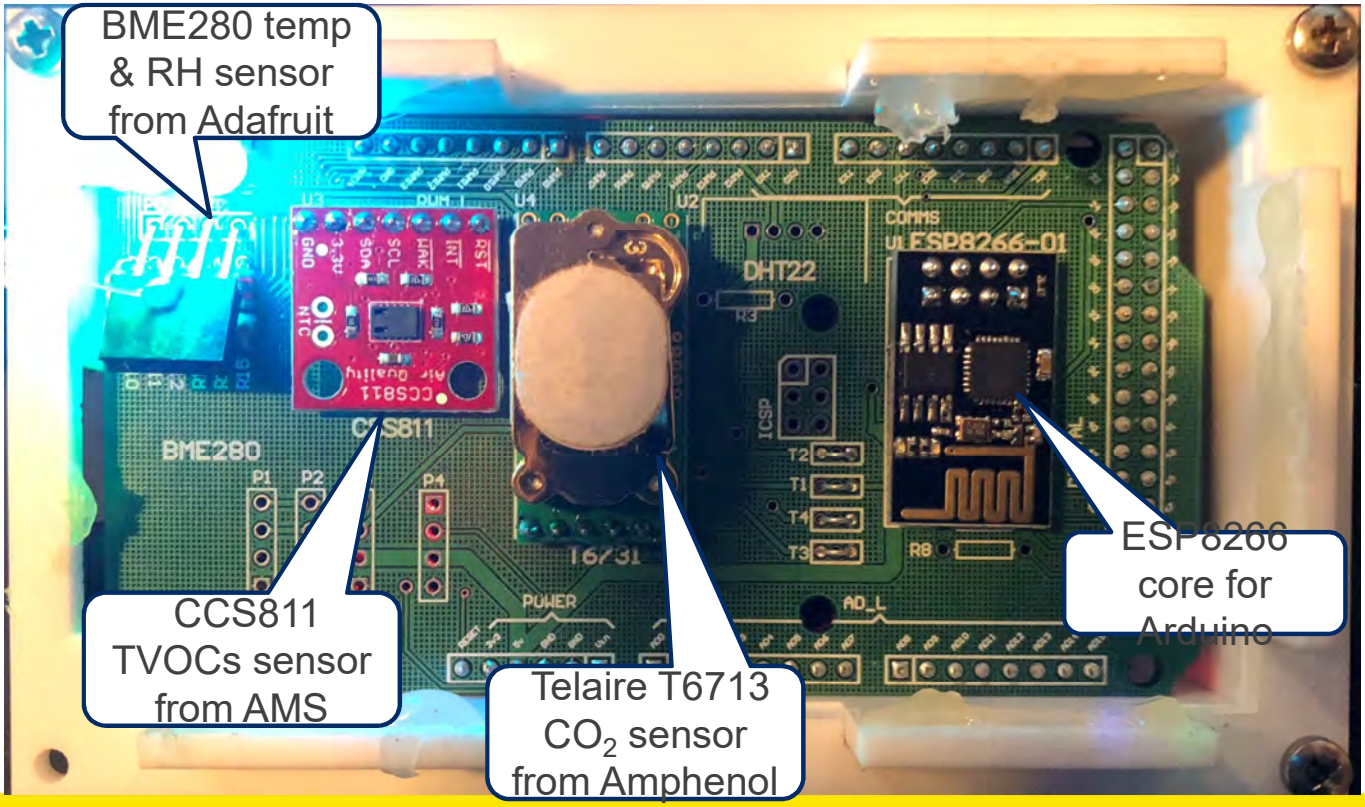


- myair devices
- thingsboard IOT platform
- custom web front-end

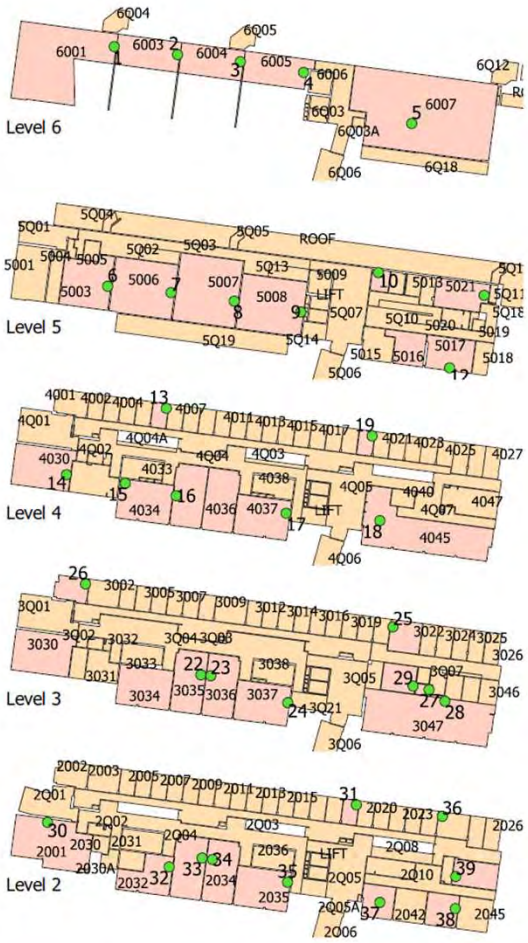


# myair

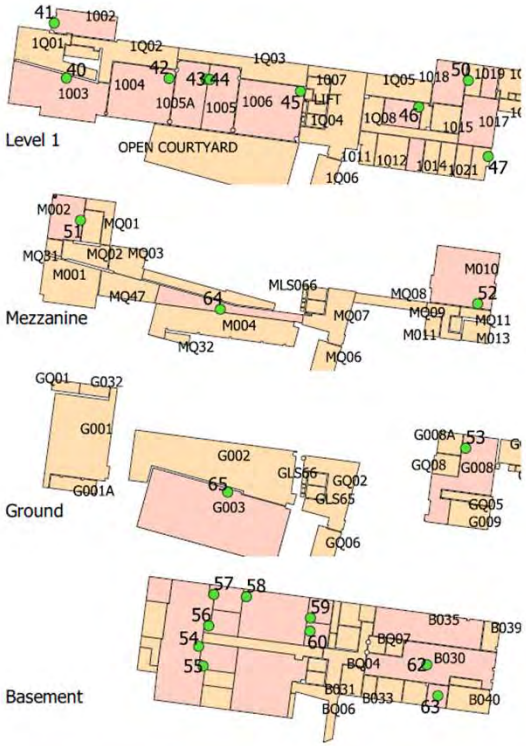
Open source hardware
based on Smart Citizen

