A Multi-domain Hybrid Recommender Systems Based on a Dynamic Contextual Ontological User Profile

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1 STAGE OF THE RESEARCH

The aim of research presented here is creation of a multi-domain hybrid recommender system based on a dynamic contextual ontological user profile. Recently, we have built a contextual ontology for representing user preferences. The next step that need to be undertaken is validation of correctness and completeness of this idea of representing a user profile.

We consider three context parameters: location, time and user mood. The validity of these parameters, and hence, their impact on user preferences, has been confirmed by the results of a survey among users of recommendation systems. The research on knowledge aquisition and new recommendation algorithms is still in the early stages.

2 RESEARCH PROBLEM

The area of recommender systems is well established but scientists and engineers still try to improve quality and diversity of recommendations. Some of research questions in this field that still can be addressed are:

- How can system automatically aquire and continuously improve user profile?
- What impact on the recommendations quality has a user context?
- How to append a contextual data to the user profile?

During our research we will try to answer those and some additional questions:

- Does the way of describing user preferences in the form of contextual ontology significantly improve the quality of recommendations in comparison to known methods?
- How do we measure similarity of two contextual ontologies?
- Does removal of some concepts reduce the possibilities of reasoning from contextual ontology?

3 OUTLINE OF OBJECTIVES

The objectives of presented research is to develop new methods and algorithms in the field of recommender systems. Our main goal is novel approach to modeling user preferences. We plan to derive an algorithm for user preferences aquisition. This algorithm will create a new profile ontology based on the gained information and a „metaontology" from which needed concepts and roles would be extracted. Due to the new representation of a user profile, new recommendation algorithms need to be developed. The method of comparing two contextual ontologies is also needed.

4 STATE OF THE ART

The role of recommender systems is to give possibly the most adequate recommendations to users in different situations. Scientists try to include a user context in recommendation algorithms to give more adequate results to users (Adomavicius and Tuzhilin, 2011). There are several deffinitions of what the context is. In the rest of this paper as a context we understand "any information that can be used to characterize the situation of a person, place or object that is considered relevant to the interaction between a user and application" (Blefari-Melazzi et al., 2007).

Another trend in the field of recommender systems is to apply ontologies to capture user preferences. It has been proved that ontological user profile improves recommendation accuracy and diversity (Su et al., 2012).

Recently, some context-aware recommender systems using ontologies for making recomendations have been developed and reported. AMAYA recommender system that allows management of contextual preferences and contextual recommendations was proposed (Räck et al., 2006). AMAYA also uses an ontology-based content categorization scheme for mapping user preferences to entities to recommend.

News@hand, a hybrid recommender system for ontology-based personalized and context-aware recommendations of news items was presented in (Cantador et al., 2008). The news items are automatically and periodically retrieved via RSS feeds and annotated with semantic concepts from system domain ontologies. During an interaction with the user a set of weighted concepts from the domain ontologies is collected. A user context is represented by this set. The importance of concepts fades away with the time by a decay factor. This helps to keep the user context up to date. Existing relations between concepts in the ontologies are used to find semantic paths linking preferences to context.

A context-aware system which recommends Web services to users was described in (Rodriguez et al., 2013). The main idea is using a multi-dimensional ontology model to describe Web services, a user context and an application domain. The multi-dimensional ontology model consists of a three independent ontologies: a user context ontology, a Web service ontology and an application domain ontology, which are combined into one ontology by some relations between concepts from different ontologies. Data from a WSDL file for a Web service are automatically added into the Web service ontology during the registration process. The user must specify the name, birth date, sex and occupation to build his profile. The user context ontology consists of those parameters and a list of interests. Every item of the list has a level of interest property, which is used to assign a weight to the item during the recommendation process.

5 METHODOLOGY

In this section we describe an idea of a contextual approach to an ontological user profile (Subsection 5.2). First, we need to define the contextual ontology which is done in Subsecion 5.1. The general architecture of the proposed system is presented in Subsection 5.3. A description of planned experiments and future research close this section.

5.1 Structured-interpretation Model

Contextual ontology introduced in (Goczyła et al., 2007) enables us to model different situations in which a user could find himself as a set of ontological modules. As an ontology we mean here a Description Logics (DL) ontology which consists of a terminology (TBox) and a world description (ABox). As a *context* we understand a part of TBox defined by values of a set of contextual parameters. The contexts are arranged in an inheritance hierarchy. More specialized terminologies may ,,see" more general ones, but more general terminologies are unaware of the existence of more specialized ones. To deal with possible different assertional parts of the knowledge base we can create many ABoxes for one terminology. These ABoxes are called *context instances*. To allow for a flow of conclusions between context instances, the context instances are connected by relation of aggregation. This approach to modularization, described in details in (Goczyła et al., 2012), is called *Structured-Interpretation Model* (SIM) and is illustrated in Fig. 1.

