Decentralized User Modeling with UserML and GUMO

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Abstract. We present a new architecture for decentralized user modeling and briefly discuss the user model markup language USERML, the general user model ontology GUMO for the uniform interpretation of decentralized user models, and the integration of ubiquitous applications with the `u2m.org` user model service. The motivation is that ubiquitous evaluation of user behavior with a variety of systems in the web or the physical world might lead to attractive new services.

1 Approach and Architecture

We developed the RDF-based user model exchange language UserML to enable decentralized systems to communicate over user models. The idea is to spread the information among all adaptive systems, either with a mobile device or via ubiquitous networks. `UserML` statements can be arranged and stored in distributed repositories in XML, RDF or SQL. Each mobile and stationary device has an own repository of situational statements, either local or global, dependent on the network accessability. A mobile device can perfectly be integrated via wireless lan or bluetooth into the intelligent environment, while a stationary device could be isolated without network access. The different applications or agents produce or use `UserML` statements

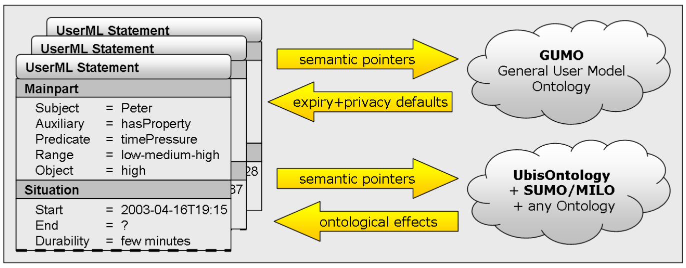

Fig. 1. The syntax-semantics interplay between USERML and GUMO

to represent the user model information. `UserML` forms the syntactic description in the knowledge exchange process, see figure 1. Each concept like the user model auxiliary hasProperty and the user model dimension timePressure points to a semantical definition of this concept which is either defined in the general user model ontology GUMO, the UbisWorld ontology, which is specialized for ubiquitous computing, or the general SUMO/MILO ontology, see [1]. The merging of partial, decentralized user models is realized by combining the different user model repositories, while the inferential integration is done by filters and conflict resolution strategies as shown in figure 2(b). Figure 2(a) and figure 2(c) show the upward and downward inference from repositories or journals to the user model and vice versa.

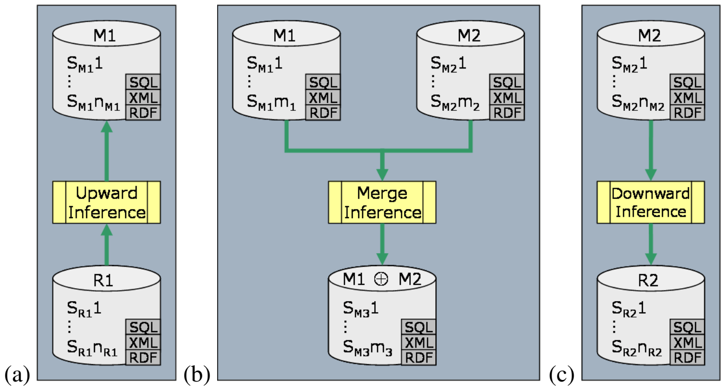

Fig. 2. User model integration with upward inference, merge inference and downward inference

2 The Background of UserML and GUMO

UserML has been introduced in [2] as user model exchange language. A central conceptual idea in USERML's approach is the division of user model dimensions into the three parts auxiliary, predicate and range as shown right below.

$$\texttt{subject}\ \{\,\textit{UserModelDimension}\,\}\ \texttt{object}$$
$$\Downarrow$$
$$\texttt{subject}\ \{\,\texttt{auxiliary, predicate, range}\,\}\ \texttt{object}$$

For example, if one wants to say *something about the user's interest in football*, one could divide this so-called *user model dimension* into the auxiliary part *has interest*, the predicate part *football* and the range part *low-medium-high*. Apart from these so called mainpart attributes, further important meta attributes have been identified for the user modeling domain. These are situation (like start, end, durability, location and position), privacy (like key, owner, access, purpose, retention) and explanation (like creator, method, evidence, confidence). UserML statements need not to use all 25 attributes that have been arranged into groups. However each of these have a predefined meaning on which specialized meta-data inference modules work.

The advantage of using `UserML` to model the user model statements is the uniform syntactical relational data structure that allows apart from the representation in an ontology also the storage of mass data in a database.

