Recent changes in the Building Topology Ontology

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Abstract. The Building Topology Ontology (BOT) was in early 2017 suggested to the W3C community group for Linked Building Data as a simple ontology covering the core concepts of a building. Since it was first announced it has been extended to cover a building site, elements hosted by other elements, zones as a super-class of spaces, storeys, buildings and sites, interfaces between adjacent zones/elements, a transitive property to infer implicit relationships between building zone siblings among other refinements. In this paper, we describe in detail the changes and the reasons for implementing them.

1 Background

Several research projects have dealt with transforming building data to open web standards for integration with linked open data such as product catalogues, Geographic Information Systems (GIS), unit conversion, material properties etc. The most general schema for describing buildings, Industry Foundation Classes (IFC) [1], has over several attempts been translated to Web Ontology Language (OWL), latest by Pauwels and Terkaj (2016) with an ontology called *ifcOWL* [2]. However, since IFC was not initially designed for being used on the web, the structure, size and complexity of *ifcOWL* makes it hard to use and extend in practice. For that particular reason (Pauwels and Roxin, 2016) suggested a post-processing of ifcOWL called *SimpleBIM*, which omitted all geometry and intermediate relation instances between objects [3].

The Building Topology Ontology (BOT)[5] is a minimal ontology for defining relationships between the sub-components of a building [4]. It was suggested as an extensible baseline for use along with more domain specific ontologies following general W3C principles of encouraging reuse and keeping the schema no more complex than necessary [5]. Currently, the ontology is being developed by the *World Wide Web Consortium (W3C) Linked Building Data Community Group* (W3C LBD-CG), and this paper provides an overview of its current state and recent changes.

[5] https://w3id.org/bot#

2 Initial version

The first version of the ontology presented at LC3 in July 2017 included 4 key classes and 5 object properties.

In Fig. 1 above the horizontal dashed line, the classes and properties of the ontology are illustrated. A building basically consists of the building itself and a number of storeys, rooms and building elements potentially related to each other. Object properties between the classes all have domains and ranges specified, meaning that classes will be automatically inferred by a reasoning engine, given that typed links between the class instances are available. The dataset, illustrated in Fig. 1 using the horizontal dashed line, shows the inferred classes. It is for instance inferred that since <buildingA> has a bot:hasStorey link to <storey01>, then <buildingA> is an instance of bot:Building and <storey01> is an instance of bot:Storey. This particular example is inferred from the domain and range of bot:hasStorey.

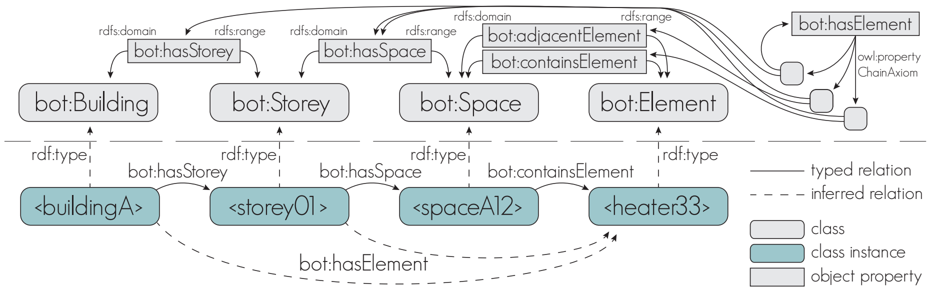

Fig. 1. BOT in the initial version. Typed links between class instances infer classes and the bot:hasElement property. Inferred relationships are illustrated with dashed arrows.

A bot:hasElement link can be inferred between some instance ?x and an element ?e: (a) whenever ?x is linked by bot:hasSpace to some ?z, itself linked to e by bot:containsElement or bot:adjacentElement, and (b) whenever ?x is linked by bot:hasStorey to some ?z, itself linked to ?e by bot:hasElement. This inference capability is obtained using OWL property chain axiom.

3 Recent development

In the W3C LBD-CG, We gathered use cases and requirements for the BOT ontology and identified new competency questions that should be answered by a new version of the ontology. Fig. 2 illustrates the updated version of BOT. The following subsections list the new competency questions and how they have been taken into account in the new version of the BOT ontology.

