Mobile application to provide personalized sightseeing tours

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A B S T R A C T

Tourist recommendation systems have been growing over the last few years, mainly because of the use of mobile devices to obtain user context. This work discusses some of the most relevant systems on the field and presents PSiS Mobile, which is a mobile recommendation and planning application designed to support a tourist during his vacations. It provides recommendations about points of interest to visit based on tourist preferences and on user and sight context. Also, it suggests a visit planning which can be dynamically adapted based on current user and sight context. This tool works also like a journey dairy since it records the tourist moves and tasks to help him remember how the trip was like. To conclude, some field experiences will be presented.

Keywords:
Mobile applications
Pervasive computing
Ubiquitous computing
Decision support
Recommendation system
Planning system
Sight information provider
Context-aware
Android

1. Introduction

When a tourist goes to a new location (country, city or region), he would certainly like to have a user-friendly tool to help planning his staying according to his objectives, preferences, knowledge, budget and available time. The tasks of planning where to go and what to do, in the limited amount of time available, are common problems encountered by tourists when visiting a city for the first time. In effect, cities are very large information spaces and in order to navigate through these spaces, visitors have available numerous guide books and maps that provide large amounts of information.

Haubl and Dellaert (2004) state that this can be a bless and a curse. Although the amount of information allows tourists to select more appropriately the points of interest to visit, it can also turn the process so complex that the tourist might not be able to assimilate adequately all the given information. A recommendation system helps the tourist narrow the universe of choice, giving results according to his preferences. Also, it processes much more information than the tourist could possibly do.

Mobile devices are very useful to use on a tourism scenario, due to its pocket size and computational capabilities. It can be used to support a tourist on planning his stay, show point of interest's detailed information or recommend nearby points of interest to visit.

However, mobile devices have limited capabilities when compared to a traditional computer, which must be considered because of possible technical, ergonomic or economic implications on the application development. Although in recent years mobile technology has evolved significantly it has yet low performance, mainly on battery life time, which is the biggest obstacle to the growth of mobile performance.

To provide an effective support to the tourist on a trip, a set of factors must be considered including actual available technology, such as connectivity, localization and user interface. Mobile device's wireless capabilities can be slower and with higher latency compared with wired data connections. Also, the use of wireless communications increases a lot the device power consumption. To develop a client–server application for a mobile environment, all of these problems and limitations must be considered to provide an effective and reliable application.

This paper is organized in the following topics. Section 2 presents some of the most important and recent works in the area. Section 3 describes PSiS (Personalized Sightseeing Planning System) architecture and functionalities. In Section 4 PSiS Mobile is compared with the systems presented in Section 2. Some lessons learnt and system results are presented in Section 5. Finally, in Section 6, conclusions are exposed, as well as, the future work.

2. Literature review

As the World Wide Web evolved into an incredible huge mass of distributed information, recommendation systems emerged to minimize the time consuming task of searching information on the web. However they present some issues that the most important to tackle is the amount of data that must be processed on the first run. Since recommendations are usually based on already existing data (*e.g.*, user profiles and history), systems need to tackle the cold start problem (Luz et al., 2010).

Although many derived approaches are emerging, recommendation systems are mostly based on three different paradigms: content-based, collaborative and knowledge-based. The content-based paradigm applies to systems that rely on item information to retrieve recommendations. On the other hand, collaborative systems compare similar users to provide recommendations. The knowledge-based paradigm tends to tackle both, content-based and collaborative, systems weaknesses and problems.

Recommendation results can be improved through the use of ontology's (or case-based rules) and a reasoning process, allowing the user to incrementally specify his needs. Since pure recommendation systems contain multiple weaknesses that can usually be tackled by merging different paradigms, hybrid systems have become the current most popular choice, especially when the system needs to deal with highly heterogeneous information. A hybrid approach can involve all the three recommendation paradigms (Luz et al., 2010).

In this section we will present a state of the art with the most significant works in the area, as well as, a bunch of the most recent ones. A more extended state of the art can be seen in some of our previous works (Anacleto et al., 2010, 2011).

GUIDE system (Davies et al., 1999) was one of the first mobile tourism guides and it was designed to guide tourists in the city of Lancaster. The mobile device uses a high-bandwidth, cell-based, wireless infrastructure (WLAN), which is available in all over the city, to locate the tourist (obviating the need for a separate location system like GPS) and to deliver dynamic information (including access to the World Wide Web). The information presented to visitors is tailored based on the visitor's user profile, contextual information and physical location.

Also, based on the current context it suggests a tailored tour which can be dynamically changed based on sights schedule restrictions. The tour can be changed by the tourist since he can agree with the next suggested attraction, or, override this recommendation by selecting a different attraction to be the next destination. Besides the tour, it provides booking facilities.

m-ToGuide (Schneider and Schröder, 2003) was a project targeted for the European tourism market and its objective is to integrate a multidisciplinary mobile tourism service that includes an decision algorithm to provide filtered information from multiple content providers. A portable terminal is used to exchange information between the mToGuide central system and the tourist. This terminal provides the end user with relevant information about the points of interest (maps, text, audio, and visual materials) and gets inputs from him. The terminal uses GPS in order to get tourist location and a GPRS modem in order to communicate with the central system. A novelty of m-ToGuide is the capability to allow transactions.

