LOCATION BASED GUIDANCE SERVICES IN A MUSEUM ENVIRONMENT: DEPLOYMENT ISSUES AND A PROPOSED ARCHITECTURAL APPROACH

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Abstract: In this paper we examine the requirements for deploying advanced Location Based Guidance Services in museum and/or exhibition environments, and we propose an architectural approach that copes with these requirements. The proposed architecture provides automatic and on demand audiovisual content retrieval, both on-site and through the Web, to different classes of users. On-site services are provided through Java-enabled devices, which exploit the user's contextual state, mainly defined as visitor location and organization of exhibits. The main distinguishing characteristic of the proposed architecture is that it separates the positioning system from the content access mechanisms, while being generic to the selection of the localization technology and the terminal device characteristics. Furthermore, it is built as an open, modular platform comprising a core of reusable components and interfaces for supporting different types of services and devices, including widespread Java and Bluetooth enabled smart phones, while being able to reuse already existing content structures. A test case of a museum e-guidance application for Bluetooth enabled smart phones is presented.

1 INTRODUCTION

One of the key technologies underpinning ubiquitous computing is that of location based services (LBS). Location-aware systems react not only to the users' input but also to contextual events from the users' environment. The designers have to carefully balance the way in which such systems react to environmental triggers (Yo-Ping Huang & Wei-Po Chuang, 2004). The museum domain has been one of the most considerable target domains where LBS are applicable for on-site guidance. In this case, mobile users who need context-dependent information should not be disoriented from the museum information (Carmine Ciavarella & Fabio Paterno, 2003).

According to (Stefan Steiniger, Moritz Neun & Alistair Edwardes, 2006), LBSs are information services accessible with mobile devices through a mobile network and utilizing the ability to make use of the location of the mobile device. If the user wants to use a location based service, different infrastructure elements are necessary.

In Figure 1 the basic components and their connections are shown:

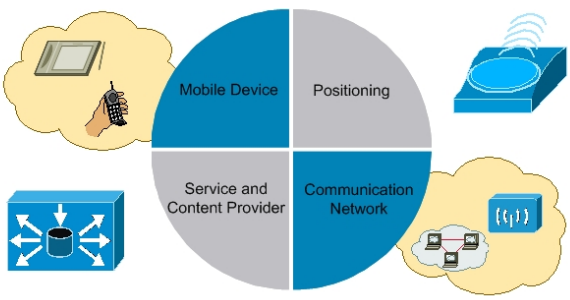

Figure 1: Basic LBS Components.

- **Mobile Devices:** The terminal device that presents the content to the end-user. Possible devices are PDA's, Mobile Phones, Laptops.
- **Communication Network:** The IP Network, used for exchange of data between the mobile terminal and the service provider.

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- **Positioning Component:** The Component used for the selection of the suitable localization technique.
- **Service and Application Provider:** The service provider which offers a number of different services to the user and is responsible for the service request processing.
- **Data and Content Provider:** The Content Management System that maintains all the museum information which can be requested by users.

In order to develop a platform to provide LBS, the following requirements need to be fulfilled, as described in (Sebastian Herden, Arman Mkrtchyan, Claus Rautenstrauch, Andrı Zwanziger & Michael Schenk, 2003): terminal independence, simple user interface, minimal communication over mobile telephone networks, integration of mobile devices, simple integration of existing Internet services, high availability of the services even at high loads, scalability, openness (support common standards and protocols), and low costs. Furthermore, in (Carmine Ciavarella & Fabio Paterno, 2003) there are analyzed the design criteria to use when developing location-aware indoor mobile applications. The most important of them are the following: easy navigation through web browsers, navigation feedback and minimal graphical interaction, orientation support in the surrounding environment and minimum redundancy in input commands.

As far as the museum domain is concerned, the term electronic-museum may include different concepts, and corresponding technologies, which till recently ranged mainly from “in museum” content presentation (e.g. by exploiting virtual reality and immersion technologies), to content publishing through the museum’s web site. The evolution of position tracking technologies and LBS has given new possibilities of both indoor and outdoor context aware guidance systems. Through such a context-aware guidance system, the visitors in a museum can receive location-based content immediately, even through their own handheld devices (e.g. mobile phones) in order to enhance visiting experience. In this case, simple interfaces for content searching and retrieval should be provided in order to appeal also to users not familiar with technology (e.g. children) and in order not to disrupt the user from focusing on the exhibits themselves. Furthermore, any platform arrangements (e.g. cables, servers, receivers) should not distort the physiognomy of the museum. The guidance system infrastructure should be easily deployable to different exhibit topologies and already existing content structures (e.g. Content Management Systems).