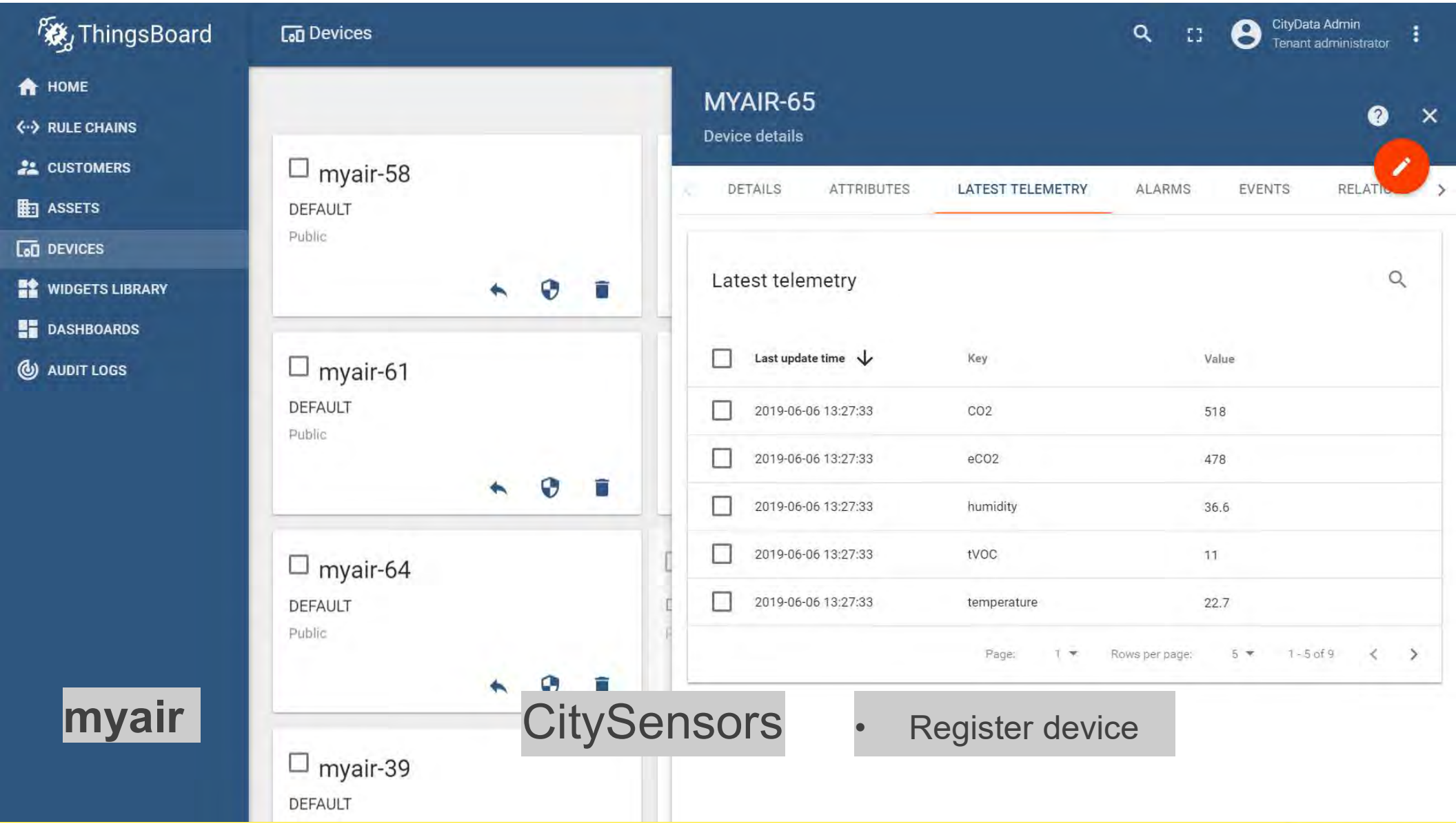


# myair




62 installed in Red Centre

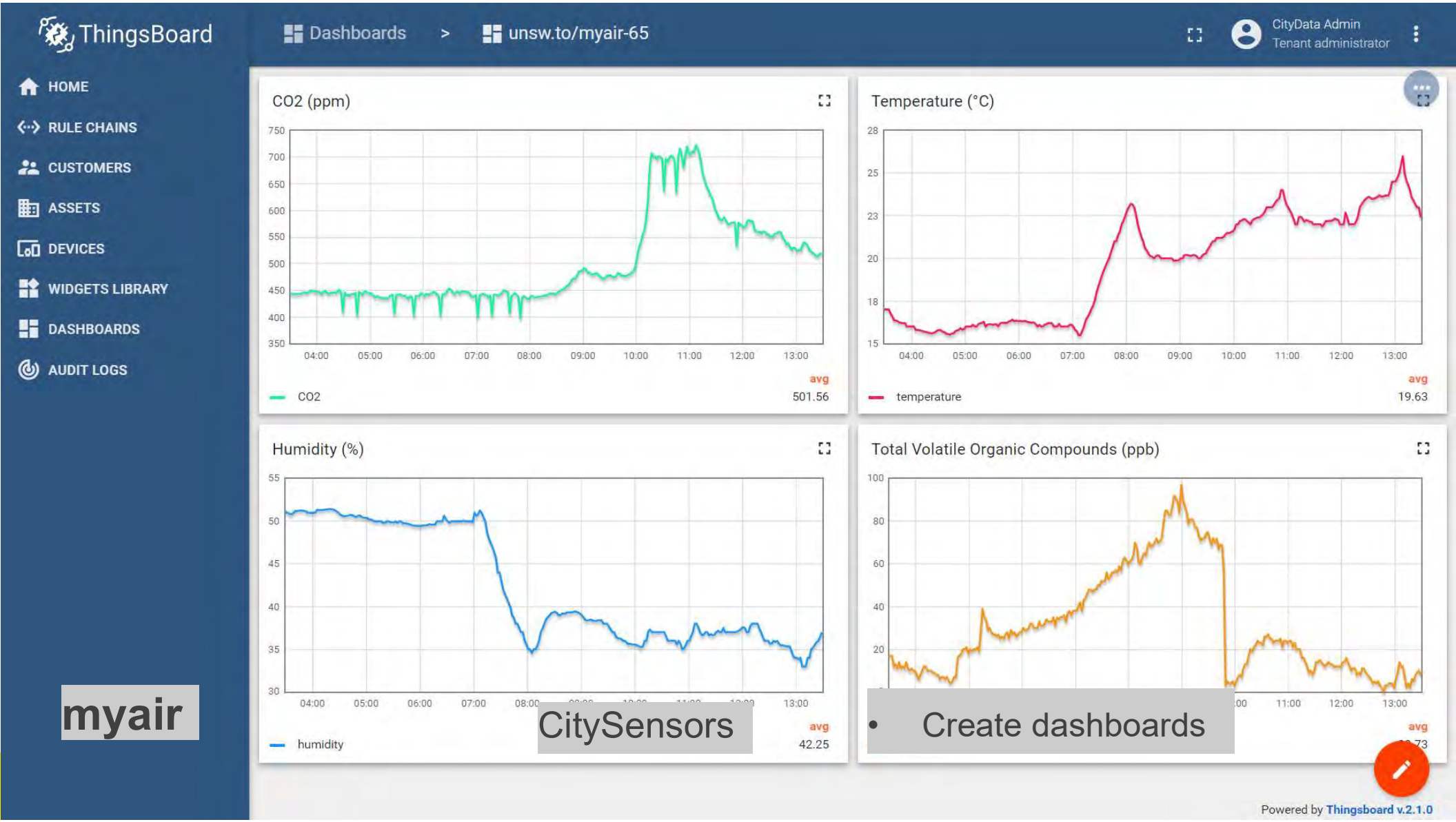





**myair**

CitySensors

- Register device



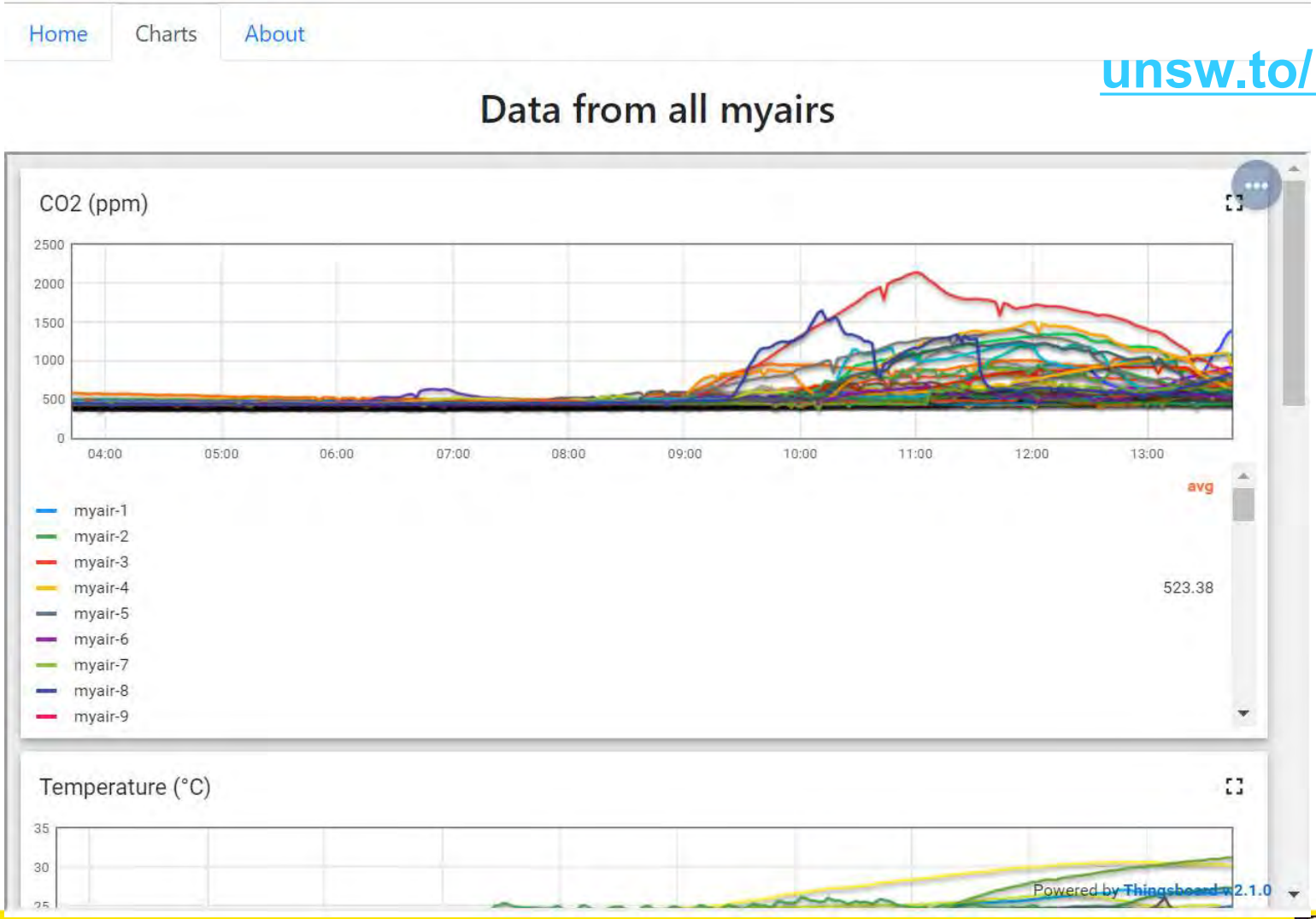

myair

CitySensors

- Create dashboards

# myair

unsw.to/myair



