Semantically Enriched POI as Ontological Foundation for Web-Based and Mobile Spatial Applications

Hardy Pundt
University of Applied Sciences Harz, Wernigerode, Germany

Abstract
While developing a web-based travel planning system, the necessity to implement a mobile component has been identified. Such a conception is aimed at a comprehensive support of a workflow that enables users to plan a trip in advance using the web-based application, but to modify the original plan wherever and whenever they want while carrying out the journey. Within both components, POI (Point-of-Interest) plays a significant role to determine a tour. It is one claim of this chapter that the relevance of POI is dependent from the perspective of a user. As a consequence, the originally used POI database was replaced by a POI ontology which promised to support the workflow more comprehensively. This conceptual change raised several questions concerning the domain dependence of the POI ontology on the one side, and universal aspects of the ontology on the other.

INTRODUCTION
Research on semantic interoperability during the last decades has resulted in various proposals on how to capture semantics for computerized applications. A challenging question is still how to transform ontological specifications into formal descriptions effectively. Such formal ontologies should be usable by computers, and therefore in running spatial applications. In such applications, ontologies can serve as comprehensive data descriptions, including not only names of and named relations between objects, but also their meaning. Furthermore, ontologies are seen as means to support knowledge sharing and reuse, and therefore interoperability between different applications (Fonseca et al., 2001).

The philosophical term Ontology, and the term ontology, the latter also having a plural, ontologies, are different issues. In the original sense, ontologies cannot exist because there is one, and only one, Ontology. In such a sense, Ontology is related to Aristotle’s word category, which the Greek philosopher used for classifying anything that can be said or predicated about anything (Sowa, 2009). Since the term is also used in computer science, it has been applied in another sense, indicating that there are different ontologies. The philosophical term includes the description and explanation of the whole in a universal sense. The term as used in computer science indicates another viewpoint. Ontologies are not meant as a description of the universal environment, the term environment including the natural and human-made world. Due to the large complexity and infiniteness of such an environment (the whole), computer scientists have taken a more pragmatic approach. This says that ontology describes a universe of discourse (UoD). Such a UoD is specific for a group of people, or information community (IC). This way, ontologies describe only parts of the universe. They represent a limited world view. This limitedness is due to the specific perspective, and requirements, of an IC. This is also true for geographic information communities (GICs) that have specific goals and tasks which reduces their perspective on only such objects, their properties, and relations, etc., that are relevant to achieve these goals. In such a sense, there is no difference between the term ontology, and the term mini world, used in database theory. Mini worlds represent only small parts of the complex, universal world. Their advantage is that they are small enough to model and formalize them adequately in computerized environments. In Artificial Intelligence (AI), the usage of formal ontologies, instead of databases, has become popular due to their capability to describe a certain reality with a specific vocabulary, using a set of assumptions regarding the intended meaning of the vocabulary words (Horrocks, 2008; Fonseca et al., 2001; Smith & Mark, 1998).
The difficulty, or impossibility, to model the comprehensive, implicitly infinite whole, makes it necessary to take a pragmatic view concerning ontology. Instead of modeling the entire natural and human entities, their relationships, as well as interferences between humans, nature, and laws, rules, regulations, institutions, etc., it is pragmatic to selectively use parts of it and describe these in a manner that fit the requirements of a user. This means to appreciate that a model is incomplete, and only usable in a (one) defined environment. The vocabulary used to describe such a model must be enriched by the explanation of the assumptions of the intended meaning that underlie the terms in use. This coincides with describing ontology as a technical term denoting an artifact that is designed for a purpose, which is to enable the modeling of knowledge about some domain, real or abstract (Gruber, 2008; Smith & Mark, 1998).

The question, whether it is reasonable to design universal ontology of geographic space, or concentrate on limited, and incomplete, but efficient models, occurs necessarily in such a framework. Well defined, but limited, ontologies have been identified as manageable, usable and effective. Large, highly abstracted ontologies seem to be hard to develop, difficult to manage, and therefore nearly impossible to be applied. A universal ontology would serve as a foundation of each existing concept of geographic space and therefore – in a formal version – as foundation for nearly all computerized spatial applications. An idea like this represents a top-down-approach: the universal ontology stands on the highest level of abstraction, whereas all concepts and models in whatever spatial field are derivations.

