A Context-Aware Mobile Recommender System Based on Location and Trajectory

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Abstract. Recommender systems have typically been used in tourism applications to filter out irrelevant information and to provide personalized recommendations to the users. With the advent of mobile devices and ubiquitous computing, RSs have begun to incorporate Location Based Services (LBS) into mobile tourism guides to provide users with interesting points of interest (POIs) according to their contextual information, mainly physical location. In this paper, we propose a context-aware system for mobile devices that incorporates some implicit contextual information that is scarcely used in the literature: the user's speed and his trajectory. This system has been specifically crafted to assist travelling users by providing them with smart and personalized POIs along their route taking into account their current location and driving speed.

1 Introduction

Recommender systems (RSs) are software tools that help people to find relevant items in large databases according to their interests, needs or tastes [3, 20, 25]. These systems filter information, removing irrelevant items and providing the best ones according to the user preferences. Traditional RSs build a user profile by analyzing the user's past actions. Most of these systems suppose that the user's necessities and tastes do not vary over time. However, this is not absolutely true as the user's necessities or preferences may change depending on different factors: user's mood, season, physical position, etc.

Context-aware recommender systems (CARSs) are a new trend in recommender systems [2, 4] that take into account these aspects. They aim to provide personalized recommendations according to both the users' profiles and their current contextual conditions. In other words, if you are in London, a CARS may recommend you "*Fifteen*" to have dinner according to your preferences, but if you are in Paris, obviously "*La Tour d'Argent*" would be a better choice than "*Fifteen*", unless you have a private plane to fly from Paris to London before dinner, even though the latter is closer to your preferences.

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In previous works we proposed REJA [21, 27], a web-based RS for restaurants in the province of Jaén, Spain. More recently, we also proposed in [22] a mobile CARS based on REJA that took advantage of the additional information that mobile devices provide, mainly their ubiquitous nature and the implicit knowledge of the user's physical location obtained by its GPS (Global Positioning System). However, additional contextual information such as direction, trajectory, speed, etc, was not considered, in spite of the fact that they are very interesting context features for tourism purposes.

In this contribution we propose a new context-aware filtering technique that enhances our previous work by adding two new contextual information elements into the recommendation process: the travel speed and trajectory of the user. This new proposal has been specifically designed to support on-the-move users using mobile devices and travelling aboard automobiles in interurban scenarios.

Our system recommends the most interesting POIs that will soon be found along their routes according to their preferences, location, speed and trajectory, and neglects those POIs that have been left behind by users according to their current trajectory and speed. This system would increase the input of personalized marketing and the loyalty of users to the enterprises (e.g., restaurants) related to the system.

The rest of the paper is organized as follows. Section 2 presents current research in mobile CARSs. In Section 3, our novel contextual filtering technique is presented. Section 4 describes a prototype that implements our technique and discusses its behavior. Section 5 concludes the paper.

2 Related Work

RSs have been widely studied in the literature, and there are several types that differ according to the techniques they use: demographic RSs [17], content-based RSs [19, 23], collaborative filtering RS [11], knowledge based RSs [7] and utility based RSs [13]. However, the RSs most commonly used in real world solutions are hybrid systems that combine two or more of the aforementioned techniques in order to overcome their own limitations and drawbacks, see for example [8, 21].

The recent increasing interest in mobile technologies and *Location Based Services* (LBSs) with the dramatic improvement of mobile devices (smartphones, tablets...) and cellular communications has led to new challenges and opportunities arising in the field of RSs. Since GPS-enabled mobile devices are sensitive to the physical conditions of the user (location, orientation, etc.), a new trend in RSs has arisen aiming to exploit this contextual information. CARSs exploit such information, suggesting items according to context-aware knowledge about the user: geographical location, mood, day of the week, season, etc.

Recent surveys by Adomavicius et al [4] and Ricci [26] provide an overview of these techniques. Several studies have proved that contextual information improves both the quality of the recommendations and user satisfaction when the system is employed [4, 5, 12].

