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Mobile Augmented Reality for Supporting Reflection

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Problem Description

Reflecting on action is critical to learn from past experiences and performing better in the future. Different tools have been developed to support reflection, as an individual or collaborative activity. The objective of the task is to investigate the usage of mobile augmented reality to support reflection on working experiences that have a strong spatial component. As main case the task will consider support for reflection among workers involved with crowd management.
The task involves the development of scenarios for the specific case and the development of a demonstrator of ideas.
The task is a collaboration of the NFR FABULA project and the EU-FP7 MIRROR project.

Assignment given: 13 January 2011
Supervisor: Monica Divitini, IDI

To who has always believed in me...

Abstract

Reflecting on past experiences is crucial for learning from them and reconsider actions that have been taken in order to make better future choices. Different tools have been developed to support reflection both as an individual and collaborative activity. Aim of these tools is to provide individuals with information related to experience in order to make them reflect about it. However reflecting in a setting which is not the one where the object of reflection happened affects the reflective process due to the lack of the context in which the experience took place.

This work aims at investigating how the usage of the Augmented Reality can be exploited in order to support reflection. In particular the main goal of the work is to study how Augmented Reality can trigger reflection on work practices that rely on deployment and management of resources in space.

The outcome of this work is the analysis of a system that allows users to collect contextual information that has a strong spatial dimension and the design and implementation of an Augmented Reality application for tablet-device in order to visualize the information collected. A high-level architecture of both the overall system and the prototype implemented is provided as well as storyboards for the solution proposal. The prototype implemented has been object of an experts evaluation in order to assess the potential usefulness of the application in real settings connected with the Italian Civil

Defense. A workshop paper based on the work done in this thesis has been also written in concert with my supervisor Monica Divitini and my co-advisor Simone Mora.

Preface

This thesis is submitted as the final work for the degree of the International Master of Science in Information Systems that has been taken by the author at the Norwegian University of Science and Technology (NTNU, Norges Teknisk-Naturvitenskapelige Universitetet). The report is based on the research conducted by the writer in the period January-June 2011 on a project assignment given by the Department of Computer and Information Science (IDI), under the supervision of the Professor Monica Divitini. This work extends the research project that has been done in the Autumn semester during the course *TDT4520 Program and Information Systems, Specialization Project*.

I wish to thank my supervisor Monica Divitini and my co-advisor Simone Mora for the constant and helpful support and precious feedback provided during the course of the project. Meetings and discussion with them were particularly interesting and really helped to achieve project goals.

A heartfelt and special thanks to my family that made this experience possible. It has been the most important experience of my life, I will never stop thanking you.

A sincere thanks to all my friends I knew during this experience. In particular I wish to thanks Riccardo who has been my norwegian family.
A sincere and special thanks to my friends Antonio and Francesca who always supported me especially in difficult moments. I want you to know that you are more than friends for me.

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Chapter 1

Introduction

This work extends the research project that has been done in the Autumn semester during the course *TDT4520 Program and Information Systems, Specialization Project*. Purpose of the project was to support the collaborative construction of places using the Augmented Reality (AR). Firstly, researches on the concept of space and place have been done. Whilst the former refers to the three-dimensional structure of the real world where we live and in which objects have a relative position and direction, place is space invested with values and meanings [20]. Therefore, it has been investigated how to augment a physical space with pieces of information in order to turn it in a place and how to use the concept of place to structure contextual information. Then, the focus shifted on the use of the augmented reality as means to support collaboration in constructing places and for visualizing place-based information.

Objective of this master thesis is to support reflection in situ on collaborative work, in particular planned, outdoor activities, with the aid of mobile technologies. The attempt is to exploit the concept and the connections of place and Augmented Reality to support reflection. In this perspective, physical spaces where activities take place are turned into places as they are augmented with information about the work experiences. Augmented Reality, instead, is used to visualize place-based information with the attempt to make individuals reflect on that information. Reflective learning refers to "those intellectual and affective activities in which individuals engage to explore their experiences in order to lead to new understandings and appreciations" [11]. Therefore reflecting on actions is crucial for learning from past experiences and acting better in the future. This work investigates how reflection can be triggered using place-based information collected in a collaborative way. This information will be used as content of the reflection session while the Augmented Reality is exploited to layer and visualize it. The aim of this work is to support *reflection-on-action* that is reflection that happens with a certain distance from the activity.

The project description given by the supervisor is:

Reflecting on action is critical to learn from past experiences and performing better in the future. Different tools have been developed to support reflection, as an individual or collaborative activity. The objective of the task is to investigate the usage of mobile augmented reality to support reflection on working experiences that have a strong spatial component. As main case the task will consider support for reflection among workers involved with crowd management.
The task involves the development of scenarios for the specific case and the development of a demonstrator of ideas.
The task is a collaboration of the NFR FABULA project and the EU-FP7 MIRROR project.

1.1 Motivations and Contributions

1.1.1 Motivations

As observed by Jonasson [30] learning in the field is effective in some situations such as geography excursions. Indeed in such situations "the context for learning is made in the particular context where the object for learning takes place and is placed" [30]. Marvell [29] reported that presentations in situ made by students about a touristic place widen the experience, create a sense of place and foster reflective learning. Therefore choosing to connect place-based information and augmented reality with the reflective learning process in this thesis is motivated by the fact that being on the field allows individuals to be immersed in the context surrounding the object of the learning. The idea of this thesis is to allow individuals reflecting in the same place where the activity took place in order to trigger a more grounded reflection.

In this perspective Augmented Reality is used to layer and access spatial information that might help user to reflect on the past activity. Comparing a photo of a place taken during the activity with the place in normal condition, for example, might help users to reconsider their past actions and possible alternatives.

1.2 Research Questions (RQ)

The research questions this thesis is trying to answer are the following:

- RQ1: How place-based information can be exploited in order to trigger reflection?

  The first research question relates with the theoretical aspects connected to space, place and reflective learning. This question is sought to be explored through a literature review on reflective learning processes and the application of previous knowledge about the concept of space and place and Augmented Reality.

- RQ2: What advantages Augmented Reality brings in supporting reflection?

  The second research question relates with the visualization of place-based information in order to make individuals reflect upon that information. This question is sought to be answered through the design, the prototyping and the evaluation of an Augmented Reality application to visualize place-based information explained later on in this thesis.

1.2.1 Contributions

In this work a literature review on reflective learning processes and Augmented Reality as means to visualize information and support collaboration was done.

The main contributions of this work are:

- The investigation of a system that support reflection on place-based information and the definition of storyboards to explain it.

- The design and prototyping of an Augmented Reality application for tablet-devices for visualizing place-based information.

Last but not least a workshop paper, based on the work done in this thesis, (see the Appendix D) has been written and accepted for the 1st Workshop on Mobile Augmented Reality at MobileHCI 2011 - Stockholm, Sweden - 30/08 - 02/09 2011 [1].

[1] http://www.elizabethchurchill.com/MARWorkshop/index.html

1.3 Research Method

Here follows the research method used during the course of this thesis (Fig. 1.1). Every step was reviewed during weekly meetings in the course of this semester with my supervisor Professor Monica Divitini and with my co-advisor PhD. candidate Simone Mora.

