Recommender Systems with Privacy for Context-Aware Services

Fran Casino *

SMART HEALTH Research Group. Department of Computer Engineering and Mathematics, Rovira i Virgili University.
Av. Països Catalans 26. 43007 Tarragona. Catalonia. Spain
Corresponding author e-mail: franciscojose.casino@urv.cat

1 Introduction

Automatic recommender systems have become a cornerstone of e-commerce, especially after the great welcome of *Web 2.0* based on participation and interaction of Internet users. Moreover, the new way to use and understand the network based on the *Web 3.0*, which enforces the user&computer interaction, leads recommender systems to another level, integrating them into everyday life in a transparent and efficient manner. Collaborative Filtering (CF) [7] is a recommender system that comprises a large family of recommendation methods. The aim of CF is to make suggestions on a set of items I (*e.g.* books, films or routes) based on the preferences of a set of users U that have already acquired and/or rated some of those items. Recommendations provided by CF methods are based on the premise that similar users are interested in similar items (*i.e* they share similar patterns). Therefore, items which pleased user u_a could be recommended to user u_b, if u_a and u_b are similar. In order to predict whether an item would interest a given user, CF methods rely on a matrix M of n users (rows) and m items (columns), where each matrix cell $M_{i,j}$ stores the rate of user i on item j. The interested reader could refer to [9] for detailed CF's state-of-the-art.

2 Recommender Systems and Context-Aware Services

Population is moving into cities and this urbanisation process poses severe challenges to cities. In big cities, factors related to economies of scale help to reduce operational costs. However, managing big cities is challenging due to the large number of inhabitants and their needs. Thus, the management procedures of cities have to be adapted to a growing and very demanding population. As a result of these needs, the concept of smart city was born. The

* PhD advisor: Agustí Solanas

cities of the future will be equipped with full of sensors and actuators (*e.g.* temperature and humidity sensors, pollution and allergens sensors, luminosity sensors or crowds detectors) that would improve the citizens' quality of life. One of the most challenging aspects within this framework is to achieve sustainable healthcare service provisioning, not only in the case of hospitalized patients, but also to monitor chronic diseases, improve social welfare and in general to improve the overall citizenship health levels. In this context, wireless communication systems play a key role, as enablers of real time and location independent connectivity, increasing system functionality and decreasing operational costs. As a result, the healthcare sector has turned into the aforementioned context to create a powerful symbiosis and create Smart Health [2], which is defined as *the provision of health services by using the context-aware network and sensing infrastructure of smart cities.*

2.1 Communication Networks and Collaborative Filtering

One of the issues to consider in the design of communication networks in the context of a Smart Health cenario is their performance in terms of coverage/capacity ratios, with particular consideration of the impact of interference due to simultaneous use of multiple users and systems. It is in this case where careful radiofrequency signal analysis, in terms of useful signal transmission and existence of potential interference levels must be estimated, as a function of user density, transceiver type and location (Figure 1). Wireless signal analysis in large complex scenarios is computationally costly and requires the use of optimized deterministic techniques, such as 3D Ray Launching (RL) and Ray Tracing approximations, coupled to Geometric Optics and Uniform Theory of Diffraction. In the case of very large scenarios, such as cities, this approach can still be computationally too demanding and combination with other estimation approaches is compulsory [8]. In order to minimize the computational cost for certain scenarios within the potential applications of Smart Health, we propose the combination of in-house developed 3D Ray Launching code with Collaborative Filtering techniques as showed in [3] and [4].

2.2 Healthcare and Collaborative Filtering

In our society, citizens perform physical activities in the city, namely cycling, jogging, running, etc. With the aim to promote these healthy habits, it would be desirable to count with a system that could dynamically adapt to the needs and tastes of the citizens. Within this context, we propose a new way of using the sensing capabilities of smart cities by means of recommender systems that allow citizens to obtain recommendations about the routes that better fit their capabilities.

