# Towards Context-Aware Recommendation for Personalized Mobile Travel Planning

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**Abstract.** The system design and development of context-aware recommendation for personalized mobile travel planning is an important issue for both research and practices. The goal of this paper is to propose a system development framework and processes for directing the design and implementation of a context-aware recommender system that provides personalized mobile travel planning services. Design science is chosen as the research methodology and technologies integrated for building the system include rule-based reasoning, model based computing, and context data modeling. A prototype system is also constructed and evaluated to validate the feasibility and effectiveness of the proposed system development approach.

**Keywords:** Recommendation services, mobile travel planning, context awareness, personalization, system development.

## 1 Introduction

Personalized recommender systems are systems capable of providing the most suitable solutions to users based on their needs and preferences. Personalized recommendation and enabling intelligent technologies have long been important yet complex research as well as practical issues. It has been noted that, without proper functional architecture and system support, the integrated processes of searching and filtering objects, comparing alternatives, as well as selecting and recommending appropriate solutions for user evaluation can be extremely complicated and hard to be carried out [4]. Furthermore, the complexities of the problem scope, solution processes, and system design and implementation methods expands drastically when taking into account the support of mobile users with a variety of mobile devices accessing personalized recommendations [1]. On the other hand, context-awareness which captures user's contextual information such as location and time, needs and interests, and/or social interactions, has become an increasingly desired mechanism for enhancing personalized mobile recommendations [2,3,5]. However, to date, existing works incorporating context awareness into personalized mobile recommendations are still very limited.

Travel planning, as a major functional service in tourism applications, is a process of searching, selecting, grouping and sequencing destination related attractions

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including sightseeing spots, events, hotels and restaurants. Due to more availability of comprehensive data about travelers and destinations as well as more exchange of information among travelers, how to provide context-aware recommendation services for facilitating personalized travel planning inevitably becomes a critical research and practical issue in the mobile tourism domain [1,4,6]. Ideal context-aware personalized mobile travel planning recommendation services should be able to integrate and match information about tourists' location and time, needs and preferences, conditions and constraints with destination and attraction information, as well as to subsequently recommend personalized travel plans in which sightseeing spots, restaurants, and hotels are bundled to best fit the user context based on suitable recommendation models and rules. Although some specific technologies such as content and collaborative filtering had been applied for conducting personalized recommendations, there are very few previous research efforts undertaking the integrated issues of context-aware personalized travel plan recommendations for mobile tourists. The objective of this study aims at filling the gap by providing system architecture and development method for efficiently and effectively guiding the design and implementation of the demanded context-aware recommender system to support personalized mobile travel planning. In the following sections, a literature review, the proposed system framework and development process, a prototype system, and concluding remarks are presented in section 2 to section 4 respectively.

## 2 Literature Review

Among many research works regarding design and development of personalized recommendation services in the tourism domain, Garcia et al. (2011) put emphasis on a domain-independent taxonomy-driven recommender system and illustrate examples of individual and group tourism recommendation services based on the tastes of users, their demographic classification and the places they have visited in former trips [6]. As for mobile tourism applications, Kabassi (2010) provides a review of user modeling and personalization techniques as well as some development steps for a personalized mobile tourism recommender system [4]. Yu (2010) proposes a system architecture that integrates personalized and community services for supporting mobile travel planning [12]. Noguera et al. (2012) presents a mobile recommender system combining a hybrid recommendation engine and a mobile 3D GIS architecture to provide tourists with 3D map-based interface and real-time location-sensitive recommendations [8]. On the other hand, Tsai and Chung (2012) develops a route recommendation service to provide theme park visitors with proper route suggestions on facilities they should visit and in what order based on their personal preferences and intended visitation time, as well as tourists' behaviors (i.e., visiting sequences and corresponding timestamps) that are persistently collected using a Radio-Frequency Identification (RFID) system and stored in a route database [9]. Yang and Hwang (2012) develops a travel recommender system to provide tourists with on-tour attraction recommendation services that employs mobile peer-to-peer communications for exchanging ratings on visited attractions with other tourists of similar interests [1].

When context aware functionalities are taken into account, previous works that explore the integrated issues involving context awareness, personalization, mobility, and recommender systems for tourism applications are very rare. Aiming at offering a taxonomy for mobile guides, Emmanouilidis et al. (2012) discuss technical considerations in several aspects of mobile applications including context awareness, client architectures, mobile user interfaces, and service functions [5]. Yilmaz and Erdur (2012) address the issue of design and development of an intelligent context-aware system for recommending attraction points to mobile users according to their contexts, and propose rule-based context reasoning and multi-agent technologies for fulfilling the jobs [7].