The opposite, a bottom-up-approach, represents the one taken in many research projects until recently. Designing small, well-defined ontologies, limited in scope but therefore easier to manage, represents a pragmatic approach toward ontology.

Both concepts, top-down, and bottom-up, should be part of the discussion on universal ontology. A universal ontology, including an underlying theory of geographic space, does not exist yet. During the last decades attempts to design general models of geographic space have been made, mostly with little success. In the database domain it has been discovered early that it is too difficult to design a universal data model. The consequence was that thousands of small data models were designed, mostly based on the Entity-Relationship-Paradigm, following limited, and clearly defined goals.

This article attempts at bridging the gap between universality, and domain-specificity. It presents ideas on the development of an ontology for POI (Points-of-Interest) as part of a concrete spatial application running as web- and mobile system to support travel planning. Until recently this system was based on a simple POI database but it has been identified that such a database is not flexible enough in terms of supporting different users in varying contexts. Ontology Engineering techniques seem to be more adequate in order to build a network of semantic associations between a point, or place, and related concepts (Alves, Antunes, Pereira, & Bento, 2009).

The design and implementation of a POI ontology means, to enrich the existing database semantically. The enrichment process includes not only the addition of attributes, but foremost the addition of the assumptions on the intended meaning of the underlying vocabulary (or vocabularies). Furthermore, the semantic associations between POI and related concepts have to be considered as well as information about the user’s context. POI ontology, instead of an ER Model, broadens the concept of POI significantly and helps to ensure a better support for users: “Having rich knowledge about a place, we open up a new realm of ‘Location Based Services’ that can behave more intelligently” (Alves et al., 2009). These authors, as well as others (e.g., Abdelmoty, Smart, & Jones, 2007), have discussed the issue of describing places, or point locations in different frameworks. They introduce important aspects and suggest conceptual views that should be considered when approaching place ontologies. POI, however, represent a different concept. The assessment, whether a place or location is simultaneously a specific POI, cannot be carried out generally. POI can only be assessed as such in a specific context. This makes a difference: A place or specific location can be a POI in one context, but in another, it might be neglected at all (Pundt & Spangenberg, 2010).

The overall goal is to enhance the usability of a resulting POI ontology for several – instead of only one – user groups that have different perceptual world views. This goal refers to the fact that
the proper semantic description of geographic information seems to be an important step in the improvement of its usage (Florczyk, Lopez-Pellicer, Béjar, Nogueras-Iso, & Zaragoza-Soria, 2010). Moreover, this could be a step toward more universality of the underlying knowledge base as well. The semantic enrichment process requires answers on several occurring questions, such as the different languages spoken in different user groups (GICs), the homonym/synonym problem, the adequate consideration of different cognitive and perceptual models of space in different user groups, and others.

To approach the subject systematically, the chapter discusses considerations on points regarding geometric, topologic, and semantic aspects. This discussion is underpinned by the presentation of the work carried out on the web-based and the mobile travel planning system. The discussion on the ontology and its universality on the one side, and context-dependency on the other, should contribute to improved and more comprehensive knowledge about ontologies.

This discussion, focused on specific issues, is illustrated on the following pages. First, some prominent features will be taken up, whereas an approach toward a POI ontology is presented thereafter. Some examples on how to approach formalization of the ontology, a prerequisite to make it usable for web-based, or mobile applications, complete the reflections. A summary takes up the discussion about universality, and domain-dependence of spatial ontologies.

**CHARACTERISTICS OF POINTS**

Spatial objects are usually described using geometric, topologic, and semantic characteristics. Geometry informs about the position and spatial extent, topology about relationships with other objects, and semantics gives the object a name, but should additionally deliver information about the meaning. In a comprehensive, ontological approach toward POI, these characteristics must necessarily be taken into account.

**Geometry and Topology**

Points are the basic geometric entity, mostly represented as zero-dimensional objects that are located using coordinates \( x, y \) and possibly \( z \) (height): \( P(x, y, z) \). More complex objects, such as lines and polygons, are based on the definition of point locations in a given coordinate system.

Graphs, suitable to describe connectivity between points and lines (or: nodes and edges) are usually used to represent networks, such as road-, railway-, river-, pipeline-, electricity-, borderline-, or other networks.

