Introducing location related aspects to mobile multimedia environments

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**Abstract:** This work describes a design of a multimedia content delivery system based on context, to provide multimedia information and other services according to the user location and his preferences. It focuses on mobility and the problem of different coherent and cohesive presentations depending on the available resources of the presentation environment.

**Keywords:** inference engine, context aware, navigation systems, mobile devices, presentation on mobile devices, intelligent multimedia systems, ubiquitous computing, pervasive computing
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1. Introduction

In this chapter is introduced the topic to be studied within the thesis and the reasons why it has been chosen. There is also explained the disposition of the report, its limitations and the acknowledgements to the people that made it possible.

1.1. Background

The use of mobile devices such as “pocket pc”, portable digital assistants (PDA), and mobile phones have become very useful tools that we use on the daily basis. Additionally, these devices have gained capabilities to manage sophisticated multimedia contents and a number of sensors, such as cameras and global positional systems (GPS), allow developing applications to solve problems in the areas of rich positional multimedia management, context-aware and navigation systems. While mobile devices capability for the management of multimedia content has increased, technical limitations of the device and limited resources such as memory, screen resolution or bandwidth, influence the presentation of this information. In order to achieve a broad band of devices, the systems must deal with the differences and transform the presentation of the information according to that. In the case of a person with a mobile device that is doing an activity within a context, all the information about the activity and the context could be used to infer possible actions to be taken in order to help the user in his task. Usually, these actions would be to deliver information (most of the times multimedia contents).

1.2. Motivation

This report has been written by David Martínez Benito, a student at the last year of Computer Engineering at the “Universitat Politècnica de Catalunya” in Barcelona, Spain. I have been an exchange student within the Erasmus Program in Växjö University during the last academic year 2005/2006. I chose this topic for my master thesis because the fast evolution of networked mobile devices offers a wide environment where can be created many new systems based on the high availability of the user and context information.
The goal of my work is to explore the possibilities of mobile devices with internet connection and integrated GPS for the development of a context aware system that periodically receives information about the user’s location and infers actions to be taken according to this information.

1.3. Disposition

In the next chapter will be formulated the problem that I will deal with in this thesis and after that will be presented the methodology that is going to be used to study this problem. In chapter 4 will be raised some scenarios in order to show how could be used the designed system and its requirements.

1.4. Limitations

The aim of this thesis is to explore the purposed topic by the study of several works related to this field and the design of a new system that offers some features not provided by any of them. Although some prototypes will be implemented in order to illustrate the design, the whole system will not be implemented due to the high complexity and the long period of time needed to do it. However, it will be studied and purposed the most suitable technology for the implementation of each part of the system.

1.5. Acknowledgements

I would like to thank the people that helped me make this thesis better with their valuable support and comments. I would like to thank my supervisor Marcelo Milrad, Senior researcher at Växjö University, for his continual support and comments to my work. Also I would like to thank professor Per Flensburg that led me during this thesis and especially in the method part. This thesis would not be as it is without the cooperation with the people from the Celekt team: Fredrik Alserin and Jonas Gustafsson during the development and test of the client application and Arianit Kurti with several comments about location-based services and context awareness. Finally, I want to express my thanks to my family for their support and interest during all this time.

Once the topic has been introduced, it will be presented the problem formulation and the questions that will be tried to answer within this thesis.
2. Problem formulation

In the last years, mobile devices have become a very powerful tool to deal with multimedia contents. Its network connectivity and computational capacity have opened the doors to the development of many new systems based on the high availability of the user (anytime anywhere) and context aspects such as geographical location, among others. Furthermore, the new devices interfaces with high quality screens, embedded cameras and sound recorders gives the possibility to visualize and create video and sound multimedia objects. The combination of all these features provides a wide framework which presents many new challenges.

2.1. Defining the problem

“Context-awareness means that the system actively constructs and updates a model of the ongoing activity by sensing, communicating, and interpreting changing conditions, resources and processes. Context adaptation takes the activity as the context to infer what actions to be taken in order to ensure the success of the overall activity.” [Dey et al., 2004] Context can be defined as a set of interrelated conditions in the user’s environment. A context-aware system performs different actions based on inferred information about the context.

The wide range of devices that can use this kind of systems raises the concept of portability as a key aspect. Thus, it is very important to be able to develop applications that can adapt the available contents in the network to be visualized using this kind of devices. On the one hand, it makes necessary to use a platform which allows the developer to create systems with independence of the devices that are going to use it. On the other hand, the different kinds of screens and multimedia formats supported need to have components to discover the capabilities of each device and adapt to it automatically.

“What these technologies have in common is that they move the site and style of interaction beyond the desktop and into the larger real world where we live and act.” [Butz et al., 2001]
2.2. **Purpose**

The aim of this thesis is to explore the possibilities of a mobile device with integrated location service from two main approaches: The mobile device as a producer of multimedia contents with contextual metadata associated and the device as a receiver of multimedia contents existing in the network with previous adaptation. Moreover, the study will take in consideration the use of the context information to make inferences and do determined actions. Thus, the questions that will be tried to answer in this thesis are:

- *How can be used a mobile device to create and receive multimedia contents with contextual metadata?*
- *How can a system use contextual information to perform actions?*

These questions are very generic and it will be difficult to answer them completely within this thesis. Therefore, a design of the system will be done and a prototype will be implemented in order to exemplify the model.

2.3. **System requirements**

According to the questions raised previously, the designed system must offer to the users the possibility to create multimedia contents using mobile devices and to upload them to the server with contextual metadata associated. Moreover, the user must be able to define a set of preferences that will be used by the system to infer which contents are interesting for him in a specific situation according to the contextual metadata and the current context of the user.

2.4. **Problem delimitations**

This study will not base the adaptation of the presentation on the user world view or apprehension of reality, but will base it on different devices capabilities. User environment as part of the context will be treated in this study only as geographical location of the user and the contents.

In this chapter it has been described the topic of this study and the formulation of the problem by raising some questions that will be tried to answer.
3. Method

In this chapter are presented the methods that are going to be used to solve the raised problems. The choice of an appropriate method is very important to make a well organized work and increase its scientific quality. Therefore, firstly will be chosen a research process model and after that will be identified the most suitable method for the formulated problem.

3.1. Research process model

The research process model will be chosen between the two models presented in Järvinen’s book [Järvinen, P, 2001]: Jenkin’s model and Wallace’s model.

