Accessible Indoor Navigation based on Linked Data in Hospitals

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***Abstract*— The paper provides a data model in the form of ontology which includes the indoor location description of hospitals, the indoor navigation features and the accessibility attributes for people with motion disabilities. The possible use of the ontology is demonstrated by outlining some SPARQL queries for the navigation features of future applications.**

Keywords—Linked Open Data, Indoor navigation, Hospital, Accessibility, Ontology

I. Introduction

The principles of Linked Open Data (LOD) [1] are related to publishing and interlinking structured data on the Web so that computers can read it automatically. This method enables that data from different sources can be connected and queried, because datasets contain links to other datasets. The standard data model for Linked Open Data is Resource Description Framework (RDF). In RDF, data is structured in triples in the form of subject, predicate and object, which is called a statement. SPARQL is an RDF query language, designed to retrieve and manipulate data stored in RDF format.

The use of Linked Data is growing and appearing in more and more domains, including healthcare, life sciences, clinical research and translational medicine as well. The mission of the Semantic Web Health Care and Life Sciences Interest Group[1] is to develop and support the use of Semantic Web technologies in this field and to produce datasets like Bio2RDF [2] and Linked Open Drug Data [3]. With our work we aim to contribute to this mission by supporting the realization of Smart Hospitals by describing a semantic model for accessible indoor navigation in this specific environment.

In this paper we address the special case of navigating inside the building of a medical facility. This means that the starting point and also the goal is a point of interest, room or department of a hospital building.

According to WHO, a hospital is "an integral part of social medical organisation, the functions of which is to provide complete health care for the population both, curative and preventive and who reach out to the family and its home environment. The hospital is also a centre for training of health workers and for bio-social research." [4] We consider this definition in our work of building ontology to support indoor hospital navigation.

We also take notice of the accessibility features of building parts to support navigation for the motion disabled visitors and patients. To accomplish this, we allow of a description of distances, number of stairs, and the presence or absence of barriers and assistance features in the building.

Outdoor navigation is widely supported nowadays by the means of information technology, and the solutions usually build on coordinates provided by GPS. Inside buildings, however, a navigation system has to cope with more complex routes and lacks the use of GPS signals. Most of the current solutions usually require special and expensive hardware for indoor positioning. Our aim is to present an inexpensive and simple indoor navigation method that can be adopted by large buildings, like hospitals. In our work we would like to exploit the possibilities of Linked Data and SPARQL for building flexible APIs providing location and routing information.

The aim of the paper is to provide a data model in the form of ontology which includes the indoor location description of hospitals, the indoor navigation features and the accessibility attributes for people with motion disabilities. Another objective is to demonstrate the possible use of the proposed model by presenting SPARQL queries for enabling the navigation process.

The rest of the paper is organized as follows. In Section 2 we describe research fields that are related to the topic, in Section 3 use cases are presented that the suggested model should satisfy. In Section 4 the ontology achieving accessible indoor navigation and indoor location description of hospitals is described. Section 5 shows examples for SPARQL queries using the developed ontologies. Section 6 provides some conclusive remarks.

II. Related Work

Constructing Linked Data requires well designed vocabularies, schemas or ontologies. There were several attempts already to provide indoor navigation ontologies. Worboys [5] provides a general 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.

[1] https://www.w3.org/blog/hcls/

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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.

OntoNav [6] 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, while in case of a large hall with many entrances it is useful to have routes inside the hall as well.

ONALIN [7] 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. Geodint [8] uses standard shortest path algorithm in a derived graph model for navigation

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 i*loc:Location* class.

SNOMED CT [9] is one of the most comprehensive medical ontologies, consisting of more than 316.000 classes organized in a hierarchical structure. It is maintained and regularly updated by IHTSDO[2], the latest version was released in September 2015. SNOMED CT contains terminology for the human body, medical procedures, pharmaceutical products, and also the logical and physical organization of healthcare facilities. The structured collection of hospital departments and room types has proven to be very useful in the process of constructing indoor navigation for medical buildings.