The system assigns to the user a default personal profile according to the kind of trip (*e.g.*, family trip, business trip) which the user is interested and adapts the contents, creating a tour based on tourist profile and transportation type. The authors claims that this system is useful for multi-day, single-day and hour/single tour usage. A trial project was performed and the results indicated that the system was useful but the charged prices were not well accepted by users.

Deep Map (Malaka and Zipf, 2000) is a mobile system able to generate personal guided tours through the city of Heidelberg (Germany). Such tour considers personal interests, social backgrounds (*e.g.*, age, education and gender) and transportation type. It proposes a 3D-reconstructed building feature that presents how the point of interest was, like a virtual time travel.

Therefore it makes usage of an agent-oriented software architecture. The agent based approach allows an easy re-use of components in different systems that may consist of a different set of agents and thus providing another range of services. This is especially important in this scenario where there are two quite different application platforms: a web-based system for home users and the mobile system for tourists on site. Another important feature is that, usually, normal maps just contain 2D information, however Deep Map includes 3D information to generate route instructions to be like “follow the street and turn right after the big red building and head towards the church”.

CRUMPET (Poslad et al., 2001) was designed to provide individualized information and services to tourists, implemented as a multi-agent system with a concept of a service mediation and interaction facilitation. For each point of interest it presents a description, maps, directions and pictures. In the first use tourists provide demographic information and while they are traveling and interacting with the system, it learns more about user preferences. The points of interest recommendation is based on personal interests and the current location (retrieved using GPS).

It uses a device-aware feature, which tries to choose the best Internet network connection according to their availability. Another interesting feature is the proactive tip, which gives a tip when the tourist gets near a sight that might interest him. The authors claim that in the realized tests the system has been acknowledged by users for its simplicity of use and for its focus on location-based services.

CATIS (Pashtan et al., 2003) is a context-aware tourist information system with a web service-based architecture. The context elements considered by this project are location, time of day, speed, direction of travel, personal preferences and device type. On the first use, the user must enter his preferences to complete his profile. After that, the system will track him with the GPS receiver, if it is available. If not, it will ask the user's current position.

The system implements three adaption capabilities. First is the location and time-based adaption, with this information the system will track tourists position and time to provide information relevant for that constraints. Second, is personal adaptation, the application provides services adapted to users specific profile. At last, there is device adaption, which is the capability to adapt the information according to the user device type, for example, if the device has a certain screen size it may not support some image sizes.

e-Tourism (Sebastia et al., 2008) is a tourist recommendation and planning application to assist users on the organization of a tourism agenda in the city of Valencia (Spain). This project focuses essentially on the trip planning and, besides activities duration, it introduces a new feature which is the use of different visit durations for each point of interest based on the different user's profiles.

The recommendation module offers to the tourist a list of points of interest that are likely of interest to him, based on user demographic classification, past trips and the preferences for the current visit. The planning module schedules this list of recommended places according to the temporal characteristics, as well as, the tourist restrictions. It is the planning system that suggests how and when the tourist must perform the recommended activities.

MoreTourism (Rey-Lopez et al., 2011) provides information about tourist resources depending on user profile, location, schedules and the visit durations. The system is composed by two parts: a mobile device using Android OS (Operating System) and a server that offers the system specific functionalities. Besides points of interest information it also provides socialization and advertising. The first one allows users to interact over social networks and create activity groups in particular locations. The second one presents different advertising campaigns according to the user profile.

This system uses a hybrid recommendation platform, which combines collaborative filtering with content-based recommendation and allows reasoning over folksonomies. Tags are used to compose a user tag cloud (weighted by the user's ratings) and the attraction tag cloud. In both clouds, the higher the number of times tags that have been assigned, the higher their weight in the tag cloud. This approach performs the recommendations comparing the user tag cloud with the attraction tag cloud taking into account not only the coincident tags in both clouds (direct relationship), but also the relationships between tags reflected in the folksonomy.

MyTourGuide (Husain et al., 2012) was created for travelers and tourism related business parties. It implements two business solutions, business to business and business to customers, and acts as the intermediary between the tourist and the tourism related parties such as hotels, restaurants, car rental services, points of interest and so on. The business parts can share tour information and promote their latest events, services or products.

The main feature of this mobile application is to provide recommended tour information for users based on user's current location, user's preferences and community rating. To present this information the tourists need to input some information like the destination to visit, their preferences and their budget, then the system will suggest the sights which suit the users' wishes. Users make changes on those suggestions to have a trip itinerary more suitable to them.

During or after the trip users can share their experiences and memories through an e-album module which enables them to upload their photos and provides a blog to share the trip experiences and a forum for tourists discuss the sights. Another included feature is an e-payment module for users to pay their transactions or subscriptions.