The Jenkin’s model contains a sequence of steps to be followed during the study. It starts with the definition of the research area and continues with library research to identify the topic. Once the topic is identified, a research strategy must be chosen. The strategy can be based on an experimental design and a subsequent analysis of the results.

The Wallace’s model defines a cycle that starts with logical deduction based on the chosen theory research to formulate Hypothesis. After that, measurable questions must be formulated in order to prove the hypothesis. Finally, the researcher takes observations based on the formulated questions and analyses its results to get an empirical generalization that lets him prove the old theory or induct a new one. The next step starts again the cycle.

3.2. Choosing a research model

The problem studied within this thesis is about constructing a new artifact. Thus, the Wallace’s model is not suitable because it focuses on proving a theory and creating a new one. Since this study lies in the constructive research area, the Jenkin’s model is the most appropriate to follow. This work started with an idea about multimedia contents sharing based on location between mobile devices. During the library research some more concepts like intelligent systems and context awareness appeared and I ended by defining the research topic of the thesis. In the research strategy will be defined the most appropriate method for the raised problem. The experimental design will start with the proposal of a generic architecture for the system. After that, a design of the system based on
the architecture will be presented. The following steps are capture and analysis of the collected data. These tasks will be done during the evaluation of the implemented prototype. Finally, the final results will be published and commented.

3.3. Research method

Once the model of research process has been chosen, an appropriate research method for the formulated problem must be chosen as well. To make this choice the categorization of the research methods presented by Järvinen will be used.

According to this categorization and the formulated problem can be concluded that the research methodology belongs to the group of approaches which study the reality. Furthermore, the research problem can be placed within the methods that stress the utility of innovation. Concretely, since the problem is about designing a new information system it fits in the scope of innovation-building approaches. The method used to build new innovations is a design-science research. This is the most suitable methodology for the raised problem.

The proposed design will be based on the existing knowledge and research and new technological advancements will be used to add innovative features like an intelligent inference engine that uses contextual information.

The design-science methodology is divided in three main parts: building, evaluation and action research. The approach used in this problem will be the building research. According to Järvinen, in this approach there are two options: The targeted stated is defined or the targeted state has to be defined. For this problem the targeted state has to be defined. In order to define it will be used scenarios. Therefore, the design of the system will be done using scenario-based methodology.

3.3.1. Scenario-based design

The scenario-based design starts by raising some scenarios in order to show how can be used the system. A scenario is a description of a use episode from the user point of view. It may include social background, resources and constraints.
According to J M Carroll, scenario-based design studies the complexity and fluidity of design by learning more about the structure and dynamics of the problem. Trying to see the situation in many different ways [Carroll, J.M, 2000]. A scenario becomes an artifact that may be modified and redefined as the design process evolves.

“Scenarios are stories. They are stories about people and their activities” [Carroll, J.M, 1999]. Defining a task, we can obtain the requirements for the artifact design. Creating the artifact also appear new possibilities for the task. The cycle ends when the possibilities of the task in the raised situation are obtained.

I have chosen scenario based design in order to define the system requirements showing a possible real case. Furthermore, I used scenarios because they let me keep the user interaction as center of the design. Thus, scenarios make it easier to satisfy the user needs in the most suitable way, because the requirements are based on the task that the user wants o perform.

This complementary approach combined with the building research provides a useful method to solve the formulated problem. Figure 3 shows the scenario based design model with its five challenges and approaches.
Figure 2: Challenges and approaches in scenario based design [Carroll, J.M, 1999]

**Action versus reflection:** This approach lets the designer know better the users and their tasks, providing a feedback with the needs that should be covered.

**Design problem fluidity:** The use of scenarios provides a high flexibility in the sense that allows the designer to change and revise the requirements during the design process.

**Design moves have many effects:** The different perspectives shown by the scenarios offer several interpretations and solutions for all the actors. Thus, the system can take into account the needs of all the different kinds of users.

**Scientific knowledge lags design application:** When the designer has a lack of scientific knowledge, the scenarios help him to focus on the adequate knowledge in order to solve the raised problem.

**External factors constraint design:** The use of scenarios takes into account all the external factors and let the users participate in the design process.
These aspects show the advantages of using scenarios as a base for the design. To base the design on scenarios lets the designer focus on the most important issues of the problem.

**Figure 3: Scenario-based frameworks [Rosson et al., 2001]**

**Problem scenario:** Stories to describe activities in the problem domain.

**Activity scenarios:** Iterative analysis and redesign to get new functionalities based on the user needs.

**Information and interaction design scenarios:** Specification of tasks and actions that helps users to understand what is happening.

After describing the methodology that will be used to solve the raised problem, it will be shows the situation of the mobile environment nowadays and some on-going research within this field, related work and why is it related to my work. Thus, it will be described the contribution of this study and there will be raised in the end the scenarios used as starting point of the system design.
4. State of the art

Following, it is described the actual state in mobile services during the last years. Firstly, a brief view of the evolution of multimedia mobile services will be given. After that, some research projects and commercial applications developed within this field will be shown. Finally, will be explained how these ideas are related to my work.

4.1. Review of multimedia mobile services

During the last years, the telecom business has evolved from voice services to value added services such as data services and networked applications [GSM Association, 2001]. In 1982, was founded in France the “Groupe Spécial Mobile” (GSM) addressed to the problem of compatibility with the development of digital radio technology. In 1987 the European Conference of Postal and Telecommunications (CEPT) started the creation of the standard GSM and two years later the European Telecommunications Standards Institute (ETSI) started the development. In 1991 began the commercial operation with Radiolinja in Finland. It became a standard for the European Mobile Phones and the major standard for mobile services in Europe and in the whole world.

![Structure of a GSM network](image)

**Figure 4: Structure of a GSM network [Wikipedia, 2006]**

The key advantage of GSM for the customer has been high digital voice quality and low cost alternatives such as SMS. For the operators, it brought the ability to deploy equipment from different vendors due to the open standard inter-operability and allows the users to use their phones all over the world.
As the GSM standard continued to develop, in 1997 the packet data capabilities were added with the General Packet Radio Service (GPRS).

The 3rd Generation Partnership Project (3GPP) was formed in 1998 for the creation of the next generation of mobile networks. It also took over the maintenance and development of the GSM specification. Higher speed has also been introduced with EDGE in the release 99.