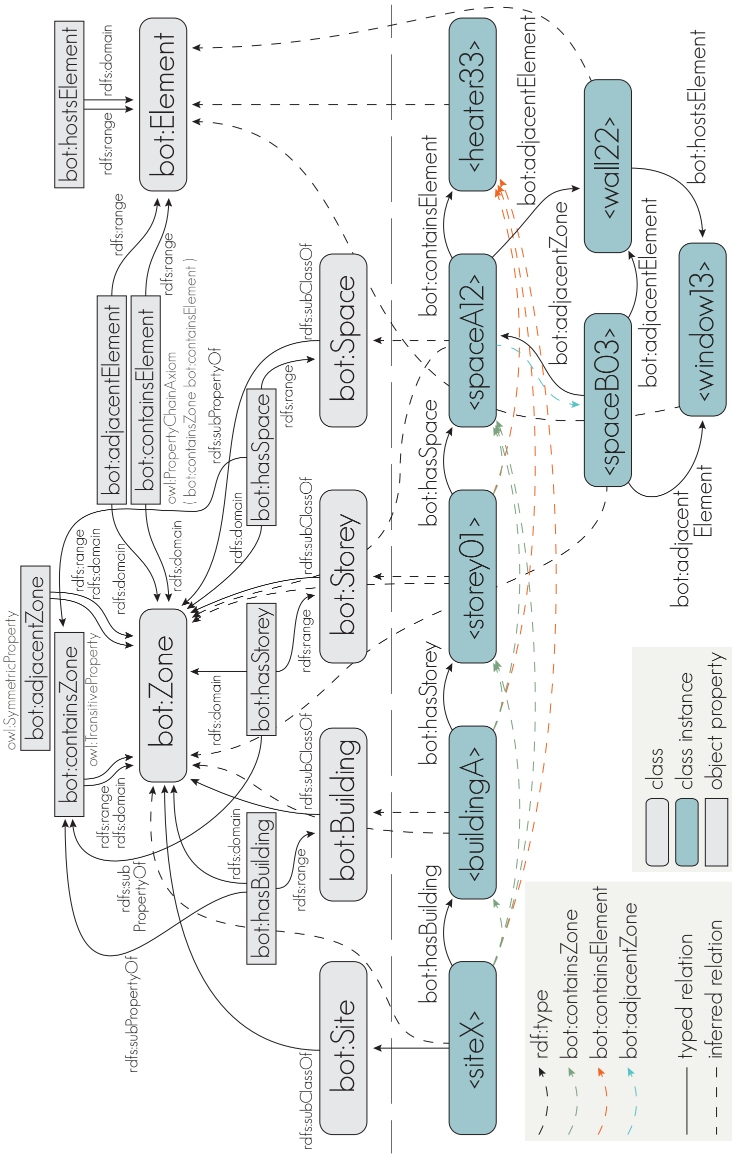

Fig. 2. BOT T- and A-Box.

3.1 Building site

New competency question: For Facilities Management (FM) purposes it is often the case that one property operator administers several buildings located at the same site. This is, for instance, the case for university campuses and hospitals. In such a case, a site and its relationship to the buildings it contains is needed.

Update on the ontology: Adding a new class `bot:Site` and an object property `bot:hasBuilding` with `rdfs:range` being a `bot:Building` to describe the relationship to the buildings contained in a site.

3.2 Domain definitions

New competency question: `bot:hasSpace`, `bot:adjacentElement` and `bot:containsElement` all had domains specified, meaning that something that has a space was necessarily inferred to be a storey. New use cases required that buildings also needed to contain spaces. Also, something that contained or had adjacency to elements was necessarily inferred to be a space. New use cases required that buildings and storeys also needed to contain or have adjacency to elements.

Update on the ontology: `bot:Site`, `bot:Building`, `bot:Storey` and `bot:Space` are all non-physical objects defining a spatial zone. A new class `bot:Zone` was added as a super-class of these. The domain of `bot:hasBuilding`, `bot:hasStorey` and `bot:hasSpace` was loosened to `bot:Zone`. A new common super-property of these object properties, called `bot:containsZone`, was added.

3.3 bot:hasElement

New competency question: The `bot:hasElement` property defined as an `owl:propertyChainAxiom`, stated that something that has a space which either contains an element or has an adjacency to one "has" the element. It further stated that if something has a storey that has such a space, then the storey also "has" the element. New use cases also required to loosen the semantics here, as in section 3.2.

Update on the ontology: The `bot:hasElement` property was changed to be valid in two situations: `bot:containsZone` followed by either `bot:adjacentElement` or `bot:containsElement`.

3.4 Hosted Elements

New competency question: The initial version of BOT did not allow for elements to be hosted by other elements. This relationship is necessary for describing situations where a window is for instance hosted by a wall, which is a fundamental part of a building's topology.

Update on the ontology: A new object property `bot:hostsElement` with domain and range being a `bot:Element` was added.

3.5 Zone connectivity

New competency question: When assessing architectural flow in a building, fire escape routes, etc., it is necessary to define a connection between zones.

Update on the ontology: `bot:adjacentZone` describes a relationship between two zones that share a common interface. With this super-property one can define more specific zone relationships stating wheter there is a direct (sharing a door), indirect (sharing a wall) or maybe an open connection between the zones. This property further enables the aggregation of zones; for instance to group architectural zones into a fire cell. In this regard `bot:containsZone` can further be used to subdivide an architectural zone into sub-zones. Fig. 3 illustrates these new concepts.

