FIG WORKING WEEK 2025
AND Locate25 THE NATIONAL GEOSPATIAL CONFERENCE
Collaboration, Innovation and Resilience: Championing a Digital Generation
FIG Geospatial Council of Australia
Brisbane, Australia 6–10 April

Voxel modelling for large 3D urban areas

Dr Jack Barton, Prof Dr Sisi Zlatanova, Dr Ben Gorte, Dr Abdoulaye Diakité

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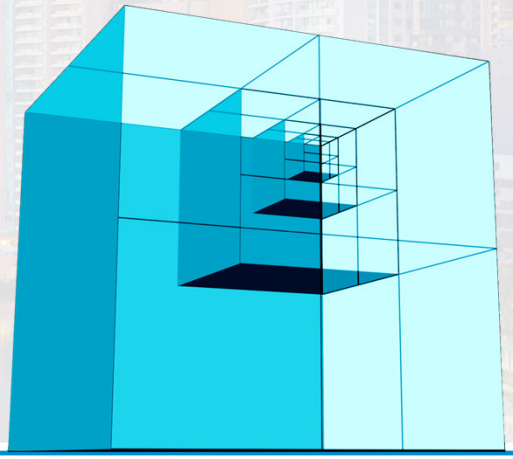

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Advancing Spatial Digital Twins with Voxel-Based 3D Data Processing

- Spatial Digital Twins are key platforms for managing and visualizing 3D spatial data.
- Data is organized into themes (terrain, transport, vegetation) or ad hoc datasets (buildings).
- Integrating 3D data into a unified model presents challenges in accuracy, resolution, and representation.

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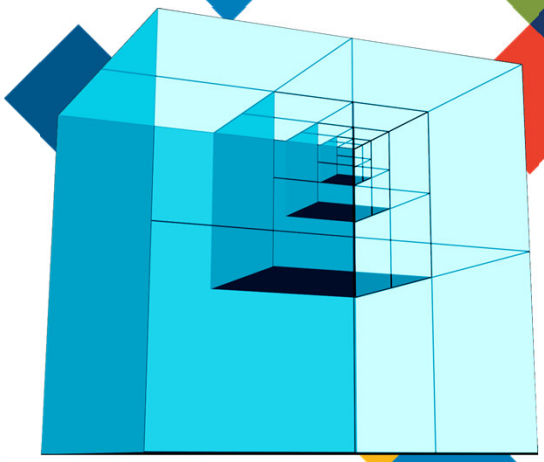
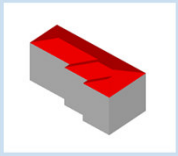
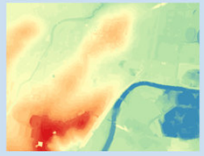
- Voxelmates consists of four mates from TUDelft/UNSW and one developer
- Voxelmates is a member of the ESRI Partner Network



Challenges in Current Spatial Digital Twins

- Much urban data is structured as raster or vector datasets
- Difficulties arise when combining these data, hence;
- Lack of advanced 3D spatial analysis (e.g., volume computation, 3D intersections).

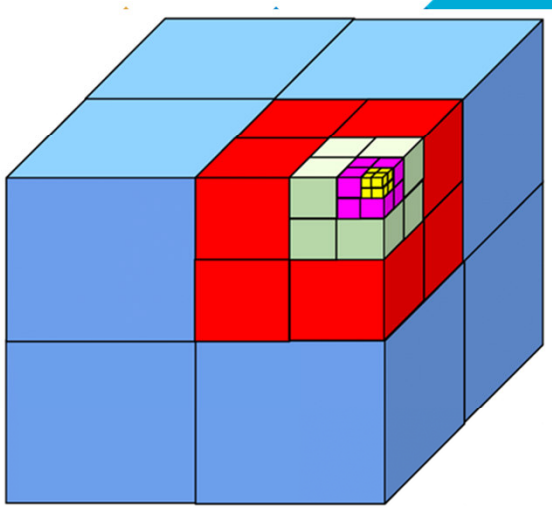
- **Voxel-based representation offers a unified and efficient solution.**

