ARLodge: context-aware recommender system based on augmented reality to assist on the accommodation search process

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Introduction

The explosive grown of the World Wide Web and its online environments has increasingly complicated the issue of information search and selection; users are usually overwhelmed by the available possibilities, which they may not have the time or the knowledge to assess. Recommender systems (RS) have proven to be a valuable tool for online users to cope with the information overload. Originally, they found success on e-commerce websites to present information about items and products that are likely to be of interest to the users. Lately, they have been increasingly employed in the field of electronic tourism, providing services like trip and activities advisory. A relatively recent development in e-tourism lies in the use of mobile devices as a primary platform for information access, giving raise to the field of mobile tourism, and bringing new challenges and opportunities to the field. In addition, augmented reality (AR) has undergone a tremendous development during the 90s. While AR experiences used to require carrying bulky custom hardware, today, a simple smartphone is more than sufficient to visualize virtual content anywhere in the real world, having important applications in marketing, gaming or tourism. Yet, one of the most successful types of AR application is the equivalent of a desktop or mobile Web browser for the physical world, generally referenced as AR browser, which is already installed in more that 50 million smartphones and with the emergence of low-cost head-mounted displays (like Google Glass) is expected to massively integrate our everyday life. This kind of browsers allow to present information on top of live videostream, providing an evident advantage over conventional "location-based" interfaces such as maps or lists. In this project, we will combine the use of AR concepts with recommender system to create a web-based application that can enhance user experience when trying to find an accommodation in an unknown destination.

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Research proposal

2.1 Justification of the topic of interest

Augmented reality (AR) is an emerging technology that embraces cutting-edge developments in sensing and smart devices, wireless communication, pervasive computing and intelligent environments. It augments users' experiences by adding virtual objects and allowing to interact in real time and space (1) and that are commonly showed through what is called an augmented reality browser (which allows the inclusion of those objects in the real world of the user) (2, 3, 4). Current AR systems are mainly based on smart devices such as smartphones *smartphones* or famous Google Glass, devices tht presents limited screen sizes. Content displayed on small screen can be difficult and frustrating for end-users, thus the use of high performance recommender systems can be very useful in most of AR mobile systems.

Recommender systems provide personalized recommendations on certain items or products to different users getting, basically, a match between them based on an estimation of the preferences of the users. This kind of systems began to appear in the early 90s and have been gaining in popularity, both in terms of research and marketing. Nowadays, there exists several classes of recommender systems, based on very heterogeneous architectures (collaborative filtering, content-based filtering, knowledge-based filtering, data mining, etc) (5, 6). We can find recommender systems in almost every website (Youtube, Amazon, Cuevana.tv, etc). Even current SMART TV models incorporate recommender systems to alert the user of their favourite shows. However, adapting traditional recommender systems to augmented reality systems on mobile devices is not a trivial task, since such systems possess a number of characteristics and/or limitations that make them different, such as the location (which makes that the nearest recommendations more interesting that those that are far from the current position); the time (which basically involves making recommendations taking into account the time of day or time of year); cold start (or trying to adapt the experience of new users to previous users's experiences when no historic information of this user is available); and especially immediate feedback, as recommender systems based on augmented reality have to react quickly to stimuli provided by users or generated by the device itself (motion sensors, GPS sensors, camera, etc). Thus, it is important to offer the user a personal response, but also a context-dependent (7, 8, 9, 10, 11) and constrained by the limited computing capacities of the mobile devices.

The main goal of this PhD. proposal is to analyze the integration of a recommender system in an augmented reality environment to offer to the user the possibility of improve and facilitate the process of finding accomodation in an, *a priori*, completely unknown city. The proposal should include, therefore, the development of an augmented reality-based mobile application, the recommender system and the underlying infrastructure to be able to implement an efficient communication between the application and the recommender system, which will be located on a dedicated server due to its complexity and the need of process massive amounts of data.

The system will use the feedback from previous users as well as user profile or historic to make recommendations on the different possibilities of accomodation in the surroundings of the area where the user is located. If there exist some possibilities that sufficiently meet the expectations of the user and that are not in the surroundings, they will also be shown to the user. Thus, accommodations will be prioritized based on the previous ratings, accomodation features based on user demands, and its distance from the current location. Given the complexity of the algorithmics, the architecture of the system will follow a client/server model, so that the logic of the recommender system will be executed on the server, thus the client application will act as a mere interface with the user. In order to make the user experience more attractive, both the content and the recommendations will be displayed in the form of augmented information using an augmented reality browser. For the development of this tool, we will use a very limited simulated database (which could correspond to the accomodation offer of a small town). In future stages of the proposal, we will try to access real databases to extrapolate the performance of the tool to larger an more realistic scenarios.

2.2 State of the art

As already mentioned in previous sections, the main topic of the present proposal can be related with two main areas which have been very active research in recent years: augmented reality and recommender systems in the context of mobile computing. For this reason, it would be necessary to introduce the state of the art in both disciplines, completely and accurately contextualizing this research project. The remainder of the section will be organized as follows: first, augmented reality concept will be introduced, along with several concepts related to it. Then, the state of the art regarding recommender systems will be analyzed, focusing on those systems implemented to be executed on mobile devices. Last, main efforts regarding the combination of augmented reality and recommender systems will be described.

2.2.1 Augmented reality in mobile devices

Augmented reality (AR) is a variation of virtual reality (VR), where VR assumes that the user is completely immersed in a synthetic environment, and AR allows the user to actually see the real world, with the virtual objects superimposed upon and composited within such real world. AR enhances, modifies and/or supplements the reality rather than totally replacing it (1). It is accomplished through a set of devices adding virtual information to the existing physical information using computer vision, object recognition, geolocation and tracking techniques to associate artificial information previously stored, that can be retrieved like an information layer at the upside part of the vision of the real world, making it more interactive and digital while practically augmenting reality (12, 13).

In (14) the idea of a reality-virtuality continuum is proposed. The reality (as we know it) can be situated at one side, and the virtual environments totally generated by computer or VR are placed at the opposite side. Moving from the side of the reality to the side of the VR can be accomplished by AR, and moving from the VR towards reality can be accomplished by using augmented virtuality (AV) techniques. In between AR and AV we can define a concept called mixed reality (MR). MR not only allows users' interaction with virtual environments, but also allows physical objects from the immediate environment of the user to be used as elements that interact with the virtual environment. In fact, MR includes applications that cannot be only defined in VR or AR terms.

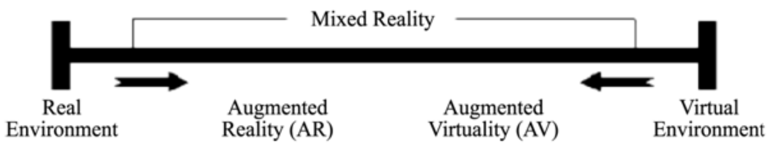

Figure 2.1: *An illustration of the virtuality continuum.*

AR has been introduced in many different areas, mainly to visualize virtual data in real environments. Such emerging areas include education, entertainment, media arts, surgery, robotics, media arts, GIS and city planning (12, 13). Several examples of projects and real applications from bussiness and academia can be mentioned apart from the two leading areas for AR experiences (augmented books and mobile AR applications (15)), including projects such as Avalon (16), which allows learning a language by foreign students inside a full MR environment. In the gaming area, examples such as Invizimals (17, 18) for the SONY PSP or ARdefender (19) available for Android and IOS have been also successful. The recently launched Open Me (20) for the PSPVITA is an original proposal of AR-based video game. In the area of medicine AR applied to surgery, several contributions are described in (21). Other proposals can also be found for the industrial and informational fields, such as Virtualware for the Spanish Postal Service Correos (22) simulating sizes of shipments. Another interesting project in the area of marketing is Magic Mirror (23), which provides a virtual fitting room that could increase sales of clothes. However, it is in the area of entertainment that we can find many successfull examples like Duran Duran project (24), based on markers showing projected AR during concerts, or the Augmented Mirror project (25), which allows real time animation of a virtual character shown to the audience as it is performed by a hidden actor. Proposals for Theme Parks (26) and musseums (27) also exist in the recent literature. In the scope of arts, ObservAR project (oriented to museums) provides a representative example (28). Nowadays, Google Glass (29) and other similar tools such as Omni (30), Kinect (31, 32) and Mobile apps. (33, 34) are representatives of three of the most active research lines regarding AR/MR/VR, along with recently proposed concepts as Smart Cities (35, 36), Serious Games (37) and Web3D (38).

