Recommendation & Mobile Systems - A State of the Art for Tourism

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Abstract — **Recommendation systems have been growing in number over the last fifteen years. To evolve and adapt to the demands of the actual society, many paradigms emerged giving birth to even more paradigms and hybrid approaches. These approaches contain strengths and weaknesses that need to be evaluated according to the knowledge area in which the system is going to be implemented.**

Mobile devices have also been under an incredible growth rate in every business area, and there are already lots of mobile based systems to assist tourists. This explosive growth gave birth to different mobile applications, each having their own advantages and disadvantages.

Since recommendation and mobile systems might as well be integrated, this work intends to present the current state of the art in tourism mobile and recommendation systems, as well as to state their advantages and disadvantages.

Tourism, Adaptive Recommendation, Mobile System, Collaborative Filtering.

I. INTRODUCTION

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 large information spaces, and in order to navigate these spaces visitors often require numerous guide books and maps that provide large amounts of information. Häubl and Dellaert [1] state that this can be both a blessing and a curse. Although the amount of information allows tourists to select more appropriate points of interest, it also turns the process so complex that the tourist might not be able to assimilate all this information adequately. A recommendation system helps the tourist narrow the universe of choice, giving results according to the tourist preferences. Also, the system is able to process much more information and points of interest than the tourist could possibly do.

The recommendation system interaction with the tourist is also of utmost importance. When the tourist interacts with the system, every taken action has meaning and can be used to complete the tourist profile. Nowadays, most systems build the tourist profile implicitly and/or use forms to request feedback. This is mostly possible through the use of mobile devices that travel along with the tourist, providing context-aware and location-aware information.

Another way to evaluate given recommendations and retrieve feedback (improving the system recommendations) is through a simulation of the tour. These simulations can be implemented using software agents and/or with 3D representations of points of interest. The representation of the actual world or reality is still a great challenge, but the merging of reality with what we know as virtual reality could not only revolutionize the tourism information systems, but the whole concept of information systems as we know it.

II. CONCEPTS AND EVOLUTION

A. *Mobile Systems*

Mobile devices are pocket-sized computing devices which popularity is growing day by day. Since they are small, simple and becoming relatively cheap, it's easy to carry them around and use them in all kinds of environments.

These devices have wireless capability that allows the device to connect to the internet even with low speed connections that networks on the go usually permit. Also, many connection failures occur because of transmission interference (weather and terrain blockage) and noise. Power consumption is also an issue, because batteries still don't provide the desired amounts of energy without the need to constantly recharge.

Because of their portability, mobile devices are ideal to create an integrated system to provide guidance, and to assist tourists in planning a trip to an unknown city according to their objectives, preferences, knowledge, budget and staying period, instead of having to look for guide prospects/bulletins which sometimes can be quite confuse [37]. This happens, since the number of tourism-related services in the Web grows every day offering hotels, flights, tickets and information of all sorts.

So, where to go and what to do, with limited amount of time for choosing all the sights to visit, are common problems encountered by tourists when they decide to go on vacations. In effect, cities are large information spaces, and in order to navigate these spaces visitors often require numerous guide books and maps.

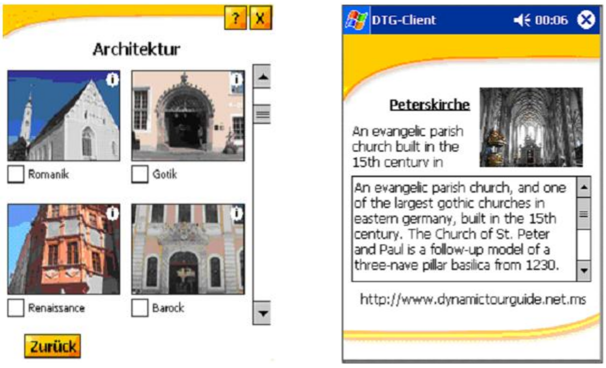

Figure 1 - Example of a Mobile Tourist Guide [16]

A major issue in offering mobile services to nomadic users is the limited display size, resolution and networking capabilities of mobile devices (figure 1). With a good networking capacity, the system could cover intelligent integration of information from different data sources and services, including geographical information systems, multi-media databases, and interactive internet data sources such as reservation systems. Thus, the question if people would like to use computers as a replacement of the traditional books and maps as tourist guides splits the tourists into two groups: traditionalists, who want to stick with classical paperwork and experimentalists, who would like to try out new technologies.

The question remains, why does the second group still not use mobile computers? The answer is simple: there aren't yet the right IT (Information Technology) systems available. In one hand, PDA's (Personal Digital Assistant) only now are becoming powerful enough, and produced with an integrated GPS (Global Position System) that allows the retrieval of location data. On the other hand, laptops are not practical because they lack the portability of mobile devices, and networking can be too slow in some regions.