GoTour (Al-Rayes et al., 2011) is a mobile tourism guide application that was designed for Istanbul city and works on mobile devices with Android OS. It contains all the information about points of interest, as well as, consulates and city services. It suggests a trip plan for tourists by taking into account location, point of interest categories, distances and current time.

Trip planning is achieved by a Variable Neighborhood based algorithm, which is a metaheuristic for solving combinatorial and global optimization problems. The solution for a trip plan is formed by using a permutation of points of interest without including the tourist's location. The solution is obtained by using the permutation as follows: starting from the first point of interest in the permutation, the points of interest are appended to tourist's location back to back until the prescribed cost limit is exceeded. The total cost of trip plan is calculated by adding straight length distance between all two sequential spots in the solution.

Apart from the planning feature this application presents the points of interest based on some categories (shopping, restaurants, parks, museums, antiquities and consulate), and the tourists can also make a list of favorite points of interest to see and request a list of available points of interest regarding current time.

3. PSiS architecture and features

PSiS (Almeida, 2008) is a tour planning support system that aims to define and adapt a visit plan combining, in a tour, the most adequate tourism products, namely interesting places to visit, attractions, restaurants and accommodation, according to tourists' specific profile (which includes interests, personal values, wishes, constraints and disabilities). Functioning and transportation schedules are also considered to generate a tour planning.

In the initial phase, tourists interact with PSiS through a web application only accessible from a web browser, but it is indispensable to have a tool to assist tourists “on the field”. Thus, a mobile tool to be integrated with PSiS, entitled PSiS Mobile, was studied and developed. As presented on system architecture (Fig. 1) a Middleware was implemented in order to enable the communication between the two sides.

The recommendation system gathers knowledge of the tourists' profile, creating groups and stereotypes with specific interests allowing characteristics inheritance. This knowledge offers a means of learning about general and specific tourists' interests that can serve for studying new forms of tourism products. In Fig. 2 is presented the PSiS web interface, where it shows a list of points of interest recommended for a tourist.

The mobile client is a very important piece in the system, because it supports the user on the go. PSiS Mobile runs in mobile devices with Android OS and it is intended to support a tourist after he plan a trip for his vacations on PSiS Web portal.

A possible usage case can be defined like this: a tourist registers on PSiS using the web application, defines his profile and requests a recommendation for a two days trip in a specific city. Then the

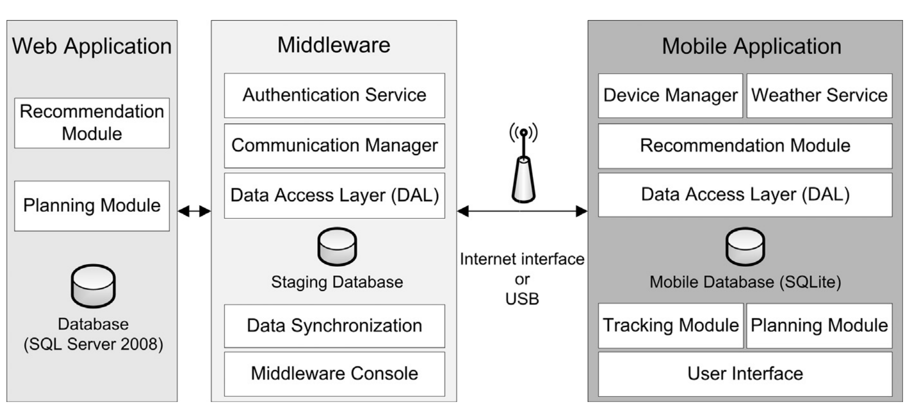

Fig. 1. PSiS architecture.

