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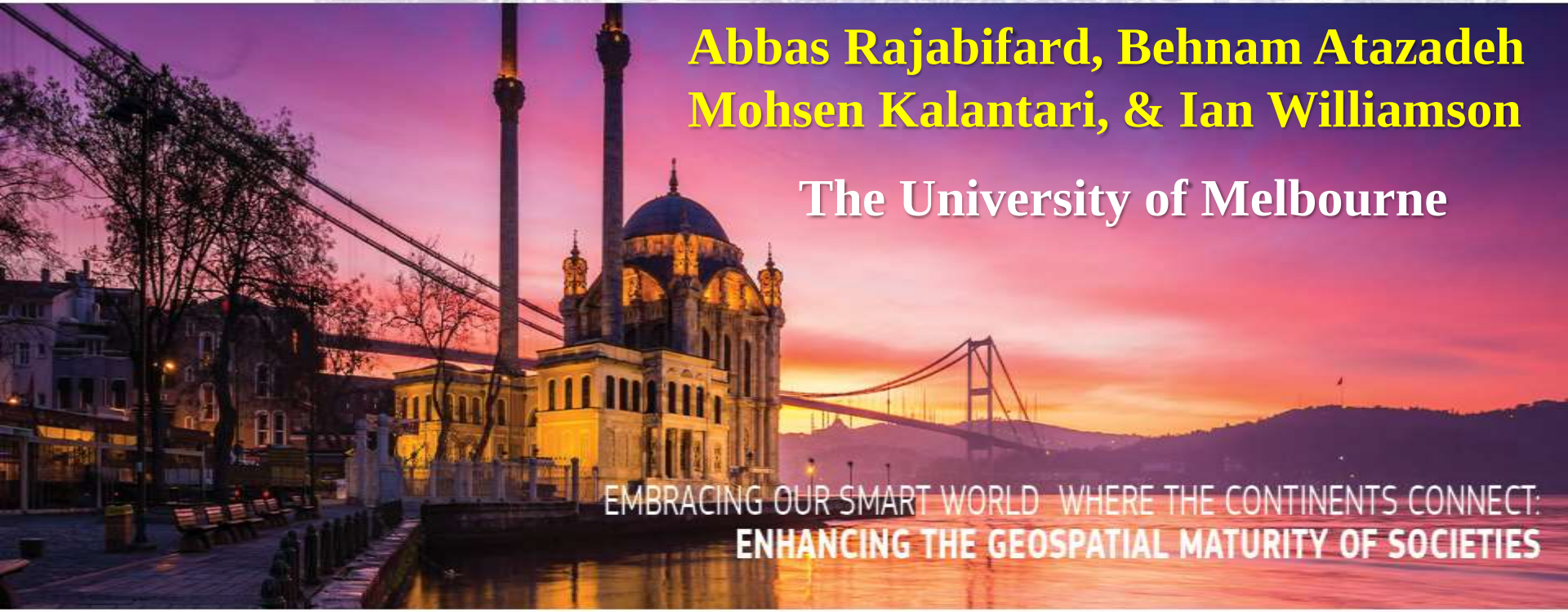
XXVI FIG CONGRESS

6-11 May 2018, İstanbul

A New Method for Integrating 3D Spatial Information of Vertically Stratified Ownership Properties into the Property Map Base



Abbas Rajabifard, Behnam Atazadeh
Mohsen Kalantari, & Ian Williamson

The University of Melbourne

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ACKNOWLEDGMENT

3D Property Ownership Map Base Project for Smart Urban Land Administration

Australian Research Council Linkage Project

2017-2019 (LP160100292)

This project aims to develop **solutions for accommodating 3D data derived from regulatory urban subdivision processes** into the current 2D property map base.