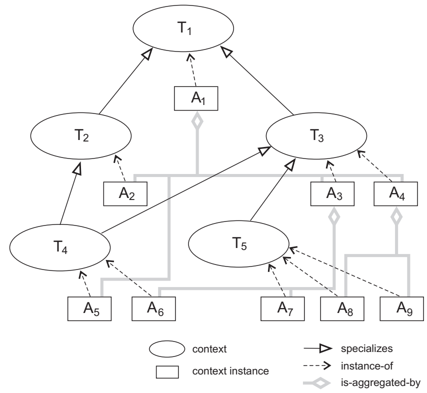

Figure 1: Structured-Interpretation Model (from (Goczyła et al., 2007)).

To explain how the contextual ontology works we use a simple example taken from (Waloszek, 2010). Let assume that an ontology consists of two contexts (TBoxes) and three context instances (ABoxes). Context T_1 provides concept *Can_resuscitate* from which concept *Doctor* inherits. *Doctor* is a concept provided in the terminology of context T_2. Context instances A_2 and A_3 describe a situation of an individual called *john_doe* from different points of view: he is a doctor in Poland but legally he is not a doctor in United Kingdom. Assertions $Doctor(john\_doe)$ and $\neg Doctor(john\_doe)$ are contradictory, nevertheless the ontology is consistent. It is because the concept *Doctor* is defined below the context instance A_1 which aggregates context instances A_2 and A_3. The concept *Can_resuscitate* is immanent for the context T_2 because it is defined on the level of the context instance A_1. Therefore the conclusions reflecting the fact that John Doe can resuscitate can flow between the two contexts (in Poland and in the United Kingdom). This example is shown in Fig. 2.

Another example is shown in Fig. 3. Here we have three contexts: T_1 that describes general notions of *Woman* and *Man*, T_2 that specializes T_1 towards description of voices in a choir, and T_3 that also specializes T_1 but towards description of social relations.

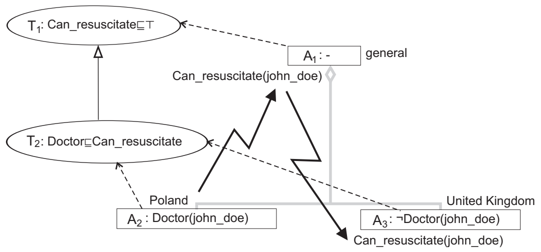

Figure 2: An example of SIM ontology (based on (Waloszek, 2010)).

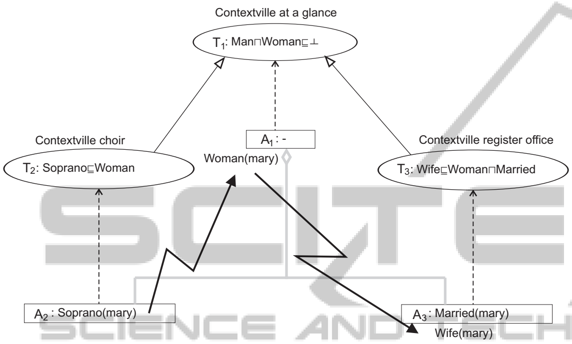

Figure 3: An example of SIM ontology (from (Goczyła et al., 2012)).

Context instance A_1 aggregates context instances A_2 and A_3. Although ABox of A_1 is empty, interpretation $\mathfrak{I}_1$ in order to be a model of the knowledge base has to assign Mary to the concept *Woman*. As a consequence of this, the same rule enforces that in the interpretation $\mathfrak{I}_3$ Mary is assigned to the concept *Wife*, as the information about Mary being a woman "flows" down the aggregation relationships." (Goczyła et al., 2012).

As we could see from the above examples, an ontology built according to SIM enables us to model complicated structure of user preferences depending on the context in which the user currently is.

5.2 Contextual Approach to Ontological User Profile

A user profile keeps all the information about user preferences. For assuring context-awareness in our recommender system, it is crucial to embed contextual parameters into a user profile. To this aim, we propose a new representation of a user profile as a contextual ontology.

We consider three contextual parameters: location, time and mood - which divides a profile ontology into context modules. By location we mean the place and other circumstances that affect the user activity, in particular: Is he at work? Or at home? Or on holidays? It is important to know if the user is at home or at work to make appropriate recommendations. For example, assume that we want to recommend some books to a Java developer who is know to have a daughter. We do not want to recommend him a book with fairy tales when he is at work, but we want to do that when he is at home. Instead, we want to recommend him a book about a new framework in Java when he is at work.

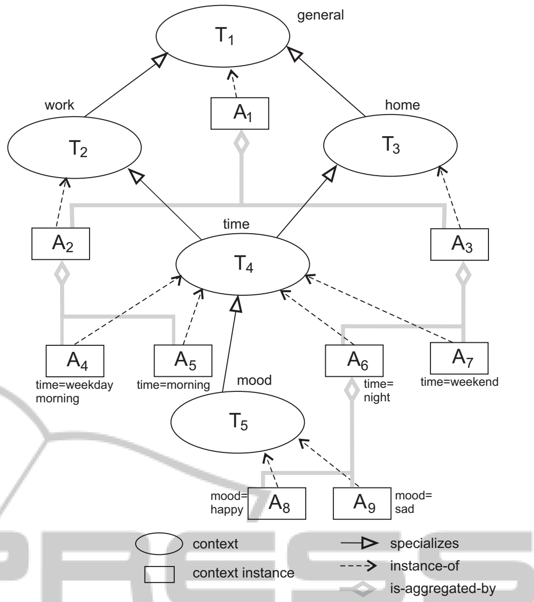

Figure 4: The general idea of a contextual user profile ontology (based on (Goczyła et al., 2007)).

