Semantic Management of Moving Objects: A MOVEment Towards Better Semantics*

Position Paper

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Abstract. Exploiting semantic techniques can bring interesting benefits to the field of moving object databases. In this position paper, we provide our perspective on this topic and outline some research challenges that need to be overcome to enable a full-fledged and intelligent semantic management of moving objects.

1 Introduction

In the field of data management for moving objects, the interest in capturing semantic aspects of moving objects (locations, trajectories, features, etc.) is increasing. This field has progressed independently from others that focus mainly on semantics. Of particular interest is the Semantic Web [1], whose overall goal is to provide a version of the Web that is understandable not only by humans but also by software, which enables a plethora of applications and services. For this purpose, several semantic techniques for knowledge representation and annotation have been developed and exploited.

We argue that, by mixing techniques developed in the fields of moving object databases and the Semantic Web, it is possible to enhance the way information about moving objects is managed (from the modeling, querying, processing and analysis points of view). As an example, recent proposals claim that linking Location-Based Services (LBS) and semantics can provide interesting benefits [2]. The ideal is to be able to develop and provide LBSs that understand the user requests and know how to behave and adapt in unexpected situations.

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2 Challenges

This section briefly outlines some research challenges expected to play an important role in the quest of a complete semantic-based management of moving objects.

Management of semantic locations. The locations of moving objects can be represented at different levels of semantic granularity, not only at the finest geographic location granularity. In other words, we could see the location of a moving object from different semantic perspectives (e.g., as GPS coordinates, as the city where the moving object is located, the building, room, etc.) and it should be possible to specify the semantic location terminology that is needed or convenient for each specific query. The concept of *location granule* has been proposed in [3] to denote these location semantic requirements in the query processing. Moreover, these semantic locations could also have attached other semantic information that could be exploited automatically during the query processing. For that reason, it is interesting to link them to concepts in an ontology. However, how to efficiently manage and effectively exploit these *semantic location granules* is still an open problem.

Management and analysis of semantic trajectories. Trajectories should not be seen exclusively as a sequence of geographic coordinates, but as something that has a meaning for the moving objects that perform them. Such a raw trajectory can be enriched with thematic information that describes the trajectory using symbolic entities (locations) at which the user stops and along which the user moves (called "*stops*" and "*moves*"). The concept of *semantic trajectory* [4] highlights the importance of representing the semantics behind a trajectory (e.g., the moving object is a person going home after work, by car, and along particular streets). Moreover, we argue that the semantic information attached to a trajectory could be represented at different levels of detail and it should be possible to easily commute from one to another based on the query requirements and existing privacy constraints.

The research in this area aims to provide conceptual modeling but also storing, query processing and analysis of massive amounts of semantic trajectories at different levels of granularities. Mining raw data about moving objects can be useful to extract information that, for example, can later be used to build semantic trajectories. On the other hand, mining semantic trajectory data that enables analysis and discovery of semantic trajectory patterns is a topic that has not been extensively considered so far in the literature.

Semantic representation of moving objects. Another important challenge is how to represent the semantic information associated to a moving object in a way that makes interoperability and reasoning possible. The idea is to manage knowledge about the types of moving objects and their features in such a way that this knowledge can be exploited later (e.g., for querying). The context of moving objects should also be represented in a semantic way. The use of semantic trajectories can help in the representation of the context (as locations and times in a semantic trajectory usually define the core of a

context model). Moreover, knowledge about the environment itself may also be relevant in certain situations.

Again, the use of ontologies plays a key role here. Moreover, the modeling solutions should not rely on centralized knowledge repositories and favor instead distributed and fragmented metadata/knowledge that can be integrated ad hoc. The challenge is how to integrate all the semantic aspects and manage them as required in a uniform and efficient way.

Participatory sensing of moving objects. With the proliferation of mobile devices with increasing sensing capabilities, an important source of sensor data has become the users with their mobile devices [5]. Thanks to an increasing number of built-in sensors (ambient light, orientation, accelerometer, sound, camera,, velocity, GPS, etc.) as well as so-called virtual sensors (active applications, user interaction, social network connections, etc.), but also user-generated content, each mobile device can continuously capture and process spatially and temporally referenced data that augment the user trajectory describing his/her context and the situation.