Museum visitors can be classified to different levels, first of all, according to their interests and background, ranging from children and regular visitors, to professionals and researchers. Each of them demands a different level of knowledge and detail. Furthermore, museum users can be classified according to the terminal device they possess. For example, laptop users may be able to get full versions of the content (e.g. 3D models, detailed maps), while small devices (e.g. smart phones or Personal Digital Assistants) users may be able to acquire a limited version of the content on-site, but they may ask for an enhanced version for off line usage (e.g. stored in a CD). In general, any guidance system should be flexible as far it concerns serving different classes of users.

Based on the above observations, we present a lightweight approach for providing location aware multimedia content retrieval, through Java enabled handheld devices. The main distinguishing characteristic of the proposed approach is that it separates the positioning system from the content access mechanisms, while being generic to the selection of the radio localization technology. So far, interfaces are provided for Bluetooth and Infrared for indoor environments, as well as for GPS for outdoor environments, while others can be developed, e.g. RFID. Furthermore, it is built as an open, standards-based, modular architecture comprising a core of reusable components and interfaces for supporting different types of services, through web technologies.

A main characteristic of the proposed approach is that it has minimum mobile device requirements, since it operates in all java enabled mobile devices. Therefore, only a Java middlet and a web browser need to be installed in the mobile device, while, in the backend what is required is an HTTP server and Content Management System (CMS) which can be determined independently. The components of the proposed approach ensure modularity, in that different types of services can be easily supported for different groups of users. Finally, flexible mechanisms, for adapting to most museums needs are present, in regard to the physical platform, computing and communication resources, to the site configuration and set up and to the user equipment.

2 LBS MECHANISMS AND THEIR MUSEUM APPLICATIONS

2.1 Position Tracking Technologies

The identification of a user's position can be performed at various levels of granularity: for example, one is the identification of the exact user position, thus, in a museum application, the system can identify the closest work of art; another level is when the system is only able to identify the room where the user is located.

Position tracking technologies aim to measure the movement of the mobile terminal. These technologies provide great accuracy, but are limited in terms of geographic coverage. To explicitly localize the users in indoor applications, three recent technologies are mainly exploited: WLAN, Bluetooth and Infrared. In (Carmine Ciavarella & Fabio Paterno, 2003) advantages and disadvantages of each of them are highlighted. In the next paragraph we provide an overview of these technologies.

WLAN technology allows devices to immediately connect to a LAN. As stated in (Carmine Ciavarella & Fabio Paterno, 2003), to locate the position of the users in a building, WLAN is not a so simple solution, because the system has to apply triangulation methods to the data coming from at least three access points near the user. Installation of many wireless access points will cause a negative effect in a museum environment. In addition, the developers have to devote a great deal of attention to prevent ambiguous situations on the borders of the intersections of the covered areas.

Bluetooth technology is an ad hoc technology that requires no fixed infrastructure and is simple to install and set up. A fundamental Bluetooth wireless technology strength is the ability to simultaneously handle both data and voice transmissions with low power. It is designed to be small and to keep costs low to be included in practically any device. Above all, it has great ability to locate neighbour devices and discover the type of services they could offer. These properties make applications easier to use for the end user, and also reduce maintenance costs, characteristics which render Bluetooth suitable for indoor environments.

IrDA protocol of communication supports high data rates and requires line-of-sight contact. But infrared has some drawbacks. Firstly, it rebounds over the surfaces and secondly requires that sender and receiver are aligned. IrDA is a point-to-point, narrow angle (30° cone), ad-hoc data transmission standard designed to operate over a distance of 0 to 1 meter. These limitations make IrDA not user-friendly for e-guidance applications.

GSM LBS provide personalized services to the subscriber based on their current position. But, cellular positioning technologies are an opportunistic development rather the original purpose of cellular networks and consequently cellular technologies are less accurate (J. Ranchordas & A. Lenanghan, 2003). Furthermore, GSM technologies add extra cost to the end-user and discourage him from using the application.

