Towards an Ontology for Ubiquitous User Modeling Interoperability

María de Lourdes Martínez-Villaseñor[1,2] and Miguel González-Mendoza[2]
[1]Universidad Panamericana, Campus México, Augusto Rodin 498, Col. Insurgentes Mixcoac, Mexico D.F., Mexico
[2]Instituto Tecnológico y de Estudios Superiores de Monterrey, Carretera Lago de Guadalupe Km 2.5, Atizapán de Zaragoza, Edo. de Mexico, Mexico

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Abstract: In order to obtain a broader understanding of the user, some researchers in the community of user modeling envision the need to share information of user models between applications. But gathering distributed user information from heterogeneous sources to obtain user models interoperability implies handling syntactic and semantic heterogeneity. It is also important to provide means for a ubiquitous user model to evolve over time. We present U2MIO a dynamic ontology with flexible structure for user modeling interoperability based in SKOS ontology. The U2MIO provides mediation based user modeling for sharing and reusing information from heterogeneous user models. A two-tier matching strategy is proposed for the process of concept alignment that permits the interoperability between profile suppliers and consumers.

1 INTRODUCTION

Today, users actively interact with systems and applications through several devices. Many service providers develop user-adaptive systems and are trying to model the user for adaptation and customization. But these efforts are frequently isolated and repeated by each supplier; each of them obtains a narrow understanding of the user. Some researchers in the community of user modeling (Heckmann, 2005) (Houben et al., 2005) Berkovsky et al., 2007) (Carmagnola, 2009) envision the need to share information of user models between applications to achieve a broader understanding of the user in order to provide better service, content and interface personalization and adaptation. Carmagnola (Carmagnola, 2009) denote "the process of gathering and making sense of distributed user information as *user models interoperability* and the systems exchanging knowledge about a user as *interoperable user-adaptive systems*". Sharing and reusing information between models can bring the following advantages:

- Prevent the user to repeatedly setting parameters in devices, applications and services which provokes inconsistency, redundancy and repeated configurations.
- Helps deal with "cold start problem" (Leonardi, 2009) when a user is new to applications and services.
- Provides enrichment to the user models obtaining a better understanding of the user having a broader picture of user's characteristics, preferences and interest as well as user's current state.

But gathering distributed user information from heterogeneous sources to obtain user models interoperability implies handling syntactic and semantic heterogeneity. Several techniques have been proposed to deal with the lack of interoperability (Viviani et al., 2010). The two major approaches for user modeling interoperability are the definition of standard ontologies that provide a common understanding among multiple systems or a conversion approach using mediation techniques to provide mappings between the different user models.

Both approaches try to deal with syntactic and semantic heterogeneity in different manners, but it has become clear in recent years, that the user model representation must be able to evolve over time, must avoid redundancy, and provide security management. In this paper, we address the syntactic and semantic heterogeneity between the sources, and the evolutivity problems of the user model.

We present a dynamic ontology with flexible structure based in Simple Knowledge Organization

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System (SKOS) (Miles et al., 2007), to provide knowledge representation for the construction of a ubiquitous user model in order to enable user modeling interoperability. A process of concept alignment determines the semantic mappings between the suppliers and consumers' concept scheme and the ontology and gives recommendations to change its structure.

Related work is discussed in section 2. The ubiquitous user model interoperability ontology (U2MIO) development is explained describing the processes of ontology set up, ontology manipulation and concept alignment for interoperability in heterogeneous user models (section 3) . We compare our approach with related work in 4 and conclude in the final section.

2 RELATED WORK

One frequently cited representative of standardization-based user modeling ontologies is GUMO, developed for ubiquitous user modeling. In (Heckman, 2005) the author describes general user model ontology (GUMO) and its basic user dimensions. This ontology is intended for the description of the user major dimensions and situational statements with the user model auxiliaries, predicate and ranges. However GUMO user model is almost static, although well suited to represent situational statements.

Some recent approaches (Sutterer, 2009) are based on user profile management selection taking into account user profile management standards and specifications like (ETSI, 2005) (3GPP GUP, 2009). Sutterer presented a user profile management framework for service platforms. The profile structure that includes situation-specific user sub-profiles for each application considered is interesting because it adapts to changing situations and is flexible to include new applications. It aggregates profiles and sub-profiles for each application and selects the best suited sub-profile for each situation related to a service platform. It also permits the aggregation of user models, these causes redundancy when saving the same profile structure with minor changes several times.