As can be seen, research regarding the development and delivery of context-aware personalized mobile travel planning recommendation services is still in its initial stage and only partial solutions have been provided. To efficiently and effectively support context-aware recommendation of personalized travel plan for mobile users, the need of an integrated system framework and development method for guiding system design and implementation is obvious and strong. The goal of this study is to tackle the key problem and propose feasible solutions.

## 3 Context-Aware Recommendation for Mobile Travel Planning

Design science is adopted as the research methodology because the nature of this study is an information system research that deals with design and implementation issues for developing personalized recommender systems. Four research activities in the design science research on information technology proposed by March and Smith (1995) are to build, evaluate, theorize, and justify; while the research outputs include constructs, model, method, and instantiation [10]. Peffers et al. (2007), instead, propose six activities for the design science research methodology that include problem identification & motivation, objectives of a solution, design & development, demonstration, evaluation, and communication [11]. Based on the design science research methodology proposed by [11], this study presents a system development framework and processes for building context-aware personalized mobile travel planning recommendation services. Intelligent information technologies integrated in this research include rule-based reasoning, model based computing, and context data modeling. A prototype system for demonstrating personalized mobile travel planning recommendation is implemented and evaluated to show the feasibility and effectiveness of the proposed system development approach. The evaluation criteria for the prototype system include user interface & layout, functionality, ease of use, understandability, satisfaction, and intention for future use.

### 3.1 System Requirements and Processes

The contextual information requirements for supporting context-aware personalized mobile travel planning recommendation include (1) users' current location and time, (2) users' needs and preferences, (3) users' conditions and constraints, (4) users' self-specified evaluation criteria, and (5) destination related sightseeing, accommodations, and dinning information. Decision requirements include decision associated model, knowledge, and processes. Specified information for sightseeing attractions includes sightseeing theme, opening hours, ticket price, location with address and map, briefings and suggested visiting time, etc. Specified information for accommodations includes hotel name, hotel class (star rating), brief introduction, hotel location with address and map, distances to nearby attractions, check-in/checkout times, room types, facilities, price per room per night, website and photos, contact information, and customer ratings, etc. Specified restaurant information includes restaurant name, food type, location with address and map, opening hours, customer ratings, and recommended food lists, etc. Functional requirements specified for the system include user profile management, tourism information management, context-aware recommendation of attractions (e.g. sightseeing spots, restaurants, hotels) and travel plans, travel plan management, as well as map-based positioning and visualization. Additional functions required for the back end system include database, model base and knowledge base management, and possibly ontology and case base management.

Based on the information and functional requirements, a system framework for context-aware personalized mobile travel planning recommendation is shown in Fig. 1. The personalized mobile travel planning recommendation services are comprised of four types of recommendations including hotel, restaurant, and sightseeing recommendation, as well as the travel plan recommendation. These recommendation processes receive requests from mobile users, retrieve user and destination related contextual data, filter and obtain data of relevant destination and attraction objects, activate corresponding recommendation knowledge and models for object evaluation, select and recommend objects with higher ranks in matching users' needs and preferences, and then present recommended results with information and maps to users' mobile devices. Rule inference is used for knowledge processing tasks that generate match scores for all items of specified evaluation criteria. Evaluation models for specific recommendations are responsible for computing the final weighted scores for selected objects and placing ranks to these objects based on their match levels. There are three back-end supportive services: the tourism-related information services, location-based services, and Google map services. These supportive services allow tourists to access tourism information, tourist location information and location aware attraction information, as well as attraction related geographical information and maps. The contextual oriented user profiles and tourism related databases, model bases, and knowledge bases, etc. are built to form the back end system.