Journey - Major Projects

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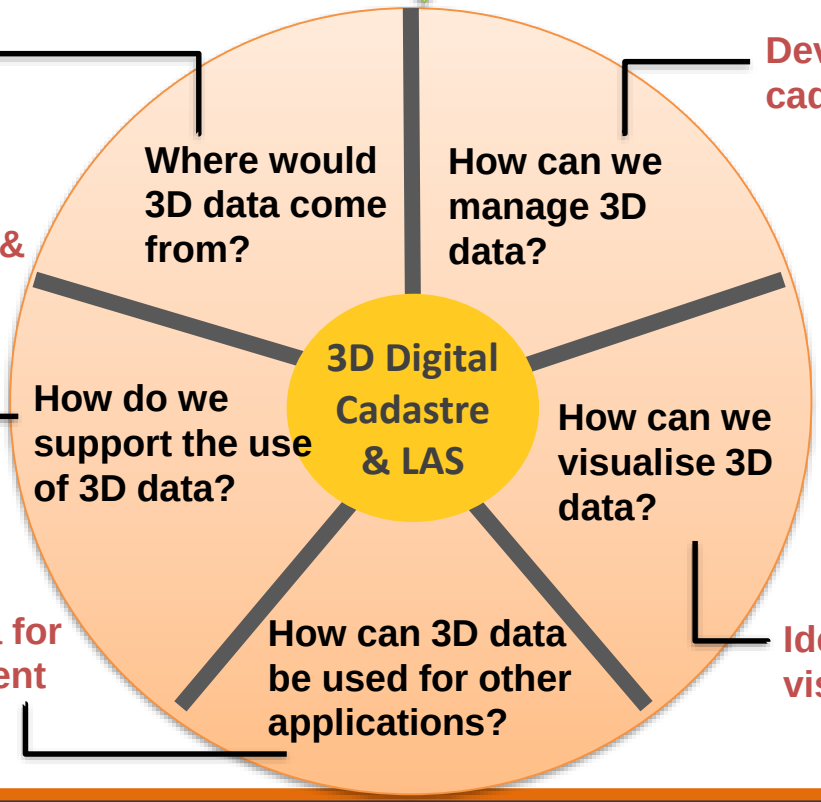
National Infrastructure for Land Information 2010-2013

Land and Property Information in 3D 2012-2016

3D Property Map Base for Smart Urban Land Administration 2017-2020



Identification of data sourcing methods

Development of two 3D cadastral data models

Identification of key institutional challenges & proposing a roadmap

Using 3D cadastral data for flood damage assessment

Identification of more than 60 visualisation requirements

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Urbanisation and Complex Developments