In a graph, points are parts of a more complex organization, in which geometrical and topological relations are significant. An intersection, for example, is characterized by a specific point; here, two lines intersect, or another object is touched. The following Figure 1 shows some examples.

*Figure 1. Exemplary geometrical and topological relations of points: a) line intersects a square at two points b) line touches a circle in a point c) two lines intersect at a point \( P \), whereas \( P \) is adjacent to points \( A – D \) d) point within a polygon e) point nearby line objects f) point \( E \) as endpoint, adjacent to point \( J \) as vertex, where two lines meet.*

Concerning graphs, where points represent the locations of nodes as represented in Figure 1, various questions can occur, for example:

- How many edges meet in a point?
- Are the point start and/or end point of a specific edge?
- Are the edges, meeting at the point, directed which would mean that the point may be the end point of several edges or both, end- and starting point for specific edges?
- How many lines intersect at one point?
- What is the distance to adjacent points?
Some of these questions can be answered in general, due to the current configuration of the graph. Other questions can only be answered in dependence from the goal that is envisaged. For instance, many route planning systems rely on algorithms of graph theory to reach the goal of finding a shortest path. Applying the Dijkstra-Shortest-Path-Algorithm requires the construction of an adjacency list of points; therefore the distance between points in a network like that shown in Figure 1 c or f must be known to ensure an appropriate calculation. However, in another application, shortest distances may not be important but only information about intersection points to describe the topological characteristics of the graph network. An example is a power line network concerning which the question occurs, where lines with a certain voltage meet, or intersect those with a higher voltage. In such a framework it is also relevant to consider the fact that objects can occur in different geometric representations. A hospital, school, or large company, for instance, can occur as point object in one application whereas it can be described as one or more polygons representing different parts of a complex object. A tool that is applied to handle such objects must consider alternatives of representation. This requires knowledge about the usage of the objects – is it sufficient to deal with them as points, or is it necessary to provide them as polygons? Such knowledge, however, can be part of an ontology and is somehow part of context information. If the tool meets the requirements it is necessarily dependent from the role, or function, which the points have, so to say, for which purposes they can be used.

Obviously, geometric and/or topologic characteristics have a significant influence concerning the usage of point objects in different applications. This is also true concerning semantics. As mentioned before, semantics can differ between different GICs, even if the same or similar vocabulary is used to describe the objects in use. Concerning semantics, the focus must be on the meaning, not on the term in a syntactical sense, when designing computer applications in such a way that they fit user requirements.

Semantics

An adequate geometrical and topological representation of a point, and point-based networks, is dependent from the (user-) requirements that underlie the representation. One specific representation may satisfy the requirements of one user group, but not those of another. The quantity and density of points to be considered in a graph, depends from the purpose the network is used for. This is also true for the semantic information linked to each point. Apart from universal information, such as the coordinates, height, and topological characteristics (see Figure 1), the semantic information is mostly domain dependent. In other words, a point in one application may be represented by x, y- coordinates, and a name, whereas it might be represented by coordinates, a name and several further descriptive attributes (including their proper description) in another. But such attributes are expressed using words which are part of a vocabulary. The semantics of the words, used to express what a point means in an application, is only interpretable if the context is known, in which the term is used. Apart from the various meanings of the term itself (see Table 1 as an example), a point may be a concrete spatial object (house, road junction, meeting point) or a POI. But what does POI mean in an application context? In one application it can be POI representing accommodation opportunities, in another it can be historical buildings, and in a third the POI may be doctors’ offices and hospitals, due to each underlying application and the special interest of users.

Table 1. Exemplary meanings of the noun, and verb, “point” in WordNet. (Adapted from WordNet, 2010, modified).

<table>
<thead>
<tr>
<th>Noun “point”</th>
<th>Meaning</th>
<th>Examples</th>
<th>Spatial relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A geometric element that has position but no extension</td>
<td>“a point is defined by its coordinates”</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>The precise location of something; a spatially limited location</td>
<td>“she walked to a point where she could survey the whole street”</td>
<td>Yes</td>
</tr>
</tbody>
</table>
The examples should underpin that the three characteristics, geometry, topology, and semantics, are only partly universal, but to a significant amount domain specific. The main driving force of defining points geometrically (with a specific exactness), topologically (describing relationships to other objects explicitly), and semantically (enriched with context information to enable adequate interpretation) comes from a specific domain. A point object, enriched by more information referring to a specific application, is distinguishable from another concerning its meaning, not necessarily its location. An ontological model of points must consider all aspects, the universal, and the domain-specific. Such aspects have been taken into account in a model presented by Florczyk et al. (2010), where the authors integrate universal, as well as domain specific aspects of “geo-concepts” into the general classification of ontologies, from top-level to applied ontologies (Figure 2). Any universal point, in this sense, must be semantically enriched to serve as object for domain-specific, spatial applications.