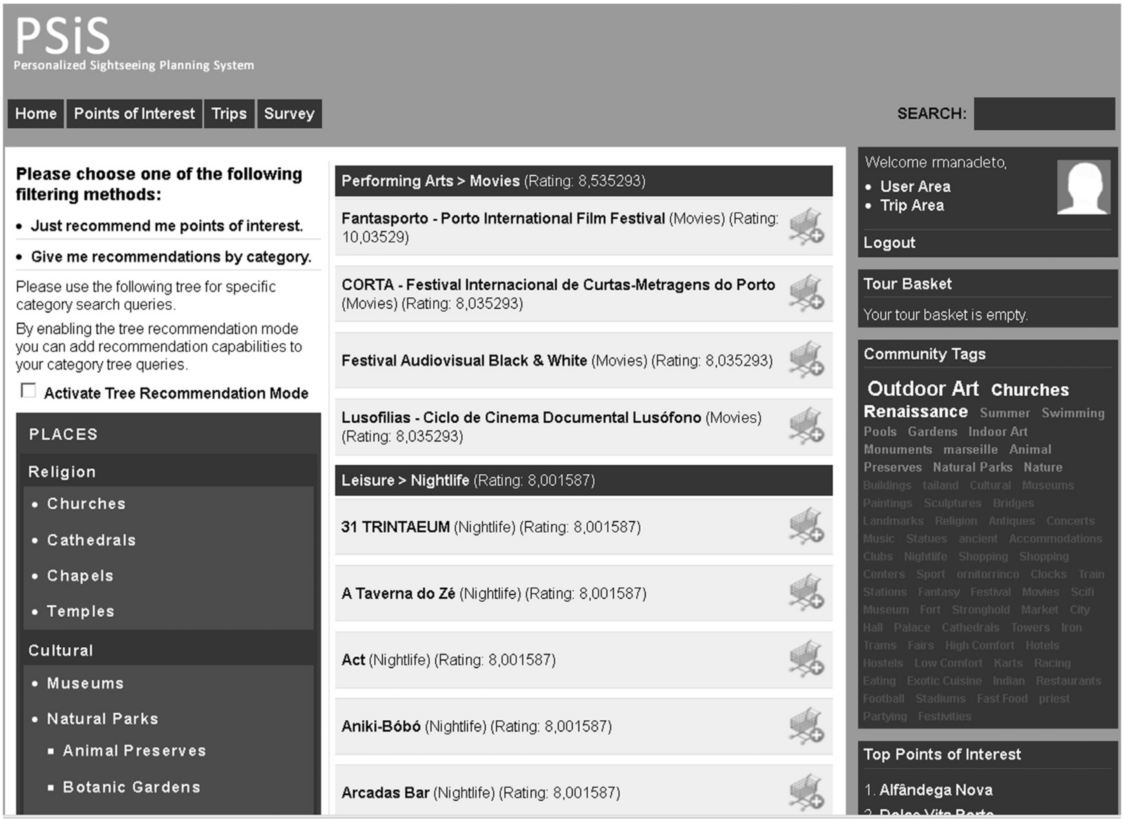

Fig. 2. PSiS web application.

tourist loads the generated information into the mobile application. Now, the mobile application has all the information about the points of interest to visit (matching user profile). With context-aware information, points of interest to visit can be suggested more effectively and, if necessary, a replan of the initial trip can be proposed. When tourists finish their visit to a suggested point of interest, they can inform the system whether or not they liked the suggestion. All trip information is sent back to PSiS in order to improve future recommendations and to create statistics about the tourists' visits.

3.1. Middleware

The middleware is a component that resides on the server side to enable the communication between the web and the mobile application. As can be seen in Fig. 1 it includes a data synchronization service, which synchronizes data between both applications.

After the user request a recommendation for a trip, all the necessary data are transferred from the server, using an Internet or USB (Universal Serial Bus) connection, and stored on the mobile device. This is necessary because of the mobile Internet low speed rates and possible unavailability. When it is referred necessary data, it means, the information about all the points of interest will be on the planning and other points of interest nearby the first ones, which are more recommended for the tourist. This information is essential if the tourist wants to visit more points of interest or if it is necessary to perform a visit replanning.

3.2. PSiS Mobile

PSiS Mobile recommends points of interest based on user preferences, and on user's and sights current context, as can be seen in Fig. 3a. Application filters the sights based on user's location, travel direction and speed in order to present the most appropriated sights to visit.

Since weather changes can happen, PSiS Mobile connects to the WorldWeatherOnline web service, to retrieve the forecast for the users' location in order to improve recommendations. For example, if it is raining, the tourist probably does not want to be wet, so a fully outdoor attraction will not be suggested.

Another implemented context feature is the current time. If the point of interest is closed it is not worth recommending to visit, however some points of interest are special since they are worth to visit because of their architectonic beauty. For these ones PSiS Mobile uses a special feature that is an architectonic identification tag, which indicates that the point of interest, apart from being closed, is worth to be visited outside. Therefore important points of interest are suggested to see despite that they are closed.

Whenever a tourist is going to visit a point of interest, PSiS Mobile shows detailed information about it (Fig. 3c). In this interface the tourist can see point of interest information, give feedback about the recommended sight (which is used to evolve tourist stereotype and preferences) or call, send email or go to the sight website. A map is also available (Fig. 3b) to help user orientation, which gives the directions from the user location to the point of interest.

PSiS Mobile is intended to be used like a journey diary, where it collects the time spent in each point of interest, photos, the given feedback, and user, sight and device context in a non-intrusive way. At the end of the tour this data is sent to the server, so that the user can do a posterior analysis of the trip.

Also, our system uses all of this information in order to improve future recommendations and to elaborate some statistical reports. With user feedback about what he liked or not, his profile on the system can be improved in order to give better recommendations in the future. Besides user profile, the estimations for visit durations can also be updated according to the time that each tourist spends visiting a point of interest.

