Semantic Annotation of OpenStreetMap Points of Interest for Mobile Discovery and Navigation

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***Abstract*—Current mobile systems for assisted navigation have limited effectiveness in satisfying user needs. The information content supporting location-based service discovery and path calculation is usually shallow. Semantic-based technologies can allow to overcome these limitations, by exploiting more accurate and meaningful descriptions of locations, points of interest, road segments and environmental conditions. This paper proposes a general framework leveraging an enriched cartography to enhance travel assistance and safety. The majority of available navigation systems is developed upon closed and proprietary solutions for both maps and software applications, so third parties cannot extend their functionality. Therefore the proposed framework is based on open standards and tools, particularly Semantic Web technologies and crowd-sourced maps available from OpenStreetMap. A case study is presented to assess provided benefits.**

***Keywords*-Location Based Service discovery; semantic matchmaking; navigation systems; OpenStreetMap; map annotation.**

I. Introduction

In latest years, the use of assisted navigation systems for vehicles and pedestrians has been growing significantly, through the adoption of either in-dash, mobile Personal Navigation Devices (PNDs) or smartphones equipped with GPS receiver and integrated sensors. Therefore, many businesses and organizations have emphasized efforts to enhance Location-based Services (LBS) for mobile users [6]. Nevertheless, current solutions have a limited effectiveness in satisfying advanced user needs and interests. The information content supporting LBS discovery is usually shallow. The only search options for points of interest (POIs) are name-based or category-based, filtered according to proximity criteria. Such rigid approaches only support exact matches, thus being inherently affected by poor recall with consequent low user satisfaction. Moreover, the user cannot indicate characteristics and properties the destination should have, so that user's personal preferences and collateral requirements are not considered. Finally, paths are calculated without taking into account factors influencing user travel, such as road congestions, accidents and dangerous routes due to either weather conditions or vehicle state.

Semantic-based technologies can allow to overcome these limitations, by exploiting more accurate and meaningful descriptions of locations, POIs, road segments and environmental conditions. The use of annotations endowed with formal machine-understandable meaning can enable more advanced LBS discovery through semantic matchmaking, as well as driver decision support capabilities during trips. This paper proposes a novel framework to enhance functionalities of navigation systems for better assisting driving/walking users, envisioning a general approach to provide and exploit enriched cartographic information, which may be useful not only to enhance travel satisfaction and safety, but also to regulate vehicle efficiency, traffic and environmental impact.

The availability of semantically annotated map data is a crucial requirement for this kind of proposals to be practically viable. Unfortunately, the majority of available systems is developed upon closed and proprietary solutions for both maps and software applications, so third parties cannot extend their functionality. In order to overcome this restriction, the framework proposed here is based on open standards and tools: in particular, it leverages Semantic Web technologies and crowd-sourced maps available from *OpenStreetMap* (http://www.openstreetmap.org/), enriching nodes and POIs with semantic annotations in order to enable innovative LBSs for traveling users. Particularly, in this paper we introduce a general method for storing semantic annotations into OpenStreetMap road nodes and POIs, expressed with respect to ontologies in standard Semantic Web languages.

A prototypical software tool is also presented for editing semantic annotations through a fully visual user interface, based on simple drag-and-drop operations. It is implemented as a plugin for the popular open source *JOSM* OpenStreetMap editor (http://josm.openstreetmap.de/), that will make any OpenStreetMap contributor capable of enriching maps with semantic information, because no specific knowledge is required about Semantic Web languages and underlying logic-based formalisms.

Finally, a semantic-enhanced navigation tool is proposed as an evolution of the one in [13] and capable of exploiting the enriched OpenStreetMap cartography. It is based on *Navit* (www.navit-project.org) open source cross-platform software for smartphones and embeds a reasoning engine in order to perform a logic-based matchmaking of POI features against an articulate user profile or request. The proposed system can be considered as a general-purpose LBS discovery facilitator, because several resource domains (cultural heritage, shopping, accommodation, etc.) can be explored by using different ontologies.