Outdoor navigation for the differently abled is a relevant topic. Several map and navigation services have accessibility options to enable wayfinding for wheelchair users, but only a small number of those exceed the limits of a single city. Perhaps the best-known international project is Wheelmap.org, an OpenStreetMap-based solution. Wheelmap concentrates on the needs of wheelchair users therefore the labels for locations are as follows: green signs show buildings that are wheelchair-accessible including all their rooms; a yellow sign means partial accessibility: the location itself is accessible but some of its rooms are not. Red signs show places that are not accessible for wheelchair users. The map also shows accessible toilets, based on the following criteria: the doorway's inner width is at least 90 cm, clear inner space is at least 150 x 150 cm, it has a wheelchair-height toilet seat, folding grab rails and accessible hand basin. [10]

Many countries of the developed world have laws to protect citizens with disabilities against discrimination, and to ensure equal access to public services by the means of enforcing accessible building structures. These rules can be included in civil rights laws, or in architectural regulations. In the USA, the Americans with Disabilities Act of 1990 (ADA) regulates public buildings including medical facilities to be accessible for persons with motion (and other types of) disabilities. [11] In Hungary, the government regulation about national settlements planning and building requirements (OTÉK) orders the newly built and renovated public buildings to be accessible for wheelchair users by providing slopes or stairlifts or elevators as alternatives to stairs, the doorways with inner width of at least 90 cm, and accessible toilets. [12]

III. USE CASES

Medical services are typically organized in several departments, each department located at different parts or floors of the hospital building. Departments usually include multiple medical-purposed rooms, such as examination and treatment, operating, or diagnostic imaging rooms, and also some non-medical rooms and services. Visitors, patients and medical staff may look for an actual room, a category of rooms (e.g. a toilet nearby), a department without the aim for a specific room, or just a location offering some services like an ATM or a vending machine.

To find a specific medical service, its name has to be known. The naming conventions of departments differ from country to country, and sometimes even among hospitals of the same area. These differences can lead to problematic cases in supporting navigation.

In some countries, gynecology departments are mostly co-located with obstetrics and neonatal care, therefore they have a common name for the three services (another example is the frequent co-location of dermatology and genitourinary care). There are examples of generalizing department names such as Internal medicine that can include several different specialties from cardiology to gastroenterology.

Navigating in a hospital environment can include the following use-case examples:

A patient arrives at the entrance of the medical building. He has an appointment with a cardiology specialist Dr. Heart, and some (incomplete) information about the location of the examination: a department name without knowing a specific room number. A useful navigation application should allow for refinement of the general location goal by offering the list of available rooms in the department (e.g. which is Dr. Heart's office) or navigate the patient to the information desk or the nurse station of the cardiology department. The navigation instructions should be simple and easy to follow: go to the end of the corridor, take the elevator to the third floor, then pass by the vending machine, and look for the nurse station near the entrance of the cardiology department.

Another example can be a visitor looking for a toilet. The navigation application should show directions toward the nearest toilet available for visitors (as opposed to toilets of ensuites belonging to inpatients rooms), without having to choose the specific room from the list of several toilets of the building.

The route search should consider the special needs of the differently abled, e.g. wheelchair users, or the elderly with motion difficulties. When initializing the query, the user gives

[2] International Health Terminology Standards Development Organisation, http://www.ihtsdo.org/

the starting point and the goal as well as the accessibility preferences for the route. These preferences should be finely tuned to the person's needs, including the maximum distance to the goal, the number of stairs, or the angle of slopes.

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. But different kinds of wheelchairs (e.g. an electric wheelchair) can travel through passages of different steepness, and a wheelchair user can overcome some smaller barriers with help. An elderly person may only look for the minimization of the number of stairs, or the distance to walk.

The support of the staff of the medical facility (e.g. students, medical residents, ambulance personnel) is also among our aims. Therefore, navigation has to extend to staff-only rooms such as laboratories.

IV. Ontology

To achieve our goal a data model had to be developed that supports the description of the indoor location data and the possibility of the accessible free-text type indoor navigation in Hospital environments. As we proposed to apply Linked Data principles to publish the indoor location data, the data model was created in the form of ontology, where the aim was to provide the indoor location description, the navigation features and the accessibility attributes for people with motion disabilities. During the ontology development our aim was to design a 4-star vocabulary described in the guidelines [2].

