RecoMMobile: A spatiotemporal recommender system for mobile users

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***Abstract*—The increasing popularity of smart mobile devices, that are opulently equipped with various sensors and permanently connected to the Internet, has made context-aware services a telco mainstream. Very popular group of context-aware services are location-based mashups – intelligent services that combine user location with other location-related data to provide users with an added value. This paper presents the RecoMMobile system that enables real-time location-based recommender service for products offered by a retail store chain to mobile users. Additionally, the RecoMMobile system is also a social recommendation tool because it allows users to forward recommendations to their friends by connecting with the Facebook social network.**

I. INTRODUCTION

An evolution of mobile technologies during the last decade [1][2][3] has contributed to significant increase in popularity of communication over the Internet using mobile devices. At any time and any place, a user is able to access Internet and retrieve the information he/she needs at that specific moment and location [4]. For example, a user who rides a train back home after work and wants to find out a result of just finished football match of his/her favourite team, can easily get this information.

In addition to explicitly searching for information on the Internet, specific information can be delivered to users implicitly, based on parameters collected from sensors on their mobile devices (e.g., *location*, *acceleration*, etc.) [5][6]. The most common implicit parameter is the user location. For example, a user who is interested in "films playing in the nearest cinema on a certain day" can easily get this information simply by asking the application on his/her mobile phone the question in quotes, without explicitly indicating the name/address of the nearest cinema (very often the user even does not know this information). In the same way, a user can also find out working hours of the nearest restaurant, location of the nearest hospital, etc. [7]. This kind of services are called *location-based services* (LBS) [8][9][10].

A research problem we investigate in this paper is the following: "how a user can subscribe to receive real-time context-aware recommendations from the nearest store of a certain retail chain?" The main idea of the proposed solution is to divide geographical area into sections, determining "jurisdiction" of a certain store from the chain. Now, a user presence in a certain area defines a store from which the user should receive a recommendation. Furthermore, based on the location of mobile device the proposed recommender system also determines additional context information [11] about the user environment, i.e., a temperature and a weather forecast [12]. Finally, our recommender system combines multi-dimensional context information to inform users about products (i.e., items) they may need at a specific location, time and weather condition.

Our spatiotemporal recommender system, called RecoMMobile, is based on data collected from user mobile device at any time without his/her intervention. Therefore, we follow Weiser's "calm technology" principle (calm technology is that which informs, but does not demand user focus or attention) [13]. For example, let us assume that at 13:00 a user is located at a coast. It is summer and the weather should generally be sunny, but it is raining at this specific moment. Our recommender system autonomously collects context information and computes a list of items to be recommended to the user. Items with higher priority are located at the top of a list while items with lower priority are on the bottom. In this specific case, the RecoMMobile recommender system predicts that the user might need an umbrella and warm clothes, resulting in those items located at a top of the list. Such a recommendation, which is unusual for user located at the coast in summer, would never be generated by a recommender system which does not takes into account real-time context information.

This paper is organized as follows. Section 2 gives an overview of related work on LBS services and recommender systems. Section 3 presents our context-aware recommender system, called the RecoMMobile. In Section 4 the architecture and the implementation of the RecoMMobile are described. Section 5 presents a RecoMMobile case study and Section 6 concludes the paper.

II. RELATED WORK

LBSs are services that integrate user device location or position with other user/context information for providing added value to the user. LBS-based applications are used in different contexts such as social networking, health, work, etc. [14]. Generally, LBSs can be classified into following categories [15]:

- *infotainment services* – services that help user to reach specific destination (e.g., locating the restaurant), find another mobile user or localize current position on a map. The main characteristic of these services is that they are pull-based – user sends query to a server and afterwards receives a result,

Sambolec, Igor; Rukavina, Ivan; Podobnik, Vedran.
RecoMMobile: A spatiotemporal recommender system for mobile users.
Proceedings of the 19th International Conference on Software, Telecommunications and Computer Networks (SoftCOM 2011).
Split, Croatia: IEEE, 2011.

- *tracking services* – services used for tracking entities equipped with mobile devices (e.g., user, car, truck, etc.),
- *information dissemination services* – services that disseminate content to mobile users based on their location,
- *location-based games* – services containing some sort of competing scenario, usually targeting young users,
- *emergency-support services* – services used to determine position of a mobile "911 caller". These services, which are very useful to the police, ambulance and fire fighters, must be enabled by network operator.

