A CASE STUDY ON DOMAIN ANALYSIS OF SEMANTIC WEB MULTI-AGENT RECOMMENDER SYSTEMS

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Abstract: The huge amount of data available on the Web and its dynamic nature is the source of an increasing demand of information filtering applications such as recommender systems. The lack of semantic structure of Web data is a barrier for improving the effectiveness of this kind of applications. This paper introduces ONTOSERS-DM, a domain model that specifies the common and variable requirements of Recommender Systems based on the ontology technology of the Semantic Web, using three information filtering approaches: content-based, collaborative and hybrid filtering. ONTOSERS-DM was modeled under the guidelines of MADEM, a methodology for Multi-Agent Domain Engineering, using the ONTOMADEM tool.

1 INTRODUCTION

Recommender systems suggest items of user´s interests using information filtering techniques (Adomavicius and Tuzhilin, 2005), which can be classified in:

- Content Based Filtering (CBF), where an item is recommended in terms of its similarity with other items that the user evaluated positively in the past.
- Collaborative Filtering (CF), where an item is recommended according to the last preferences of other users with similar interests.
- Hybrid Filtering (HF), where the two previous filtering approaches are combined.

The effectiveness of recommender systems is limited in some environments, such as the Web, due to lack of semantic mark up of the information contained in this environment. An approach to this problem is the Semantic Web, where the information is represented in knowledge representation structures like ontologies.

This work describes the domain modeling task of the MADEM ("Multi-agent Domain Engineering Methodology") methodology (Girardi and Marinho, 2007) and introduces ONTOSERS-DM, a domain model that specifies the common and variable requirements of a software family of multi-agent recommender systems based on the Semantic Web technologies.

The paper is organized as follows. In section 2, an overview of the domain analysis phase of the MADEM methodology is introduced. Section 3 describes the development of ONTOSERS-DM. Section 4 analyses some related work on similarly developed domain models and on the application of the Semantic Web technologies in recommender system development. Finally, section 5 concludes this paper with a discussion on further work being conducted.

2 AN OVERVIEW OF THE MADEM DOMAIN ANALYSIS PHASE

The modeling concepts of the MADEM methodology as well as its products are represented as instances of the ONTOMADEM ontology, a knowledge-based tool that supports the modeling tasks of MADEM (Girardi and Leite).

The modeling concepts, tasks and products of MADEM are based on techniques for Domain Engineering and Multi-agent System Development. MADEM is divided in the domain analysis, domain

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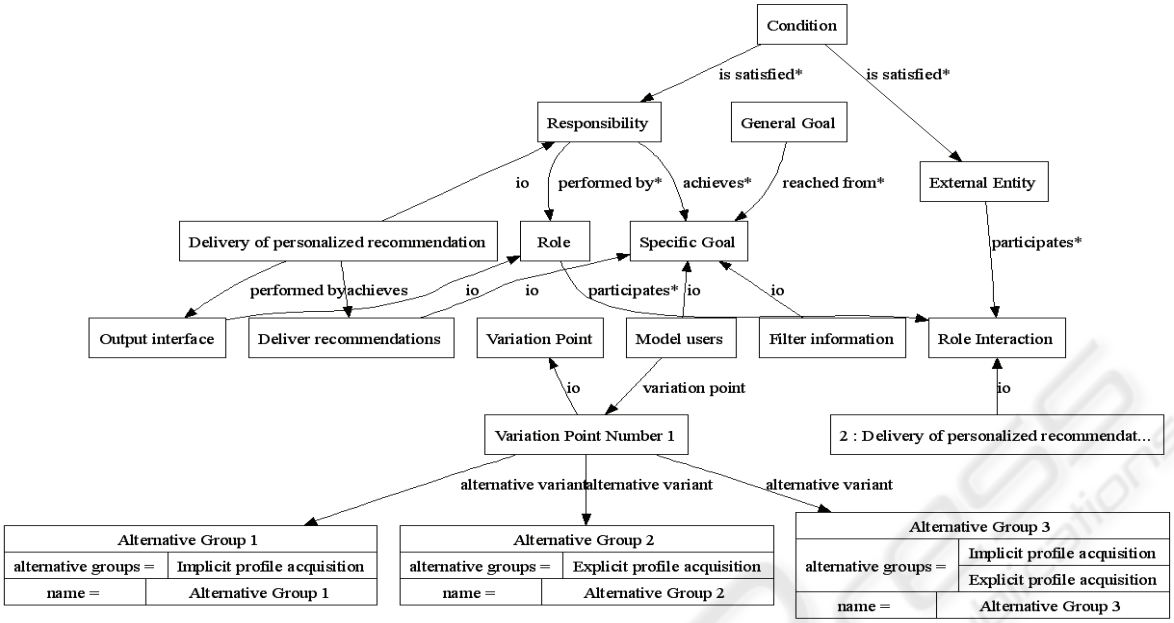

