Interlinking Building Geometry with Existing and Developing Standards

Kris McGlinn, Peter Bonsma, Anna Wagner, Pieter Pauwels, Lorraine McNerney, Declan O'Sullivan

2017-11-13 @ LDAC 2017

The ADAPT Centre is funded under the SFI Research Centres Programme (Grant 13/RC/2106) and is co-funded under the European Regional Development Fund.

Introduction

- Geometric data is required to support many use cases related to buildings
  - retrofitting, energy simulation, architecture, automation, navigation, etc.

- Managing geometric data across a building lifecycle (BLC) may involve multiple geometric representations
  - requiring transformation between formats when passed between different CAD tools.

- Building Information Modelling (BIM) sets out to address interoperability in building models and BIM.
  - Standards like the Industry Foundation Classes (IFC) aim to provide a reference model

Introduction

- IFC provides not only capabilities for storing multiple geometric representations
  - Can potentially describe parametric data, but the results are highly dependent on the way the data is interpreted by the tool.

- IFC has not yet been aligned with widely used web technologies
  - nor modern mathematical descriptions of geometry or graphics libraries (DirectX, OpenGL, VULCAN).

- There are also use cases which may not require full 3D models of geometry
  - require less complex 2D representations, or even just a geolocation point, and IFC may be over engineered for these use cases

Overview

- This presentation explores some of the considerations which must be addressed for a building geometry model:
  - What are some of the existing and developing geometry models to support building geometry related uses cases?
  - How to support interlinking with other relevant data models?

- We also examined developments towards a more complete geometry reference model called GEOM
  - addresses a number of the shortfalls of IFC and ontologies such as OntoBREP

- As well as an alternative geometric representations, called GeoSPARQL, which relies on a Well-Known Text (WKT) mechanism for representing 2D polygon-based geospatial data

Representing Building Geometry

- Visual representation models such as Collada and X3D are based on triangles, lines and points
  - lack the richness of geometrical concepts available within IFC.
  - such as basic CSG (Constructive Solid Geometry) on basic shapes like Sphere, Cylinder, Box, Boundary representations and faceted representations, as well as detailed parametric representations like C, I, L, T, U, Z profiles

- IFC is driven by the need to support data exchange across the entire building life cycle
  - must support relations, classification, properties, as well as geometric data
  - e.g. a wall with a window is stored within IFC as a solid wall with a separately defined opening
    - enables receiving applications to adjust, move or remove the window.

- Makes a full import of IFC geometry a time consuming and error-prone

- Also, how to link IFC to other standards?

Geometry, Linked Data and Building Data on the Web

- ifcOWL, and newer developments such as BOT, are opening up the capability to interlink and publish linked building data on the web.
  - with existing ontologies, including SOSA/SSN, GeoSPARQL, SAREF, DogOnt
- Question remains: is Linked Data appropriate and necessary for representing geometry?
- OntoBREP sets out to describe geometric entities in a semantically meaningful way
  - e.g. a circle is represented by a coordinate frame and a radius (instead of a set of polygons)

