iLOC – Building In-door Navigation Services using Linked Data

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ABSTRACT

Currently, there are hardly any indoor navigation services utilizing Linked Data, and there is also a lack of available vocabularies or ontologies for the description of building plans. This paper presents the iLOC ontology as a generic approach for in-house wayfinding and location description. The suggested Linked Data model enables the integration of various datasets related to buildings and can be used in museums, shopping malls, hospitals, campuses, stadiums, airports, etc. Possible use cases include the description of nearby places, planning routes or finding places with given features, even in emergency situations. iLOC supports three levels of details for a building plan, with increasing complexity and capabilities. Furthermore, routes can be calculated with flexible constraints for users' goals and abilities. The ontology is demonstrated with a smartphone application helping university students to find their lectures.

CCS Concepts

H.4 [**Information Systems Applications**]: World Wide Web – *Web data*;
H.4.5 [**Description languages**]: Semantic web description languages

Keywords

Indoor Navigation; SPARQL; Ontology; Linked Open Data

1. INTRODUCTION

Outdoor navigation is widely available nowadays and helps people to find a place while driving or walking or using public transport. This type of navigation is usually based on coordinates provided by GPS. Inside buildings, however, a navigation system has to cope with more complex routes and with the lack of GPS signals. The current solutions usually require special and expensive hardware for indoor positioning. Thus, opposed to the outdoor scenario, there is no single, accepted basic methodology for navigation. The paper presents a technologically inexpensive and simple indoor navigation solution that can be adopted by large buildings even with low budget (such as universities or medical institutes). For this, we would like to exploit the possibilities of Linked Data and SPARQL to provide location and routing information. The typical use case is supporting students at a university in finding their next lecture, guiding patients to their destination within a hospital, supporting shopping in a mall or navigating to a gate at an airport.

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The rest of the paper is organized as the following: section 2 introduces the related work, in section 3 the ontology specification is described, Section 4 introduces the different navigation methods the ontology supports. In section 5 some modeling best practice and the ontology evaluation is discussed and finally, we conclude in section 6.

2. RELATED WORK

Worboys [1] provides a thorough overview of the state of the art, and defines a top level taxonomy to classify indoor models into semantic and spatial categories. Semantic indoor space models represent entity types, their properties and relationships. Topological models are concerned with the connectivity within a space. Geometrical models add quantification of distance and finally hybrid or multilayered models provide combined features of all the above.

Although OGC (Open Geospatial Consortium) provides a standard open model called IndoorGML [2] built on top of CityGML[3], these are not RDF based, and therefore their use as Linked Data is not feasible. The INSPIRE[4] directive aims to create a spatial data infrastructure in the European Union. It has a very complex data model covering transport networks and buildings as well, but building inside is not covered yet. Furthermore, there is no accepted way of using INSPIRE as Linked Data. [4] proposes an RDF vocabulary, but it was not finalized at the moment of our review. The iLocate project[5] builds on IndoorGML extending it with sound privacy and security policies.

In the following, we review the field of indoor navigation ontologies. OntoNav [5] is a semantic indoor navigation system and an ontological framework of handling routing requests. OntoNav navigates the users inside floors and buildings, but it does not provide navigation instructions within rooms. In case of a large hall with many entrances it is useful to have routes inside the hall as well. iLOC navigates on a POI network, so it can provide a more generic solution for this case.

ONALIN [6] provides routing for individuals with various needs and preferences; it takes the ADA (American Disability Act) standards, among other requirements, into consideration. Buildings are modeled as hallway networks, and feasible routes can be identified for users having specific constraints.

[4] http://inspire.ec.europa.eu

[5] http://www.i-locate.eu

These implementations rely on custom reasoning algorithms and does not provide navigation through SPARQL queries, as the primary purpose was not Linked Data support. None of the above ontologies is accessible at the moment of writing this paper, however some parts of the conceptual semantic model were reused from these earlier work inspiring the hierarchy of the *iloc:Location* class.

The classification of different parts of a building is out-of-scope for our ontology. One can find multiple Linked Data sources for such purpose (e.g. DBpedia has a list of room categories). The best source would be the OmniClass Construction Classification System (OCCS)[6], which is a classification system for the construction industry.

