Context-Aware Recommendations in Mobile Environments

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Abstract. Traditional recommendation systems offer relevant items (e.g., books, movies, music, etc.) to users, but they are not designed for mobile environments. In those environments, the context (e.g., the location, the time, the weather, the presence of other people, etc.) and the movements of the users may be important factors to obtain relevant and helpful recommendations. The emergence of context-aware recommendation systems has prompted the growth of recommendation algorithms that incorporate context information.
However, most existing research in this field considers only static context information, despite the fact that exploiting dynamic context information would be very helpful in mobile computing scenarios. Moreover, the design and implementation of generic frameworks to support an easy development of context-aware recommendation systems has been relatively unexplored. In this paper, we present our ongoing work to develop a context-aware recommendation framework for distributed and mobile environments, which will allow suggesting relevant items to mobile users.

Keywords: context-awareness, recommendation systems, mobile computing.

1 Introduction

Recommendation Systems (*RS*) are applications which suggest (relevant) items to users. The suggestions can help to solve certain decision-making problems which are presented to the users, such as which books to buy, which movies to watch, or which online news to read. They try to adapt the suggestions to each user individually, based on his/her preferences. Depending on how the recommendations are obtained, a recommendation system can be classified in three main categories [1]: *content-based*, based on *collaborative filtering*, and *hybrid*.

Traditional RS operate in a *two-dimensional* (2D) $User \times Item$ space. Moreover, generally, traditional collaborative filtering techniques take into account all the collected ratings of the items to generate the recommendation models. These techniques assume that the context is homogeneous, but actually a user can assign different ratings to the same item in diverse contexts, as the relevance and interest of a specific data item for a user may depend on his/her current context.

Motivated by that observation, more modern RS consider contextual information in the recommendation process. Examples of contextual information are the location, the time, the weather, the user's current activity, and the network/communication capabilities. A pioneer proposal in the field of context-aware recommendation systems is [2], which advocates using context information to improve the recommendations. To do so, the authors extended the classical 2D paradigm to a *multidimensional recommendation model* (*MD model*) that provides recommendations based on multiple dimensions: $User \times Item \times Context$. RS that incorporate context information in the recommendation process were denominated *Context-Aware Recommender Systems* (*CARS*).

In this paper, we present our undergoing work regarding the development of a new context-aware recommendation framework for mobile environments, which will support the suggestion of useful recommendations to mobile users. The rest of the paper is organized as follows. In Section 2, we introduce the scientific problem domain addressed. Section 3 summarizes some studies related to the topic of context-aware recommendations. In Section 4, we describe the methodological approach proposed to solve and validate the solution to the problem presented. In Section 5, we explain the research that we have carried out so far. Finally, the expected contributions of this work are provided in Section 6.

2 Problem Domain

Context-Aware Recommender Systems (*CARS*) is still an emerging field. Indeed, Adomavicius and Jannach claimed recently that there is still much research needed in the field of CARS [3]. Most researchers so far have worked on research issues related to the problem of understanding and representing the context in the recommender systems (e.g., [2]). So, they basically have tried to determine how the context could be modeled in recommendation systems. Other researchers have proposed different recommendation algorithms which include context information in the recommendation process (e.g., [4, 5]). Recently, in [6] the authors introduced a software framework to build complex context-aware applications. However, there is still significant work that needs to be done in this area. So, despite these efforts, the design of flexible and generic architectures and frameworks to support an easy development of CARS has been relatively unexplored, particularly if we consider mobile computing environments.

Based on the above issues, we focus on the following scientific problem: *how could we facilitate the development of CARS in distributed environments to provide mobile users with relevant recommendations?* So, the object of our research study is the process of context-aware recommendation for mobile users. Specifically, we pursue the following general goal: the development of a mobile context-aware framework which will allow providing relevant recommendations to mobile users. We aim at generic mobile computing scenarios where different communication technologies (e.g., 3G, WiFi), interaction protocols (centralized approaches vs. mobile peer-to-peer), and data access modes (push-based data access, pull-based data access, and hybrid data access) may be available. Moreover, the

relevant data used as a basis for the recommendations may be available locally on the mobile device, centralized on a server, or distributed among different data sources (mobile devices and other static nodes). The recommendation framework should thus adapt itself to different typical mobile computing scenarios.

3 Related Work

The interest of incorporating contextual information into recommendation systems has been emphasized in studies such as [2]. In [7], the authors proposed three recommendation paradigms: *pre-filtering*, where the contextual information is used to filter the data set before applying traditional recommendation algorithms; *post-filtering*, where the ratings are predicted using a conventional 2D recommendation system, taking all the input data available into account, and then the resulting set of recommendations is adjusted (contextualized) for each user by using contextual information; and *contextual modeling*, which uses the context information directly in the modeling technique.

The models proposed in [8, 9] are examples of the contextual modeling paradigm, but these proposals model information in very specific application domains, and so their cannot be easily reused in other recommendation scenarios. There are also some proposals that try to exploit available contextual information and be more generic, but they have some limitations. Thus, in [10] the authors emphasize that those approaches usually represent information that either concerns particular application domains (e.g., tourism, movies, etc.) or more abstract domains (e.g., products, web services, e-learning, etc.), but that a truly generic contextual model for CARS was missing, which motivated their work. As an example, [11] presents a generic model using an ontology, which can be used in different types of recommender systems and models data, context, and the recommendation process itself. Recently, [10] carried out a study to try to determine whether a more generic modeling approach could be applied for CARS. As a result of the study, the authors proposed a novel generic contextual modeling framework for CARS, which was theoretically evaluated with positive results.

