Journal of Computational Science 12 (2016) 83–94

Contents lists available at ScienceDirect

Journal of Computational Science

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

# Design of a recommender system based on users' behavior and collaborative location and tracking

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ARTICLE INFO

*Article history:*
Received 7 October 2015
Received in revised form
19 November 2015
Accepted 27 November 2015
Available online 10 December 2015

*Keywords:*
Recommender
Location-based
Collaborative
Implicit ratings
Users' behavior

ABSTRACT

During the last years, mobile devices allow incorporating users' location and movements into recommendations to potentially suggest most valuable information. In this context, this paper presents a hybrid recommender algorithm that combines users' location and preferences and the content of the items located close to such users. This algorithm also includes a way of providing implicit ratings considering the users' movements after receiving recommendations, aimed at measuring the users' interest for the recommended items. Conducted experiments measure the effectiveness and the efficiency of our recommender algorithm, as well as the impact of implicit ratings.



## 1. Introduction

The increasing volume of information received by people in their daily lives usually presents the challenge of deciding what information is useful for them, and which does not. Recommender systems are tools that can be used to suggest items that may not have been found by users themselves [1]. In this context, the advent of mobile devices has allowed the use of location information to provide context-aware recommendations by considering the distance between users and items, as well as their subsequent movements. The ability to combine users' location and movements, together with other aspects like users' preferences, items' properties, or users' ratings provides more valuable information that can help to suggest more accurate items of potential interest to users.

### 1.1. Motivation

Designing a recommender system with the previous aspects is a complex task, as it should need to combine a large number of parameters, such as the ones defined in collaborative (CF) [2], content-based (CBF) [3], and context-aware (CAF) [4] filtering techniques. First, the user-based CF methods recommend items by taking into account the feedback (ratings) of users with similar preferences to the target user. Secondly, the CBF approaches operate with the similarity of the items, so similar items to the ones liked by the target user are recommended. Finally, the location-based CAF approaches use the location of users to recommend items close to them. These techniques present certain challenges that have to be addressed adequately; namely:

- How to find similar users so as to consider their ratings when generating new recommendations in the CF models.
- How to create users' profiles and classify items in the CBF approaches.
- How to use the location and the tracking of users in the location-based CAF approaches, also taking into account the environment information where the elements (users and items) are.

These techniques also present additional drawbacks [5], such as sparsity and cold-start in the CF approaches, the need of human knowledge to classify items and users considering different aspects (e.g. establishing the relationship between the items' information and the likes of users) in the CBF approaches, and the use of complex systems to represent and model the users' context in the CAF approaches. Although current hybrid recommenders combine

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http://dx.doi.org/10.1016/j.jocs.2015.11.010
1877-7503/

**Table 1**
Comparative of recommender systems.

| | Information | Recommenders | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | [10] | [11] | [12] | [14] | [15] | [16] | [17] | [18] | Ours |
| CBF | Items' properties | √ | | | | | | | | √ |
| | Users' preferences | | | | | | √ | | | |
| | Users' profile | | | | √ | | | | | |
| CF | Ratings | | √ | | | √ | | √ | √ | √ |
| | Tracking | | | | | | | | | √ |
| | Users' preferences | | | | √ | | | | | √ |
| CAF | Location | | | √ | | √ | √ | √ | √ | √ |
| | Direction | | | | | | | | | √ |
| | Time | | | | √ | | √ | | √ | √ |
| | Social relationships | | | | √ | | √ | | | |
| | Physical conditions | | | | √ | √ | √ | | | |

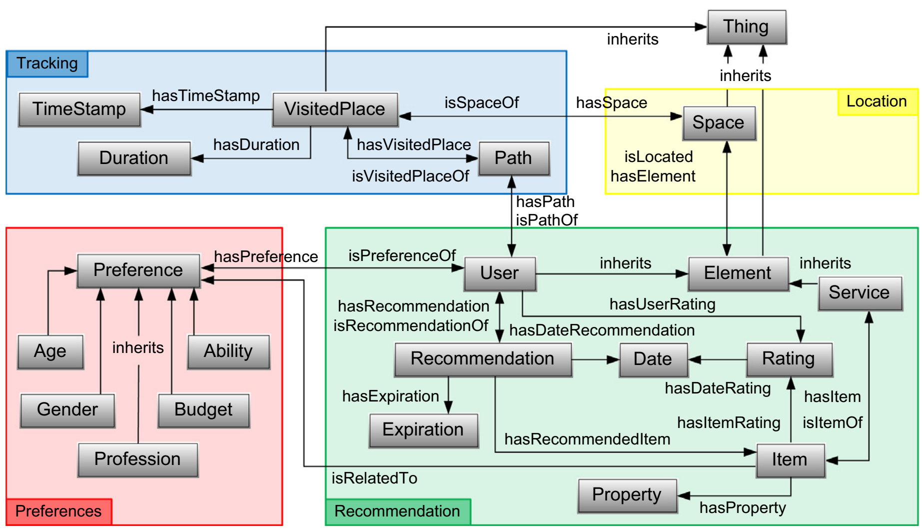


**Fig. 1.** The recommender ontology.

some of the previous approaches in order to minimize the previous drawbacks and provide most valuable items [6], more work is still required. Moreover, rating is another major aspect in recommender systems. Most existing solutions only rely on users to rate recommendations, although it is proved that a large number of users do not usually spend time rating items. We believe that ratings should be mostly generated by recommenders automatically, as indicated in [7,8].

### 1.2. *Our contribution*

In order to conduct the tasks mentioned earlier, we propose in this paper a hybrid recommender with an implicit rating support. Specifically, our recommender algorithm ranks the suggested items by considering ratings given by our rating procedure for similar users to the target one (CF approach). We think that the ratings of users similar to the target are useful in order to offer new recommendations to him/her. In this sense, similar users are found out combining their implicit ratings about items, their preferences (likes, gender, budget, etc.), and their tracking in the environment where they are. The majority of the collaborative filtering solutions only use the ratings of users to measure their similarity, but we also think that in location-based solutions the users' tracking should be considered to know the places most visited by users and, therefore, their likes and preferences. Furthermore, items' properties are used by our recommender algorithm to measure the similarity between items, with which we can suggest new items with similar properties (type, price, etc.) to the items usually liked by the target user (CBF approach). Finally, the context-aware information related to the location and description of elements close to the users, as well as their relevance and meaning (CAF approach), is used by our recommender to rank and filter items. The information managed by the combination of these approaches allows us to provide accurate recommendations and decrease problems like cold-start and sparsity [9].

Regarding the way of generating implicit ratings automatically, we propose a novel rating procedure that takes into account the users' movements after receiving the recommendations (user behavior-aware approach). It considers the time and the locations of users and items in order to measure the users' interest for the recommended items to provide a rating score. An example of using time to measure the interest is when the time since a user receives a recommendation until he/she reaches the item gets shorter, the rating for the item gets greater. Note that the implicit rating procedure proposed here may be adopted in any other location-based recommender algorithm. Furthermore, our recommender algorithm and rating procedure are configurable through parameters, allowing being adapted to different environments.

### 1.3. *Paper organization*

The remainder of the paper is structured as follows. Section 2 discusses the main related work regarding other recommender systems. Section 3 presents our solution, where the ontology managed