In particular, AR is a concept that is increasingly being considered by tourism applications, where most of existing approaches are application based on the principle of *video-see-through* or magic lens (39, 40, 41). Using AR browsers like Argon (4), Layar (3) or Junaio (2, 42), which can be considered the equivalent to web browsers in desktop computers or mobile devices to explore the real world and that can be easily installed in smartphones or tablets, the users can enrich their real world view using interactive virtual information thus allowing, for instance, identifying the most important and/or closest points of interest and obtaining more information about the surroundings. This kind of mobile applications usually take advantage of their own built-in cameras, while the GPS location system and internet connection allows the virtual art to be projected over the top of the camera's image of the observed space (43), which can be either an indoor space (44, 45) or an outdoor space (46, 47, 48, 49).

2.2.2 Recommender systems in mobile devices

Recently, the increase in the use of different technologies has changed the way that users access, manage and distribute the multimedia information (9). As a consecuence, there exist an important overload of information every time a user tries to access a given object. In this sense, many techniques have been recently proposed to cope with this overload of information. As stated in previous section, recommender systems (RS) are being used intensively, as an effective mean to mitigate information overload and reduce the amount of information displayed to the user citeAdomavicius, burke . Traditionally, a RS compares a user profile with some reference attributes to predict the value or preference that the user will have over a particular object not known yet.

It can be said that, in the beginning, the RS only generate a match between users and objects, without considering a context or environment which may influence the recommendations. Originally, the RS were successfully applied in websites dedicated to e-commerce, to introduce object information and products likely to be interesting to users (movies, books, news, web pages, ...). However, in many applications, it is not enough to consider users and objects, but it is important to incorporate contextual information in the recommendation process (50).

2.2.2.1 Classification of recommender systems

Nowadays, there exist several models to create personalized recommendations for each user from the provided information and a respository of their historic ratings/preferences. We can classify the recommender systems according to the different techniques that can be used to generate the recommendtions. Attending to the differences in the supporting information, the input information and the recommendation technique, the following five types of recommender systems are defined in (6):

1. **Collaborative filtering**: can be considered as the most succesfull recommender technique so far. It is based on the idea that the recommendation of an item/object to a user can rely on previous ratings provided by other users of the system (*show me what is popular among my peers*). We can substantiate between *based on user* or *based on object* collaborative filtering (depending on whether we perform the comparison between the ratings among the users or the rating among the items), considering that hybrid techniques may also exist (51). The first step is to identify users (or objects, depending on the approach) which are most similar to the target user and then use the ratings of the most similar users to generate recommendations for this target user. Both models are based on a very simple data structure: a user x object matrix. Depending on how this matrix is managed, we will have memory-based or model-based techniques.

   (a) **Memory-based collaborative filtering**: consist on using the whole user x objetc matrix to produce recommendations. First, similarity between users is measured using some of existing heuristic functions (Pearson correlation coeficient, angle, etc), generating an ordered list according to the similarity of the users. Then, the k-most similar users, whose ratings will be taken into account to make the recommendation. When the number of user is very high and/or we have real time constraints, this kind of techniques are not effective, thus model-based techniques are required.

   (b) **Model-based collaborative filtering**: there exist several techniques to produce a model-based collaborative filtering, as, for instance, probabilistic techniques (52, 53) or machine learning approaches (54), which are generally very specifics for the particular context in which they have been developed.

The main problem regarding the collaborative filtering techniques is related with the sparsity of the data. Generally, it is difficult to find common patterns in the ratings and, therefore, it is not easy to to measure the similarity between different users. Even when considering well known users (long term users), it can be the case that they share reviews on common objects with very few users.

2. **Content-based filtering**: is the second most commonly used approach to generate recommendations. It has its origin in the information retrieval techniques (55) and it is based on the idea that the user would like similar items to those he has enjoyed previously *show me more of the same that I have liked*).

   While collaborative techniques based their recommendations over items on the fact that other similar users have enjoyed them, content-based filtering try to build a user profile which will be used to predict/estimate the user's opinions about items not yet presented. If these systems work properly or not will strongly depend on the profile capacity to represent the preferences of the user. The profiles can be derived from the opinions of the users regarding the items or can be directly provided by the user (56).

   Generally, the key issue to create a good content-based system consists on labeling the items with information about the content, which is usually achieved by using feature/value or keyword/frecuency pairs. An good example of labeled content for a restaurant would be the following:

   (a) **Characteristics**: Name, Address, Cuisine, Price, Customers

   (b) **Valores**: McDonalds, Avda. Libertad, Fast food - hamburguers, low, childs - youth - families

   Just as users profiles, the objetcs have also content profiles consisting on the same features or keywords that the user profiles. To measure the utility of an object for a particular user, heuristic functions are typically used (like angular similarity metrics or the Pearson correlation coefficient, which are also used in collaborative filtering). Other approaches construct models based underlying training data, using on machine learning techniques, such as bayesian classifiers, decision trees or artificial neural nets (5, 56).

Such systems are often used in applications where the frecuency with which a new objetc is introduced (with the need of labeling all the information) is relatively low, but if the number of daily new objetcs is high, collaborative recommendations are often used, as it does not require labeling the content, but is only based on previous assessments. Moreover, such recommender systems will never provide serendipitous suggestions, as it is always based on previous experiences of the user.

3. **Knowledge-based filtering**: this is other of the systems identified in (6), which bases its behaviour in the coding of the knowledge of how the item satisfies uder requirements using a serie of data structures used by the system to infer recommendations. Such knowledge coding can be done in different ways, such as rules in a rule-based system (57).

4. **Demographic-based filtering**: base their recommendations in personal attributes of the users, depending on which the users are grouped to receive similar recommendations (58).

5. **Hybrid recommender systems**: these systems combine the use of two or more recommendation techniques to overcome weakness of each technique by itself and enhance its strengths. We can categorize these techniques attending to how the hybridization occurs (57):

   (a) **Weighted**: lthe final recommendation is obtained weighting the utility values provided by several independent recommender systems.

   (b) **Switched**: depending on a number of conditions the decision will be made among several systems for each particular recommendation.

   (c) **Mixed**: several recommender systems operate simultaneously, generating recommendations that are presented together.

   (d) **Combination of features**: where collaborative information is used as additional features of the object in a content-based approach.

   (e) **Cascade**: first, a recommender system filters a set of candidate objects that are refined by a second technique before making the final recommendation.

(f) **Feature extension**: is based on using techniques to create additional features/ratings which can be used by a second system to create the recommendations.

(g) **Meta-level**: a first approach builds a model that is used as input for the second technique that generates the recommendations.

Although almost any combination of techniques is possible, hybrid recommender systems are usually based on a combination of collaborative and content based-based techniques, either combining their outputs, using the features of one of them as inputs to the others or generating a model that combines and unifies both techniques (56).

2.2.2.2 Implementations of recommender systems

Considering the architecture used to implement the recommender system on mobile devices, we can establish the following taxonomy:

1. **Web-based recommender systems**: these are typical client-server systems, wherein a mobile application (client) corresponds to the presentation tier and the recommendation logic is maintained on the server (hence, continued network connectivity is required).Web-based recommender systems may exploit the sufficient computational resources of the server to execute sophisticated recommendation algorithms. As regards the client-side of web-based recommender systems, that may either be based on mobile browsers (potentially enhanced by JavaScript/Ajax code for asynchronous browser-server information exchange), implemented as Java ME, .NET Compact Framework, Android or iOS applications (59) or based on the use of augmented reality browsers (3, 4).

2. **Standalone recommender systems**: these refer to full-fledged mobile applications that incorporate the recommendation logic and the tourist content. They are typically downloaded and installed on mobile devices thereafter functioning in disconnected mode. As a result, recommendation techniques based on matching different user profiles (e.g. collaborative filtering-based approaches) are out of scope in those systems.

3. **Web-to-mobile recommender systems**: these systems provide a typical web interface for the pre-visit stage, whereby users initially select content and then build a customized tourist application, incorporating the recommendation logic. Similarly to standalone systems, the application is subsequently downloaded and installed on a mobile device thereafter executing offline and achieving cost savings (e.g. 3G roaming charges). On-demand connections to a remote server may be used, for instance, to update POI information or public transportation data. Similarly to standalone systems, collaborative filtering-based recommendations are unsuitable for web-to-mobile recommender systems.

Recently, the use of mobile devices as the primary platform has revolutionized many areas of application. This has been the case of e-tourism, which has evolved into mobile tourism, incorporating new features, challenges and opportunities that did not fit a few years ago (60, 61, 62). For instance, the knowledge of the exact location of the user allow us to provide location-based services (location-aware recommender systems, LARS), as user mobility allows taking advantage of the knowledge related with the hystory of the movements/locations of the user, the social environment (identity/profile of the user) or material surrounding the user in a given range. From this basic information, the applications are usually incorporating new kinds of contextual information, such as the date, the season of the year or the climate/temperature (63), or even more complex data, like aspects related to the emotional state (and other abstraction levels) of the user (64), thus resulting in what we know as context-aware recommender systems (CARS). Gnerally, the main goal of CARS applied to tourism is to replace the services provided by travel agents that manages the destinations of the users under time and/or money contrains. Several clear examples of web-based CARS can be found in the Internet, with powerful search engines that filter the available information according to user preferences and context (amazon.com,YouTube, etc), being TripAdvisor (65) one of the most known and worldwide used websites applied to tourism. Similarly, today is very common to develop mobile applications that can provide customized characteristics and taking fully advantage of the capabilities of the devices to provide context-aware services (8, 50, 66) which can also be combined with augmented reality concepts in order to present more attractive applications to the final users (10, 11, 67, 68).