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  - Goal of the project
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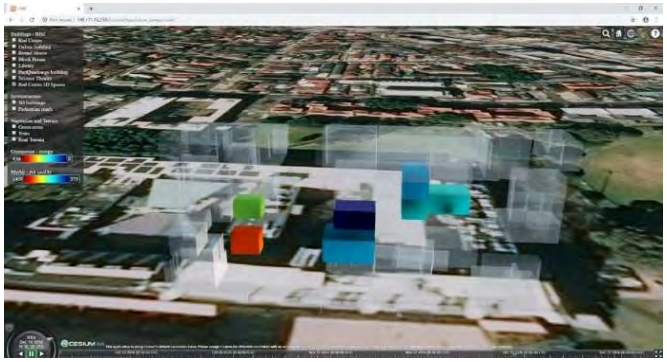
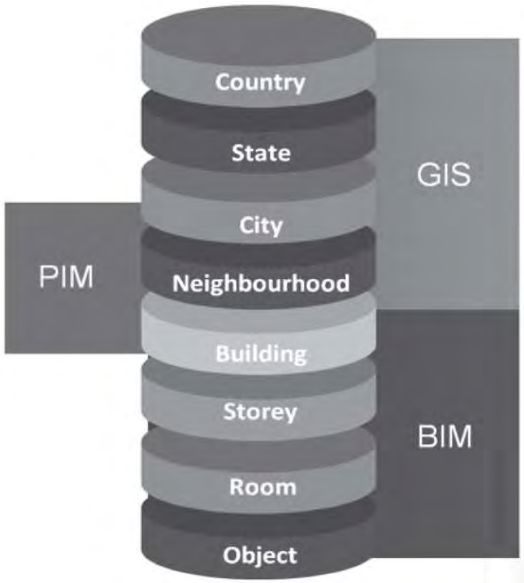
- Data processing
  - 3D reconstruction
  - BIM georeferencing
  - MyAir Sensors
- **Data management**
- Query and visualisation