Proposed recommender system, the RecoMMobile, can be classified as an information dissemination service, because this type of LBSs are used to give the user information which he/she may need at a specific location and at a specific time. They are often used in mobile commerce (m-commerce) systems because they enable companies to reach their customers directly via personal mobile devices and offer them exactly what they may need in specific circumstances. However, a timely provisioning of relevant information to users has become the main challenge for developers, content providers and network operators. The biggest challenge is how to design algorithm which takes all location-based parameters and quickly provides aimed information. This algorithm must also be robust regarding network delays which can depend on signal coverage of user location or general state of mobile network.

Recommender systems are usually classified into three categories: *collaborative*, *content-based* and *hybrid* recommender systems [16]. Collaborative recommender systems try to predict the rating of an item for a particular user based on how other users previously rated the same item. In content-based recommender systems, on the other hand, the rating of specific item is based only on data obtained from the user. That data could be ratings assigned by the same user to other items that are similar to specific item or some other data obtained from the user (e.g., his/her purchase history). Hybrid recommender systems combine collaborative and content-based approaches. They maintain user profiles based on content analysis using specific information retrieval methods and compare the resulting profiles to determine similar users in order to make collaborative recommendations [19]. As it is going to be described, proposed recommender system, the RecoMMobile, can be classified as a content-based recommender.

Finally, the state-of-the art in the area of LBS recommender systems is described in [17] and [18]. The former paper presents location-based service recommendation model (LBSRM), where authors propose personalization of information recommendation through adaptive method including a combination of long-term and short-term mobile user preference adjustment. Specifically, the authors take into consideration the factor of distance attribute, in order to satisfy the distinct mobile applications. The latter paper discusses the need for embedding multi-dimensional context-awareness into the design of applications that provide dedicated, targeted and personalized information access to users. Further to this, the authors highlight the challenges that must be overcome in obtaining contextual information in a mobile computing scenario.

III. RECOMMOBILE: REAL-TIME CONTEXT-BASED RECOMMENDER SYSTEM

The RecoMMobile is content-based recommendation system where rating of an item is calculated based on user context information, such as location, time of the day and year, weather forecast and temperature.

A. Context-based product profiling

The rules for connecting each product to be recommended with a specific set of context attributes can be derived in different ways.

One possible solution could involve an administrator who manually determines the relations. However, there are two disadvantages in such an approach: i) an accuracy of the recommendation depends on the administrator's (subjective) estimate, and ii) complexity of a task requires lots of administrators.

Alternative approach includes integration of specialized software in stores' cash registers. This software records time (in a day), period of year, the store location and weather information at the moment when specific product is sold. Afterwards, a central server collects this data from all cash registers across all stores and calculates necessary relations for recommendation. These relations are based on each store's location, enabling recommendation system to analyze user location-based data, compare it to the nearest store selling data and recommend the best-selling products at specific situations. This method, compared to administrator-based solution, is more objective and efficient, as well as recognizes the real needs of users at a specific moment.

The basic advantages of proposed system over traditional recommendation systems are:

- a user, who is potential retail store customer, in described type of situation does not have to enter any kind of data to describe his/her context but the system does that for him/her (i.e., "calm technology" principle,
- a retail store reaches out to potential customers in the most intimately manner – through his/her personal mobile device.

The RecoMMobile system also allows a retail store to indirectly promote products through their customers (i.e., social recommendation) – customers can publish an interesting product on social networking site *Facebook* or send a description via SMS (*Short Message Service*). This enables product recommendations to even reach users who do not use the RecoMMobile system directly. Finally, the RecoMMobile system enables a user to browse the nearest store within a store chain using *Google Maps* and GPS (*Global Positioning System*) services.

