A Multidimensional Semantic Framework for Adaptive Hypermedia Systems

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Abstract

This paper introduces a multidimensional semantic framework for adaptive systems. Different planes allow us to represent ontologies of user, her actions, context, device, domain, while the intersection between planes allow us to represent the semantic rules for inferring new user features or adaptation strategies. The adoption of ontology-based framework aims at creating a server for user modeling and adaptation strategy.

1 Introduction

The Semantic Web aims at representing information in the WWW such that machines can use it for automation, integration and reuse of knowledge across applications. The advantage of such an approach can be particularly useful in the field of adaptive hypermedia systems. These systems typically reflect some features of the user in the user model and apply this model to adapt various aspects of the system (content, interface, navigation, etc) to the user [Brusilovsky, 1996]. Current adaptive systems may also take into account other features, besides the user model, such as the context of interaction, the device, etc. Usually the corpus of the documents and services the system can adapt is already known at the design time and can be defined as a *closed corpus of adaptation* [Dolog et. al, 2004]. The application of Semantic Web technologies to those systems and the use of shared ontologies and metadata to describe resources can contribute to extend the closed corpus to an *open corpus of adaptation.* Thus, external documents and resources, which are semantically annotated, can be considered during the adaptation to the users. Furthermore, representing the user model with a semantic formalism and shared ontologies can be the base for building a user model server: a server that enables the reuse of user models across applications [Kay et al., 2002]. Different adaptive systems can query the same user model server, be primed with the user model that has already built up and share the common knowledge.

This paper describes an ontology-based framework for adaptive hypermedia systems which is aimed at providing a methodological approach for the semantic definition of two kinds of relevant knowledge for adaptation: (i) knowledge regarding what features of the system have to be adapted and which dimensions (of the user, context, etc.) have to be taken into account to perform adaptation; (ii) knowledge regarding adaptation strategies and rules for inferring new knowledge. Following the 'equation' *ontology=(i) taxonomy + (ii) axioms* proposed by the RuleML Initiative [Boley et al, 2001], we represent (i) the declarative descriptions of user models, domain knowledge, etc., with taxonomies expressed in the standard semantic markup language for the Semantic Web, OWL[1], and (ii) the adaptation rules with RuleML[2], a candidate rule markup language.

2. Goals of the project

While many works exploit ontologies to describe application domains and some recent ones adopt them to represent user models, devices features, context of interaction, etc. (e.g., UbisWorld, http://www.u2m.org/), the semantic representation of reasoning strategies is still little addressed in mature projects. Nevertheless, besides the discussed advantages of using standard markup languages for the ontological representation of knowledge, a semantic representation of rules could extend this goal. Indeed, it could allow applications (and designers) to share reasoning strategies, to detect incompatibilities, to validate or eventually refuse them.

Furthermore, the conjunction of *taxonomies* with a semantic representation of *rules* brings benefits to both of them. For example, in adaptive systems, it allows to provide explanations about the inference of new user features, the system behaviour and the forms of adaptation by exploiting the ontological description of terms which are involved in the rules. Moreover, since the semantic representation of rules provides a proof of the reasoning of the system, it is also relevant for the so called *proof layer* of the Semantic Web, which "involves the actual deductive process as well as the representation of proofs in Web Languages and proof validation"[Antoniou et al., 2004].

3. Framework description

[1] http://www.w3.org/TR/owl-features/
[2] http://www.ruleml.org/

The framework aims at supporting the visual design, the semantic representation and the implementation of rules in adaptive hypermedia systems based on symbolic reasoning.
These rules include *user modeling rules* (which can be considered *derivation rules*) that add new knowledge about user, starting from her current environment, usage data and context of interaction, and *adaptation rules* (which can be considered *reaction rules*), that define adaptation strategies (content, presentation, modality).

The choice of using a semantic formalism in order to define the framework arises from the evidence that user modeling dimensions are common to different applications and, if semantically descripted, they can be shared among them (e.g. the feature *user familiarity with the system* is used by almost all adaptive systems). Defining these dimensions once for all represents an interesting opportunity in terms of reducing costs of design and optimization of results. Similar considerations can be made for modality and contexts of interaction. While for the domain and service features, the reason to exploit an ontological representation especially deals with the diffusion of this kind of ontologies on the web, and the possibility to link such ontologies and integrating with Web Services [Mizoguchi et al, 1997].

For the definition of this semantic framework we developed a multidimensional matrix [Torre, 01] in which *each plane* contains the *ontological representation of a specific kind of knowledge* (user model, user actions, device, domain, context and adaptation ontology).
Being a framework, the ontologies on the planes are application independent, modular and layered in a first level ontology, containing the definition of general concepts, and successive levels with specialized concepts. In this way, the framework can be used by different applications, selecting a sub-part of the most generic ontology, in the considered planes, and instantiating only the concepts they are interested in.

The basic idea of the matrix is that derivation rules and reaction rules derive from the intersection of planes and that the matrix representation helps the visual design of such rules. For example, for the definition of derivation rules, on the X_1-plane we put the ontology which describes the *user actions* on adaptive system (selection, bookmark, print, etc.); on the X_2-plane the ontology which describes the possible *domain features* (business, tourist, e-learning etc); and on the X_3-plane, the ontology of the *user model dimensions* (demographic features, preferences, interests, etc).
From the intersection of dimensions on these planes we can define user modeling rules (derivation rules), in the form of:

If *((X_1Plane user actions=a)* ***AND*** *(X_2Plane domain_feature=b)*
AND*(X_3Plane explicit_user_features=c,d))*
Then *(inferred_user_feature=i)*

in which the *Left Hand Side* specifies the dimensions that contribute to define the value of the inferred feature and the *Right Hand Side* represents the assignment of this value.

The same methodology can be applied to infer other dimensions, such as, user's goals and plans, or to define the adaptation rules, clearly changing the planes to take into account. For instance, to identify adaptation rules, on the Z_1-plane we put the ontology that describes the *device* that can be used by the user (PDA, PC, mobile phone, on-board system etc.); on the Z_2-plane we put the ontology of the *adaptation* (adaptation of content, interface, etc.); on the Z_3-plane, the ontology of context conditions (e.g. driving, walking, night, etc.) and on the Z_4-plane, the ontology of the *user model dimensions*, integrated/updated with the user's dimensions inferred by the previous user modeling rules.

The ontologies on the planes are written in OWL, while rules, at the intersection of planes, are written in RuleMl. Both of them can be translated into popular rule engines such as CLIPS and Jess.

Conclusion and Future Work

In future we plan to use the proposed methodology with different adaptive applications (e.g., [Amendola et al., 2004]) we developed in the past in order to use these applications as test bench to evaluate the correctness of our approach.

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