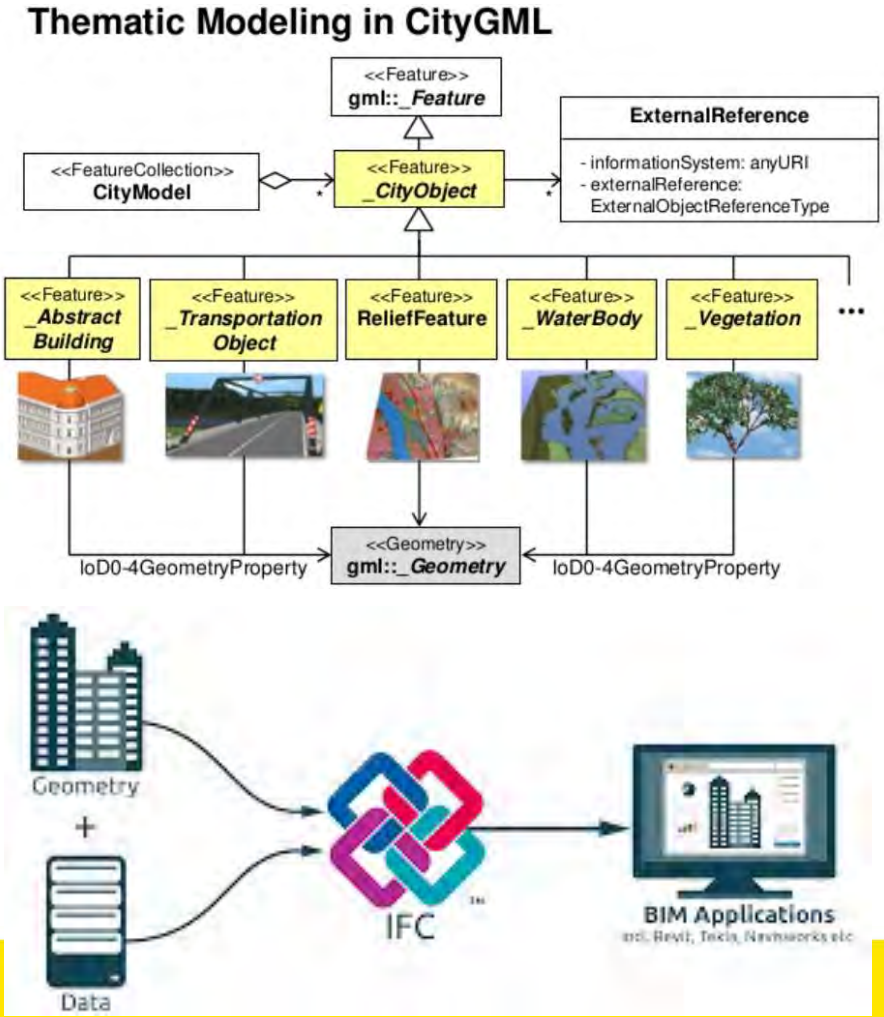


Wei Li

# Open standards: CityGML and IFC for the PIM



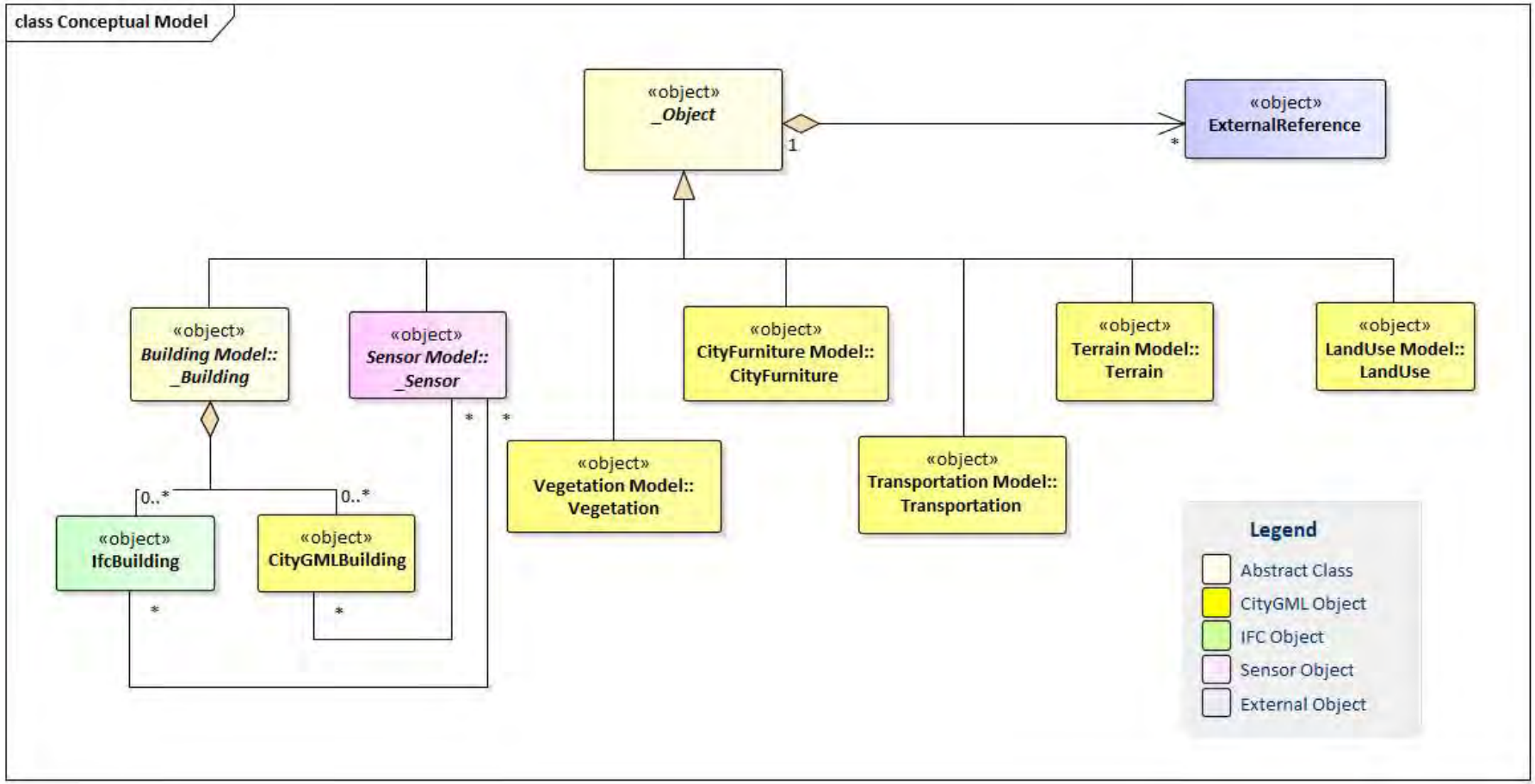

Spatial information platforms for built environment (Newton et al 2017)