Finally, GPS is used from the majority of LBS systems for outdoor tracking environments. The position calculated by a GPS receiver requires the current time, the position of the satellite and the measured delay of the received signal. The position accuracy is primarily dependent on the satellite position and signal delay.

2.2 Localization Systems for Museum Environments

Many localization and navigational based mechanisms and frameworks are available in museums nowadays, aiming to provide indoor and outdoor LBS to end users. Their main disadvantages are that they are tightly coupled to the localization technology, user device, and content access mechanisms and technologies. Thus, specialized hardware and software capabilities are needed to exploit them. Finally, human interaction is needed most times not only to install them but also to support them during their operation.

CMUseum provides location-aware video streaming services with other add-on features which enable automatic tour guidance without user intervention. This design requires specialized hardware, as it incorporates an 802.15.4 Zigbee sensor network for collecting information as well as an 802.11 Wi-Fi network for streaming video contents. Yo-Ping Huang and Wei-Po Chuang propose a pull-based approach guide system that combines the positioning technique and location-awareness service to provide the surrounding information for users. The guide system not only accepts the user's search query to find the target but also receives the information from other users who took notes during the tour guide (Yo-Ping Huang and Wei-Po, 2004).

Musex (Koji Yatani, Masanori Sugimoto & Fusako Kusunoki, 2004) is also implemented to support children's learning in a museum with use of RFID for localization and a tour guide system which is built for understanding how pervasive computing can support a museum-like experience. The Hippie/HIPS project (R. Oppermann & M. Specht, 2000) concerns the development of an exhibition guide, which provides guidance and information services. The guide senses infrared beacons installed near all exhibits. From these observations about the visitor's journey through the exhibition the system creates a user profile and suggests interesting exhibits augmenting them with background information. The limitation of this approach is that often the user's position alone is not enough to indicate interest in the closest work of art. Thus, the risk is that the system erroneously identifies the user interests and determines the corresponding user model.

According to (Christian Kray & Jorg Baus, 2005), in terms of positioning, roughly half of the systems rely on GPS while a large group of them use infrared beacons. Furthermore, about half of the systems include some means of interacting with the user to determine his position. As far as the architecture is concerned, some systems are based on the client-server paradigm while others are built using interactive applications. The first have the advantage that, given a reliable connection between client and server, they allow easy adoption of multiple clients. The later offer a more decentralized approach, but they may depend on a certain device/platform.

In (Y. Wang & all, 2004), among others, advanced wireless services are provided in the International Airport based on GPS and WLAN technologies, on a distributed, agent-based architecture. Also, in (P. Kalliaras & all, 2004), an ambient information system allowing GPS based, location-aware, interactive guidance is presented. In this system, a guidance session includes complex content retrieval composed of geographical, historical and geological information and can be realized both on-site through handheld devices, and through the Internet and TV channels. System architecture is built based on the client-server paradigm and Web technologies, with the focus being on serving multiple communication channels through a common content server. Based on the experience acquired from the above frameworks, we present a lightweight approach for providing Location Based Content Retrieval in order to support different e-Museum guidance services.

3 THE PROPOSED ARCHITECTURAL APPROACH FOR LOCATION-BASED MUSEUM GUIDANCE

In this section a proposed architectural approach for providing web-based location based multimedia content retrieval through Java enabled devices is presented. In order to avoid system lock-in and to reduce development costs our approach is based on open standards and open source components, where possible. Furthermore, independence from the underlying hardware and software, by selecting generic widespread approaches, is provided.

The main advantage of the proposed approach, in comparison with the implementations reported in previous sections, is first of all, that the various system components are designed and implemented in a modular manner in order to select the most appropriate in each specific installation. This modularity regards:

- The separation of the positioning system from the content access mechanisms.
- The selection of the localization radio mechanism, accordingly with the implementation site.
- The selection of the terminal mobile device. The only requirement for the mobile device is to be Java enabled, something very common in the majority of the new generation mobile phones, PDAs e.t.c. The content is being presented to the device through any available web browser.
- Independence from the underlying hardware infrastructure. The entire system is based on Web technologies, which can be deployed easily in any server.
- Independence from the content being available to the end-user. All the content is available through the content management server, and can be renewed dynamically without any change and any intervention to our system.