The remaining of the paper is structured as follows: in Section II, relevant related work about semantic-enhanced map annotation and navigation is briefly surveyed. Next, in Section III the proposed framework is described evidencing the three above-mentioned core contributions and in Section IV a case study is used to clarify main benefits of the proposed approach. Finally, conclusion and future work close the paper.

II. Related work

Significant research and industry efforts are focusing on location- and context-aware service/resource discovery in mobile and ubiquitous computing. Advanced LBS discovery approaches based on classic (rigid) service categorization, such as [7] for music venues and [8] for traffic information and taxi availability, incur low generality of matching frameworks –based on overly specialized and complex ranking functions– and difficult manageability of information as systems evolve. Ontology-based annotations have been considered as an enabling technology for greater interoperability and flexibility [1], [17]. Nevertheless, the main challenge is to provide paradigms and techniques that are effective and flexible, yet intuitive enough to be of practical interest for a potentially wide user base.

In [10], a prototypical mobile client was presented for semantic-based mobile service discovery. An adaptive graph-based representation allowed OWL ontology browsing. However, a large screen seems to be required to explore ontologies of moderate complexity with reasonable comfort. Also preference specification required a rather long interaction process, which could be impractical in mobile scenarios. Authors acknowledged these issues and introduced heuristic mechanisms to simplify interaction, *e.g.*, the adoption of default values.

In [16] a mobile semantic-aware client was proposed for ubiquitous tourism. The goal of integrating multiple information domains led to a division of the user interface into many small sections, whose clarity and practical usability seems questionable. Moreover, knowledge was extracted from several independent sources to build a centralized RDF triple store accessible through the Internet. The proposed architecture is therefore hardly adaptable to mobile ad-hoc environments. Similarly, in [9] a route planning framework was introduced, based on an ontology modeling road segments w.r.t. both user preferences and context. Though remarkable, the approach requires a single ontology to be adopted by everybody. Hence, the solution cannot be extended easily to cover new application requirements.

A significant issue for research in advanced LBS has always been the limited availability of cartographic corpuses, since the largest and most detailed map data sources belong to enterprises, requiring expensive license fees. In latest years, however, "peer production", *i.e.*, the collaboration of volunteer communities, has been impacting the software industry and many other sectors [6]. In particular, Internet-based collaborative projects have been created for worldwide map crowd-sourcing. The most mature one is OpenStreetMap (OSM). It provides map data in an open, well-documented format under the Creative Commons Attribution-ShareAlike 2.0 license, granting anyone the permission to use, copy, share and modify them. Large-scale data availability helped overcome barriers between fragmented mobile services [6] and fostered research initiatives concerning semantic-enhanced LBSs.

An open framework was presented in [2], allowing the translation and publication of OpenStreetMap data into an Open Linked Data [4] repository in RDF (Resource Description Framework, www.w3.org/TR/rdf-primer/). Users submit queries in *SPARQL* RDF query language (www.w3.org/TR/rdf-sparql-query/) to a public endpoint on the Web, in order to retrieve geo–data of a particular region, optionally filtered by property values. Nevertheless, developed facilities currently cannot support advanced LBSs such as semantic matchmaking for POI discovery.

Van Aart *et al.* [15] presented a mobile application for location-aware semantic search. An augmented reality client for Apple iPhone devices sends GPS position and heading to a server and receives an RDF dataset relevant to locations and objects in the direction of the user. Applicability of the approach is limited by the availability of pre-existing RDF datasets, since the problem of creating and maintaining them was not considered. Our previous research efforts for Internet-based mobile semantic POI discovery [12] were affected by similar issues. This prompted us to leverage open map data formats and crowd-sourcing.

Becker and Bizer [3] introduced a mobile application, which allows user to search for resources located nearby, by means of information extraction from DBpedia (dbpedia.org) and other open datasets. The system also enables users to publish pictures and reviews that further enrich POIs. The user may filter the map for resources that match specific constraints or a SPARQL query. However, in the former case approximated matches are not allowed; a resource is found if and only if all constraints are satisfied. In the latter, SPARQL query builder requires the user to know language fundamentals. The approach presented here aims at overcoming both restrictions by introducing these novel features:

1) Exploiting standard Semantic Web technologies for creating and sharing geographic resource annotations.