Figure 2. Modeling the spatial representation of a geo-concept, from Florcyk et al. (2010), modified and adapted to the exemplary application “travel planning”.

**SEMANTIC ENRICHMENT OF POI**

Context-dependency of POI leads necessarily to a domain specific view. As it has been mentioned before, this does not mean that there are no universal aspects. However, when it comes to an application-specific representation of POI, the UoD, or domain, plays the central role when describing the properties, assumptions about and context-related characteristics of POI.

**Domain Ontologies**

Reasoning about the conception, development, and formal implementation of ontologies has been an important part of computer science, foremost artificial intelligence, since more than three decades (e.g., Ferrario & Guarino, 2009; Guarino & Musen, 2005; Guarino, 1998; Uschold & Gruninger, 1996). This is also true in spatial sciences, and Geoinformatics, where various authors dealt with ontological issues, among others, Kuhn (2005), Egenhofer (2002), Frank (2001), Smith and Mark (1998). Meanwhile, the focus is on the formalization of domain ontologies, aiming at making them usable for computer applications. Such ontologies determine what can be represented and what can be inferred about a given domain, using specific formalism of concepts (Baglioni, Fernandes de Macedo, Renos, Trasarti, & Wachowicz, 2009). Domain ontologies are almost describing a specific world-view, related to a geospatial information community. The foregoing discussion on points has shown that, apart from the domain-specific, there are also universal characteristics of points. However, underneath a domain-specific ontology, there can be application-related ontologies due to the fact that an application can be focused on a small, very well-defined problem, and therefore it does not represent the complete domain, but only a part of it. In such a sense, a hierarchy occurs which is presented in Figure 3.
To enable computers to deal with ontologies requires their formalization. The formalization of ontologies using standardized markup languages has been done several times, in different fields. This is due to the rapid development of XML based languages that have the advantage of interoperability, freedom from proprietary, platform independence, and therefore a universal usability. The XML derivates RDF and OWL, the Web Ontology Language, must be mentioned in such a framework (Horrocks, 2008).

The “OWL Web Ontology Guide” describes the goals and the definition of the Web Ontology Language. It starts with an example that introduces the basic problem of defining a basis for a specific computerized application (W3C, 2010):

“Tell me what wines I should buy to serve with each course of the following menu. And, by the way, I don't like Sauternes.” It would be difficult (...) to construct a web agent that would be capable of performing a search for wines on the web that satisfied this query. Similarly, consider (...) assigning a software agent the task of making a coherent set of travel arrangements.” (W3C, 2010).

After these introductory words, the W3C specification brings the example of developing a wine ontology. It represents a concrete domain instead of a more comprehensive, universal world view. The wine ontology should support users to choose the right wine for a specific situation. This example clarifies both, the domain (“wine”), and the context in which a concrete wine might be emphasized in comparison with another. The approach is pragmatic in the sense that defining a limited environment, or domain, is easier than dealing with the whole, universal environment of humans, or at least with “all existing drinks”. This point has been taken up in our research on a POI ontology which is explained during the next sections.

**POI Ontology**

A Point-of-Interest (POI) is a specialization of the category point, indicating an interesting location. An interesting location does not exist in general. Something can only be interesting, if a concrete context is given. An interesting point can be a shop, a restaurant, a fuel station, a cash point, a pharmacy, a hospital, a cinema, a sports ground, a geological landmark, a natural vantage point, etc. In many applications, such points are generally signed as POI, however, this is not exact. For users, only some of such points will be interesting, others not. In other words: without knowledge about the context, there is no POI. The context is only definable within the framework of a specific activity of a group of people, or an individual person. In such a sense, the specific interests of such a group, or an individual, form the context. Only if a point object plays a significant role in such a concrete context, it is a POI. It is a simple, but important, conclusion that POI can be relevant, or interesting, for one group, but irrelevant for another. Surprisingly, few applications consider this aspect when providing maps flooded with “POI”.