1.4 Research Context

This thesis has been carried out as part of the FABULA[2] and Mirror[3] projects. Next sections briefly describe objectives of both the projects.

1.4.1 Fabula Project

FABULA stands for FremrAgende By for Undervisning og LAering (Seamless networks for transforming the city into an arena for learning).

Figure 1.2: The Fabula Logo

Aim of the project is to construct a (web-) services based e-learning system for mobile networks, and to support informal collaborative mobile learning activities (i.e. it supports learning which happens inside a learning group

[2] http://www.fabula.idi.ntnu.no/

[3] http://www.mirror-project.eu/

whose members can communicate with each other) in a city wide context. The target is a collection of individual users who carry sophisticated mobile devices with them. Such a system is intelligent because it is aware of the context of the learner and adopts its behavior accordingly. Intelligence is built over ontological reasoning and semantic interoperation. Moreover, FABULA is able to recommend learning content to the user and to tailor different learning activities based on the information collected about the context.

1.4.2 Mirror Project

MIRROR is a European funded project which overall objective is to empower and engage employees to reflect on past work performances and personal learning experiences in order to learn in real-time and to creatively solve pressing problems immediately.

Figure 1.3: The MIRROR Logo

MIRROR shall help employees to increase their level and breadth of experience significantly within short time by capturing experiences of others. A prerequisite for exploring innovative solutions in this context is to rely on human ability to efficiently and effectively learn directly from tacit knowledge - without the need for making it explicit.

1.5 Report Outline

The thesis is organized into the following chapters:

- **Chapter 2 - State Of The Art** This chapter covers the theoretical background of the concept of reflective learning as well as of Augmented Reality. Different reflective learning theories will be analyzed together with the Augmented Reality as means to visualize information and to support collaboration.

- **Chapter 3 - Problem Elaboration and Analysis** This chapter describe the research problem in a more grounded way. Firstly the scenario used throughout the work is presented, then issues related to how the structure collected information, its visualization and challenges to face are analyzed. This chapter ends providing functional and non-functional requirements needed by the system.

- **Chapter 4 - Use Cases And Storyboards** This chapter provides use cases with relative GUI mockups for the user scenario in order to give a better understanding of tasks in which individuals can be engaged.

- **Chapter 5 - Solution Proposal and Implementation** This chapter provides a solution for the research problem. Firstly the architecture of the system and mobile application are presented. Then implementation details for the proposed solution are covered.

- **Chapter 6 - Evaluation** This chapter describes how the solution has been evaluated. The evaluation is done on the prototype implemented from the solution proposal and aims at investigating its applications in real scenarios and its usability.

- **Chapter 7 - Conclusion** This chapter concludes the report by presenting discussion. Furthermore some ideas for research and future works are presented.

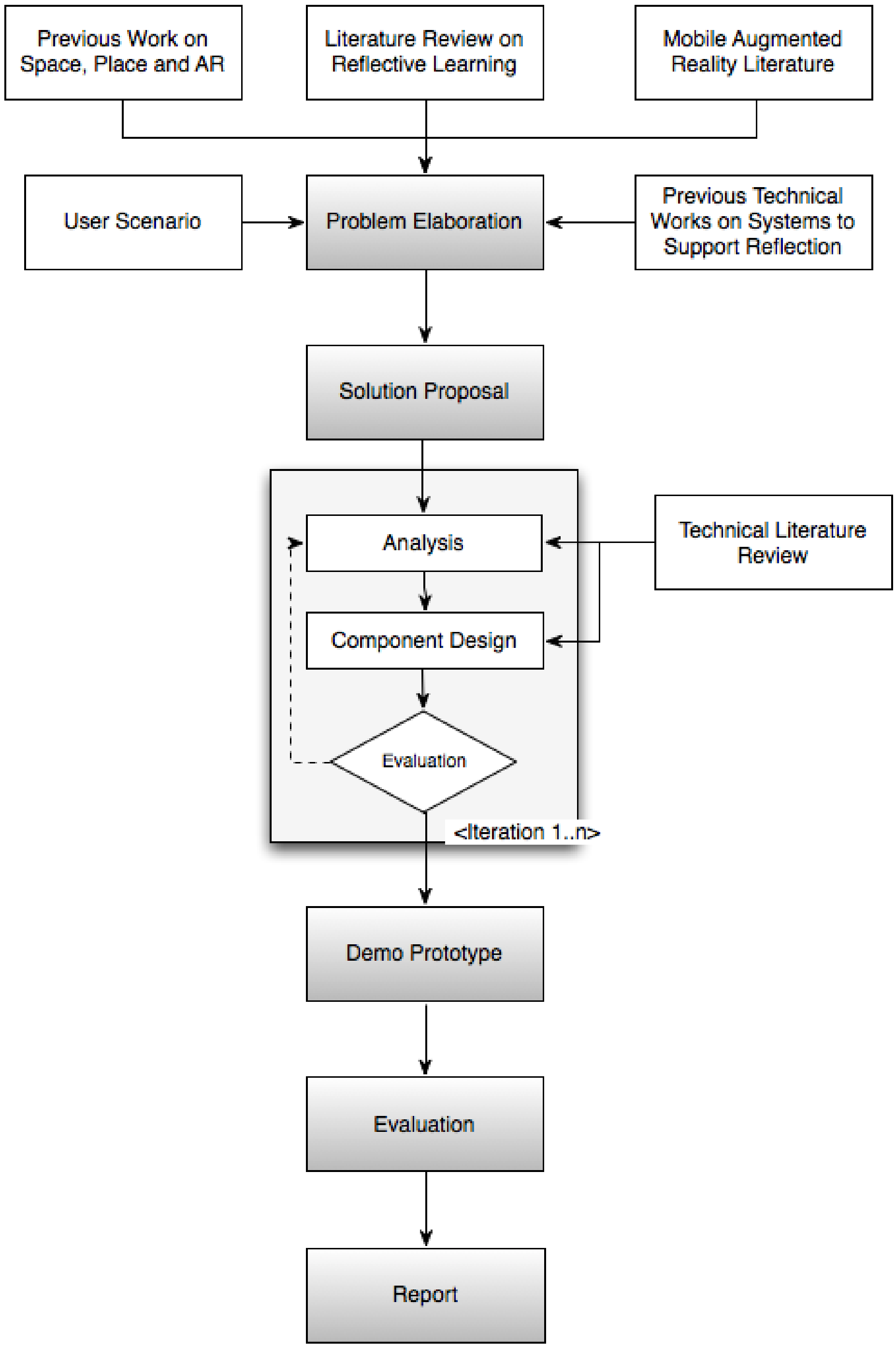


Figure 1.1: Research Methodology

Chapter 2

State-Of-The-Art

2.1 Reflection

According to Kolb [23] learning is "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience". Reflection plays a key role in the experiential learning and it is crucial for practice as well. Indeed reflecting on experiences leads individuals to obtain an understanding that make them take better future choices [39]. Because of its power, reflection is widely used in the educational field and in industry practices, for example in post-mortem project evaluations [24] and nursing [19].