There are efforts, for example [7] or [8], where graph algorithms such as Dijkstra shortest path algorithm is run on semantic location data. These solutions utilize a separate spatial database for the route finding algorithms, and the data model is very complex. The content of the spatial database is not published as Linked Data. The iLOC data model is optimized for to be consumed via SPARQL.

2.1 Why a new ontology?

The main motivation of developing a new ontology was born during the implementation of a university campus map and indoor plan for buildings as Linked Data. Publishing Linked Data best practices[7] recommend to use standard vocabularies or ontologies when possible. Standard vocabularies are widely used and can be located by tools like purl[8] or lov[9]. Unfortunately, neither OntoNav, nor ONALIN can be found online.

The objective of the iLOC ontology is to support the publishing of indoor location and navigation data as Linked Open Data and to support the development of applications using the data. The major benefit of Linked Data publishing is that, path finding can be combined with additional semantic queries, even federating with 3rd party datasets. The reviewed other solutions require a separate spatial database, and therefore do not support the Linked Data best practices.

iLOC facilitates location description and links to relevant other data. It is also able to describe how two places are connected including distance or constraints (e.g. a route section is not recommended for wheelchair users). Our requirements also included the low implementation cost, as well as supporting a broad usage (the solution should not require any special device to consume and leverage the data, it should be able to operate with a generic smartphone or tablet).

3. ONTOLOGY DESCRIPTION

According to the classification of Worboys, iLOC is a hybrid ontology that supports both taxonomical and topological description. iLOC provides cost-effective building modeling and navigation based on simple SPARQL queries.

The ontology supports three levels of navigation, one based on the building hierarchy and two on POI networks within the building.

Figure 1 illustrates the topological model, which supports the path based indoor navigation within the POI network.

Classes defined in this ontology are using the *iloc* prefix, classes and properties used from other ontologies are prefixed with their

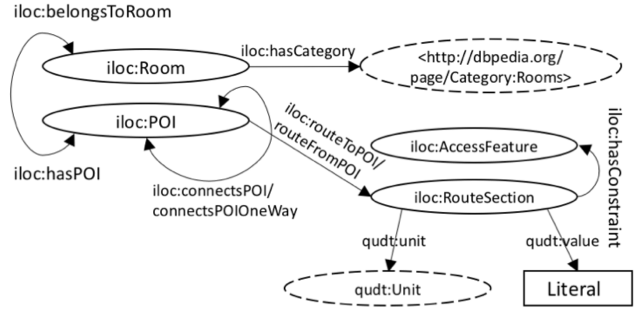

Figure 1: The topological model

own and such classes are marked with dashed line. The Point of Interests (POIs) have special role in the navigation, as these are the elements of a classical indoor route. There are several transitive properties in iLOC (e.g. isPartOf, connectsPOI). There are options for using rules to complete missing connections, for example if two POIs are connected via a RouteSection, then connectsPOI is also true for the two POIs. Such rules can minimize the number of triples which need to be explicitly defined in a building model.

The *Location* class is used to represent all the necessary entities describing indoor locations. It has three direct subclasses Building, Building Part and POI. Entities of the *Building* class have internal structure that the ontology aims to describe. *BuildingPart* provides an abstract concept to the different parts of the internal structure of a building. It has two subclasses: *Floor* and *Room*. The Room class has a subclass: *VerticalPassage*, which has two further subclasses: *Stairway* and *Elevator*. They connect Floors, which can be exploited in the simplest navigation.

The *POI* (Point of Interest) class has significant role in the navigation, as POI entities constitute the elements of a classical indoor route. The *POI* class has one subclass: *Entrance*, which is further specified as *RoomEntrance* and *BuildingEntrance*. The Entrance instances have the special meaning of defining the connections between rooms or the entry point to buildings. POIs can also be 'landmarks' inside the buildings such as statues, vending machines, receptions and favorite meeting points.

The *Route Section* class represents a traversable path between two POIs, the *Route Constraint* class represents any permission or ability required to traverse a Route Section. Such Route Constraints can be a required employee badge or the ability to climb stairs.