Figure 1: Some relationships between concepts and its instances in ONTOSERS-DM.

design, domain implementation and pattern extraction and representation phases. Each phase has its respective set of tasks and generated products. The domain analysis phase consists of the concept modeling, goal modeling, role modeling, role interactions modeling and user interface prototyping tasks (Table 1). The concept modeling task represents a brainstorming of main domain concepts. The goal modeling task represents the general goal, external entities and specific goals. The role modeling task represents the detailing of each specific goal, with indication of the associated roles, knowledge, pre-conditions, post-conditions and external entities. The role interactions modeling task defines how the roles cooperate to achieve their goals. The user interface prototyping task aims at constructing a prototype of the requirements expressed in the Goal, Role and Role interactions models. Variability modeling is carried out in parallel with goal, role and role interactions modeling to determine the common and variable parts of an application family. This is done by identifying the "Variation Points" and its correspondent "Variants". A variation point is the representation of a concept subjected to variation. A variant represents the alternative or optional variations of such concept. For example, in Figure 1 the "Variation Point 1" indicates that the specific goal "Model User" has three alternative variants, being each variant an instance of the "responsibility" concept. A general goal is reached from the execution of a set of specific goals (relationship "reached from" of Figure 1). Specific goals are reached from the execution of responsibilities (relationship "achieves"). A specific goal can have as variation points responsibilities that are selected according to the characteristics of each particular application.

In the example of Figure 1, the "Model users" specific goal has a variation point with alternative groups of responsibilities for user profile acquisition, being possible choosing between three variants: "Implicit Profile Acquisition", "Explicit Profile Acquisition" or both. Each role is in charge of one responsibility (relationship "performed by"). Pre-conditions and post-conditions must be satisfied (relationship "is satisfied"). The participant entities can be external, that interact with the system, or internal who play roles (relationship "participates").

3 DOMAIN ANALYSIS OF ONTOSERS-DM

This section describes the development of the tasks and their respective products, of the domain analysis phase of the MADEM methodology for the construction of the domain model ONTOSERS-DM.

Table 1: Resources, tasks and products of the domain analysis phase of the MADEM methodology.

Phases	Tasks		Products	
Domain Analysis	Concept Modeling		Concept Model	Domain Model
	Variability Modeling	Goal Modeling	Goal Model	
		Role Modeling	Role Model	
	Role Interactions Modeling		Role Interactions Models	
	User Interface Prototyping		User Interface Prototype	