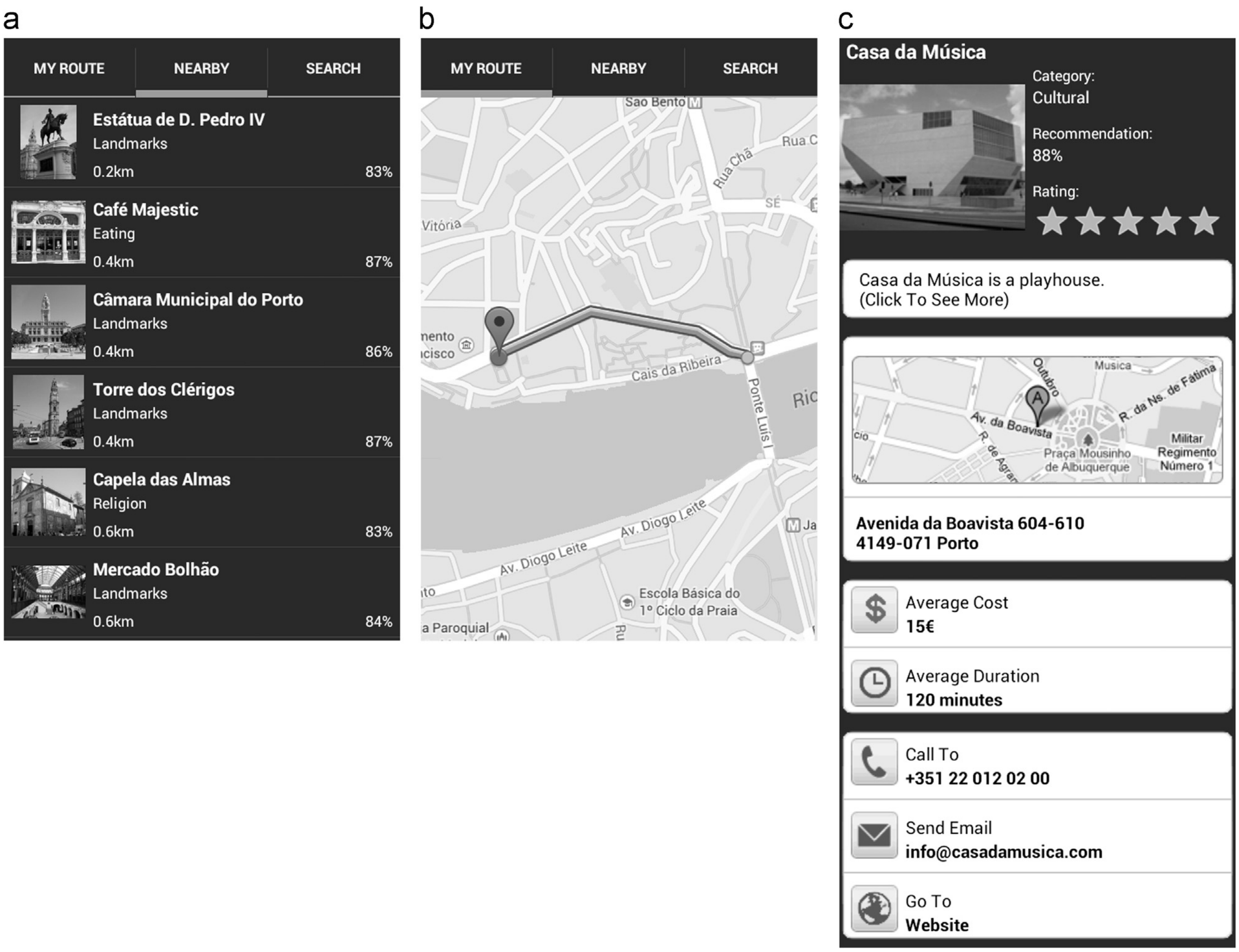

Fig. 3. PSiS Mobile user interface.

The reports are very important to city councils, since with this information city councils can improve their products. These reports give feedback about the city tourist stereotype to, for example, city councils organize promotional pack's for families or single couples for a specific set of points of interest.

Nowadays mobile devices' biggest challenge is the limited battery power, so in order to save battery and permit a better application usability a device manager module was developed, which is responsible to adapt the application according to the mobile device context – battery status, Internet connectivity (Wi-Fi or 3G) and GPS activity.

PSiS Mobile was designed to be an occasionally connected application (smart client) in order to reduce network traffic, so a temporary database is used on the mobile device to permit access to data. However it has some limitations, like no access to new points of interest. The data is uploaded and downloaded automatically and the network is only active if the battery has at least 30% of power left. Also, if the Internet connection is unstable the system adapts to it, sending/receiving only one result at a time instead of a list with many results. This feature is useful to reduce information loss.

GPS is the hardware which consumes more battery power on a mobile device. It was verified that in a continuous use it can consume all the battery power, of a current top range smartphone, in less than 7 h (Gaonkar et al., 2008; Kjasrgaard, 2012). Since our application massively uses GPS to locate the tourist, an algorithm was implemented which is capable of adjusting the GPS updates (more or less time) in order to minimize battery consumption. With this tweak the application, in our tests, has increased the smartphone battery life from 6 to 8 h (using only PSiS Mobile, without calls, etc), supporting the user for a longer time.

When tourists are visiting the sights some context changes can occur, so the original visit plan can be outdated. In Sections 3.2.1 and 3.2.2 the replanning feature will be discussed in more detail.