2) Collaborative editing of semantic-based annotations.
3) Ability to use any publicly available ontology or newly created ones.
4) A tool to facilitate embedding of semantic annotations into OSM maps.
5) A navigation system with semantic-based discovery capabilities.
6) User-friendly design to hide complexity of underlying logic-based formalisms.

III. Framework and Approach

The proposed open framework for semantic resource annotation and retrieval in ITS (Intelligent Transportation Systems) is based on standard Semantic Web technologies and crowd-sourced maps available from OpenStreetMap. The overall architecture is depicted in Figure III: a general method and a tool are presented here for semantic annotation of maps so allowing a collaborative crowd-sourced enrichment of OSM cartographic data. Enhanced maps can be so downloaded into the navigation system described hereafter, which enables a discovery of POIs via logic-based matchmaking. Is is supported by an exploratory search GUI for request composition, results examination and query refinement. Each component is discussed in greater detail in what follows.

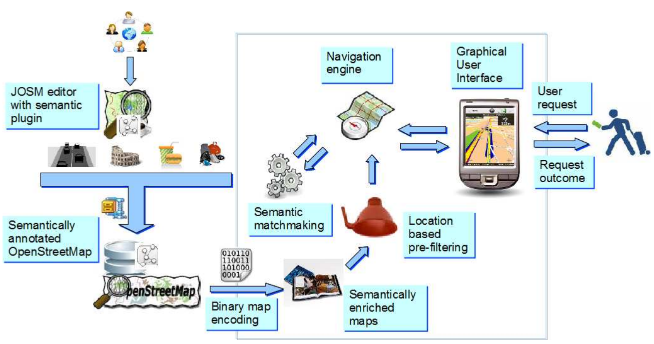

Figure 1. Framework architecture

A. Map Enhancement

OpenStreetMap data are exported and edited in XML format adhering to a quite simple schema. It includes three basic elements: (i) **nodes**, representing single geospatial points; (ii) **ways**, intended as ordered sequences of nodes; (iii) **relations**, grouping multiple nodes and/or ways. In addition to a unique identification code, coordinates and versioning information, each element can include general-purpose informative *tags*. A tag is a key-value pair of Unicode strings of up to 255 characters. Users can create new tag types without restriction (albeit following OSM community guidelines is highly recommended) to accommodate previously unforeseen map usages.

In order to store semantic annotations within map elements, we introduce new tags with the following structure:

```
<tag k="semantic:n:key" v="value" />
```

The *semantic* prefix is used to distinguish semantic annotations from other tags. The index *n* identifies different annotations –possibly referring to different ontologies– associated to the same map node. *Key* name suffix and *value* format differ for each proposed tag type, as follows.

- <tag k="semantic:n:ontology" v="URI" /> denotes the ontology the semantic node annotation refers to. All the ontology languages supported by W3C (World Wide Web Consortium) for the Semantic Web are supported, *e.g.*, standard RDFS (RDF Schema, www.w3.org/TR/rdf-schema/) or OWL (Web Ontology Language, www.w3.org/TR/owl-features/). Accordingly, annotations can be expressed in RDF and OWL. The tag value is the unique ontology URI (Uniform Resource Identifier), as recommended by W3C specifications, which usually consists of a URL (Uniform Resource Locator) where the ontology can be retrieved from.
- <tag k="semantic:n:encoding" v="format" /> specifies the compression format used to encode the semantic annotation. Compression techniques are needed in order to cope with the well-known verbosity of XML-based ontological languages such as RDF and OWL. The tag value denotes one of possible sets of encoding formats, including *e.g.*, the *EXI* W3C standard (Efficient XML Interchange, http://www.w3.org/XML/EXI/) or experimental algorithms such as *DIGcompressor* and *COX* [14].
- <tag k="semantic:n:counter" v="data" /> tags contain the *Base64* string representation of the compressed semantic annotation. If its length is $L \leq 255$ characters, a single tag is used, else it is split in 255-character segments and each one is stored in a tag. The *counter* suffix is assigned as a segment index, starting from 1.