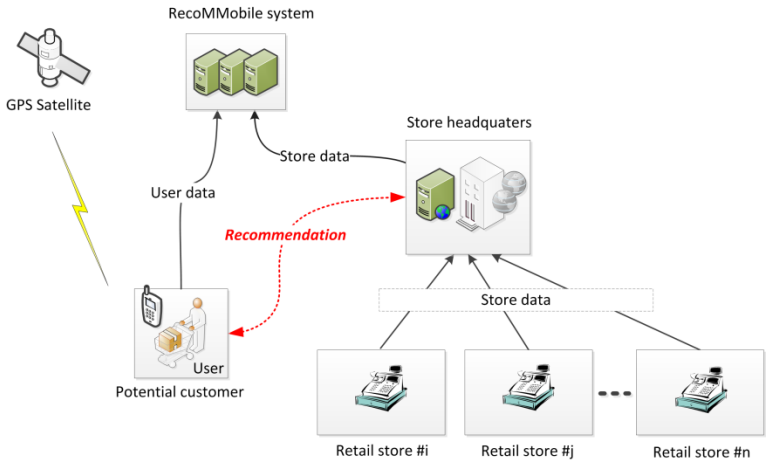


Figure 1. A model of location-based recommendation system for mobile users

B. *Recommendation algorithm*

In the proposed recommendation model there are two types of data used (Figure 1):

1. *user data* – describes the user context,
2. *store data* – describes the context in which a specific product is sold.

User data, which represents the user context, is based on two parameters collected from the user mobile device:

- location,
- time.

Time defines the period of a day and current year season. This data is used to connect the time in which the user is observed and products that were purchased by other customers at a similar time. The user location data is taken from a GPS device integrated in the user's mobile device. All other collected/computed data is based on the identified user location. Namely, the weather forecast data is taken from the *Google Weather* service which provides API for that feature. Weather forecast data includes:

- temperature (minimum, maximum, current),
- current weather condition (rainy, sunny, etc.).

Depending on the temperature and current weather forecasts, the RecoMMobile system can deliver information about the product that user may need at an observed moment. For example, the system detects that it is raining and recognizes that the user might need an umbrella. Furthermore, location data also enables user to locate the nearest store, as well as store to locate a user. For example, user is interested in some item and wants to buy it. He/she can locate the nearest store. On the other hand, system can detect that a RecoMMobile user is near certain store that has been recently open and inform him/her about that. Furthermore, the proposed system supports adding different notification data related to different retail stores. For example, a certain retail store has a product on sale. This information can be sent to all users that may locate themselves near that store.

Store data represents the context in which products are sold. This data is used to record statistics of product demand for a certain context. For every sold product our system records:

- sale time,
- store's GPS location.

Sale time defines the period of a day and current year season. Based on this information the RecoMMobile system calculates statistics for the best selling products for particular period of a day and current year season. More specifically, based on store's GPS location system calculates statistic for best selling products for a particular location.

TABLE I.
A FORMAL MODEL OF THE RECOMMOBILE SYSTEM

Type of data	Label	Description
User data ($\boldsymbol{u}$)	$\boldsymbol{u_L}$	location
	$\boldsymbol{u_{WC}}$	weather condition
	$\boldsymbol{u_T}$	temperature
	$\boldsymbol{u_{TD}}$	period of day
	$\boldsymbol{u_{TY}}$	year season
Store data ($\boldsymbol{s}$)	$\boldsymbol{s_L}$	list of best selling products for a specific location
	$\boldsymbol{s_{WC}}$	list of best selling products for a specific weather condition
	$\boldsymbol{s_T}$	list of best selling products for a specific temperature
	$\boldsymbol{s_{TD}}$	list of best selling products for a specific period of a day
	$\boldsymbol{s_{TY}}$	list of best selling products for a specific year season

Table 1 defines a formal model of the RecoMMobile system. Furthermore, we can denote a list of all products with $\boldsymbol{P}$, a list of recommended products with $\boldsymbol{R}$ and a number of recommended products with $n = |\boldsymbol{R}|$. Now, we can formally define the RecoMMobile system as a function:

$$f(\boldsymbol{P}, \boldsymbol{u}, \boldsymbol{s}, n) = \boldsymbol{R}$$

where

$$\boldsymbol{u} = (\boldsymbol{u_L}, \boldsymbol{u_{WC}}, \boldsymbol{u_T}, \boldsymbol{u_{TD}}, \boldsymbol{u_{TY}}),$$
$$\boldsymbol{s} = (\boldsymbol{s_L}, \boldsymbol{s_{WC}}, \boldsymbol{s_T}, \boldsymbol{s_{TD}}, \boldsymbol{s_{TY}}),$$

and

$$|\boldsymbol{R}| <= |\boldsymbol{P}|.$$

Finally, Listing 1 presents a pseudo-code of the recommendation algorithm for the RecoMMobile system.