Particularly in mobile environments, where the user is moving and the context is highly dynamic, it is important to provide precise recommendations and avoid overloading the user with the suggestion of many items. Generally, mobile devices such as smartphones have important limitations in comparison to traditional mobile or desktop computers. For example, they usually provide restricted input facilities (e.g., lack of a comfortable keyboard). Therefore, a recommendation system should try to relieve the user from having to type or introduce significant information as an input, favoring implicit recommendations (based on the context and user preferences) over explicit (query-based or user-initiated) recommendations. Along these lines, [12] proposes a proactive recommender system that pushes recommendations to the user when the current situation (i.e., the context) is considered appropriate, without explicit user requests.

A new class of ubiquitous context-aware recommendation systems, called *UbiCARS*, has been proposed in [13]. The idea is to combine characteristics of

both ubiquitous systems and CARS. Systems in this category are ubiquitous in the sense that they capture information from the environment and react on it. At the same time, they are context-aware because they consider the context in the recommendation process by using multidimensional contextual datasets.

Some open research problems for CARS, identified in [14], have been addressed to a certain extent in recent studies. For example, in [15] the authors performed an evaluation and comparison of the effectiveness (accuracy vs. diversity) of existing paradigms, in order to identify strengths and weaknesses of each paradigm and to determine which one is better in different circumstances. Moreover, the inclusion of *diversity* as an important element in context-aware recommendation systems was considered for the first time in [16]: the idea is that the users should be provided with recommendations that are diverse enough rather than very similar to each other, which is an idea that had been exploited before in Information Retrieval (IR) contexts [17].

Recently, a software framework called *Hybreed* [6] has been presented for building complex context-aware applications. The framework is based on a quite generic notion of context. Its creators actually solved some of the open research problems identified in [14]. However, the authors identified elements pending for future work, such as developing and providing advanced learning algorithms as part of the framework, the development of a processing engine that supports distributed and asynchronous workflows, and addressing privacy issues.

Based on the above, there is a need to define a generic and abstract framework for the modeling of CARS in mobile environments. With our work, we attempt to bring recommendation systems to dynamic mobile computing environments.

4 Methodological Approach

To accomplish our goal, the first step is to perform a detailed study of the state of the art on context-aware recommendation systems, as well as an analysis of existing frameworks which may solve some of the problems arising in this field. The next step is to develop an appropriate and general architecture that supports context-aware recommendations in generic mobile environments. Then, a framework implementing that architecture will be developed using Java and exploiting useful class libraries that facilitate the use of recommendation models (e.g., Mahout) and machine learning techniques (e.g., Weka).

On the other hand, we will evaluate and validate the proposed framework by considering several application scenarios. Unfortunately, most existing datasets used to evaluate traditional recommendation algorithms do not consider the contextual information or the existence of mobile users. So, an important difficulty that we will have to face during the experimental evaluation of the framework will be the collection of appropriate data sets for CARS in mobile environments.

Moreover, performing experiments with real mobile users and mobile devices (e.g., mid-range smartphones) would be expensive and impractical. Therefore, we will require the use or the development of a simulator that should be able to model both mobile users and items, as well as their context. Moreover, the

suggestion of items to mobile users could affect their behavior and mobility (e.g., in case a user decides to move towards an item recommended).

5 Research Carried Out

So far, we have performed an initial study of the state of the art on context-aware recommendation systems. We identified that most research focuses on the problem of understanding and representing the context. So, existing proposals have mainly tried to determine how the context could be modeled in recommendation systems. There are also some proposals of recommendation algorithms which include contextual information in the recommendation process. However, the design of generic architectures and frameworks to support an easy development of CARS has received little attention, especially in mobile environments.

We have also started the development of a generic context-aware mobile recommendation architecture. It will include several traditional recommendation algorithms (e.g., *collaborative filtering based on users/items* and *content-based*), as well as hybrid algorithms that combine several of them to try to improve the accuracy of the recommendations. Furthermore, it will provide different context-aware recommendation paradigms (e.g., *pre-filtering*, *post-filtering*, and *contextual modeling*). The recommendation process will consider both static context information obtained from the user's profile as well as dynamic context data obtained from the environment (e.g., by using sensors). Moreover, it will support the exploitation of other external data sources available, such as geospatial information services, social networks, and web services.

The user will be able to receive both proactive recommendations (real-time recommendations of items without explicit requests from the user) and reactive recommendations (obtained as an answer to a query submitted by the user and evaluated by the system as a continuous query). Different types of environments, including *outdoor* environments (e.g., roads, pedestrian paths) and *indoor* environments (e.g., a mall, a hotel, a supermarket), will be supported.

6 Expected contributions

The ultimate goal of this research is to develop a framework that will provide relevant context-aware recommendations for mobile users. We will also probably need to develop a suitable simulator that will allow to represent mobile users that receive real-time context-aware recommendations in both indoor and outdoor scenarios. An intermediate contribution will be the design of a generic architecture to support an easy development of context-aware recommendation systems for mobile users. Overall, with this research, we hope to contribute to bridge the gap between recommendation systems and mobile computing.

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