Though this paper focuses on enriching POIs with semantic-based annotations, the proposed method is open and general-purpose. Leveraging the OSM collaborative approach, annotations can be defined for any map element type (road segments, urban areas, archaeological sites, land features, and so on). Users can refer to already published ontologies in the (Semantic) Web, but also new ontologies could be defined to meet specific requirements of applications or interest groups/communities (using given ontology editors, *e.g.*, *Protégé* [11]).

A small example of OWL annotation is shown in Figure 2 for *Karlskirche* point of interest in Vienna. It describes a Baroque church with elliptic floor plan, with a dome in Romanesque style. It is easy to notice that a semantic-based approach grants higher expressiveness and accuracy w.r.t. category-based POI classification offered by current navigation systems. Figure 3 refers to the corresponding OSM node, whose semantic annotation has been compressed using COX algorithm (cited before among experimental compressors). Semantic-based tags are highlighted.

```
<rdf:Description rdf:about="#Karlskirche">
  <rdf:type>
    <owl:Class>
      <owl:intersectionOf rdf:parseType="Collection">
        <owl:Class rdf:about="#Church"/>
         <owl:Restriction>
          <owl:onProperty rdf:resource="#has_style"/>
          <owl:allValuesFrom>
            <owl:Class>
              <owl:intersectionOf rdf:parseType="Collection">
                <owl:Class rdf:about="#Baroque"/>
              </owl:intersectionOf>
            </owl:Class>
          </owl:allValuesFrom>
        </owl:Restriction>
        <owl:Restriction>
          <owl:onProperty rdf:resource="#has_floor_plan"/>
          <owl:allValuesFrom>
            <owl:Class>
              <owl:intersectionOf rdf:parseType="Collection">
                <owl:Class rdf:about="#Elliptical"/>
              </owl:intersectionOf>
            </owl:Class>
          </owl:allValuesFrom>
        </owl:Restriction>
        <owl:Restriction>
          <owl:onProperty rdf:resource="#has_dome"/>
          <owl:allValuesFrom>
            <owl:Class>
              <owl:intersectionOf rdf:parseType="Collection">
                <owl:Restriction>
                  <owl:onProperty rdf:resource="#has_style"/>
                  <owl:allValuesFrom>
                    <owl:Class>
                      <owl:intersectionOf rdf:parseType="Collection">
                        <owl:Class rdf:about="#Romanic"/>
                      </owl:intersectionOf>
                    </owl:Class>
                  </owl:allValuesFrom>
                </owl:Restriction>
              </owl:intersectionOf>
            </owl:Class>
          </owl:allValuesFrom>
        </owl:Restriction>
       </owl:intersectionOf>
    </owl:Class>
  </rdf:type>
</rdf:Description>
```

Figure 2. Example of POI OWL description

B. Semantic-based map editor

The availability of semantically enriched cartographic data is a crucial issue to assess the usefulness of our proposal. Hence, we developed a prototypical software tool for editing semantic annotations, through a fully visual user interface based on simple drag-and-drop operations. We chose to extend the open source JOSM (Java OpenStreetMap editor) application for several reasons: (i) it is the most widely used and supported OSM editor; (ii) it is cross-platform, being written in Java; (iii) it offers a plugin mechanism to extend core functionality. Thanks to an easily understandable GUI, the proposed tool can make any OpenStreetMap contributor capable of enriching maps, because no specific knowledge of Semantic Web languages and underlying logic-based formalisms is required. A screenshot of actual prototype GUI is shown in Figure III-B.