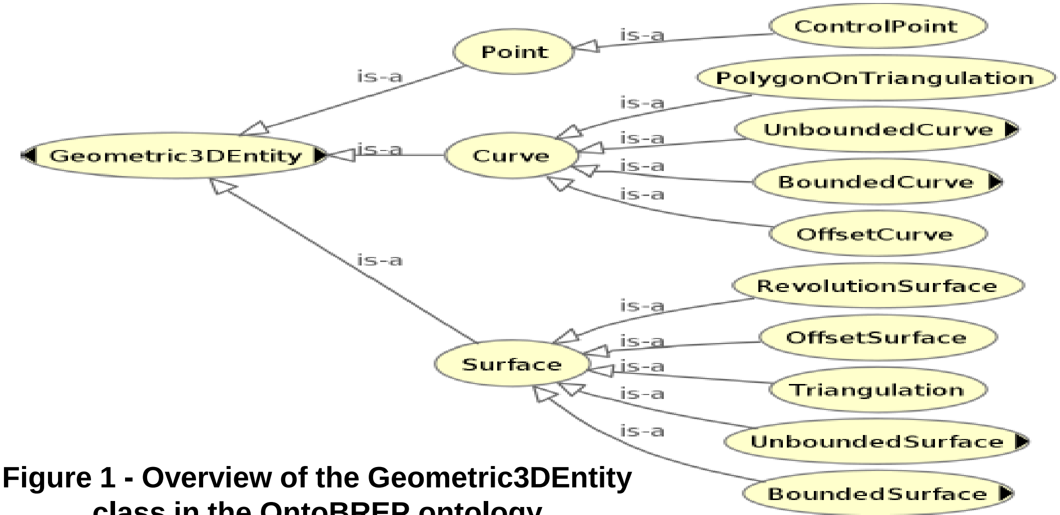


Figure 1 - Overview of the Geometric3DEntity class in the OntoBREP ontology

GEOM Ontology

- OntoBREP does not provide support for complex geometric operations such as Boolean Operations in 2D and 3D, Clipping etc.
- The GEOM ontology +/- 100 Classes (Geometrical Concepts), incl.:
  - Points, Curves, Surfaces, Solids
  - Boolean Operations
  - Boundary Representations
  - NURBS, B-Splines, Bezier Curves & Surfaces
  - Repetition
  - Cube, Sphere, Cylinder, Arc, etc.
  - Colors, Textures
  - Lights

GEOM Supporting Software

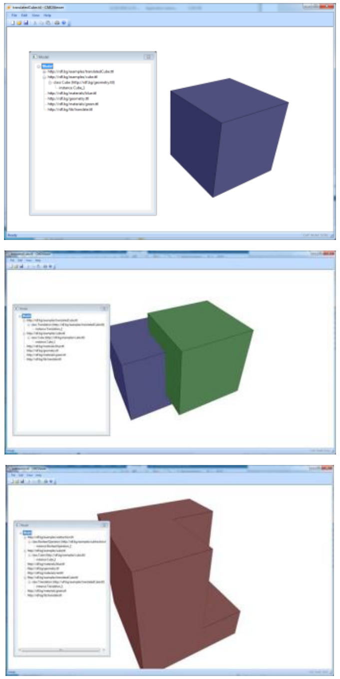
- Available Software

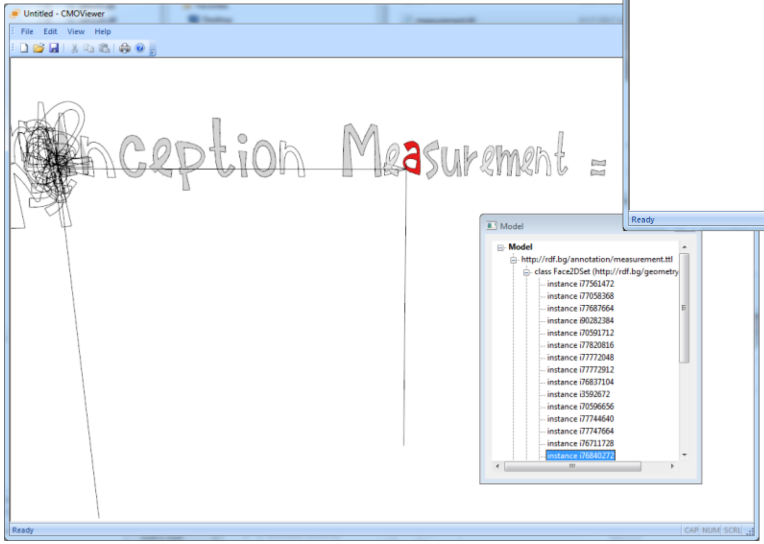
- Population of Content
  - IFC2x3 TC1 / IFC4 ADD2 / IFC4x1 FINAL to GEOM converter available (based on IFC Engine library)
  - Collada to GEOM converter available
  - DWG to GEOM converter in development (based on Theigha library)
  - Annotation / 3D Text generator available (based on Freetype and Geometry Kernel libraries)