A tourist that uses a system like this expects location-aware information about the destination domain including history, culture, folk, art, economics, environment and nature. Advanced tourists also expect individualized information and services taking into account their own interests and their history of activities and information [14].

To provide a good mobile tourism service there are a lot of technologies available to use. A tourist with his mobile device or with a specific tourism guide mobile system can retrieve information via SMS (Short Message Service), MMS (Multimedia Messaging Service) or WAP (Wireless Application Protocol)/Web. A tourism guide mobile system is the most reliable and user friendly option, but it needs a communication channel to retrieve data for the user.

Over the last years, these technologies are more and more advanced and the data transfer rates are rapidly increasing. GPRS (General Packet Radio Services) was the first to appear and has a low data transfer rate of approximately 40 kbps. In the year of 2000, UMTS (Universal Mobile Telecommunications System) appears with a data rate of approximately 220 kbps, finally providing good enough speed to support a system like this and to confirm the capabilities of this technology. The UMTS is available world-wide, a very important factor when implementing mobile systems.

After UMTS, the HSDPA (High-Speed Downlink Packet Access) appears with a typical performance of 750 kbps. Although the data transfer rates are higher, the coverage area is smaller. These technologies are used in a global scope, but there are also indoor specific technologies (*e.g.*, Wi-Fi and Bluetooth) that usually outperform them. Although they have better performance, they cannot usually be implemented outdoors and limit the application context to indoor specific sights. Also, places that restrict the use of mobile devices to avoid noise can render the application obsolete.

B. *Recommendation Systems*

As the World Wide Web evolved into an incredible huge mass of distributed information, recommendation systems emerged as an option to minimize the time consuming task of searching the Web.

Although the concept is not new, the used techniques have been subject to research and evolved into different techniques. Most of these evolved ideas result from the merge of different pure techniques, where individual weaknesses are cut and tackled to form new improved concepts.

How the recommendation system interacts with the user is also very important. Retrieving feedback is time consuming, thus leading the user to avoid the explicit submission of feedback. Transparency might also be important to some users, as they want to know why they are receiving certain recommendations. The right transparency helps the recommendation system getting higher trust levels from its users.

The initial amount of data when the recommendation system first runs is also a big issue. Since recommendations are usually based on already existing data (*e.g.*, user profiles and choice history), systems need to tackle this issue so they don't suffer cold start problems.

Latest implementations begin to use ontologies, thus featuring a semantically enriched knowledge representation that empowers the recommendation system.

Although many derived approaches are emerging, recommendation systems are mostly based in three different paradigms: content-based, collaborative and knowledge-based. The content-based paradigm applies to systems that rely on item information to retrieve recommendations. This means that item attributes and ratings are used to see what best fits the user needs. On the other hand, collaborative systems compare similar users to provide recommendations.

The knowledge-based paradigm tends to tackle the content-based and collaborative system weaknesses. Through the use of advanced knowledge representation techniques, such as ontologies and case-based rules, a reasoning process is performed, allowing the user to incrementally specify his needs and interests.

Since pure recommendation systems can't satisfy the current needs for the recommendations, hybrid systems are the current popular choice, especially when the system needs to deal with highly heterogeneous information.

To Montaner, López e Lluís de la Rosa [23], the key concept in recommendation systems is the user profile. With the user profile in mind, they define recommendation systems according to two essential factors: the profile generation and maintenance, and the profile exploitation.

The profile generation and maintenance contains the profile representation techniques, the initial profile generation and profile adaptation and learning techniques. Also, when and how to retrieve feedback, are attributes that can be defined into the profile generation and maintenance.

Figure 2 describes techniques used to tackle every issue contained in the profile generation and maintenance category.

Some systems implement profile learning techniques that halt the system to run the learning process. However, most techniques use a lazy learning approach through which the system can update the model while making recommendations, thus having no offline period.

Inside the profile exploitation, there are information filtering methods, user profile matching and user profile-item matching techniques (figure 3). The following figure contains the main options used by recommendation systems for each of the previously mentioned characteristics under the profile exploitation category.