Buildings	Terrain	Transportation (rail, roads, etc.)	Water	IoT Sensors
3D Polygons	DEM (grid)	3D Lines and 2D Polygons	3D Lines and 2D Polygons	Values / feeds
				

Voxel-Based Representation

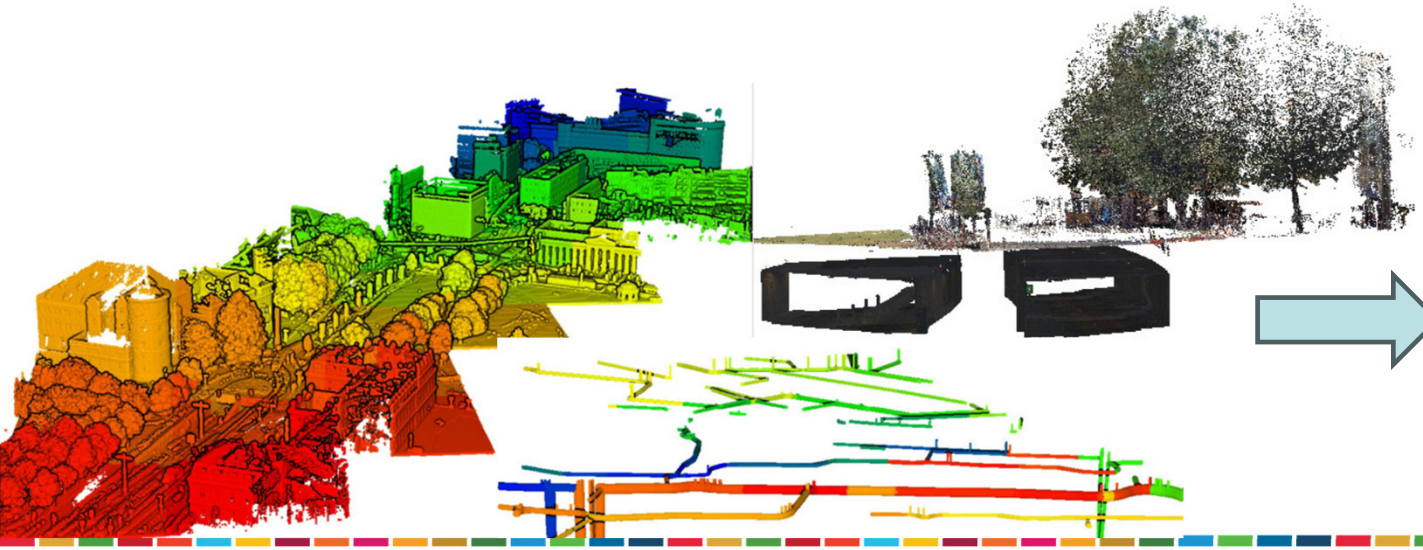
- Voxels are the 3D equivalent of pixels in raster images: Volumetric (vox) Elements (els)
- Objects are represented as sets of voxels in a regular 3D grid
- Variable grid size, multiresolution

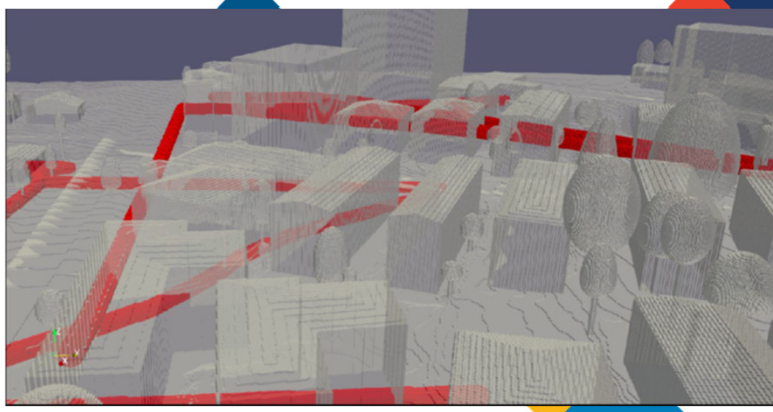
- Voxel advantages:
  - Unified data structure
  - Robust neighbourhood operations
  - Powerful 3D analytics for urban applications across full 3D space, including airspace.