Algorithm 1: Generate list of recommended products;
Input: P – list of available products, **u** – user data, **s** – store data, n – number of recommended products;
Output: R – list of recommended products.

foreach *product* in $\boldsymbol{s_L}$
  if *product* has good selling for $\boldsymbol{u_L}$ insert *product* into $\boldsymbol{R}$
end foreach
foreach *product* in $\boldsymbol{s_{WC}}$
  if *product* has good selling for $\boldsymbol{u_{WC}}$ insert *product* into $\boldsymbol{R}$
end foreach
foreach *product* in $\boldsymbol{s_T}$
  if *product* has good selling for $\boldsymbol{u_T}$ insert *product* into $\boldsymbol{R}$
end foreach
foreach *product* in $\boldsymbol{s_{TD}}$
  if *product* has good selling for $\boldsymbol{u_{TD}}$ insert *product* into $\boldsymbol{R}$
end foreach
foreach *product* in $\boldsymbol{s_{TY}}$
  if *product* has good selling for $\boldsymbol{u_{TY}}$ insert *product* into $\boldsymbol{R}$
end foreach
sort $\boldsymbol{R}$ by number of occurrences for each *product*
delete multiple elements from $\boldsymbol{R}$
return first *n* elements from $\boldsymbol{R}$

Listing 1. The recommendation algorithm for RecoMMobile system

IV. RECOMMOBILE ARCHITECTURE AND IMPLEMENTATION

The RecoMMobile system is built on top of a client-server architecture. It is composed of four separate components that communicate using HTTP (*Hypertext Transfer Protocol*): *the Server, the Mobile Client Application, the Google Services Server* and *the Web Browser Client*.

Server component is implemented using PHP programming language [20] and it communicates directly to MySQL database [20] and *Google Weather* service. There are two server sub-components:

1. *Mobile Client Services – MCS,*
2. *Web Client Services – WCS.*

The MCS provides web-service to mobile client for retrieving product and general store data and it communicates with other system components. Product data include:

- product image URL (*Uniform Resource Locator*),
- product title and description,
- product price.

General store data include working time and location of each store. The product and general store data are stored in a MySQL database. Changes in the database are done through WCS sub-component which represents a web administration application implemented using PHP and AJAX [21]. Context information about a user current location is dynamically supplied by *Google Weather* service. This component uses GPS coordinates provided by the user device.

The *Mobile Client Application* (MCA) is an application developed for mobile devices based on Android operating system [22]. At a start-up, the *Mobile Client Application* (MCA) checks whether the user location can be determined by an integrated GPS device or mobile network itself, as well as network connection status. If these conditions are met, the application sends coordinates to the MCS and requires a product list. The same activity is scheduled for every 30 minutes. The MCS now contacts *Google Weather* service that returns the current state of the user environment. After processing obtained data, the MCS generates a list of products from a store offer. The MCS is trying to predict which products would be interesting at the specific moment to the potential buyer and sets them on the top and the less interesting to the bottom of the list, as already described. Figure 2 shows the sequence diagram of the described activity. Additionally, the MCA allows users to view locations of stores across Croatia. By selecting this option, the application tries to re-establish access to the Internet and determine user location. After that, it requests a list of store locations and any information related to nearby stores in relation to the identified user location. The MCS returns a list of locations of all stores in Croatia and information related to the nearest stores to the user. This data is processed and displayed on the *Google Maps*. Figure 3 shows a sequence diagram of the described activity.

