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# Converting BIM Data to CityGML for 3D Cadastre Purposes

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# Overview

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# Introduction

- Currently, stratified property rights are registered and managed using 2D subdivision plans.
- These plans do not accurately depict property spaces in complex situations.
- The advancements in 3D GIS and BIM integration enabling methods for modelling urban spaces geometrically and semantically.
- Several works have been explored on BIM and 3D GIS for 3D cadastre.
- Such as transformation between IFC and CityGML - semantic mapping between the two schemas.

# Introduction (cont.)

- The current situation of BIM to 3D cadastre - the use of Strata XML by Malaysian mapping authority.
- The limitation on the Strata XML for 3D physical geometry storage - there is a need to adopt CityGML for the 3D data storage.
- Strata XML - to store strata objects information for the management and registration.
- This study – focuses on the 3D data from the BIM model (support the **legal ownership boundaries**, **cadastral attributes**, and **3D visualization** of the Strata XML objects).

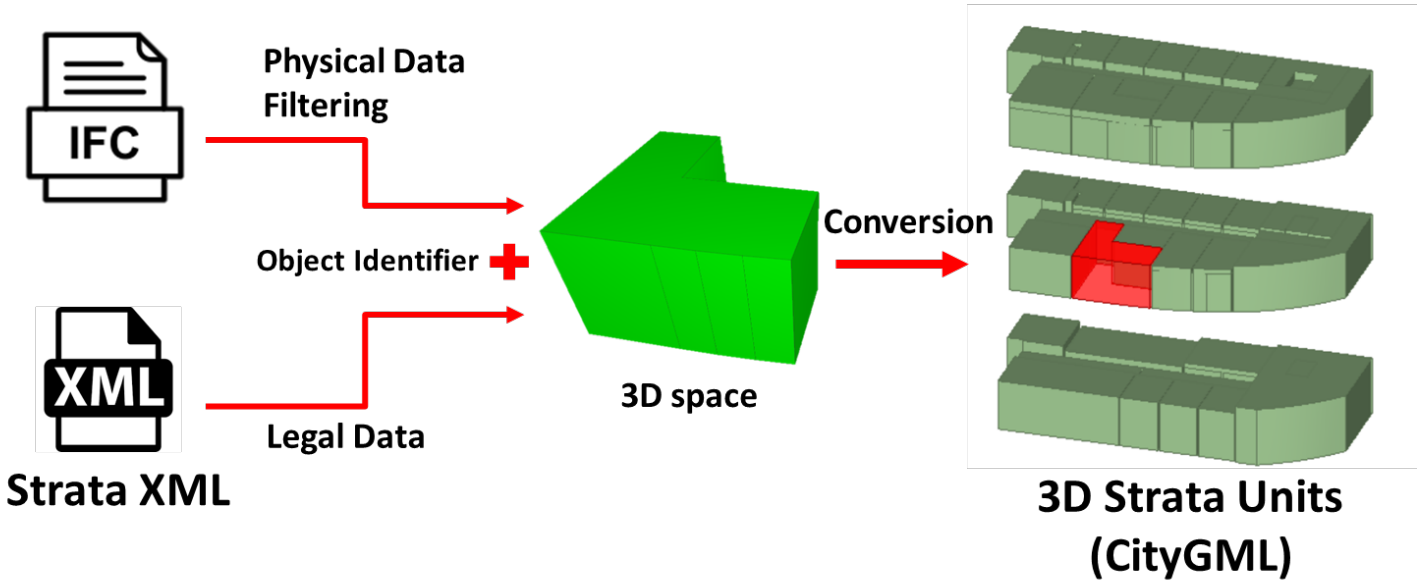
# The previous works

| Country | Author(s) | Deliverables |
|---|---|---|
| **Australia** | Rajabifard et al., 2019; Atazadeh et al. 2019; Atazadeh et al. 2021; Atazadeh et al. 2018 | Developed an approach enriching BIM with cadastral information, where the IFC standard is broadened with various data requirements in urban cadastre such as boundaries, attributes, administrative plan information, legal ownership space etc.<br><br>Extending IFC data by harnessing LADM data elements to support the integration of legal and physical view. Create a relationship between BIM and LADM environment which would subsequently provide a better understanding of legal spaces |