One of the most typical applications of CARSs is to mobile tourism guides [26]. Traditional mobile tourism guides [1, 9, 24, 29] took advantage of contextual information, mainly the physical position of the user, but were not able to recommend POIs according to user preferences. Recently, different proposals have been suggested taking into account both contextual information and user preferences, following either content-based [18, 28, 30] or collaborative filtering [6, 14, 15, 16, 22] approaches. Context-aware information can be incorporated into the recommendation process following different approaches. Adomavicius et al. [4] described the following approaches: (i) *Contextual pre-filtering*, firstly, information is filtered using contextual information to select relevant items. These items are provided to a traditional RS as an input, which selects the best ones according to the user's preferences. (ii) *Contextual post-filtering*, a traditional RS processes all the available items and generates a list of interesting items according to the user's preferences. Contextual information is then used to adjust the list. (iii) *Contextual modeling*, in this approach, contextual information is used directly in the recommendation process.

3 Location and Trajectory Aware Recommendation Approach

Our proposal consists of using users' contextual information to provide more accurate recommendations regarding their current situation. Thus, we propose a basic architecture that combines two subsystems: a) a context-aware filter; and b) a traditional recommender technique. Both elements are independent, the proposed context-aware filtering can be used to add context-awareness to any traditional (i.e. non-context aware) RS.

This section describes our proposed context-aware filtering approach. This filter determines the user's physical position, speed and trajectory and uses them to guide the recommendation process.

3.1 Contextual Filtering

In previous works [22] we proposed a contextual prefiltering based on the user's position. This filtering considered an *area of interest* (AOI) defined by the current user's location P and a radius R_{outer}, see Figure 1a. R_{outer} was a user-defined parameter that expressed how far she was willing to travel to visit a POI. Outside this area, the items were not considered and discarded by the filter. Consequently, they were not recommended by the RS. Here, we define a new contextual filtering that enhances our previous solution by considering two new contextual variables: speed and trajectory.

Consider the following scenario: a user is moving along a motorway and wants to stop at a restaurant, see Figure 1a. If we employ an AOI centered on her current location to discard distant items, recommended restaurants may be located in the opposite direction to that in which she is heading. We overcome this issue by calculating an *adjusted AOI* that is centered on a new point P', located on the road

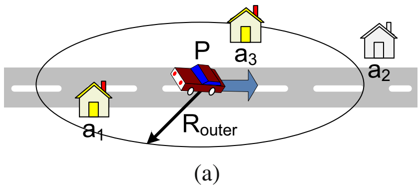


Fig. 1 Displacing the AOI according to the speed and the user-defined parameter R_{outer}

ahead of the user, according to the current travel direction, see Figure 1b. The faster the user moves, the more this new adjusted AOI will be displaced. Therefore, the system is able to anticipate interesting POIs that the user will pass by in the near future.

This contextual filtering has been designed for cascade hybridizing with any other traditional RS either as a contextual pre-filtering or as a contextual post-filtering [4].

3.2 Calculation of the Adjusted Area of Interest

In what follows, we describe in further detail how to calculate the adjusted AOI previously described. Let us suppose a user located at a geographical position P. In order to calculate the adjusted AOI, we must translate the point P to obtain a new point P', so that P' is located ahead of the user (according to her direction). Also, as the distance from P to P' depends on the user's speed, the performance of the following 2D geometric transformation [10] on P is required:

$$P' = P + T \tag{1}$$

Where $T(t_x, t_y)$ is the translation amount needed to move $P(x,y)$ to $P'(x',y')$. In order to determine T, we proceed as follows. First we calculate the current direction of the user. Several methods can be used for this purpose. For example, we could use the GPS receiver to sample a set of way-points obtained at regular intervals of time. A cubic parametric curve could then be calculated using these points as restrictions. The parametric tangent vector of this curve at the user's current location gives us the velocity of the user, which can be used to determinate her direction. See [10] for a thorough study on curves representation.