Different kinds of reflective models are present in literature depicting how individuals should look back over their experiences and learn from them. Each model involves distinct stages that should be gone through in order to accomplish the learning process. Most of them involve a cycle where after an action is taken, it is reviewed and reflected upon, improved and then back to the beginning with the new action [9]. Among these models the most commonly cited is the one named *"Experiential Learning Cycle"* (Fig. 2.1) presented by Kolb [23].

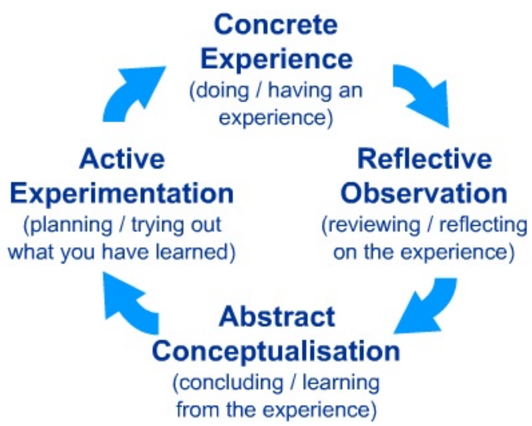


Figure 2.1: Kolb's Experiential Learning Cycle

In this model a person is first engaged in a Concrete Experience followed by a Reflective Observation on that experience, the formation of Abstract Conceptualizations through the application of known theories, then the Active Experimentation to apply the new concepts developed in a new Concrete Experience.
Depending on the topic, reflection can happen during the experience take place, *Reflection-in-action*, or over days, weeks, months, *Reflection-on-action*.

According to Krogstie [24] "experience is not purely rational and not all experience can easily be expressed". Since the complex nature of experience Baud, Keogh and Walker presented their reflective model (Fig. 2.2), an extension of Kolb's experiential learning cycle.

Figure 2.2: Baud's Reflective Model

In this model the authors highlight the main elements of an experience: behaviour, ideas and feelings. In the Reflective Process the individual returns to experience, attends to feeling removing obstructive and using positives ones, then re-evaluate the experience. The outcomes can be a new way of doing something, new perspectives on the experience, a resolution of an issue, a change in behaviour and the like [24]. The process tends to follow the sequence described above even if it might be cycles between stages, repetitions of important elements and so on [11].

Reflection occurs when important events such as a critical event or a failure happen. Therefore reflecting on experience is not a natural process but its a skill that can be developed through training and facilities [19]. For that reason technology can be exploited to capture triggers and their emotional impact and to provide users with information in a format that provoke them to reflect. [39]. That is why it is very important how information is presented to the users.

2.2 Systems to Support Reflection

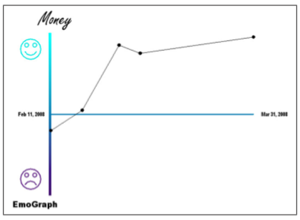
This section aims at investigating systems used to trigger reflection. Reasons of analyzing some systems rather than others are discussed at the end of the section.

In the last years, systems that supports user's reflection have been object of great interest. Particular attention has been given to those systems termed *affective*; such systems like VIBES [44], EmoteMail [37] and Affective Diary [26], rely on an interactional model in which emotions are socially constructed and lived and where reflection happens on own or significant other's emotions. Therefore reflection is supported providing a way through which users can understand, interpret and experience emotions. [39]

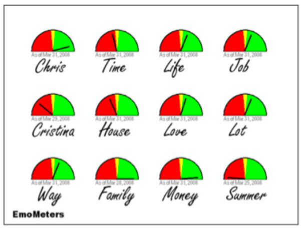
VIBES [44] uses the emotions associated with topics in web blogs to further users' self-reflection. Through information retrieval (IR) techniques the system extracts significant topics from web blogs, measures the emotions associated with those topics and provides this information to the user. Focus of the system is to describe the emotional continuum about a specific topic expressed by a user. Once the emotions of the topics are measured the system visualizes this information in three different modes: *EmoGraph*, *EmoMeters*, *EmoCloud*.

- EmoGraph (Fig. 2.3(a)) use a basic graph to describe the emotional trajectory of a topic over time.
- EmoMeters (Fig. 2.3(b)) provides an emotional snapshot of topics mentioned in the blog. Unlike EmoGraph it does not show changes on emotions over time but it depict static data.
- EmoCloud (Fig. 2.3(c)) provides further details about a specific topic showing both positive and negative words associated with it.

Particularly interesting is also ARTLinks [16], a reflective system which aims at using technology to make people reflect on museum exhibits by creating meaningful social experience. Indeed the system allows the user to



(a) EmoGraph

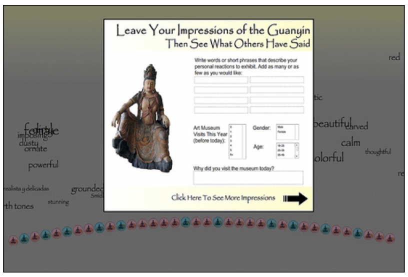


(b) EmoMeters

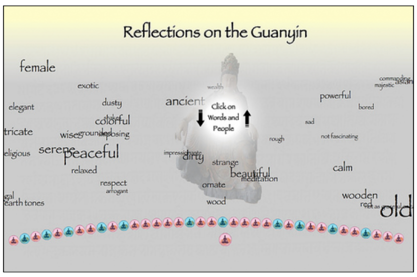
(c) EmoCloud

Figure 2.3: VIBES emotional information visualization

share his/her thoughts on an exhibit, make him/her aware of other visitors' sentiments and show the connection between these reactions. After entering personal information such as age, gender, reason for visiting the museum and so on, users are asked to use some words to describe their emotions on the exhibit (Fig. 2.4(a)).



(a) ArtLinks - User's input



(b) ArtLinks - Users' thoughts

Figure 2.4: ArtLinks - Initial screens

Visitors, represented by meditating orbs, compose an arch located at the bottom of the screen (Fig. 2.4(b)). The user is placed at the center of this arch while the words used to express their emotions randomly float on the center of the screen where the picture of the exhibit appears in background. Only words inserted at least by two people are shown. Tag-cloud visualization is used for that purpose. Therefore the more a word occurs for the exhibit the bigger is its size. The system shows also the connection between the words associated with the exhibit and people who inserted them. When the user hovers over a word with the mouse, connections between that word and its "owners" are shown while other words disappear in the background. When the user hovers over an orb representing a person, connections appear between the user and the words who has inserted. Orbs for individuals who inserted the same words light up.

As it has been previously mentioned, reflecting is crucial for the learning practice. Whereas computers have been used to support learning environments, the collaboration furthered by personal computers (PCs) is often limited; for example by the confines of a classroom [34]. With the advent of mobile and wireless technology it has been possible to move from the metaphor of desktop computer, overcoming its limitations, toward new computer-supported learning environments that support different kind of collaborations. In their work, Price et Al. [34] investigated how different kinds of interactions can support different forms of reflection. Indeed being engaged in different multiple collaborations can entail different forms of interaction that provoke individuals to reflect in different way. The authors designed an outdoor learning experience to engage children in different collaborative interactions. Indeed the learning experience consisted of three different stages to support collaboration between children, children and their facilitators in different settings such as the classroom and the experience field. The objective was to make children develop and apply scientific enquire skills while learning about ecosystems and habitats. To support these interactions, learners were equipped with mobile technologies such as personal digital assistant (PDA) to display the information, GPS to track their movements during the exploration in the field, walkie-talkie for remote collaboration, and a device like a periscope to display virtual augmented information.