One of the earliest mobile CARS examples employed in tourism is the Cyberguide project (69), which encompassed several tour guide prototypes for different handheld platforms. Cyberguide provided tour guide services to mobile users, exploiting the contextual knowledge of the users' current and past locations in the recommendation process.

(70) proposed a context-aware system for mobile devices that incorporates the location of the user, his trajectory and speed (while driving) to personalize POIs recommendations. POIs are chosen among those located within a radius around the user's location; the radius is calculated based on the trajectory and speed. The contextually-filtered POIs are then fed into a hybrid recommender system (71) as an input, which selects the most appropriate ones according to the user's preferences.

Gavalas and Kenteris (72) introduced the concept of context-aware rating to denote the higher credibility of users that upload reviews, ratings and comments while onsite (via their mobile devices) in comparison with others that perform similar actions through standard web interfaces. In this context, the system assigns increased weights to ratings/content provided by tourists actually visiting a POI compared to ratings submitted by web users. Hence, the defined system captures context-aware user evaluations and ratings and uses such data to provide recommendations to other users with similar interests, using a collaborative filtering-based recommender system engine. Furthermore, the system delivers several personalized recommendation services to mobile users, taking into account contextual information such as the user's location, the current time, weather conditions and user's mobility history.

I'm feeling Loco (73) is a ubiquitous location-based recommender system which considers automatically inferred user preferences and spatiotemporal constraints for sites recommendation. The system learns user preferences by mining a user's profile in the foursquare location-based social network (74). The physical constraints are delimited by the user's location and mode of transportation (walking, bicycle or car), which is automatically detected (based on measurements taken by a smartphone's accelerometer sensor) through the use of a decision tree followed by a discrete Hidden Markov Model. The individual only has to explicitly define how she is currently feeling, to determine the type of places she is currently interested in visiting.

Magitti (75) is a mobile leisure guide system that detects current user context, infers current and likely future leisure activities and recommends content about suitable venues (stores, restaurants, parks, movies). Magitti supports three key features: context-awareness (current time, location, weather, venues opening hours, user patterns); activity-awareness (it filters items not matching the user's inferred or explicitly specified activity modes); serendipitous, relaxing experience (users do not need to enter profile, preferences or queries).

2.2.3 Integration of augmented reality and recommender systems in mobile computing

As already mentioned, both augmented reality and recommender systems are techniques that have been introduced to mobile computing in the last years. However, very few efforts show the integration of both approaches simultaneously in the same application. It has been previously stated the fact that, most of the mobile devices present a very small display. This along with the fact that tourism application have generally to manage with great amounts of information represent a major problem, as many points of interest must be showed to the user in a very limited space. This issue strongly affect the design of the augmented reality interface, which is heavily constrained by space and visualization limits. The combine use of AR and recommender systems will help to overcome the above mentioned limitations while allow the application to provide more accurate recommendations/filtering in relation with the user preferences (76), instead of filtering information based only in the location of the user.

Traditionally, the interfaces of mobile recommender systems are based in the use of list or maps. However, the possibility of integrating video streams with virtual layers (using, for instance, AR-browsers) have not been yet extensively exploited in the context of generating recommendations. Next, some of the scarce approaches available is the related literature would be shown.

MoreTourism (77), is an Android-based platform which provides information about tourist resources through the use of mashups, integrating images, videos, augmented reality videos, geo-localization, guide services, etc. Recommendations are based on an hybrid approach that combines content-based recommendations with collaborative filtering and allows socialization interacting with popular social networks.

Another approach is RAMCAT (76), which present a context-based hybrid recommender system oriented to integrate augmented reality in management systems for tourism destinations. This application is able to provide category filtering, map or video visualization modes, personal preferences-based recommendations, detailed information about a selected POI, etc, and mobile and web versions are available.

More limited applications can be found in (78), where an location-based restaurant recommender which makes use of augmented reality is presented. In this application, 3D bar graphs are created to display the recommendations of similar restaurants with regards to a previously introduced favourite restaurant for each user.

TagMeAR (79) is a context-aware mobile recommendation system for improving quality of life on university campus that combines existing campus information services. Its recommendation engine uses Markov Logic Network to provides users only relevant information according to current context and previous usage. TagMeAR's information browser shows information overlaid on live image of physical space by using built-in camera, compass and GPS module.

In (67) authors propose a random walk algorithm for AR recommendation based on a graph model, incorporating user preference, behavior patterns, history records, and social network information.

Up to the knowledge of this PhD. candidate, those are the most representative approaches regarding the integration of AR with recommender systems in e-tourism-based mobile applications. It is then clear the fact that this is an emerging research line which represents a wide and open area to be explored, thus providing this proposal with plenty of possibilities for the next few years.

2.3 Research questions and objectives

The main research question of this proposal will be stated as follows:

¿Is it possible to integrate a context-aware recommender system and the use of augmented reality to enhance the user experience when searching for accomodation in an unknow destination?

In order to answer this question, we will have to narow down the field of research. For this purpose we pose some specific research sub-questions that will guide the process and that will be answered in the final conclusions of this thesis:

1. What are the most appropiated recommender systems in the context of our proposal?

2. What are the attributes or characteristics that should guide the recommendation process design?

3. Which is the necessary communication scheme between the mobile device and the server that implements the service recommendation?

4. Which is the most appropiated augmented reality browser in the context of our proposal?

5. How sould the information be displayed to the user to allow a fast recognition of the recommendation?

6. Which is the performance of the proposed approach in the context of the project?

7. Which are the main advantages/disadvantages of the proposed approach regarding previously developed solutions?

8. Is it possible to apply the proposed approach in larger environments in the context of e-tourism?

2.4 Reseach methodology

Research, according to Oates (80). is the creation of new knowledge, using an appropiate process, to the satisfaction of the users of the research discussed. The process of research must be modeled according to a conceptual model which provides rigour and correctness. In the case of the present proposal, the model adopted is shown in Fig. 2.2. The rest of this section is devoted to the definition of the research methodology which will be adopted in this work to achieve the main objective and to answer the research questions stated the in previous section.

2.4.1 Literature review

According to Oates (80), there are about 7 steps (see Fig. 2.3) in reviewing the literature critically. The steps are searching, obtaining, assesing, reading, evaluating, recording and writing a review. At this stage, the state of the art in the field/s will be properly reviewed, with particular emphasis on recommender systems and augmented reality-based systems, focusing on augmented reality applications for mobile devices and based

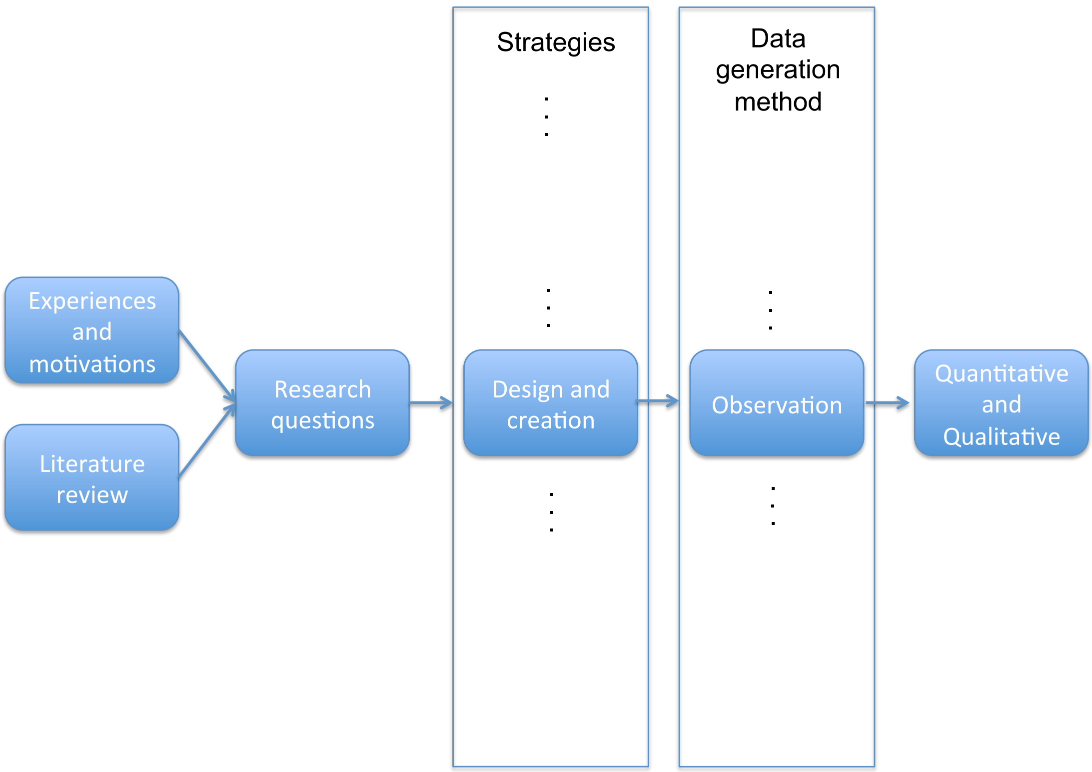

Figure 2.2: *Model of the reseach process.*

on the use of AR browsers. Technological aspects concerning mobile technologies and software for programing the systems and aspects regarding how to integrate the navigation system with additional sources of information will also be explored along with projects integrating recommender systems with AR-based native applications in their final solutions. Specifically, it is felt that the literature review conducted successfully covers the following concepts:

- Concept of recommender system.
- Taxonomy of recommender systems.
- Recommender systems on mobile devices.
- Concepts of virtual reality, augmented reality and mixed reality.
- Augmented reality systems.
- Augmented reality systems on mobile devices.

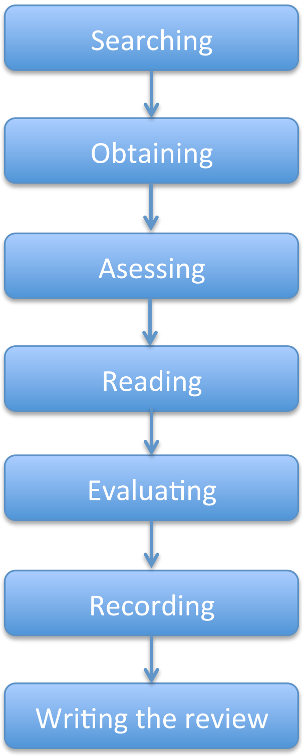

Figure 2.3: *Steps in conducting literature review.*

- Augmented reality browsers for mobile devices.

2.4.2 Research strategy

The ultimate goal of this proposal is to design a recommender system which shows its suggestions on a mobile device taking advantage of augmented reality concepts, thus allowing to the user to interact with the surrounding context, providing an enhanced experience by generating additional information (from the contextual and historical information of the user's interaction with the application) which will be displayed using additional layers superimposed on the user's view on this mobile device. This objective can be clearly considered a design and creation approach, with the clear intention of creating tools that serve the purposes of the human being, and also crearly guided by the available technology. In (81), a research framework to model research activities that fit a design and creation procedure is defined. In this framework, there are four main artifacts (constructs, models, methods and instantiations). Once determined that our approach will consist on the development of an instantiation (realization of an artifact in its own environment), we will need a plan to onduct research, which is usually accomplished through an iterative process involving five critical steps (80): awareness, suggestion, development, evaluation and conclusion. Awareness and suggestion, which are related to the articulation of the problem and the preliminar idea of how it eill be addressed, can be considered covered in this proposal. However, although development, evaluation and conclusion have been planned in this research proposal, they will be completed in future steps, once the research procedure would be in a more mature stage. The process of designing a system prototype will follow the prototyping steps proposed in (82) which can be seen in figure 2.4. We will begin by identifying the users of the system and their requirements (we will achieve this basically through a literature review process). The following step is to begin the development of the prototype, customizing, testing and debugging the system in a loop focused on identifying the problems of the intermediate implementations and fixing them.

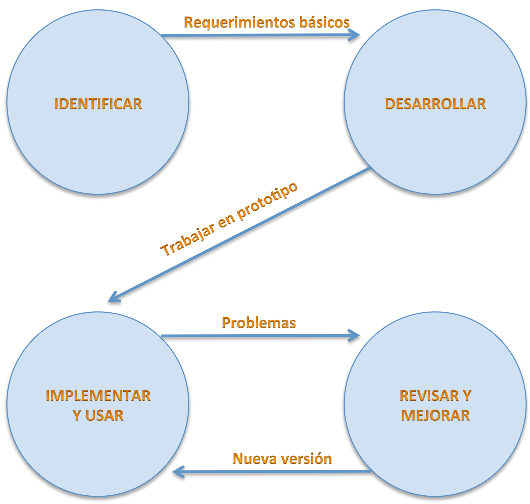

Figure 2.4: *Pasos para el desarrollo de un prototipo.*

2.4.3 Evaluation methodology

Evaluation is one of the most important steps during research process. Accoding to (83) there exist several ways in which artifacts can be evaluated: functionality, completeness, usability, consistency, accuracy, performance, reliability and how well they fit the context. The evaluation process of this research process will focus on evaluating the functionality, usability, accuracy and reliability of the implemented system. The results of this evaluation will help us to implement changes in the system itself. Similarly, the suggestions of users can be used to improve the prototype in the future. To accomplish this evaluation process, we will focus primarily on two main tasks: quantitatively evaluate the accuracy and reliability of the system (during the different phases of the design and implementation and comparing it to similar approaches) and develop an online survey allowing system users to qualitatively evaluate its functionality, usability and reliability.

In the first main task we will rely on traditional evaluation metrics which have been applied to recommender systems (84, 85). It is not easy to state that a recommender systems is better than another. In general, we usually refer to the probability that a system is better than another based on the opinions and previous experiences of several users, calculating significance degrees or p-values (such as sign test (86)). As system developers, we can also focus on the evaluation of the different tasks that are performed by the system to make its recomendations. Thus, we will focus on the evaluation of the system from the following viewpoints:

- **Predicting ratings:** in this task, the goal would be evaluate the ratings predicted by the system and the precision of this predictions. The system will rely on the estimation of several ratings over several objects to generate its recommendations. In this sense, the recommendation accuracy will definetely depend on the accuracy of the predictions, thus evaluating this accuracy can be considered as a crucial step. There exist several evaluation metrics originated to evaluate regression and classification algorithms and which can be found in machine learning and statisctics literature (87, 88). Most notably, the Root Mean Square Error (RMSE) is a popular method for scoring an algorithm. Other variants of this family are the Mean Square Error (MSE) and Mean Average Error (MAE), or the Normalized Mean Average Error (NMAE).

- **Recommending good items:** related with the evaluation of the recommendation of objects (not the estimations on which the system is based to make such recommendations) we will generally be interested only on binary ratings (if the object was choosen or not), trying to avoid the dispersion of the limited available data, thus generating more dense ratings. In this sense, we will focus on the evaluation of the result through the well known Receiver Operating Characteristics (ROC) curves and the existing area under this curves (89).

- **Optimize utility:** trying to estimate the utility of the recommendation list provided by the system to the user and the method used to display it, which is generally based on a model (*half-life utility score*) which suggests that the probability of a user to select a relevant object decreases exponentially when going down in the recommendation list. However, additional metrics would be needed in our system, as the system will also base its recommendations on the distance of the object from the current location of the user and the way to show this recommendation swill be affected by used the virtual visualization techniques. Thus, the definition of metrics are deferred to later stages of the research.

These and other evaluation methodologies will be used during the development of the prototype. They will also assist during the re-implementation of the different versions of the prototype, as well as to evaluate the final version.

For the second part of the system evaluation, we have decided to develop a survey which will be used to get the opinion of the first users of the tool in a controlled experience, assisted by collaborators which will help users with any problems they will have while using the application. The users will receive the questionnaire (which is included in the Appendix I) via e-mail and they will be encouraged with some kind of reward to complete it before a given deadline.

1. **Recruiting the candidates**: we decided to recruit 12 participants for the experimentations, equally representing both sexes and within an age range between 18 and 50 years old. All participants would be tourists looking for accommodation and who have not planned anything before their trip.

2. **Welcoming the participants**: before the beginning of each experimental session, participants would be welcomed and introduced to the research team, who

will provide with detailed information about the scope of the study. They will be alerted that they have been selected to evaluate the proposed application and that they will be assisted, during the experience session, by a collaborator who will help them with any problem. In addition, they will be notified that they will be recorded with the goal of allowing a direct observation of each experience session. Last, they will also be informed about the need of answering a survey related with their experience (once they would have found accomodation).

3. **Searching experience**: as mentioned before, tourists will be invited to look for accomodation after providing them with a mobile device with the developed application installed and with a sufficient internet conexion (to avoid problems with the speed of the conections). The beginning of each user's experience would be recorded by an expert assistant.

4. **Survey completion**: after the searching experience, the users will answer a survey. They will do it inmediately (using an online form and receiving the reward directly) or provide an e-mail and answering in a week.