The previous technique, although powerful, is computationally expensive for a mobile device. Therefore, we propose a simpler technique to approximate the user's trajectory that only requires two points: the current and the previous locations, P and P_{prev}, provided by the GPS by sampling the user's location at regular intervals of time. We use them to determine a direction vector $\vec{v} = P - P_{prev}$. After normalizing $\vec{v}$, we obtain the unitary vector $\vec{u}$ that estimates the user's trajectory.

With this vector, we can determine T as:

$$T = \vec{u}\ d\ R_{outer} \tag{2}$$

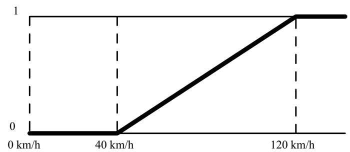


Fig. 2 *d* depends linearly on the user's speed

Where $\overrightarrow{u}$ and R_{outer} have already been defined, and $d \in [0,1]$ is a fuzzy parameter that depends on the user's speed. We define d as follows:

$$d = \begin{cases} 0 & if \quad speed < a \\ \frac{x-a}{b-a} & if \ speed \geq a \ and \ speed < b \\ 1 & if \quad speed \geq b \end{cases} \tag{3}$$

Where *speed* is the average user's speed at the point P. Considering the speed limits in most countries, we propose $a = 40$km/h, $b = 120$km/h, see Figure 2. If the user's speed is lower than 40 km/h, we suppose she is in an urban environment, and therefore, the AOI is centered on her current location. As her speed increases, the AOI is progressively translated forward. Since 120 km/h is a common speed limit, we do not consider translating the circle further.

By applying equation (1), the AOI around the user is translated according to the user's current trajectory and speed a maximum distance of R_{outer}, as shown in Figure 3.

4 System Overview and Discussion

We have built an operational prototype that implements the ideas described in the previous Section. Our goal is to study the behavior of our proposal under real world contextual conditions. Our prototype is aimed at providing recommendations of restaurants in the province of Jaén, Spain.

The implemented system follows a classical client-server paradigm that comprises two elements: the recommender server and the mobile clients. The logic of the RS runs on a dedicated remote server. In our implementation, the filtering method described in Section 3 has been used as a contextual pre-filtering in cascade with a traditional hybrid RS, known as REJA, described in [21, 27]. Figure 4 portrays the system. The client, on the other hand, consists of a mobile application that is installed on a mobile device (e.g. a smartphone). This application is in charge of interacting with the user, processing contextual conditions and requesting recommendations from the server when needed.

Prior to using the system, users are required to install the mobile application on their devices. When the application is launched, the user has to provide his

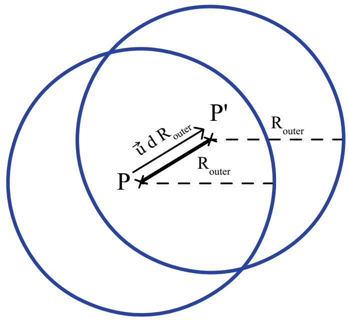


Fig. 3 The AOI is translated from P to P', according to the user's speed and trajectory

log-in data and the desired value of R_{outer}. Then, the built-in GPS receiver (currently included in most mobile phones) is used to determine the user's location and speed.

The computation of the user's travel direction and speed described in Section 3 is carried out entirely by the mobile device. This means that the server is unaware of the current location of the user, P, and only requires P' to compute the recommendations. This reduces the workload on the server and enhances scalability. Consequently, to request a recommendation list from the server, the client computes P' according to the user's location P, her speed and direction, and transmits it to the server. The user's unique ID and the value of R_{outer} are also transmitted. In response, the server generates an XML file containing the recommended items, their coordinates, recommendation values and other descriptive data. This file is downloaded via HTTP. Once the initial recommendation list has been downloaded, the mobile device continues to track the user's speed and trajectory, and issues new requests whenever the user moves a distance greater than a predefined threshold. In this way, recommendations are updated in real time as the user travels. Recommended items are portrayed on a map-based interface built on top of *Google Maps*.

