Expert Systems with Applications 42 (2015) 4216–4228

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Developing a recommender system in a consumer electronic device

Belén Barragáns-Martínez [a], Enrique Costa-Montenegro [b,*], Jonathan Juncal-Martínez [b]

[a] Centro Universitario de la Defensa, Escuela Naval Militar, Marín, Pontevedra 36920, Spain
[b] Telematic Engineering Department, School of Telecommunication Engineering, University of Vigo, Vigo, Pontevedra 36310, Spain

ARTICLE INFO

Article history:
Available online 31 January 2015

Keywords:
Recommender system
Movies
Android
Commercial device
Consumer electronics

ABSTRACT

Nowadays we can witness the proliferation of Android devices, mostly smartphones and tablets. We are particularly interested in one of these types of devices (Android-based multimedia devices) that are also finding their place in the world of consumer electronics. Part of our previous work is related to the design and development of recommendation systems always under the same conditions (shared by the overwhelming majority of these systems): the process of recommendation is executed by powerful servers that try to recommend to the users different types of items (movies, tv series, music, etc.) that will suit them according to different parameters, like their profile, their ratings of previous consumed items, the ratings of people with similar taste, etc.

In this paper, we will face a new challenge: we will use our previous background to design and implement a recommendation system that will run in an Android-based multimedia device. In particular, this system will recommend movies to the users that fit in well with their profile and previous ratings. The main challenges that will face the design of this system are the restrictions of this kind of devices, like limited processing capabilities, sharing the CPU with more important processes, restricted connection to Internet, etc. The final system must be able to recommend contents to the user, both available locally or online.

The significance of this paper lies in the fact that, to the best of our knowledge, our development is one of the first recommender systems running completely in a multimedia device without the support of a dedicated server for the execution of the recommendation algorithms. Our development is expected to be included soon in an Android-based multimedia device sold by the Spanish company Blu:Sens.

1. Introduction

The popularity of Android devices has enormously grown in recent years. According to a Google executive (Melason, 2013), in 2013 1.5 million Android devices were activated per day, most of them smartphones and tablets. However we can find more types of Android devices like e-readers, televisions, game consoles, etc. In this research, we will use an Android-based multimedia device that will allow the user to play any type of media, available both locally or online, browse Internet web pages, launch apps, etc. This device is connected to the TV through the HDMI port and controlled by the user using a remote controller. In Fig. 1 we can see the development kit we have used in our research.

The great amount of information available these days leads the users to the information overload problem. This means that the user does not know what option to choose between the huge number of possibilities. We may have this problem when accessing different types of information like movies, music, TV series, TV programs, books, apps, etc. The recommender systems try to solve this problem by providing the users the options more suitable to them by using their profile, their ratings of previous consumed media, the ratings of people with similar taste, the locations, the actual time and date, etc. Currently there is a huge variety of recommender systems for the different types of items cited before. These recommender systems require powerful servers. This processing power is required because they use complex algorithms to compute their recommendations. The results of these recommendation algorithms are usually shown to the user through a web page or mobile app. We should point out that the user has to feed the recommender system with information, like ratings, in order to improve the quality of the recommendations offered by the system. If the user does not provide feedback to the recommender system, this would not have information to provide a suitable recommendation.

In this paper we will present a movie recommender system (in future versions, we will try to extend the application domain to

* Corresponding author.
E-mail addresses: belen@cud.uvigo.es (B. Barragáns-Martínez), kike@gti.uvigo.es (E. Costa-Montenegro), jonijm@gti.uvigo.es (J. Juncal-Martínez).

http://dx.doi.org/10.1016/j.eswa.2015.01.052
0957-4174/

music, TV series and TV programs). This system recommends to the user movies available on a local storage device connected to the Android-based multimedia device or in different online services. The recommender system that we have developed runs in an Android-based multimedia device instead of in a powerful server. This was a mandatory requirement as the company that will sell these devices focuses its business on selling hardware not on providing services, so the device must be autonomous regarding the recommendation process.

We have also developed a categorizer, whose main purposes are to look for new or updated content in the local storage device and to categorize it by using the information available in an online movie database.

The decision of not using a server introduces some degrees of difficulty to this development due to the features of the Android-based multimedia device, such as low processing power, sharing the CPU with more important tasks such as the media player, lack of permanent Internet connection or the inability to execute recommendation algorithms when the device is off.