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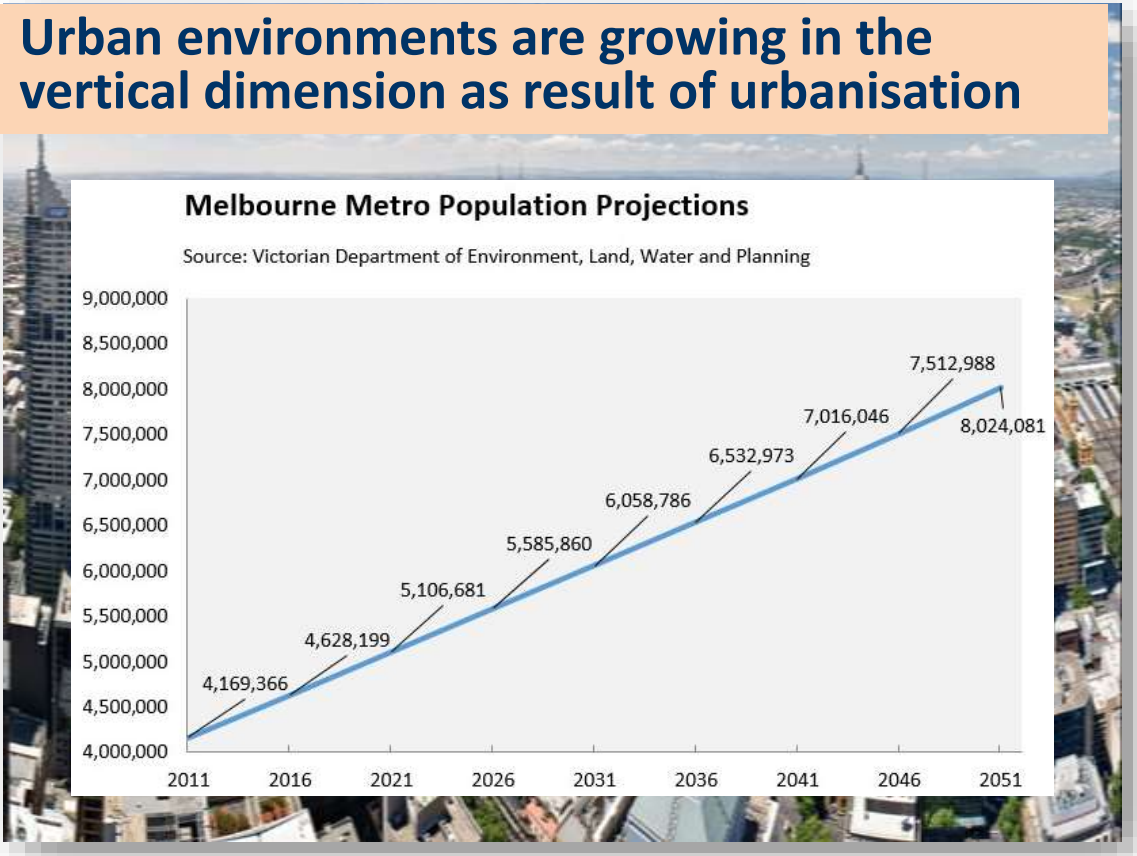
Urban environments are growing in the vertical dimension as result of urbanisation



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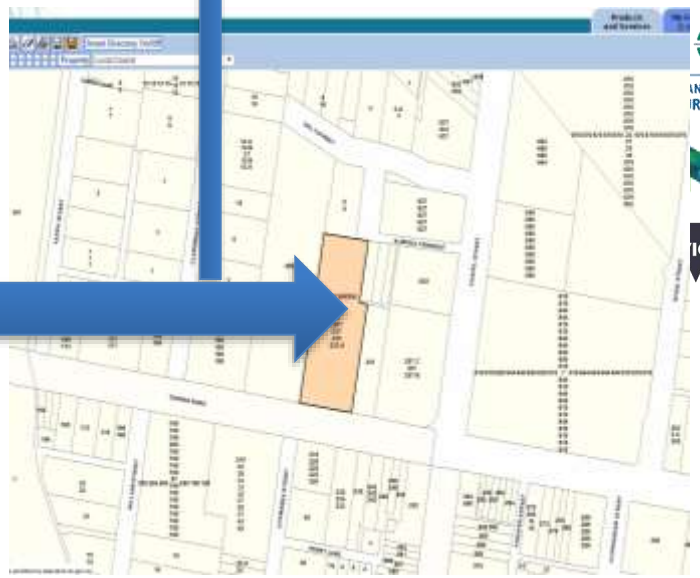
Current Property Map Base are 2D

- The **spatial dimensions of properties located above and below the ground are not represented in property map bases** of most jurisdictions around the world.
- Current approach relying on **2D subdivision plans provides a fragmented representation** of spatial arrangements of vertically located properties.

2D subdivision plans for vertically located properties



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Consequences of 2D Approach

- **Extra surveying activities** in complex ownership situations.
- **Costs associated with duplication** of 3D spatial information.
- It **affects the reputation of authorities** responsible for maintaining the property map base and providing critical spatial information services to the community.
- **Unpredictable damages** can be done to other assets, particularly those assets located below the ground.
- **Ineffective support for spatially enable decision making** in managing and planning other aspects of urban settings (e.g. launching National Broadband Network for multi-level developments)

Property Map Base

- **Property map bases** represent the most complete, authoritative graphical representation of land parcel and property boundaries (cadastral information).
- **Property map bases** are core business for land registries, national mapping agencies and local governments.
- **Property map bases** are **an enabling infrastructure and a source of intelligence** to support land and property decision-making across government, businesses and communities.