The research in this area aims to provide representation, processing and analysis of large volumes of moving sensor data that describe user activities while moving (sitting, walking, running, driving, but also talking, searching on the Web, etc.) and provide insights about how the movement was made and what the environment of movement is [6].

Semantic query processing and reasoning on moving objects. Even with all the semantic elements in place, a key issue is how to exploit the semantic information in the query processing, in a way that is both efficient and effective. This involves using reasoning in a truly useful way that allows inferring useful facts that have not been explicitly asserted and exploiting them during the query processing. Besides, users should be able to submit queries in a flexible way (e.g., keyword-based queries), without requiring them to know any kind of schema information or single knowledge base.

Semantic-based privacy protection for moving objects. Location privacy is an important concern when dealing with information about mobile users. As suggested in studies such as [7], simply introducing noise in the geographic coordinates of the moving objects whose location must be protected is not enough. Instead, semantic-based approaches are needed. Semantic locations and trajectories increase the threats to privacy. Finally, the increasing availability of sensors and other data sources available on mobile devices may facilitate privacy attacks, due to the risk of combining data from different sources with background knowledge.

The research in this area includes the development of effective methods that exploit background information to detect potential privacy attacks and prevent them.

3 Conclusions

In this position paper, we have outlined some research challenges that lie in the path towards a more semantic management of moving objects. Some recent initiatives try to tackle the problems mentioned, such as *SHERLOCK (System for Heterogeneous mobilE Requests by Leveraging Ontological and Contextual Knowledge)* [8] or a project on Semantic LBSs in indoor environments [9]. However, more efforts are needed to tackle all the challenges identified.

References

[1] Nigel Shadbolt, Tim Berners-Lee and Wendy Hall, *"The Semantic Web Revisited"*, IEEE Intelligent Systems, 21(3):96-101, 2006.

[2] Sergio Ilarri, Arantza Illarramendi, Eduardo Mena and Amit Sheth, "*Semantics in Location-Based Services - Guest Editors' Introduction for Special Issue*", IEEE Internet Computing, 15(6): 10-14, 2011.

[3] Sergio Ilarri, Carlos Bobed and Eduardo Mena, "*An Approach to Process Continuous Location-Dependent Queries on Moving Objects with Support for Location Granules*", Journal of Systems and Software, 84(8): 1327-1350, 2011.

[4] Zhixian Yan, Dipanjan Chakraborty, Christine Parent, Stefano Spaccapietra and Karl Aberer, *"SeMiTri: A Framework for Semantic Annotation of Heterogeneous Trajectories"*, 14th International Conference on Extending Database Technology (EDBT/ICDT 2011), ACM, pp. 259-270, 2011.º

[5] Nicholas D. Lane, Emiliano Miluzzo, Hong Lu, Daniel Peebles, Tanzeem Choudhury and Andrew T. Campbell, *"A Survey of Mobile Phone Sensing"*, *IEEE Communications Magazine*, 48(9):140–150, 2010.

[6] Bratislav Predic, Zhixian Yan, Julien Eberle, Dragan Stojanovic and Karl Aberer, *"6: Integrating Daily Activities with Air Quality using Mobile Participatory Sensing"*, 11th IEEE Pervasive Computing and Communication (PerCom) Workshops, IEEE, pp. 303–305, 2013.

[7] Maria Luisa Damiani, Elisa Bertino and Claudio Silvestri, *"The PROBE Framework for the Personalized Cloaking of Private Locations"*, Transactions on Data Privacy, 3(2):123-148

[8] Roberto Yus, Eduardo Mena, Sergio Ilarri and Arantza Illarramendi, *"SHERLOCK: Semantic Management of Location-Based Services in Wireless Environments"*, Pervasive and Mobile Computing, to appear, 2013.

[9] *"Semantic Location-Based Services in Indoor Environments"*, PHC Pavle Savic, Serbian–French Research Cooperation, 2012-2013, Cyril Ray (Naval Academy Research Institute, Brest, France), Dragan Stojanovic (University of Nis, Serbia).