In addition, the entire process is transparent to the user. In opposition with other LBS frameworks, no input is requested from the end-user. He just receives the appropriate content in his display, in correspondence with his position. The system is designed so that all the amount of data is transferred through the local communication infrastructure.

3.1 Overall Architecture

In this section, we describe the core elements of the proposed system architecture. The different components of our approach are the end-user terminals, the backend platform components and the communication infrastructure. The core elements of the proposed system architecture and the way they are connected are shown in Figure 2.

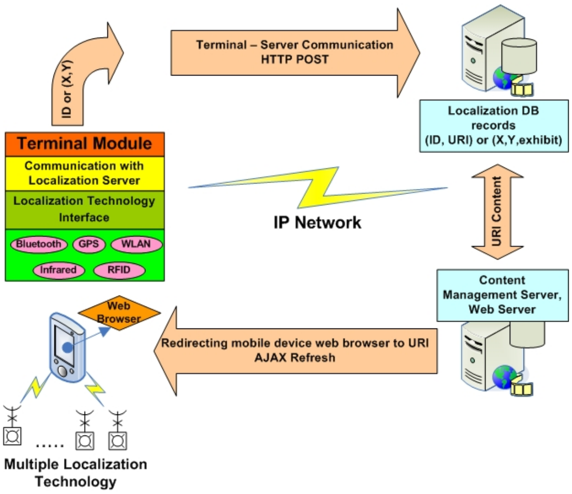

Figure 2: Core System Elements.

The main characteristics of these components are the following:

- *Localization technologies* such as Bluetooth, Infrared or GPS. These can be integrated to the user device or provided as a separate hardware module.
- *The communication network,* which can be any IP enabled access network, e.g. a WLAN network, GPRS or 3G network.
- *The Terminal Module,* that runs on the mobile device. This is essentially a J2ME middlet which implements the generic localization approach, enables location tracking by using the terminal localization device interfaces, and communicates with the server-side component, which translates physical location to content URI. It also provides the appropriate Graphical User Interfaces.
- *The localization server* for providing association between location information given by the user terminal and a specific point of interest. The association can be performed independently of the localization mechanism selected - the content is completely orthogonal to the localization mechanism and can be renewed easily. This kind of association is URI-based, because each point of interest corresponds to a specific content URI in the server.
- *The content related to each point of interest* which becomes automatically available to the user terminal by the content management system (CMS), through the IP access network.

The redirection mechanism, which is based on AJAX technologies (Jesse Garrett, 2005). As far as the terminal-side is concerned it has to support JavaScript. Otherwise, the redirection is implemented through periodic HTTP refreshes to the server-side.

3.2 System Components

3.2.1 Mobile Device Software – Terminal Module

In order to search and select the desired point of interest, we have developed a Java middlet that can be installed easily in any mobile device that supports Connected Limited Device Configuration - CLDC and Mobile Information Device Profile - MIDP of Java Platform Micro Edition - J2ME.

There is a configuration menu in the start form of the middlet, where each user can select language, audio and video options and complexity level for the application. In case of indoor environments, the end-user performs initially a search for localization interest points -that exist within the scope of the terminal- and the ID's of all the detected interest points are returned. Otherwise, in case of tracking technologies that are based on user coordinates (e.g. GPS), the localization mechanism sends an exact geographic coordinate instead of the ID. An extra module is implemented in the server which converts specific coordinates to unique IDs of points of interest. All this information is transmitted through the IP access network and is stored in the localization database.

3.2.2 The Location to URI Database – Localization Server

The database of the entire system is set-up on the server. The database holds information about the points of interest, the devices that executed the application and information regarding the association between them. Extra data are also saved, correlating each point of interest with a URI, which leads to the specific content for this point of interest. Each time the Java middlet is started, the database is updated with the new information sent from the mobile device.

Every location corresponds to a URI at the CMS server, as described earlier, – featuring some content – static or dynamically generated. Almost everything is controlled from the server, increasing a lot the easiness of use for the end-user. Changes in

the content don't affect our application, rendering it content independent.
We have defined various actors for different users in our database scheme. The knowledge level and the level of specialisation of every user are stored. Different URIs are saved according to the native language, the skills and the experience of the end-users.