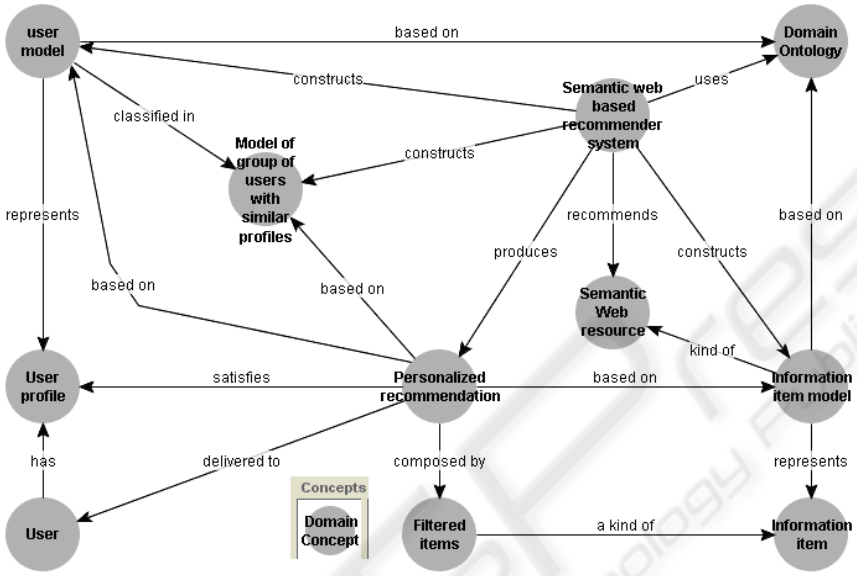

Figure 2: Concept Model of the ONTOSERS-DM.

3.1 Concept Modeling

The Concept Model of the ONTOSERS-DM is illustrated in Figure 2. The main difference between traditional recommender systems and the "Semantic Web-based Recommender Systems" are that the last one uses "Information Item Models" that are a kind of "Semantic Web Resources". This way, they take advantage of the Semantic Web technologies to represent "Information Item Models" and "User Models" as instances of a "Domain Ontology". A "Personalized Recommendation" is constructed based on an "Information Item Model" and "User Models". In the case of Content-Based Filtering, the recommendation is based on an "Information Item Model". In the case of Collaborative Filtering, the recommendation is based on a "Model of Group of Users with Similar Profiles". A "Personalized Recommendation" satisfies a "User Profile". Such recommendation is composed by "Filtered Items" and is delivered directly to the user.

3.2 Goal Modeling

Figure 3 represents the goal model of ONTOSERS-DM. The "Provide Recommendations using Semantic Web Technology" general goal is reached through the "Model Users", "Filter Information" and "Deliver Recommendations" specific goals. Figure 4 shows the variation points of the specific goals defining the variability of the responsibilities needed to reach this goal. In order to achieve the "Filter Information" specific goal, it is necessary to perform the "Ontology Instance User Model Creation and Update" responsibility, which also contributes to reach the "Model Users" specific goal. Besides that, the "Grouping of user models", "Information Items based on Ontology Instance Representation" and "Similarity Analysis" responsibilities are needed. The "Grouping of Users Models" responsibility allows identifying groups of users with similar interests.

The "Information Items based on Ontology Instance Representation" allows representing information items in a structure that can be processed by software agents. The "Similarity

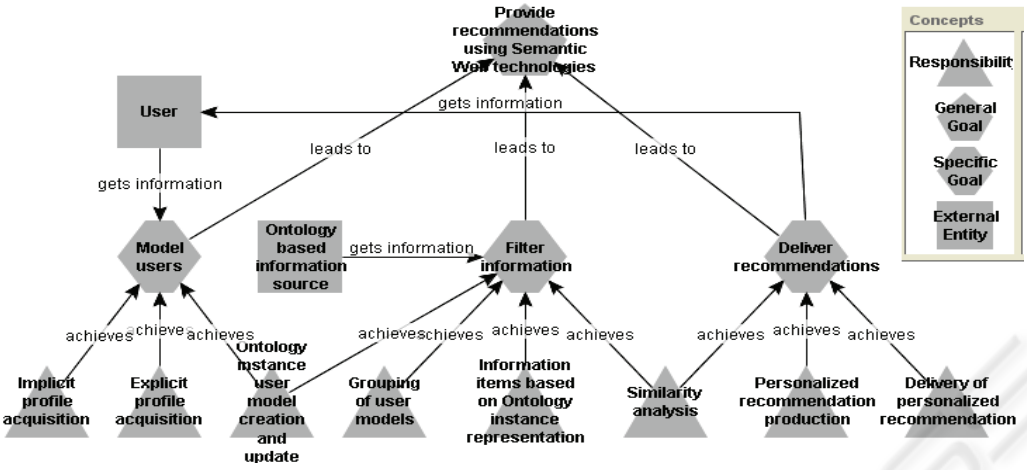

Figure 3: Goal Model of ONTOSERS-DM.