Choosing to analyze these systems has different reasons. In VIBES [44] was interesting to show how different representations of information support different forms of reflection. In particular among the different approaches proposed to visualize information, it is interesting to see how the emotions associated with a certain topic evolve over time. The attention on the other two systems resides in the fact that they highlight social and collaborative aspects of reflection. ArtLinks [16] enable individuals to reflect on and relate to others' emotions about exhibits. In the work presented by Price et Al. [34] in addition mobile and wireless technologies are used to foster reflection on collaborative experiences in outdoor setting.

2.3 Augmented Reality (AR)

Purpose of this section is to give a clear overview about Augmented Reality. Different issues of this technology will be analyzed. Rather than focus the attention on low level details such as visual information processing theories, we will shift it to the different fields of application in particular we discuss about its application in ubiquitous computing and collaborative settings.

2.3.1 Introduction

"Augmented reality (AR) refers to the mixing of virtual cues into the user's perception of the real three-dimensional environment" [27]. The success of the augmented reality is due to its ability to present different kind of information to the user overlaying them to the physical space. Its aim is to enhance user's perception at all senses as visual, audio and haptic [28]. User's environments are in this way augmented with visual cues such as virtual notes, videos, sounds, pictures, directions, 2D and 3D objects that are not physically visible. For these reasons its domain of application is extended to many fields ranging from medical and military applications, to tourism and interactive entertainments.

The first time the term Augmented Reality was cited was in a paper of 1992 by Caudell and Mizell as the results of their research in Boeing [14]. The system that they developed consisted of a head mounted apparatus used to show virtual instructions on its display in order to help worker engaged in the manufacturing and assembling process. Nevertheless even if the term "Augmented Reality" was not used before, previous researches were made during the 1960s as show the system proposed by Sutherland [43]. He and his colleagues developed a head mounted display (HMD) (Fig. 2.5) through which a user could see computer-generated images mixed with real objects [8].

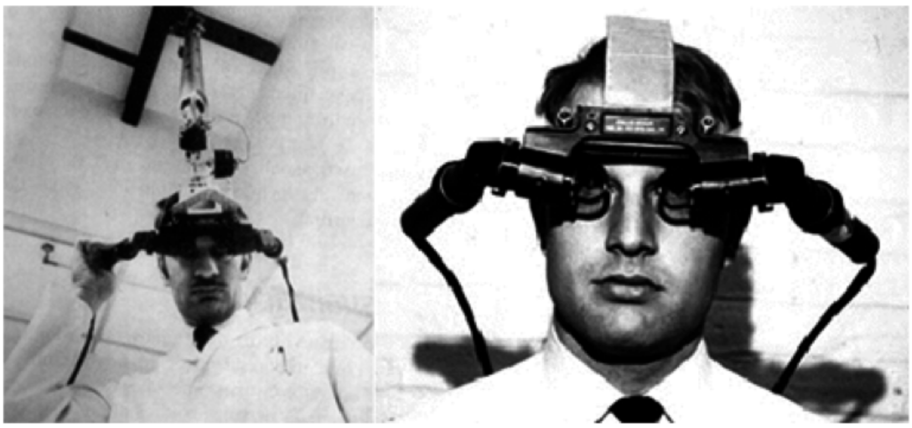


Figure 2.5: Sutherland HMD

The research on the HMDs and the interests arose from the potential of this technique found application in the military field. Pilots of the US

Air Force were equipped with helmets that enhanced their vision showing information overlaid on their goggles [21].

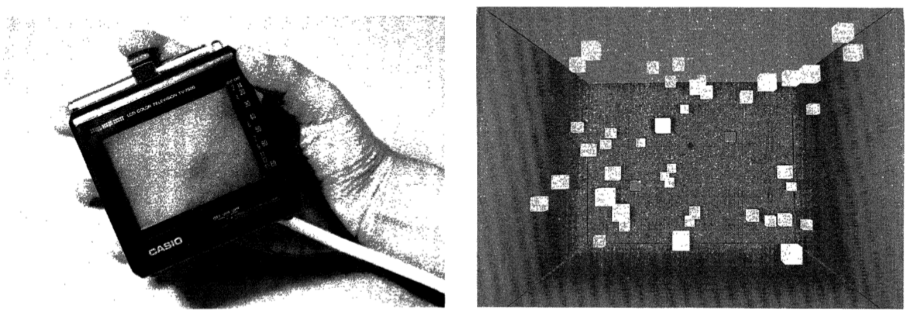
In the last years Augmented Reality have had more attention from scientists and industry, both for its multidisciplinary character and for the explosion of the number of mobile devices. One of the most important field in which Augmented Reality find its application is the Ubiquitous Computing. Indeed, in this field the Augmented Reality has found as an approach to specify next generation user interfaces [32].

Nowadays handheld devices have high computing capabilities and are provided with technologies such as camera GPS, compass, and gyroscope that enable to exploit Augmented Reality capability to support various activities such as work, leisure and navigation.

2.3.2 Mobile Augmented Reality

In the recent years handheld devices increased their computing capabilities. At the beginning mobile devices such as personal digital assistant (PDA) were designed just to run simple software such as organizers; nowadays, instead, they became multimedia devices able to run complex applications as well as 3D games [40]. Moreover today's handheld devices are provided with built-in cameras, GPS location system, compass and even with gyroscope that enable to take advantage from Augmented Reality capability in mobile settings.
Even before the advent of this new generation of mobile devices research on handheld Augmented Reality was made in order to replace obtrusive systems consisting of a backpack plus a head-mounted display with Tablet PCs. For this purpose Tablet PCs were used to display real-time augmented images captured with a camera linked to the Tablet. This approach had two benefits; on one hand it was cheaper than a traditional AR system; on the other hand

it was more comfortable [40]. One of the pioneering project in handheld Augmented Reality is Chamaleon [17]. This system uses a palmtop computer that is spatially aware. Through this system users could navigate in a virtual 3D space by changing the orientation and location of the palmtop (Fig. 2.3.2).



(a) Chameleon - Palmtop unit

(b) Chameleon - What the user sees in the 3D workspace

Figure 2.6: Chameleon

NaviCam [36] is a portable system that allows to build computer augmented environments. The system consists of a portable computer and a small video camera. It allows to recognize real-world situation and overlay contextual information to the camera feed. The recognition of world situation is made through color-codes. When a user look at a color-code the system recognize it by using the camera, then the image is processed and the information related to that color-code is retrieved and superimposed on the camera feed (Fig. 2.7).