The GSM Association launched in 2001 the Mobile Service Initiative to bring a new level to data services and a new wave of wireless internet applications. This year was created in Japan the first large scale real-life commercial Universal Mobile Telecommunications System (UMTS) network operated by DoCoMo. Since then, UMTS networks have been implemented all over the world increasing substantially the data transfer rates.

### 4.2. Research activities

The fast evolution of mobile networks made smart phones become an area of high interest for the telecom sector and content providers. Many research studies have been made, in order to exploit the possibilities offered by mobile handsets and to create different kinds of context-aware and intelligent multimedia systems based on the mobility and the high availability of the users.

In this section will be presented the results of some research studies related to the use of smart-phones and the development of location-based and context-aware services.

Gregory D. Abowd and other authors from the Georgia Institute of Technology in Atlanta made the earliest work on developing a location-aware system tourist guide [Abowd, G. D. et al., 1997]. In this study, they describe a set of applications for the guide of tours based on location and discuss the general research issued that have emerged in their experience context-aware applications in a mobile environment. “The long-term goal is an application that knows where the tourist is, what she is looking at, can predict and answer questions she might pose, and provide the ability to interact with other people and the environment” [Abowd et al., 1997].

Another relevant research work on this field is the prototype GUIDE. It was developed by Keith Cheverst and other researchers from the Distributed Multimedia Research Group of Lancaster University. The prototype consists of a
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location-aware application for PDA that supplies relevant information about the city of Lancaster [Cheverst, K et al., 2000]. In the article they describe technical aspects of the system and their experience testing the prototype with several users of different ages, interests and knowledge.

Context Phone is a context-aware platform developed by Mika Raento and other authors form the University of Helsinki and the Helsinki Institute for Information Technology [Raento, Mika et al., 2005]. The article describes the architecture and some applications for this platform.

4.3. Related work

There are many systems already developed related to the topic of this thesis. Some of them are made for the creation and sharing of multimedia contents using handhelds and some others are designed to get information depending on the user’s context, mainly based on location and preferences. Since this study is related to both fields, multimedia contents sharing and context-awareness, some existing applications have been studied in order to see different ways to design the system. Following, some of these projects will be described.

4.3.1. MUPE platform

The Multi-User Publishing Environment [Suomela et al., 2004] is an open source platform created by Nokia and designed for the development of multi-user context-aware systems for mobile devices. The main advantage of this platform is that it provides a basic server framework that the developer can modify in order to create his own system. The client application is the same for all different systems and the business logic is then implemented on the server side. The communication between the server and the client is done using an xml based script language. This script language defines all the operations which can be done on the client device. Therefore, the server receives information about the events from the client application and sends back to the client script control instructions to perform the requested operations.

Advantages

- This architecture allows the developers to modify the system without needing the user to reinstall the application on the device.
- The client application is already created.
- The same client application can be used for multiple systems.
- The developer has to focus only on the server side. He can develop applications much faster than creating the whole system on his own.
- The developer does not need to care about the portability of the application.

**Disadvantages**

- A high flow of information between the server and the client is needed.
- In order to develop a server application for this platform it is necessary to learn how to use the script language used to manage the client.
- The script language restricts the developer to exploit all the device capabilities.
- The constant flow of information could overload the network and the server affecting the scalability of the system.
- The application cannot work without having almost permanent connectivity to the server.
- The response times can grow because almost all actions need to connect to the server.

Mupe Gui, a sample application to share multimedia items between different users, has been tested in order to evaluate the performance of the platform. This application allows the user to take pictures, to record sounds and to write notes using the embedded camera, the sound recorder and the text editor of the mobile device. Once the content is created, it is uploaded to the server and shared with all the other users connected to it. Thus, the application shows a list which contains all shared items and allows the user to download and visualize them.
Although the system has the disadvantages previously raised, this platform could be very useful for the development of real time multi-user games, but in my opinion, it is not appropriate for the development of applications as the tested example and the proposed application. However, the source code is available and, since this application has many similarities to the one expected to be designed within this thesis, it can be a good example to see how the device can be used to develop a prototype.

4.3.2. **Dodgeball**

Dodgeball, Mobile Society Software, is a commercial system that delivers sms messages in user communities, alerting them about friends proximity. Although it does not use any location system such as GPS or cell connection, the idea of friends proximity and notifications is similar to the system going to be designed. Instead of a location system, this system uses the information provided through SMS by the user to know his location and send him information about other users that are near. Dodgeball has become very popular and nowadays is used in 22 cities of United States by thousands of users.
4.3.3. **ImaHima**

This system is a location-integrated, community and instant messaging service that allow users to share their current personal status, such as location, activity or mood, with their friends publicly or privately and send pictures and instant messages to them. There are 250,000 active users in Japan accessing the service through mobile phones. It also let users to keep in touch with users who are online with their computer. This service alerts users by mobile email or SMS when a friend is near or feeling lonely.

![Figure 7: Imahima](image)

4.3.4. **Relation to this work**

This section shows the relation among the described systems and the one that will be designed in this work. The main point that makes those systems relevant for this study is that they are focused on mobile users and their environment. Contextual aspects such as user location and presence of specific elements in the environment are combined in order to provide information according to the current situation.

Mupe platform is an experimental platform not focused on a concrete application or area of the context. It shows a generic model for the creation of context-aware applications with device-independent graphical interface and contents sharing. Therefore, it is a good example for the design of the proposed system.

Dodgeball and Imahima are commercial systems mainly based on location. Since both systems are used by a high amount of people, they are good examples on how location based systems could be successfully used in social networks.


4.4. **Putting all together**

The following table shows the main differences among the described systems. The first row compares the communication protocols used by each one. The second row shows the area of the context used. The MUPE platform is designed to be adapted for the use of any desired area of the context, so it is open to the developer’s purpose. All the following rows refer to the features provided. Thus, the table shows for each feature if it is provided and how. The ‘contents’ row refers to the exchange of multimedia files between the users. Inference is about the capacity of the system to deduct information relevant to the users in a specific situation. As instant messaging it means a presence service for the communication among the users such as msn messenger, icq and others. Finally, the concept of navigation means that the system is able to provide location based information to show to the user were is an element placed geographically and how to get there.