| **Netherlands** | Storter et al., 2017; Oldfield et al., 2016. | BIM is considered as a primary source of 3D digital data 3D cadastre. Enactment of BIM for 3D cadastre based on a new workflow to facilitate cadastral registration using 3D PDF. |
| **China** | Ying et al., 2019 | The study focused on the developed easement modelling approach (EMA) by utilising BIM environment. It's determined that IFC standard is an effective data model for easement specialization. BIM environment enhances the representation of 3D cadastral objects.<br><br>Developed and analysed a conceptual model based on IFC standard. Finally, it was presented that the integration of legal and spatial information in BIM was named as a successful approach for handling and functioning buildings as well as planning and developing a compressed city in China. |
| **Sweden** | Andree et al., 2018; El-Makawy et al., 2014; Sun et al., 2019 | A smart built environment was created to serve as a strategic program to identify potential methods for effective utilization of BIM data during the building development process including planning, building permit, property formation and management.<br><br>The following were taken into consideration, legal problem, financial aspect, and technical matters.<br>More recently research has proposed a generic framework for 3D cadastre by integrating IFC and CityGML data the integrated model was later link to LADM data in order to provide a comprehensive legal and spatial view of indoor and outdoor ownership spaces in a complex built environment. |

# The Methodology

- The methodology involves three phases:
  - BIM data filtering
  - 3D objects extraction and conversion
  - Integration with Strata XML

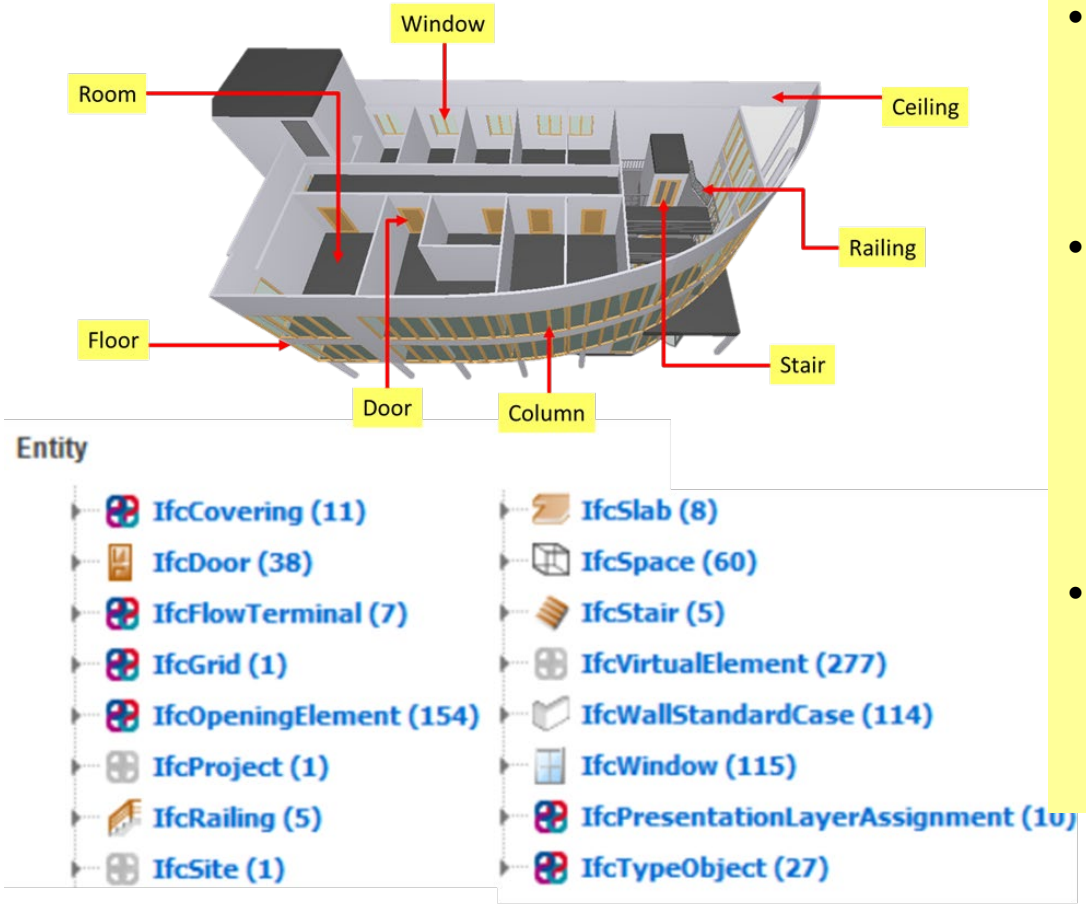
The use of geometric data from IFC model is to build a 3D cadastre in the context of buildings (by conversion into CityGML format).