Our work was based on the iLOC ontology [14], which objective is to support the publishing of indoor location and navigation data as Linked Open Datasets in general environments. We further developed this model to enable its usage in Hospital environments and to provide support for people with motion disabilities. To achieve the goals we reviewed and extended the original iLOC ontology and regard the new one as iLOC version 2 [15].

First the specification of the extended iLOC ontology is presented that provides free-text type indoor navigation in general environments, also supporting people with motion disabilities. Afterwards we describe the additional hLOC ontology [16] that enables the usage of iLOC in Hospital environments.

The overview of the iLOC ontology is presented in Figure 1. External classes are marked with dashed lines, dotted arrows mark the subclass relationships. Classes are represented as ovals, properties as arrows. The ontology description includes the class definitions, the properties of the entities of the classes and the hierarchical relationships between classes (the parent-child relations between two classes). The source file of the ontology can be found at http://lod.nik.uni-obuda.hu/iloc/iloc-20160409.owl. The ontology uses the prefix *iloc*.

The *Location* class has three direct subclasses: Building, Building Part and POI and is used to represent all the necessary entities describing indoor locations. 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*. The VerticalPassage instances connect Floors, which can be exploited in the navigation methods.

Subclasses of the Room class can be defined in additional ontologies designed for specific environments (like Hospital, Airport, University). These subclasses don't play a role in the navigation process; they can be used as custom filters to get a list of specific types of rooms. Some typical Room subclasses

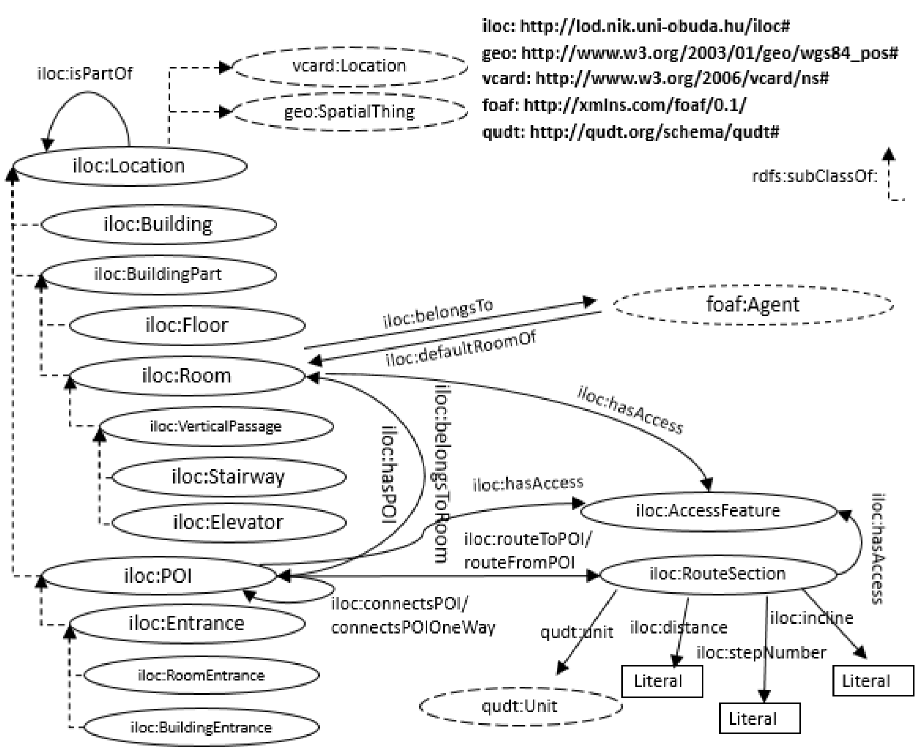

Figure 1. The overview of the iLOC ontology

in the Hospital environment are Operating room, Emergency room or Patient room.

The *POI* (Point of Interest) class has a significant role in the navigation, as its 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. Similarly to the class *Room*, additional *POI* subclasses can be defined for special environment ontologies if necessary. Examples for POI class instances are bank automats, vending machines or internet terminals.

The *RouteSection* class describes a traversable path between two POIs. The *AccessFeature* class represents different disabilities that require special features to traverse a Route Section or to use a Room or POI instance, for example the necessity for a step-free zone or an accessible toilet for wheelchair users.

