Modeling Behavior of Users in Adaptive and Semantic-enhanced Information Systems: The role of a User Ontology

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Abstract. The Ontology-based modeling has become a topical subject in the last few years as ontology-based representations can result in better methodologies for conceptual design of data and knowledge bases, facilitating knowledge sharing and reuse. The focus of this paper is ontology-based user modeling and its concrete use in the context of Knowledge Management Systems (KMS). In particular, this paper presents the process of building a user ontology, its integration and use in an ontology-based user modeling framework. This paper proposes a model of user behaviour and it discusses its use for KMS. The paper summarizes our reflections on the role of ontology-based representations for achieving adaptive, personalized features within semantic-enhanced information systems.

Keywords: user modeling, user profiles, personalization, information systems, adaptation, knowledge management, semantic web, ontology.

1 Introduction

In the last few years, the concept of ontology has started to be used frequently in connection with Semantic Web research. An ontology enables the conceptualization and the domain knowledge specification of an application. Ontology aims to structure and represent domain knowledge in a generic way which may be reused and shared across various applications and groups of people. Annotating resources, representing concepts and the relationships between concepts is key for implementing semantic-enabled applications and achieving the Semantic Web vision [1].

Creating flexible, powerful representation knowledge structures on the web is the grounding for achieving advanced, web-enabled, personalized systems. These knowledge structures need to better capture and describe the semantics of data. Ontology-based representations are flexible and powerful representation structures, and they have become a topic of much discussion recently. The process of building an ontology is often a complex, challenging task. It is the first step to achieve semantic web-enabled systems. The complexity lies in its cross-disciplinarity including new techniques, methods and tools. Building a user ontology is a highly interdisciplinary and complex process that requires the expertise in several areas including: knowledge engineering or ontology engineering, software engineering, object-oriented programming, user modeling, artificial intelligence and other domains.

This paper presents the process of building a user ontology as well as its integration and use in an ontology-based user modeling framework. This paper summarizes our reflections on the role of ontology-based representations for adaptive, enhanced-user support. The paper is structured in five sections. The following section describes the process of building the user ontology. The third part describes an Ontology-based User Modeling framework (OntobUMf) prototype built upon the user ontology and it exemplifies how the user profiling can be applied in the context of a Knowledge Management System. The last section concludes and pinpoints towards future work.

2 Ontology-based user modeling

User modelling processes are key for achieving personalized interaction. The personalization process requires access to the user's data and it entails representing, accessing and storing users' related information. The user ontology has been developed based on a top-down approach starting from IMS LIP specification, employing Ushold and Gruninger methodology [2]. The process of building an ontology is divided into three basic steps: capturing, coding, and integrating with existing ontologies. The user ontology has been specified, taking into consideration end-user requirements provided by two Spanish companies involved in development of Knowledge Management Systems (KMS) combined with research of work on user modeling, adaptive hypermedia and user-adaptive interaction and knowledge management. Knowledge Management Systems are information systems dedicated to manage organizational knowledge[3].

At the time the first version of the ontology has been specified, an extensive survey of the user modeling and student modeling literature and its application domains has been done between December and April 2002. According to our findings there was no direct research in the area of user modeling applied in the field of Knowledge Management Systems.

The user ontology is structured according to IMS LIP specification: "*The intent of the specification is to define a set of packages that can be used to import data into or extract data from an IMS compliant learner information server*." [IMS LIP]. IMS LIP package is structured in eleven groupings in order to enable learners to customize their experience and formulate it in a general form. These groupings include the following assimilated concepts: Identification, Goal, QCL (Qualifications, Certifications and Licenses), Accessibility, Activity, Competency, Interest, Affiliation, Security Key and Relationship. According to the IMS LIP specifications, the learner information can be packaged from a variety of systems that are not limited to just Human Resource, Student Information and Learning Management systems.

The concept **Identification** contains attributes and sub-concepts that enable the identification of an individual (name, address, email, etc) within the system. **Affiliation** includes information on the descriptions of the organizations associated with the user/learner. **QCL** contains concepts related to the user's different qualifications, certifications and licenses the user has. **Competency** contains **s**kills associated with formal or informal training or work history. **Activity** includes activities related to the education/training work of the user. **Accessibility** contains concepts related to: user preferences, language information, disabilities etc. The concept **Interest** contains information on hobbies and other recreational activities. The concept **Goal** contains learner's or user's goals, sub-goals and aspirations.

As the top level ontology provided by IMS LIP does not cover the whole features of the user model, we had to extend it with a new concept that model the behavior of the user. **Behavior** is defined as a concept that models characteristics of a user interacting with a system. Behavior concept doesn't exist in IMS LIP package. It is defined as an extension of the existing concepts. Inferred fields grouped as Behavior are calculated based on the data extracted from the log files. For a KMS heuristics and fuzzy logic rules enable to "measure" the **Type_of_Activity**, the **Level_of_Activity** and the **Level_of_KnowledgeSharing** of the users in a KMS. The Type of Activity captures what types of activities a user mainly does; is the user mainly a reader? a writer? or a lurker? Based on their level of activity users are classified as: very active, active, passive or inactive.