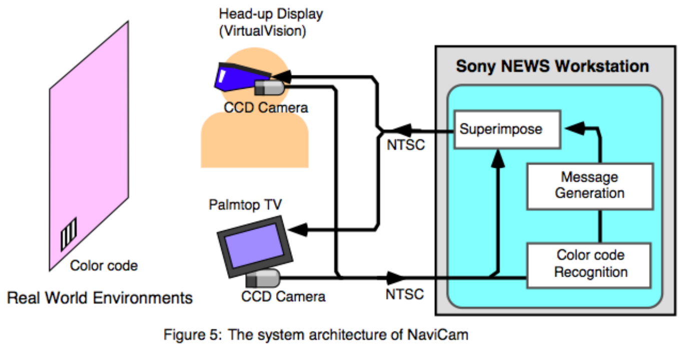


Figure 2.7: NaviCam Architecture

Figure 2.8 shows one of the application of NaviCam. The Active Paper Calendar enable users to see their personal schedule looking at the calendar.

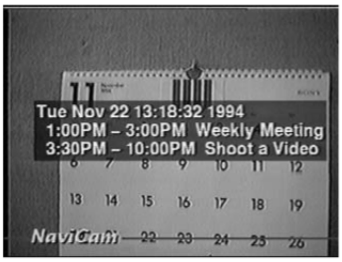


Figure 2.8: Visualizing user's personal schedule with NaviCam

CyPhone is a prototype of mobile phone designed to support multi-user multimedia services that are context-aware exploiting the augmented reality [35]. Context-awareness is achieved through GPS-based navigation and detection algorithms to recognize 3D landmarks in the environment. The system, consisting of a wearable computer and HMD glasses (Fig. 2.9(a)), is used to support personal navigation in an outdoor setting. In the scenario proposed the user is provided with virtual information that shows him/her the shortest routes about few location where the user can eat. Figure 2.9(b) shows the information provided by the system. On the left top corner a map shows the path to reach the destination through red dots, distance and estimated time of arrival are shown on the top right corner.

(a) CyPhone - System (b) CyPhone - Personal Navigation

Figure 2.9: CyPhone

In this work Augmented Reality will be used on a handheld device, in particular on a modern tablet-device.

2.3.3 Collaborative Augmented Reality

Since the recent interest and development, Augmented reality has become accessible to a wide public and one of its points of strength is to provide support for collaboration. Indeed for Billinghurst and Kato AR is suitable for co-located and remote collaboration since is able to address two major issue in CSCW: *enhancing the reality* and *seamlessness* [10]. Through the AR people engaged in collaborative work can experience the same workplace feelings with the advantage in this case that people can be virtual and remote [8]. From the work of Schmalstieg et al [40] different advantages in using AR for collaborative environments came out:

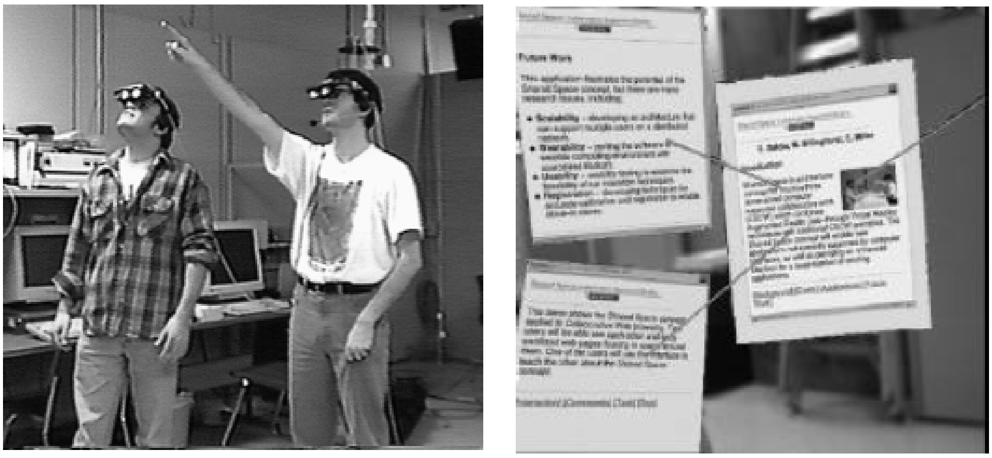
- *Virtuality:* Objects that do not exists or are not accessible in the real world.
- *Augmentation:* Virtual annotations used to augment real objects.
- *Cooperation:* Multiple user can interact in normal ways through voice, gestures and so forth.
- *Independence:* Users are enabled to move independently from the others.
- *Individuality:* Each users can have his personal view of data according with the application's needs and user's choice.

In the next section will be presented and analyzed AR systems that mediate collaboration in co-located settings since it is mainly the type of collaboration this work wants to support.

2.3.4 AR for Co-located Collaboration

Augmented Reality enables co-located users to have a shared understanding of the virtual cues associated with the physical environment and at the same time allow them to take advantage of the rich communication bandwidth we encounter in face-to-face interaction. In their work Kato and Billinghurst [10] present a collaborative three dimensional web browser that enable users to place and browse web pages around themselves in the physical space. Therefore web pages floating around users (Fig. 2.10(b)) who can interact with and discuss about them through natural gestures and communication (Fig. 2.10(a)).

This system consists of a head mounted display and it is characterized by a handless usage. Indeed web pages are selected looking at them and tasks



(a) Users' Interaction (b) Users' View

Figure 2.10: The Collaborative Web Space

such zooming in/out a page, loading external links and so forth are performed using voice commands. Moreover web pages are user-centered and float in the environments thereby they are not attached to real world locations.

Squire et al. in their work [42] propose different place-based augmented reality games for learning. Each game, based on the user's experience of places of Madison (state of Wisconsin) focus on designing solutions. Indeed players have to face emotional challenges, unlock new capabilities and design solutions to problems. These games are played in real locations such as historical sites, neighborhoods but using technology to add additional information to the real world. This information could be pictures, videos, texts and so forth that designers use to create game characters, events and even the real world. The information could be also tied to time and space thereby when a player arrives in a specific location like a statue, information on the sculptor, the history of the statue or other historical information related to that place could be presented to the user [42]. In this kind of games, augmented reality is not just a matter of displaying information. Since the games are thought to foster users problem solving, doing virtual investigation for example, the purpose of this games is to give users experiences and to let them learn through their work. A key role aspect on this game-based learning is that users can learn personifying a particular identity such as a journalist for example [41]. This hybrid identity between the player and his role in the game is, according to Squire et Al [42], an opportunity to perform and effective learning.

An example of this AR place-based games for learning is "Mad city mystery". It takes place in the Lake Mendota near the campus of University of Wisconsin-Madison. The players, organized in teams, have to solve a case of a mysterious death thereby during their investigations they have to interview characters, gather information and data, examine government documents to put together a case explanation. Therefore the players will develop scientific investigation, inquiry and argumentation skills and rather to guess the solution they have to think, form hypothesis and theories and gain evidences related to educational issues surrounding the place and related to local concerns (Fig. 2.11).