The tool exploitation experience consists of a natural extension of the typical map annotation workflow with JOSM:

```
<node id="60664053" lat="48.1982965" lon="16.3713229">
  <tag k="amenity" v="place_of_worship"/>
  <tag k="building" v="yes"/>
  <tag k="name" v="Karlskirche"/>
  <tag k="religion" v="christian"/>
  <tag k="wikipedia:de" v="Wiener Karlskirche"/>

  <tag k="semantic:1:ontology"
    v="http://sisinflab.poliba.it/cultural.owl"/>
  <tag k="semantic:1:encoding" v="cox"/>
  <tag k="semantic:1:1" v="CkByZGY6YWJvdXQAAIEOQH
       JkZjpwYXJzZVR5cGWIs4oNQHJkZjpyZXNvdXJjZRBn
       lAlvd2w6Q2xhc3PfzJwPb3dsOlJlc3RyaWN0aW9upo
       mzEW93bDphbGxWYWx1ZXNGcm9toti/Em93bDppbnRl
       cnNlY3Rpb25PZnA+yA5vd2w6b25Qcm9wZXJ0eZh22A
       9yZGY6RGVzY3JpcHRpb24gKuIIcmRmOnR5cGVHYvIw
       Q29sbGVjdGlvbv/+RupwiCN"/>

  <!-- second annotation segment omitted -->

  <tag k="semantic:1:3" v="2RkAH/kYD7uu/cf5ojaGFz
       X3N0eWxl/pGA5YC3w9Soas2RkAH/kYCNqjmEI1JvbW
       FuaWP+kYDlgOWA5YDlgOWA5YDlgOWA5YDlgOWA5YDl
       gA=="/>

</node>
```

Figure 3. OSM XML excerpt of POI with semantic annotation

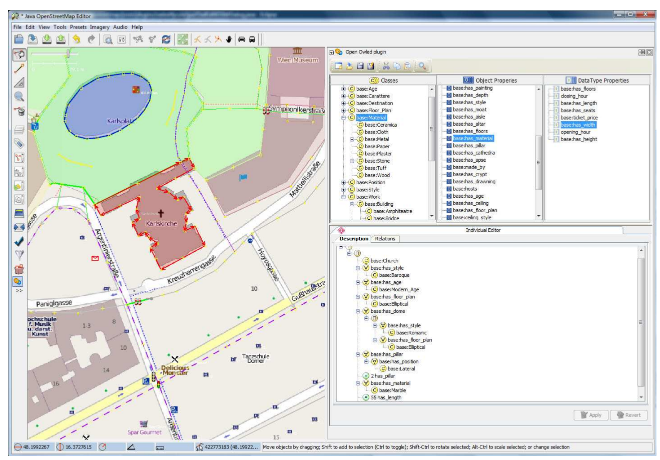

Figure 4. JOSM ontology-based plugin

1) The user selects a geographic area of interest to be downloaded from OSM server, then selects the element she wants to annotate (POI, street, urban area, etc.) on the map.
2) The plugin loads semantic annotation(s) of the selected map element, if present. Annotation content is shown in the lower portion of the plugin area. An intuitive tree-like graphical representation is provided, typical of ontology editors [11]. Meanwhile, the ontology referenced by the annotation is loaded and its elements are displayed in the upper part of the GUI: (i) *classes*

a.k.a. *concepts*, denoting types of objects in the application domain (*e.g.*, *Museum*, *Painting* for a cultural heritage ontology); (ii) *object properties* a.k.a. *roles*, denoting relationships between pairs of objects (*e.g.*, *hasStyle* could link a work of art to its reference artistic style); (iii) *datatype properties* a.k.a. *features on concrete domains*, associating objects to data-oriented attributes (numbers, strings, dates and so on, *e.g.*, the creation year of a work of art or the opening hours of a venue). User can edit the annotation through drag-and-drop of classes and properties of the associated ontology: context menus appear whenever additional information should be specified.

3) If the selected map point lacks annotations, or none satisfies the user's needs, then she can add a new one. She selects the ontology that suits the domain better (*e.g.*, cultural heritage, shopping, road safety, climate, traffic condition). Like in the previous case, user can then compose the annotation by simply selecting properties and classes from UI panels.
4) After user saves changes, the application embeds the annotation into OSM data, by storing the tags described in Section III-A. Finally, the enriched map can be submitted to OSM server through usual JOSM functions.

