Towards a Reference Model for Social User Profiles: Concept & Implementation*

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ABSTRACT

Despite the recent *spreading of social networks*, which leads to *scattered social user profile* information, current *user models* hardly incorporate social aspects. In addition, user models are often *heterogenous* with respect to *focus* and *coverage*. A *comprehensive view* on social user profiles, however, would be required, for instance, for building sophisticated recommender systems, or to provide users with means to *control disclosure and usage* of their *integrated profile* data. Therefore, we encountered the need for a *reference model*, which can serve as a basis for developing more specialized models and facilitate communication among stakeholders. In this paper we present such a reference model *for social user profiles*, which is *extensible* as well as *comprehensive*. The proposed model provides a *generic core* for extensions, and a comprehensive set of concrete concepts from *existing social networks and user models*, as well as concepts to represent *meta information*. In addition, a first prototypical implementation in terms of an ontology in OWL is discussed.

1. INTRODUCTION

In recent years, online social networks have gained great popularity amongst internet users, serving different purposes and communities (e. g., publishing short messages on Twitter, or establishing professional networks in LinkedIn). As a consequence, the profiles of social networkers, who are often using multiple social networks, are scattered among different sites [2]. In order to create a comprehensive and yet extensible social user profile, which allows the provision of fully personalized services, it is necessary to integrate these specific profiles, firstly, among each other, and secondly, with external knowledge bases, such as DBpedia[1] or Freebase[2], statistics sites, or ontologies from various domains, such as psychology, sociology, or geography.

Prior to this spreading of social networks, in the last 20 years, approaches to model users and their characteristics have been developed for various application areas (e. g., adaptive hypermedia [7], or ubiquitous web applications [17]). *User modeling* approaches, however, have not yet particularly focused on modeling *social aspects of users* [8], although several proposals for representing these social aspects emerged (e. g., using FOAF [2]). At a first glance, some of these user models seem to be employable as basis for integrating social user profiles. Though, previous surveys have shown significant differences between these modeling approaches, concerning focus, coverage, and granularity of supported concepts [8] [31] [32].

In the course of developing a *social user profile ontology* to integrate profiles for our own application [18] we evaluated existing user modeling approaches with respect to potentially useful and reusable concepts, especially focusing on *meta information* (cf. [19]). Thereby, we encountered the need for a reference model to evaluate existing user models and meta information ontologies from different domains with respect to *suitability for social user profile modeling.* Such a reference model shall be comprehensive, thereby include concrete facts from existing social networks and user models, and extensible, to cover further concepts in the future. The terminal goals are to *implement* the model in form of an ontology in OWL, and to make it publicly available for reuse, as well as to employ it for our own application in the domain of social user profiling.

Thus, in this paper, we propose a comprehensive and extensible reference model for social user profiles on a conceptual level, as well as on an implementation level.

2. RELATED WORK

This section gives an overview of (i) approaches addressing user modeling and social aspects, (ii) more specialized approaches stemming from the area of user modeling and social network integration, (iii) and approaches providing relevant concepts with respect to meta information.

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[1] http://dbpedia.org
[2] http://www.freebase.com

The General User Model Ontology (GUMO) [14], one of the most comprehensive user modeling approaches, aims at the simplification of exchanging user model data between different user-adaptive systems based on OWL. GUMO explicitly details on users' characteristics and some meta information, but, though generic in nature, it does not detail on certain social aspects like social relationships.

User Role Model (URM) [35] is an ontology-based user model designed for modeling users and their roles according to the service they accessed. It defines five dimensions including social relationships, which can be extended as needed. However, it disregards meta information and other information not fitting in those dimensions.

The unified user context model (UUCM) [22] is an ontology-based model as well, and a basis for the exchange of user profile information between multiple systems. It is generic and extensible in nature, as it defines a sort of a meta model for concrete information to be captured in the user model. However, expressivity is limited since information needs to be related exclusively to one of four disjoint dimensions: cognitive pattern, task, relationship, or environment. Concepts not fitting those dimensions cannot be expressed. Furthermore, meta information is regarded in a very limited way.