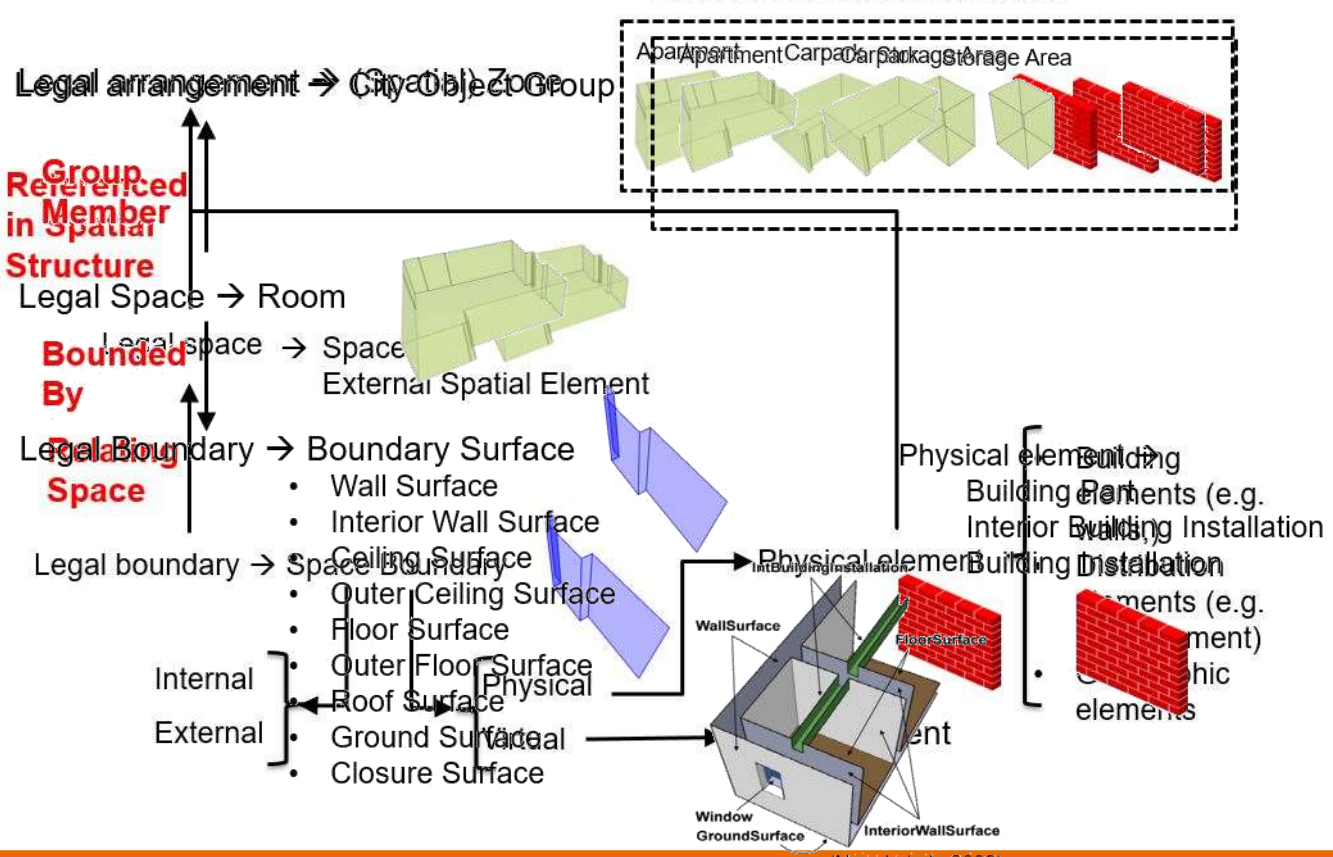
Challenges in Developing a 3D Property Map Base

- **Spatial Integrity Challenges**
  - A single 3D property object is defined by a **valid volume**.
  - Spatial **validity** **of legal interests associated with a set of 3D property objects** (e.g. Common properties) or the whole 3D property map base.