- A **reader** is defined as somebody who mainly reads/access the knowledge assets of the system.
- A **writer** is defined as somebody who reads/access the knowledge assets but also submits knowledge assets in the system.
- A **lurker** is defined as somebody who does not contribute and who reads/ access very few knowledge assets in the system.

According to the **level of activity** users are classified as: very active, active, visitor or inactive.

- A **very active** user is somebody who reads, accesses and contributes with knowledge assets.
- An **active** user has less activity in the system then a very active user.
- A **visitor** is somebody who rarely uses the system.
- A person with no activity in the system classified as **inactive.**

According to the level of knowledge sharing the users are classified as: **Unaware, Aware, Interested, Trial,** and **Adopters** inspired by Roger's theory [2] related to diffusion of innovation extended for modeling user's behavior towards adoption of knowledge sharing practices [4].

As a next step in order to realize a computable ontology involves coding it in a formal language. The user ontology has been implemented using ontology editors such as: OntoMat, later using OI-Modeler, KAON and more recently using Protege. KAON is a tool suite for ontology management and for the development of ontology-based applications [5]. It comprises a set of tools and APIs. KAON language is an ontology representation language built on top of RDF/RDFS.

Guarino [6] emphasizes some characteristics of upper level ontologies: they are largely independent of particular applications, they may be possibly language independent, at least within a common culture, they are easily understandable by everybody, in order to be extensively reusable. The next step describes the ontology's integration and use within an ontology-based user modeling framework.

3. Ontology-based user modeling framework

The user modeling techniques and the personalization mechanisms are represented as intelligent services. The architecture of OntobUMf is modular, designed as a service oriented architecture dedicated to user modeling and personalization. The user model data for a specific user is acquired based on an explicit definition, provided by the user, through the user profile editor, and by an implicit part maintained by the category extractor [7-9] represented as intelligent service. Category extractor classifies users based on their activity in the system. As represented below, the activity of the users within the system is captured in the log instances. As depicted in Figure 1, the architecture of OntobUMf integrates the following components:

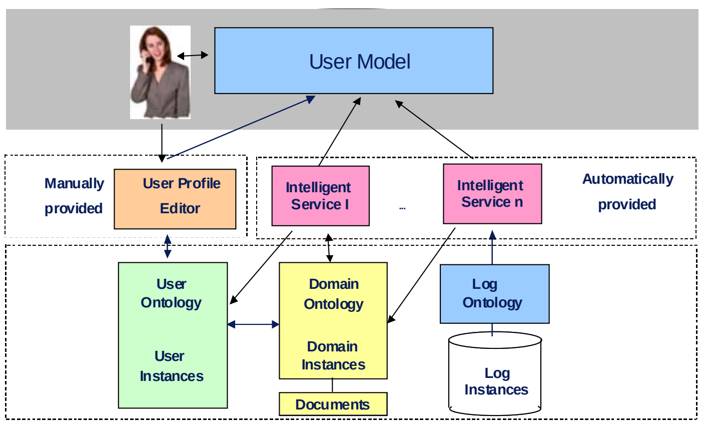

Figure 1 Ontology-based User Modeling framework (OntobUMf) architecture

The **User profile editor** is a specialized ontology editor, dedicated to the end-users to instantiate the user ontology. The user profile editor instantiates the user model but it also enables the user to visualize it, to revise it and update it afterwards. OntobUMf has a modular architecture which enables to add incrementally different intelligent services. Intelligent services can deliver various adaptation methods and personalization techniques. OntobUMf i**ntelligent services** have two main roles in the system:

- to update and maintain the user model on the basis of data available from the running system through the **category extractor.** Category extractor integrates specific mechanisms for modeling the characteristics of the users interacting with a KMS. OntobUMf classify users according to their level of activity, type of activity and level of knowledge sharing.
- to provide **personalized services** based on the characteristics of the users.

OntobUMf is a generic framework however in the following we will outline characteristics of its use in the context of a KMS.

Adaptation methods and personalization techniques relate to specific objectives of KMS. These specific objectives include the following: how to motivate people to create knowledge and submit new knowledge assets in the system, how to stimulate collaboration and knowledge sharing between knowledge workers irrespective of their location, how to alleviate information overload, how to simplify business processes and work tasks.

We define **personalization of a KMS** as the process that enables interface customization, adaptations of the functionality, structure, content and modality in order to increase its relevance for its individual users [10].