Grapple User Modeling Ontology (GRAPPLE) [3] builds upon GUMO and provides a generic structure in terms of *7-tuples*, which contain, besides subject, predicate, and object, also meta information about its creator, temporal aspects, its evidence, and trust. Being solely generic, it does not predefine the kind of user information to capture, and therefore it cannot be used as a schema.

An effort to identify the *overlap of social user profiles* is presented by Abel et al. [2], investigating on quantitative and qualitative levels, how specific attributes of social networks can be complemented with information provided by FOAF[3] and vCard[4]. Although this work gives valuable indications of the actual complementarities of social networks and some user models, it focuses on a limited set of user properties, only, and does not strive for a comprehensive user model.

With respect to integration of user models Carmagnola et al. [8] focus on architectures for user model interoperability. OntoPIM [20] provides a framework for personal information management dealing with heterogenous data wrapping and personal information. Both approaches, however, do not focus on social aspects.

Regarding the integration of social networks foremost OpenSocial[5] needs to be considered, since it provides a common cross-platform API to access social networks, supported by a series of major providers. Consequently, it covers the major social networks to a large extent, but it is limited to this predefined information, only. In contrast to OpenSocial, San Martín et al. [30] illustrate the potential of employing RDF and SPARQL for representation and querying of social network data.

Finally, interesting works with respect to specific aspects of *meta information*, which we considered in the design of our reference model, include: provenance (describing generation, usage, and changes of resources) [9] [25], user control and privacy [21] [29] [34], context (the environment of a resource) [6] [17] [23], and quality [4] [11] [26].

[3]http://www.foaf-project.org

[4]http://www.imc.org/pdi

[5]http://www.opensocial.org

3. CONCEPTUAL MODEL IN UML

Similar to the reference models we designed for other domains (e. g., aspect oriented modeling [16]), the reference model for social user profiles (cf. Fig. 1) was developed on the one hand in (i) a *bottom-up manner*, adding user features from specific social network APIs (relying on Facebook, MySpace, LinkedIn, XING, and Twitter), general ones (OpenSocial), and user modeling approaches (focusing on social aspects, like URM [35], UUCM [22] [27], or being generic as GUMO [14], GRAPPLE [3], or PAROS [15]), and on the other hand in (ii) a *top-down manner* from literature, including concepts discussed in several existing surveys on user modeling [8] [32] and preference representation in database systems [31]. Fig. 1 contains a simplified overview of *key packages* in the reference model, and shows several *sample classes*, giving a first impression of the rationale behind the design.

In accordance with research on flexible user modeling [1] [2] [31], the conceptual reference model comprises a generic part (cf. package Core), which is capable of covering arbitrary *resources* (entities) and *relations* (relationships). This resembles the generic structure of RDF, which would allow queries in SPARQL, but it does not, however, ascertain any technology decisions. Note, that Relation, while describing relationships between Resources, is an extension of Resource itself, thus allowing relations to *participate in relationships*, as well as to attach *arbitrary meta information* also to *relations* (cf. below).

Extensions to this generic part are specified, firstly, by associating resources with *meta information* (cf. MetaInfo), and secondly, by specializing *resources and relations* to provide specific concepts for the domain of social user modeling.

The package MetaInfo contains several subpackages, incorporating a variety of meta information concepts. Provenance describes generation and usage of resources, constituting their history (cf. [25]). Amongst other topics, Privacy includes access control and permissions, disclosure preferences, and concepts to ensure integrity and anonymity (cf. [34]). Context describes the environment of a resource or relation, such as date and time of a transaction, duration of a statement's validity, location, or hard- and software (cf. [6] [17] [23]). Also Quality of instance data can be measured using various criteria, for instance completeness, consistency, accuracy, relevance, reliability, or verifiability (cf. [4] [26]). Since MetaInfo is a subclass of Resource, meta information can also be attached to meta information. For instance, a user might want to express privacy settings about provenance data, while the system might keep track of provenance about privacy settings at the same time.