The Challenge of Large-Scale Voxelization

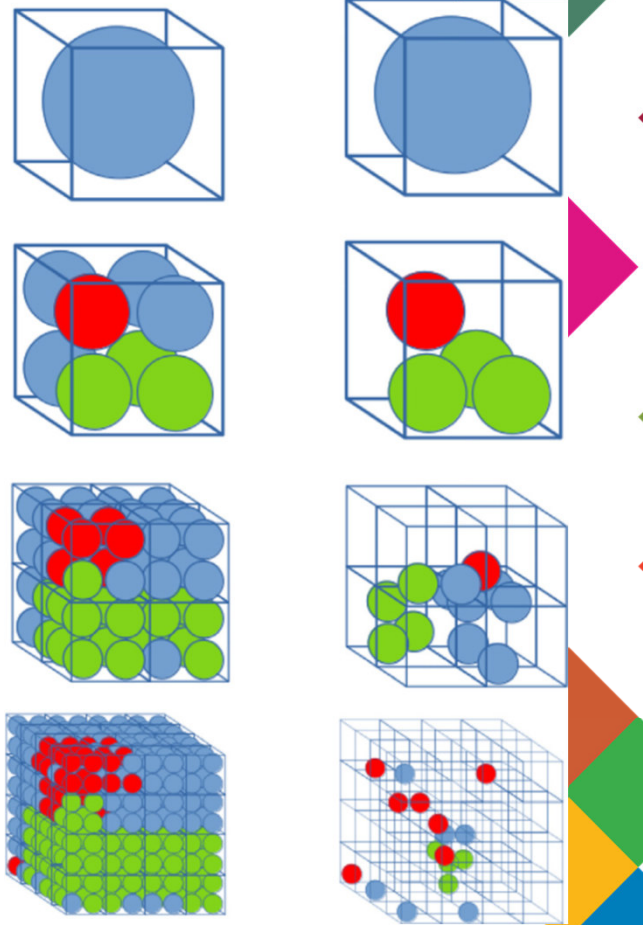
- Fine-resolution voxels provide high accuracy but significantly increase data size.
- Data grows cubically with resolution, making city-scale models difficult to process.
- Requires efficient data structures for storage and analysis.





Solution – Optimized Octree Data Structure

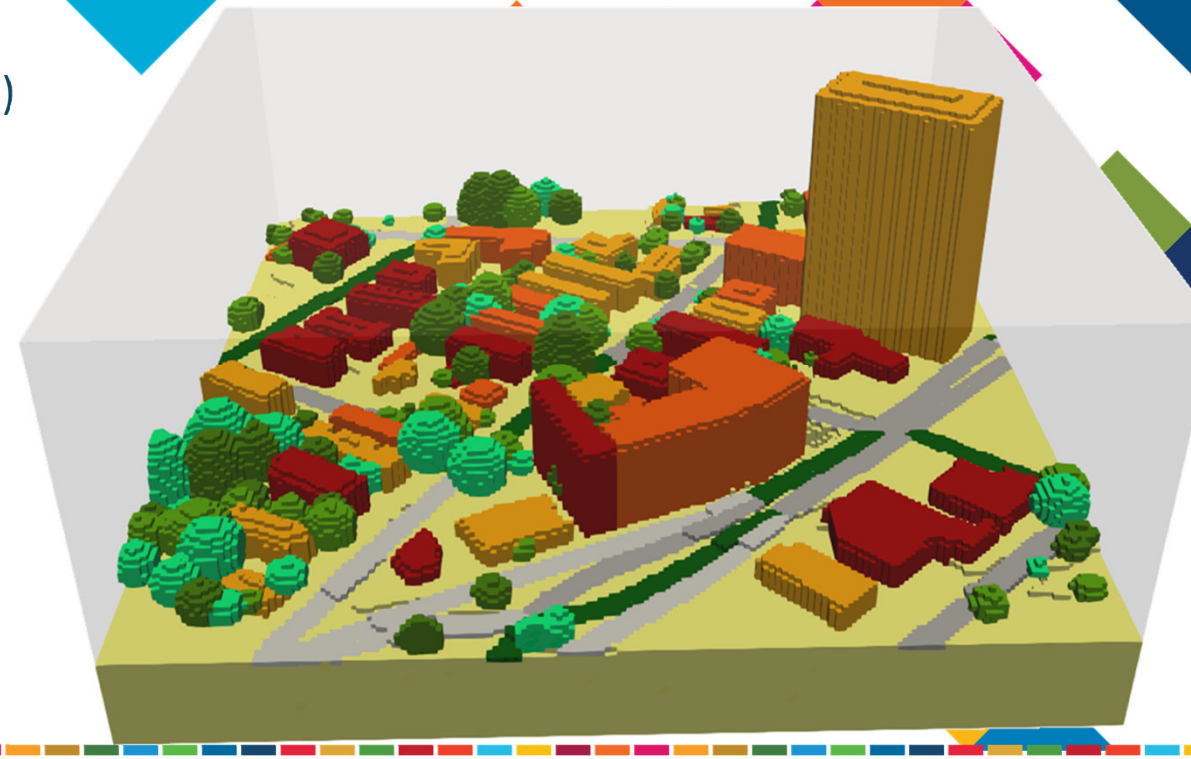
- Octrees provide an efficient way to manage voxel data hierarchically.
- Quadratic growth vs cubic growth in data size.
- Supports multi-resolution object representation.
- Optimized octree structure implemented in SQLite.
- Voxelmates have developed ESRI Add-ins for:
  - Accessing voxel data
  - Performing 3D analyses
  - Exporting LAS and NetCDF files.