To embed the relation between POI and context it must be discussed what context means. Context in a linguistic sense refers to the setting of a word, or phrase, among the surrounding words, phrases, etc. Here, the context is used for helping to explain the meaning of the word, phrase, etc. If this basic meaning of context is transferred to spatial objects, a point may be an entity that is embedded in a spatial context which means it is surrounded by other spatial objects. It is relevant to be considered due to a specific goal of a group or an individual user for which a specific context is of interest: POI is (always) context-dependent.

For applications this means that a more sophisticated approach to support users would be to look on the context first. If the context is known, the relevance of POI can be assessed and their display is possible. This is an approach that requires the definition of individual, context-specific characteristics which enable, to a certain extent, an application to evaluate the relevance of POI (Pundt, 2008). For such a purpose, a formal ontology could be the adequate approach. This aspect will be discussed in the following sections.
Context-Dependency

Based on ongoing project work aimed at developing an individualized travel planning tool we argue that individualization means the integration of user requirements and personal wishes into the planning procedure which includes the selection of interesting, or relevant, POI, instead of a general provision of all POI near to a certain location (Garbers, Niemann, & Mochol, 2006; Czifersky & Winter, 2002). The current system relies, among other information sources, on a points-of-interest-database (POIDB). This POIDB stores mainly simple x-, y-, z-coordinates. The description is available in two forms, relational as well as in XML/KML (Figure 4). Additionally, points include a name and eventually some more attributive information, e.g., opening times if the POI stands for a cultural institution, a museum, for instance.

<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2">
  <Document>
    <Placemark>
      <name>POI_24</name>
      <description>Weather Hut</description>
      <Point>
        <coordinates>8.42,48.36,0</coordinates>
      </Point>
    </Placemark>
  </Document>
</kml>

Figure 4. Basic information on a POI, described in XML/KML.

The overall idea of the project is aimed at a qualitatively better support of travel arrangement. Qualitatively better does mean that individual requirements and personal wishes of users should be considered dynamically when planning a trip (Pundt & Spangenberg, 2010).

The goal is to produce a complete travel plan in dependence of such requirements. This plan can be produced in advance of the trip by using a web service which is already available in a basic version. This plan, however, can be modified whenever and wherever the user wants due to the parallel development of a mobile variation of the system, running on PDAs as well as Smartphones, optimized for the Google Android operating system (Figure 5). The reasons to choose Android were manifold. Among others, the facts that this operating system is open source and that there is no proprietary alliance with only one or few Smartphone providers were important. With iPhone OS it is the most widespread operating system worldwide for such mobile platforms and the developer community provides lots of new functionalities every day, based on the Java programming language and a free software developer’s toolkit.

Due to this two-sided approach to travel planning (web-based system on the one, mobile component on the other hand) and the resulting complexity of the project in general, the focus here is foremost on the underlying POI ontology. Due to individual user requirements that may occur, the POIDB must be enriched to enable the system to interpret, to a certain extent, the models that underlie the POI. This refers to the complete model, consisting of geometry, topology, and semantics, as briefly explained in the foregoing sections.

Figure 5. a) A snapshot of the mobile travel-planning tool; b) POI as chosen in the mobile travel planning system in dependence from individual, context-specific requirements; only in such a context, these POI are relevant.
SAME OBJECTS – DIFFERENT CONCEPTUALIZATIONS

Bridging the semantic enrichment process mentioned before and the well-known definition from Gruber (1993, 2001), it is necessary to think about the relevant elements of a POI ontology (Alves et al., 2009; Kim, Yu, Kim, & Ga, 2005).

Conceptualizations refer to an abstract model of how people reason about real world entities. In this framework, such entities are POI. The reasoning processes are usually restricted to a particular subject area. Due to the fact that different information communities acquire and process spatial data that refer to the same spatial area, but reason in different ways about possibly “same” spatial entities, e.g., POI, heterogeneities between conceptualizations are unavoidable. The heterogeneities are foremost of semantic origin. An explicit specification means that the concepts and relationships in the abstract model are given explicit names and definitions. Definitions associate the names of entities in the particular area with human-readable text describing what the names mean and saying how a term necessarily relates to other terms.