The Room class entities might belong to foaf:Agent subclasses with the *belongsTo* property. With this property Room instances can belong to environment specific organizations, and also to certain persons. Environment specific ontologies should define the necessary organization-type subclasses. A default Room instance might be assigned to a specific foaf:Organization subclass with the *defaultRoomOf* property.

The *isPartOf* object property expresses hierarchical structural relationships in the ontology, e.g. a specific Room entity can be in *isPartOf* relation with a specific Floor entity. 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, needed 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. The *hasAccess* property can be used to associate a specific disability constraint to a RouteSection, Room or POI instance. The *distance*, *stepNumber* and *incline* properties can add extra information to a specific Route Section that can be used in patient customized wayfinding queries. 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.

In the process of iLOC ontology development the aim was to provide indoor location description and navigation features. The proposed navigation process builds on the structural description of the building and also on the special points in the space (POI). The route one can choose to navigate through is a network of POIs within the building. This approach supports instructions like: „Enter the main hall. Pass the vending machine. Go to the stairs. Go to the 3rd floor. Pass the restrooms. Look for Room 318."

One of the objectives of the iLOC ontology was to provide accessibility features in the navigation process. As we focused on supporting people with motion disabilities, the following instances were defined for the AccessFeature class: *Wheelchair*, *EWheelchair*, *WheelchairWHelp*, *Stretcher*, *Stroller* and *RestrictedAccess*. In the future additional instances can be added to the list in order to widen the accessibility features.

The hLOC ontology extends iLOC by semantically classifying the indoor structure of hospitals in order to enable the iLOC usage in this specific environment. The overview of the hLOC ontology is shown in Figure 2. This ontology uses the prefix *hloc*. It extends the iLOC ontology by defining three