In contrast to these domain independent concepts, the package Resource contains a *classification* into concrete domain concepts. For instance, agents are discerned into human users and non-human agents, and Inertia and Changeable are introduced for passive objects and simple data types.

Finally, the package Relation contains several subpackages, distinguishing between various kinds of Universal and Social relations (with Social specializing Universal), which can be structural (Structure) or behavioral (Behavior) in nature. For simplification, the actual specializations of Relation are not shown in Fig. 1. They are illustrated exemplary, however, in Fig. 2 in the appendix. *Universal structural* relations (e. g., a user owning a book, or being described by a par-

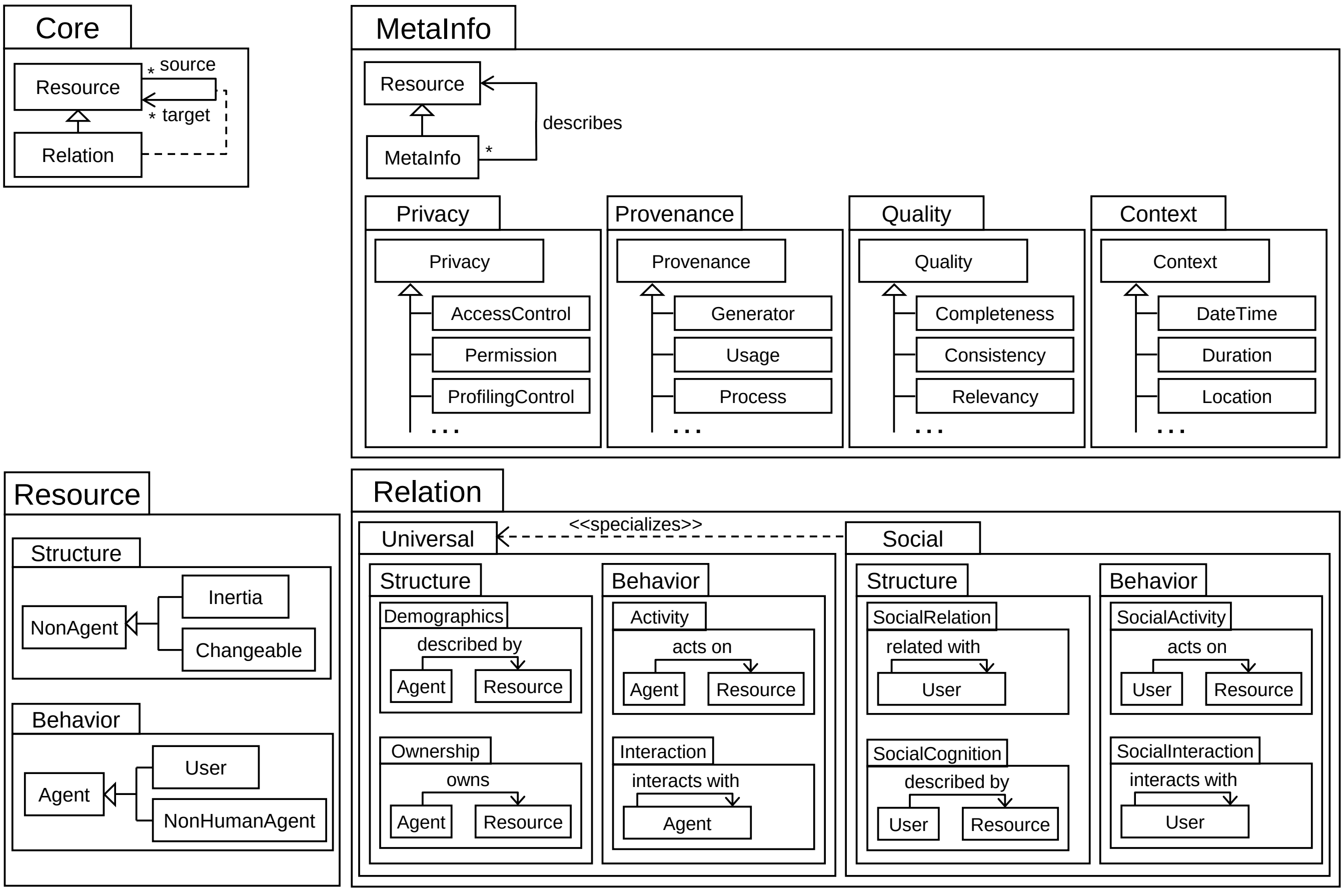

Figure 1: Overview of main packages and classes in the conceptual reference model