Ontologies are widely accepted mechanisms for capturing the semantics of the information and to make content explicit (Jones et al., 2002). They represent a resource for applications as they make available a knowledge representation language and a dictionary of classes and relations that (web and/or mobile) applications can use to describe content and reason about it. Describing and reasoning, however, affords a semantic enrichment process of spatial data, here POI, the definition of concepts under consideration of different world views and cognitive perceptions of the natural and human environment. Including such aspects into a specified and implementable system means to deal with “ontologies”, instead of traditional databases.

As an approach toward a POI ontology three different contexts were identified. They include the traditional aspects which have to be considered properly when dealing with spatial data, but add the semantic issues that have been mentioned before. Referring to a POI, the contexts are the descriptive, spatial, and semantic context, as shown in the Figure 6.

Figure 6. Approaching a conceptual view of a POI ontology. The dotted lines characterize three contexts (descriptive, spatial, semantic) that are considered for a comprehensive POI description.

Figure 6 shows only a first attempt to model a POI ontology aimed at supporting the web and mobile services for travel planning. It is still limited and would support, in this first step, only vector based models.

The basic idea of such an approach is to represent POI as comprehensively as possible. However, comprehensive, does not mean to include all available information in the POI ontology, but to represent POI in specific, but varying contexts. The ontology is only applicable in a context which has been evaluated as “relevant”. The evaluation can be done by the ontology itself, if the necessary context information has been implemented adequately. Of course, those contexts that aren’t considered, will lead to non-usability of the ontology for certain purposes. In this exemplary approach, the context is on travel planning. Due to many different interests of users in the field of travel planning, the upper level context “travel planning” can therefore be divided in various “sub levels” that represent different user contexts and types.

The ontology must take into account different contexts adequately. The semantic context shown in Figure 6 should include such information in a way that is machine interpretable to enable the mentioned evaluation and provide the right POI for a specific travel plan. Some of the questions that have to be answered by the ontology are, for example:

- Which information about the requirements and the context of the user is available?
- Do the requirements and the context information enable the definition of a user type?
- Which POI are relevant for such a user type (and which not)?
- Which POI should be selected in the context of such a specific user for the travel plan?
In such a way the ontology represents not only the geometric and topologic aspects, but especially the semantic context – in which different UoDs hint on different user requirements which lead to different user type evaluations, and therefore to different travel plans. To enable the ontology/the application to carry out such comprehensive assessments requires a formal description and implementation. As briefly mentioned before, common machine-readable languages exist to serve this aim, such as RDF and OWL. There exist several attempts of formalizing ontologies using OWL. A relatively comprehensive approach has been taken in the OntoSpace project, for instance, where one outcome was the *Generalized Upper Model* (GUM). Here, a semantic perspective of natural language has been taken and the GUM includes many concepts of spatial objects which can be seen, in a sense, as universal (therefore the authors speak about a *generalized upper model*). The underlying concepts are described by Bateman and Farrar (2004). GUM is completely available in OWL (OntoSpace, 2011). However, it does not take into account the various conceptualizations resulting from domain- or application specific world views which require a formalization of specific vocabularies and related semantic assumptions.

Within the framework of the project considered here, we are aiming at using OWL to implement the ontology. This guarantees interoperability which is important to enable the travel planning system to cooperate with different information sources, integrate knowledge and to evaluate in which context a user is searching for a route. When the context is known, only such POI will be used for the calculation of the route, which are relevant in the context of the user. Of course, this requires the consideration of comprehensive context knowledge within the underlying ontology which is hierarchically organized. An XML based approach ensures furthermore the exchange with other databases, such as a huge system providing accommodation data in XML, for instance TISCOVER (2010). It is important to mention that much material on the significance, description and formalization of spatial ontologies is available not only at organizations such as the Open Geospatial Consortium, providing standardized languages such as GML and City-GML (OGC, 2011), but also at the W3C that provides, to mention only one initiative, the W3C Geospatial Vocabulary (Lieberman, Singh, & Goad, 2007).