Analysis" responsibility looks for determining the relevance of a given item for a user. The "Filter Information" specific goal has a variation point that has as variant alternatives: the "Grouping of users models" responsibility, required in systems that use CF; and the "Information Items based on Ontology Instance Representation" responsibility in the ones using CBF. To reach the "Deliver Recommendations" specific goal is necessary to perform the "Similarity Analysis" responsibility. The "Deliver Recommendations" specific goal is also reached through the execution of the "Production of Personalized recommendations" and "Deliver Personalized Recommendations" responsibilities. The "Model Users" specific goal has a variation point with groups of responsibilities for user profile acquisition, being possible to choose between three alternative variants: "Implicit Profile Acquisition", "Explicit Profile Acquisition" or both. The last responsibility, "Ontology Instance User Model Creation and Update" is fixed, i.e. it is required in all the applications of the family. The "Deliver Recommendations" specific goal does not have variation points, therefore the "Similarity Analysis", "Personalized Recommendations Production" and "Delivery of Personalized Recommendations" responsibilities are required in all the applications of the family, then belonging to the fixed part of the goal model.

3.3 Role Modeling

In the Role Modeling task, each one of the responsibilities identified in the Goal Model is assigned to an internal entity playing a role. This is expressed in a Role Model. Each role responsibility requires the usage and the production of certain knowledge and the fulfillment of pre-conditions and post-conditions. Figure 5 shows the role model related to the "Model Users" specific goal. The "User Monitor" role plays the "Implicit Profile Acquisition" responsibility. This responsibility has the pre-condition "User is connected". The "Explicit Profile Acquisition" responsibility, associated to the "Input Interface" role, can be performed if the "User filled a form" pre-condition is satisfied. This responsibility produces a "User Profile" and has a "User Profile Acquired" post-condition. To execute the "Ontology Instance User Model Creation and Update" responsibility, the "User Modeler" role uses a "User Profile" and produces an "Ontology based User Model" thus having the "User models are created" post-condition satisfied.

Figure 6 shows the Role Model related to the "Filter Information" specific goal. The "Grouping of User Models" responsibility is executed by the "Miner" role. This responsibility uses a "User Model" and produces "Groups of Users Models" thus satisfying the "Groups Available" post-condition. When a "New Item of Information is available" pre-condition is satisfied, the "Information Item based on Ontology Instance Representation" responsibility is exercised using a "New Information Item" and producing an "Information Item Model", thus satisfying the "Information Item is represented" post-condition.

The "Similarity Analysis" responsibility is executed by the "Filter" role for determining how much an information item can satisfy the information needs of a user, represented in a User Model.

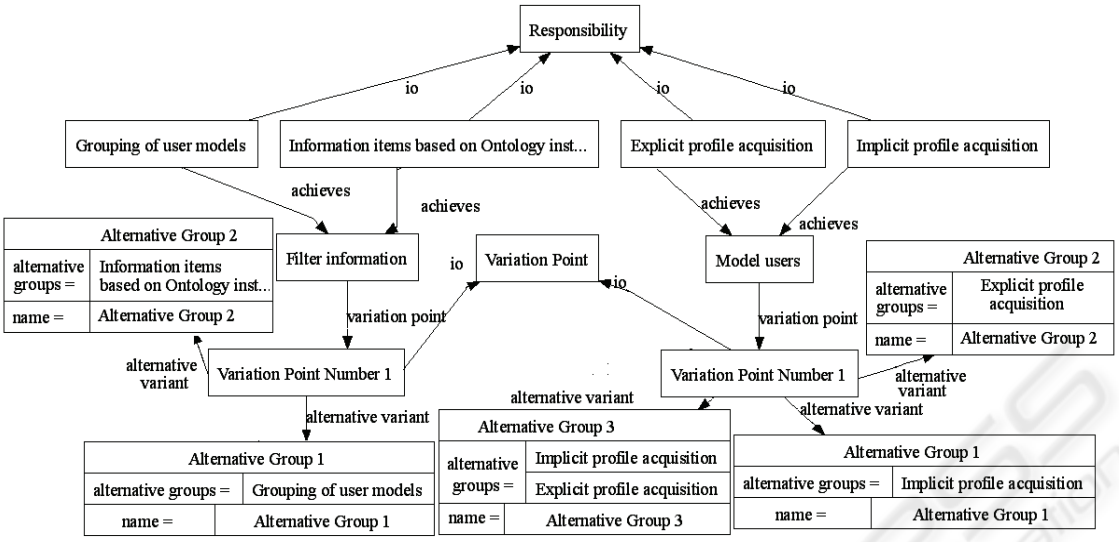

Figure 4: Variation Point of the Specific Goal Model Users.