ticular age) and *universal behavioral* relations (e. g., agents interacting with each other, or acting on resources in terms of production and usage [12]) characterize the relationships between *agents* and other resources. *Social structural* relations (e. g., users being related with each other, and being described by their personality, desires, preferences, believes, feelings, interests, and tastes [12] [14] [31]) and *social behavioral* ones (e. g., social *activities*, such as studying and working, and social *interactions*, such as chatting and blogging) specialize relationships of and between *users*. These packages may be refined further, according to specific requirements. Examples would be to incorporate emotions and competences, or to classify activities to be either preplanned or environment-driven, and to be either explicit or implicit [10].

A first rough overview of our reference model has been given previously [19], however, lacking the details outlined in this paper, as well as a description of the implementation.

The proposed conceptual reference model may serve as a starting point for building *comprehensive user profiles*. Several *benefits* arise from the fact that the model comprises domain specific extensions of a generic core on different *levels of abstraction*. First, having a *generic core* allows the mapping of arbitrary social network data and user models. If the model does not contain suitable target concepts, such concepts can be added via subclassing of Resource. Alternatively, the generic concepts Resource and Relation can be used to express the source data in a generalized way as well. Second, the hierarchical organization of *domain specific packages* and concepts allows for using the model as a taxonomy, i.e., it aids the *communication among stakeholders* by providing a common vocabulary between users and service providers [24]. In addition, attachment of meta information is thereby facilitated. For instance, a user might want to specify privacy settings on coarse- or fine-grained levels. Setting and querying for such preferences is *less ambiguous* than if only generic resources are being used. Furthermore, computation of *statistic information*, or development of profiler components for profile enrichment and personalization may benefit from such a taxonomy.

4. IMPLEMENTATION IN OWL2

A first prototypical implementation of the model has been realized in OWL2 using Protégé 4.0.2[6]. The model in UML was transformed to RDF in a straightforward manner, basically building a class hierarchy under a generic class Resource. Details and some specifics are dealt with in the following.

For the Core package the generic concepts Resource and Relation were directly translated to classes in RDF. Relation then has two *object properties*, namely hasSource and

[6]The OWL files are available from the TheHiddenU project website at `http://social-nexus.net`. Note that the ontology is still under development and subject to change.

hasTarget. Explicitly modeling relations as classes implies an indirection for relationships. Hence, arbitrary *multiplicities of associations* can be expressed in a clear and coherent manner. It also guarantees, that their instances will have a URI, allowing to directly attach meta information to *arbitrary resources* and relations (cf. previous section). Nevertheless, in order to keep querying as comfortable as possible, direct relations between resources can be inferred using inverseOf and property chains. For instance, isSourceInRelation is defined as the inverse of hasSource, the property chain `isSourceInRelation o hasTarget` may then be used to infer hasRelationWith between two resources, which can then be used in SPARQL queries, given that an appropriate reasoner is present.

Furthermore, concepts for meta information as well as specific extensions for social user profile modeling are realized as subclasses of Resource. To distinguish, for instance, different kinds of relationships between users, such as friendOf and enemyOf (cf. Relationship vocabulary[7]), both of them should be defined as subclasses of Relation. Alternatively, relationships can be asserted directly (restraining, e.g., attachment of meta information), or they may be inferred using a profiler.