- **Challenges in 3D Boundary Query and Analysis**
  - An appropriate spatial query language to identify the spatial relationships between 3D property boundaries and their corresponding physical elements.

Spatial Data Models for 3D Property Map Base

- LADM (Land Administration Domain Model)
- IFC (Building Information Modelling)
- CityGML (3D City Information Models)



(Nagel et al., 2009)

Potential 3D Platforms

- Spatial Databases (Oracle Spatial, PostGIS)
  - These DBs provide the ability to store and manage 3D spatial data

- 3D City Database:
  - A free geospatial database to managing 3D urban information models
  - Based on the CityGML schema
  - Enables complex analyses in the urban context

- BIMServer
  - An open source server for managing BIM models on the cloud
  - Based on IFC schema
  - Querying and visualising BIM models on the web

Pathway Towards 3D Property Map Base

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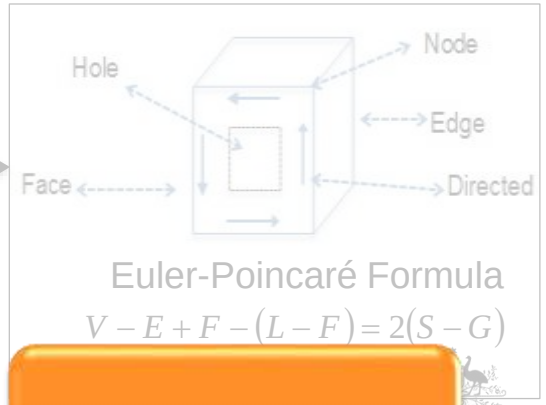
Subdivision Plan