Figure 5 illustrates the behavior of our system running on *iOS* (*iPhone*) under different contextual circumstances. These images are screenshots of the user interface of our mobile client application. The user location P is depicted on the map by a

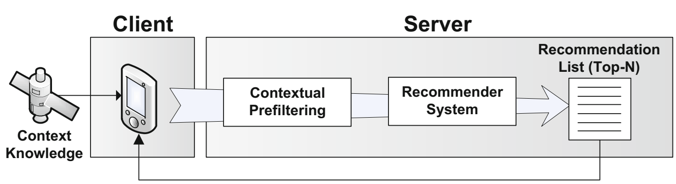
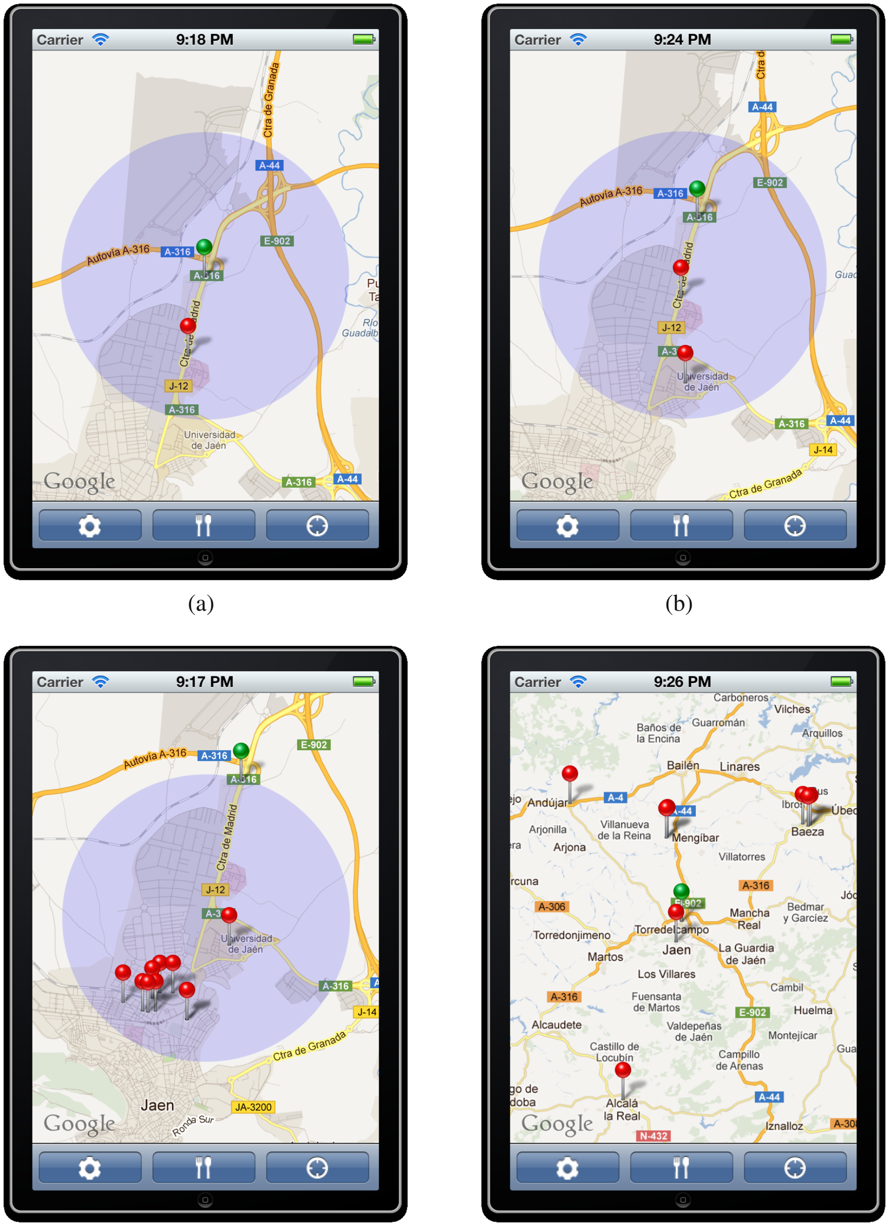