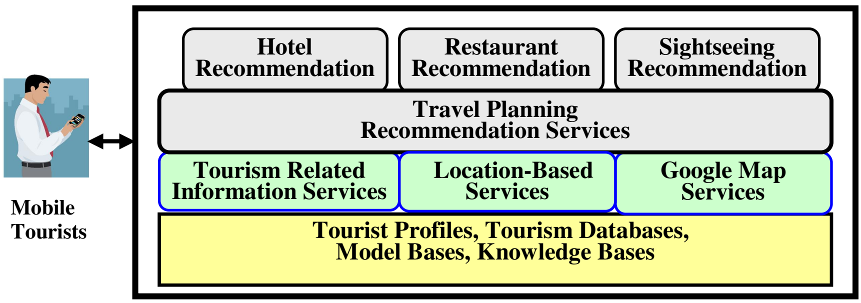


**Fig. 1.** A functional framework for personalized mobile travel planning recommendation

In the following, a complete recommendation process of context-aware personalized mobile travel planning for an example scenario is described and illustrated in Fig. 2. Assume that a tourist just steps out of the main station of a city and requests the recommendation of a one-day tour plan via his smart phone. He specifies the time periods for lunch and dinner time to be 11:00 am -14:00 pm and 18:00-21:00 pm respectively, the maximal number of visiting places to be 7, and the time for the end of the single day tour to be 21:00 pm. The search range of attractions is set to be 3 km from the current location. The needs, preferences, and evaluation criteria for selecting the sightseeing spots, restaurants, and hotels are specified online and/or obtained from the user profile. As the travel planning recommendation process started, the tourist's current location and time are identified and recorded. During the recommendation process, if the updated current time is around the lunch time or dinner time periods, and the tourist has not eat yet, then the restaurant recommendation service is launched to locate preferred restaurants of specified food type and within specified search range. If the current time is not in the lunch and diner time intervals and is no later than 21:00 pm, the number of visited sightseeing spots is less than 7, and there are suitable nearby unvisited sightseeing spots still open with sufficient time to visit, then the recommendation process continues to perform the sightseeing recommendation services. If the current time reaches the time constraint 21:00 pm or the number of visited sightseeing spots reaches 7, then the hotel recommendation service is processed. Finally, the complete tour plan consisting of sequentially arranged attractions including recommended sightseeing spots, restaurants, and hotel is sent with information and maps to the tourist's mobile device.

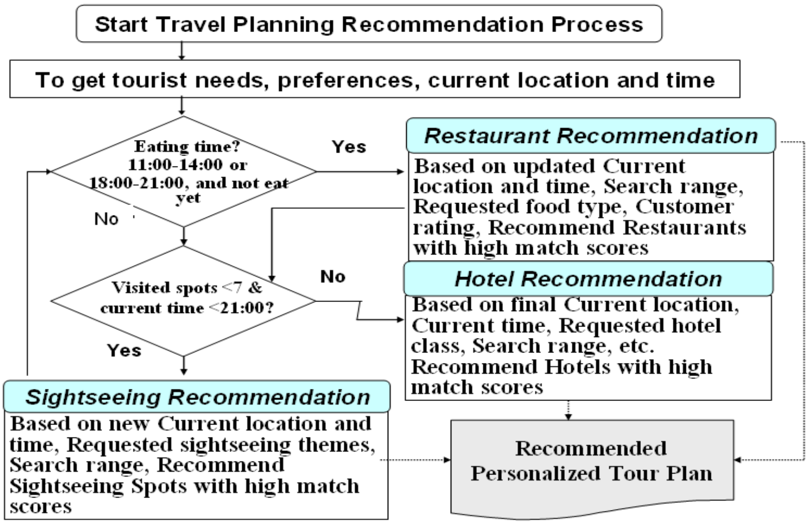


**Fig. 2.** An example recommendation process of context-aware mobile travel planning

### 3.2 System Design and Implementation

To facilitate the design and development of the contextual database, the object-oriented (OO) database design approach is applied to create the conceptual data model, and then the OO data model is translated into an entity-relationship (ER) model which is further transformed into the internal relational model for physical database implementation. In the OO data model, identified objects include Tourist, Tourism Information, Recommendation Process, and Tour Plan. The Tourist object composes of Needs and Preferences (N&P), Search and Evaluation Criteria, as well as Current Location and Time objects. The general N&P object is further classified into specific Sightseeing N&P, Restaurant N&P, and Hotel N&P objects. The Tourism Information object has three sub-class objects including Sightseeing Spots Information, Restaurant Information, and Hotel Information objects. The Recommendation Process object contains several component objects including Process Input, Recommendation Model, Recommendation Rule, and Process Output. The Tour Plan object consists of Sightseeing Spot Selection, Restaurant Selection, Hotel Selection, and Plan Schedule objects.

Table 1 describes partially the relational schema of the database. Relational tables created for the prototype system include the Tour plan table, Tour plan schedule table, Hotel table, Hotel room type description table, Hotel room status table, Restaurant table, Food type description table, Sightseeing spot table, Sightseeing theme description table, as well as tourist's location and time tables, and a set of needs, preferences, and criteria tables with respect to sightseeing spots, restaurants, and hotels. A field with underline represents the primary key of the table while the dotted underline indicates the foreign key. The mobile phone number is used as the identification of the tourist, and set as the primary key or part of the composite key for tourist related tables. Based on different types of recommended attractions, the attraction place ID in the tour plan schedule table is linked to the hotel ID in the hotel table, the restaurant ID in the restaurant table, or the sightseeing spot ID in the sightseeing spot table.