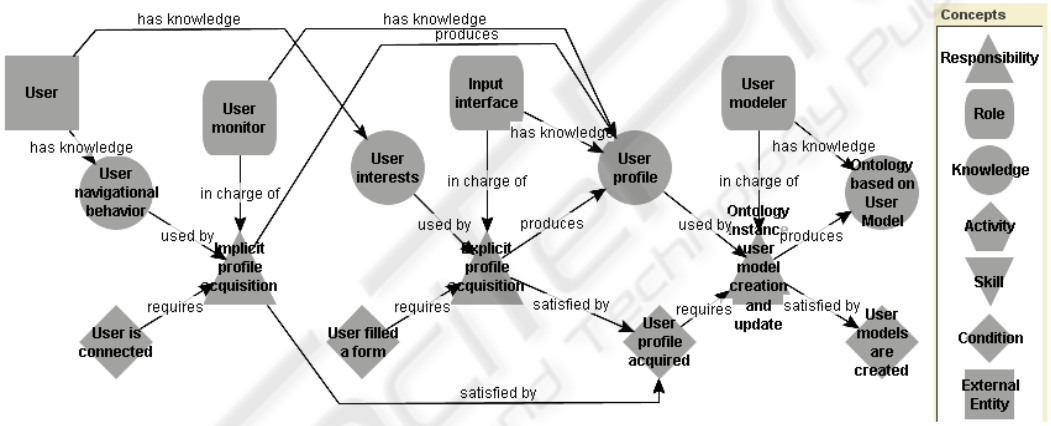

Figure 5: Role Model of the “Model Users” Specific Goal.

This responsibility uses a “Groups of Users Model” and/or an “Information Item Model” and produces a set of “Filtered items”. The “Deliver Recommendations” specific goal is reached through the performance of the “Similarity Analysis”, “Personalized Recommendations Production” and “Delivery of Personalized Recommendation” responsibilities, executed respectively by the Filter, Selector and Input Interface roles (Figure 7).

3.4 Role Interactions Modeling

Each one of the Role Interactions Model shows the interactions between the internal and external entities related to each specific goal. The interactions are numbered according to their sequencing.

Figure 8 shows the Role Interaction Model related to the "Model User" specific goal. The Monitor role captures user navigational behavior. A user profile, acquired implicitly, is transferred to the “User Modeler” role so that it can create a user model. Another alternative is explicit profile acquisition in which the user explicitly specifies his/her interests through the “Input Interface” role that sends the profile to the “User Modeler” role. The alternative responsibilities of the specific goals determine alternative interactions between roles. During the role interactions modeling new variation points are associated to the specific goals containing variant groups of role interactions. For the “Model Users” specific goal (Figure 9) the variation point “Variant Point Number 2” was created having as variants a set of role interactions according to the variant responsibilities associated to this goal.