3.2.1. Tracking module

The tracking module is responsible for tracking the tourist on the move, save tourist route, record time spent on a point of interest and pop up relevant information.

For each location update the tracking module checks if a trip replan is necessary based on any context changes. When a tourist arrives to a point of interest the application presents detailed information, and when the tourist leaves the point of interest a dialog is shown to the user to classify and comment it.

3.2.2. Planning module

The planning module dynamically adapts the original route for the tourist according to the current user and points of interest context (open/close hours, weather, location, speed, direction and time).

Since mobile devices are slower than a traditional computer, a complex algorithm like a traveling salesman problem was not implemented. Instead, a decision tree based solution was developed.

This is a decision support tool that uses a tree-like graph of decisions and their possible consequences. So, it was managed to have a fast algorithm that require low system resources with an almost instantaneous response.

When this module is invoked, by the tracking module, it starts the interactions by checking if the tourist is ahead or behind schedule, or there are any weather changes. If he is ahead schedule a point of interest can be inserted according to his current location, speed and direction.

If the tourist is behind schedule the replanning algorithm starts by verifying if the next point of interest scheduled in the planning is compatible with the new arrival and departing hour (arrival time plus visit duration). If this is true, no new point of interest is suggested. Otherwise, a new point of interest will be recommended to visit instead of the one in the schedule.

When a user is ahead schedule or a new point of interest must be suggested the algorithm retrieves from database the existing points of interest and checks if the visiting duration plus both travel durations (from and to the point of interest) are compatible with the ahead time (time gap). If more than one point of interest can be inserted, the best alternative is chosen using the best choice algorithm.

The best choice algorithm assigns a rating to each point of interest. This rating is calculated based on the following rules:

- TimeSpent (Eq. (1)) represents the total time (traveling plus visiting times) spent to visit a point of interest. If it is equal to the gap time, it gives 100 points to that point of interest. For each minute less, one point is subtracted:

  $$TimeSpent = 100-(g-(d+dt+df)) \quad (1)$$

  where g represents the gap time, d the visit duration, dt the traveling duration to the point of interest and df the traveling duration from that point of interest to the next one.
- POIR (Eq. (2)) is the percentage of recommendation for that point of interest based on the highest rating from all of them. The highest receives 100 points and each percentage less represents one point less:

  $$POIR = 100-(hr-pr) \quad (2)$$

  where hr is the rating of the most recommended point of interest and pr is the rating of the tested one.
- TravelTime (Eq. (3)) is used to get the lowest traveling duration. The point of interest with less travel duration receives 100 points and the others receive less one point for each minute more:

  $$TravelTime = 100-((dt+df)-lv \quad (3)$$

  where dt is the traveling duration to arrive on that point of interest, df is the traveling duration from that point of interest to the next one and lv represents the lowest traveling duration from all of them.

The final result is the average of the three values. The same weight was chosen to these values because all of them have similar importance.

The point of interest with the highest score will be returned by this algorithm.

4. Systems comparison

In this section PSiS Mobile is compared with the systems described in Section 2. Although all the described systems are designed to support tourists on a trip and to recommend points of interest based on the user profile, there are factors that distinguish them. Table 1 presents five requirements which we considered to be key factors in order to build a recommendation and planning mobile tourism guide:

- Recommend personalized tour – capability to recommend a personalized tour based on the tourist profile and known context.
- Context-aware features – enumeration of the context features used by the system to recommend a tour.
- Dynamic tour adaptation – ability to dynamically adapt a recommended tour according to context changes.
- Device-aware – adapt the application behavior according to the device context and characteristics.
- Feedback – capability to retrieve user and application feedback to improve future recommendations.
- Other features – unique features implemented by the system.

Apart from the recommended personalized tour all the studied systems implement also context-aware features. These features are important to recommend the tour based on some context restrictions, like location, weather, etc. Comparing our system with the studied ones it can be seen that our system incorporates more context features, nevertheless none of them are new for the state of the art only the inclusion of all of them in one system.

Another important feature that some surveys (Kenteris et al., 2011; Emmanouilidis et al.) already have identified is the capability to dynamically adapt the recommended tour. The studied systems recommend a tour based on user interests and context. However, those approaches (apart from GUIDE) do not dynamically adapt the tour, in real-time, if a context change happens. For example, if the user chooses to interrupt the tour or the weather changes unexpectedly.

GUIDE has the capability to adapt the tour, but only using time restrictions. Speed, direction and weather changes are not used. Also, it only does a replan when the tourist arrives to a point of interest, since it works under a WLAN interface with several access points spread along the city, not in real-time as our application does according to all the context changes that can happen.

During our tests with tourists and in the literature review we encountered an interesting problem related to the capability of filtering sights considering their schedule and the actual time context. Some tourists found in some cases this adaptation frustrating since they are interested in visiting an attraction regardless of whether it was open or closed. This happens since they simply wish to view the building's architecture, and not only the inside of it. It was with this in mind that PSiS Mobile implements different visit durations and schedules for architectonic points of interest whether they are open or closed. This feature is entitled as Architectonic tag, since it can associate a exterior visit to a point of interest, besides its normal schedule to see the artworks or other artifacts inside, it is important to tourists because sometimes the outside can be as, or more, beautiful as the inside. This is the main advance of our work in the dynamic tour adaptation, because points of interest schedules are considered but also the availability to see them from outside regardless of their normal schedule.