The overall data integration from IFC model and Strata XML into 3D Strata Unit.

# The Methodology (cont.)

## BIM data filtering



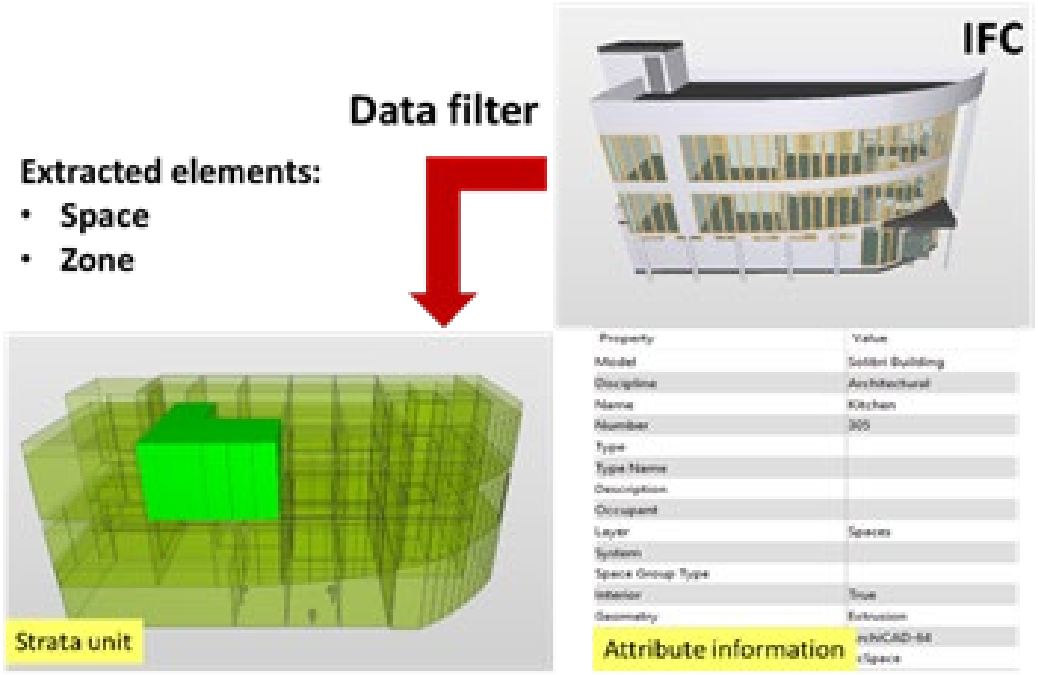

- Identifying the important elements (e.g., **IfcSpace** and **IfcZone**) in the IFC model.
- The physical BIM data which is IfcSpace filtered to create 3D cadastral **objects** based on the legal data contain in the Strata XML.
- The space data can be used to provide legal boundaries in 3D which is **limited** in the current 2D strata and subdivision plans.

The IFC model for 3D cadastral purpose.

# The Methodology (cont.)

## 3D objects extraction and conversion

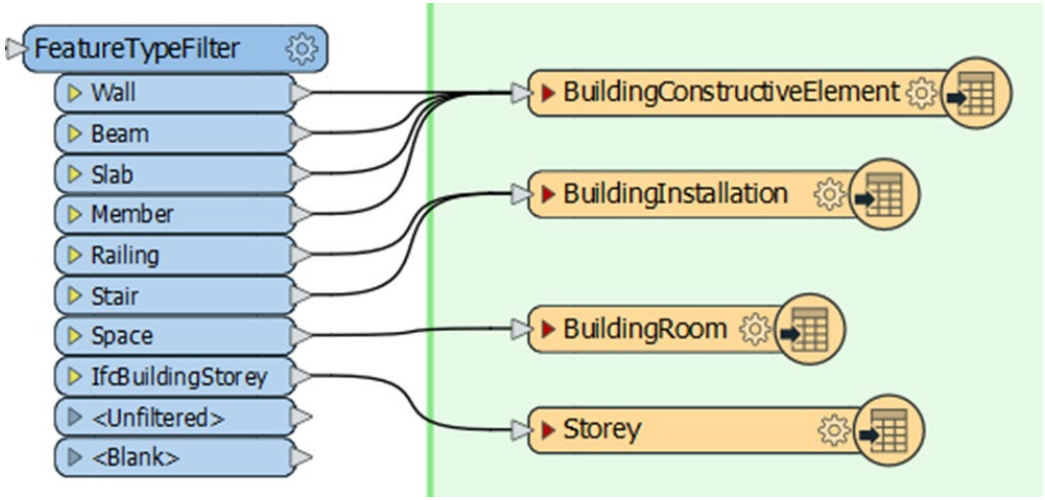
- The 3D physical object extraction phase involves the extraction of geometries and semantic data from the IFC model.
- The IfcSpace and IfcZone entities are **filtered to match** with the strata objects in the Strata XML file.