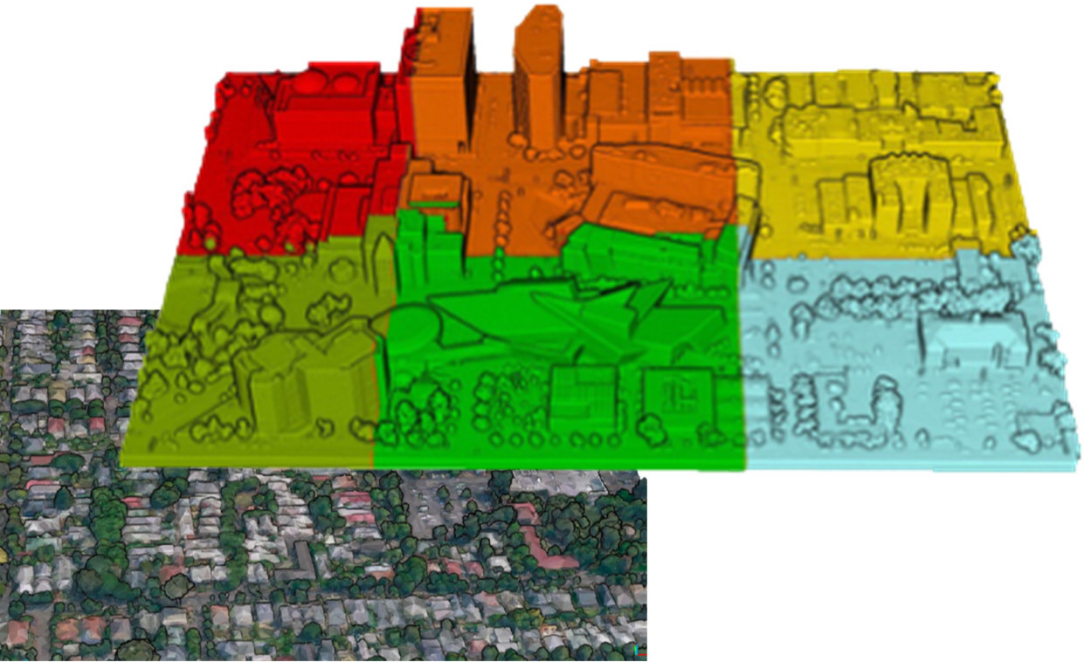
3D Data Integration

- Enabling many spatial operations
  - Boolean (union, difference, intersection, etc.)
  - Clustering / Segmentation
  - Neighbourhoods / Connected Components
  - Morphology
  - Distance Transforms
  - Etc.