3.2.3 The Redirection Mechanism

After the initial installation of the middlet on the end-users terminals, their browsers point to the web-pages describing the corresponding nearest point of interest. Ajax technology is used in order for the terminals to remain active, waiting for the middlet to update the database with the next point of interest. As soon as the middlet inserts a new entry in the database, new content is pushed to the browser by the use of Ajax. The web-page is refreshed asynchronously pointing to URI of the new point of interest. In this way the web pages do not have to be reloaded periodically. This is done only in case where the terminal device does not support JavaScript. The intent is to make web pages more responsive by exchanging small amounts of data with the server behind the scenes, so that the entire web page does not have to be reloaded each time the user requests a change. This is meant to increase the web page's interactivity, speed, and usability.

3.3 Demonstration - Museum Implementation

A museum e-guidance system application has been developed in the scope of the E-Museum project (*) that utilizes Bluetooth localization technology for the positioning of the museum exhibits and WLAN technology for the IP network communication. Content management functions are built based on an existing CMS, as well as on e-museum specific extensions. The open source Joomla CMS has been selected. In addition, we have developed special templates for mobile devices with the use of the Xe-Media Mobile Template for Joomla. In each request, the server checks the browser that makes the request and accordingly returns the page in the appropriate template.

As far as the implementation is concerned, we chose to use a Nokia E61 smart phone with Symbian OS, a 3COM 802.11g WLAN access point, 3 Bluetooth access points with power management (class 1, 2 and 3) and a Linux HTTP and MySQL Database Server. The development of this middlet has been accomplished with Netbeans IDE 5.5 extended with the Mobility Pack for CLDC/MIDP, while the simulations were implemented with Sun Java Wireless Toolkit for CLDC 2.5.
The E-museum system overview is shown in Figure 3.

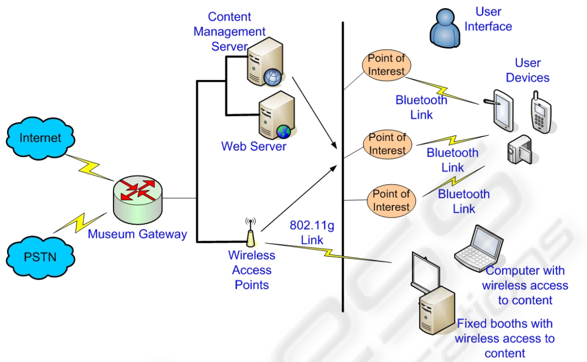

Figure 3: E-museum System Overview.

Screenshots from the mobile device used are shown in Figures 4 and 5.

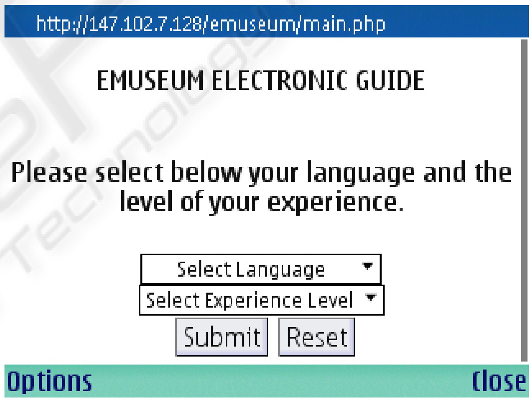

Figure 4: E-museum Screenshot.

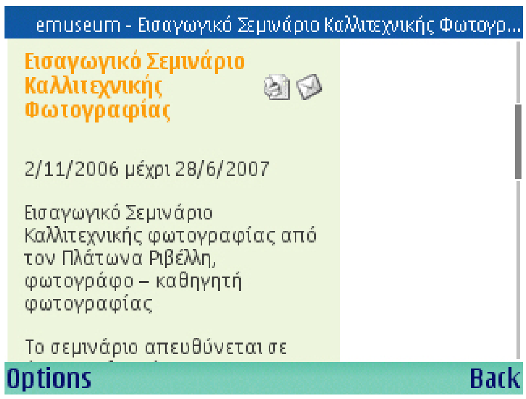

Figure 5: E-museum Screenshot.