The design of the survey is based on similar previous experiences. A subsequent quantitative and qualitative analysis of the responses will provide important conclusions about the need to modify or refine the tool in future works.

Additionally, viewing the experiences of the 12 selected users will also be very useful to detect possible improvements and avoid non-scheduled situations during the design stages.

2.4.4 Synthetic/simulated data development

With the goal of achieving an accurate evaluation of the system, we should carefully generate the set of simulated data to work with. There exist several free available databases to evaluate this kind of systems, such as Netflix (90), Movielens (91), Jester (92) or Book-crossing (93). However, accessing real databases related with hotels along with user's ratings is almost impossible. Thus, it will be necessary to develop the design and implementation of adatabase of simulated data which can cover the initial requirements in the design and evaluation steps.

The design of this database will be one of the tasks of the research and will consists on building an entity-relationship (ER) model with the following *a priori* entities:

- **Accommodation:** from which we will need to know their type, name, address, phone number, web page, description, image directory, the offered services (bar, internet, pets, restaurant, room service, suites, swimming pool, handicap access, rooms, etc), the offered quality, its geolocation, etc.
- **Users:** with their related information, like name, login, password, address, e-mail, city, postcode, country, opinions, ratings, date in the system, data of the last review/assesment/rating..
- **Prices:** which will be considered by the system as a range between a minimum and a maximum price per day and person.
- **Opinions and ratings:** from which it should be known the user that provides it, the accomodation for which is provided, the opinion/rating itself and the date of submission.

In the following section we will provide a research plan according to a doctoral program of 3 years, in which the proposed tasks will be completed along with others related with the dissemination of the results among the scientific community.

2.5 Research scheduling

Next, a realistic schedule of the tasks to be developed during 36 months will be shown considering that this is the necessary and sufficient extension for the development of the proposed research process. The beginning of these 36 months was on February, 2014, thus the writing of this research proposal is also included in the considered period.

The table 2.1 shows the tasks to be developed to achieve the declared goals along with their acronyms and estimated extension (in months).

Tarea	Acronym	Extension (months)
Research proposal	RP	4
Literature review	LR	24
Synthetic database generation	SDG	6
Implementation of the client application for mobile devices	ICAMD	4
Design of the augmented reality-based interfaz for the client application	DARBI	6
Experimental design and partial evaluation	EDPE	3
Writting and submission of scientific contributions	WSSC	2.5
Implementation of the recommender system in the server	IRSS	12
Experimental design and partial evaluation	EDPE	3
Writting and submission of scientific contributions	WSSC	2.5
Implementation of the final prototype	IFP	6
Experimental evaluation of the final prototype	EEFP	6
Writting and submission of scientific contributions	WSSC	7
Writting and review of the PhD. Thesis	WRT	10
Lecture of the PhD. Thesis	DT	0

Table 2.1: Acronym and duration (in months) for each of the main tasks of the present research proposal.

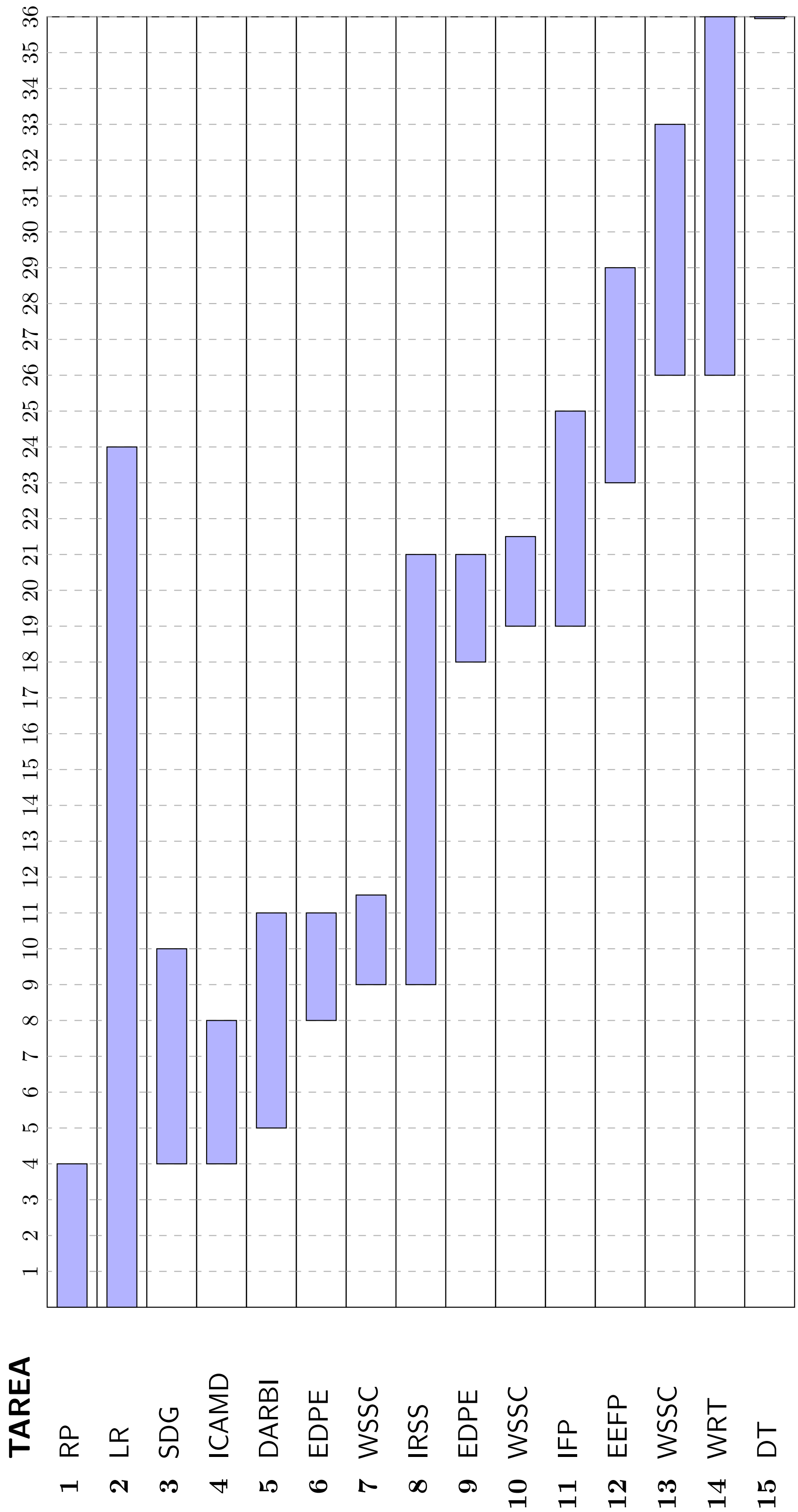

Figure 2.5: Tentative schedulling of the main tasks

Figure 2.5 shows the tentative schedule for the development of the PhD. Thesis. For illustrative purposes we have used the acronyms defined in 2.1 to represent each of the main tasks. As can be seen in figure 2.5, the thesis begin with the writing of the present Master Thesis (research proposal), which has been completed during four months, overlapped with the literature review task, that will last for 24 months.

The development of the synthetic database for the preliminary evaluation of the system will be completed between the months 4 and 10. In parallel, the first tasks of the thesis will (related with the implementation of the prototype of the client application for mobile devices and the design of its augmented reality-based interface) will be completed by the 11th month. The evaluation of the client application and the publication of the main developments achieved at this stage would take place between the months 8 and 11,5.

From month 9 to 21 we will focus on implementing the recommender system to be executed on the server side. Its evaluation and the dissemination of the obtained results are expected to be finished by the month 22. Last, the implementation of the final prototype will begin on month 19 and will take 6 months. The evaluation of this final prototype will also last for 6 months (from 23 to 29) and will partially overlaps with the 2 last tasks of the thesis, the writing and submission of scientific contributions derived from this thesis and the writing and review of the thesis memory that will last until the defense of the thesis, at the end of the third year.

3

Thesis director

3.1 Director proposal

The proposed director for the PhD. thesis is Enric Guaus, researcher in sound and music computing at the Music Technology Group, Universitat Pompeu Fabra (UPF), and professor at the Sonology Department, at the Escola Superior de Música de Catalunya (ESMUC). He obtained a PhD in Computer Science and Digital Communications (UPF), in 2009, with a dissertation on automatic music genre classification. His research interests cover music information retrieval and human interfaces for musical instruments. He is assistant professor in acoustic engineering at the Universitat Pompeu Fabra (UPF) and lecturer in maths, electronics and computer science at the Escola Superior de Música de Catalunya (ESMUC). He is also a consultant professor at Universitat Oberta de Catalunya (UOC) and collaborator at different master programs. He is member of the Observatori de de prevenció auditiva per als músics (OPAM) i de la Barcelona Laptop Orchestra (BLO). He is the author or coauthor of more than 40 publications on sound and music computing, including journal citation report papers, book chapters and international conference proceedings papers.