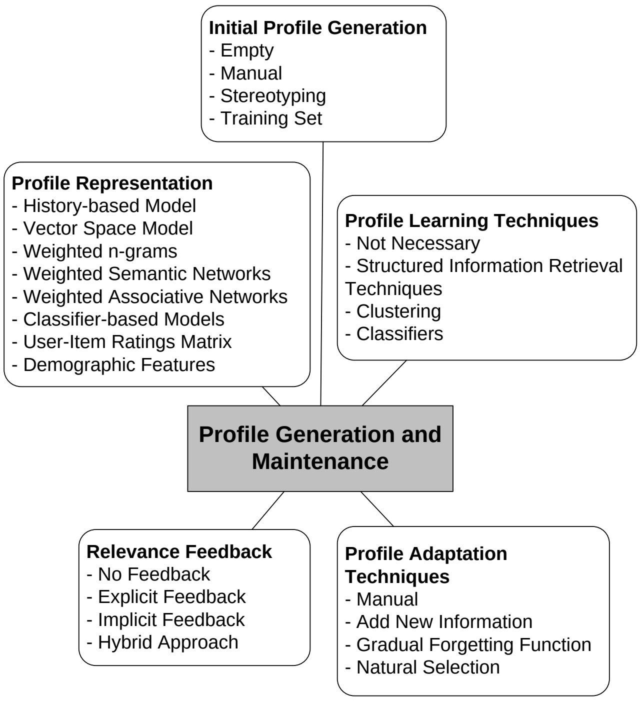

Figure 2 - Profile Generation and Maintenance

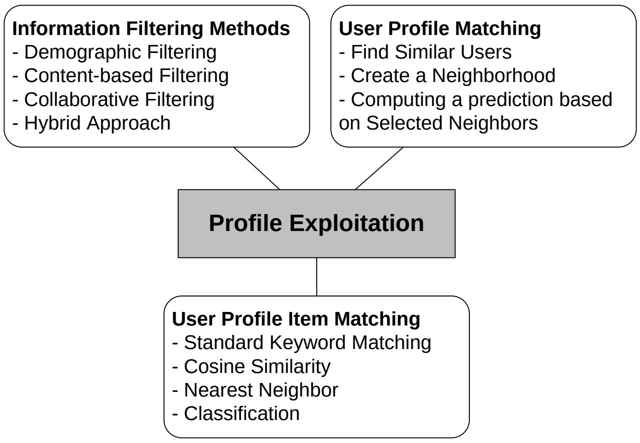

Figure 3 - Profile Exploitation

Information filtering methods often include content-based, collaborative, demographic or knowledge-based filtering. TABLE I. contains the main characteristics of the information filtering methods previously described.

TABLE I. CHARACTERISTICS OF THE INFORMATION FILTERING METHODS

Content Based	**Collaborative Filtering**	**Demographic Filtering**	**Knowledge Based**
Similarity between items characteristics and user preferences.	Similarity between users.	Stereotypes using demographic information.	Rely on an explicit representati on of knowledge (*e.g., ontologies*).
Suffers from *cold start* and *over specialization*.	Suffers from the *cold start* and the *gray sheep* problems.	Useful when combined with other filtering methods.	Can benefit from machine learning and semantics.

According to Berka and Plößnig [17], travel recommender systems can be quite difficult to develop since they need to deal with a great range of rich and heterogeneous information. As each one of the information filtering methods deals with different kinds of information, hybrid approaches are very well suited to tourism recommendation systems.

Agent based architectures are also dominant on the latest recommendation system proposals. Maes and Kozierok [18] state that under certain conditions, an interface agent can “program itself”. This is an important feature since the system needs to adapt and learn from the tourist behavior and interaction. We can say that agents are very well suited for the task.

III. STATE OF THE ART

A tourist companion, or mobile device application, provides important services to guide the tourist along its travel. On the other hand, recommendation systems allow the tourist to plan and select an appropriate route and set of points of interest. Although these systems can be (and should be) integrated, very little approaches integrate them.

TIP [2] provides recommendation services through mobile devices for tourism. These services implement hybrid algorithms to calculate tourist preferences, using the defined tourist profile and location data (location-aware).

Heracles [3] also uses mobile devices, like GPS to give location-awareness to its recommendations.

Proximo [29] is a location-aware mobile and recommendation system that fits the pure paradigm approach. It guides users through tours within buildings using Java and Bluetooth technologies. The user's mobile device also tracks the user location and builds a context, providing the system with important information.

The user position is taken by "sniffing out" the fixed Bluetooth devices or low-cost beacons deployed in the area of use. This room-level accuracy means improved precision and is accurate enough for a certain class of trail-based applications such as a tour guide. The mapping service on the mobile device displays a map of the intended area of use which can be manipulated in a variety of ways. Also, the application constantly monitors the user location and displays the active area of the building (the area the user is in) accordingly.

Since this is an indoor application, Quigley and Parle conducted tests under a gallery context at the University College Dublin School of Computer Sciences and Informatics building, where the system was able to guide users through the gallery, and provide recommendations of paintings using collaborative filtering techniques.