4 SERVICES OFFERED AND OPERATION SCENARIO

In this section we describe the services that our system offers to museum visitors. We support a wide range of services targeted to the needs of different user requirements. The most important of them are the following:

1. Automatic (push) content retrieval based on visitor proximity to an exhibit or group of exhibits: The handheld device that the user carries identifies his location in relation with a certain exhibit or group of exhibits, through a suitable positioning technology. After location identification, a request for audiovisual content related with a certain exhibit (or group of exhibits) is created automatically.
2. On demand (pull) content retrieval: This service is enabled via the E-Museum wireless communication infrastructure and it addresses more experienced users. Context aware information, related with the user's position, is used to help him to browse the E-Museum's collections and/or to create more targeted search queries.
3. Directional information (e.g. vector maps), indicating the user's current location in the museum and how he can move throughout the museum, can be offered to the user terminal after request. The next desirable point of interest can also be specified. In this occasion, a graphic interface showing the most efficient route to that spot is displayed instantaneously. In addition, a traffic assistant can show the snapshot of the current traffic flow in the museum. This feature enables the visitor to avoid big crowd in his tour.
4. Creation of live linear guidance: User provides his profile and preferences (e.g. concerning a certain historical period that wants to examine) and the system automatically creates linear guidance including only the exhibits of interest and excluding exhibits that are not of interest to the user. Guidance and location information is also provided in this service.
5. Registration of path and content of interest for offline usage: Users with handheld devices may be able to get only a small subset of the content while on-site, due to limitations in the processing power of their devices. However, the path with exhibits of interest is registered and presentations with full versions of content are created for offline usage (e.g. stored in CDs that the user buys after the visit to the museum).

In the following section we describe the simple steps that a user has to follow in order to access the application.

1. The user downloads the middlet from the IP network and installs it in his mobile device.
2. Then, his mobile device scans repeatedly, in a defined time space, for points of interest through the Bluetooth SDP.
3. Every time the middlet scans a new point of interest, it communicates with the server and informs it about the new data. The communication is done via HTTP POST messages.
4. The server holds information about the nearest point of interest at which each user is every moment and consequently sends to the terminal device all the related content.
5. The user needs only to open a web browser to his terminal device in a default page and, through the redirection mechanism he will be redirected to the page with the content of the selected point of interest.
6. Each time a new localization trigger is received, the user will be redirected to the content of the new point of interest.

Special attention has to be given on the right placement of the points of interest. In case of redundant points that need to be identified within a limited space, only one localization interface is installed. The corresponding web page with this interface is displayed on the user terminal display, with multiple thumbnail images for the points of interest, to allow the user to select the desired web page. By this procedure, the offered application is reliable in all cases.

All the above user steps are shown in Figure 6.

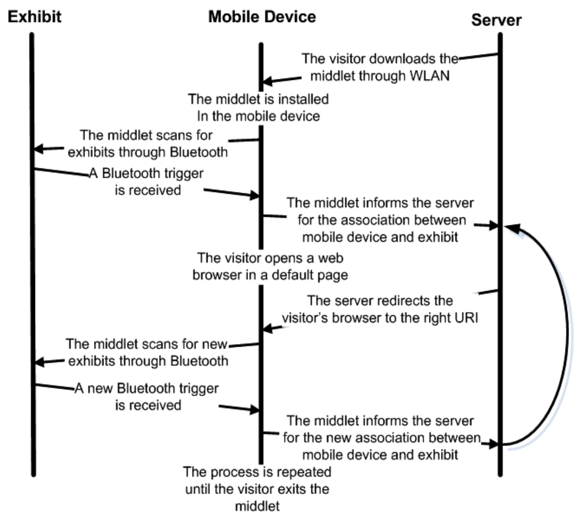

Figure 6: Operation Scenario.

5 CONCLUSIONS & FURTHER WORK

Based on the assumptions that it is desired to allow a museum guidance system to dynamically select localization technology, the appropriate software and hardware for the backend platform, as well as the terminal mobile device, we have argued that a comprehensive solution for museum location-based guidance services should address the challenges of modularity and openness. We therefore proposed an approach for providing Location Based Guidance Services that attempts to address these issues, while we described an architectural framework for enabling such a system. The application of the framework has been evaluated in a prototype e-museum guidance system, highlighting some of the issues involved in the use of location-based services.

Future work will include the support of user-transparent handover process aiming at the selection of the most suitable localization technique, in heterogeneous environments (e.g. indoor-outdoor). Experimental work is currently underway towards evaluating the behaviour of the different localization techniques in several, environments.

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