The location of the game is chosen "for its cultural and emotional significance" since the local political, scientific and cultural attention as well as its capabilities to support scientific understandings. Regarding the collaboration three different roles can be chosen by the players such as medical doctor, environmental specialist and government official each of which with different abilities and access to information. Non-players characters are also included in the game to make it as interactive as possible. For example a non-player character could be inquired in order to get clues such as the habits of the victim. During the game events are triggered allowing user to collaborate and enabling reflection in action. Indeed players are free to

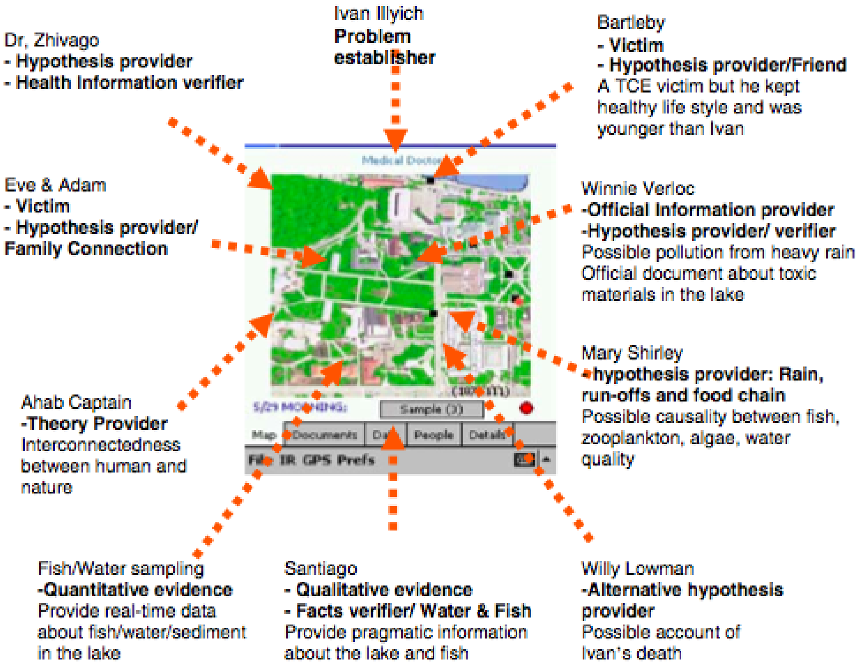


Figure 2.11: Mad City Mystery Gameboard, potential interactions and their functional/cognitive roles in the game.

decide with whom they should speak, requiring them to evaluate their information. Example of triggered events are new non-player characters that become available during the game. They are used to make people reflect on what they know and do not know, and according to Klopfer and Squire triggered events promote inquiry "as opposed to treasure-hunt" activity [22]. Team members are fostered to analyze evidences in order to form hypothesis as long as new evidences are collected. Therefore it is clear that a tight collaboration between players is necessary to put all the pieces of the puzzle together and solve the mysterious death. The "Mad City Mystery" game is conceived to be played on handheld devices (PDA, mobile phones) that are less obtrusive than head-mounted display. Virtual cues such as text, documents and multimedia are triggered by the application when the user is in a particular location determined by the use of the global positioning system (GPS).

The approach used in this work is to exploit the visualization of information provided by the Augmented Reality to provoke users reflect upon place-based information. The system proposed in this work is designed for handheld devices that according to Klopfer and Squire [22] bring the learner to place and present the following features:

- *Portability:* the ability to take computers off site.
- *Socioability:* the ease to exchange data and engage in face to face collaboration.
- *Context Sensivity:* the ability of the system to show real time data based on the location.
- *Connectivity:* ability of the system to be connected to other handheld devices, resources through network protocols.

Virtual information is overlaid on the real world as seen through the tablet-device camera and showed on the tablet-device screen. Since the information is place-based it has a strong degree of spatiality thereby it has a specific position in the physical space. Regarding collaborative aspects, cooperation mediated by Augmented Reality is mainly focused on co-located settings even if in some cases could be useful providing functionalities that enable cooperation between distributed user.

Chapter 3

Problem Elaboration and Analysis

This chapter aims at analyzing in a deeper manner the main problem and the related challenges that this work tries to address. Firstly the reader is provided with a case scenario in order to give a better understanding of the problem then follows an analysis of the issues and challenges related to it. The chapter ends with a list of requirements the system should fulfill.

The main objective of the project is to support reflection on collaborative work practices through a spatial representation information of work experience with the aid of mobile technologies. In particular it is investigated how the usage of the Augmented Reality can bring advantages for reflecting on that information which has a strong spatial dimension.

The main goal of this work can be broken down into two different subgoals. The first one is related to the collaborative construction of the information. Here falls issues regarding the types of information that are relevant to acquire and the definition of the different actors who interact with the system. The second one regards the visualization of the information acquired on which users will reflect upon. In this part falls issues related to the layering of the information that is a critical task due to the limitation of mobile devices screen.

Even the focus of this work is centered on the visualization of the information to support reflection, an analysis of the overall system it will be also provided.
Next section depict a possible case scenario to make the user aware of the main problem to address.
Section 3.2 deals with the problem of structuring information.
Section 3.3 deals with the reflective process and its collaborative aspects.
Section 3.4 covers challenges and issues that the system should address.
Section 3.5 ends the chapter providing a list of requirements that the system should fulfill.

3.1 Case Scenario

Here follows the scenario envisioned that aims at introducing challenges and issues to face and showing the interactions between the system and its users. The scenario is built on ethnographic researches that include interviews, users shadowing and observation on the field made by my supervisor Monica Divitini and my co-advisor Simone Mora during a big event in a large italian city. These researches aimed at investigating about planning, information relevant to acquire, mechanisms to support collaboration among co-workers and so forth.
The scenario will be illustrated through the use of storyboards in section 4.2.

"Different organizations such as Italian Civil Defense (Protezione Civile Italiana), local police (Polizia Municipale), Italian red cross (Croce Rossa

Italiana) and so on cooperate during the event to ensure people's safety for the entire progress of it. Everything must be planned down to the smallest details in order to avoid unpleasant and dangerous situations. In the planning phase, coordinators of Italian Civil Defense are provided with the risky zones that must be monitored. The coordinators are responsible to assign the resources to the zones to monitor; each of them coordinates about twenty volunteers organized in groups of two. By this time the task of the coordinator is to decide where to place the volunteers and who to pair up with whom based on their features such as experience, personality and so on. Stefano and Mario together with other members of the Italian Civil Defense monitor the risky zones as planned in the briefing phase of the event. During the event information is continuously exchanged in order to coordinate activities and to assure the safety of people. Information is acquired by individuals and also mediated by tools. Civil Defense staff and participants in the event can report unpleasant and dangerous situation sending different kinds of information to the system from their handheld device. This information can consist of textual messages, Tweets and pictures with an associated meaningful string. In addition the Civil Defense staff can send their GPS location to help the personnel in charge of the debriefing and reflection phase to keep track of their position when an event happened. Furthermore the system is able to capture data from environmental sensors such as noise level sensors and camera feeds from mobile and static checkpoints. The day after, Mario and Stefano, the coordinators in charge to reflect upon the event, go to the place where it happened. Stefano starts the reflective process choosing to navigate through the Tweets left the previous day by individuals and other Civil Defense members participating in the event. Among these tweets he decides to reflect on those described by the keyword Overcrowding. Therefore the sys-

tem suggests Stefano where this kind of information is located in the space. Stefano starts his reflective tour moving toward those Tweets. Stefano navigates through the tweets located in the space and reflect on them to understand what generated that unpleasant and dangerous situation. If the tweets only are not useful to understand what led to that situation he can choose to visualize pieces of information acquired from other source such as camera feeds, to have a better understanding. If this attempt is not useful he can move to an other zone suggested by the system where is present the same kind of information. Moreover he can leave a comment on or rate the information to make aware his colleagues. Stefano in addition wants to reflect on how the situation evolved over time. In particular he wants to understand how people moved in relation to that situation, check if after a certain time the situation is solved and where the personnel in charge of supervise that zone were located. Then he selects the time desired on a timeline on the screen. Stefano finds an interesting Tweets left by a participants in the event that it is helpful to understand the situation and decides to leave a comment so Mario can read and reflect on it. Stefano finds a tweet quite relevant to understand what happened the night before so he decides to rate it. On a scale to one to five he assigns four stars "" to the tweet. During the reflection session, Stefano notice a puzzle of information that makes him think that such situation happened due to variables not foreseen in the planning phase of the event. Therefore he decides to share the snapshot of this information together with his GPS location with the disaster manager in order to make him reflect about the risky points not covered.".*