3D Digital Subdivision Model

Validate Model



Euler-Poincaré Formula

$$V - E + F - (L - F) = 2(S - G)$$

Constructing

Validating

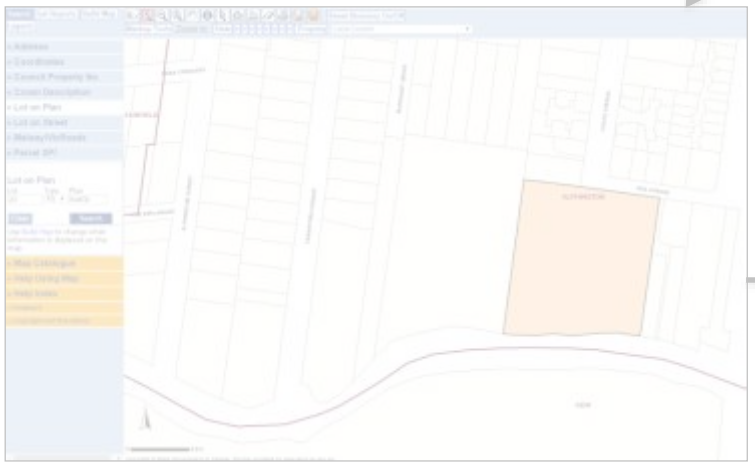
Querying and Analysis

el into

Base

Spatial

Property



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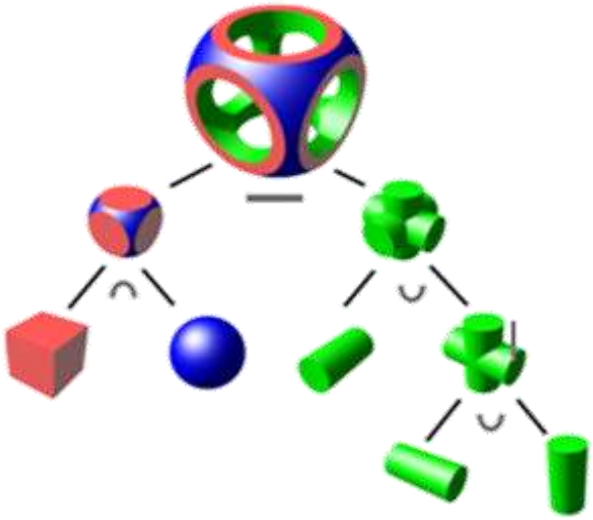
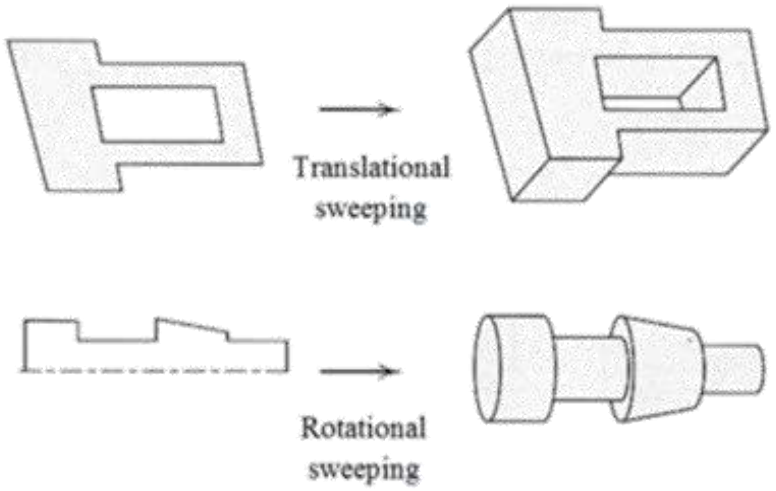
Constructing 3D Digital Property Models

User Friendly Solid Modelling Approaches in **CAD** and **BIM**

- Constructive Solid Geometry (**CSG**)
- Sweeping

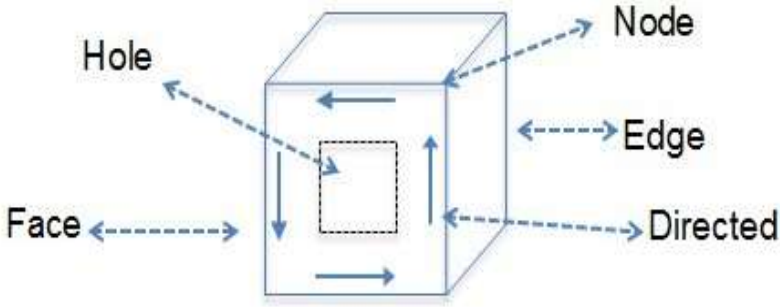




(Wikipedia, 2014), (Anand, 1996)

Validating 3D Digital Property Models

- To adopt **the boundary representation (B-rep)** with full **Topology** of 3D property objects and develop **process** for engineering **validation rules**.
- The geometry of 3D property objects (**could be in Constructive Solid Geometry-CSG or sweeping solid**), should be converted into **B-rep-based solid models**.
- Geometrical rules specific to 3D property objects (**eg. no overlaps/no gaps**) must be applied.



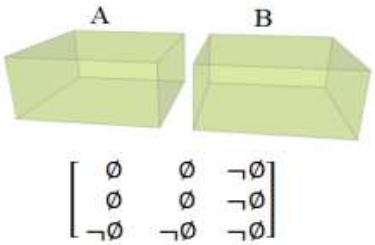
F-E+V-L = 2(S-G)

3D Spatial Query and Analysis

Topological Operators

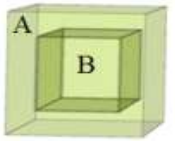
- The 9-Intersection Model

$$I = \begin{bmatrix} A^o \cap B^o & A^o \cap \partial B & A^o \cap B^e \\ \partial A \cap B^o & \partial A \cap \partial B & \partial A \cap B^e \\ A^e \cap B^o & A^e \cap \partial B & A^e \cap B^e \end{bmatrix}$$