The location parameter is a special parameter in our approach. Different values for this parameter require different terminological parts, thus we limited possible values to the following two: *at home* and *at work*. It is shown in Fig. 4.

The time parameter is considered in two dimensions. The first one specifies if the current day is a weekday or a weekend day. The second one specifies the part of day: morning, afternoon, evening and night. Such a division is justified by the fact that normally we are searching for different things on the Internet on weekday morning (for example, some news update) than on weekend evening (for example, what movies are shown in nearby cinemas).

Another contextual parameter that is worth adding into the user profile in user mood. The fact that one is happy or sad could really influence his behavior and current preferences. Let us consider a simple example. Mary had fallen in love and actually she is very happy. She is a great fan of documentary movies. If we did not take into account her current mood, we might recommend her an interesting movie about the Second World War. But Mary might not want to watch this movie at this time because it is too depressing for her.

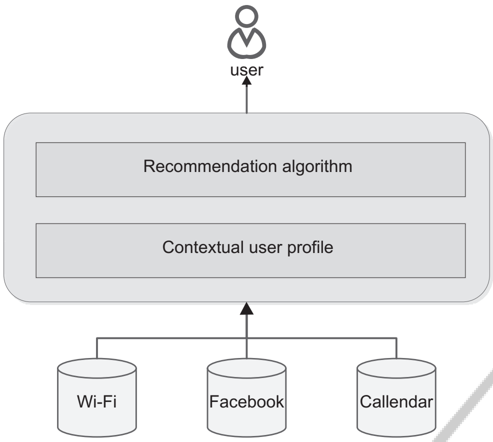

Figure 5: The general architecture of the context-aware recommender system based on an ontological user profile.

Initially the profile ontology will not contain any context instances. When we first get information about a user (i.e. when he registers to the system), new ontology will be created. The terminological part of it will contain only those concepts and roles from the model taxonomy („metaontology") that would be relevant to the data retrieved and stored as the assertional part of the profile ontology.

5.3 The Architecture of the System

One of the main problems in the field of recommender systems is the cold-start problem. Our system will be partly based on collaborative filtering techniques, thus it should be exposed to the existence of this problem. On the other hand, we model user preferences by using a contextual ontology, thus we use advantages of the semantic approach to modelling. To avoid the cold-start problem, we will provide to our system a possibility to log in with a specific Facebook account. Then, after a user logs into the system for the first time, we will automatically build a profile ontology based on the user data obtained from the social media account. To make this process transparent to the user, we would do it in background and for making recommendations „in real time" after his first login we use only the user's latest „likes". It would give us possibility to get access to a lot of user data that he shares throughout the social media. In case the user does not intend to use the Facebook account, he could create a new one and give us only some selected information about himself, including e.g. his current mood.

The current position of the user we could get from GPS or a Wi-Fi adapter. The current time we will obtain from the system clock and the calendar. To get the information about a user location (at work or at home) we need to know the user's schedule. The simplest way to do that is to connect our recommender with the Google Callendar, assuming that most of users already use it.

If the user shares with the system information about his current mood, the system could return the most appropriate recommendation - the recommendations will be made basing on the most specific context (bottom nodes of the graph in Fig. 4). If not, the recommendation will be performed in more general context in the user profile ontology. For this purpose we need to compare a specified context of the user X with the same contexts in different users profiles to find a k-Nearest Neighbors. After that, we could recommend items to the user X basing on the preferences of top k-Nearest Neighbors in that specific context. The general architecture of the context-aware recommender system based on the ontological user profile is shown in Fig. 5.

5.4 Planned Experiments and Research

The next step that needs to be undertaken is validation of correctness and completeness of the proposed user profile. To this aim we plan to conduct qualitative research in a group of some fifty people. Firstly, we will create some kind of subsystem which will allow only to register, log in, and present to the user data from the profile broken down into contexts. The people will be divided into two groups. The first one will be asked to log in with their Facebook accounts. The second one should create new account from scratch. After that, all people will complete a survey about their profile information and corectness of dividing their preferences into contexts.

Next, we will conduct at least two experiments. The first one will involve testing the influence of the size of the ontology (and richness of hierarchy) on the time efficiency and the quality of recommendations. The second one will cover comparison of the results returned by the proposed system with the results returned by existing recommendation systems.

6 EXPECTED OUTCOME

The aim of the decribed research project is to provide a new multi-domain context-aware recommender system that will:

- minimalize the cold-start problem;
- improve the quality and diversity of recommendations;
- facilitate search of relevant information from Internet that would be of interest to a user;

- automatically create an adequate user profile;
- allow for dynamic update of a user profile.

To achieve the results, some new methods and algorithms in the area of recommender systems will be developed.

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