The Proximo pure collaborative recommendation system relies on its user's item ratings to provide recommendations. As long as an item doesn't have its first rating, it cannot be recommended. Also, user profiles are built using interaction data from the user's mobile device. This data is processed through a weighted nearest neighbors algorithm, leading to the construction of the user profile.

Apart from Heracles, TIP and Proximo, the described systems either fall under the mobile or recommendation systems groups.

A. Mobile Systems

More and more people combine several purposes with travelling, such as business, leisure, entertainment, and education. Such people may not have time to pre-plan a travel schedule in detail. They need location-aware information about the destination domain and expect individualized information and services. Mobile tour guides are the result of years of research in the areas of recommenders, ambient intelligence and pervasive computing. There are systems that only display information about sights, like MultiMundus [4] that have as primary goal to provide multimedia information (texts, images, cards, audio and video sequences) of a sight to the tourist on his personal mobile device. With this content it can provide moderated audio guides for travel groups, automatic detection of the tourist physical position on the map and presentation of the sight closest to him.

MYJATRA [5] is an infotainment-based application on tourism which acts as a complete digital tourist guide, it provides necessary and meaningful information and services to the travelers in both pre-tour and on-tour. It also provides information of various locations, weather report, field report, social awareness and supports all phases of travelling, including preparation and post-tour activities. This application with an attractive and user-friendly interface is installed on the device and includes basic information about sight and routes, but it can be updated by GPRS. The application is integrated with basic mobile features like call, SMS, etc. This is very useful so the user doesn't have to terminate or suspend the application.

The GeoNotes [32] system tries to blur the boundary between physical and digital space (ubiquitous computing and augmented reality), and at the same time strives to socially enhance digital space (collaborative filtering, social navigation, etc.) by allowing users to participate in the creation of the information space. It is a location-based information system that allows the user to access information in relation to the user's position in geographical space. The main goal of this project is to provide location-based information free to all users.

With this mobile application, tourists can retrieve notes regarding their current location. These notes are introduced by other tourists that visit the same place. These notes are retrieved using collaborative filtering algorithms rather than using a content-based approach.

LoVEUS (Location aware Visually Enhanced Ubiquitous Services) [33] project aims to provide the European citizens, ubiquitous services for personalized, tourism-oriented multimedia information related to the location and orientation within cultural sites or urban settings. These places are occasionally enriched with relevant advertisements. The information received on the user's terminal will be personalized, matching his individual preferences in terms of content focus (*e.g.*, sports), format (*e.g.*, audio, video) and language.

MacauMap [6] is a tourism-oriented mobile GIS (Geographic Information System) application for the city of Macau that has map navigation displaying user's current location, and provides information about public bus network and bus guide for calculating an optimal bus route from a starting bus stop to a destination bus stop. It provides sightseeing guides with information about museums, churches, temples and other places of interest as well as their location on the map. Also, hotel and restaurant guides with a choice of restaurants and hotels matching criteria results are included.

etPlanner [7] a mobile planning aid, that allows to design personalized tourism stays. Using a mobile device (*e.g.*, PDA, mobile phone) the costumer's stay is intelligently planned and assistance is provided, during and after the journey. The guest is able to react in real-time to special destination offers but also to relevant occurrences like flight delays or adverse weather.

The personal mobile assistant mobiDENK [8] has been developed for a tour to the Herrenhausen Gardens in Hanover and includes points of interest on which historical information and images of the most significant features are presented on a PDA. It focuses on drawing the user’s attention to historic sites and provides location-based multimedia information at the different sightseeing spots, and displays the person current location on a map.

AccessSights [35] is a subproject of this system and is intended to provide tourist information to both normally sighted users and visually impaired people traveling in the Gardens. The user receives visual and audio information. Normally sighted users will make use of both senses to obtain information and may simply follow a guide map, while blind people listen to information. The system uses loudness in order to point out the distance between the user’s current location and point of interests, by simply making the voice signal get louder as the user comes closer to the point. A mobile chase game is included and realizes a location-aware game that allows its players to find a set of geo-referenced checkpoints and solves the associated hypermedia riddles. The checkpoints are proximity-aware, exploiting the player’s location. After the riddle is solved, the player physically moves on to another checkpoint indicated on the map. The paper chase game has also been enhanced by auditory support to support the players with weakly intrusive navigation and orientation support.

Tourist Guide [9] is a location based tourist guide application for the outdoor environment and it was developed for visitors to the Mawson Lakes campus of the University of South Australia and the North Terrace precinct in the Adelaide city center. The user interacts with the system using a PDA that displays his current position, showing detailed information about specific features linked to the current position (a self guided tour of a specific area) like building view, attractions and nearby equipment, such as public telephones and toilets. This system can be operated in three different modes: Map mode shows user's current position on the map and the attractions nearby; Guide mode, which supplies the user with a map showing a tour of related attractions, and Attraction mode, which provides textual information as well images and sounds about a sight.