The *isPartOf* object property expresses hierarchical structural relationship in the ontology. The *connectsPOI* describes a direct route between two POI instances, and a consecutive sequence of such direct routes generates a possible navigation between two POIs. The *connectsPOIOneWay* is the asymmetric parent property of the connectsPOI property, to describe one-way routes between points.

The *hasPOI* property and its inverse property (*belongsToRoom)* express POI and Room relationships, a specific Room entity contains a given POI entity. Finally, the *hasAccess* property can be used to associate a specific constraint to a RouteSection instance, requiring permission or ability for one to traverse it. The *distance*, *stepNumber* and *incline* properties are important to advise about required abilities. Metrics for the distance property value can be specified by a unit with the QUDT ontology (providing generic measures and units to reuse). The walking distance and walking time would be the natural metrics here.

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[6] http://www.omniclass.org

[7] http://www.w3.org/TR/ld-bp/

[8] http://purl.org

[9] http://lov.okfn.org/dataset/lov/vocabs

The *defaultRoomOf* property provides location description for *foaf:Agent*s (Persons and Organizations). With the help of this property personal offices or reception rooms can be specified.
The ontology is licensed under the terms of Creative Commons 3.0[10] The iLOC ontology is self-documenting. Based on the request MIME type it can be downloaded in different formats including the human consumable HTML output, which is automatically generated from the following properties: *rdfs:label, rdfs:comment, rdfs:domain, rdfs:range*.

3.1 Integration with other ontologies

The root level class (*iloc:Location*) is a subclass of the geo:SpatialThing class reusing the W3C Basic Geo Vocabulary[11], so indoor and outdoor spaces can be linked.
The vCard Ontology[12] is used to describe addresses of buildings. The Quantities, Units, Dimensions and Data Types (QUDT) ontology [10] provides properties for quantifying the route sections (distance, walking time, etc.). The QUDT ontology also defines a large set of metric unit definitions for reuse.
The LinkedGeoData ontology provides a long list of POI subclasses; although most of them only apply to outdoor use cases, few of them are applicable indoor too: VendingMachine, WasteBin, etc.
The general purpose Room and POI classes can be further specified by subclasses or using the *iloc:hasCategory* property, which can point to room and POI categories defined in DBpedia or to other custom categories. The room categories can be used as filters to list specific type of rooms. Similar extension point is the *iloc:AccessFeature* class, which refers to restricted areas, requiring permission to enter, or specifies abilities required to traverse a route section. iLOC defines some basic instances of this class by default, which can be used to model accessibility for wheelchair users.
It can be useful to add exact geolocation data to POIs using a geospatial ontology such as the W3C Geospatial Vocabulary[15].

3.2 Implementation best practices

Larger indoor spaces should be divided up to smaller areas, where one can see all the potential next POIs. Rooms having multiple connections to nearby rooms (e.g. hallways) should have a central POI acting as a hub, which will provide the connections to the surrounding rooms. Entrances to Vertical Passages are good POI-hub candidates. Staircases connect different floors, but sometimes large auditoriums also have doors to different floors. In this sense the floor level of a room can be ambiguous.

4. INDOOR NAVIGATION METHODS

The navigation builds on the top of the structural description, introducing special points in the space: Point of Interest (POI). One POI instance is connected to one or multiple other POI by the *iloc:connectsPOI* property. The route is a chain of POIs within the POI network. As rooms can be the target of a navigation task, it is important to relate them to the POI network. The *iloc:belongsToRoom* and *iloc:hasPOI* properties are connecting the rooms to the POI network by the nearby or including POIs. The second approach is more aligned to the instructions one would expect asking someone familiar with the building: *„Enter the main hall. Pass the coffee machine. Go to the elevator. Go to the 2nd floor. Pass the restrooms. Look for Room 212."*