Only to illustrate how the formalization of the model, as shown in Figure 6, could be approached, Figure 7 presents some basic extracts in OWL. Here, the OWL-class “context” has been defined, from which the sub-classes “ContextA” and “ContextB” derivate. In addition to classes it is necessary to be able to describe their members. In this example, POI are seen as individual members of the sub classes A and B. An individual POI is minimally introduced by declaring it to be a member of a class. In this small, and incomplete, extract of OWL code, POI_2 is relevant in two different contexts A and B, whereas POI_1 and POI_3 are relevant in only one specific context. This means, for instance, that POI_1, identified as relevant in Context A, is not assessed as “POI” in another context B. Behind context A and context B (and further contexts N) a formal description of these contexts has to be provided, which is not included here.

```xml
<owl:Class rdf:ID="Context"/>

<owl:Class>
  <owl:oneOf rdf:parseType="ContextA">
    <rdfs:subClassOf rdf:resource="#Context" />
    <rdf:description "ContextA" (...) />
    <owl:Thing rdf:about="#POI_1" />
    <owl:Thing rdf:about="#POI_2" />
  </owl:oneOf>
</owl:Class>

<owl:Class>
```
Figure 7. Within a POI ontology, POI is not a general concept as “place” or “location”, but plays only a role in a specific context.

Referring to Figure 6, the three identified contexts of POI should be represented in an adequate way. This would mean that the class structure should be modified as presented in Figure 8, where the class “Context” is hierarchically superimposed to the classes “DescriptiveContext”, “SpatialContext” and “SemanticContext”. The first mentioned classes would contain the geometric and topologic aspects related to POI, the latter class would represent more content-related information for the POI, including context information, assumptions about the meaning, and specific aspects concerning the vocabulary in use. This refers to the suggestions of removing poor descriptions of places, or POI, by ontologically enriched representations (Antunes, Alves, & Pereira, 2008). In Figure 8, “Context” is a kind of super class whereas the three contexts (descriptive, spatial, semantic) can be seen as sub classes of “Context”. Specific, UoD-related contexts are exemplary included in the Semantic context class, where, for instance, “ContextA” and “ContextB” describe which POI are relevant in these contexts. The “one of” element in OWL refers to an instance of a class; of course it is debatable if a simpler class/sub-class structure would also fit the model. However, the OWL extracts are meant as illustration that the ontological description is possible using such languages, which are furthermore capable of being integrated with other XML derivates, such as GML, KML, etc. (W3C, 2010a, b; Horrocks, 2008).
CONCLUSIONS

The article started with a discussion about basic aspects of ontologies and focused afterwards on the development of a POI ontology. The model presented in Figure 6 serves as a universal basis which can be used by different groups to integrate their specific concepts, which differ from each other cognitively, linguistically and semantically. This means that there is a conceptual basis for a POI ontology which can be used for different purposes. Concerning the discussion brought before, this can be seen as upper level ontology. It serves as foundation for a domain ontology containing specific facts and knowledge identified as relevant in a specific field, in this case travel planning. The step from domain- toward application ontology, representing a classification, vocabulary and/or taxonomy, requires describing the concepts, operating in a given domain, sufficiently detailed to capture the semantics of the domain (Wachowicz, Macedo, Renso, & Ligtenberg, 2009). In the web-based and mobile applications presented here, this means that the application ontology, as an outcome of the domain ontology, would represent the individual requirements of different users in the field of travel planning, whereas above all the upper level ontology represents the abstract model (see Figure 4). A further conclusion is that an upper level ontology is not equal to a universal ontology – the upper level ontology still represents concepts being relevant in a superior, but defined field, splitting into different, related domains. An example could be the superior field of travel planning, which splits up into various sub areas, or contexts, e.g., travelling by bike, by car, by train, hiking, or combinations of these. The different requirements behind such different travel options are obvious – and must be considered within the framework of the applications. This is possible using an ontological approach, the different kinds of ontologies (upper level, domain, applied) structured by the level of abstraction. Universality is obviously much restricted to relatively few concepts that have such a character; approaching concrete applications, the various domains and the specific characteristics must be taken into account. Universal ontology in the sense of representing the whole, comprehensive, natural and man-made world, seems to be not realistic; each field of science, and practical work, has universal, but to a certain extent specific objects of interest, rules, axioms, and characteristics. This seems to be supported by studies in spatial sciences: “Il en resulte que le projet de deriver tout les geographies d’un seul axiome ou d’une systeme d’axiomes unifie est impossible a realiser” (Nicolas, 2011). This might furthermore be seen in context to the finding that “the initial project of building one single ontology, even one single top-level ontology, which would be at the same time non-trivial and also readily adopted by a broad population of different information systems communities, has largely been abandoned” (Smith, 2004).