Fig. 4 In our prototype, contextual information is incorporated into the RS by means of a contextual pre-filter



(a) (b) (c) (d)

Fig. 5 Screenshots of the implemented prototype. The green pin marks the user's location, whereas the red pins are recommended restaurants. The blue circle represents the area within R_{outer} (2km). Traveling south along a motorway at a) 40 km/h, b) 80 km/h, and c) 120 km/h. d) Non context-aware version. The user location remains constant in all images.

green pin, whereas recommended restaurants are represented by red pins. The blue shaded area represents the AOI considered by the system when providing recommendations, see Section 3, and its radius is $R_{outer} = 2km$. Note that this circle is not actually shown to the user, but it has been introduced here for illustrative purposes.

Figure 5a represents a user travelling south by car at 40 km/h along a motorway. Given this low speed, the system assumes that the user is either in an urban environment or that she is likely to change directions soon. Therefore, all restaurants around her are potentially interesting. Under these circumstances, the mobile device makes P equal to P', and thus, the AOI is centered around her physical location.

In Figure 5b the user speed is assumed to be 80 km/h. We can observe that under these new contextual conditions, the system automatically adjusts the AOI and translates its center P' according to the travel direction. As a result, a new restaurant ahead of the user's location is recommended.

In Figure 5c, the user is moving south very quickly (120km/h) along the motorway. Here, the system avoids recommending restaurants behind the user's location by translating the AOI according to her direction in such a way that the user is located just on the border of the area, i.e. $|PP'| = R_{outer}$. We can see that several restaurants located in the city are recommended, but on the contrary, the restaurant that was previously recommended in Figures 5a and b has disappeared. This stems from the fact that now the system has more items available to recommend, and thus only the best ones are provided to the user.

Finally, and for the sake of completeness, we also show the recommendations provided by our system after turning off its context-awareness, see Figure 5d. In this case, the user's location and speed are neglected, and only her profile is taken into account when computing recommendations. Therefore, the recommendations provided are spread all over the geography of the province, which is clearly of little interest to a user travelling in a car and looking for a place to eat soon.

5 Conclusions

In this paper, we have proposed a novel method to improve recommendations provided by classical RSs by using a context-aware filtering. Our technique defines an area of interest (AOI) that depends on the user's speed and travel direction. Only POIs within this area are considered for recommendation. When the user speed is low (e.g., inside a city), the center of the area coincides with the user's position. However, as the user speed increases, the area is gradually displaced ahead in the estimated direction of the user. In this way, those POIs left behind by the user are excluded from the recommendation process. By contrast, more distant POIs that are in her estimated future trajectory are taken into account when making the recommendations.

A prototype has also been developed to show the possibilities of using CARSs on mobile devices. This type of system might facilitate the marketing processes of companies and increase their impact due to its flexibility, accuracy and personalization. Specifically, our proposal would contribute to the success and customer loyalty of tourism platforms.

With regard to future works, we plan to study smarter techniques to estimate the future direction of the user, e.g., an interpolation of the user location in the future based on cubic parametric curves. Different shapes and sizes of the AOI can also be considered. We also plan to use GIS (Geographic Information System) technologies to apply path techniques to vector maps of the road network in order to use estimations of the time needed to reach the POIs instead of the Euclidean distance.

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