C. Semantic-enhanced mobile navigation

In order to allow users to exploit enriched maps, we developed a mobile navigation software tool which introduces novel advanced functionalities for semantic-based resource discovery. It is an extension of *Navit* cross-platform navigation tool for smartphones, released under the GPL General Public License. In [13] we originally introduced a first basic implementation, to verify the feasibility of our proposal. Here we describe a newer version, with more user-friendly interface and better performance.

User can access all functionalities in a quick and straightforward way. Particularly, requests can be composed using list-based GUI forms which are familiar to most mobile phone users. Navit navigation engine already supports OSM maps; in particular, it uses a compact binary encoding of XML map data, defined by the OSM project. The engine has been extended to exploit semantic-enhanced maps. A mobile matchmaker using non-standard reasoning services was integrated in the system. It has been adapted to mobile LBS discovery by using a *utility function* to combine the partial scores obtained from semantic matchmaking and geographic distance calculation.

Semantic matchmaking can be defined as the process of finding the best matches among several resources (points of interest, in our reference scenario) with respect to a given request, where both request and resources are annotated w.r.t. a common reference ontology [5]. Standard reasoning services for matchmaking include *Subsumption* and *Satisfiability*. Given a request *R* and an available resource *S*, Subsumption checks whether all features in *R* are included in *S*: its outcome is either "full match" or not. Satisfiability verifies whether any constraint in *R* contradicts some specification in *S*, hence it divides resources in "compatible" and "incompatible" ones w.r.t. a request. This approach usually gives poor results, because full matches seldom occur and unsatisfiability is frequent when matching articulate descriptions. Therefore we adapted non-standard inference services, *Concept Abduction* and *Concept Contraction*, originally formalized and applied in e-commerce scenarios [5]. If compatibility is not satisfied, Contraction detects what part *G* of *R* contradicts *S* (and should be given up, *i.e.*, retracted from *R*, in order to achieve compatibility) and what part can be kept. Therefore Contraction provides an extension and an explanation of (un)satisfiability. If *R* and *S* are compatible, but *S* does not fully satisfy *R*, Abduction identifies what is missing in *S* in order to reach a full match. In other words, Abduction provides an explanation for (missed) subsumption, returning what additional feature set *H* should be hypothesized in *S*. Furthermore, *penalty functions* can be associated to *G* and *H*, in order to compute a semantic distance score of each available resource w.r.t. a given request [5]. Finally, the *Bonus* service returns features that are present in *S* but were not requested in *R* [5]. In our system, this knowledge is proposed to the user in order to refine her initial query, since it may provide features she was unaware of but is interested in. In the next section, we explain in depth how the system works in a practical case study.

IV. CASE STUDY: WHERE ARE YOU GOING?

In what follows a simple case study in cultural heritage tourism sector is reported with the aim to show the benefits of the proposed framework. For the sake of readability, ontology constraints and concept expressions (for both request and POIs) are summarized in textual form.

Semantic-enhanced POI search. *James is a tourist visiting Vienna for the first time. He knows little about the city, but he loves art and he would like to discover interesting cultural attractions.* So he installs the prototype tool and during first launch setup wizard, he builds his profile, selecting cultural heritage among his interests. Then a customized subset of OSM city map is downloaded on local memory. POI discovery can happen in two different ways. (i) User explicitly submits his request selecting related features. Basically he indicates a general search category (*e.g.*, Cultural Heritage, Accommodation, Entertainment, Dining), each of them corresponding to a specialized ontology. Then he can browse concepts and roles within the ontology to compose his request. (ii) Alternatively, the navigation tool is able to retrieve POIs best matching user interests in a transparent fashion simply referring to the inserted profile.

