Contextual Intelligence for Mobile Services through Semantic Web Technology

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Abstract. The success of future mobile services will largely depend on their ability to maximize their value in varying context. Contextual intelligence in devices, mobile applications and service platforms is needed to manage different mobile terminals, personalize content and services or to narrow down possibly very large sets of applicable services in a given situation. With this vision

of Contextual Intelligence in mind, we are exploiting the use of OWL and related technologies with a particular focus on providing access to the Semantic Web for mobile applications. The aim of this paper is to provide a brief and concise overview of our respective project activities at DoCoMo Euro-Labs.

1 - Introduction

For future mobile services and applications to succeed, a substantial amount of contextual intelligence in devices, mobile applications and service platforms will be required. By "contextual intelligence" we mean added capabilities of mobile services and applications that allow flexibly adapting to and maximizing their value in varying contexts. To this end, we are exploiting Semantic Web technology as an enabler for this added intelligence in context-aware mobile services. Our vision is to overlay the Semantic Web on ubiquitous computing environments making it possible to represent and interlink content and services as well as users, devices, their capabilities and the functionality they offer.

Our research in the Evolutionary Systems Project at DoCoMo Euro-Labs focuses on user guidance and contextual intelligence in living systems to keep up with a continuously changing environment. We identified flexible services and service platforms that adapt in response to changes in their context utilizing knowledge-based augmentation as key targets. Here, knowledge representation techniques such as ontologies are of great importance. Services will be modeled and tailored to preferences and needs of individual customers to better meet their requirements,

matching the capabilities of devices and platforms available. While changes to our environment happen continuously and implicitly, our technology has to be kept current and in sync explicitly. Even more effort is required to meet steadily increasing expectations of customers of mobile communication systems. We believe that semantically wellfounded personalization concepts with a universal serviceability to be an important step into this direction. The aim of this paper is to provide a brief and concise overview of the group's related project activities at DoCoMo Euro-Labs.

2 - Project Overview

Figure 1 sketches the range of projects related to the Semantic Web that we currently pursue in our laboratories. On a research map, the ongoing activities can be aligned according to their level of concern with representation fundamentals, in our case mostly through OWL, as well as reasoning support.

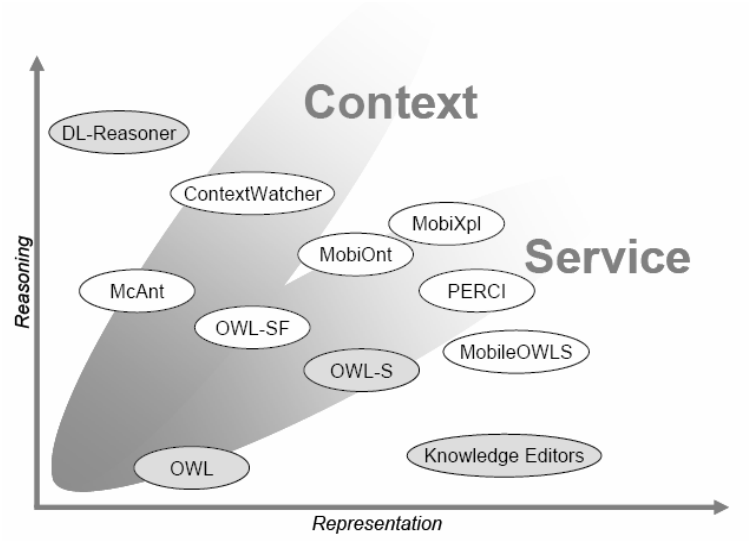

Figure 1: Project activities exploiting Semantic Web technology.

The projects are also projected to an additional application dimension representing activities that target at semantic-based mobile applications in terms of support for context representation and management, support for semantic mobile services or both of these aspects. The single activities are described in further details in the following.

2.1 - OWL-SF

Major challenges in designing ubiquitous context-aware systems include the distributed nature of context information and the heterogeneity of devices that provide ser-vices and deliver context. We have approached these challenges within the project OWL-SF [1], a distributed semantic-based service framework. In the OWL-SF prototype, OWL is used to capture high-level context elements in semantically well founded ways. Devices, sensors and other environmental entities are encapsulated and connected to the upper context ontology using OMG's Super Distributed Objects technology and communicate using the Representational State Transfer model. An early use case of OWL-SF studies enhanced presence control to realize intelligent call forwarding [2].

