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Fast track article

UTravel: Smart mobility with a novel user profiling and recommendation approach

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ABSTRACT

The exponentially growing availability of online information calls for personalized search and recommendation. Such systems provide recommendations typically based on user profiles built taking into account user actions. Not yet fully explored, is the domain of context-aware recommendation. In this article, we introduce a novel approach, where user profiling and context-based data filtering both concur to recommendation production. Based on the aforementioned approach, UTravel is a smart mobility application that recommends points of interest (POIs) to end users. After describing the UTravel architecture and implementation, we present the results of an experimental evaluation we carried out involving both simulated and real users.

1. Introduction

The overwhelming growth of the quantity of online information, offered by multiple Internet-connected sources, is an evident phenomenon. Although being a great opportunity, facing such a huge and variegate amount of data can become an obstacle for the user, which needs new decision support tools that must be effective and easy to use. Such a problem has been studied, in recent years, mainly focusing on supporting the *personalized search* of products and services in the Web [1–3]. Personalization means the ability of an information system to automatically filter contents and reshape their presentation, based on user characteristics. Thus, a personalization system can be intended as a computer-based application that monitors the user behavior to create and manage his/her profile, with the purpose to select only relevant products/items (*recommendation*), within a very large repository, or to support other applications and services in adapting to the specific needs of each user.

The main components of a personalization system are usually (1) content description, to be intended as the classification of products or items that the system provides to the user, (2) user profiling, and (3) content selection (filtering), trying to best match the user profile. User profiles are usually derived from collected information about user behaviors and interests. The filtering phase is typically associated to an application, such as an e-commerce site (*e.g.*, Amazon), a search engine (*e.g.*, Google), or a social network (*e.g.*, YouTube), where personalized products or multimedia items must be presented to the user. Google, for example, provides personalized and *contextualized* results, taking into account past history, and trying to understand the purpose behind user queries.

The study of context-awareness has gained momentum also for the pervasive diffusion of smartphones, and mobile devices with high computing, storage and bandwidth capabilities, as well as sensors (such as GPS, accelerometer and

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camera). In particular, the presence of on-board sensors allows the implementation of mobile applications which provide useful information and contents to the user, according to her/his location and current actions.

In this article we present the novel Universal Profiling and Recommendation (UPR) approach, based on context-awareness. In particular, we describe our first UPR-based mobile application, namely *UTravel*, which informs and guides users toward points of interest (POIs). According to the context and to the selected categories of interest, UTravel suggests the best POIs in a user-defined range, with respect to his/her current location. The suitability of POIs is inferred from previously shared user evaluations, according to the principles of *collaborative filtering*. The main purpose of the proposed architecture and application is to illustrate how context-awareness can contribute to improving the recommendation process of POIs for mobile users.

The first methodological contribution of UPR is a hybrid strategy for user profiling, which builds an approximated description of the user, by taking into account not only its individual behavior, but also the behavior of other similar users. Our main reference has been the product recommendation system recently proposed by Park and Chang [4]. With respect to the latter approach, our one clusters users by taking into account not only their demographic profiles, but also their preference profiles. To this purpose, the UTravel architecture integrates evaluation and rating mechanisms that are well known in the field of personalization systems [2,5]. In particular, the UTA* algorithm [6] is used to build preference profiles, allowing the creation of a model of the value system which intervenes in the user decision process. In UTravel, such a model is built by elaborating the multi-criteria evaluations that the user assigns to the POIs proposed by the system. The preference profile and the demographic profile are used to find groups of similar users, with the K-Means clustering algorithm [7]. Such groups are taken into account to define the behavior profile of each user. To this purpose, the system tracks her/his interactions with the mobile applications, including clicks, data saves, evaluations, check-ins and preferences which are expressed by selecting or updating the categories of interests. The second methodological contribution of UPR is a filtering strategy that exploits context data collected by the user mobile device, such as its current location, as complementary information to the behavior profile.

The paper is structured as follows. In Section 2 we discuss some relevant related works in the field of context-awareness, user profiling and recommendation for smart mobility. In Section 3 we illustrate the UPR approach by outlining the UTravel architecture. Section 4 describes the UTravel implementation, which is a platform including services, databases and mobile application (here we refer to the Android version only). In Section 5 we show the results of a medium-scale experimental evaluation of UTravel, involving both simulated and real users. Finally, in Section 6 we conclude the paper, with a summary of the presented research work and further ideas for future development.

2. State of the art

The background of the UPR project includes context-awareness, user profiling, information filtering, as well as smart mobility supported by mobile applications.

2.1. Context-awareness

Depending on the adopted perspective – user-side or application-side [8] – contextual information can be classified into three main categories, namely: user context (such as location, company of other people [9,10], emotional status [11]), device context (*e.g.*, connectivity, network bandwidth) and physical context (*e.g.*, date, time, weather, temperature [12,13]). As the interpretation of context depends on the application domain, it is not possible to provide a unique definition of the concept. In modern recommendation systems, user and physical context play a major role in supporting the information filtering process, for which products, routes, or other items are suggested to the user, by taking into account the circumstances in which the user will make her/his choice [14–17]. In the e-commerce scenario, it is important to know the motivation of the user. Is she/he looking for a product for personal use, or for a gift? In the ubiquitous/mobile computing scenario, instead, it would be important to know the user location, as well as the identity of the persons nearby the user, and the environmental conditions. A mobile user will take a different decision depending on, for example, if she/he is with the family or with friends, how is the weather, and so on.

Within the data mining community, context is sometimes defined as those events that characterize the life stages of a customer and can determine a change in his/her preferences, status, and value for a company [18]. Knowledge of this contextual information helps mining patterns to focus only on the relevant data and selecting only relevant results. The contextual information can be obtained (i) explicitly, *i.e.*, by asking direct questions to the user; (ii) implicitly, *i.e.*, from the data or the environment, such as a change in location; or (iii) by inference, using statistical or data mining methods, such as Naïve Bayes classifiers and Bayesian Networks. Explicit and implicit approaches are mostly used in recommendation systems based on *context-driven querying and search* of repositories of resources [19]. Inference, instead, is used for *contextual preference elicitation and estimation*, a more recent trend in context-aware recommender systems literature [20–23], attempting to model and learn user preferences, *e.g.*, by observing the interactions of this and other users with the systems or by obtaining preference feedback from the user on various previously recommended items. The UTravel system presented in this paper is based on a hybrid approach, where preference feedback is used to build user profiles that support context-driven querying and search.

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