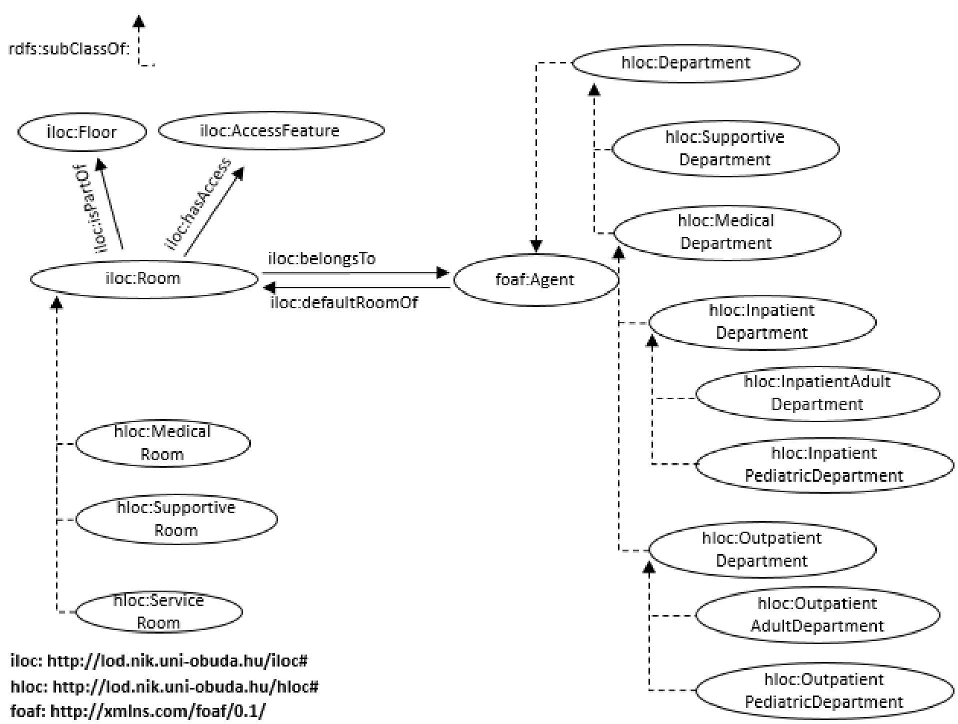

Figure 2. The overview of the hLOC ontology

TABLE I.
RECOMMENDED HLOC:ROOM SUBCLASSES

MedicalRoom	SupportiveRoom	ServiceRoom
AnestheticRoom	Bathroom	Chapel
DeliveryRoom	Cashier	Hairdresser
EmergencyRoom	ChangeRoom	Library
Ensuite	CleanersRoom	NewspaperStand
IsolationRoom	ConsultingRoom	Opticians
Laboratory	Decontamination Room	Pharmacy
MedicalImagingRoom	EducationRoom	PostOffice
PatientRoom	Hall	Restaurant
PreoperativeHolding Room	Kitchen	Shop
RecoveryRoom	Laundry	SnackBar
SeclusionRoom	Locker	
ScrubRoom	Lounge	
TreatmentRoom	Office	
	Reception	
	Store	
	Toilet	
Unspecified	WaitingArea	

iloc:Room subclasses in compliance with the room categories in the hospital environment. These are the classes: *MedicalRoom*, *SupportiveRoom* and *ServiceRoom*. In Table 1 we give a recommendation for the list of iloc:Room subclasses (falling under *MedicalRoom*, *SupportiveRoom* and *ServiceRoom*) based on [9, 17].

The hLOC ontology contains the class *hloc:Department* as the subclass of foaf:Organization. The hloc:Department has two direct subclasses: *SupportiveDepartment* and *MedicalDepartment*. MedicalDepartment can be further classified according to the following features: inpatient, outpatient, adult and pediatric. In this way we get the following subclasses: *InpatientPediatricDepartment*, *InpatientAdultDepartment*, *OutpatientAdultDepartment* and *OutpatientPediatricDepartment*.

In Table 2 we give a recommendation for the subclasses of the different Medical Departments by studying the structure of several prestigious hospitals in Hungary and abroad and also the SNOMED CT taxonomy [9]. Due to lack of space the table contains a general list for MedicalDepartment subclasses. The exact name for a certain MedicalDepartment subclass arises as follows: [Inpatient | Outpatient] || [Adult | Pediatric] || [MedicalDepartment_name]. For example for the term *Cardiology* in Table 2 *InpatientPediatricCardiology* is generated as an *InpatientPediatricDepartment* subclass.

TABLE II.
RECOMMENDED HLOC:DEPARTMENT SUBCLASSES

AddictionServices	Gynecology	Pathology
Anesthesiology	Hematology	Physiotherapy
Andrology	Hepatology	PlasticSurgery
Cardiology	Immunology	Psychiatry
ClinicalLaboratory	InternalMedicine	Psychology
CriticalCare	Microbiology	Respirology
Dentistry	Nephrology	Radiology
Dermatology	Neurology	Rehabilitation
DiagnosticImaging	Neonatology	Rheumatology
Dietetics	Obstetrics	SportsMedicine
Emergency	Oncology	Surgery
Endocrinology	Ophthalmology	Toxicology
Gastroenterology	Orthopedics	Trauma
Genetics	Otolaryngology	Urology
GenitourinaryMedicine	PalliativeCare	

V. USAGE EXAMPLES

The objective of publishing indoor location data as LOD is to support the development of mobile and web applications using this dataset. In this section example SPARQL queries are presented to demonstrate the way of querying data that application exploiting the dataset can use.

The first query demonstrates a quick solution to the first use case, when the visitor just arrived to the hospital and looking for a specific person, and their location with the campus or the actual building:

```
prefix iloc: <http://lod.nik.uni-obuda.hu/iloc/iloc#>
prefix hloc: <http://lod.nik.uni-obuda.hu/hloc/hloc#>
prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>
prefix foaf: <http://xmlns.com/foaf/0.1/>
SELECT DISTINCT ?rl ?fl ?bl where {
  ?drx iloc:belongsTo ?room ;
    a foaf:Person;
    rdfs:label "Dr. Hearth".
  OPTIONAL {?room rdfs:label ?rl.}
  OPTIONAL {?floor rdfs:label ?fl.}
  OPTIONAL {?building rdfs:label ?bl.}
  ?room iloc:isPartOf ?floor.
  ?floor iloc:isPartOf ?building.
  OPTIONAL {?room iloc:isPartOf ?building.}
}
```