To the best of our knowledge, this is one of the first recommender systems fully running in a consumer electronic device without the need of a dedicated server. The results of this research are expected to be included soon in an Android multimedia device sold by the Spanish company Blu:Sens.

This research was made possible by the Platino project funded by the Ministry of Economy and Competitiveness of the Spanish Government and developed in cooperation with the Spanish companies Igalia, Blu:Sens, Imatia and Cinfo, and the Galician Research and Development Center in Advanced Telecommunications (Gradiant).

This paper is organized as follows. Section 2 describes the state of the art in recommender systems. Section 3 explains the restrictions we have found for the development of our recommender system due to the fact that it must run in a consumer electronics device. In Section 4 we describe the development of the categorizer while in Section 5 the development of the recommender system. Section 6 contains a brief case study in order to clarify how the system works. Finally Section 7 shows the conclusions and future lines of work.

2. State of the art

Recommendation algorithms are well studied (in Bobadilla, Ortega, Hernando, & Gutiérrez (2013) the reader can find a recent overview of recommender systems as well as their evolution). They are widely used particularly in e-commerce for personalized suggestions of products or services.

Fig. 1. Picture of the development kit used in our research.

2.1. Recommender algorithms classification

Recommender systems suggest items of interest to users based on their explicit and implicit preferences, the preferences of other users, and user and item attributes. So, based on how recommendations are made, recommenders systems are usually classified into the following three categories (Adomavicius, Sankaranarayanan, Sen, & Tuzhilin, 2005; Adomavicius & Tuzhilin, 2005; Balabanovic & Shoham, 1997):

1. *Content-based filtering* (CBF): Recommendations are provided by automatically matching a customer's interests with items' contents. Items that are similar to ones the user preferred in the past are now recommended. Notice that recommendations are made without relying on information provided by other customers, but solely on items' contents and users' profiles.
   In content-based filtering the features used to describe the content are of primary importance. The more descriptive they are the more accurate the prediction is.
2. *Collaborative filtering* (CF): Recommendations are made for items that people with similar tastes and preferences liked in the past. Most CF-based algorithms recommend items for users based on the nearest-neighborhood method (Herlocker, Konstan, Borchers, & Riedl, 1999). A typical nearest-neighborhood procedure can be separated into three steps. The first step is to determine a neighborhood for the active user or item through the similarity value, which is usually defined by the Pearson correlations. Then, a prediction is calculated from a weighted combination of selected neighbors' ratings for the active user or given item. Finally, a descending sorted list is made from these predictions. Recommendations are generated by choosing the top N items on this list.
   A most critical issue with these algorithms is how to determine the similarity between two users or items. The two most popular approaches are the correlation-based approach (Resnick, Iacovou, Suchack, Bergstrom, & Riedl, 1994) and the cosine-based approach (Breese, Heckerman, & Kadie, 1999; Sarwar, Karypis, Konstan, & Riedl, 2000).
3. *Hybrid approaches*: In order to exploit the advantages of available recommendation methods several hybrid approaches have been proposed, in their vast majority concerning combinations of collaborative filtering and content-based filtering.

2.2. Movie recommender systems

Recommender systems have proved to be a useful tool for addressing the information overload phenomenon in the movies domain.

As in any other domain, they have evolved from a first generation using traditional web sites (Resnick et al., 1994), going through a second generation using web 2.0 and gathering social information (Barragáns-Martínez, Rey-López, et al., 2010) to reach finally a third generation with integrated devices on the Internet (Ko et al., 2011). Among the most recent proposals in this field, we find (Moreno, Segrera, López, Muñoz, & Sánchez, 2013) where authors deal with some important drawbacks still present in current recommender systems by using data mining algorithms. We should also highlight works as (Winoto & Tang, 2010) where authors study how users' mood can have an impact on their appraisal of movies in different genres, which in turn can help inform recommender system of picking up movies that are appropriate for users in different mood.

Regarding TV domain, our previous work (Barragáns-Martínez, Costa-Montenegro, et al., 2010) presented a hybrid recommender system of TV programs. Some of the algorithms used have been applied to this work. Some recent proposals in this domain are