Another important aspect is the mobile devices context and capabilities, which most of the described systems does not consider in order to adapt the application behavior, for example, to save battery power the application can automatically disable the GPS while the user is visiting a museum. With this adaptation the mobile device battery can last longer.

Feedback feature is essential to improve future recommendations and planning, some systems had implemented this feature, however our proposal gives a step forward since it records all the tourist moves in order to improve recommendations and also to generate reports about the person's profile (age, stereotype,

Table 1
Mobile tourism guides comparison.

System	Recommend personalized tour	Context-aware features	Dynamic tour adaptation	Device-aware	Feedback	Other features
CATIS	×	Location, time, speed, direction		Adjust content		
CRUMPET	×	Location		Internet connection	×	
DeepMap	×	Season, weather, traffic, time				3D reconstructed sight
eTourism	×	Location, time			×	Different visit durations for each profile
GoTour	×	Location, time	Location, time			
GUIDE	×	Location, time, traffic, weather	Time			
MoreTourism	×	Location, time				Socialization, advertising
mToGuide	×	Location, time				Tickets
MyTourGuide	×	Location	Location			e-album, e-payment
PSiS Mobile	×	Location, time, speed, direction, weather	Location, time, speed, direction, weather	Internet, GPS	×	Dynamic visit durations, architectonic tag

Table 2
Test route.

Point of interest	Arrival hour	Departure hour
Pousada do Porto	–	9:00
Palácio da Bolsa	9:25	10:15
Alfândega Nova	10:25	10:30
Igreja de S. Pedro	10:35	10:40
Estátua “O Cubo”	10:50	11:00
Ponte D. Luís	11:15	11:25
Cais de Gaia	11:45	12:00
Cruzeiro Douro Azul	12:00	16:30
Café Majestic	16:50	17:40
Câmara Municipal do Porto	18:00	18:15
Torre dos Clérigos	18:30	19:00
Restaurante Cufra	20:00	21:30
Porto Palácio Hotel	22:00	–

Table 3
Results for suitable points of interest to the replan.

Point of interest	Time spent (%)	POI recommendation (%)	Travel time (%)	Score
Igreja de S. Francisco	94	87	100	94
Capela de S. Miguel-O-Anjo	95	92	89	92
Sé Catedral	–	94	95	63
Igreja da Nossa Senhora da Vitória	88	84	96	89
Igreja de Santo Ildefonso	94	85	90	90
Chafariz S. Lázaro	86	84	98	89
Ponte da Arrábida	–	98	86	61
Ponte Infante D. Henrique	90	100	92	93

nationality, etc.) that visits each point of interest, and how much time spent visiting it.

The one site visit durations are used to dynamically adapt, in the system database, each point of interest average visit duration for the correspondent person stereotype. With this feature we can have the visit duration that each person stereotype really spent on visiting the point of interest.

Both functionalities were introduced when we were developing this project and communicated with Porto city council, where they mentioned that this type of information is essential to adapt the city offers to the real people that visit them.

5. Case study

A case study was conducted, to our system, using 10 tourists on the city of Porto, Portugal. The audience was very diverse (6 male and 4 female) with ages between 21 and 67 years old (average of 33 years old), with different educational backgrounds and interests, and some of them already knew the city. All participants were introduced to the overall concepts and functionalities of the system, and were told and encouraged to register on PSiS Web Application and request a trip planning for a day (an example in represented in Table 2). Then, it was transferred to PSiS Mobile and followed in the real world.

The average number of suggested points of interest to visit in a day was 10, including restaurants for lunch and dinner, with an average visit duration of 7 h (without lunch and dinner durations). In the real world the average number of visited points of interest was 11 (the tourists spent less time than expected visiting the point of interest), so the system has recommended other sights to see. The average visit duration was the same as the suggested (7 h), with an average traveled distance of 8 km.

In one of the evaluation tests we forced an unscheduled delay and we will present how the system worked. When visiting “Palácio da Bolsa” the tourist had only remained 30 min instead of 50 min originally planned. So, he was ahead schedule 20 min and the replanning algorithm tried to retrieve from database some points of interest that fits on ahead gap (which has a visiting duration less than or equal to 20 min) that was not already included on the route and that are open on the desired schedule (from 9:55 to 10:25) – see Table 3. Since there were more than one point of interest that can be fitted in the route, the replanning algorithm invoked the best choice algorithm.

Table 3 presents the calculated values, where the highest score is given to “Igreja de S. Francisco”. Time Spent, POI Recommendation and Travel Time values were calculated according to the formulas presented in Section 3.2.2.