Iqbal et al. (Iqbal et al., 2010) (Iqbal et al., 2011) presents a privacy-enhanced innovation framework designed considering standard semantic web tools for interoperability and integration of data from multiple sources like social networks,Friend of a Friend (FOAF) (Brickley, 2007). Their approach is important in the matter of dealing with personal and corporate issues to foster enterprise collaboration. They also set up the personal profile extracting information from heterogeneous sources, but they do not provide mapping between the sources in order to permit automatic reuse and sharing of individual concepts.

The Generic User model Component (GUC) presented in (van der Sluijs and Houben, 2006) proposed to construct combined ontologies for exchanging user models between web-based systems. GUC allows the configuration of a distributed management of mappings between user models. The schema mappings were determined by a human and the possibility of automatic merging techniques was discussed but implemented requiring human effort. Carmagnola et al., (Carmagnola et al., 2009) proposed a solution with high flexibility representing user models and providing semantic mapping of the user data from heterogeneous sources. However, to take part in the interoperability process every provider needs to comply with a standard format for the exchange and maintain a sharable user model.

3 U2MIO ONTOLOGY

In this section, we first outline relevant aspects for the ubiquitous user model interoperability ontology (U2MIO) development. Subsequently, we describe the processes of ontology set up, manipulation and the concept alignment for interoperability in heterogeneous user models.

3.1 Purpose and Scope of the Ontology

The ubiquitous user model is part of a user-adaptive system that will facilitate knowledge sharing and reuse between heterogeneous user profiles. The aim of ubiquitous user modeling interoperability ontology is to provide a shared and common understanding between profile suppliers and consumers in order to achieve cross-system personalization and sharing and reuse of user models. We are considering social network profiles, data from advanced sensors attached to personal gadgets, semantic web technologies like FOAF and personal health records as profile suppliers. Some of these devices and applications can be profile consumers also. Other profile consumers considered are web services, as we intend to use the information as parameters of web service in order to help personalization. The main problems that the ontology is presumably solving are:

- To support semantic interoperability overcoming differences between concepts at knowledge level.
- Represent a flexible user profile structure, with domain independency which provides the possibility for the ubiquitous user model to evolve during time.
- It must support that new profile suppliers and consumers take part in the interoperability process without effort of the provider or consumer system.

The adaptive system must be able to contemplate new sources, applications, devices and web services. Given the semantic diversity of the heterogeneous user models considered (and to come) as profile suppliers and consumers, a flexible ontology that permits ".. ongoing modeling, ongoing sharing and ongoing exploitation" (Heckmann, 2005) is needed.

The system's end user is any person using social network applications, personal gadgets with sensors, personal health records, FOAF and web services that would like to avoid repeatedly setting his profiles, by letting the system automatically set and enhance them as well as automatically use this information for adaptation and personalization, in particular web service personalization. The ubiquitous user model information could be useful in content and interface personalization. The user model structure and dimensions must be determined and initialized in the set up process to avoid cold start problem, but it must be flexible to adapt to ubiquitous changing environment. A process of concept alignment for interoperability will provide articulation between heterogeneous sources. This process will automatically maintain the ontology structure and dimensions. We briefly describe this process in 3.2.3.

3.2 User Profile Structure and Dimensions

People interact with many systems and applications through various devices that gather information of the user in order to provide a more personalized service, but a person ends with many isolated user profiles and models, tailored to the application, device or system for which it was intended. The domain of user profile is therefore very complex, but our user model must be domain-independent. The task of building a flexible ubiquitous user model ontology that represents knowledge of the user of all possible profile providers and consumers actually used by a person and to come is very ambitious. Many attempts have been made in the user modeling community to provide cross-system personalization and foster sharing and reusing user models by developing a commonly agreed ontology of a domain as we described in section 2, but including in it all possible applications and context is not a feasible solution for sharing and reusing.

We have to compromise and provide the ontology set up with a user representation of a flexible user profile for some commonly used applications and devices and enable the ontology to continually adapt to new systems and applications requirements.

3.2.1 Ontology Set Up

The main idea of our approach is to crumble the information extracted from supplier's profiles at concept granularity, and find the semantic relations between each of them and the most similar concept already present in the U2MIO ontology. Once the relation is found, a link is established via semantic relation and mapping properties. A data model that provides us a common understanding is used in combination with OWL as a formal knowledge representation language. SKOS is a W3C recommendation since 2009.

With the purpose of defining the profile structure and dimensions considered for our ubiquitous user model, we reviewed some of the international initiatives towards standardization of user profile structure, and user profile schemas of most commonly used applications and devices.