The second query is a solution to a variation of the first use case, when the visitor is rather interested in the location of a department. The location will be represented by the default room (which can be reception) of the department, the building and the floor within the building.

```
prefix iloc: <http://lod.nik.uni-obuda.hu/iloc/iloc#>
prefix hloc: <http://lod.nik.uni-obuda.hu/hloc/hloc#>
prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT DISTINCT ?rl ?fl ?bl where {
  ?department a hloc:Department;
        rdfs:label "Cardiology".
  OPTIONAL {?room rdfs:label ?rl;.}
  OPTIONAL {?floor rdfs:label ?fl.}
  OPTIONAL {?building rdfs:label ?bl.}
  ?room iloc:defaultRoomOf ?department.
  ?room iloc:isPartOf ?floor.
  ?floor iloc:isPartOf ?building.
  OPTIONAL {?room iloc:isPartOf ?building.}
}
```

To find route between two rooms or POIs one can leverage SPARQL 1.1 queries with symmetric properties inference. The following is an example query to select the shortest (least intermediate steps) route between two rooms in the same building (with maximum length of 3 steps for the sake of terseness):

```
PREFIX iloc: <http://lod.nik.uni-obuda.hu/iloc/iloc#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT ?distance ?sl ?l1 ?l2 ?l3 ?el WHERE {
BIND (<room1> AS ?start ).
BIND (<room2> AS ?end).
OPTIONAL {?start rdfs:label ?sl.}
OPTIONAL {?p1 rdfs:label ?l1.}
OPTIONAL {?p2 rdfs:label ?l2.}
OPTIONAL {?p3 rdfs:label ?l3.}
OPTIONAL {?end rdfs:label ?el.}
?p1 iloc:belongsToRoom ?start.
?p1 iloc:connectsPOI ?p2.
?p2 iloc:connectsPOI ?p3.
?plast iloc:belongsToRoom ?end.
FILTER (?p3 = ?plast || ?p2 = ?plast || ?p1 = ?plast )
BIND (if( ?p3 = ?plast , 3, if( ?p2 = ?plast , 2, if( ?p1
= ?plast , 1, -1))) AS ?distance)
} ORDER BY ?distance LIMIT 1
```

The ontology also supports the use case of “find the nearest room” to satisfy specific personal needs. The next query is an example how one can get from the main entrance to the nearest wheelchair accessible toilet. This query is a specialized navigation query.

```
prefix iloc: <http://lod.nik.uni-obuda.hu/iloc/iloc#>
prefix hloc: <http://lod.nik.uni-obuda.hu/hloc/hloc#>
prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>
prefix ex: <http://example.org/>
SELECT ?distance ?sl ?l1 ?l2 ?l3 ?el WHERE {
  BIND (ex:MainEntrance AS ?start ).
  ?end a hloc:Toilet;
        iloc:hasAccess iloc:WheelChairAccess.
  OPTIONAL {?start rdfs:label ?sl.}
  OPTIONAL {?p1 rdfs:label ?l1.}
  OPTIONAL {?p2 rdfs:label ?l2.}
  OPTIONAL {?p3 rdfs:label ?l3.}
  OPTIONAL {?end rdfs:label ?el.}
  ?start iloc:connectsPOI ?p1.
  ?p1 iloc:connectsPOI ?p2.
  ?p2 iloc:connectsPOI ?p3.
  ?plast iloc:belongsToRoom ?end.
  FILTER (?p3 = ?plast || ?p2 = ?plast || ?p1 = ?plast )
BIND ((if( ?p3 = ?plast , 3, if( ?p2 = ?plast , 2, if(
?p1 = ?plast , 1, -1)))) AS ?distance)
} ORDER BY ?distance LIMIT 1
```

VI. CONCLUSION AND FUTURE WORK

In this paper we presented two ontologies iLOC and hLOC for supporting accessible free-text type indoor navigation in hospitals. The possible use of the ontologies was demonstrated by presenting SPARQL queries that future applications can build on to provide these navigation features. According to the classification of Worboys, iLOC with the extension of hLOC represents a hybrid indoor model, since they contain semantic, topological and geometrical features as well, in the form of entity information, connectivity and distance descriptions.