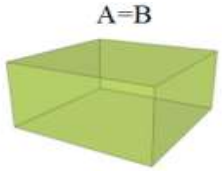
$$\begin{bmatrix} \emptyset & \emptyset & \neg\emptyset \\ \emptyset & \emptyset & \neg\emptyset \\ \neg\emptyset & \neg\emptyset & \neg\emptyset \end{bmatrix}$$

A *disjoint* **B**



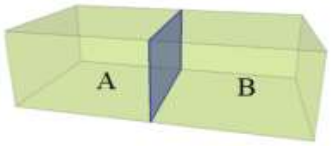
$$\begin{bmatrix} \neg\emptyset & \neg\emptyset & \neg\emptyset \\ \emptyset & \emptyset & \neg\emptyset \\ \emptyset & \emptyset & \neg\emptyset \end{bmatrix}$$

A *contains* **B**
B *inside* **A**



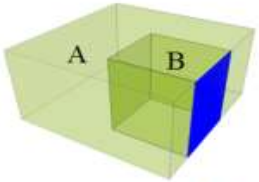
$$\begin{bmatrix} \neg\emptyset & \emptyset & \emptyset \\ \emptyset & \neg\emptyset & \emptyset \\ \emptyset & \emptyset & \neg\emptyset \end{bmatrix}$$

A *equals* **B**



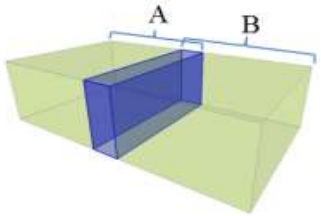
$$\begin{bmatrix} \emptyset & \emptyset & \neg\emptyset \\ \emptyset & \neg\emptyset & \neg\emptyset \\ \neg\emptyset & \neg\emptyset & \neg\emptyset \end{bmatrix}$$

A *touches* **B**



$$\begin{bmatrix} \neg\emptyset & \neg\emptyset & \neg\emptyset \\ \emptyset & \neg\emptyset & \neg\emptyset \\ \emptyset & \emptyset & \neg\emptyset \end{bmatrix}$$

A *covers* **B**
B *covered by* **A**



$$\begin{bmatrix} \neg\emptyset & \neg\emptyset & \neg\emptyset \\ \neg\emptyset & \neg\emptyset & \neg\emptyset \\ \neg\emptyset & \neg\emptyset & \neg\emptyset \end{bmatrix}$$