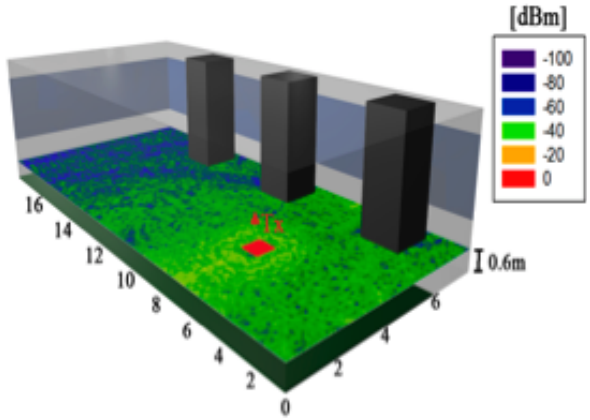

Fig. 1: Example of a scenario with received signal power estimations.

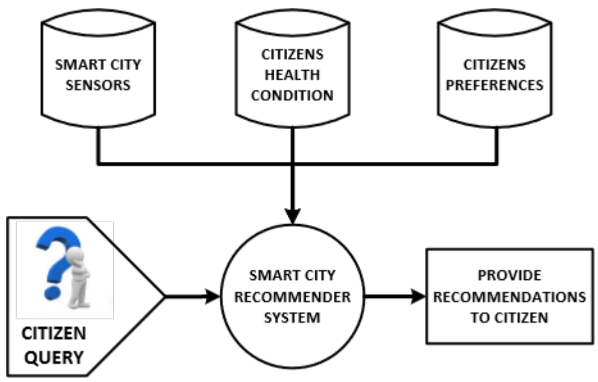

Fig. 2: Overview and basic operation of a Smart Health recommender system.

The system would consider real-time constraints and information from several sources: (i) citizens' preferences, (ii) citizens' health conditions and, (iii) real-time information provided by the smart city infrastructure.

The architecture of our system and its main actors are shown in Figure 2. Sensors provide real-time environmental information (*e.g.* luminosity, temperature, humidity, pollution) to the Smart City Recommender System (SCRS) through the communication infrastructure of the smart city. Upon the reception of citizen queries the SCRS checks the health information of citizens and their preferences and cross them with the real-time information of the smart city sensors to finally compute real-time recommendations that are forwarded back to the citizens.

3 Privacy and Collaborative Filtering

The collection of private behavioural information in a wide variety of contexts (*e.g.* places to go, things to do, or products to buy), which conforms the basis of CF systems, provides great opportunities and benefits to both companies and users. However, the lack of privacy for the contributing users is a major drawback. Careless management of personal information, besides being agains the legislation of most countries, could lead to serious consequences for both users, whose information is stored, as well as companies. In order to address such privacy issues, current research focuses on Privacy Preserving Collaborative Filtering (PPCF) methods [6]. Users' privacy concerns affect their behaviour, resulting in a reduction of both the number of given assessments as well as their quality. The lack of privacy could also result in a massive information retrieval conducted by companies, which could acquire data of the preferences of many users in a given market, getting a big advantage over other competitors. Moreover, the existence of large monopolies on the Internet (Google, Amazon) allows for the sharing of data between different entities managed by large companies, without user's awareness. Whilst privacy preserving CF methods obfuscate and/or hide information on user profiles, sometimes users wish to find other users having similar profiles and form a community. Indeed, communities are very usual in the network, but they can be a double-edged sword. On the one hand, users can conveniently obtain reliable recommendations on items from communities in a particular context. On the other hand, communities can generate a *value homophily* problem in the network, so that recommendations outside the context of the community would give results with little sense, precisely because of the homogeneity of the group. For more on PPCF, we point the interested reader to [1], where a PPCF survey is presented and to [5], where a classification of PPCF methods is given according to how information is stored and how recommendations are computed.

4 Conclusions and Future Work

Collaborative Filtering is a recommender system used to perform automatic recommendations to users in multiple contexts. Despite the great advantages of using CF, we have highlighted its downside regarding users' privacy, which is probably the most significant challenge to overcome.

In addition, we have proposed the idea of using recommender systems integrated with the sensing infrastructure of smart cities to improve the sustainability by optimizing the resource usage in the communication networks field. Moreover, we have focused on the citizen's quality of life and proposed a method to provide citizens with real-time routes recommendations that take into account their health conditions and preferences.

Future work will focus in the implementation of new ontologies which could use more context-aware information to improve the citizen's quality of life while preserving their privacy.

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