In the future we plan to extend the work by studying the architecture possibilities of applications achieving the navigation process. Furthermore we plan to publish indoor location linked data of a real hospital building based on iLOC and hLOC ontologies. Runtime of SPARQL queries achieving the navigation description between two points will be tested on different LOD servers (like Virtuoso, Marmotta or MarkLogic). The developed ontologies can stand as data models for datasets using different kinds of databases. In our case the use of graph based NoSQL databases (like Neo4j) might be promising in achieving the navigation task.

The accessibility features can be extended in the future taking into consideration for example the needs of visually impaired people.

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REFERENCES

[1] Berners-Lee, T. (2006). Linked data-design issues, http://www.w3.org/DesignIssues/LinkedData.html

[2] Belleau, F., Nolin, M. A., Tourigny, N., Rigault, P., & Morissette, J. (2008). Bio2RDF: towards a mashup to build bioinformatics knowledge systems. Journal of biomedical informatics, 41(5), 706-716.

[3] Samwald, M., Jentzsch, A., Bouton, C., Kallesøe, C. S., Willighagen, E., Hajagos, J., ... & Stephens, S. (2011). Linked open drug data for pharmaceutical research and development. Journal of cheminformatics, 3(1), 19.

[4] World Health Organization. Role of Hospitals in Programmes of Community Health Protection. WHO, Geneva, 1957, http://apps.who.int/iris/bitstream/10665/40375/1/WHO_TRS_122.pdf

[5] Worboys, M. (2011, November). Modeling indoor space. In Proceedings of the 3rd ACM SIGSPATIAL International Workshop on Indoor Spatial Awareness (pp. 1-6). ACM.

[6] Anagnostopoulos, C., Tsetsos, V., & Kikiras, P. (2005). OntoNav: A semantic indoor navigation system. In 1st Workshop on Semantics in Mobile Environments (SME05), Ayia.

[7] Dudas, P. M., Ghafourian, M., & Karimi, H. (2009, May). ONALIN: Ontology and algorithm for indoor routing. In Mobile Data Management: Systems, Services and Middleware, 2009. MDM'09. Tenth International Conference on (pp. 720-725). IEEE.

[8] Matuszka, T., Gombos, G., & Kiss, A. (2013). A New Approach for Indoor Navigation Using Semantic Webtechnologies and Augmented Reality. In Virtual Augmented and Mixed Reality. Designing and Developing Augmented and Virtual Environments (pp. 202-210). Springer Berlin Heidelberg.

[9] SNOMED CT. Systematized Nomenclature of Medicine - Clinical Terms, http://purl.bioontology.org/ontology/SNOMEDCT

[10] Wheelmap.org. How does Wheelmap work?, https://community.wheelmap.org/en/about/how-to-map/

[11] The Americans with Disabilities Act of 1990 and Revised ADA Regulations Implementing Title II and Title III, http://www.ada.gov/2010_regs.htm

[12] 253/1997. (XII. 20.) Korm. rendelet az országos településrendezési és építési követelményekről - Akadálymentesítésre vonatkozó kivonat, Mozgáskorlátozottak Egyesületeinek Országos Szövetsége (MEOSZ), www.meosz.hu/doc/p26-2otek_segedlet.doc

[13] Janowicz, K., Hitzler, P., Adams, B., Kolas, D., & Vardeman II, C. (2014). Five stars of Linked Data vocabulary use. Semantic Web, 5(3), 173-176.

[14] Szász, B., Fleiner, R., & Micsik, A. (2015). iLOC – An Indoor Ontology, http://lod.nik.uni-obuda.hu/iloc/iloc-20151201.html

[15] Szász, B., Fleiner, R., Micsik, A. & Simon-Nagy, G. (2016). iLOC – An Indoor Ontology, http://lod.nik.uni-obuda.hu/iloc/iloc-20160409.html

[16] Fleiner, R., Simon-Nagy, G. & Szász, B. (2016). hLOC – A Hospital Ontology, http://lod.nik.uni-obuda.hu/hloc/hloc.html

[17] Department of Human Services, Victoria. (2004, November). Design Guidelines for Hospitals and Day Procedure Centres http://www.healthdesign.com.au/vic.dghdp/dghdp_content/guidelines/dghdp_part_b_complete_20_377.pdf