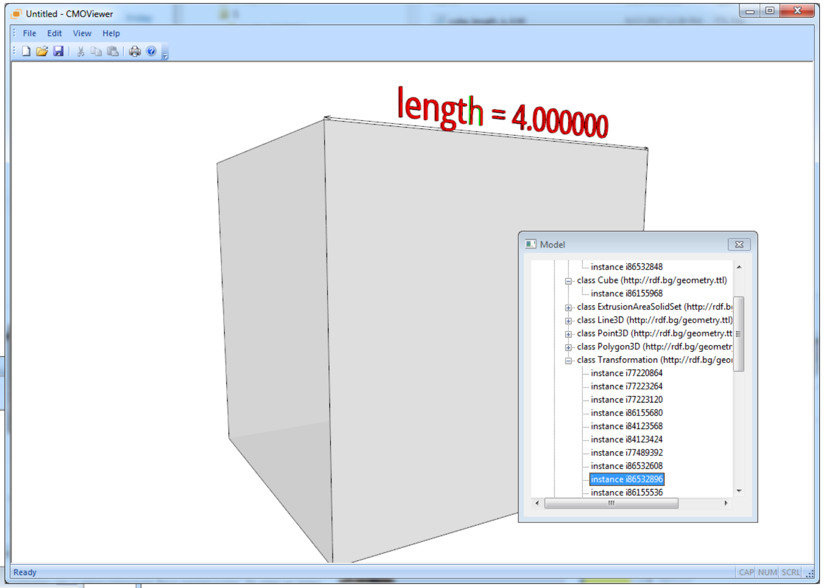
- Use of Content
  - GEOM Viewer available (based on CMO library)
  - GEOM to JSON converter available incl. HTML5 / WebGL front-end (based on CMO library)