Mobile recommender systems based on profiles have the potential to substantially enrich tourist experiences. As their handling marks a big challenge for ordinary users, its acceptance can only be evaluated when utilized by the intended user group itself - real tourists. One of them was the m-ToGuide [10] project. This project is targeted for the European tourism market and offers location-specific multimedia information about major monuments and points of interest. A portable, handheld terminal is used to exchange information between the m-ToGuide system and the tourist. All information and services delivered to the tourist will be relevant to his/her specific location (location-based) and tailored to that end-user's personal profile.

A trial project was performed and tested with an on-the-go ticketing facility that allows tourists to make bookings and reservations directly from the terminal via GPRS. The m-ToGuide experience can be personalized to give tourists direct access to the information and services they prefer. The trial results indicated that the system was useful but the charged prices were not well accepted by users.

Your Tour [11] allows the planning of sightseeing tours considering a tourist's personal preferences, wishes and constraints. With these preferences the system is able to select attractions to visit and hotels to stay overnight.

The TIP (Tourist Information Provider) system [12] was created to provide sight related information to the users. This system provides not only sight information but also gives recommendations regarding nearby sights, which match the user preferences and his current location. The whole system has a database which contains user profiles, user context, sights context, user travel history as well as their feedback given to the sighs they have visited. The user interacts with the system through a handheld device (*e.g.*, PDA or mobile phone), defining his profile (*e.g.*, type of sights and type of sight information he’s interested in) and giving his current location (*e.g.*, by the GPS of PDA) which is used by the system to recommend sights to visit.

The GUIDE [13] project has been developed to provide Lancaster, U.K., city visitors up-to-dated and context-aware hypermedia information while they explore the city. Visitors view this information through a Fujitsu TeamPad 7600 hand-held device. This unit is equipped with an 802.11 wireless networking card. To give support to the device, several 802.11 base stations have been installed all over the place. In GUIDE, the adaptive hypermedia presented to visitors is tailored to both environmental context (the major attractions in the city) and the visitor’s personal context, where he can produce a customized tour of the city so he can explore it his own way. Examples of the personal context used to drive the adaptation process include the visitor’s current location, the visitor’s profile (interests), and the set of attractions already visited. Other features include the possibility of making reservations for dinner in a restaurant and sending messages to other users, or to the staff of the tourist information center.

CRUMPET [14] provides new information delivery services for a far more heterogeneous tourist population. The services proposed by CRUMPET exploit the integration of four key emerging technology domains: location-aware services, personalized user interaction, seamlessly accessible multi-media mobile communication, and smart component-based middleware or ‘smartware’ that uses Multi-Agent Technology. This system provides location-based information with customized services and information. The user begins by supplying some demographic information to the system. The system then learns more about the user’s preferences while he’s traveling and interacting with the system itself. If, for example, the user has visited a number of parks perhaps he’d also be interested in other parks.

Cyberguide [15] was developed at the Georgia Institute of Technology (GIT), Atlanta, USA. It is based on the ubiquitous computing concept and focuses on mobile context-aware tour guide. The user interacts with the system using a mobile device. The system was designed to assist a visitor in a tour to the GIT, and helps the user obtaining information about the demos in display. Knowledge of the user’s current location and a history of past locations are used to provide more of the kind of services that we come to expect from a real tour guide. The system is currently only being used indoors through infrared beacons, but in the future it will be possible to use it outdoors through GPS. On the other hand, it has very limited tourist information and recommendation capabilities.

CATIS [34] is a context-aware tourist information system with a service-based architecture. The context elements considered in this project are location, time of day, speed, direction of travel and personal preferences. This system tracks the user and provides relevant location-aware and temporal-aware information. For example, if the user is traveling at midday, a simple integration of the time context, the location and respective user preferences for restaurants, will result on a list of possible restaurants to lunch. CATIS main goal is interoperability, thus its web service-based architecture.

Deep Map [36] realizes the vision of a future tourist guidance system that works as a mobile guide and as a web-based planning tool. Deep Map is a mobile system able to generate personalized guided walks for tourists through the city of Heidelberg. Such a tour shall consider personal interests and needs, social and cultural backgrounds (*e.g.*, age, education and gender), type of transport (*e.g.*, car, foot, bike or wheelchair) as well as other circumstances (from season, weather, traffic conditions to time and financial resources). The core of Deep Map is a typical geographical information system (GIS).

The system can also handle spatial and topological queries while allowing navigation and route finding.

Tourism information is location-dependent by nature. Each sight, building, hotel and restaurant does have a spatial location. Therefore Deep Map is taking a step further, making use of the so-called 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.