3.2 Categorization of Information

The large amount of information collected during an event and the fact that the information will be visualized on a mobile device screen make the process of layering the information critical.

Two important aspects must be kept into account in that regard; firstly the users should not be overwhelmed with too information, secondly the system should enable the user to select and visualize different kinds of information depending on what he/she wants to reflect upon.

Visualization of information is a challenge in designing mobile applications due to the limitations of mobile devices such as the small size of their screens compared to the desktop ones. From a user point of view a key role problem could be the presentation of the information. The difficulty to navigate and search information in which users are interested in grows with the amount of information presented [15]. Avoiding to consider these aspects leads to make the application useless.

Based on what the user wants to reflect upon, information about work experiences can be categorized relying on the following factors:

- *Source of Information:* Categorization based on type of the source of information. As described in the scenario, information can come from participants in the event, applications supporting the work and sensors located in the environment.

- *Semantic of Information:* Categorization based on the semantic of the information according to the Boud's reflective model [11].

- *Place Conceptualization:* Categorization based on the different dimensions of Place stated by Casey in 1996 [13].

3.2.1 Source of Information

The scenario above described should make clear that during the event different types of information are constantly collected from different sources of information to achieve different goals. In this perspective layering the information based on these sources of information is helpful for supporting different kinds of reflection. Indeed an operator could reflect on information collected by participants in the event or on information mediated by other tools such as environment sensors to have different perspectives of what happened during the event.

Participants in the Event

Individuals engaged in the process of collecting information are people attending the event and different operators of the Italian Civil Defense. They act within the scenario in different contexts and they have different goals. People attending the event can, through their smartphone, send pictures, videos, textual messages or use tweets to inform about unpleasant and/or dangerous situations. Indeed it is easy in this kind of scenario that such situations happen. Members of the Italian Civil Defense in addition can send their GPS locations. Data from their stress sensors are also captured. GPS locations are helpful to understand where volunteers and other members were located when something happened while their stress level helps to figure out how it affected their work.

Environment/Third Party Applications

In the scenario envisioned information is not only generated by users but different pieces of information come also from the environment or applications that support the work. In the former case falls pieces of information such as pictures or camera feeds captured by mobile and static checkpoints. Furthermore data can be acquired from sensors such as noise and humidity sensors located in the physical space. In the latter case instead falls information such as the recording of radio communications during the event and the like. Information captured from these tools is very helpful as means to support user generated information. Indeed whereas information collected by individuals is not helpful to understand a situation the information generated by tools can be used to get a complete picture of that situation.

3.2.2 Boud's Reflective Model

A further approach for categorizing the information is based on the semantic of the information according to Boud's reflective model [11]. As mentioned in Chapter 2 in this model an experience is constituted by:

- *Behavior* in which learners are engaged.
- *Ideas* of which learners are aware.
- *Feelings* which the learners have experienced.

Using these different dimensions of experience make possible layer information acquired during the event as follows:

- *Behavior:* GPS tracks of emergency vehicles.
- *Ideas:* Suggestions on how to handle a situation differently.
- *Feelings:* Stress level of workers expressed with textual messages or emoticons.

3.2.3 Place Conceptualization

The focus of the work carried out during the course *TDT4520 Program and Information Systems, Specialization Project* was on the concept of *place*. The concept of place is largely discussed in literature since it is related to different study fields such as philosophy, geography, architecture, anthropology, environmental psychology [25] as well as Computer-Supported Cooperative Work [38]. Among the conceptualizations of place analyzed the one used in that work was the conceptualization elaborated by Casey in 1996 [13] and also used by Rossitto as an analytical and methodological framework for her field study in her Doctoral thesis [38]. The notion of place proposed is strongly based on people's experience and it is used to understand how people sense a places and attribute meanings to them. The concept of space and place are tightly related, a "place is not simply added on spaces as an extra layer; on the contrary, the spatial dimension is subsumed into the place" [38]. According to Rossitto, place it's emergent and arises from people's experience of it along four interrelated dimensions:

- *A Psychological dimension,* including individuals' memories, values and toughts;
- *A Physical dimension,* that is the geometrical and the physical structure of space;
- *An Historical dimension, encompassing* the past of a place and the memories of it;
- *A Social dimension,* presence of other people, rules, norms and other cultural aspects that might shape and determine individuals' behaviors.

Information included in these dimensions are not defined a priori, but emerge from the activities and experiences of people's who "live" the place, through space and time. An important aspect of Casey's conceptualization is also the dynamism of place. It is not perceived in the same way for all the individuals' but rather it changes depending on the ongoing activities, users needs and situations. The reason of choosing this approach was motivated by the fact that the dimensions of experience of place are well defined, even if they does not live a priori. It means that it can be possible to turn a space in a place enriching it with information along these dimensions of experience. Furthermore this approach could allow a mapping between each dimension of experience of place to its relative Augmented Reality information layer allowing users to explore physical space through the mobile device and enabling them to co-construct information that turn the space in a place, any-time.

It is clear that the information collected during the event composes a place, since it consists of pieces of information that are related to the experience of physical space. In this perspective the information can be categorized along the different dimensions of place stated by Casey in his work.

3.3 The Reflective Process

As mentioned in Chapter 2 the kind of reflection this work wants to support is *reflection-on-action*, that is, reflection that take place after an activity is occurred. Therefore the reflective process should start with a certain distance from the event. Furthermore the work aims at supporting collaborative, planned outdoor activities. In the scenario above described emerges that the process of collecting information during the event involves different actors working in different contexts. For that reason even when the reflective process is made by just an individual it is collaborative since it relies on information that are collected by different people.

3.3.1 Collaborative Aspects

So far only collaborative aspects related to collecting information emerged. Even during the reflection phase it is important to foster collaboration among individuals in order to create a shared understanding of what happened during the event. In this perspective the system should provide the users with different mechanisms to support different kinds of collaboration depending on the degree of "situatedness" of the individuals. If for example users are co-located they could communicate through synchronous or asynchronous messages such as instant messaging or prioritizes messages. If users are co-located but distributed in time the system can foster their collaboration enabling them to interact with the collected information. In this perspective users can leave comments to pieces of information or rate them. Moreover in some cases it could help using voice over internet protocol (VoIP) calls and/or sharing screen view with other colleagues in order to get feedbacks and opinions about certain situation/location.