Figure 4 presents application steps sequence that the user had to follow in order to accept the proposed replanning. Figure 4a shows the original route. Then, when the user left the point of interest, “Palácio da Bolsa”, a warning appeared asking if he wanted to add the point of interest “Igreja de S. Francisco” to his traveling plan (see Fig. 4b). When the user accepted it, the new plan was presented, as shown in Fig. 4c.

After the tests, users were asked about various aspects of our system, such as quality of planning adaptation and usability. From the users' answers, we have found that users have understood the automatic adaptation process. However, the older ones, that are not so familiarized with mobile devices and recommendation systems, found to be confusing because it has performed some actions automatically, which had confused their minds. An

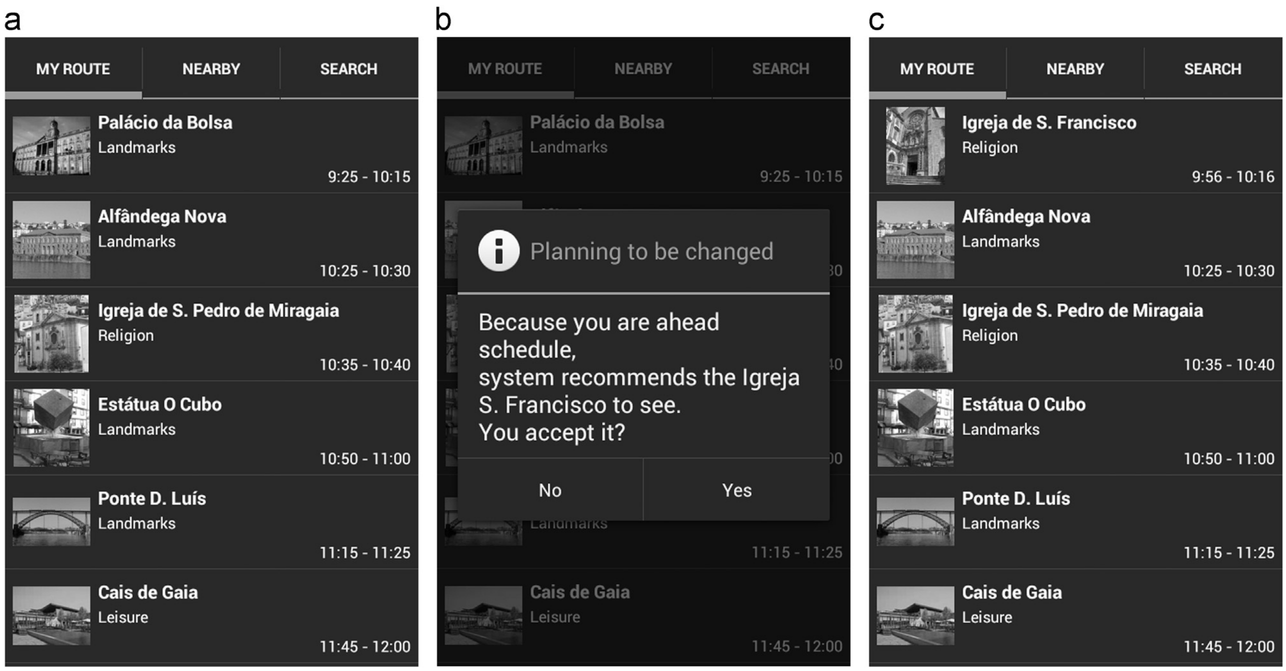

Fig. 4. Replanning steps in PSiS Mobile.

improvement can be an adaptive interface according to the user stereotype. Also, the study revealed that our system helped, the ones that were not from Porto, on discovering more tourism attractions than they were expecting.

Our final perception is that a system like this is particularly useful for first-time visitors, in order to discover interesting points of interest to see. After the visits the mobile devices' batteries were almost at the end, which can be a problem since tourists can run out of battery power before finishing their tour.

6. Conclusions and future work

The main purpose of this work was to develop an application to a mobile device, which extends PSiS project, to support a tourist on his staying at a city by recommending and planning his visits based on his preferences and current context.

PSiS Mobile provides dynamic adaptation of the tourist route according to context changes beyond the time restriction. Also, since time restrictions cannot be welcomed by the users we use an architectonic feature, which indicates that the building can be closed but it is worth visiting its architectonic part.

Since mobile devices consume a lot of battery power the application adapts itself according to mobile device context. Like e-Tourism, our system uses different visit durations for each person's stereotype however, PSiS Mobile updates that durations according to the real time that the users spend while visiting them. Finally, the application generates automatically some feedback that is useful in order to create statistical reports about what the tourists saw and for how much time.

One big problem in this type of device is the small screen, however tablets are trying to overcome this problem but they are uncomfortable to use in a tourism context, and they also consume a lot of battery power. Nowadays battery power is the biggest problem for these systems, because the batteries take a lot of time to charge.

In the future, this application will be adapted to an audio guide, since it is uncomfortable to be always looking to the mobile device screen. Also, we are trying to integrate PSiS Mobile with an inertial navigation system adapted to the person's body, to also offer indoor guides.

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