<table>
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<th>MUPE</th>
<th>Dodgeball</th>
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<td>Http</td>
<td>SMS</td>
<td>Http and Mobile email</td>
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<td><strong>Context</strong></td>
<td>Open</td>
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<td><strong>Contents</strong></td>
<td>Sharing</td>
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<td><strong>Inference</strong></td>
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<td>Users proximity and matching</td>
<td>Users proximity</td>
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<td><strong>Instant Messaging</strong></td>
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<td>-</td>
<td>Yes, desktop users too</td>
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<tr>
<td><strong>Navigation</strong></td>
<td>-</td>
<td>Addresses from places name</td>
<td>-</td>
</tr>
</tbody>
</table>

*Figure 8: Related systems comparison*

These systems are relevant to this work because they offer some features related to the questions raised in the problem formulation. On one hand, MUPE platform uses mobile devices for the creation and sharing of contents and lets developer adapt it to use contextual information whether to add metadata to the contents or to consider users current situation in real time. The other two systems are examples on how users contest information can be used in order to decide what information must be sent to whom and when.
4.5. **My contribution**

The aim of this work is to design a location-based multimedia system for handheld devices in order to explore the possibilities of context-awareness in mobile environments. The system will include most of the features provided by the ones previously described and other new functionalities, such as creation and sharing of geo-tagged multimedia contents and inference of which ones are relevant for a concrete user, according to his current location and predefined preferences. It will also provide detailed maps and route information to show the user how to find the places associated to the contents. This system will be designed in order to answer the questions raised in the problem formulation.

4.5.1. **Scenarios**

The use of scenarios lets the designer deduce the functionalities that must be provided by the system and define its structure. This section describes the scenarios used as starting point in the design of the system.

4.5.1.1. **Tourist guide**

John and Lisa are tourists visiting Barcelona. They are walking around in the old town and want to receive information about the closest places to see. John starts running the application on his PDA with GPS and camera integrated. He adds to his preferences that he wants information about buildings, monuments and museums. They start walking and few minutes later receive a notification about a cathedral that is close to them. They open the link provided by the notification and get a picture of the building, a brief text description and a map showing its location. After few minutes, they arrive to a square with a big gothic cathedral on one side. They stay there for a while and, before leaving the place, they ask somebody to take a picture of them in front of the building. Finally, John writes a short description and uploads it to the repository. John has defined in his preferences that between 12:00 and 14:00 he wants information about Italian and Chinese restaurants. Few minutes after 12:00, he receives several notifications about some restaurants close to them. There is information about the menu, the prices and the location of each one. They also read some reviews from users that have been there the last month. Finally, they decide to go to an Italian restaurant. After having lunch, they
continue the tour around the old town. They visit some other interesting places and upload some more pictures to the repository. Some hours later they decide to get a Taxi and go back to the Hotel. He takes his PDA and sends a message to the closest taxis using the application. The closest available taxis receive a request that shows John’s location on a map. One of them replies and goes to pick them up. John and the other warned taxis receive a message saying that a taxi is already on the way. Few minutes later the taxi is there. When they arrive to the hotel, John turns on his laptop and logs into his account to see where they have been today and where can they go tomorrow.

4.5.1.2. Package delivery

Jonny works in a package delivery company called Arrow. This morning, he went to the store to fill his wagon with all the packages he has to deliver today. In the wagon he has a PDA with GPS and camera integrated. He uses the camera to scan the barcodes of each new packet before putting it in the wagon. The barcodes contain information about where must it be delivered and to whom. Then, before starting the delivery he checks the system and it provides him a map showing the locations where must be delivered each packet. After three hours on the road, the system sends him a notification about a close gas station. He notices that the van is going out of gas and decides to go there to fill the tank. In the way to the gas station something happens to the engine and he gets stacked in the middle of the road. Jonny sends a message to the closest road service van.

Anders is one of the road service workers and he is just going back to the central station when receives the message from Jonny showing his location. He replies to Jonas saying that he is going there. Jonny receives a message saying that the help is coming and after 15 minutes Anders is there. Half hour later the car is fixed and Jonny can go to the gas station and continues the delivery.

Once the context and the scenarios have been described, next chapter contains the system design from a conceptual view.
5. System design

The first idea of this work was to design a client application for multimedia contents sharing between mobile devices and develop a prototype. The application was expected to use the phone camera and a location system to upload to a repository and download multimedia contents with location metadata and other information provided by the user. Thus, the library research started with this idea in mind. Due to the fast evolution of mobile devices and the wide range of possibilities offered by this new mobile environment, it was easy to find a lot of information related to this topic. Several research articles and applications were studied in order to find the most suitable way to design and implement it. Some concepts came up during the research such as context-awareness and intelligent multimedia systems and brought new ideas to have into account. During the library research, I started the client application design and some small prototypes were developed in order to evaluate the possibilities offered by the available technologies. Although I had already started to work on the client application, the idea of context-awareness and location based systems made me redefine the goal. Finally, following my supervisor comments I decided to design an intelligent system also on the server side instead of just designing a client application. Thus, I started by raising some scenarios in order to define the system and its requirements.

5.1. Requirements

The chosen way to define the system requirements is to describe situations where users are using it (scenarios). This approach lets the designer keep the user as center of the design and make it as easy to use and user friendly as possible from the beginning.

According to the raised scenarios the main needs of the system are:
- The system needs to receive location information from the user periodically. This information will be used by the system to infer the actions to be taken.
- The system has to authenticate the users.
- The user must be able to manage his groups, contacts and preferences to define the information he wants to receive.
- The user can upload and download multimedia contents. Therefore, the system needs to have a repository where all this contents can be stored with its corresponding metadata.
- The system has to combine user preferences, contents location and user’s location in order to send the right information.
- The user must be able to send messages to other users.

The client application have to be able to use the device’s tools like the camera or the sound recorder to create multimedia objects, attach contextual metadata automatically like time and location or manually added by the user, and upload them to a repository. The system must be able to send information to the users about contents that are relevant for them depending on their location and their preferences. Therefore, the application must send context and presence information to the system in order to receive proper information about the existing contents around him and to provide instant messaging and presence services.

**Figure 9: Generic diagram of the application**
5.2. **Use cases**

Once the requirements are defined, the next step is to specify the use cases. The figure below shows the use cases diagram extracted from the defined requirements.

![Use cases diagram](image)

*Figure 10: Use cases diagram*

5.3. **System architecture**

The proposed architecture consists of a set of components in charge of the different tasks needed to be performed by the system. The components distribution is based on the use cases. Each use case is related to one or more components. The functionalities that the system must provide are:

- Users management
- Contents management
- Inferences based on location and user preferences
- Messaging and presence
- Proper presentation of the information
- Location management
The distribution in several components gives independence between the different domain areas and lets each part to be modified without affecting the whole system. This is a key aspect in order make the system scalable, modifiable and reliable.