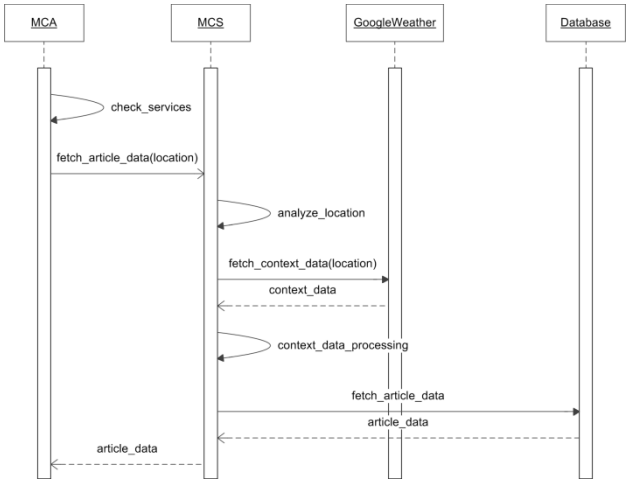


Figure 2. Sequence diagram of receiving recommendations

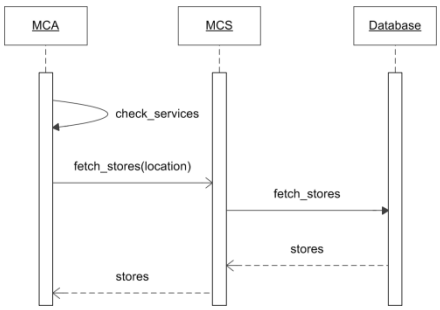
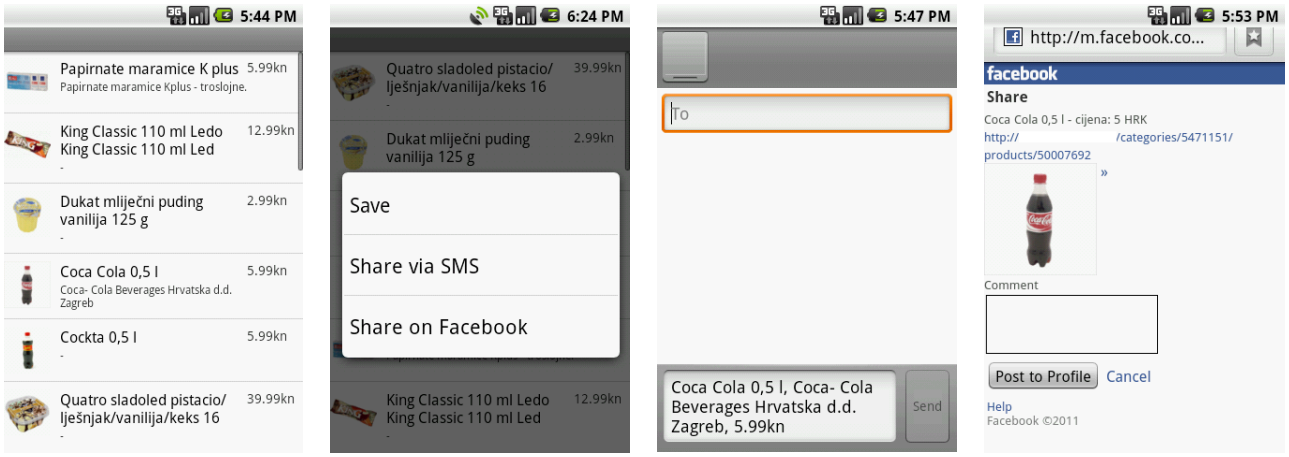


Figure 3. Sequence diagram of receiving store data



a) b) c) d)

Figure 4. a) A list of recommended products; b) Product options; c) Sending an SMS; d) Publishing on a Facebook Wall

Finally, the *Web Browser Client* component is used for administration of the recommender system via web browser.

V. RECOMMOBILE CASE STUDY

The implemented RecoMMobile system can be accessed via two different interfaces: *user application for mobile devices* and *administrative web application*.

A. User application

After the user starts the RecoMMobile application, a list of recommended products is shown (Figure 4.a). The user can view the list of recommended products and preform some specific actions on the desired product. By selecting the desired product user can choose one of the following actions (Figure 4.b):

- *Save*,
- *Share via SMS*,
- *Share on Facebook*.

By selecting the *Save* option the user can store product information in the device memory for later use. On the other hand, the *Send via SMS* option allows users to send product information to the desired recipients as a text message (Figure 4.c). Finally, the user can also share product information with his/her friends on the Facebook by selecting the option *Share on Facebook*. After entering Facebook username and password, the user can edit the content of the message which is going to be published on his/her *Facebook Wall* (Figure 4.d).