As for the design of model base and knowledge base, the process modeling, decision modeling, and rule base approaches are used. Examples of the recommendation process model as well as associated decision model and rules for the tour plan recommendation and restaurant evaluation are shown in Fig. 3-4. The inputs to travel planning recommendation process include tourist current location and time, search range (e.g. 3 km to the current location), constraints and criteria (e.g. 11:00 am - 14:00 pm and 18:00 - 21:00 pm as the lunch and dinner time periods respectively, 7 as the maximal number of visiting spots), as well as needs and preferences for sightseeing spots (e.g. specific sightseeing theme type), restaurants (e.g. specific food type), and hotels (e.g. specific hotel class, room type, room rate, and room facility). The resulting output elements of a recommended tour plan include tour plan ID, sequential number of recommended attractions, type of attractions (sightseeing, restaurant, hotel), attraction ID, attraction name, suggested time for visit, distance to attraction, and a map showing all ordered recommended attractions. By clicking on specific attractions, the tourist can access detail information of recommended sightseeing spots (e.g. name, location, address, distance to the updated current location, sightseeing theme, suggested visiting time, etc.), restaurants (e.g. name, location, address, distance to the updated current location, food type, suggested eating time, customer rating score, etc.), and hotel (e.g. name, location, address, distance to the updated current location, hotel class, room type, room rate, check-in/check-out times, facilities, distances to point-of-interest, distance to the updated current location, customer rating score, etc.).

**Table 1.** Relational Schema (partial)

| Table | Field |
|---|---|
| Tour plan | TourPlanID, MobilePhoneNumber, travelDate |
| Tour plan schedule | TourPlanID, AttractionID, sequenceNo, attractionType, recommStartTime, recommEndTime, distanceToPrevLocation |
| Hotel | HotelID, hotelName, hotelClass, hotelPhoneNumber, hotelAddress, hotelCheckinTime, hotelCheckoutTime, hotelBriefing, hotelPhoto, hotelMap, hotelLongitude, hotelLatitude, hotelCustomerRating |
| Room type description | RoomTypeID, HotelID, roomTypeName, roomTypeDescription, roomRate, numberOfRoom |
| Room status | RoomID, HotelID, roomNo, RoomTypeID, facilityList, roomAvailability |
| Restaurant | RrestaurantID, restaurantName, restaurantPhoneNumber, restaurantAddress, restaurantOpenHours, restaurantBriefing, r-Map, r-Longitude, r-Latitude, r-CustomerRating |
| Food type description | FoodTypeID, RrestaurantID, foodTypeName, foodTypeMenu |
| Sightseeing spot | SightseeingID, sightseeingName, sightseeingPhoneNumber, sightseeingAddress, sightseeingOpenDays, sightseeingOpenHours, sightseeinBriefing, recommVisitingTime, ticketPrice, s-Map, s-Longitude, s-Latitude, s-CustomerRating |
| Sightseeing theme description | SightseeingThemeID, SightseeingID, sightseeingThemeName, sightseeingThemeDescription, featureList |
| Tourist needs | MobilePhoneNumber, searchRange, requestedHotelClass, requestedFoodType, requestedSightseeingThemes, requestedCustomerRating |
| Tourist location | MobilePhoneNumber, touristLongitude, touristLatitude |

Record tourist current location
Set restaurant search range, requested food type, requested customer rating
Retrieve restaurant distance to the current location, food type, customer rating

If Restaurant distance to the current location = 0, then T1 = 100
    Else T1 = 100 - 10*(Restaurant distance to the current location)
If Customer rating c >= Requested customer rating c1, then T3 = 100
    Else T2 = 100 – 20*(c1-c)
If Food type f = Requested food type f1, then T3 = 100
    Else If f is in the set of tourist preferred food type, then T3 = 50
        Else T3 = 0

SET RT = Sum(T1*W1, T2*W2, T3*W3) Subject to Sum(W1, W2, W3) = 1
Where RT = total score of restaurant evaluation
Ti and Wi are value and weight of the ith restaurant evaluation criteria, i = 1, 2, 3