The adaptation techniques, at the level of the user interface, can be classified into three categories: adaptation of structure, adaptation of content, adaptation of modality and presentation following Kobsa's taxonomy of personalization. For instance, in the range of adaptation of structure, the system can offer personalized views of corporate knowledge based on interest areas and the knowledge of the users, or its competencies. "Personalized views are a way to organize an electronic workplace for the users who need access to a reasonably small part of a hyperspace for their everyday work." [11]

Adaptation of content refers to the process of dynamically tailoring the information that is presented to the different users according to their specific profiles (needs, interests, level of expertise, etc.). The adaptation of content facilitates the process of filtering and retrieval of relevant information. In a KMS, recommender systems, information filtering agents, and collaborative filtering techniques can be applied with the purpose of adaptation of content. The adaptation of presentation empowers the users to choose between different presentations styles, such as different layouts, skins, or fonts. Other preferences can include the presence or absence of anthropomorphic interface agents, the preferred languages, and so forth. Different types of sorting, bookmarks, and shortcuts can also be included in a high functional system. Adaptation of presentation overlaps in a certain extent with interface customisation. The adaptation of modality enables changes from text to other types of media in order to present the information to the user (text, video, animations, or audio) if they are available in the system.

One of the main objectives of KMS is to make available the knowledge assets: "at the right time to the right people." From this perspective the main sources of personalization are: the user's interests' domain, his/her current goal, his/her work tasks, his/her competencies, etc. We have particularly looked at modeling characteristics of the users' specific to a KMS. KMS need to encourage people to codify their experience, to share their knowledge and to develop an "active" attitude towards using the system. Based on the users' activity in the system, CE infers the user's behavior and it updates certain characteristics of the users interacting with a KMS. A detailed description of the inferences and rules used for modeling the user's behavior can be found in [8, 9]. This behavioral model can be associated with agent-based intervention for the adoption of knowledge sharing behaviors and change management as described in [12].

4 Related Work

The use of ontology for user modelling has been recently proposed for different scenarios: In a ubiquitous computing scenario users can delegate tasks to different agents acting on various devices with computational capability. Context features and situational statements for ubiquitous computing have been proposed as a General User Model Ontology (GUMO) by [13, 14]. The use of user modelling, rules and ontology-based representations for real-time ubiquitous applications in an interactive museum scenario has been proposed by [15]. Dolog and Nejdl, also emphasize the use of ontology for adapted learning content and smart learning spaces. Kay [16] pinpoints to the challenge and need of being able to construct domain ontology automatically and cheaply.

5 Conclusions and Future Work

This paper has presented the process of building a user ontology and its integration and use in an ontology-based user modeling framework. Building a user ontology can be a complex, confusing task for a non-expert in the field.

At the time the first version of OntobUMf ontology was built, we tried to integrate an academic, research-oriented perspective with a more business-oriented perspective. We noticed that the user profiles provided by the two companies involved in the project were different in terms of the terminology employed even though they were from the same country. We observed that many of the user's profile characteristics were synonyms. Trying **to reconcile a different terminology and different world's views can be difficult and in our case the use of a specification facilitated this process**. When beginning the process of building the user ontology, deciding on what concepts to include and how to name them was not simple. In building the user model the strategy was to identify the key user's model characteristics and to identify their associated functionality for the system, in our case a Knowledge Management Systems (KMS). At the beginning we did not try to be exhaustive in identifying all the possible concepts and sub-concepts of the user model ontology. We questioned how these characteristics can be acquired, how to map them into the IMS LIP groupings and what role they will play within the system. The system can capture the user's characteristics explicitly or implicitly. Some of the user's characteristics should be explicitly captured, filled-in by the users via a user profile editor or other means, while other can be inferred based on the user's interaction with the system. Some of the user's dimensions are static while others are dynamic some features change fast while others can change slowly in time. We distinguish between 'must have' and 'nice to have' advanced features of the system.

The use of specifications can help in building the user ontology but it can be limitative as well. **The use of a specification guarantees an agreed-upon a conceptualization and it implies interoperability with other systems compliant with this specification**. Not all the groupings provided by IMS LIP have been employed as concepts, because it was found that not all these concepts were relevant for our specific application domain.

The user ontology has been integrated in OntobUMf user modeling system. The OntobUMf can capture the user's characteristics explicitly or implicitly. Some of the user's characteristics should be explicitly captured, filled-in by the users using a user profile editor while others can be inferred based on the user's interaction with the system. Some of the user's dimensions are static while others are dynamic. Some features change fast (e.g. mood, location) while others can change slowly in time (e.g. type of activity, level of activity, interests, hobby). The Behaviour concept was introduced as an extension of IMS LIP in order to model the behaviour of the user. OntobUMf classify the users according to the level of activity, type of activity and level of knowledge sharing.

Future work involves to extend and test the OntobUMf model of behaviour to classify the users based on their social behavior within communities of practice and social networks. Moreover we plan to define and provide a new set of adaptive, personalized services. Furthermore we plan to apply the same approach of building ontology in an e-government scenario which will be applied within ITAIDE[1] (Information Technology for Adoption and Intelligent Design for e-Government) project.

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