Map-Agent is a Java based Deep Map module that gets the geometric data of the spatial features that have to be displayed from a geo-server instance, and renders this vector data on client side. Normal maps just contain 2D information, but Map-Agent includes 3D information to generate route instructions that do not sound as:

“go 205.4 meters straight, turn 30 degrees to the right and go 67.9 meters straight,”

but rather like,

“follow the street and turn right after the big red building and head towards the church.”.

In the future, virtual tours in a 3D-reconstructed city will be possible. Because many types of data are not only spatial but also temporal, *e.g.*, environmental, climate, or city development data, Deep Map handles 4D data, facing questions of tourists standing in front of a historical place like a ruin of a castle asking "how did that look like when it was not destroyed?". In this case we would like to turn back in time and allow the user to go through a virtual time travel displaying a reconstruction of that place as a virtual model.

DTG (Dynamic Tour Guide) [16] is a local guide, who understands the individual interests and timeframe. It also knows the local situation and gives a personal tour to each tourist. The purpose of the application is to devise a tour, just like an expert guide would do after getting to know a tourist’s preferences, using new technologies like mobile applications and context-aware computing. A field trail was made to evaluate the usage of this application by real tourists, clarifying the questions if and how long tourists really use mobile information systems and if it has any effect on their behavior when exploring a destination [26]. The trail results were very positive to DTG application proving the efficiency of this type of software.

TABLE II. contains some comparison factors between the presented tourist mobile systems. Although they all have guiding capabilities, there are other factors that distinguish them well. The table is divided into seven functional requirements:

Tour recommendation (FR1) which defines the system capability to recommend a personalized tour based on the tourist profile.

Sightseeing guide information (FR2), to support the delivery of timely information the system has to support the registration of the user position.

User profiles and information filtering (FR3) that describes systems that support personalized information delivery. The user preferences have to be defined and stored. The information provided to the users is to be filtered according to the profile.

Booking (FR4) is the functionality to book a restaurant, a hotel and so on.

Personalized recommendations based on history (FR5) states if the system should recommend sights that match the user profile, their travel history, their current position or other users with similar profile and tastes.

Domain of the system (FR6), that describes if the system should work in any place of the world and not only in a specific location.

TABLE II. COMPARISON TABLE FOR MOBILE TOURISM INFORMATION SYSTEMS

	FR1	FR2	FR3	FR4	FR5	FR6
MultiMundus	-	+	-	-	-	+
MYJATRA	-	+	-	-	-	+
GeoNotes	-	+	+	-	+	+
DeepMap	+	+	+	-	-	-
Proximo	+	+	+	-	+	+/-
LoVEUS	-	+	+	-	-	+
CATIS	+	+	+	-	+	+
MacauMap	-	+	+	-	-	-

etPlanner	+	+	-	+	-	+
mToGuide	+	+	+	+	-	+
Your Tour	+	+	+	-	-	+
TIP	+	+	+	-	+	+
Tourist Guide	-	+	-	-	-	-
Guide	+	+	+	+	+	-
CRUMPET	+	+	+	-	+	+
Cyberguide	+	+	-	-	+	+/-
mobiDENK	-	+	+	-	-	-
DTG	+	+	+	-	+	-

B. Recommendation Systems

Recommendations can be given for multiple, vast concepts and different areas of knowledge. In highly content-based recommendation, there are already many implemented systems. Some of the most popular examples go from Amazon to CDNow. Also, some systems have not only the ability to retrieve highly rated items, but to know which ones are disliked or not interesting at all (*e.g.*, WebSell).

While highly content-based systems might not need a profile learning process, tourism recommendation systems must have effective profile learning techniques implemented to be valuable through time. Amazon, for example, uses purchase history and product lists to retrieve recommendations, thus not having the need for a profile learning process.

Many approaches have already been implemented on many different business areas. From news, to movies and music, recommendation systems have grown in popularity as the World Wide Web grows in size. Tapestry [28] dates from 1992 and uses content-based and collaborative filtering to filter mail messages. Although it is not the usual kind of recommendation system it works the same way.

To provide filtering, Tapestry saves the reactions of the users when reading documents thus allowing a user-item rating to be kept. The user is also able to specify filter queries, avoiding unwanted documents to end up inside the mail box.

Although pure recommendations have their own weaknesses, in some types of recommendation systems, it might not be a critical issue.

WebSell [30] is a recommendation system that uses case-based reasoning and decision trees. Along with collaborative filtering, it is designed to support single business selling a range of products or services. WebSell was tested through the implementation of an agent capable of giving recommendations for apartment renting. The agent requests feedback using a web form that is later used to calculate preferences according to similar cases.