**Fig. 3.** Restaurant evaluation model and rules

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Record current location and current time
Set restaurant search range, requested lunch and dinner food type, restaurant rating
Set sightseeing search range, requested sightseeing theme, opening hours
Set hotel search range, requested hotel class, room type, room rate, facility, customer rating
Set temp_time=current time
Set temp_location=current location
While loop
If temp_time is between 11:00 am and 14:00 pm and lunch status=no
    or temp_time is between 18:00 pm and 21:00 pm and dinner status=no
        then Activate Restaurant Recommendation Service Model (temp_location, restaurant
        search range, requested food type, requested customer rating)
    temp_time = temp_time + suggested_eating time
    temp_location = location_of_recommended_place
If temp_time<21:00 pm and the number_visited_site< 7
        Then Activate Sightseeing Recommendation Service Model (temp_location,
        sightseeing search range, requested sightseeing theme, opening hours)
    temp_time = temp_time + suggested_visitng_time
    temp_location = location_of_recommended_place
End loop
Activate Hotel Recommendation Service Model (temp_location, hotel search range,
        requested hotel class, room type, room rate, facility, customer rating)
Output tour plan (selected sightseeing spots, restaurants and hotel with sequence numbers)
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**Fig. 4.** The process model for context-aware travel planning recommendation

# 4 The Prototype System

A prototype system that enables the provision of the context-aware personalized mobile travel planning recommendation services is developed for demonstration and evaluation. In the system operating environment, system and application software used in the back-end server side include Windows XP, Microsoft IIS Web Server 5.1, Microsoft SQL Server 2008, Microsoft Visual Studio 2010, and Google Map API 3.0. The CHT Windows Mobile 5.0 Smart Phone Emulator is used as the client-side emulator. Besides, one HTC 3G PDA phone and one Apple iPhone 4S are used for system testing and evaluation.

Fig. 5 illustrates some example screenshots of the prototype system. The two left side screenshots indicated as (A) and (B) displays user interfaces for setting needs and search criteria by inserting values to listed items such as search range, sightseeing themes, lunch and dinner food types, hotel class, room rate, and facilities, as well as levels of attraction related customer ratings. The third screenshot (C) presents the overview of the recommended tour plan with photos and names of attractions, sequential numbers (in red balloon), distances to previous locations, suggested time frames for visit, and location maps. Clicking on these attractions will show enlarged pictures and detailed information of the corresponding recommended sightseeing spots, restaurants, and hotel. The right hand screenshot (D) is a Google Map display that visually spots all recommended places with sequential numbers.


(A) (B) (C) (D)

**Fig. 5.** Example screenshots of context-aware mobile travel planning recommendation services

The system evaluation of the prototype system is performed through laboratory experiment with actual mobile devices and 3G mobile Internet connections. In the experiment, the user location is configured to a pre-specified geographical region in Taipei, Taiwan. Compared with emulators in the notebooks, the actual mobile devices reflect the real usage for mobile users. The user location is pre-defined because as a testing mobile service, it is hard for this study to access the location of the mobile phone number from 3G operators for privacy issues. Survey questionnaire is employed as a data collection method for system evaluation. Participation is voluntary and anonymous. Testing candidates are randomly selected in a university cafeteria. After a brief orientation explaining the purpose and procedure of the study and experiment, those who agree to participate are presented with a quick review of the prototype system. Participants are encouraged to practice with the prototype system to get familiar with the menus and functions of the recommendation services for personalized mobile travel planning. Then, the participants are asked to perform some typical travel planning tasks using the prototype system and to complete the system evaluation questionnaire. Data of the prototype system evaluation is collected from a sample of thirty participants with 50% being female. Based on a 5-point Likert scale (1 as strongly disagree and 5 as strongly agree), the average scores of six performance criteria including user interface & layout, functionality, ease of use, understandability, satisfaction, and intention for future use are 3.93, 4.13, 4.14, 4.48, 3.80, and 3.87 respectively. The overall average score is 4.06. This result indicates positively the applicability and effectiveness of the proposed recommender system framework and development method for context-aware personalized mobile travel planning.

## 5 Concluding Remarks and Future Studies

Based on the design science research methodology, this paper proposes a system framework, process models, as well as design and development methods for building context-aware recommender system to support personalized mobile travel planning. This research integrates advanced mobile and recommendation technologies to direct and facilitate the development and delivery of powerful context-aware recommendation services for enabling pre-trip and/or during-the-trip personalized travel planning that take into account mobile tourists' location and time, needs and preferences, as well as constraints and criteria. The construction, testing, and evaluation of the prototype system reflect the feasibility and effectiveness of the proposed system framework and development processes. In short, the system design and development approach presented in this paper provides guidance and example for both the academia and professionals in the separate and integrated fields of context-aware recommendation and personalized mobile travel planning.

In order to fully realize the potential of the proposed system development approach, some directions for future works are as follows. Firstly, as a technical extension, intelligent technologies such as ontology mapping and case-base reasoning will be incorporated into the recommendation functions. Secondly, formal evaluation of the proposed methods and systems will be conducted using a set of real businesses cases with different levels of complexity and different types of mobile devices to capture the impact relationships between specific design practices and performance outcomes.

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