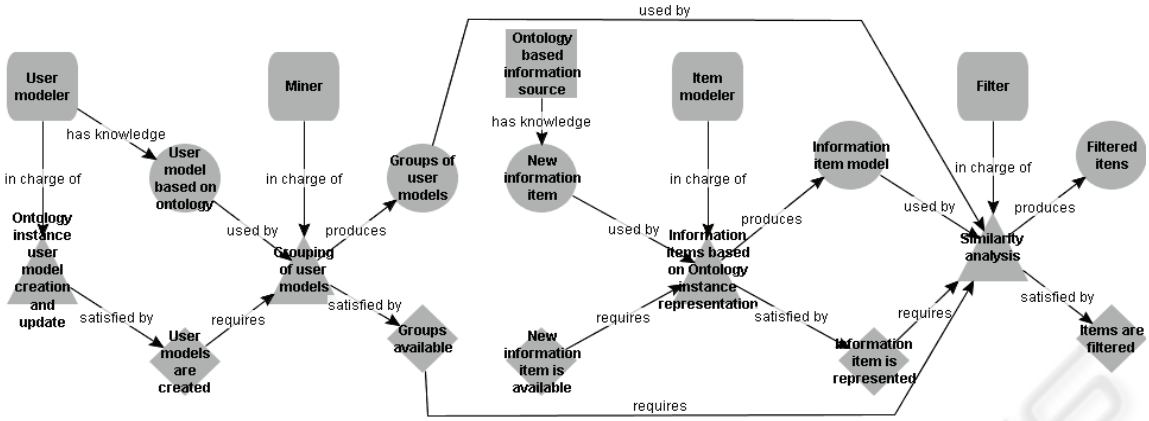

Figure 6: Role Model of the "Filter Information" Specific Goal.

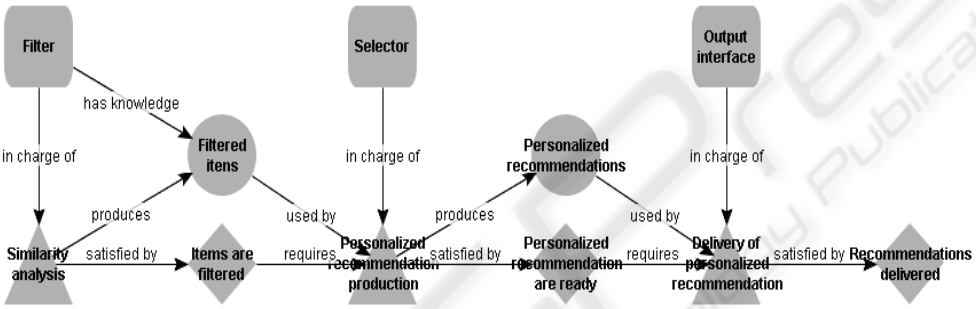

Figure 7: Role Model of the "Deliver Recommendation" Specific Goal.

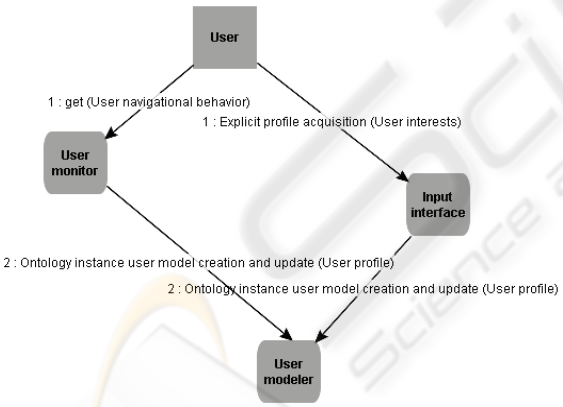

Figure 8: Role Interactions Modeling related to the "Model Users" specific goal.

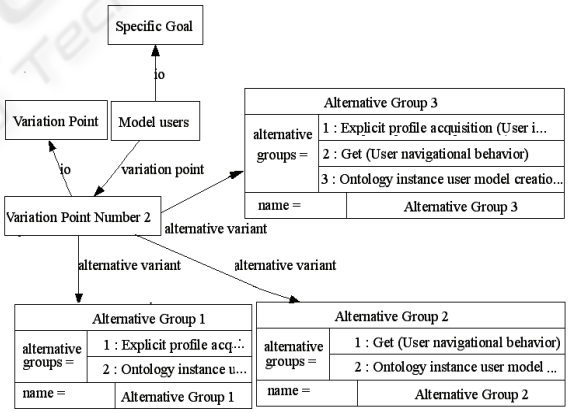

Figure 9: Variability modeling of role interactions associated to the "Model users" specific goal.

3.5 User Interface Prototyping

This phase aims at creating generic screens that will guide the construction of the user interfaces of the applications reusing ONTOSERS.

In the login interface (Figure 10) the user informs his/her login and password in order to be identified by the respective User Interface agent.

Figure 10: User Interface Prototype (Login).