From European Telecommunications Standards Institute (ETSI) (ETSI, 2005), 3rd Generation Partnership Project (3GPP) GUP (3GPP GUP, 2009) and we established that the profile should be flexible and redundancy must be avoided.

In a user-centric multi-application environment, the nature of user's profile data is static, semi-static and dynamic. This information is recollected explicitly or implicitly by profile suppliers. We selected the following types of profile suppliers and consumers in order to include information we believe is most commonly available in the providers' systems and needed by profile consumers.Therefore, for the ontology set up, we decided that the user profile structure must contain concepts to define knowledge in the following dimensions.

The ubiquitous user model (U2M) is modeled as a skos:ConceptScheme and each dimension corresponds to a skos:Collection (Figure 1), and thus it is modeled as an OWL class. The collection is meant to group concepts that belong to each dimension. In the set up process, we determined a

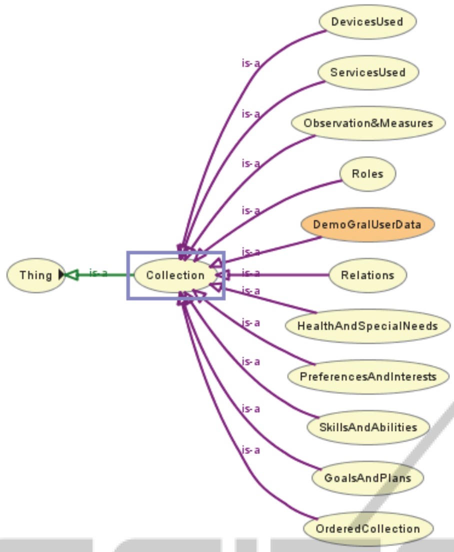

Figure 1: Ubiquitous user model collections.

set of concepts to initialize the U2M concept scheme and each collection (and sub collection) based on the profile suppliers and consumers chosen. First of all we decided to include FOAF ´s concepts as it is currently considered as one of the best populated ontologies and is extensively adopted to describe a user and his relations (Ding et al., 2005). "The FOAF ontology is the most widely used domain ontology on the semantic web" (Finin et al., 2005).

We also included concepts of social network user basic profile since these applications have a great popularity among internet users. According to (Nielsen, 2011) social networks continue to dominate American's time online. Although social network user profile is available through dedicated APIs, they do not always provide accurate schemas and documentation. Efforts have been made to semi-automatically derive social network schemas from social network data (Kapsammer et al., 2012). So taking into account schemas provided by Facebook, LinkedIn, Twitter, and Google+, and generated models and diagrams published by (Kapsammer et al., 2012), the concept schemes and concepts were created using Protégé.

First a concept scheme was included for each profile provider or consumer with their concepts related to relevant user profile data. Subsequently a concept is included in the pertinent collection in the U2M concept scheme avoiding redundancy. Mappings are established via SKOS semantic relation object properties using only skos:exactmatch if the concepts are interchangeable. An example of the concept Age set up is shown in figure 2. We finally add concept schemes related to Microsoft Health Vault personal health record and basic observations and measurements. Credentials needed for authentication to both the profile supplier web site and profile consumer, were given explicitly by the user in order to avoid privacy issues.

3.2.2 Ontology Manipulation

The ubiquitous user modeling interoperability ontology (U2MIO) is part of an adaptive Web-based system. The ontology is stored in OWL/XML format and is manipulated by a C# program which includes OwlDotNetApi (Pellens, 2006) created to manipulate OWL ontologies. In order to integrate a ubiquitous user model gathering information from heterogeneous sources and be able to reuse this information, alignment between similar concepts must be done.

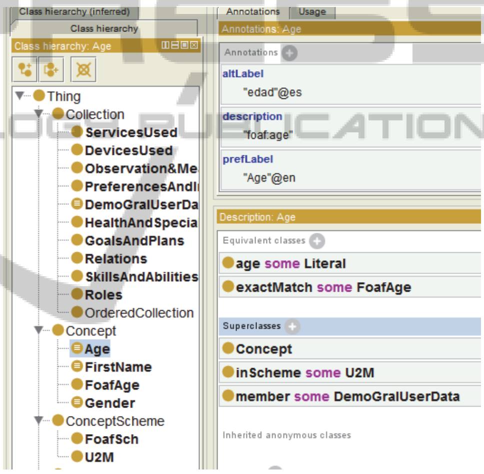

Figure 2: Example of concept set up (AGE).