3.2 Relation to UOC

The relationship of the proposal with the UOC is given by the fact that the candidate will finish his Master studies in this university, under the advisory of Prof. Guaus, who is a consultant professor at the UOC and researcher in sound and music computing and expert in signal processing and classification. Besides, the developments presented in the PhD. proposal can derive in technology and applications that can be very useful for the University environment.

4

Research Work

As mentioned in the previous chapter, the implementation of the client application for the mobile devices (ICAMD) is one of the first tasks considered in the adopted tentative schedulling, along with the design of the augmented reality-based interface (DARBI) and the synthetic database generation (SDG). In this chapter we will focus on the design of the client application and the preliminary design of the augmented reality interface. Instructions regarding the steps that should be taken to execute the proof of concept are descibed in Appendix II.

4.1 Implementation of the client application and preliminary design of the augmented reality interface

In table 2.1 the acronyms and durations of the main tasks for the completion of this proposal are shown. As can be seen, two of the first task are devoted to the implementation of the client application and its augmented reality interface. Considering that the estimated duration for both tasks is 4 and 6 weeks respectively, in this section we will describe only the very first developments related to the mobile application.

As already mentioned at the begining of this proposal, the main objective for this research is to analyze the integration of a recommender system in an augmented reality environment to offer to the user the possibility of improve and facilitate the process of finding accomodation in an, *a priori*, completely unknown city. Therefore, it is necessary the development of an augmented reality-based mobile application prototype that allow the users to interact with the environment providing an enhanced experience by displaying additional information, using additional layers superimposed on the user's view on this mobile device, taking advantage of all kind of available media and trying to personalize the experience through geolocalisation capabilities.

The proposed approach should overcome the main existing drawbacks, like the fact that the interaction surface is usually small or the overload of information. Selecting and manipulating items and recommendations might prove to be a difficult task, specially for the elder or for visitors not acquainted with mobile technologies. In addition, the use maps is to generally tedious for users, so that geolocalisation could be a very helpful feature, specially knowing the direction towards which the visitor is looking. Finally, it should be noticed that creating links between real world and its digital counterparts is challenging. Difficulties in associating objects with the available digital resources could perturb visitors that get easily frustrated when the use of the apps. comes to complex, therefore severall linking approaches should be proposed.

4.1.1 Development Framework

After carefully considering the aforementioned issues, we have decided to develop a multiplatform application, compatible with both Android and IOS, and thus available for tablets and smartphones which, based on web-based technologies, would be able to generate additional information to enhance the users' experience. As mentioned during the planning of this work, the application will be designed using an augmented reality browser. In this work, we decided to use Argon (4), a recently developed AR browser which also provides a very amenable environment to support authoring applications. This environment is based on KARML, an extension of Keyhole Markup Language (KML), which is an XML notation for expressing geographic annotation and visualization within the internet-based 2D maps and 3-D browsers (it is, indeed, the markup language used by Google Earth or Google Maps) in addition with a set of standards like HTML, CSS, JavaScript, this allowing the developers to use tools like HTML5, CSS, PHP, JavaScript, DreamWeaver, Yahoo Pipes, Google Maps, etc, to create theirmobile AR applications. In addition, Argon features extra functionalities like the ability to use panoramic images in the background, instead of live video (in the line of Google StreetView and Bing Maps), thus allowing the creation of panoramic images for online browsing and visual enhacements.

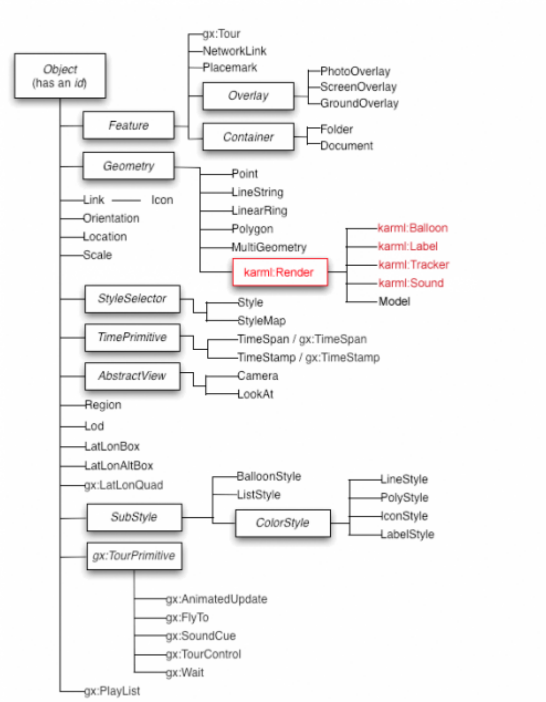

Figure 4.1: *KARML extensions to the KML 2.2 specification.*

The KARML extension to KML seeks to make as few modifications as necessary to author and display AR experiences. The most important limitation of KML is the lack of control the user has over the display and placement of labels, icons and the HTML content in balloons.

In order to allow greater control over each rendering element, the KARML extension adds an abstract class above KMLModel called KMLRender (see figure 4.1 from which a KMLBalloon, KMLLabel, KMLSound and KMLTracker node are derived. These classes inherit the same location, orientation and scaling elements that the current KMLModel element has. This allows the user to optionally specify the exact positioning of the label, icon and balloon content individually. Because these elements are usually billboarded towards the user, the system added an orientationMode to allow the user to accomplish

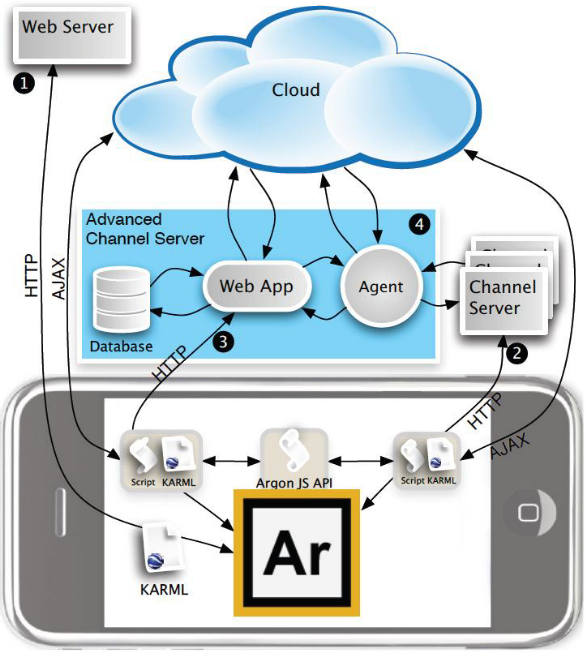

Figure 4.2: *Argon leverages multiple web architecture.*

anything from relative size billboarded content to fixed orientated and scaled content within the world. In addition to orienting content fixed to the world, it is also added a relative option to both the locationElement and the orientationElement so that objects can be located and oriented relative to the user or another element in the scene.

One of the main advantages of Argon is that it takes advantage of web technologies by tightly integrate itself into the web. Figure 4.2 illustrates a spectrum of web programming models that can be adopted in using Argon throught its integration:

1. **Static KARML/XML**: this is the simplest model for serving content to users. The static files are hosted on a web server and requested by an specific URL. All the content elements are contained within the returned document and referenced resources are resolved by the browser without requiring explicit management by the content author, just as with traditional HTML content.

2. **KARML + Ajax + Client Side Processing**: in this approach, the returned document will include a portion of the content or user interface elements used by the channel and a collection of scripts that use AJAX techniques to make requests to 3rd party data sources. Using the Argon JavaScript APO, content elements

are instantiated with the returned JSON or XML data. The client side scripts may also contain custom layout and user interaction code provided by a channel author.

3. **Web application with dinamically generated KARML**: web applications dinamically generate content similar to that discussed in previous options. The web application keeps track of user sessions and sends updates either through the standard KML NetworkLink mechanism or by responding to AJAX requests.

4. **Server side aggregation and processing**: and advanced channel server communicates with 3rd party data sources and/or other channel servers on the client's behalf, in an effort to provide a maximum level of server side processing. This configuration acts as an intelligent agent, where additional processing may take place such as image/content analysis or computation of complex layout/filtering/-clustering algorithms. This extension would result very interesting when developing the recommender system, allowing to divide its computational complexity between the server and external agents.

As shown in figure 4.2 there are several ways in which Argon can interact with the web, thus providing us with sufficient degree of freedom when designing theimplementation of the recommender system. Once decided that Argon would be the main module used as development framework, we will focus on the implementation of the client applications taking advantage of the KML and KARML extension provided by the selected AR browser.

Summarizing, this section has descibed the main modules in which we will base the implementation of the client application along with the main communication links that would be necessary to establish with the server. Next, we will describe the main developments already accoplished in relation with the client application and its interface.