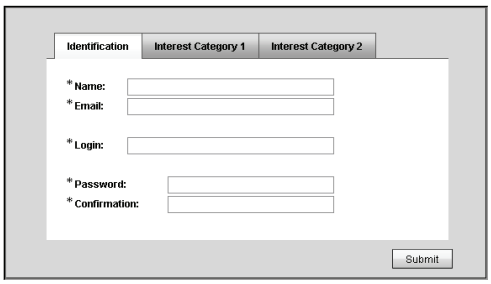

Figure 11: User Interface Prototype (User Identification).

Before logging into the system, the user needs to specify its profile, which is composed by the identification and interests of the user. Figure 11 shows the user interface prototype for specifying the user identification, composed by the name, e-mail, login and password of the user.

User interests are organized into categories. The User Interface Prototype for specifying the interests within a certain interest category is shown in Figure 12.

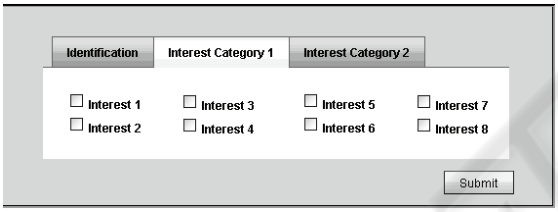

Figure 12: User Interface Prototype (Interest Category 1).

The Personalized Recommendation Interface prototype presents to the user the recommended items, with their identification and the similarity with the user model (Figure 13). By clicking on the information item users can visualize all its content.

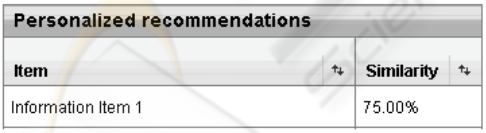

Figure 13: Recommendation Interface Prototype.

4 RELATED WORK

A domain model similar to the one described in this work is presented in Girardi and Marinho (2007). ONTOWUM-DM is a domain model that describes the requirements of recommender systems based on use mining and collaborative filtering. ONTOSERS-DM extends this model, incorporating the responsibilities associated to explicit user profile acquisition, content based filtering and hybrid filtering. Also, ONTOSERS-DM is based on Semantic Web information sources. Thus, the reuse potential of the model is improved by increasing the variable part of the model thus allowing the generation of a greater number of recommender systems based on the different available techniques. Also, ONTOSERS-DM was developed using a new version of the MADEM methodology and the ONTOMADEM tool (Girardi and Leite, 2007, Girardi and Marinho, 2007).

Semantic Web technologies make use of ontologies which are a formal and explicit specification of a conceptualization (Gruber, 1995). Some works already explore the potential of the ontologies and Semantic Web technologies for the improvement of the effectiveness of recommender systems. Middleton et. Alii (2002) developed an approach for user modeling based on ontology inferences, representing the user profiles in terms of an ontology of scientific articles. In Ziegler (2004) and Ziegler et al. (2004) is introduced an approach for hybrid information filtering, that computes the user profiles and generates recommendations based on a product taxonomy. A similarity measure between concepts expressed using description logics is introduced in Fanizzi et al. (2005). As description logic is the formalism for ontology representation, such similarity measure can be applied for information access in the Semantic Web. ONTOSERS-DM is a specification of the requirements of applications based on these techniques.

5 CONCLUSIONS

This work introduced ONTOSERS-DM, a domain model that specifies the common and variable requirements of recommender systems based on the Semantic Web technology. The variability of the concepts related to user modeling and information filtering was described. ONTOSERS-DM was constructed following the guidelines of the MADEM methodology with the support of the ONTOMADEM tool (Girardi and Leite, 2007). The modeling process revealed being consistent and capable of generating products with high potential of reuse.

Currently we have finished the architectural, detailed design and implementation models of ONTOSERS, where a solution for the requirements

specified in ONTOSERS-DM was mapped to a multi-agent framework.

The ONTOSERS system family was reused in the construction of a recommender system in the area of Tax Law, according to the guidelines of the MAAEM methodology (Lindoso, 2006a, Lindoso, 2006b, Girardi and Lindoso, 2005). Such system is called INFOTRIB and supports collaborative and content based filtering. We are currently working on its extension in order to support also hybrid filtering techniques.

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