The most peculiar feature of the WebSell recommendation system might be its support for customization and configuration. Although there are many recommendation systems that are based on simple fixed products or items (like books, movies or CD's (Compact Disc), WebSell tries to give support for complex item recommendation. This includes holidays, insurance plans and many other recommendations that involve a large quantity of variables.

To achieve customization, WebSell uses two different approaches: operator-based customization and incremental component replacement. Operator-based customization allows the user to apply a set of operations that change the provided recommendation product or service into a customized final item. Incremental component replacement assumes that products and services are structured into components. These components can be replaced for other (more similar to the user preferences) components.

Godoy and Amandi [31] took collaborative recommendation one step ahead by proposing a trust-aware boosted recommendation system called FilmTrust.

FilmTrust is a web-based system that explores trust in a movie related social network. With FilmTrust, the users can not only express their particular opinion about a movie (by rating or writing reviews), but also define a trust degree for other users and their opinions. This follows the principle of basing predictions on reliable peers, instead of solely similar ones.

To achieve improved recommendations, FilmTrust contains a set of personal agents that help users find relevant information. While these agents retrieve the user preference profile and provide the desired content-based and collaborative recommendations, they can communicate to improve results. On the other hand, user profiles use taxonomies to hierarchically organize the topics in which the users are interested in, adding knowledge-based capabilities to the recommendation system.

Triplehop's TripMatcher and VacationCoach's Me-Print [19] are web-based recommendation systems that use the content-based approach, but also implement features to tackle the weaknesses of a pure content-based recommendation system. Me-Print uses a mechanism to group new tourists, so it can fill the information gaps. On the other hand, TripMatcher has a more complex way of matching similar tourists using statistics and computed predictions based on past travels and similar profiles.

DieToRecs [19] is also a web-based tourism recommendation system. It uses case-based reasoning (that may be a particular case of a knowledge-based paradigm) to provide recommendations which are obtained using tourist profiles and contextual information. Five main products and services are included in the recommendations, which are accessibility, amenities, attractions, accommodation and ancillary services. Also, the system provides two types of recommendations: single travel items and complete travel bags. Many single travel items (*e.g.*, hotels, destinations, activities) form travel bags. This way DieToRecs can also allow the users to build their own travel bags by choosing preferred travel items.

Intending to simulate the process of interaction between current physical travel agents and the tourist DieToRecs implements algorithms to learn through interaction. Also, it uses a hybrid paradigm that takes advantage of both content-based and collaborative filtering approaches, while having the learning capabilities of a regular case-based system. The collaborative filtering approach does not focus on similar users, but instead it focuses in similar cases that are product of similar sessions. These similar cases form what Arslan, Ricci, Mirzadeh and Venturini [27] call the Reference Set. With the Reference Set, the recommendations can be given according to two basic conditions: user constraints satisfaction, and similarity to items existent in similar cases.

Hinze and Junmanee [20] also proposed a hybrid recommendation model for TIP. Their model is based on the three recommendation paradigms: content-based recommendation, collaborative filtering and knowledge-based recommendation. This hybrid model solves most of the problems for which pure models lack the solution. Especially in an area which deals with very rich information like tourism.

The main problems tackled by the TIP recommendation model are the cold start issue, the gray sheep individuals and over specialization.

The cold start issue due to the lack of feedback information (associated to pure collaborative filtering approaches) is solved, since any user can be supported even without giving feedback.

Also, gray sheep cases (tourists that don't fit in any group profile) are diminished. This happens because the system does not rely only on the user feedback information to recommend.

Over specialization is another of the issues that this model pretends to eliminate. Since tourists don't want to be provided with the same recommendation over and over, the recommendation system widens the possible point of interest universe, helping tourists discover new interests.

The proposed recommendation system by Casali, Godo and Sierra [21], uses graded BDI agents to deal with uncertainty and graded mental attitudes. Based on previously created tourism packages, the BDI model relies on the agent's beliefs (B), desires (D) and intensions (I). Using this model, the system calculates a preference level used to recommend the most suitable packages. Also, the ontology used allows the system to analyze every destination point described in the package, so although the system cannot propose a dynamically generated set of destinations, all package destinations are used to measure the tourist preference level. Since this system relies on ontologies, it is, at least, a knowledge-based recommendation system.

In his work, Knoblock [3] used a set of software agents to retrieve travel information from the web. The tour planner, called Heracles, uses real-time collected data from the software agents to provide recommendations. Since it is constraint-based, the tourist needs to specify the desired criterion. This system does not recommend the conventional points of interest, but rater recommends a travel route along with choices of flights, hotels, ground transportations, and others.