Figure 11 shows the system components distribution. The tasks performed by each one are as follows:

- The inference engine gives “intelligence” to the system. It uses information about the closest items to the user, his preferences and the items categories in order to infer which information is relevant to the user.
- The presentation engine serves the client requests and adapts the contents according to the client device capabilities. The client interaction with the system is always done through this component.
- The navigation engine is in charge of the historical location information and the retrieval of maps and route information.
- The contents module is in charge of the content repository and the metadata.
- The messaging service provides instant messaging and presence.
- The user profile module contains the user data and his preferences.
5.4. **Components description**

This section describes the set of tasks to be performed by the different components and the structure of each one.

5.4.1. **Inference Engine**

Application in mobile environments needs to be context-aware so that they can adapt themselves to changing situations and execute actions to help the user in his activities [Ranganathan et al., 2003]. To promoting context-awareness is necessary to develop a flexible and expressive model that allows performing complex operations and lets to cover the variety of possible context [Anagnostopoulos et al., 2005]. Several context models have been proposed, such as “Context created by the user” [Dey et al., 2004], first order predicate calculus [Ranganathan et al., 2003] and ad-hoc models [Cai et al., 2006]. These models try to solve the problem using different artificial intelligence techniques.

The Inference engine is designed as set of distributed software agents. Each agent has a working memory (WM) and reasoning about context in his own way using the most appropriate techniques for each particular region of the context domain. This allows concentrate the development of each agent in a specific context. Each agent could implement different reasoning mechanisms like temporal logic, neuronal networks, modal logic, fuzzy logic, statistical methods, rule-based inference, Bayesian inference etc, depending on the problem.

As non agent has all the knowledge of the context, they interact between each other asking and receiving information. Also the agents have a set of components, called sensors, used to update the values of the changing context, for instance the position of the user. The effectors (Ei) are the components used to communicate or trigger the actions to other components of the system. Each user in the system has set of agents and the set of WMs from the agents are the context information of the user.

Model of context describe the properties and structures of context information and the kinds of operations that can be performed [Ranganathan et al., 2003].
A possible model of context presented in [Ranganathan et al., 2003] is based on first order logic predicates. Context predicates have arguments in a subject verb object (SVO) format. Thus the structure of these predicates is \((<Subject>,<Verb>,<Object>)\).

The structures of different context predicates are specified with an ontology. The ontology is used to check the validity of context predicates. It also makes it easier to write different context predicates since we know what the structure of the predicate is and what kinds of values different arguments can take. The ontology also allows different pervasive environments to inter-operate since it is possible to define translations between the terms used in the ontologism of these environments. Since the structure of context predicates are specified in the ontology, it allows different agents in the system to have a common understanding of the semantics of different contexts. [Ranganathan et al., 2003]

### 5.4.2. Presentation Engine

“In order to produce a coherent and cohesive presentation, it is necessary to adapt a presentation to the available resources of the presentation environment” [Kray, C. et al., 2003]. Several factors related to the technical resources of the target device must be taken in consideration in the presentation process. This
issue raises several problems such as the device capabilities detection and the adaptation of the presentation according to this information. “Content and applications need to offer suitable front-ends, capable of adapting to devices differing substantially in form factor, screen resolution and aspect ratio as well as in their input and output capabilities” [Simon et al., 2005].

The adaptation of the presentation can be done depending on cognitive resources based on the user profile or even context information. For instance, a user with a sound reproduction capable device could get speech information while he is driving his car but text or visual information when he is in the library and it is not allowed to make noise. In this case appears also the concept of multimodal technologies that provide the possibility to deliver contents in different media formats (voice, text, image…) depending on the current situation or other factors. Therefore, the combination of all this elements needs a complex system equipped with artificial intelligence to decide in each case which is the best option. However, the presentation engine posed within this study will not focus specially on cognitive resources or context information, but it will consider the technical resources of the device in order to find the most suitable way to deliver the information according to its capabilities.

In addition to multimodal technologies, the real time conversion of multimedia contents based on information about the supported formats, screen size and other capabilities is also an important issue. Thus, a multimedia content available in the network can be converted to another format and rescaled in real-time to make it possible to be visualized by the device that is requesting it.

The number of devices that can be supported by an application is a very important factor that could determine its success. In order to be able to run it on any device it is necessary to identify the device where the application is running on and get all the information about its capabilities. There are several ways to do it depending on which kind of application is used for. For example, a web application that adapts its contents to the client type that is requesting them can identify the device extracting information from http headers. In the case of a client application running on the device, the capabilities can be obtained locally and be sent to the server, but also the same method as for a web application could be used in this case.
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There are several ways to get information about the device that is connecting to a server. Some information can be obtained from the http header:

- **Accept**: Contains MIME media types supported.
- **User-Agent**: Line of text that can be used to identify the device and that may also contain information such as the OS, browser version and Java capabilities.
- **Accept-Charset**: Specifies the supported character set.
- **Accept-Language**: Contains information about the language preference of the user.
- **X-wap-profile**: Contains the url where the UAProf document can be obtained.

As can be seen, just using the Http headers it is not possible to obtain all the required information to adapt the contents to the client device. However, the x-wap-profile provides another way to obtain a detailed description of the device and its capabilities. “When a profile is sent as part of a request to a CC/PP enabled server, the server may use the information contained within the profile to adapt the content to the target device” [Gilbert et al., 2005].

User Agent profile (UAProf) is an XML document that contains information about the features and capabilities of a mobile device. It is a standard defined and maintained by the Open Mobile Alliance [Open Mobile Alliance, 2006]. It was created according to the CC/PP (Composite Capabilities/Preferences Profiles) framework using the schema RDF (Resource Description Framework). Both were defined by the W3c (World Wide Web Consortium).

User Agent profiles are stored in a server called profile repository. Usually, a profile repository is maintained by a device manufacturer.

It is possible to get much information about the device capabilities from a client application running on it. Although this can be another good way to get information to adapt the contents, it is needed to collect this information on the client and send it to the server. Thus, concerning content adaptation and retrieval it is a better solution to use UAProf when it is possible, keeping this option as an alternative when the profile is not available. Anyway, the capabilities detection on the client application could very useful to develop portable applications that can run on different devices without modifications. Furthermore, non static capabilities such as memory status can be obtained and
active tests to check the bandwidth can be performed before transferring data. Thus, the application can avoid requests of contents that the device would not be able to store or warn the user when a transfer is going to take too long time.