3.2.3 Process of Concept Alignment for Interoperability in Heterogeneous User Models

The alignment process achieves interoperability between a user model document written or translated to XML (named source) with the ubiquitous user model (named target). The ubiquitous user model (u2m) will provide articulation between heterogeneous profile suppliers/consumers given the mappings from all individual concepts of the document sources with the corresponding ubiquitous user model concepts. The ubiquitous user model can also provide articulation with profile consumers, for example, Web Services' preferred values when they are requested.

We describe the process of alignment between a given concept c_s of the source concept scheme X_s and the best suited for alignment skos:Concept c_{tb} in the target concept scheme X_t.We consider a concept scheme as (C, H_C, V_C) where C is a set of concepts arranged in a subsumption hierarchy H_C. V_C is the set of corresponding concept values available.

Each concept c_s in a set of concept source C_S is defined by a label *string1* and subclass relationships. The attribute or element identifier corresponds to *string1* and it is typically described as a simple or compound word in natural language. The hierarchical structure must be described as a skos:ConceptScheme.

A concept on the target side C_T is described by set of labels included in the target skos:Concept consisting of lexical labelling, notation and documentation SKOS properties.

The alignment process consists of two steps:

a) An element level matching in which concepts are directly compared to each other without considering the hierarchy structure and values. Its goal is given concept c_s of the source concept scheme X_s, find the best concept label c_{tb} from a set of concept candidates for alignment in the target concept scheme X_T.
b) A structure level matching in which context of the source and target concepts are considered. The ultimate goal of this process is determine one-to-one mappings between the concept c_s of the source concept scheme X_s and the best concept c_{tb} from the set of labels C_t of the target concept scheme X_T.

The first step in the element level matching process is finding a set of concept candidates for alignment in the target concept scheme X_T. In order to perform this task a method combining three different similarity methods based on Dice coefficient similarity (Dice,1945), longest common substring and a similarity based in Wordnet lexical base for English language (Fellbaum,2005) is proposed. Each relation between c_s and c_t is classified as equivalent, related or independent based on previous results.

The process of structure level matching consists of three steps:

1. Select the sets of neighbours N_s and N_T from the source hierarchy H_s and the target hierarchy H_t respectively, which define the context of each concept source c_s.
2. Calculate a new similarity matrix between the two sets of neighbours N_s and N_T.
3. Applying a set of IF THEN rules to determine the one-to-one mappings between the concept c_s of the source concept scheme X_s and the best concept c_{tb} from the set of labels C_t of the target concept scheme X_T.

4 DISCUSSION

In set up process, U2MIO ontology was initialized with the core information to represent a generic ubiquitous user model. The user-adaptive Web based system will manipulate the ontology allowing the user modeling interoperability. The process of concept alignment enables the interoperability between individual concepts from a source document and the skos:concepts of the ubiquitous user model ontology.

Our approach differ from standardization-based user modeling ontologies like GUMO (Heckmann, 2005), in which user modeling interoperability participants have to adhere to a standard. Our ontology evolves to adapt itself to new sources and consumers. Systems based on user profile management selection like (Sutterer, 2009) aggregate different versions of the user model and automatically select the best suited version for the user state. This approach implies redundancy and inconsistencies between the user models of heterogeneous sources. As we combine the concepts of the heterogeneous sources in one user model represented by the ontology, the system resolves the conflicts between the semantic meanings avoiding redundancy and inconsistencies. In other mediation based user modeling systems (Van der Sluijs & Houben, 2006) mappings are made by human effort making it hard to include new participants in user modeling interoperability. In (Carmagnola,2009) the authors presents a highly flexible system, but to take part in the interoperability process, every provider need to comply to a standard format for the exchange and maintain a sharable user model which includes the fragments of user model as RDF statements. User modeling systems must do the effort of maintaining a sharable user model in a standard format. In our approach, the effort of syntactic and semantic interoperability is made by the user-adaptive system.

5 CONCLUSIONS

We present U2MIO ontology for user modeling interoperability based in SKOS ontology. The ontology initially includes the core dimensions and profile structure to represent a generic ubiquitous user model, and the user-adaptive system provides the possibility for the user model to evolve during the time it is used. The U2MIO provides mediation based user modeling for sharing and reusing information from heterogeneous user models. A two-tier matching strategy is proposed for the process of concept alignment that permits the interoperability between profile suppliers and consumers .Our on-going and future work includes further research in the automatic transformations needed at instance level in order to establish interchange ability at instance level.

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