GEOM Examples

- Boolean Operations example
- Annotation examples
- Automated measurement



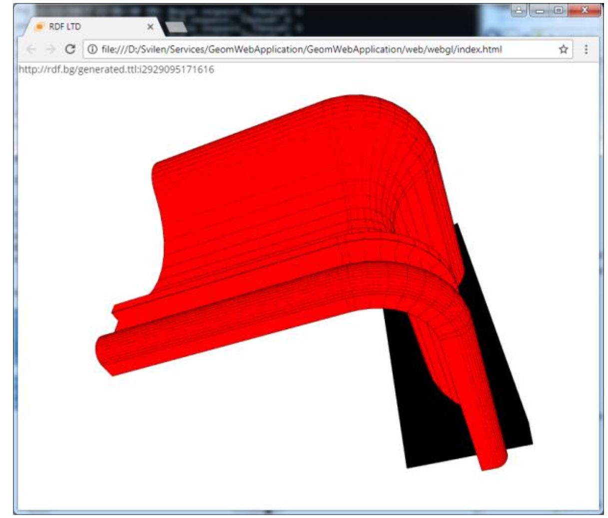


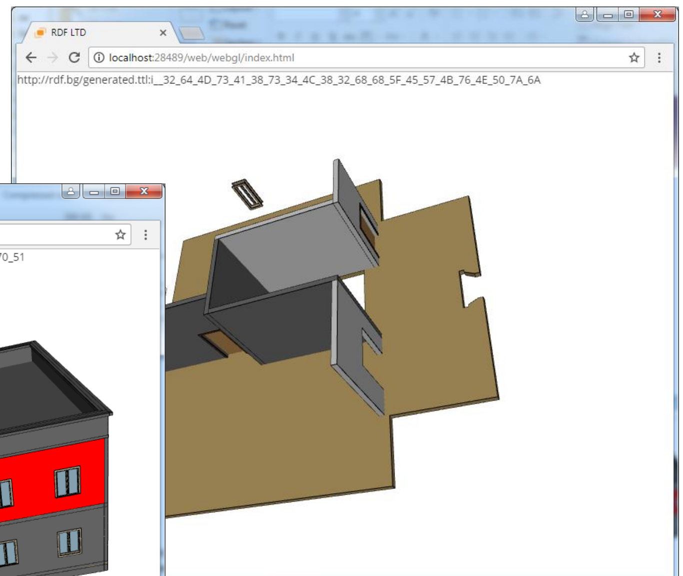


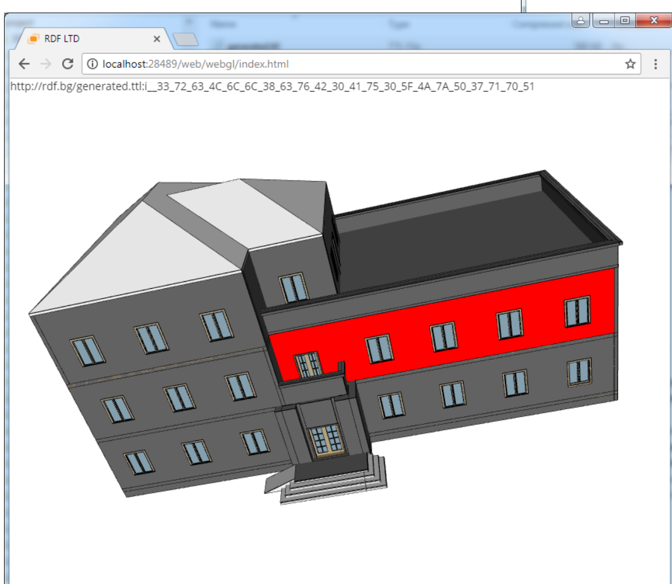
Ordnance Survey Ireland

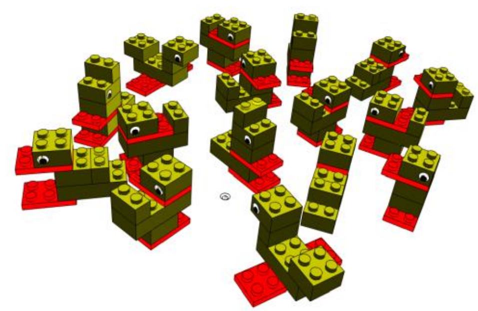
GEOM Examples

- Object visualization
- Interconnected models from different sources
- Select any subset









OSi Ordnance Survey Ireland

ADAPT

Geometry Related Use Case 1: Linking Geometric and Semantic Data

- Research project: “Holistic Integration of Energy Active Facade Components in Building Processes” (SolConPro)
  - TU Darmstadt
  - Ed. Züblin AG
  - Fraunhofer ISE

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

- Aims to integrate complex, multi-functional façade elements into building and planning processes
  - Digital description of products
  - Distributed databases for manufacturers
  - Central management of queries and databases

Geometry Related Use Case 1: Linking Geometric and Semantic Data

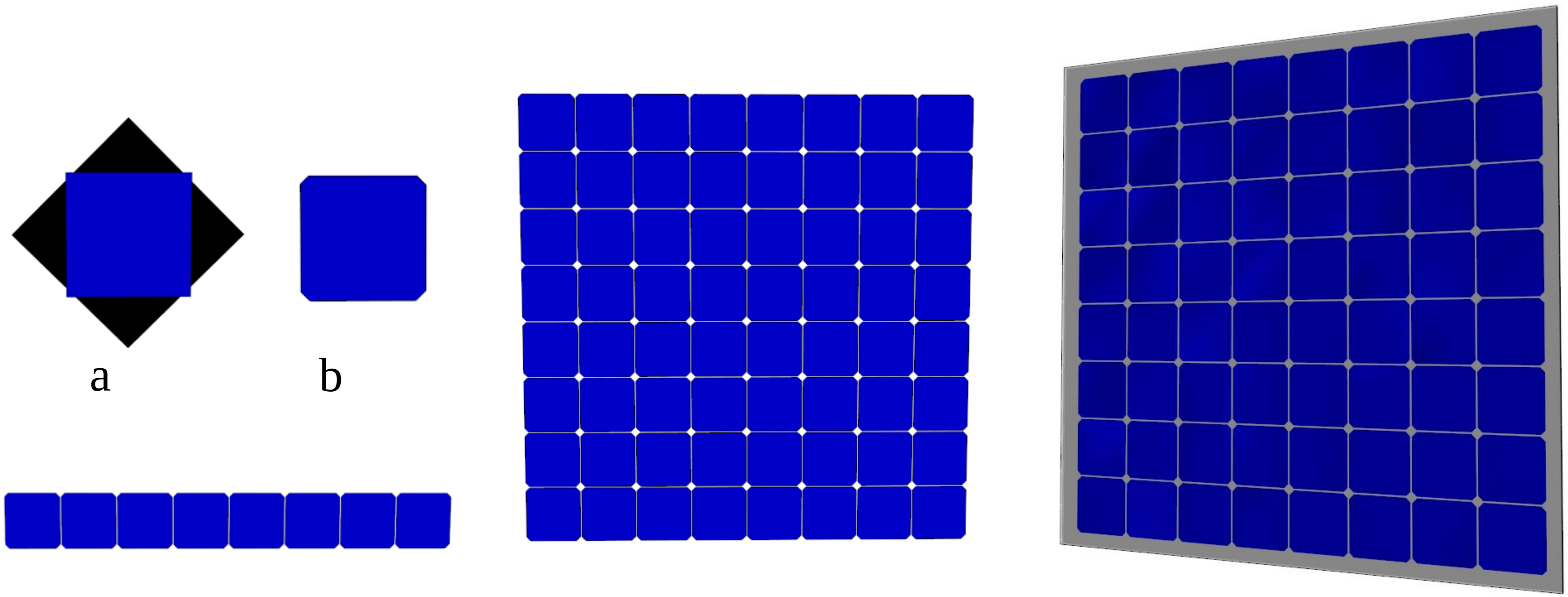
- Requirements to the data schema
  - Multi-inheritance
  - Parametric Geometry
  - Coherences between geometric and semantic information