This component is in charge of the device capabilities detection and the adaptation of the contents to be visualized in the most suitable way. It is placed between the end users and the system and it is the responsible to receive the client requests, deal with the system to obtain the required contents, transform them if it is necessary and deliver them to the client. It also can receive push information from the system that has to be sent to the specified clients.

For the first case, the client device detection is performed on the server-side using information extracted from the HTTP headers and device profiles repositories. For the push information it is not possible to use this technique since it is the server who starts the communication and it is not required that the user is logged into the system when this information is sent. In order to solve this problem several solutions could be adopted. One option is to keep in a database each user’s client device profile name and upload it each time the user connects to the server, but it is not possible to be sure always that the user will receive the information in a proper way because he could be using a different device than the last time he was connected to the server. Therefore, the best solution is to use a technology that is supported by all possible client devices and provide just a short notification about the event and the address where the user can obtain all the information if he is interested. Thus, the user will also request this information and the presentation engine will be able to adapt it as it is described above.

5.4.3. Navigation Engine

This module is in charge of maps and route instructions dynamical generation. When a user receives information about places of interest around him the core engine requests this module to get a map showing the location of these places. This component provides also route instructions to get the desired place from the current location.

To produce route instructions several steps have to be taken. First, the origin, intermediate location and target have to be determined. Second, search of the most suitable route that does not only lead from origin to target but
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ideally takes into account the context (situational factors, user’s preferences, means of transportation). “If the resulting route is to be described incrementally, it is also necessary to divide it into smaller segments. In the later case, several presentations need to be generated that have to be timed according to the movement of the user, and the system has to present them at the right location” [Butz et al., 2001].

For the presentation of route instructions on mobile devices some issues should be taken in mind: Technical resources include factors such as computational power, bandwidth and screen resolution, among others.

The cognitive resources of the user can also influence the way that information is presented. An electronic tourist guide should for instance avoid computing routes on which inexperienced users are likely to get lost.

In many cases a system has to know factors such as speed, heading, view direction and acceleration to push the user services at a specific location. For example, turning instructions depends on the reference direction and also the speed and acceleration is relevant to decide when the instructions have to be given. In other cases, it is difficult to determine the user position precisely, so in order to be robust, the system must deal with missing or imprecise location information. There are many ways to show route information. The most suitable depends on the context and the device. A common depiction of routes is route maps. They show the route as a sequence of turning points connected by lines.

The proposed design consists of a database where historical user route information is stored and external GIS services to obtain maps and route information. When the core engine receives a new user location, it sends this location to the navigation engine if the user wants to save the route and requests the inference engine to get a list of entities close to the user which fit with his preferences. This list is sent back to the user. Then, if the client requests information about a concrete location, this module is used to generate a map showing its location and instructions to go to this place from his current location. In order to do that, the navigation engine uses the external GIS service that generates the required map and route information.
5.4.4. Contents Module

This module manages the storage of multimedia contents and the metadata related to each one. All this contents are created by the users and the metadata contains information about its location, the date of creation and other data added by the user when it was uploaded. The most relevant information for the system is the date of creation, the location, the creator and its category. This information will be used by the inference engine to deduct which ones are interesting for a concrete user according to his preferences. It also provides search functionalities that let users or other components obtain a set of contents that satisfy the specified conditions. These conditions could be by creator, category, format, time and location area among others.

This module has a database to save all the information about the contents and a repository where the multimedia files will be stored. It has also a search engine that deals with the metadata database. The search engine allows access to the contents using queries that can combine different metadata field values. The inference engine uses the search engine to get specific contents according the user preferences and location. These searches can also be requested by the user.
5.4.5. **Users Module**

The Users Module keeps all the information about users, such as personal data, preferences and access rights, and the groups of users. The inference engine communicates with this module in order to obtain the user preferences and his access rights. Thus, when a user logs into the system, the authentication information is obtained from this component and the inference engine instantiates an agent using his preferences and access rights.

This component needs a database to store all the user information. This database contains the username and password used when the user logs into the system, a list of preferences defined by the user and another list where are defined the access rights for this user. The access rights list consists of a set of rules that define which contents can be accessed for this user. Each user belongs to one or more groups and for each group he could have permissions to upload contents or download contents. The user preferences define the information that the user is interested in. Each preference contains a group that can be accessed by the user according his access rights, a category of contents, time of creation of the content (one week ago, one month ago...) and a time interval when the user is interested in receive this information. The users groups are also managed by this component. Therefore, the database will contain also a table for the existing groups.
5.4.6. **Messaging Service**

The messaging service is in charge of instant messaging and presence functionalities. When a user logs into the system, this component provides information about the availability of the users present in his contact list and sends presence information to the users which have him in their contact list. Thus, this component lets each user send instant messages to the available users.

In order to keep information about user presence, the client application needs to poll the service periodically. Each time the client polls the service, updates his presence information and receives the present information of his contacts and the messages sent to him. Therefore, the service needs to store information about each user’s contacts list and a queue for each one to keep his pending messages.

In the first stage of the design, it was not planned to integrate instant messaging and presence functionalities. Even though, since the client needed to poll the system periodically in order to update the location of the user, it made sense to take advantage of this periodical communication and provide this
service. Thus, the presence information sent by the client application contains also the location of the user. Furthermore, the responses of each presence message contain a list with the contents close that fit with the user's preferences.

5.5. **Client applications**

The clients of this system could access it whether from a static computer or a mobile device. From a static computer the user can only manage his account and browse information such as items location and historical route information. When the user accesses the system from a mobile device he is also able to use location-based functionalities such as reception of relevant information according to his current location and preferences, creation of multimedia contents with location and user metadata and accessing to detailed maps and route information to find the places referred by these multimedia contents. Thus, for a static client the system will only need to retrieve information stored in the database upon demand, while for a mobile client, the system will also be polled periodically in order to update presence and location information and get relevant information. Therefore, the mobile client application will deal with the camera and sound recorder for the creation and uploading of geo-located contents.

In this chapter it has been defined the system design and the components distribution from a conceptual view. The next chapter describes the technical aspects regarding the implementation of these components and the implemented prototypes.
6. Technical approach and prototypes

This chapter describes the proposed technologies for the implementation of the defined components and the developed prototypes.