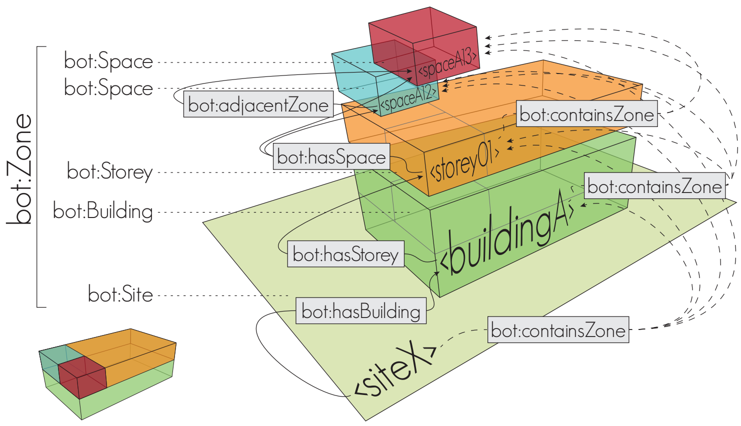

Fig. 3. BOT zone connectivity.

3.6 Interfaces

New competency question: For heat loss calculations, thermal simulations and other applications it is necessary to qualify the connection between elements or zones. A wall can cover several zones, but when defining the heat transfer area, only the shared surface between the zone and the element is of interest. BOT did not cover this representational need.

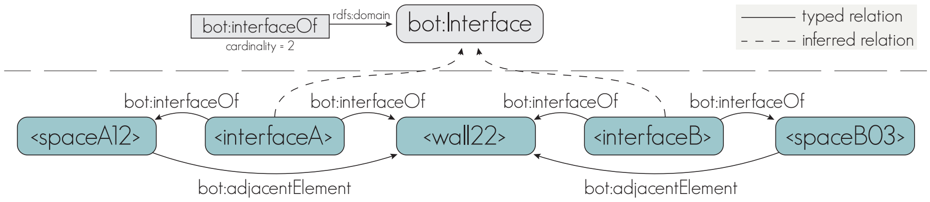

Fig. 4. BOT interfaces T- and A-Box.

Update on the ontology: A new class `bot:Interface` qualifies zone and element connectivity, i.e. the surface where two building elements, two zones or a building element and a zone meet. The interface is assigned to exactly two instances of either type `bot:Element` or `bot:Zone` by the object property `bot:interfaceOf`. Fig. 5 and 4 illustrate how to qualify the two separate adjacencies between <`spaceA12`> / <`wall22`> and between <`spaceB03`> / <`wall22`>. The same approach can for example be used to qualify a relationship between a pipe segment and the individual zones and wall elements it shares common interfaces with. These concepts are adaptations of the *Systems and Connections* pattern as defined in [6].

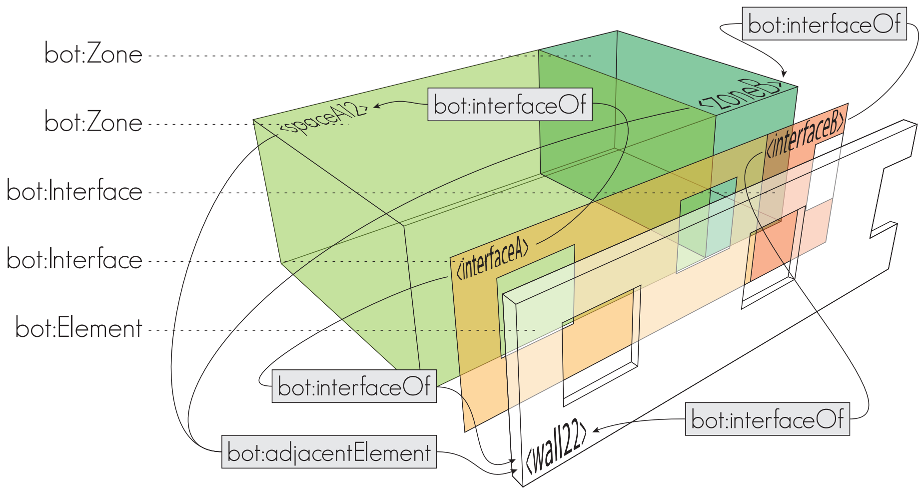

Fig. 5. BOT interfaces used to quantify each relationship between the zones and a wall which they have a shared adjacency to.

4 Conclusions and Future Work

This work provides an overview on the latest revisions and updates made to the initial version of the Building Topology Ontology (BOT) [4]. The supplementary classes and object properties enable the BOT ontology to answer six new competency questions: (1) how to define a building site, (2 & 3) how to enable transitivity when querying for either a zone of a zone or the elements that a zone "has", (4) how to have elements hosting other elements, (5) how to define adjacencies between zones (6) how to define interfaces between zone/zone, element/element or zone/element .

General development of use cases where BOT is used along with other domain ontologies is on the agenda for the W3C LBD-CG. Individual ontologies for geometry, products and properties are being developed in domain working groups, and these are all being aligned with BOT.

Implementations with existing BIM tools for extending with linked open data on the web is also on the agenda.

Acknowledgements

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