→ Combination of different ontologies

- Semantic
- Geometry
- Parametric
- Domain

Geometry Related Use Case 1: Linking Geometric and Semantic Data

- Example: Building Integrated PV (BIPV) Module



a b

c d e

Geometry Related Use Case 2: Linking BIM with Geospatial Data (Irish Context)

- In Ireland, the Ordnance Survey Ireland (OSi, Ireland's national mapping agency) have developed a spatial data storage model known as Prime2,
  - object-oriented model implemented using the Oracle Spatial and Graph database technology.
  - over 45,000,000 spatial objects, 3,532,263 building objects.
- Buildings include a geodetic coordinate as well as a 2D polygon representing the footprint of the building,
  - along with buildings form (e.g. Terraced Building) and function (e.g. Residence) and also its life cycle stage (e.g. In use).
- The challenge is how to manage mappings between OSi geospatial data, standards such as IFC and BOT, and other open data sets (e.g. DBpedia).

Geometry Related Use Case 2: Linking BIM with Geospatial Data (Irish Context)

www.adaptcentre.ie

- To support this interlinking, the OSi authoritative geospatial boundary data has been converted into GeoSPARQL
  - made available through GeoHive (data.geohive.ie).

- GeoSPARQL is an Open Geospatial Consortium (OGC) standard which defines a vocabulary for representing geospatial data on the Semantic Web
  - also specifies an extension to the SPARQL query language for processing geospatial data.
- The OSi building ontology extends the OSi ontology to support capturing data about OSi buildings.
  - a building is a subclass of GeoSPARQLs Feature
    - thus supporting interlinking between ontologies based on the placement of the building, i.e. those buildings with the same geolocation can be considered the same.

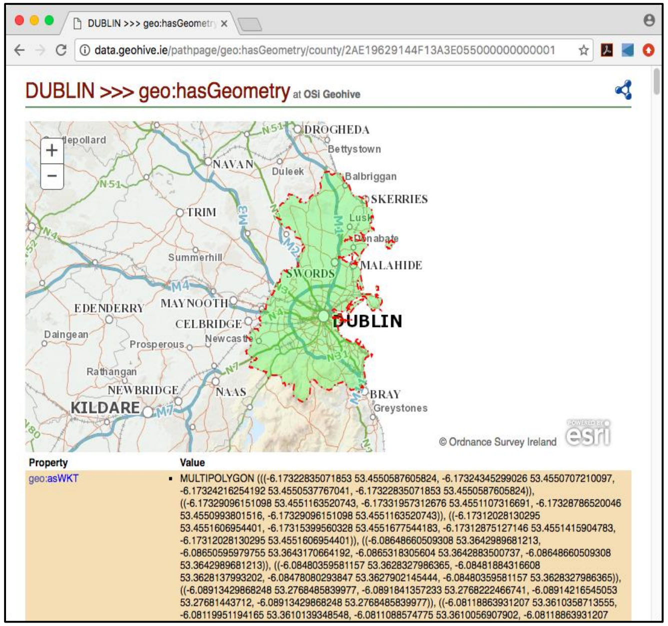


Fig. Plotting OSi's Polygon on OSi's base maps, part of the HTML served to users.

Geometry Related Use Case 2:
Linking BIM with Geospatial Data (Irish Context)

- The OSi data has been uplifted into RDF and made available as Linked Data
  - linking of DBpedia through geolocation demonstrated
- Initial mappings have been explored with ifcOWL
  - by creating a new relationship geo:hasGeometry for IfcSite to represent the longitude and latitude as a WKT point

Geometry Related Use Case 2:
Linking BIM with Geospatial Data (Irish Context)

Tabular Data → **Data Uplift**: Identify Alignments; Generate RDF → Data in RDF (OSi Building Data)

IFC STEP → **Data Conversion**: Ifc->owl; Ifcowl- > ifcowl_geo → IFC in RDF with added Geolocation

DBPedia RDF → **Data Conversion**: SPARQL CONSTRUCT → DBpedia with added Geolocation

SPARQL

<u>Integrated Building Information</u>

OSi-Geometry: Footprint
OSi-Form: Building General
OSi-Function: Residence
DBpedia: Architect
IFC: Structure (walls, windows, materials, etc.), Control Systems, Electrical Systems, etc.