4.1.2 Application implementation

In this section we will focus on the design of the KML files that will be used to generate the user application. As already mentioned, the system has been developed using a series of building blocks that have been properly connected and integrated into a unified framework that allows efficient exploitation of our tool by end-users. The main

Figure 4.3: *The Argon augmented reality browser.*

component of our system is the Argon augmented reality web browser, developed at Georgia Tech2, which provides the basic framework for all other components. The geo-location tasks have been implemented using the keyhole markup language (KML). In our implementation, KML is used to represent geographical data (in three dimensions, using flags and self designed graphics) which would represent the suggestions provided by the recommender system. We will also use this kind of files to overlap the interface with the browser, thus allowing to access the preferences form (which acts as an overlay). The extracted data are displayed in the Argon augmented reality web browser and also in Google Maps, which is also accessible from the Argon browser.

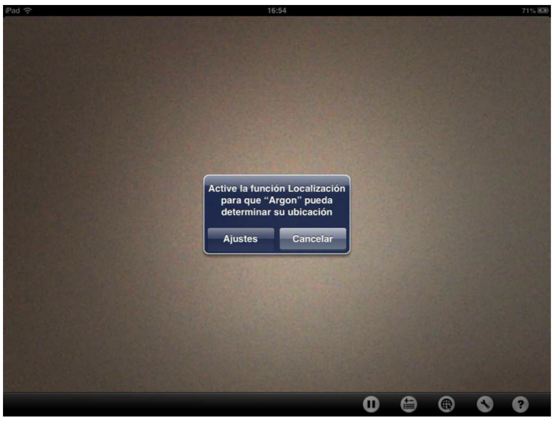

Figure 4.4: *Allowing authomatic location by the Argon AR browser.*

For the shake of simplicity, we will describe this section as a step-by-step proof of concept, which will summarize the necessary steps to allow interaction between system and user. It must be noticed that the described work represent a very preliminary implementation of the client application skeleton, which would be further enhanced in future developments.

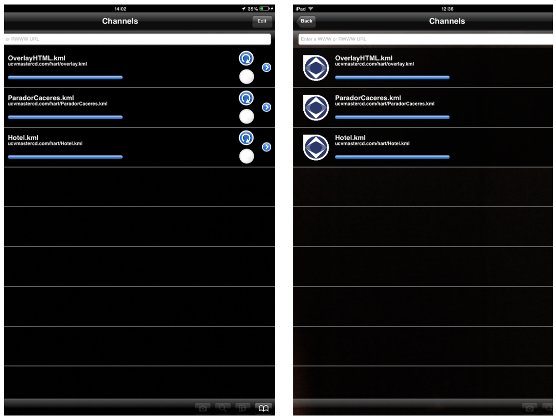

Figure 4.5: *Desactivation/Activation of KML flags and OCR overlay in the developed system.*

The first step in order to interact with the system (which can be run or tablets and mobile systems) is to launch the Argon augmented reality browser. Figure 4.3 shows a screenshot of the Argon browser that we are using in our implementation (version 1.3.6, release 1481).

Once the browser has been launched, the system automatically asks for a confirmation so that the Argon browser can automatically obtain the current geographical location of the user. This step is illustrated in figure 4.4.

When the Argon AR web browser has been updated with the current geo-location coordinates, it displays the information regarding the KML objects which have already been established by the system and allows the activation of such objects, as well as of the user interface overlays that will implement the user application 4.5.

It should be noticed that, every object or interface that we would like to overlay on the user view must be previously coded using KARML extension. In the client application, objects and interface are implemented as overlays (and therefore are implemented using KML extensions while forms to determine user's preferences are implemented using JQuery Mobile (94), an HTML5-based user interface system designed to make responsive web sites and apps that are accessible on all smartphone, tablet and desktop devices.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2"
xmlns:gx="http://www.google.com/kml/ext/2.2"
xmlns:kml="http://www.opengis.net/kml/2.2"
xmlns:atom="http://www.w3.org/2005/Atom">

<Document>
    <name>Hotel.kml</name>
    <Style id="s_ylw-pushpin">
        <IconStyle>
            <scale>1.1</scale>
            <Icon>
                <href>bandera.png</href>
            </Icon>
            <hotSpot x="20" y="2" xunits="pixels" yunits="pixels"/>
        </IconStyle>
    </Style>
    <StyleMap id="m_ylw-pushpin">
        <Pair>
            <key>normal</key>
            <styleUrl>#s_ylw-pushpin</styleUrl>
        </Pair>
        <Pair>
            <key>highlight</key>
            <styleUrl>#s_ylw-pushpin_hl</styleUrl>
        </Pair>
    </StyleMap>
    <Style id="s_ylw-pushpin_hl">
        <IconStyle>
            <scale>1.3</scale>
            <Icon>
                <href>bandera.png</href>
            </Icon>
            <hotSpot x="20" y="2" xunits="pixels" yunits="pixels"/>
        </IconStyle>
    </Style>
    <Placemark>
        <name>Hotel V Centenario</name>
        <description><![CDATA[

<img src="http://www.ucvmastercd.com/hart/hotel.png"/>
        <a href="http://ucvmastercd.com/hart/hotel.html" target="_blank">
<img src="http://www.ucvmastercd.com/hart/hotel.png"/>