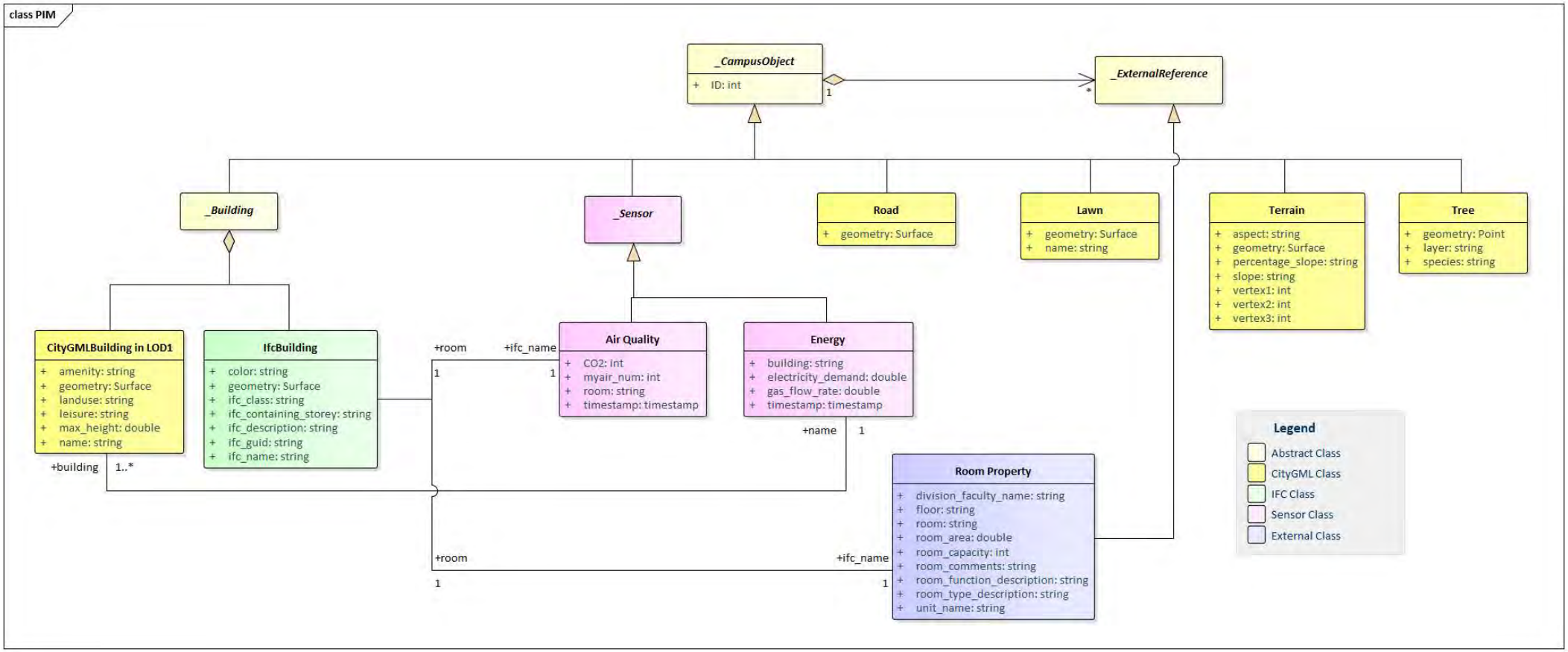

CityGML

IFC

# UML of the Conceptual PIM design



# UML diagram for the case study of UNSW campus



# Relational Database design for PIM

- Modelling tool Enterprise Architect
- Data type mapping

- Mapping an inheritance hierarchy onto one table

- Mapping classes at the same inheritance hierarchy level onto one table

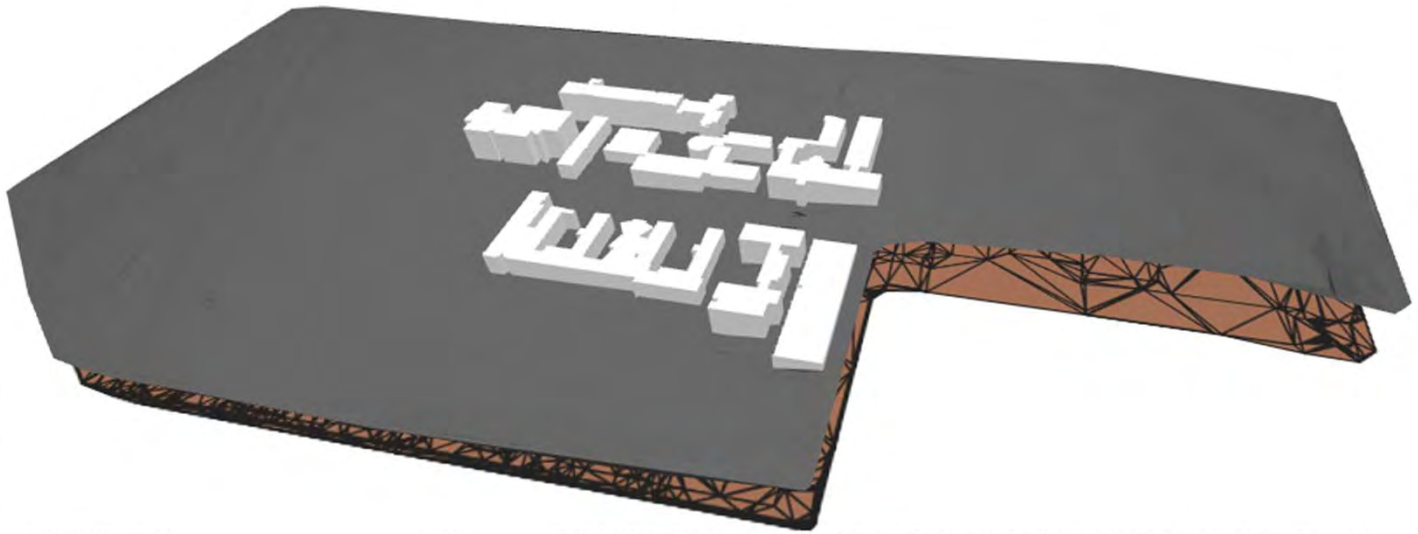
# PostGIS tables for the IFC

| | ifc_class character varying | ifc_guid character varying | ifc_name character varying | ifc_description character varying | ifc_containing_storey character varying | geom geometry | color character varying |
|---|---|---|---|---|---|---|---|
| 1 | IfcBuildingElementPr... | 3o3Kh7zyL1GPkZem... | stage:stage:429999 | | Fifth | 010F0000A0E61... | rgb(130, 130, 130) |
| 2 | IfcBuildingElementPr... | 3o3Kh7zyL1GPkZem... | stage:stage:429999 | | Fifth | 010F0000A0E61... | rgb(130, 130, 130) |
| 3 | IfcBuildingElementPr... | 3o3Kh7zyL1GPkZem... | stage:stage:429999 | | Fifth | 010F0000A0E61... | rgb(130, 130, 130) |
| 4 | IfcBuildingElementPr... | 3o3Kh7zyL1GPkZem... | stage:stage:429999 | | Fifth | 010F0000A0E61... | rgb(130, 130, 130) |
| 5 | IfcBuildingElementPr... | 3o3Kh7zyL1GPkZem... | stage:stage:429999 | | Fifth | 010F0000A0E61... | rgb(130, 130, 130) |
| 6 | IfcColumn | 31I4Udr9H7k8a4Gbg... | Rectangular Column:... | | Basement | 010F0000A0E61... | rgb(102, 102, 102) |
| 7 | IfcBuildingElementPr... | 3o3Kh7zyL1GPkZem... | stage:stage:429999 | | Fifth | 010F0000A0E61... | rgb(130, 130, 130) |
| 8 | IfcBuildingElementPr... | 3o3Kh7zyL1GPkZem... | stage:stage:429999 | | Fifth | 010F0000A0E61... | rgb(130, 130, 130) |
| 9 | IfcBuildingElementPr... | 1Hj9oGsYPAWA0I2s... | roofObject:roofObjec... | | Fifth -1.19 | 010F0000A0E61... | rgb(130, 130, 130) |
| 10 | IfcBuildingElementPr... | 2ukwPmY4578gdku... | Trim-Window-Exterio... | | Second+.52 | 010F0000A0E61... | rgb(193, 193, 190) |