RDF Representations with added geolocation to support geospatial functions

Ordnance Survey Ireland

Geometry Related Use Case 2:
Linking BIM with Geospatial Data (Irish Context)

- The challenge remains, how to represent 3D geometries, as these are not currently supported by GeoSPARQL?
- Three possible solutions:
  1. extend the OSi ontology to satisfy multiple geometric representations
  2. extend GeoSPARQL to hangle 3D geometries
  3. make use of BOT as a reference ontology which maintains relations to these other geometric representations, thus requiring OSi to maintain only one relation, rather than multiple.

Geometry Related Use Case 2: Linking BIM with Geospatial Data (Irish Context)

- Link BOT to GeoSPARQL for representing building footprint, geolocation -> bot:Building as subclass of Feature

- Link BOT to GEOM at Element level, providing support for 3D representations.
  - GEOM can potentially also be used to generate WKT representations based on slices of the 3D object.

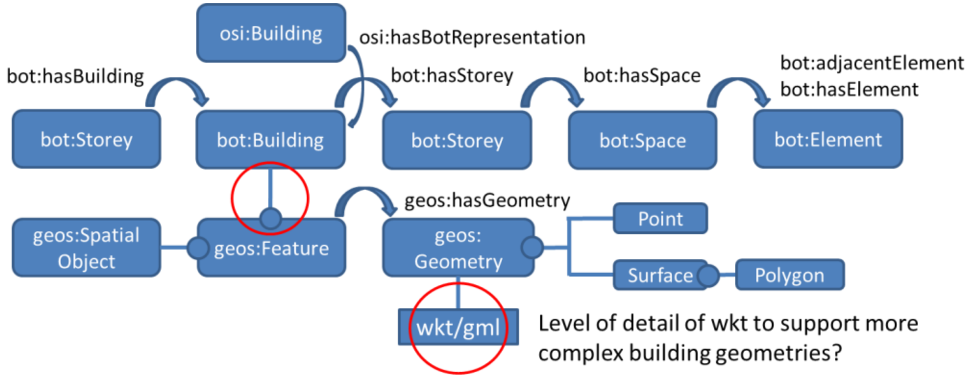


Fig. Mapping BOT to GeoSPARQL

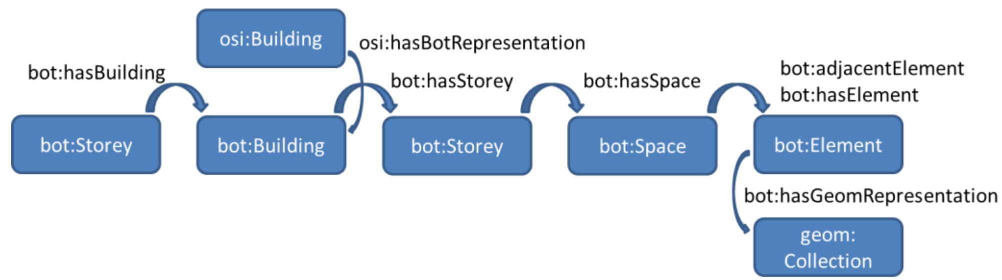


Fig. Mapping BOT to GEOM

Conclusions

- Here we presented the GEOM ontology as a potential reference ontology to address some of the shortcomings of existing approaches.
  - GEOM provides a rich taxonomy of concepts for representing geometric entities mathematically, some of which were presented here.
  - GEOM already supports the geometric representations handled by the semantically rich IFC schema and in UC1 the use of Boolean operations is demonstrated.

- Alternatively, other geometry models may be sufficient to support geometry related use cases, for example, those which require geospatial functions and interlinking based on geolocation can use GeoSPARQL.
  - In UC2 it is shown how geospatial geometries can be supported, such as GeoSPARQL, to support the conversion of IFC into geospatial data

- Alternatively, linking between BOT and multiple geometry models can also provide a method for managing several geometric representations.

Future Work

- Parametrically connecting GEOM to semantic ontologies, such as BOT

- Explore extension of GEOM to support conversion to WKT geometries.
  - Slicing 3D GEOM geometries and converting to geospatial coordinate systems

Thank you for your attention!

Questions?