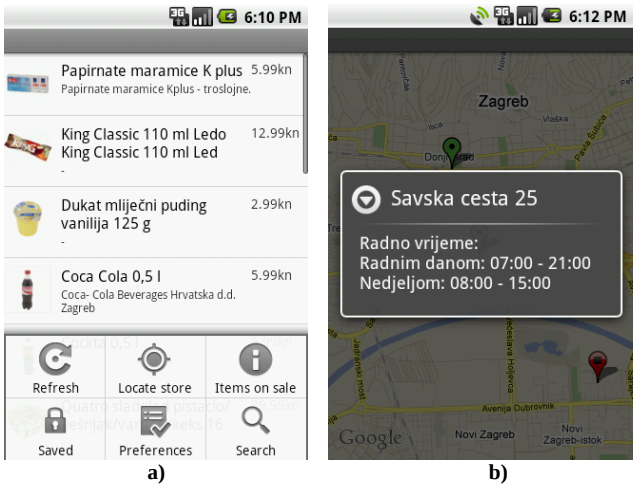
Furthermore, the user can choose one of the options from the main menu (Figure 5.a). The *Refresh* option refreshes the list of recommended products. If the user data has been changed (e.g., GPS location, weather conditions, etc.), the *Refresh* option will generate new list of recommended products based on the new user data. On the other hand, the *Store locator* option allows the user to view his/her location and locations of nearest stores on the *Google Maps*. User can easily navigate on interactive map and find the shortest path to the nearest store. When the user selects the specific store, the dialog with working time and store address appears (Figure 5.b). The user also can select his/her desired product categories to filter the list of recommended products by selecting the *Preferences* option. Finally, the user can also search for desired products by the keyword if choosing the *Search* option in the main menu. After entering the keyword the list of related products is shown on the screen.

B. Administrative application

The administrative application is used for editing product/store data and testing the RecoMMobile system by performing recommendation simulations. Administrator has to be logged in the application and then he/she can choose one of the following options in the main menu:

- *Manage products*,
- *Manage stores*,
- *Products preferences*.

The *Manage products* option allows administrator to add new products, where a product is defined by its name, price,



a) b)

Figure 5. a) The RecoMMobile application main menu; b) Google Maps and detailed store information

description, image and a group. The *Manage store* option allows administrator to add new stores, where a store is defined by its GPS location, address, telephone number and working time. The *Product preferences* option simulates mechanism for calculating the best selling products and allows administrator to explicitly pair specific product with context parameters defining when the product is usually purchased.

VI. Conclusion and Future Work

This paper describes the RecoMMobile system, a real-time context-aware recommender system. The RecoMMobile system enables recommendation of items from a retail store offerings to mobile users. Users with smart mobile devices are tracked by the RecoMMobile system through observing their devices' GPS locations. Based on the user location, the proposed system autonomously determines the other context parameters such as weather, time of day, etc. After all context data is collected/computed, the RecoMMobile system predicts which items from store offerings might be of interest to the user at specific moment and at specific location.

A possible disadvantage of the proposed system is the fact that this is currently only a context-aware system, but it lacks a personalization mechanism – while the RecoMMobile system "putts forward" the most popular (i.e., best selling) items based on the current user context, recommendations are the same for every user in the same context as implemented approach does not account in any way for the user interests or past preferences. Moreover, this is also the reason why we could not evaluate the recommendations.

On the other hand, one of the main advantages of the proposed system is an option of indirect marketing of retail stores through Facebook – users may perform social recommendations when they recognize an interesting product. Facebook marketing potential is huge – firstly because of the large number of users who can see the recommended products and, secondly, social recommendations are very credible.

Our future work includes upgrade of the RecoMMobile system with personalization mechanism and integration of mobile shopping feature which would allow users to buy items at the same time they have been recommended. Additionally, we plan to evaluate the technical performance (e.g., the "footprint" of the implemented client on the mobile device or the bandwidth required for the system operations), as well as the user acceptance of the proposed system. The former will be assessed through comparison with other recommender systems, while the latter will be measured by conducting user trials.

Acknowledgements

The authors acknowledge the support of research project "Content Delivery and Mobility of Users and Services in New Generation Networks" (036-0362027-1639), funded by the Ministry of Science, Education and Sports of the Republic of Croatia.

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