Chapter 39
Answering Continuous Description Logic Queries:
Managing Static and Volatile Knowledge in Ontologies

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ABSTRACT

During the last years, mobile computing has been the focus of many research efforts, due mainly to the ever-growing use of mobile devices. In this context, there is a need to manage dynamic data, such as location data or other data provided by sensors. As an example, the continuous processing of location-dependent queries has been the subject of thorough research. However, there is still a need of highly expressive ways of formulating queries, augmenting in this way the systems' answer capabilities. Regarding this issue, the modeling power of Description Logics (DLs) and the inferring capabilities of their attached reasoners could fulfill this new requirement. The main problem is that DLs are inherently oriented to model static knowledge, that is, to capture the nature of the modeled objects, but not to handle changes in the property values (which requires a full ontology reclassification), as it is common in mobile computing environments (e.g., the location is expected to vary continually). In this paper, the authors present a novel approach to process continuous queries that combines 1) the DL reasoning capabilities to deal with static knowledge, with 2) the efficient data access provided by a relational database to deal with volatile knowledge. By marking at modeling time the properties that are expected to change during the lifetime of the queries, the authors'system is able to exploit both the results of the classification process provided by a DL reasoner, and the low computational costs of a database when accessing changing data (mobile environments, semantic sensors, etc.), following a two-step continuous query processing that enables us to handle continuous DL queries efficiently. Experimental results show the feasibility of the authors' approach.

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INTRODUCTION

Mobile computing has attracted an intensive research attention and is nowadays everywhere. Indeed, important progress has been performed thanks to the popularity and technological advances of mobile devices and wireless networks. So, we now consider applications where users continuously access data of interest independently of the specific communication technology used (e.g., 3G, WiFi), the type of network (infrastructure-based vs. ad hoc), the access model (push, pull, or hybrid) (Delot, Ilarri, Thilliez, Vargas-Solar, & Lecomte 2011), the data providers (powerful data servers, peers, or simple sensors with limited capabilities), the volatility of the data of interest (e.g., access to relatively static data stored on databases vs. highly-dynamic data fed by a Data Stream Management System (Golab & Özsu, 2003) or retrieved by sensors on the fly), and even the mobility of the users and the data sources (e.g., classical mobile users with a smartphone vs. drivers in a vehicular ad hoc network (Cenerario, Delot, & Ilarri, 2011). In general, scenarios with dynamic data (e.g., location data or other data provided by sensors) are quite frequent in this context.

Abstracting users from the heterogeneity of the underlying data and providing them with more accurate and understandable results is crucial, and Semantic Web technologies could facilitate undertaking this challenge. They can help the development of mobile computing applications, as they facilitate understanding the meaning of data and the meaning of the user requests. As an example, the problem of processing continuous location-dependent queries has been extensively studied (Ilarri, Mena, & Illarramendi, 2010). However, most existing systems do not support a flexible way of formulating queries.

Whereas the use of ontologies (Gruber, 1995) and Description Logics (DLs) (Baader, Calvanese, McGuinness, Nardi, & Patel-Schneider, 2003) could help in this sense, they are not suitable for situations where there are changes in the property values. For instance, the GPS position of a mobile device is subject to constant changes. These changes in the knowledge can require to reclassify the full ontology before reasoning with it. For example, if the definition of the class of available emergency vehicles depends on their location, the constant changes in their positions require to reclassify the ontology continuously. However, this is not acceptable in applications where the changes in the data are a common situation, as this may dramatically decrease the performance of the system.

Apart from mobile scenarios, where the location is potentially continuously changing, there is indeed an important number of applications that require dealing with data streams, such as intrusion detection in computer networks, monitoring applications using sensor data, or online analysis of stock prices (Cugola & Margara, 2012). Indeed, attributes that could change frequently are very common in many environments (e.g., availability of a taxi cab, occupants of a vehicle, etc.).

In this paper, we give a step forward in the direction of performing reasoning with continuously changing data by proposing an efficient approach to process continuous queries over semantic data streams. Specifically, we present *QueryGen*, a Knowledge Management system which is able to deal with data that are continuously changing. QueryGen is not an ontology reasoner, but combines the benefits of DL reasoners and databases to manage the dynamicity of the knowledge, making it possible to retrieve the instances that are relevant to a given query in a continuous way.

The main features of our proposal are:

- It is based on the identification of dynamic data at modeling time, in order to deal with such data in a way that the performance of the reasoning is not compromised. To this end, we propose classifying properties into two classes: *volatile* and *static* ones. For instance, the location of a car could constantly change, so we consider it as vola-

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