The extraction of 3D space from the IFC model.

# The Methodology (cont.)

## 3D objects extraction and conversion




Data extraction and conversion from IFC to CityGML through FME.

- The process of physical data extraction, mapping, and conversion are conducted via data integration platform (FME).
- The **role of CityGML** is for the 3D physical data storage due to limitation of Strata XML.
- Legal data from the Strata XML *(*e.g., *Building, Parcel Unit, Accessory Unit, Land Parcel, Common Property Unit, Limited Common Property Unit, etc.)* are transferred to CityGML and stored as attributes information.

# The Methodology (cont.)

## Coordinate transformation (Affine)

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = Ax \begin{bmatrix} Wx \\ Wy \\ Wz \end{bmatrix} + \begin{bmatrix} x \\ y \\ z \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

where:

| | |
|---|---|
| $(Wx, Wy, Wz)$ | : represents the direction Vector of sweeping |
| $A$ | : represents the sweeping distance. |
| $(x', y', z')$ | : represents the LCS. |
| $(x, y, z)$ | : represents the GCS. |

- Two categories of information are significant:
  - *IfcLocalPlacement*
  - *IfcProductDefinitionShape*

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\varphi x & sin\varphi x \\ 0 & -sin\varphi x & cos\varphi x \end{bmatrix} \begin{bmatrix} cos\varphi y & 0 & -sin\varphi y \\ 0 & 1 & 0 \\ sin\varphi y & 0 & cos\varphi y \end{bmatrix} \begin{bmatrix} cos\varphi z & sin\varphi z & 0 \\ -sin\varphi z & cos\varphi z & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} + \begin{bmatrix} \Delta x \\ \Delta y \\ \Delta z \end{bmatrix} \quad \text{----------(2)}$$

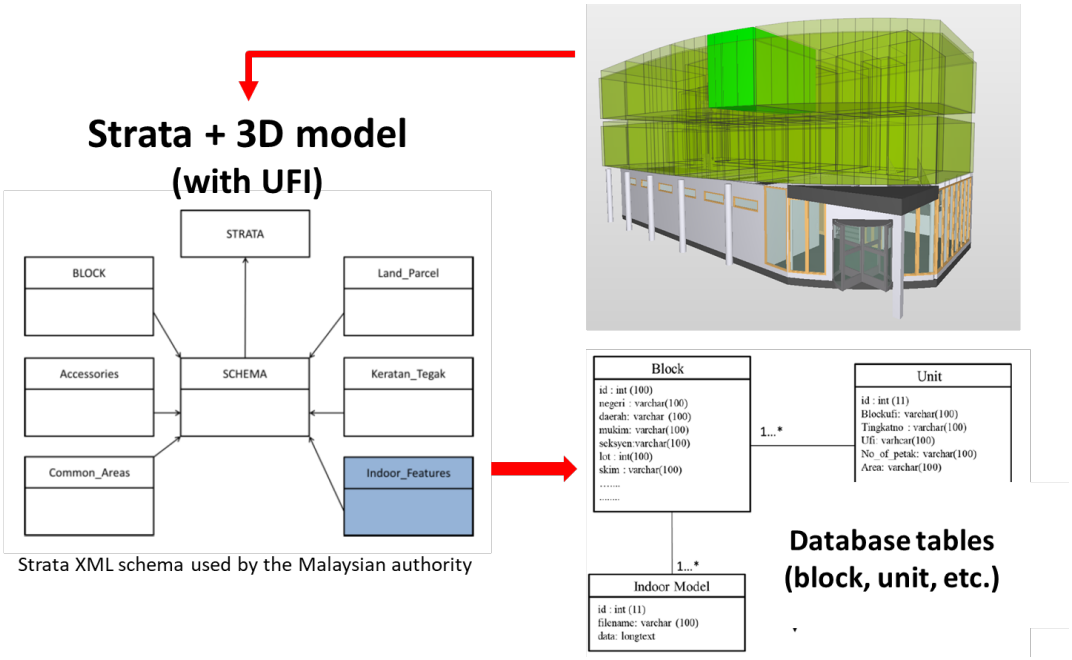
where:

| | |
|---|---|
| (x,y,z) | : represents the GCS. |
| (x',y',z') | : represents the LCS. |
| (Δx,Δy,Δz) | : represents translation (change) from LCS to GCS from the origin. |
| (φx,φy,φz) | : respectively represents the angle of rotation with respect to (x-axis, y- axis and z-axis) |

The computation and transformation of the LCS to GCS using a transformation matrix equation.

# The Methodology (cont.)

## Integration with Strata XML

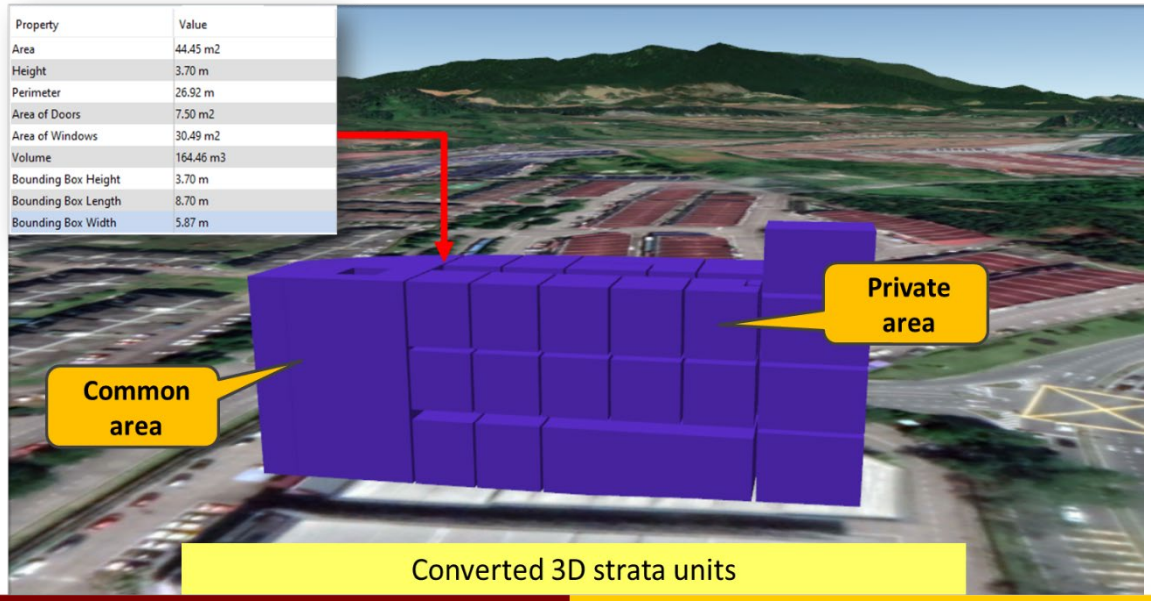



Process of linking the extracted 3D physical geometry with the strata objects (legal data) via the utilization of UFI.

- The integration phase involves the process of **identifying** and **linking** the extracted 3D physical objects with the legal data from the **strata objects (Strata XML).**
- **Unique Feature Identifier** (UFI) is used to represent multi-level buildings such as Apartments and commercial buildings.
- The linked data (Strata XML and 3D model) is output into the destination format (i.e., CityGML) **enriched with the physical and legal information**.

# Discussion

- The method for converting BIM data to CityGML for 3D cadastre purposes to support:
  - the legal ownership boundaries
  - cadastral attributes
  - 3D visualization of the strata units.




Converted 3D strata units

# Conclusion

- **The conversion** able to produce strata data into CityGML based format building with several floors and strata units.
- Furthermore, especially the **ownerships** of a strata units can be identified such as blocks, buildings, accessories, land parcels and common area.
- This paper strongly believes that the work obviously requires more attention in the aspect of physical geometry data filtering, and semantic data mapping.

# Conclusion

- Currently, the work focuses on the **modelling** and the **Rights** (ownerships) aspects as part of addressing strata based cadastre in Malaysia.

- Important aspects of 3D cadastral such as RRRs will be investigated further in the near future.

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# Thank You