A *overlaps* **B**

3D Spatial Query and Analysis

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Topological Operators

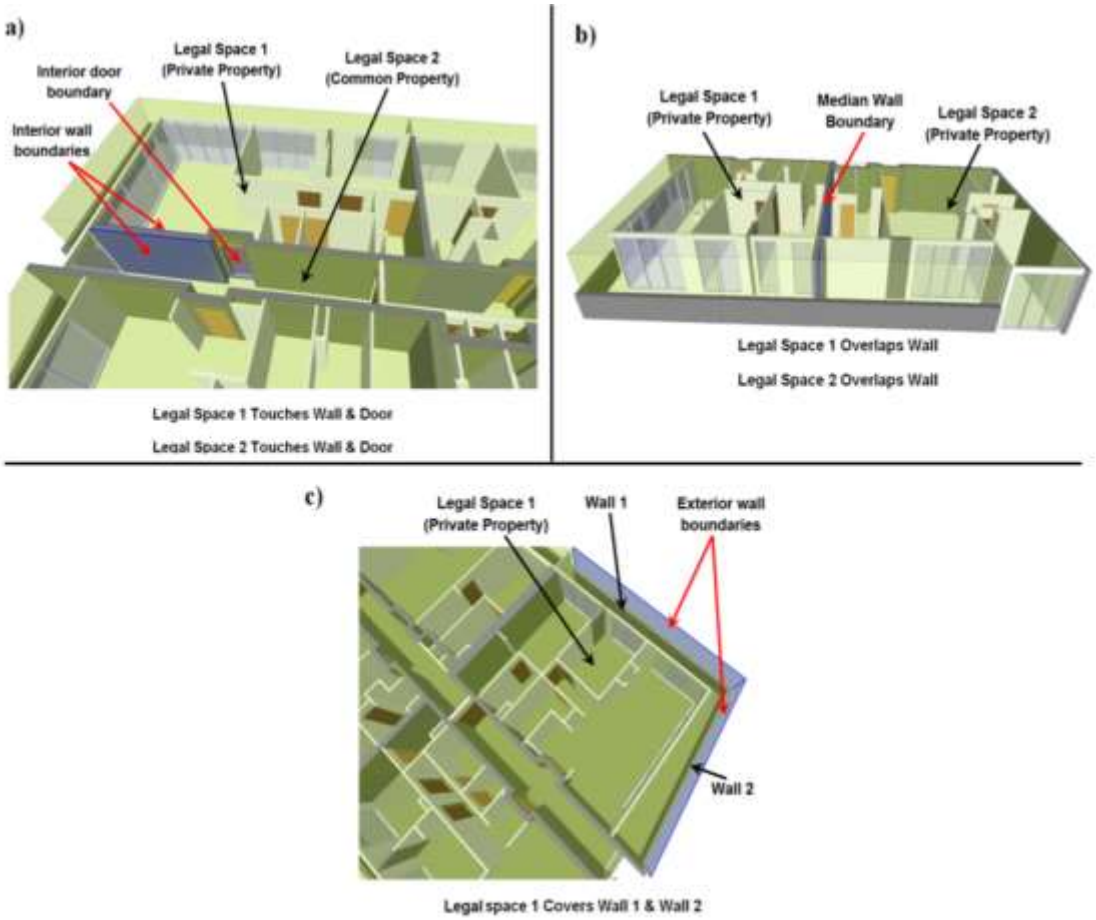
- The 9-Intersection Model

$$I = \begin{bmatrix} A^o \cap B^o & A^o \cap \partial B & A^o \cap B^e \\ \partial A \cap B^o & \partial A \cap \partial B & \partial A \cap B^e \\ A^e \cap B^o & A^e \cap \partial B & A^e \cap B^e \end{bmatrix}$$

A Touches B → Interior Boundary

A Overlaps B → Median Boundary

A Covers B → Exterior Boundary



New Attributes of 3D Property Map Base

- Spatial location of vertically located properties can be clearly determined in 3D property map base.

- **Changes in current practices**: Stakeholders need to interact and communicate in a 3D digital environment.

- The authorities can make better decisions when a new development is constructed, **3D property map base can represent how** this development will affect surrounding properties (underground/aboveground).

New Attributes of 3D Property Map Base

Emergence of new use cases for property map bases:

- **Estimating the density** of occupancy in 3D space.
- **3D analysis** based on population and employment forecasting to enable capacity modelling of existing and proposed services.
- Produce **interactive and narrative products,** which facilitate better community participation in the decision-making process.

Obstacles to Realise 3D Property Map Base

- **Institutional barriers -** in the current legislative and policy settings, as well as organisational culture of jurisdictions.

- The new **3D digital validation rules** must be **rigorously reviewed and approved** by the authoritative organisations.

- **Lack of required software and hardware across the organisations** for processing and rendering 3D digital data.

Takeaway Messages

- **3D property map base** could provide **solutions to resolve spatial problems** in communicating and managing vertically stratified properties.
- Development of 3D property map base entails **technical and institutional challenges**.
- A new approach for integrating 3D property information - vertically stratified ownership properties, into the current 2D property map base was proposed.
- The integrated 3D digital representation of the property map base would provide **intelligence in making spatial decisions with legal ownership of underground and above ground properties**.

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Thank You

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