Another peculiarity of this design is that simple *data type properties cannot be attached directly* to resources, because then, again, no meta information can be attached to the property (neither predicates nor objects have unique instance identifiers). Therefore, an intermediate resource has to be introduced, which then has an attribute hasValue. For example, a user's name could be expressed using the following namespaces and triples.

```
u = http://social-nexus.net/thu/
m = http://social-nexus.net/meta/
i = http://social-nexus.net/instances/

<i:user35name>        <u:hasValue>  "Jon Arbuckle"
<i:user35havingName> <u:hasSource> <i:user35>
<i:user35havingName> <u:hasTarget> <i:user35name>
```

Hence, *meta information* can be attached, such as the date when the name was set, or the access policy for the relationship of the user having this name.

```
<i:user35havingName> <m:setOn>     "2011-06-06"
<i:user35name>        <m:access>    <m:publicAccess>
```

Alternatively, the access policy for the name can be asserted indirectly, in order to represent the transaction time of setting the policy.

```
<i:user35accessName> <u:hasSource> <i:user35name>
<i:user35accessName> <u:hasTarget> <m:publicAccess>
<i:user35accessName> <m:setOn>     "2010-10-20"
```

Finally, the implementation in OWL allows to *enrich* the profiles using description logics and by employing *reasoners*, either operating on the generic or on domain specific concepts. The data being stored in RDF format significantly alleviates import and usage of additional knowledge bases. Additionally, it facilitates the export of enriched user profiles according to the *Linked Data Initiative.*

[7]http://vocab.org/relationship

5. EVALUATION

One of the key roles of a reference model is that it can be used to develop specialized models, supporting specific requirements and scenarios [24]. In this sense, for the evaluation of a reference model for social user profiles, it is vital to assess the coverage of available data from social networks, and concepts from existing user modeling approaches. Therefore, multiple fine-grained user attributes and profile concepts were classified into the packages of the reference model (cf. Table 1)[8]. Details on *coverage and overlap* of social networks and user models were illustrated previously [19].

Table 1: Mapping of user attributes and user profile concepts to packages of the conceptual reference model.

Package	Concepts
Structure (Universal)	Identification, demographics, ownership
Activity	Participation, production, usage, action
Interaction	Communication
SocialRelation	Friendship (user to user), membership (group)
SocialCognition	Personality, desires, preferences, beliefs, feelings, interests, competence, taste
SocialActivity	Studies, work
SocialInteraction	Blog (user to group), chat (addressed)
Privacy	Access control, policy, permission, preference, integrity, anonymity
Provenance	Artifact, process, agent, usage, generation, control, trigger, derivation, role, originator, submitter, generator
Quality	Completeness, conciseness, consistency, accuracy, timeliness, relevancy, reliability, believability, reputation, objectivity, verifiability, understandability
Context	Location, time, date, duration, software, hardware

Altogether, the evaluation yields *three major findings*. First, the integration of multiple social networks results in more comprehensive user profiles. However, some parts of user profiles are not covered at all. For instance, several social cognition attributes (personality, desires, preferences) are not included in any of the user models we have evaluated, but would be a pre-requisite, for instance, for *sophisticated product recommendation* [12].

Second, social networks keep track of demographic information and support extensive communication facilities around which their focus is built (e. g., work, study, and competence description on LinkedIn; beliefs, feelings, and interests on MySpace; tastes, interests, and events on Facebook). On the contrary, user models are mostly more diverse and focused. Nontheless, two models have a rather broad focus: With respect to *social cognition* GUMO provides a comprehensive set of concepts, however, omitting social relationships, whereas the OpenSocial API complements this view with communication and social interaction concepts.

Finally, as expected, the OpenSocial API is a good overall fit for representing information from the evaluated social networks. In case that a particular focus is of interest, other more specialized models may be more appropriate (e. g., GUMO for representing social cognition information in MySpace; UUCM for representing products in LinkedIn).

[8]Details can be found at http://social-nexus.net.

To complement and extend this evaluation, further examinations and experiments on a more fine-grained level should be conducted, as outlined in the next section.