Example of table created in PostGIS to store IFC file

# Query and visualisation with QGIS

**Query-1: Which buildings are within 100 metres from "Red Centre Building" ?**



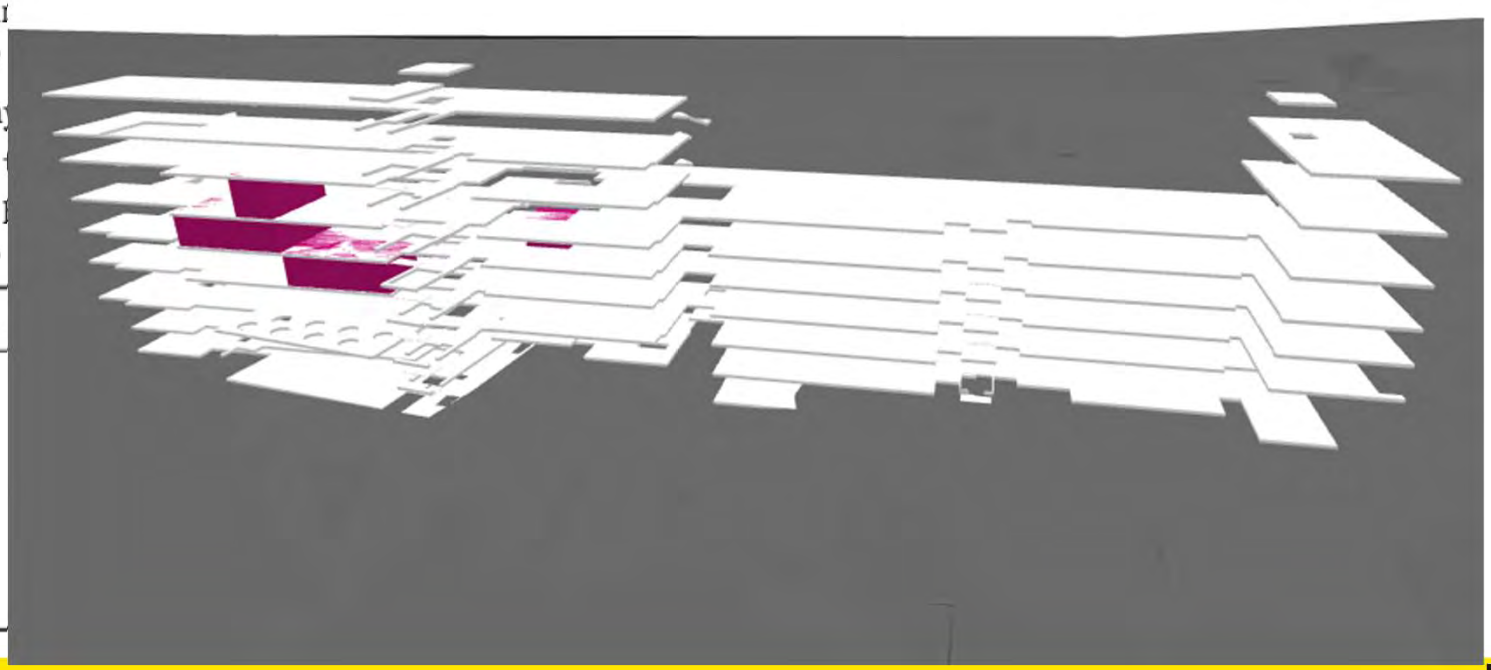
| | | |
|---|---|---|
| Electrical Engineering | 60.01 | GEOMETRYCOLLECTION Z (POLYGON Z ((336482.348728 ...))) |
| Keith Burrows Theatre - J14 | 7.18 | GEOMETRYCOLLECTION Z (POLYGON Z ((336385.037031 ...))) |
| ..... | ..... | ..... |
| Webster Theatres - G15 | 54.71 | GEOMETRYCOLLECTION Z (POLYGON Z ((336409.433132 ...))) |
| Willis Annex - J18 | 80.69 | GEOMETRYCOLLECTION Z (POLYGON Z ((336509.586164 ...))) |

# Query and visualisation with QGIS

**Query-2: Which rooms of red center building whose height is larger than 38 metres (considering terrain height) and total $CO_2$ level is larger than 100000 in one week (between Dec.10 and Dec.16 2018 ) ?**

```
SELECT I
FROM bi
(SELECT
 FROM m
 WHERE
 GROUP
```

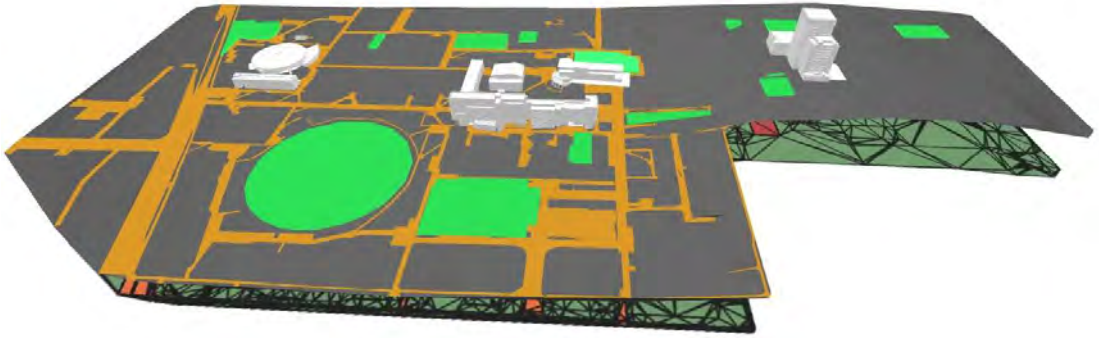
| Room |
|---|
| 2034 |
| 2035 |
| 3034 |
| 3035 |
| 3040 |
| 4035 |