6.1. Proposed Technologies

The technologies that can be used for the implementation of this system include programming languages, open source platforms, public services and communication protocols. Following are listed the ones proposed for the development of each component.

- **Inference Engine**
  A suitable implementation of this component is to use XSB, a Logic Programming and Deductive Database system for UNIX and Windows. XSB allows full Prolog functionality in tabled code including cuts, (subject to weak semantic restrictions), in meta-logical predicates, in second-order predicates, etc. Other related technologies are DAML+OIL [20]. The list of items inferred by the engine is delivered as an RSS document created using the Rome Api. Rome is an open source java api designed for the creation and parsing of rss documents.

- **Presentation Engine**
  The proposed design for this component is to use a web server to receive the user requests over Http. The server will have an integrated tool to customize the presentation for the different devices. It will also have a module to extract the information from the Http header and get device profile information automatically, providing all the information about the device capabilities during the dynamical presentation generation process.

  The proposed technology for this module is an Apache Tomcat Server with Apache Cocoon and Delivery Context Library (DELI). The Tomcat server is the web server that processes the user requests, while the Cocoon component generates the different presentations according to the device information obtained using the DELI API. Push advertisements can be sent using just SMS messages.
• **Navigation Engine**
  The proposed technology to implement this component is a MYSQL database to store the historical user route information and a java API to access the Arcweb public services. Arcweb offers a set of services such as dynamical maps generation, geo-coding, route instructions and other GIS solutions. The communication between the navigation engine and Arcweb public services is done using web services. The communication with the core engine is also done through web services. Therefore, this component uses an Apache Axis server to provide its services.

• **Contents Module**
  All the metadata associated to the contents will be stored in a MYSQL database. The repository where the contents will be stored consists of a server with several hard drives and high storage capacity each. The communication with the other modules is done using web services. Therefore, this component uses also an Apache Axis server to provide its services. The proposed technology to implement the search engine is the java platform.

• **Users Module**
  For the management of all this information will be used a Mysql database. The communication with the other modules is done using web services. Therefore, the component will use an Apache Axis server to provide its services.
• **Messaging Service**

The proposed solution for the development of this component is to integrate the Jabber platform. Jabber defines and XML based protocol called XMPP (Extensible Messaging Presence protocol) designed for instant messaging and presence services. There are several open server implementations that can be modified and adapted for a specific system. Jabberd 2.0 is a java one that provides all the functionalities needed for this system.

• **Client applications**

For static clients that access the system from a desktop computer will be used a web interface implement with JSP. For the mobile clients, the application could be implemented on the J2ME platform using the profile MIDP 2.0. This profile consists mainly of an api, existing in most of new mobile devices, that lets the developer create a portable application able to run on most of devices with different capabilities and screen sizes. Thus, using this platform can be avoided the development of several different applications for each device. Due to some issues described in the next section, it has been chose to use and external GPS Bluetooth. For the implementation of the Jabber client, an open source client developed in J2ME called Mobber could be integrated.

### 6.2. **Prototypes developed**

Some prototypes have been developed in order to illustrate the functionalities of the system and explore the possibilities of the available technologies. Since the beginning of this study the goal was to design and develop a full functional client application for the creation and sharing of multimedia contents with contextual metadata for handheld devices. Thus, while I was writing the introduction, problem formulation and methodology chapters, I started to think about the design of the application and to implement a first prototype for a Nokia 6330 provided by the university to start the evaluation of the technology. The developed application lets the user take a picture with the phone camera, add metadata and upload it to a server. It was going to be used in a project of the Celekt group from the Växjö University that was coordinated by my supervisor, Marcelo Milrad. This project consisted of the development of a multimedia system based on location for supporting outdoor
activities performed by students of a primary school from Växjö. Due to technological issues, it was decided to use a personal digital assistant with integrated GPS and camera instead of a cell based location system or an external Bluetooth GPS with the mobile phone. Therefore, my Supervisor gave me an HP IPAQ 6900 and I started to develop a new prototype for this device. It was not difficult to get the GPS information, but the library provided by HP for this model had problems with the camera and after some attempts we realized that it was not possible to use the camera until HP solves this problem. Due to these facts, this prototype was only getting information from the integrated GPS and sending it to a server periodically to receive information.

The GPS prototype was used successfully during the activities performed in the Amulets project during June of 2006. The activities consisted of outdoor learning activities carried out with 32 children from 4th grade class distributed in eight groups. Their goal was to find five hidden places in the forest where they had to solve different problems such as measuring the size of a tree using a stick or obtaining the age of a cut tree by counting the circles on it. The mobile phone camera was used to scan Semacodes (special image codes to encode URL’s) posted on some trees. Once a Semacode was scanned, they got a video created by the Celekt team where there was explained the task to be performed. Each group was also carrying an IPAQ 6900 with the GPS prototype running on it. The GPS information sent by the IPAQ was stored in a database and used to trace location of the groups during the activity. The routes were shown to the students later in class. This test allowed me to check out the reliability of a periodical polling system to update location and receive information.

Although it was not possible to develop a unique prototype for the same device, these two prototypes illustrate how mobile devices can be used for the implementation of the designed system. The camera application shows the creation of multimedia contents with associated metadata, while the GPS application shows how the location of a user can be periodically updated in order to receive relevant information.

Once the client features have been successfully tested, the next step was to develop a server prototype in order to illustrate how the system can use the information provided by the client to send relevant information for the user. Therefore, a database and a web application were developed to illustrate this
functionality. By combining this prototype with the Camera and Gps prototypes, the main features needed to illustrate the system had been implemented:

- Creation of contents with metadata.
- Periodical update of user location.
- Delivery of information according to contents metadata, user location and predefined preferences.

1. Jonny has lunch in an Italian restaurant. After eating, he takes a picture from outside, adds some metadata and uploads it to the repository. He belongs to the group Gastronomy and adds it to the category Italian restaurant food.

During the server prototype implementation I couldn’t use the mobile devices used for the other two prototypes because I was not in Växjö. Therefore, some routes and items were inserted in the database in order to perform inference simulations. The next step is to connect all prototypes in a test with several users. Each one uploads some contents with the camera prototype, while the Gps prototype updates his location and shows him the relevant contents close to him. Following each prototype is described with more details.

