Semantics in Location-Based Services

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Advances in wireless networks and mobile devices have motivated an intensive research effort in mobile computing and mobile data services. The goal is to provide users with anywhere and anytime connectivity to the Internet and access to services that are valuable according to the context of the user. One of the most interesting context factors is the location of the user. Thus, context-awareness, and particularly *Location-Based Services* (*LBS*) [7, 10, 15], have attracted a great interest. Moreover, rapid progress in developing Semantic Web[1] standards, tools and techniques, including applications that are rich in spatial and temporal dimensions [19] and the vision of the *Geospatial Semantic Web* [3, 5] enable the development of more intelligent LBS.

The Importance of Location-Based Services

A key driver for the importance of LBS and context aware services is their economic value. Thus, for example, Strategy Analytics predicts that the consumer and advertiser expenditure on LBS will approach $10 billion by 2016 ("The $10 B Rule: Location, Location, Location")[2]. The importance of the emerging location-based social networking is also expected to increase in the upcoming years; thus, ABI Research estimates that revenues up to $3.3 billion by 2013[3]. One reason for this will be the ever-growing availability of embedded GPS devices. According to Berg Insight, the global number of GPS-enabled handsets will grow from 175 million units in 2007 to 560 million units in 2012[4]. New positioning systems such as Galileo[5], which is expected to provide "positioning accuracy down to the metre range"[6] and work indoors, will also contribute to an increased interest in LBS.

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[1]`http://www.w3.org/2001/sw/`
[2]`http://www.strategyanalytics.com/default.aspx?mod=reportabstractviewer&a0=6355`
[3]`http://www.4psmarketing.com/the-rise-of-location-based-social-networks.html`
[4]`http://www.berginsight.com/News.aspx?m_m=6&s_m=1`
[5]`http://www.esa.int/esaNA/galileo.html`
[6]`http://www.esa.int/esaNA/GGGMX650NDC_galileo_0.html`

The above situation has motivated the development of many interesting applications, such as tracking services (e.g., monitoring of vehicles), emergency services (e.g., for roadside assistance), navigation services (e.g., digital travel assistants), information services (e.g., location-dependent yellow pages), location-dependent advertising (e.g., location-based offers or coupons), or even location-based games (e.g., Geocaching[7]).

Within LBS, the efficient processing of *location-dependent queries*, which are queries whose answers depends on the location of certain *objects*, is an important research issue [12, 13]. As an example, consider a user who is searching for a taxi. A taxi-finder LBS could provide the user with information about available nearby taxis, by submitting a location-dependent query that retrieves taxis in his/her vicinity. Notice that this also happens to be an example of a *continuous query*, as the objects that may affect the result of the query (in the example, both the mobile user and the taxis) may move constantly and the answer becomes obsolete very quickly.

The Importance of Managing Semantics in LBS

The use of semantic technologies in the development of software applications is one of the clearest trends in recent years. Numerous advances in technologies of the Semantic Web, regarding the development of systems that enable machines to understand and respond to human requests based on their meaning[8], can have an interesting application in the development of LBS. Thus, they could enable the automatic processing of information and more accurate searching services for users (e.g., with the development of semantic search engines instead of the traditional syntactic-based search engines [1]).

So, towards the development of semantic LBS, a number of research challenges and opportunities appear. One of the key elements in the Semantic Web area is the use of *ontologies* (a formal, explicit specification of a shared conceptualization) [8, 9, 24] for knowledge representation, which can be encoded in languages such as *OWL* [11]. Ontologies can provide LBS with knowledge about the context, leading to software applications that *know* how to behave in certain, sometimes unexpected, situations (a capability until now restricted to humans). Thus, by linking LBS and semantics, it is possible to enable reasoning and develop intelligent LBS.

Linking LBS and Semantics

On the one hand, the main attractiveness of LBS is that the users do not have to enter location/movement information manually, as this information is automatically pinpointed and tracked in order to provide information relevant

[7] `http://www.geocaching.com/`

[8] At this point it is interesting to emphasize the rapid emergence of the *Web of Data* (or *Linked Open Data*), that offers the ability to transform unstructured and heterogeneous data in semantically annotated structured data that is more machine processable and understandable.

for their location. On the other hand, semantic technologies could be applied to provide natural interpretations of the information available and the information needs of the users. These two worlds are complementary and can benefit from each other. In the following, we describe some aspects where the use of semantic techniques could lead to smarter LBS.

Flexible Querying

Information access in existing LBS is constrained to a predefined data schema that mobile users (or end-user applications) have to manage in order to submit their requests of information. On the contrary, it would be much more interesting to enable some form of keyword-based searching [22] or an intelligent query answering approach [27] that takes the context of the user into account.

Supporting this kind of flexible querying requires the application of semantic techniques. For example, a semantic approach is needed to disambiguate the keywords/terms introduced by the user. Moreover, the accessible information should be categorized somehow, such that if for example a user searches for "transportation means" he/she will find information about the different available alternatives[9], depending on the location and context of the user. When different data sources are involved, the relationships between the data at the different sources should be inferred. Finally, in some cases, automatically matching the user query with an appropriate information service may be needed.

Management of Semantic Locations and Trajectories

On the one hand, a user should be able to use the location terminology that he/she requires. Thus, the access to information should not be limited to requests regarding the current geographic GPS-like locations of the objects. On the contrary, any concept of location that may be interesting (*semantic locations*) should be supported (e.g., neighborhood, city, province, building, room, etc.). These symbolic locations can be represented by using ontologies, making explicit their properties and relationships [4, 21]. Moreover, a system that supports semantic locations should also manage transparently the location information provided by the different positioning mechanisms available, which may offer a different accuracy. The challenge is then how to efficiently exploit such a semantic location information in order to offer the user a better access to the information required.