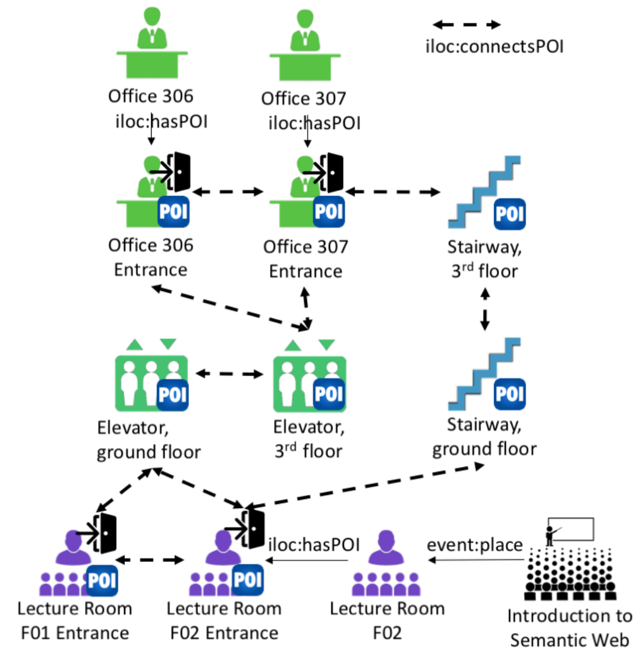

Figure 2: iLOC POI network example

Figure 2 illustrates a simple POI network of a building; the diagram was simplified to fit in the paper. The building has two offices on the third floor and two lecture rooms on the ground floor. Each office and lecture room has one or multiple entrances, represented by POIs. One of the lecture rooms hosts the Introduction to Semantic Web course. An elevator and a stairway connect the different floors. Route sections can be further described as restricted, one-way or by metrics to provide length or time duration between them. The iLOC homepage[16] contains example queries.

5. ONTOLOGY USE CASES

The ontology has been evaluated in real life use cases: aiding students, lecturers and visitors at university campuses, patient navigation in hospitals [8].

5.1 The Óbuda University use case

The data for evaluation was created manually based on building layout diagrams of the Óbuda University (OU). The buildings are linked to the corresponding country and city instances in the GeoNames[17] geographic dataset.
Figure 3 shows a screenshot of a mobile indoor navigation application developed for the university. The application explains the route from the F07 Lecture room to Lab 115. It consumes linked open data by accessing a SPARQL endpoint of the university's LOD server[18].

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[10] http://creativecommons.org/licenses/by/3.0/

[11] http://www.w3.org/2003/01/geo/#vocabulary

[12] http://www.w3.org/TR/vcard-rdf/

[15] http://www.w3.org/2005/Incubator/geo/XGR-geo/

[16] http://lod.nik.uni-obuda.hu/iloc/iloc-20160409.html

[17] http://www.geonames.org/

[18] http://lod.nik.uni-obuda.hu

Figure 3: Screenshot of the mobile application

The application is designed to show a POI based navigation route from a given starting point to a specific end point. The actual position can be read in from a QR code on the wall or if such code cannot be found nearby, the user can use the autocomplete search feature of the application. The result is displayed either as a list of POIs in one page representing the route, or in consecutive pages, each showing the description of the next POI with an optional photo. As OU publishes timetable and other information as linked open data, the application is able to navigate to a person's office, or to the location of a specific course event.

5.2 Patient navigation in hospitals

Hospitals are usually complex public places with thousands of visitors each year. Majority of them has very limited knowledge about the building or the campus. People requiring accessible routes especially need such publicly available information. For example, a person using a wheelchair generally needs elevators between floors, wide-enough doors to cross, and avoid stairs, high door thresholds, and steep slopes. An elderly person may look for the minimal number of steps, or the distance to walk. To support such needs, iLOC can be integrated with a domain ontology describing the different accessibility options as well as the built in properties can be used to provide generic route information: whether a route includes any steps or slopes. With SPARQL queries the maximal distance one can walk can be considered and some lengthy paths can be excluded.

5.3 Linked Data for Crisis Management

Accessing key building data in a crisis is one strong example, where such available Linked Data could literally save life. While it is unrealistic to have firefighters to download a separate mobile application for every building, a standard ontology and single application consuming the different, distributed datasets is a more realistic scenario. iLOC is a good candidate to fulfill this requirement.

6. CONCLUSION

The iLOC ontology enables data providers to publish navigation data about buildings. It supports three levels of modelling where each one provides more features but also requires more work during the modeling phase. iLOC can provide very simple and easily maintained Linked Datasets for navigation, without the use of geospatial databases and algorithms.

Future plans include further experimentation with rules and reasoning to improve the generation of routes and also to cover special cases such as more personalized routing for disabled people.

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