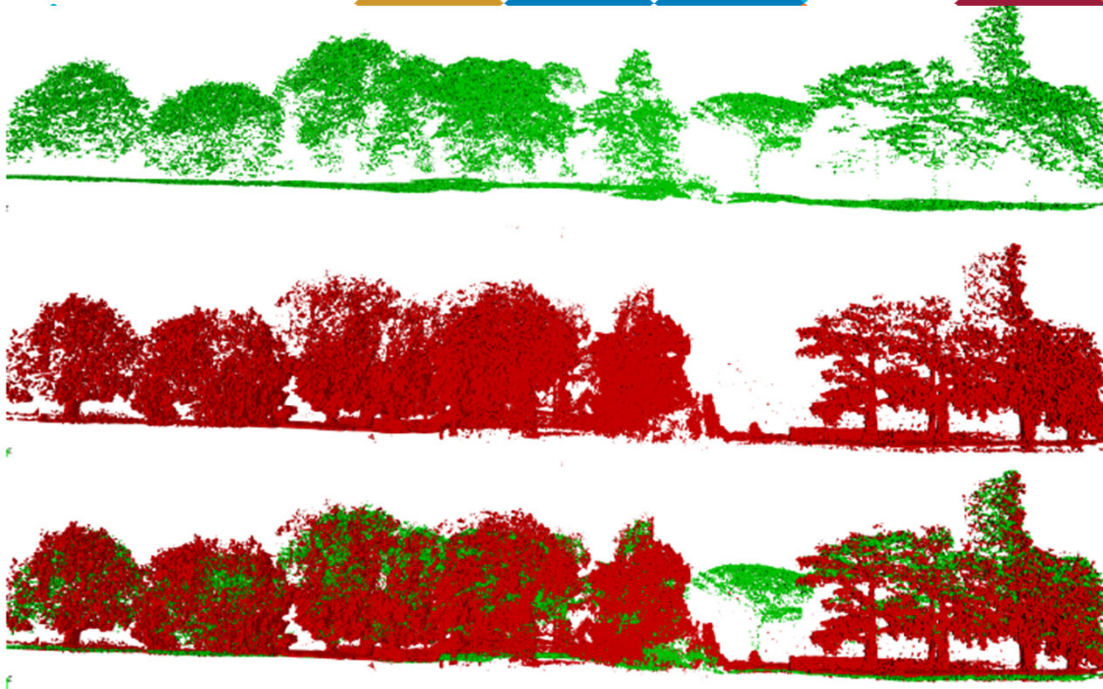
A grid of 3000x4000x100m at a resolution of 20cm would require 150Gb of memory! We got it only 1.9 Gb