The Heracles tour planner is based on online information to provide recommendations, and provides two possible ways of submitting recommendation requests through supervised machine learning techniques, and through unsupervised grammar induction. Although the first can achieve high levels of accuracy, it requires a significant amount of user input data. On the other hand the unsupervised grammar induction does not need additional data, but the accuracy rate can be low.

To allow the progressive reduction of the need for user input data, the Heracles contains a machine learning algorithm called Stalker.

Also the system features monitoring agents that supervise different aspects involved in the route that may change over time. Some of these aspects go from airfare monitoring to a real-time restaurant finding agent. Tourists are also able to define their own monitoring agents.

TABLE III. RECOMMENDATION SYSTEMS PARADIGMS, USE CASES AND RECOMMENDATION CHARACTERISTICS

	Paradigm	**Use Case**	**Recommends**
Amazon	Extended Content-Based (Hybrid)	Web (E-Commerce)	Products
Tapestry	Extended Content-Based (Hybrid)	Application (Mail Filtering)	Mail (Filtering)
Proximo	Collaborative Filtering	Mobile Device (Indoor Items)	Items
WebSell	Hybrid (Case-Based)	Web (single business selling a range of products)	Items or Products
FilmTrust	Hybrid (Trust-Aware with Software Agents)	Web (movie related social network)	Items (Movies)
TripleM.	Extended Content-Based	Web (Holiday Destinations)	Pre-Created Packages
Me-Print	Extended Content-Based	Web (Holiday Destinations)	Pre-Created Packages
DieToRecs	Hybrid (Case-Based)	Web (Outdoor Destinations; Travel Bags)	Dynamically Generated Plans
TIP	Hybrid	Mobile Device (Outdoor Sights)	Dynamically Generated Plans
gBDI	Knowledge-Based	Web (Argentinean Destination Packages)	Pre-Created Packages
Heracles	Hybrid (Software Agents)	Web (Outdoor Destinations; Environment; Transportation)	Routes along with Points of Interest.

TABLE III. contains general information about each of the recommendation systems previously described. TABLE IV.

describes the used information filtering methods, usually matching the implementation paradigm.

TABLE IV. INFORMATION FILTERING METHODS

	Content	**Collab.**	**Demog.**	**Knowledge**
Amazon	+	+	-	-
Tapestry	+	+	-	-
Proximo	-	+	-	-
WebSell	-	+	-	+
FilmTrust	+	+	-	+
TripleM.	+	-	-	-
Me-Print	+	-	-	-
DieToRec	+	+	-	+
TIP	+	+	-	+
gBDI	+/-	+/-	-	+
Heracles	+	+/-	-	+

(+/-) means more information is needed

Finally, the TLTIS (Travel, Leisure and Tourism Information Service) [22], intends to provide adaptive tourist maps and 3D visualization of the buildings and sights. Using location-aware information, the system is able to adapt the presented 3D map and object representation according to the tourist culture and weather condition. Also, the tourist special needs and physiological limitations are evaluated using a tourist profile.

One of the issues that the TLTIS system tackled regarding adaptation is the cultural aspect. Since different cultures, make different interpretations of symbols and colors, maps need to be rendered according to those interpretations. These kinds of systems highly rely on user interaction, thus needing cultural and social research.

IV. CONCLUSION

In recommendation systems, adaptation is very important. The implementation of agents capable to learn and improve, that acquire information from tourist interaction and feedback might as well be one of the best approaches. Transparency is also an issue when providing recommendation, since for many users, knowing how the recommendation is given is an important factor to trigger trust.

A tour simulation might help improve the final given recommendation, either being through simulating the tour and presenting reports or by allowing the tourist to previously see the tour points of interest using a 3D application.

The 3D representation of points of interest can present the tourist with an incredible level of detailed information. Although some communities that tend to create a virtual world parallel to what we know as reality are emerging, the virtual representation of objects like points of interest can be quite difficult. It not only deals with great amounts of visual information, but also with constant change. The slightest change in the point of interest structure and the virtual representation might be rendered obsolete.

The heterogeneity of the described systems shows that there are many ways to improve recommendations. Trying to extract all their qualities and combine them into a single recommendation system reveals to be a challenge. This happens not only due to the high complexity resulting from this kind of system, but also because it can turn out to be a double-edged sword, that ends up providing inaccurate results or high performance drops.

Besides the desired recommendations, when a traveler goes on vacations, he would appreciate to have a quite simple tool in his pocket (Application to a mobile phone), that can assist him in planning his staying. At the moment, several applications exist to do this, but they are very basic and don't have a solid implementation to be used in the real world.

Some real tests have been done to some of these applications, and they have proved the utility of those systems providing tourists more knowledge about sights than if they have a simple map and/or prospects/bulletins. Tourists with this type of applications can know more information about a sight, only with a simple click.

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