- **Camera application**

  This application was developed in java over the J2ME platform and the MIDP 2.0 profile. It was tested on a Nokia 6330 and it was able to use the phone camera to take a picture by using the Mobile Media Api. Once the picture was taken, it passed to another screen where the user could add some metadata to
the picture. Finally, the picture and its metadata were sent to a server where it was stored.

1. Picture creation.

2. Add metadata:
- Who: Patrick, Talia and me
- When: 24/09/05 14:40
- Where: Stockholm (GPS)
- What: Visiting the city...
- How: JPEG 1536x2048, ...

3. Upload content and store it into a repository.

**Figure 18: Camera prototype**

- **Gps application**
  This prototype was implemented with C# over the .net platform. It was tested on HP IPAQ 6900 and it used the integrated GPS to obtain the current location of the user and send this information to a server over http. On the server side, Fredrick Alserin and Jonas Gustafsson from the Celekt team had developed and application with a database where this information was stored and Google Maps was used to show the location of the users and their routes. As was explained above, this application was used in the activities performed with the students of a primary school for the Amulets project to trace the path followed by the different groups. It worked by polling the server periodically updating the current location of the user. This test was successful and let me conclude that this is a good solution for the implementation of the designed system.
• **Server prototype**

The last developed prototype is a web application for the management of the system’s database and the simulation of users moving and receiving information about places of interest close to them, according to their defined preferences. This system allows the creation of different users, groups of users, categories and items. Each user can be assigned to several groups and has a set of preferences. There can be defined a set of categories and geo-located items associated to a user, a category and a group of users. Thus, the preferences of a user consist of pairs group-category, that means that the user would like to receive information about items of this category created by a member of the specified group.
The web interface has been implemented with Java Server Pages and a Mysql database. For the simulation of user movement it has been used Google Maps and Ajax.

Following, there can be found several screenshots that show with more details the performance of this prototype.

**Figure 20: Users management**

This image shows the list of existing users in the database. New users can be created by pressing the ‘New User’ button and the already created ones can be edited and modified or deleted. Each user preferences and groups can be accessed by clicking on the links ‘preferences’ and ‘groups’ placed on the right side of each row. On the left side, it can be seen the main menu that lets to access the different sections of the website: Users, Groups, Categories, Items and Routes.

**Figure 21: User preferences**
This screenshot shows the preferences of the user David. In the designed system a preference includes also time of creation of the items and between which times the user ones to be notified, but in this prototype it was not included because the simulation does not deal with the current time.

Each user can be a member of several groups. Thus, the user is able to create items for the categories related to this group and to receive information about proximity of other users from this group.

New groups can be created on this section and also the existing ones can be modified. New users can be added to a group by clicking on the link ‘users’ placed on the right side of each row.

Next image shows the categories management section, where new categories can be created and the existing ones can be modified.
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Figure 24: Categories management

Next figure shows the list of existing items. For each one, there is information about the creator, group, category, title, description and time of creation.

Figure 25: Items management

Each item has an associated location and a multimedia object. For this prototype it had been only used jpg images. In the designed system these objects can only be created by a user from a mobile device. For the simulation included in this prototype, it has a section where new items can be created and the existing ones can be modifies. The location of each one can be set clicking on a Google Map and the referred picture can be added by writing his path on the server.
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Figure 26: Item edition

Next figure shows the simulation of four users walking in the center of Barcelona. Each user belongs to some groups and has a set of preferences. The simulation shows how each user receives information about items that are close to him and fit with his preferences.

Figure 27: Route simulation

The technical study and the prototypes developed prove that the designed system can be implemented with existing technologies. Next chapter discusses the implications of location in mobile multimedia environments, the conclusions of this study and the possibilities in the future.
7. Reflections upon my work, conclusions and further development

The aim of this work is to study the possibilities brought by the use of location information in mobile multimedia environments. In order to study this field, two questions have been raised in the problem formulation. The first one talks about the creation of multimedia contents with contextual metadata using mobile devices, while the second one is about how this contextual metadata can be combined with the current user context to infer actions to be taken. In this case, these actions are mainly the delivery of information relevant to the user. Context comprises all aspects related to the user’s environment. This information can be used to infer what can need a user in a specific moment. For instance, if a system knows that a user is walking in a forest when a big storm starts there, the system can infer that he would like to know where the closest refuge is. This example shows how a system can deduct what information could be of interest for a user by knowing his current context. Nowadays, most of information available in internet is accessed upon user request. This means that when a user needs some information he has to look for it. Obviously, in most of cases this is the only way to do it unless a system is able to know what the user is thinking and send him the desired information. At the moment this is not possible, but with the introduction of mobile devices connected to the network and equipped with sensors, such as camera, micro and location systems, it has become possible for a system to get some information about the current user’s environment. The combination of this information with user profiles lets the system deduct what a user wants to know in concrete situations.

This study is focused on location because it is a very useful component of the user context available in the mobile environment. Concretely, it is studied how location can be used to send to the user rich multimedia information at the right place and time. In order to study this topic, I decided to design a generic system able to combine geo-located information, user profiles and user location to make inferences. Therefore, the initial requirements of the system were creation of contents with location metadata, management of user profiles and a periodical communication system to obtain user location. Another requirement involved by the use of mobile devices was the need of make the system able to
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The most interesting aspect I have found in this study is how the level of intelligence of the system can be improved. The possibility of combining user profiles and learning systems based on historical information opens a wide field to explore. Historical data about user activities, such as requested information and visited places, could be added to the user profile. By knowing when and where a user has rejected specific information, the system can base the inference on success rates associated to actions performed before in similar circumstances. The inference engine could also be improved by adding support to other components of the context, whether using sensors connected to the client device or accessing external sources, such as weather or traffic information among others. Information about the whole community of users can be used as well in the inference process. Thus, the system can consider the amount of users that have requested concrete contents or users matching according to their profiles and proximity.

In order to solve the formulated problem, this work has been approached from a functional perspective. However, the use of location and historical information requires a high level of privacy. Therefore, the implementation of...
the designed system needs a robust security system, although it has not been deeply described in this work.

This system has been designed to answer the questions of the problem formulation. It shows a possible solution to the problem based on existing technologies. Therefore, from a theoretical approach, the goal of this work has been reached, but the wide area covered by the problem made me keep the design in a very high level. The implementation of such a system needs a long period of time and many tests that could lead to several changes in the initial design. The developed prototypes try to show that the main functionalities can at least be implemented. However, in general terms this study offers an example of the new kinds of systems that could be developed in the future within the field of mobile multimedia environments.
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