This does not mean that universality, as well as domain-relatedness of the usage of spatial objects is not to be considered. In an upper ontological view, POI have a universal dimension. On the domain-specific level, points inherit the universal properties, but the application model must be enriched foremost in terms of semantics. An additional point is the temporal dimension which has not been considered explicitly so far. Especially in the context of mobile, location aware services not only the spatial, but also the temporal dimension can play a significant role, e.g., information on the time and duration of POI (Schmeiß, Scherp, & Staab, 2010). In any case, spatial, and temporal, aspects of
semantics, are context-dependent and therefore no universal ontology seems to be able to capture the various different meanings which POI can have in thousands of spatial applications.

REFERENCES


ADDITIONAL READING


Kuhn, W., 2000. Ontologies from Texts. In M.J. Egenhofer and D.M. Mark (Eds.), *1st International Conference on Geographic Information Science (GIScience 2000)*, Savannah GA.


KEY TERMS & DEFINITIONS

Applied ontology: A formal ontology aimed at supporting a concrete and defined application. The applied ontology is situated in a specific domain, thus representing objects and their relationships in the sense of one geospatial information community.

Domain ontology: A formal representation describing comprehensively the set of concepts, or mini world, of a geospatial information community. Only those objects, attributes, and relationships are relevant that belong to the universe of discourse of this information community.

Mobile application: An application or service, including spatial applications, which runs on every kind of mobile computers, such as PDAs, cell phones, smartphones, or alike. In spatial applications, often an integrated GPS receiver enables context awareness of such mobile tools.

Ontological Engineering: The process of conceptualizing a domain. This includes the modeling of the domain, as well as the definition of terms used in this domain, and the next step, the formalization, using adequate techniques and languages.

Spatial Semantics: Spatial semantics deals with the meaning of words used in spatial domains. Semantics of words is only interpretable if the context, in which the word is used, is known. This is the reason why semantics includes more than simply giving spatial objects a name. It must be explaining, in which context the object, which has been given a name and relations to other objects, is used. The study of (spatial) semantics intersects with other areas, e.g., lexicology, pragmatics, etymology. With the upcoming formal ontologies, the problem of how to describe and formalize the semantics of (geospatial) objects and their relationships has led to the semantic web activities. One goal is to enable web services to discover the meaning of words not only syntactically, but semantically. Semantics of spatial objects is strongly related to specific geospatial information communities, who use terms in a specific sense, which may differ from other information communities, who use the same words.

Semantic enrichment: Semantic enrichment is a process which is aimed not only at describing spatial objects by names and attributes (which have also names), but to add information about the context, in which these objects are used, and in which frameworks it is adequate, to use them (which means also to define, in which frameworks they should not be used). Enabling computers to understand the meaning of an object requires additional information that must be formalized using suitable languages. The Resource Description Framework (RDF), and the Web Ontology Language (OWL), both based on XML, approach the goal of enriching data models semantically and make them interpretable for computers.

Travel planning: All activities of a user who wants to make a journey or trip to another, or several other, destinations. Travel planning can be carried out from different perspectives, dependent from the duration of the trip, the form of travelling (car, train, motor bike, bicycle, hike, boat, or combinations of those), and other reasons. Therefore travel planning applications have to consider these different perspectives adequately which makes it necessary to add context information in the sense of semantic enrichment to such applications.

Upper level ontology: An upper level ontology describes comprehensively the classes, objects, attributes, relationships between objects and classes on a high abstract level. In general, an upper level ontology can be the foundation for several domain ontologies which relate somehow to each other. It contains often a glossary in which terms are defined which are used in different contexts, but show certain similarities. The term should not be misused in the sense of universal ontology. Universal and upper level ontology are different kinds of ontologies.

Vocabulary: A collection of vocabulary terms, usually linked to a document or domain that defines the precise meaning of the descriptors and the domain in which the vocabulary is expected to be used.

Web-based application: A web-based, or web application, is a software that is accessed over the internet (or intranet) and carrying out specific tasks to the benefit of the user.