GUMO has been introduced in [3]. It is designed according to the approach of dividing basic user model dimensions into triples. The advantage of using GUMO in decentralized settings is the semantical uniformity. Loads of `auxiliaries`, `predicates` and `ranges` have so far been identified and inserted into the ontology that can be inspected with a foldable tree browser at the web page `http://www.gumo.org`. However, it turned out that actually everything can be a `predicate` for the `auxiliary` *hasInterest* or *hasKnowledge*, what leads to a problem if one does not work modularized. The suggested solution is to identify basic user model dimensions on the one hand while leaving the more general world knowledge open for already existing other ontologies on the other hand. Candidates are the general suggested upper merged ontology SUMO, see [1], and the UBISWORLD ontology to model intelligent environments, see `http://www.ubisworld.org`. This insight leads to a modular approach which forms a key feature of GUMO. A commonly accepted top level ontology for user models could be of great importance for the user modeling research community. But which groups of user dimensions can be identified? In [4] and [5] rough classifications for such categories can be found. Furthermore, this ontology should be represented in a modern semantic web language like OWL and thus via internet be available for all user-adaptive systems at the same time. The major advantage would be the simplification for exchanging interpretable user model information between different user-adaptive systems. differences between existing user modeling systems could be overcome. We are collecting the user's dimensions that are modeled within user- adaptive systems like the *user's heart beat*, the *user's age*, the *user's current position*, the *user's birthplace* or the *user's ability to swim*. Furthermore, the modeling of the user's interests and preferences like *reading poems*, *playing adventure games* or *drinking certain French Bordeaux wines* is analyzed. Identified user model `auxiliaries` apart from *hasKnowledge* and *hasInterest* are for example *hasBelieve*, *hasPlan*, *hasProperty*, *hasGoal*, *hasPlan* and *hasRegularity*. User model `predicates` that fit to the `auxiliary` *"hasProperty"* are called *BasicUserDimensions*. Examples are `Emotional States`, `Characteristics` and `Personality`. The following listing presents the concept *PhysiologicalState* defined as `owl:Class`. It is defined as a subclass of *BasicUserDimensions*. A class defines a group of individuals that belong together because they share some properties. Classes can be organized in a specialization hierarchy using `rdfs:subClassOf`.

```
<owl:Class rdf:ID="PhysiologicalState.700016">
  <rdfs:label> Physiological State </rdfs:label>
  <rdfs:subClassOf rdf:resource="#BasicUserDimensions.700002" />
  <gumo:identifier> 700016 </gumo:identifier>
  <gumo:lexicon>state of body or bodily functions</gumo:lexicon>
  <gumo:privacy> high.640033 </gumo:privacy>
  <gumo:website rdf:resource="&GUMO;concept=700016" />
 </owl:Class>
```

Every concept has a unique `rdf:ID`, that can be resolved into a complete URI. The attribute `gumo:privacy` defines the default privacy status for this class of user dimensions. The attribute `gumo:website` points towards a web site, that has its purpose in presenting this ontology concept, to a human reader. The abbreviation `&GUMO;` is a shortcut for the complete URL to the GUMO ontology in the semantic web. `rdf:Desc-`

ription. The attribute gumo:expiry provides a default value for the average expiry which carries the qualitative time span of how long the statement is expected to be valid. In most cases when user model dimensions are measured, one has a rough idea about the expected expiry. For instance, emotional states hold normally no longer than 15 minutes, however personality traits won't change within months. Since this qualitative time span is dependent from every user model dimension, it should be defined within GUMO. Some examples of rough expiry-classifications are:

- physiologicalState.heartbeat - can change within seconds
- characteristics.inventive - can change within months
- personality.introvert - can change within years
- demographics.birthplace - can't normally change at all

The idea behind gumo:expiry is that if no new actual value is available on the user model server after a while, one can still work with old values, probably combined with reduced confidence values. The semantic web ontology language OWL allows to construct complex, graph-like hierarchies of user model concepts with multiple-inheritance, which is especially important for ontology integration. For example, *happiness* is defined as rdf:type of the class *EmotionalState* and *FiveBasicEmotions*. The GUMO vocabulary includes gumo:identifier, gumo:expiry, gumo:image, gumo:privacy, gumo:website, gumo:image and gumo:lexicon. To support the distributed construction and refinement of GUMO, we developed a specialized online editor to introduce new concepts, to add their definitions and to transform the information automatically into the required semantic web language. Related ontologies and knowledge-sharing projects have been analyzed. However, a profound investigation of the possible application of student model standardizations into the domain of ubiquitous computing has to be undertaken.

3 Decentralized and Mobile Services and Applications

A user model *service* manages information about users and contributes additional benefit compared to a user model *server*. The u2m.org user model service consists of a set of application-independent servers with a distributed approach for accessing and storing user information, the possibility to exchange and understand data between different applications, as well as adding privacy and transparency to the statements about the user. Applications can retrieve or add information by HTTP requests like:

```
http://www.u2m.org/UbisWorld/UserModelService.php?
subject=Peter&auxiliary=hasProperty&predicate=Happiness
```

We have tested the approach in a MOBILEMUSEUMSGUIDE, see [6], in a POSITIONINGSERVICE, see [7] and in an ALARMMANAGER application, see [8]. The latter one is a notification service for instrumented environments that adapts the presentation of announcements to the user's state of arousal and the user's location. Both are retrieved from the UserML and GUMO enabled user model service. The location is derived from the POSITIONINGSERVICE application. This service runs on the user's PDA and uses infrared beacons and active RFID tags that are installed in the environment to estimate the location of the user which is then send via WiFi to the user model service. Figure 3 shows three identified conceptual situations to decentralized user modeling.

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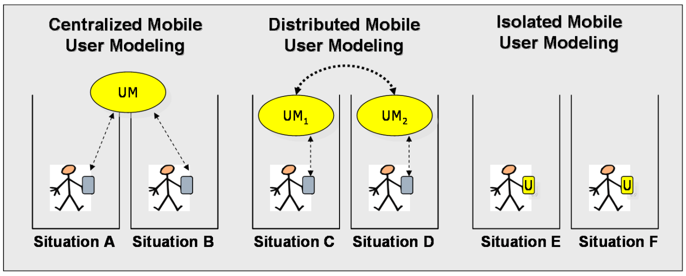

Fig. 3. Concept of Centralized, Distributed and Isolated Mobile User Modeling

Summary & Acknowledgements

We presented architectural modules for decentralized user modeling, especially the user model exchange language `UserML` and the general user model ontology GUMO. We discussed the possibilities for semantic integration and briefly demonstrated the approach with ubiquitous user-adaptive applications. The combination of the GUMO ontology with the exchange language `UserML` together with the decentralized `u2m.org` user model service seems to be promising. This research is supported by the German Ministry of Education and Research (BMB+F) under grant 524-40001-01 IW C03, the project SPECTER and by the German Science Foundation in its Collaborative Research Center on Resource-Adaptive Cognitive Processes, SFB 378, Project EM 4, BAIR.

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