</a>]]></description>
        <LookAt>
            <gx:ViewerOptions>
                <gx:option enabled="0" name="historicalimagery"></gx:option>
                <gx:option enabled="0" name="sunlight"></gx:option>
                <gx:option name="streetview"></gx:option>
            </gx:ViewerOptions>
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            <latitude>39.46677170312199</latitude>
            <altitude>0</altitude>
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            <tilt>81.50338236623122</tilt>
            <range>3142.275749200348</range>
            <gx:altitudeMode>relativeToSeaFloor</gx:altitudeMode>
        </LookAt>
        <styleUrl>#m_ylw-pushpin</styleUrl>
        <Point>
            <coordinates>-6.378795182921486,39.4663245357137,461.3989220975922</coordinates>
        </Point>
    </Placemark>
</Document>
</kml>
```

Figure 4.6: *KML code of an object of the system (the code implements a hotel).*

The core element for building AR experiences with KARML is the *placemark*, which can attach several objetcs like sounds, ballons, labels and geostpots. This is the way of generating virtual objects in KARML.

In figure 4.6 shows the implementation using KML extension of a hotel example, used by the system to provide recommendations. In addition, figure 4.7 shows the codification of the form implemented using JQuery Mobile to allow user to introduce his preferences.

Next, once the visualization of KML objects and UI overlays is activated, the first step would be to complete the form with our searching preferences, which would be used to complete a user profile. This profile will be a key issue when developing the hybrid recommender system. Both, the sent of the completed form and the reception of suggestions made by the recommender system will be implemented using AJAX (Asynchronous JavaScript and XML), which allow us to execute a background reception without affecting the visualization or the general behaviour of the web application.

Figure 4.7: *Codification of the form corresponding to the user's preferences implemented using JQuery Mobile.*

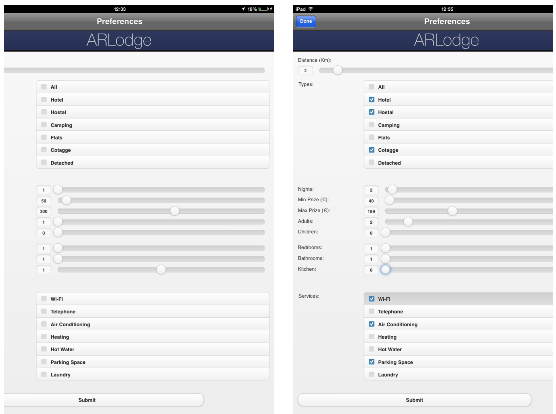

Figure 4.8: *Default and selected preferences of the searching process.*

Figure 4.9 shows two examples of visualization of activated objects through the application. The two KML objects correspond to a Hotel and a Parador, both already stored in the database of the developed system. The system shows an overlay with the name of the accomodation along with the recommendation score. This score is generated by the recommender system and represent the degree of confidence that the system has in this accomodation regarding the user profile and the available ratings (completed by other users) about this place in the system. In addition, a simple click allows the user to access extra information (stored in the system) regarding this accomodation, like previous reviews, offered services, etc. This information is shown using several forms also implemented using JQuery Mobile (see figure 4.10). This interface

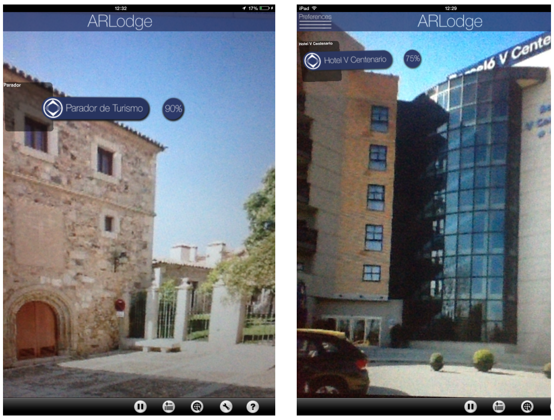

Figure 4.9: *Interface for the recommender system suggestions (two of the stored items).*

represents a first attempt to provide quicklook info. regarding the recommendations of the systems. Further studies related with alternative interfaces needs to be performed before considering a definitive prototype.

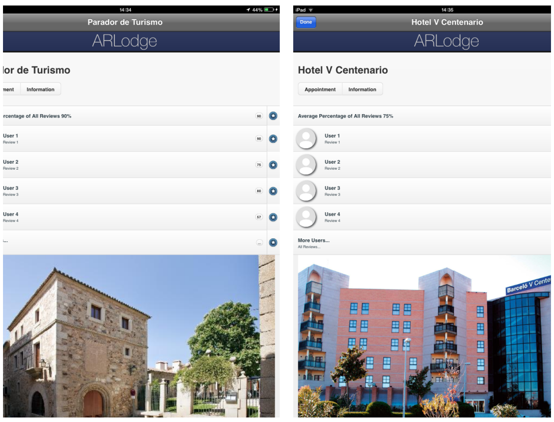

Figure 4.10: *Additional information regarding different accommodation (previous ratings, offered services, etc).*

The application offers the possibility to display our current position and the geo-localized objects (see figure 4.11, displaying also information about the geo-localized objects (such as "Parador". In addition, satellite view of the objects can be used. Visualization is performed using Google Maps (through the Argon browser), thus allowing a straightforward representation of the location of the user with regards to the points of interest.

This chapter has described a simple proof of concept for the ARLodge system,

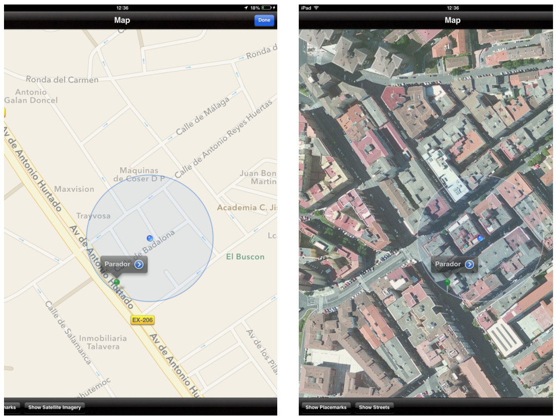

Figure 4.11: *Visualization of the object "Parador" in both street and satellite view modes.*

demonstrating how the system works (as a whole) and the integration of a set of different tools used for each stage of this preliminary development. The proof of concept indicates that the system allows, in a very straightforward way for the end-user, to collect relevant information about the environment and to use it for improving its interpretation (in terms of both geo-location and information content by the user. This is done at the bowser level by recognizing context-aware information providing an output which is automatically integrated with the AR browser. This proof of concept has also summarized the steps involved in a typical interaction with the user.

Although this is only a preliminary design and implementation effort and additional improvements are still posible, the proof of concept indicates that the different modules considered have been properly integrated and harmonized in order to develop an easy to use tool that can be executed using widely available devices such as tablets and mobile systems.

5

Appendix I

5.1 Survey

5.1.1 Welcome and introductory note

Hello everybody,

you are invited to answer this online survey concerning your experience using the augmented reality-based hotel booking recommender application. This questionnaire contains questions regarding several aspects of your visit.

The estimated duration for the completion of the questionnaire is about 15 minutes.

Your answers will be treated anonymously. The publication of the results will not reveal in any case personal data. It will also be impossible for any other person not related with the experimentations to have access to your personal data.

For any question regarding the survey and the questions, you can always contact me at my email address (detailed below).

Thank you once again for your participation, your remarks, your enthusiam and your help. Please kindly proceed now with the answering of the questions by clicking on the "next" button below.

Best regards,

Carlos Plaza Miguel E-mail: carlosplazamiguel@gmail.com

5.1.2 General questions

1. How old are you? ....

2. Please, write down your name and surname: ....

3. Your email address is ....

4. In general, you visit a new city:
   ☐ Very often (¿ 4 times per year) ☐ Regularly (2 to 4 times) ☐ Rarely ☐ Never

5. If you have already visited a city, do you prefer visit:
   ☐ Alone ☐ With friends or family ☐ In group

6. Do you usually arrange the booking of your accommodation prior to the travel?
   ☐ Yes ☐ No

7. If yes, do you usually use (one or more answers are allowed)
   ☐ Online recommender systems ☐ Web site of the hotel/appartment? ☐ Travel agency ☐ other: ....

8. Have you already visited this city?
   ☐ Yes ☐ No

9. If yes, your last visit was .... ago

10. You own a mobile phone from the age of ....

11. Generally speaking, you use your mobile phone to:
    ☐ Only speak ☐ Speak and send text messages ☐ Access internet services ☐ Almost everything

5.1.3 Questions regarding the use of the application

1. Identifying the augmented information information was easy
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

2. Navigating in the content was easy
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

3. Using the application was easy
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

4. The display of the virtual objetcs alongside with the real ones facilitated my access in the content
☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

5. Is there anything that you would like the application to do ....
....
....

6. Is there anything that you would like the application to NOT do ....
....
....

7. What did you most appreciate ....
....
....

8. What did you find most difficult...
....
....

9. Before today had you already heard the term "Virtual Reality"?
☐ Yes ☐ No ☐ Maybe

10. Before today had you already heard the term "Augmented Reality"?
☐ Yes ☐ No ☐ Maybe

11. If yes, do you think you could give a definition for the term Augmented Reality?
....
....

5.1.4 Questions related with the content of the application

Interface adequacy

1. The information available for each item were comprehensible:
☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

2. The information available for each item were sufficient:
☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

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Quality of recommendations:

1. The items recommended to you matched your interests:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

2. The recommender gave you good suggestions:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

3. You are not interested in the items recommended to you:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

4. The recommendation that you receive better fits your interest than what you may receive from a friend:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

5. A recommendation from you friends better suits your interests than the recommendations from the system:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

6. Some of the recommended items are familiar to you:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

7. You are not familiar with the items that were recommended to you:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

8. The items recommeded to you are attractive:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

9. The items recommended to you are novel and interesting:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

10. The recommeder system helps you to discover new possibilities:
    ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

11. The items recommended to you are diverse:
    ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

12. The items recommeded to you are similar to each other:
    ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

13. You were only provided with general recommendations:
    ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

14. The items recommeded to you took your personal context requirements into consideration:
    ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

15. The recommendations are timely:
    ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

Interaction adequacy:

1. The recommender provides an adequate way for you to express your preferences:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

2. The recommender provides an adequate way for you to revise your preferences:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

3. The recommender explains why the items are recommeded to you:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

Ease of use

1. You became familiar with the recommeder system very quickly:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

2. You easily found the recommeded items:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

3. You found easy to tell the system about your preferences:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

4. You found easy to make the system recommend different items to you:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

5. You were able to take advantage of the recommender system very quickly:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

Preceived usefulness

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1. The recommeded items effectively helped you to find the ideal option:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

2. The recommeded items influence your selection of products:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

Control/Transparency

1. You feel in control of telling the recommender what you want:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

2. You understand why the items were recommeded to you:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

3. The system helps you to understand why the items were recommeded to you:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

Attitudes

1. Overall, you are satisfied with the recommeder system:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

2. You are convinced of the products recommeded to you:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

3. You definetely enjoyed the item recommended to you:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

4. The recommeder can be trusted:
   ☐ Mostly Agree ☐ Somewhat Agree ☐ Somewhat Disagree ☐ Mostly Disagree

Thank you again for your participation!

6

Appendix II

6.1 Steps to execute the proof of concept

Although the steps are included in the proof of concept shown in chapter 4, the following section summarizes the steps to execute the proof of concept.

1. **Download the Argon AR browser**: it can be easily downloadad from Apple Store. It should be noticed that a new version called Argon2 Isotope will be soon available, which will be fully compatible with Android and laptop devices.

2. **Authorize Argon to geo-localize your device**: it is simply done by clicking "yes" when the system ask you or going to your settings menu.

3. **Activate the KML objects and the user interface**: to allow the system to use the implemented KML objects and the interface forms which are hosted in a private web-server) the paths of this objects must be provided to the AR browser. The neccesary paths are:.

   (a) http://www.uvcmastercd.com/hart/overlay.kml.

   (b) http://www.uvcmastercd.com/hart/ParadorCaceres.kml.

   (c) http://www.uvcmastercd.com/hart/Hotel.kml.

   (d) After including them it would also be necessary activate them to allow system to access these objects.

After these three simple steps, the proof of concept can be executed to see the performance of the system.

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