Urban Applications

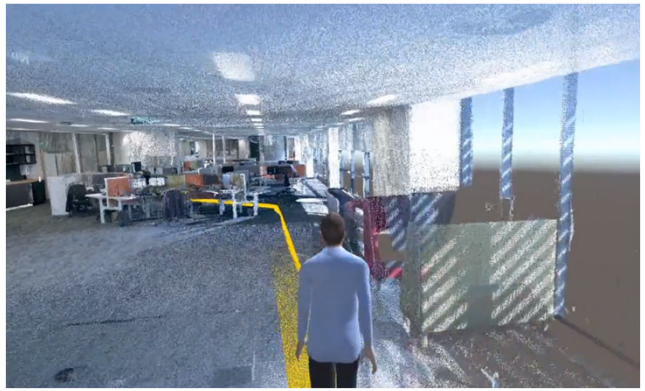


Aerometrex: processing of reality meshes

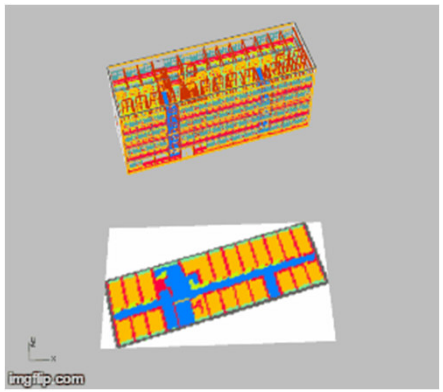


City of Melbourne: vegetation change detection

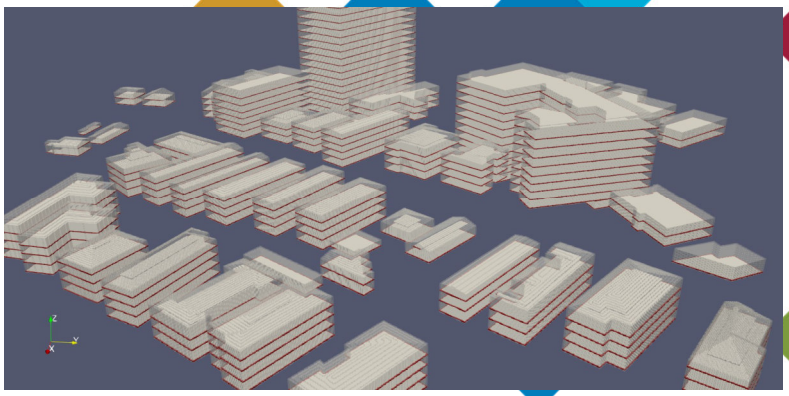
Urban Applications



Pathfinding in Point clouds

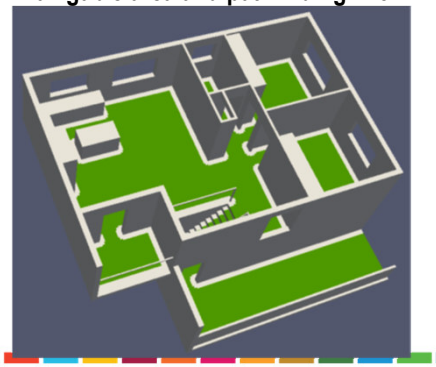


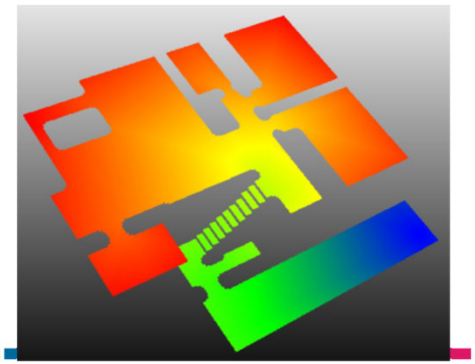
Sections

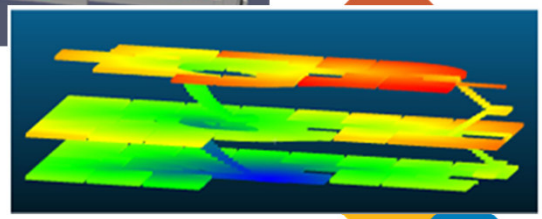


Volume and area

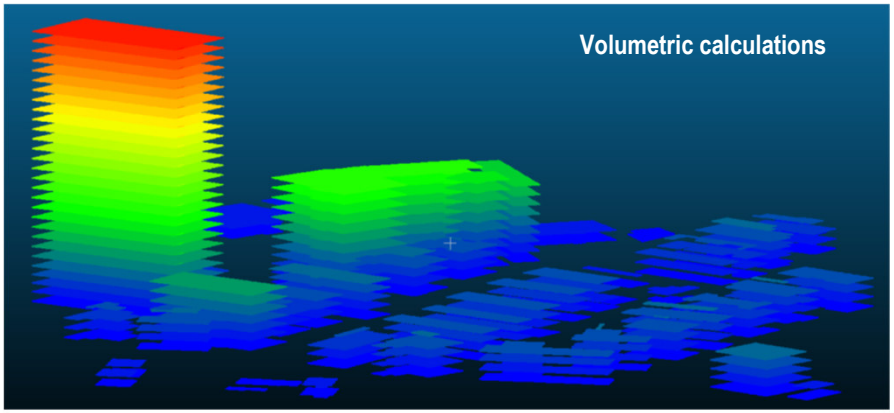
Navigable area and pathfinding in 3D

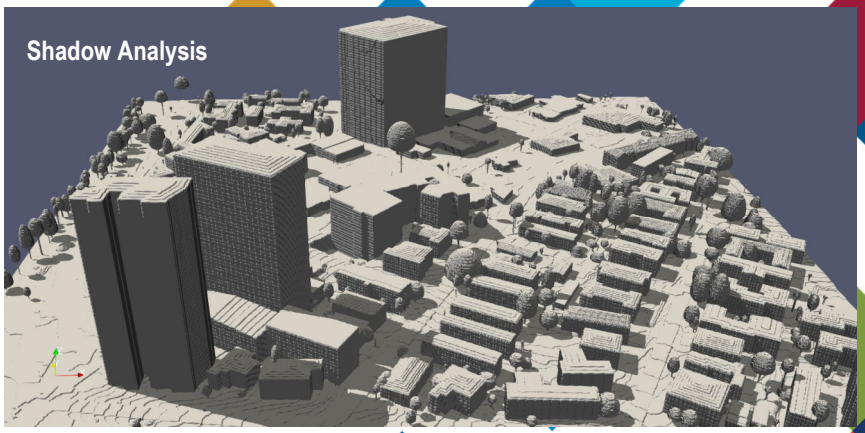


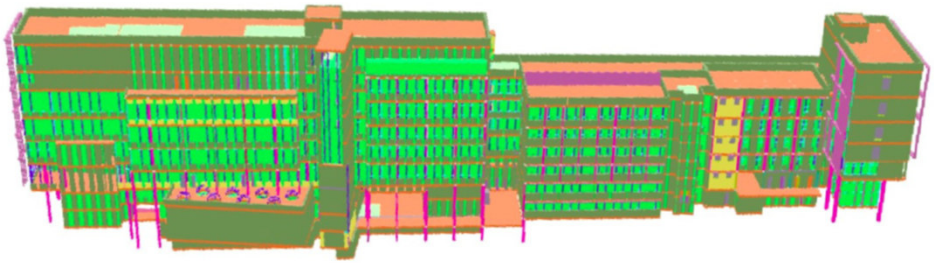




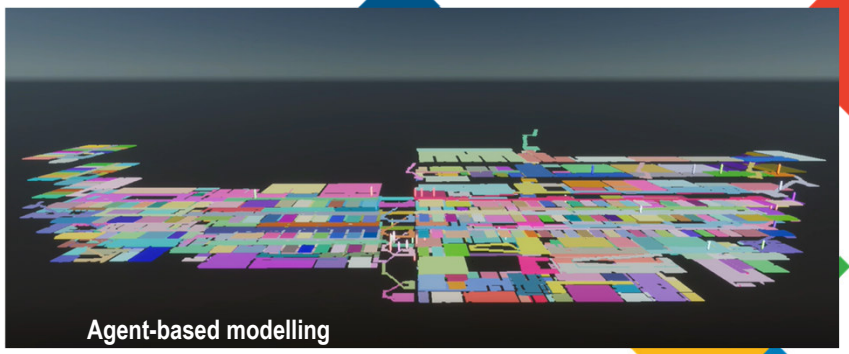
Urban Applications







Indoor analysis (hazard distribution)



Key takeaways and next steps

- Voxel-based methods provide a structured, scalable approach to 3D data integration.
- Octree optimization significantly reduces memory and processing overhead.
- ESRI Add-ins enable practical implementation in existing GIS workflows for urban planning, infrastructure, and environmental modeling.
- **We are keen to collaborate in developing and assisting:**
  - Emergency response (indoor and outdoor)
  - 3D data fusion for different purposes
  - Microclimate and wellbeing (indoor and outdoor)
  - Safety and security (indoor, outdoor, underground)

The most relevant SDGs related to the presentation and theme of this session

1st relevant SDG

2nd relevant SDG

3rd relevant SDG

SUSTAINABLE DEVELOPMENT GOALS

International Federation of Surveyors supports the Sustainable Development Goals

THANK YOU!

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