6. DISCUSSION AND FUTURE WORK

Recently emerged user models, as discussed above, targeting the information available in social networks (cf. [2]), rely on fairly *small sets* of generic concepts in order to achieve extensibility. As a consequence, represented information and queries are either rather *inexpressive*, or are *dependent* on a particular domain extension of the user model. The reference model proposed in this work comprises a generic and extensible core, while at the same time unifying concepts from particular *domains* (in this case user modeling based on social networks). Furthermore, it contains concepts tailored to achieving particular *tasks* (e. g., enforcing privacy policies). Both extensions to generic modeling concepts are ubiquitous in ontology engineering, emphasizing the importance of both, *domain* and *task* ontologies, expressed in terms of an *upper-level* ontology as the basis for developing particular applications [13]. Such ontologies have already been applied successfully, for instance, in the domain of road traffic management [5].

The feasibility of the design of the reference model has been demonstrated by *comparing different social networks and user models*. For a more detailed *future evaluation* categorizations of user modeling approaches and social networks pose to be of assistance (e. g., [28] [33]). To perform queries on *integrated and enriched user profile data*, using vocabularies from established user models, it is necessary to define comprehensive *mappings* from both, current social networks and common user models, to the reference model. Thereby, the transformation of instances should always be to the most specialized class in the class hierarchy, in order not to loose information and keep later queries as simple as possible. If many equal or similar concepts from non-generic models have to be mapped to generic classes (e. g., Resource or Relation), an *extension of the model* should be considered. After executing the mappings with real social network data, *genuine queries* are to be carried out, involving specific concepts, meta information, and external knowledge bases, or computing statistical information on the *entire model*. Besides detailing the requirements for further extensions to the generic core of the reference model, such a query set may additionally serve as a *performance evaluation framework* for social user profiles.

As foundation, we will investigate the right *level of detail* for domain specific extensions (tradeoff between generality and expressiveness). Other open issues are the degree of reusing existing concepts from social networks and user models, as well as the degree of formalization of such a conceptual reference model (i. e., how precise and strict should semantics be specified, e.g., *informal comments vs. exchangeable formalized rules*). Altogether, these concerns have an influence on the comprehensibility and computational complexity of a resulting ontology.

Summarizing, the primal next step will be to complement the conceptual viewpoint on domain concepts and tasks employed by this work, with an *instance and application viewpoint*. Thereby, the focus will be on (i) *domain extensions* by providing an overview on concept coverage of instances in particular social networks (cf. [2] for a first step in this direction), as well as (ii) *task extensions* by providing query sets for each of the meta information packages and for the social user profile domain.

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Appendix

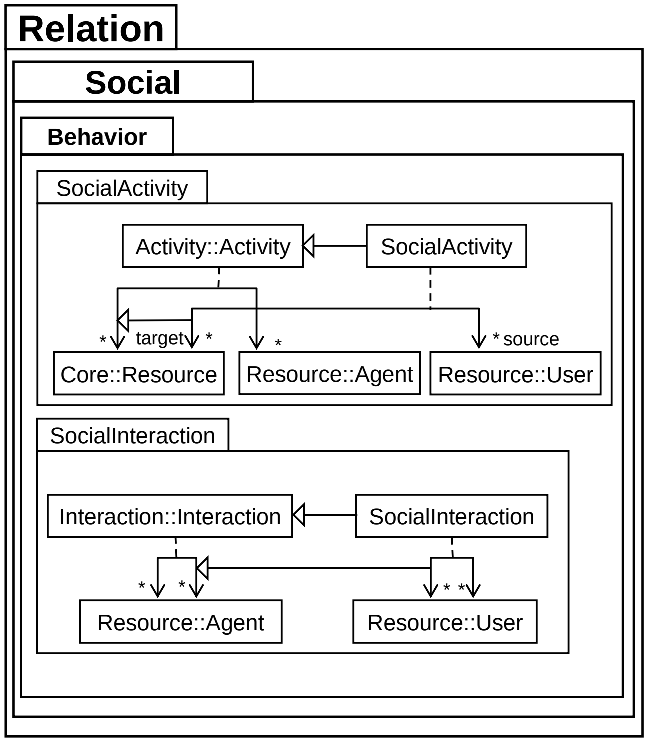

Figure 2: Packages SocialActivity and SocialInteraction with relationship classes shown in detail.