On the other hand, an application should understand a trajectory of a moving object as an important element that characterizes the spatio-temporal behavior of an object, which is beyond just a raw sequence of locations. So, in a variety of scenarios (location-based social applications, tourism, geo-fencing, etc.), semantic abstractions of the trajectories (*semantic trajectories*) may be needed [20, 25, 26]. The idea is to enrich the raw data of a trajectory with higher-level information (semantic annotations) that is useful for a given application (e.g., if a tourist is in a touristic place for a certain amount of time it can

[9] For example, taxis, buses, trains, or even donkeys! in some picturesque places.

be inferred that he/she is probably visiting that place, or if it can be detected that the tourist is following a typical touristic route it is likely that he/she will continue following that route).

Interoperability Among Different LBS and Providers

LBS should provide users with a location-independent wide-area access, which means that the use of a service should be the same regardless of the location. For this purpose, sharing and exchanging data among different LBS should be possible. Therefore, interoperability issues and the integration of similar services in different geographic areas is an important challenge to solve. Besides, developers of LBS should have a means to handle positioning mechanisms (such as GPS, cell-id identification, Wi-Fi-based positioning, etc.) transparently.

Some standardization initiatives have tried to solve some of these problems. For example, the *Mobile Location Protocol* (*MLP*), supported by the *Open Mobile Alliance* (*OMA*)[10], defines a set of rules for querying and representing location information. Similar approaches exist for location modeling [14, 21]. In this context, semantic technologies could play an important role, for example as a means of representing the information managed in an unambiguous way or trying to save the existing differences between different location services by semantic matching. Indeed, some works have proposed the use of semantics to address interoperability issues in the context of LBS [16, 17, 23].

Protection of Personal Location Information

Location privacy is an important requirement for LBS. A common strategy to protect location privacy is based on forwarding to the LBS provider a coarse location of the user (an obfuscated location) instead of his/her actual and precise location [18]. Obfuscation methods are generally based on the use of geometric methods, which do not account for geographical knowledge which could enable the inference of semantic locations and so lead to the disclosure of sensitive location information and thus to privacy leaks.

New proposals are appearing that try to avoid that situation by taking into account the semantic context in which users are located. In this line, in [6] the authors present a framework that manages a semantic-aware obfuscation model. Significant progress in geospatial semantics and widely usable geographic data in Linked Open Data [3, 5] is likely to expedite the deployment of such capabilities.

Reasoning in Complex and Dynamic Contexts

A key research issue is how to effectively exploit the available semantic information to provide intelligent LBS. This implies performing reasoning with the available semantic information. On the one hand, it is possible to perform some simple spatial reasoning (e.g., if the user is at a certain room and the room is

[10] `http://www.openmobilealliance.org`

within a certain building, then the user is in that building). On the other hand, a more sophisticated reasoning involving other elements may be necessary in some cases. For example, a user may just ask for a good and convenient place to eat, and an LBS could infer what “good” and “convenient” mean for that user at that particular moment and location, as well as the most suitable type of “place” (e.g., restaurant, bistro, bar, etc.) that could be considered. In a more complex scenario, the user could even just say “I’m hungry” and the system infer that he/she needs a certain place to eat (according to his/her preferences and context).

A scenario like the ones described above require modeling and reasoning with elements such as locations, the preferences of the user (user profile), his/her context, and the context related to potential targets. Some models have been proposed for spatio-temporal reasoning with ontologies [2]. Besides providing more accurate information to the user, reasoning in the context of LBS could also help to detect inconsistencies in the available data or unsatisfiable user requests (e.g., due to contradictory requirements).

In this Issue

With this special issue, we wish to highlight the interest of joining the advances in the fields of mobile computing and the Semantic Web in order to build new semantic LBS.

Irene Celino, Daniele Dell’Aglio, Ralph Grothmann, Florian Steinke, Volker Tresp, and Emanuele Della Valle, present the article “Semantic Traffic-Aware Routing for the City of Milano using the LarKC Platform”. They propose the integration of statistical learning techniques (for traffic prediction), operational research algorithms (for routing), and conceptual query answering. As an application scenario, a service is presented that offers traffic-aware routing services for the city of Milano.

The article “A Framework for Integration, Exploration and Search of Location-Based Web Data Services”, by Alessandro Bozzon, Marco Brambilla, Stefano Ceri, and Silvia Quarteroni, presents a framework for searching and exploring resources based on the notion of nearness. It allows users to navigate through the resources based on their location, closeness, and other semantic relationships. A prototype has been implemented, that supports different forms of visualization and the ranking of the results according to different criteria.

Finally, the article “Supporting the Mobile Querying of Existing Online Semantic Web Data for Context-Aware Applications”, by William Van Woensel, Sven Casteleyn, Elien Paret, and Olga De Troyer, presents the mobile application framework SCOUT. This framework could facilitate the development of location-based and context-aware applications. It supports linking physical entities with online semantic sources available on the Web and provides a service that manages, integrates, and queries data transparently.

The three articles in this special issue address only some topics in Semantics for Location-Based Services. As semantic technologies become more mature and experience regarding their application in different contexts increase, we can expect and increasing number of research works that will try to merge both worlds.

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