2.2 - ContextWatcher

Within the IST project MobiLife[1] [3] we have implemented ContextWatcher, an early prototype for semantic-based monitoring of mobile users. The project aims at frameworks for context-aware services that support users in their daily life. OWL upper context ontologies define the basic contextual categories and the relations among them. Such high-level structuring of context information enables its integration and consolidation on a semantic basis. Furthermore, the axiomatic descriptions of context elements such as personal situations (i.e., *Working*, *At_home*, etc.) can directly be used by logical inference engines to realize reasoning about the user's presence and virtual location [4]. Context Watcher acts as a client within the MobiLife Context Management Framework which defines a general framework for gathering contextual information and is itself based on Web service technology.

2.3 - McAnt

With our prototype McAnt we try to explore possibilities and core technologies towards leveraging the Semantic Web for desktop application enhancements [5]. The idea is to deploy qualitative reasoning on the user's personal desktop environment to enable a more refined support for personal information organization. As in our related activities, OWL and DL-based reasoning are explored as enabling technologies for semantic enrichment. McAnt currently extends Apple's desktop environment in terms of the Apple Address Book and the iCal calendar tool. The project introduces a set of core ontologies that describe novel OWL-based smart groups that build on Apple's smart groups and folders.

2.4 - MobiONT and MobiXPL

The discovery of adequate services will become a more and more demanding problem especially for the mobile user who has to cope with changing context and limitations of mobile terminals. We have implemented MobiOnt and MobiXpl – a semantic matchmaker for service discovery and a personal mobile client – to explore mobileuser-centered services on the Semantic Web [6]. Our vision is to take full

advantage of future complex service offerings on limited client devices and to handle the need for personalized service discovery in mobile environments. Main contributions are in support for browsing service ontologies, the cooperative discovery of services as well as an intuitive preference model that can be easily managed on restricted clients [7].

2.5 - MobiOWLS

MobiOWLS is a new project in which we attempt to extend the OWL-S [8] upper ontology for services to describe services for mobile and ubiquitous computing. Our initial investigation concentrated on extending the OWL-S Profile to include crucial quality-of-service information and contextual information that in our experience is required to locate the best service that satisfies the needs of the user. For example, we extended OWL-S with properties such as *Media* that specifies the type of media, such as video vs text, that is used to deliver the service, or the *CostModel* of the service, such as flat rate or a fee-per-use.

2.6 - PERCI

The interaction between mobile devices and physical objects is gaining more and more attention since it is an intuitive way to request services from real world objects. We currently see several solutions for the provision of such services, most of these are proprietary, designed for a special application area or interaction technique and provide no generic concept for the description of services requested from real world objects. On the other hand ubiquitous environments with many tagged and networked objects – which are also often referred to as the *Internet of Things* – could provide generic standard methods for physical tagging and interfacing. In our project PERCI (Pervasive Service Interaction) we aim at leveraging Semantic Web technology to enrich and orchestrate such standard tagging and interaction methods. In particular we study how Semantic Web service frameworks such as OWL-S could be extended towards ubiquitous service interaction.

3. Concluding Remarks

In our research – with the vision of contextual intelligence for mobile and ubiquitous service environments in mind – we are exploiting the usage of Semantic Web Technology within several practical projects that we briefly introduced above. These projects are either concerned with fundamental support for OWL-based development and/or with ontology-based services and applications in the mobile computing arena.
In this paper we presented our activities to date, and we highlighted some of the challenges that we are facing right now. We have gained considerable experience on handling contextual information and on the infrastructure that is required. Yet, despite the progress that has been made, we feel that there are still impressive challenges to

tackle. Within the context of our projects we have also identified limitations and problematic issues in using Semantic Web Technology. In particular, in exploiting OWL we found limitations in the language specification itself as well as in the tool support that we reported elsewhere [10].

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