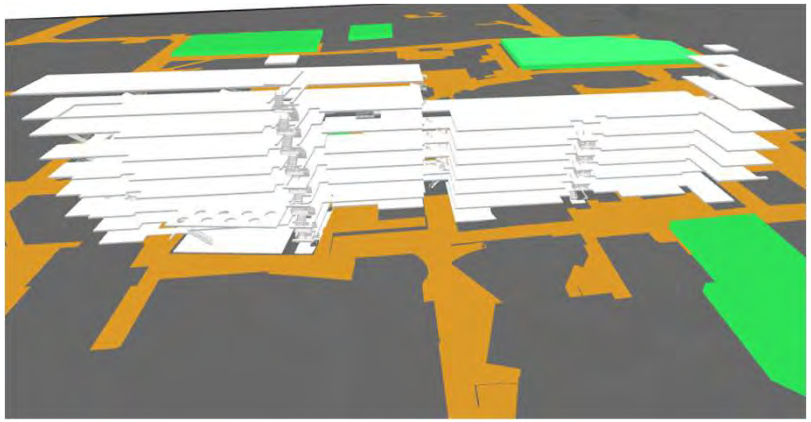
# More queries and visualisation

**CityGML LOD1 buildings, green areas, roads and trees**

**BIM**



**Querying BIM**



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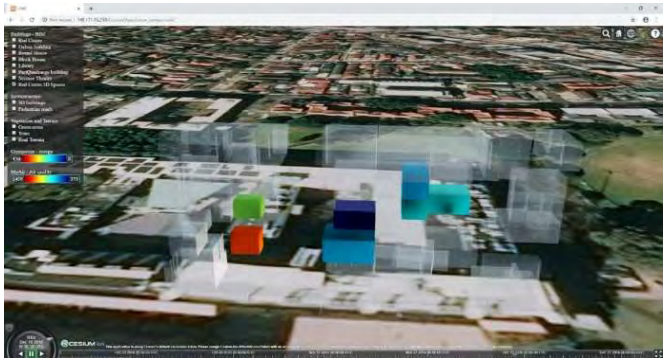
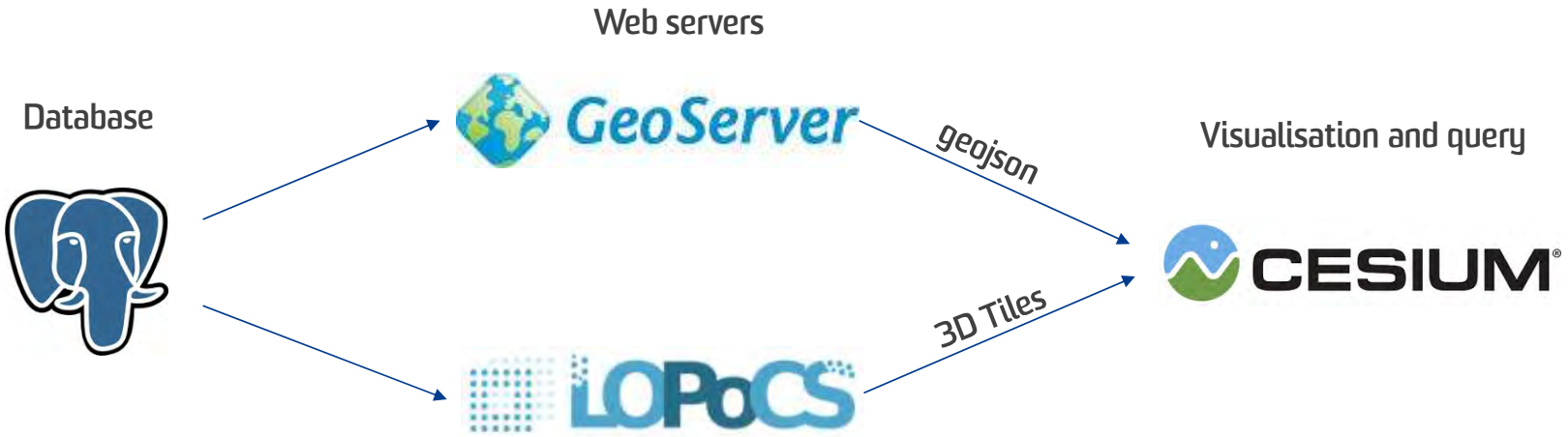


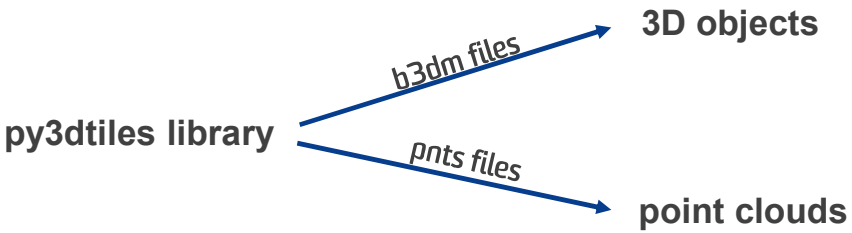
Mitko Aleksandrov

# Web visualisation and query using Cesium




- GeoServer (2D and simple 3D content)
- LOPoCS server (point clouds)

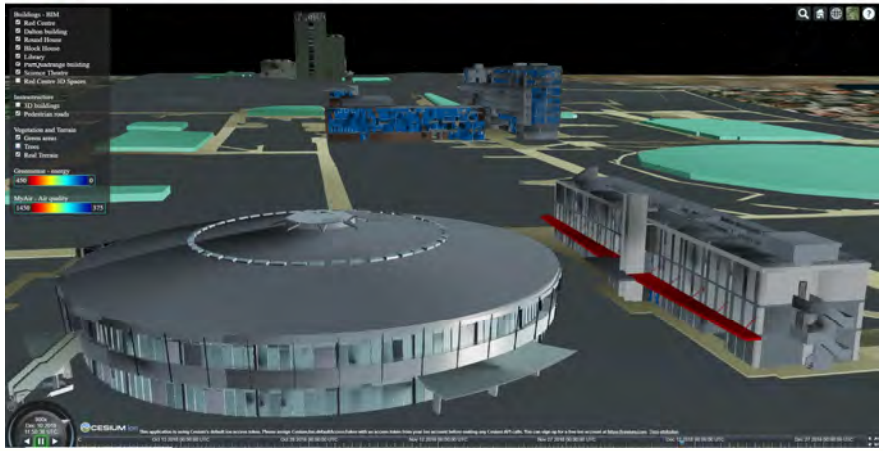
# 3D Tiles creation




2D space subdivision creating tiles

3D view of created tiles

# Cesium – BIM/GIS integration

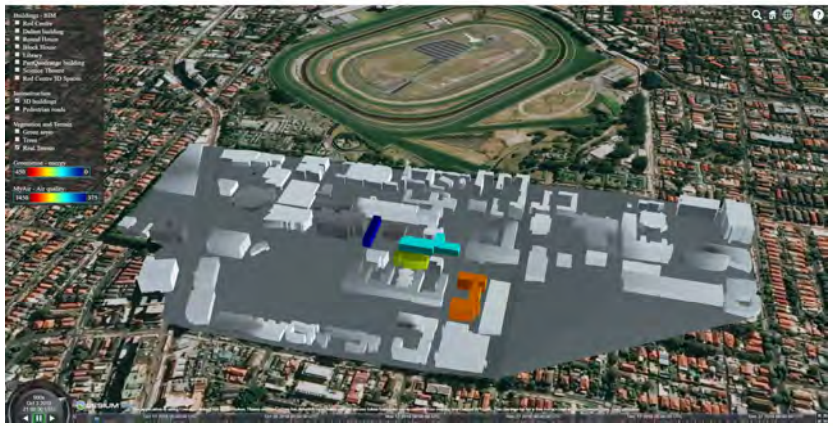


CityGML - LOD1 buildings, green areas, roads and trees

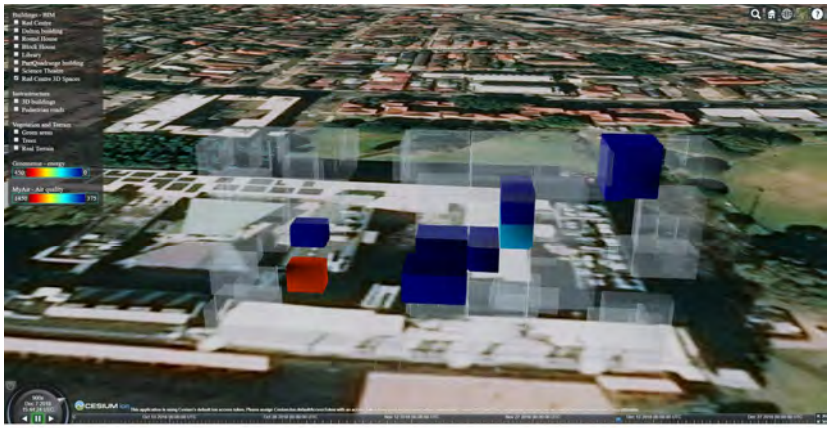
BIM and CityGML - LOD1 buildings integration