Figure 5. Semantic-enabled navigation system

Request composition. *James decides to search a modern-age church, built in Baroque style. While browsing ontology features, he notices that the type of floor plan can be specified too, so he tries choosing an elliptical one*. User can set request constraints by means of the embedded ontology browser. As shown in Figure 5-a, he can select desired characteristics by navigating through the class hierarchy and property lists, without seeing the underlying Semantic Web language or logic-based formalism. The tool adopts familiar UI patterns, in order to make interface comfortable to users. Finally he can review composed request and he can set a maximum acceptable distance from his current location, as in Figure 5-b.

Results review. In a pre-processing step, distance is exploited as a filter to exclude POIs outside the user-specified range. Let us suppose that, in addition to *Karlskirche* reported in Section III-A, there are two POIs in user's range: *Stephansdom*, described as a middle-age Romanesque and Gothic church, with centralized floor plan and two towers, hosting paintings and sculptures; *Hofburg*, described as a medieval and modern palace in Renaissance style with Baroque elements. The embedded reasoning engine applies semantic matchmaking between the request and each POI annotation. The overall resource score is then computed using the utility function:

$$f(S,POI) = 100[1 - \frac{s\_match(S,POI)}{s\_match(S,\top)}(1 + \frac{distance(User\_GPS,POI\_GPS)}{max\_distance})]$$

where $s\_match(r,POI)$ is the semantic distance between request S and *POI*; this value is normalized dividing by $s\_match(s,\top)$, which is the distance between S and the universal concept (a.k.a. *Top* or *Thing*) and depends only on axioms in the ontology. Geographical distance (normalized by user-specified maximum range) is combined as weighting factor.

Results are displayed in Figure 5-c. *Karlskirche* completely satisfies user request. *Stephansdom* has a good score because it has no conflicts w.r.t. the request, since artistic styles and floor plan types are not modeled as mutually exclusive in the reference ontology. *Hofburg* has a lower score because it is a palace, which is in contrast with the request (according to concept definitions in the ontology); nevertheless, some requested features are satisfied, *e.g.*, age and style.

Query refinement. *James wants to review search outcomes.* When selecting a resource, he can see its relevant features, which are grouped into different panels, in order to provide a clear explanation of them (Figure 5-d). *What else* panel lists all missing features computed through Concept Abduction; in our example, if user selects *Stephansdom*, he can see that it is not a modern age Baroque church. *Keep* panel lists request properties that are satisfied by the POI, whereas *Give Up* panel lists incompatible elements; *e.g.*, he can see that *Hofburg* is incompatible w.r.t. *church*. Finally, *Bonus* panel lists additional features of the selected POI that were not asked for, *e.g.*, the presence of paintings and statues in *Stephansdom*. *James can refine his request until he is satisfied*. He can easily add or remove features, by selecting them from *Bonus* or *Give Up* panels respectively, and submit the request to the embedded matchmaker again. *Finally, James finds something he would like to see.* When he selects a POI in the results list, the tool computes the path to the destination and displays the route on map, using Navit engine.

V. Conclusion

The paper refers to a framework for semantic and location-based services exploiting enriched maps. A general technique for semantic annotation of crowd-sourced OpenStreetMap cartographic data is proposed along with an innovative ontology-based map editor. Moreover, an advanced navigation system is presented, equipped with an embedded micro-matchmaker for semantic-based discovery of points of interest, having significantly greater expressiveness and flexibility w.r.t. current navigation systems. A case study, focused on cultural heritage domain, provided a small example of benefits of our approach. Due to the possibility of addressing different application fields by simply switching the reference ontology, the proposed framework can be fruitfully exploited not only for LBS discovery.

Future work will aim at extending the envisioned approach to allow automated semantic-based analysis, annotation and storage of map information. We are currently investigating an enhancement of the navigation tool by integrating a semantic-based driver assistance, which detects vehicle condition by means of *OBD-II* On-Board Diagnostics car interface. The embedded micro-reasoner will automatically infer risk or inefficiency situations from the semantic characterization of vehicle performance, traffic, road surface and environment. Such information will be shared among driving users, possibly through OSM service and/or VANETs (Vehicle Ad-hoc Networks).

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