# Cesium – sensor integration

## CityGML LOD1 and energy consumption



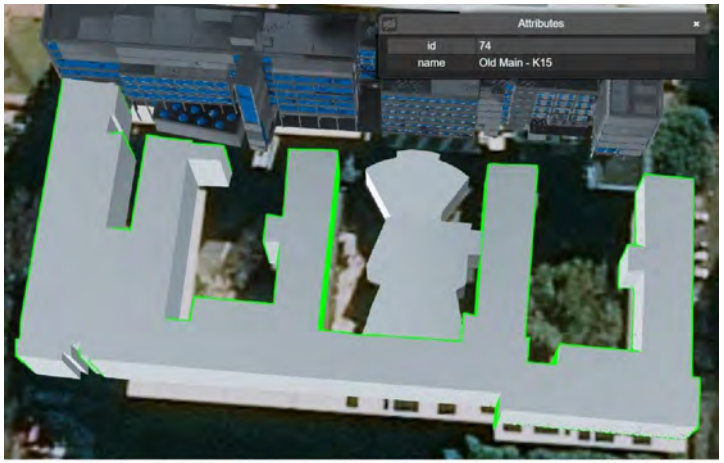
## IFC and air quality data

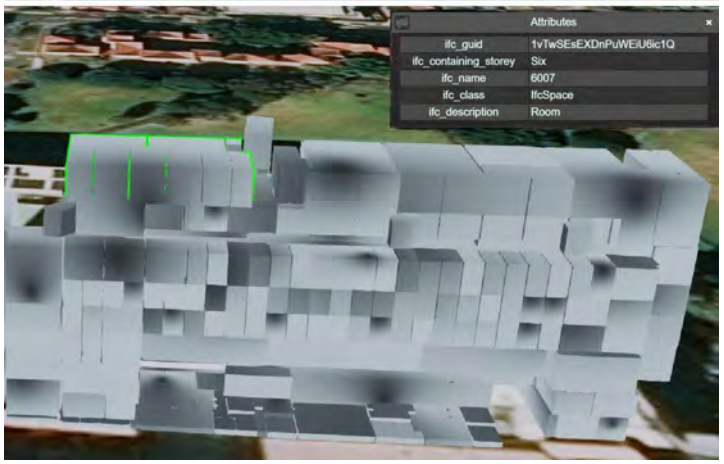


# Cesium query and visualisation

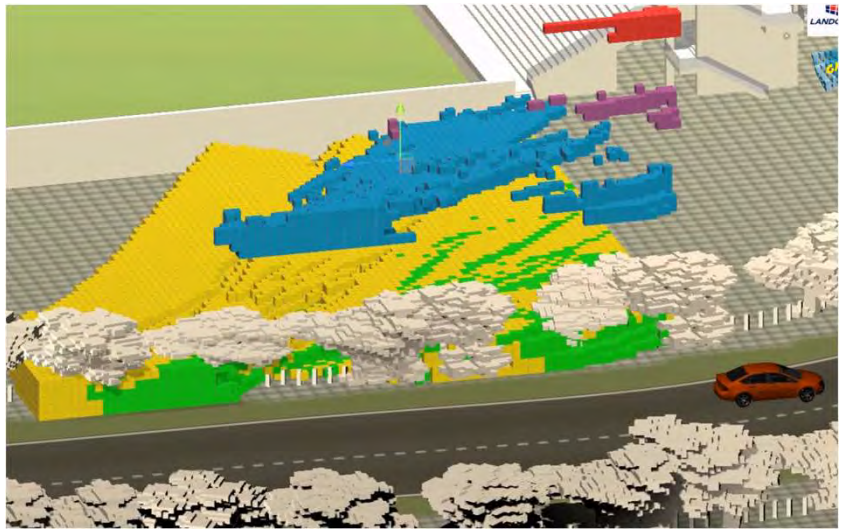
## Point clouds

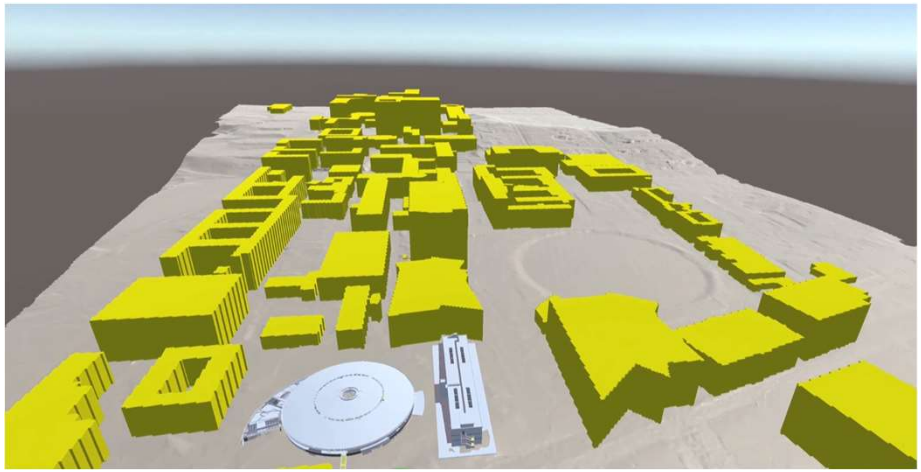
## Attributes query

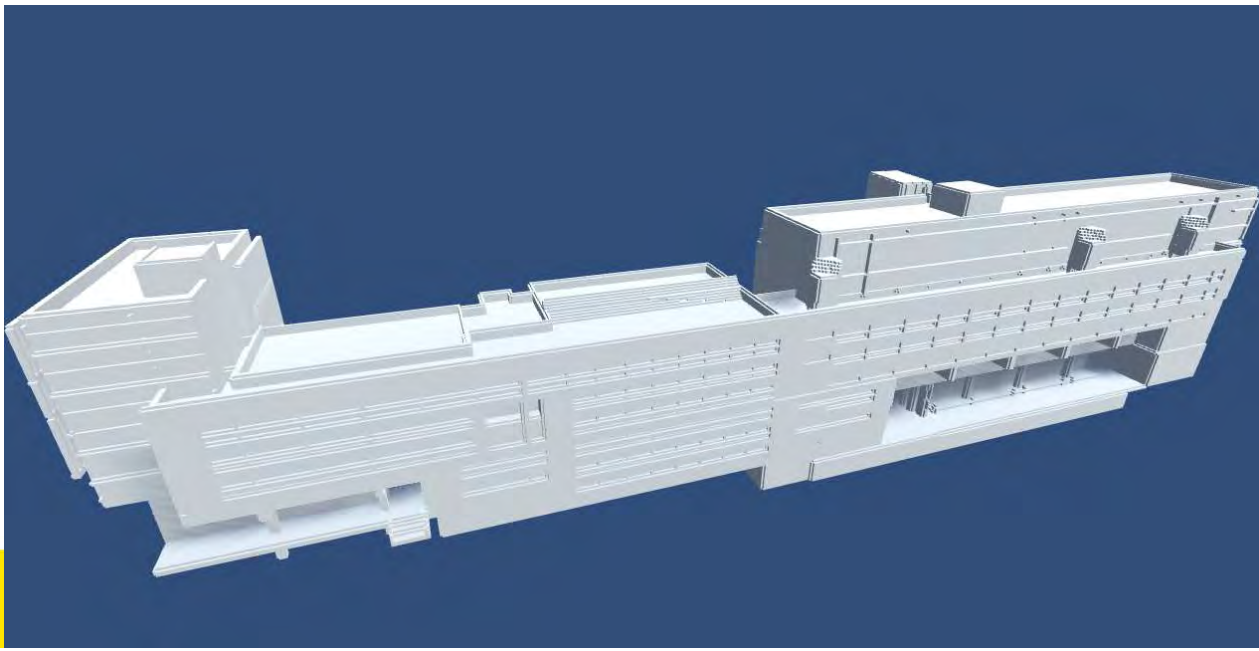


# Voxels







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# THANK YOU!

https://www.be.unsw.edu.au/research/research-activities/grid-home/projects/unsw-campus-and-beyond-bim-and-3dgis

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