3.4 Challenges

In designing the system there are different challenges that need to be addressed. It is crucial that pieces of information collected during the event are well contextualized provided that people have to reflect on it. The system has to be designed to reduce as much as possible misleading information. Indeed if the user reflects on information that he/she thinks is referred to a context but in reality is not the reflection phase would be without any sense.

In addition the system should provide the user with functionalities that make him/her reflect along different dimensions.

3.4.1 Relevance of Information

It is very easy that information collected by the users is very similar for a certain situation/location. Since the kind of event envisioned in the scenario could be attended by hundreds or thousands people it is easy that a dangerous or unpleasant situation will be reported by a lot of individuals with the result of having most of the information similar for that situation. Since the limited screen dimensions of a tablet-device it is important that the user is not overwhelmed with pieces of information that are similar (Fig. 3.1). Another issue to consider regards the association of the information to a place and the related level of granularity that should be considered. If for example an individual takes a picture to report something that happened in a certain point of the square, who is reflecting on that information does not know if the person wanted to capture a detail in the square or wanted to refer to the whole location (Fig. 3.2).

In order to face these challenges it should be considered a pre-processing phase in which the system elaborates the information collected before visualize it. Whereas Tweets are automatically categorized specifying an *hashtag* *"#"*, used to mark keywords or topics in a Tweet [1], it is not possible to do the same with media content such as pictures and videos. A possible approach consists of enabling the user to associate a short caption to media types and use information retrieval techniques (IR) to extracts meaningful keywords that will be used to categorize those kinds of data.

On one hand this approach helps to reduce the visualization of similar

[1] http://support.twitter.com/entries/49309-what-are-hashtags-symbols

Figure 3.1: Similar Information for a Specific Situation

information since fragments of the information can be clustered in a specific category. Therefore only categories will be shown on the device screen. In case the user selects one category he/she could navigate through the pieces of information that compose it. On the other hand it helps to reduce misleading information provided that the user specifies what he/she wants to refer to through the use of those captions.

3.4.2 Temporal Dimension

In addition to the spatial dimension, time plays a key role in the reflective process. Whereas sometimes it might be enough reflecting on all the information connected to a place in some cases it could be useful to capture the evolution of the situation. For example who is performing the reflection wants to have an overview before, during and after a certain event happened to see how a certain situation evolved over time. For that purpose the user should be provided with a mechanism that enable him/her to perform a time-based navigation of the information.

Figure 3.2: Granularity of the Information - In red the Detail of the location

3.4.3 System-Assisted Reflection

Seeking for information located in the physical space could prove a difficult task without some aids from the system. Indeed exploring a space through the device in order to find relevant information could not be a natural operation for many users and in some cases they could miss relevant information for a certain reflection session. In this perspective, the system should assist the user in exploring the space and it should suggest him/her where relevant information are located to make the user reflect on that information. The system should not only provide support along the spatial dimension but it should consider other dimensions such as time revealing pieces of information that occurred in a certain period of time and connection among the information suggesting the user where other similar information is located. For example information with similar tag in case the user is reflecting on information categorized by its tag.

3.5 Requirement Specification

This section analyzes both functional and non functional requirements that the system should have to better support the elaboration and the implementation of the final solution.
Each requirement is described by a tern (*ID, Description, Priority*) where:

- ***ID:*** unique identifier associated with the requirement.
  Naming requirements abide by the following rules:

  - **FR:** states Functional Requirement.
  - **NFR:** states Non-Functional requirement.

  Moreover for functional requirements tags such as **D, GF, DC, DN, SC** are used to point out:

  - **D:** Device's requirements.
  - **GF:** General functionalities of the system.
  - **DC:** Data Capture requirements.
  - **DN:** Data Navigation requirements.
  - **SC:** Supporting Collaboration requirements.

  For non-functional requirements tags such as **PT, US, SC, PR, D, G** are used to point out:

  - **PT:** System Portability.
  - **US:** System Usability.
  - **SC:** System Security. Include privacy issues.
  - **PR:** System Performance.

   - **D:** Device non-functional requirement.
   - **G:** General non-functional requirement.

- ***Description:*** brief explanation of the requirement.
- ***Priority:*** degree of importance of requirement's priority stated by *High, Medium, Low.*
   - **High:** The requirement must be met by the system.
   - **Medium:** The requirement should be met by the system.
   - **Low:** The requirement should be met by the system, but is not a priority.

3.5.1 Functional Requirements

Table 3.1: System Functional Requirements

ID	Description	Priority
	General Functionalities	
FR-GF1	User must be able to log in the mobile application.	H
FR-GF2	The system must pre-process the information acquired in order to reduce similarities and misleading information.	H

Table 3.2: System Functional Requirements

ID	Description	Priority
	Data Capture	
FR-DC1	User must be able to send text messages and media types such as pictures and videos to the Application Server.	H
FR-DC2	User, if Civil Defense staff, must be able to send his/her GPS location to the Application Server.	L
FR-DC3	System should be able to capture data from sensors and third party systems.	M
	Data Navigation	
FR-DN1	User must be able to visualize pieces of information selecting the desired type.	H
FR-DN2	User should be able to visualize different types of information at the same time.	H
FR-DN3	User should be able to visualize pieces of information based on their time of acquisition.	H
FR-DN4	User should be able to visualize pieces of information based on their rating.	L
FR-DN5	System should be able to suggest the user where the desired type of information is located.	H
	Support for Collaboration	
FR-SC1	User must be able to leave comments on pieces of information.	H
FR-SC2	System should notify users when someone leave a comment on a piece of information.	M
FR-SC3	User must be able to rate pieces of information.	H
FR-SC4	System should notify users when someone rate a piece of information.	M
FR-SC5	User should be able to share his/her screen view with other users.	H

3.5.2 Non-Functional Requirements

Table 3.3: Non-Functional Requirements

ID	Description	Priority
Portability		
NFR-PT1	Client application must run on tablet-devices.	H
NFR-PT2	The user should be able to carry around the device easily.	H
Usability		
NFR-US1	User must be able to send data in a easy way to the Application Server.	H
NFR-US2	User must be able to easily select the type of information desired.	H
NFR-US3	User must be able to leave comments in a easy way.	H
NFR-US4	User must be able to rate pieces of information in a easy way.	H
NFR-US5	User must be able to easily share a snapshot of the view.	H
Performance		
NFR-PR1	User must be able to send data in a quick way to the Application Server.	H
Security		
NFR-SC1	System must not be able to capture personal information from the participants in the event.	H
NFR-SC2	Participants in the event must not be able to retrieve data from the Application Server.	H
Device		
NFR-D1	Tablet device must support Augmented Reality visualization of information.	H

Table 3.4: Non-Functional Requirements

ID	Description	Priority
General		
NFR-G1	System must agree to a common data exchange format in order to support interoperability.	H
NFR-G2	Clients and third party systems must agree to a common data model in order to support system source data extensibility.	H
NFR-G3	System should avoid possible overhead and network latency during the exchange of data.	M

Chapter 4

Use Cases and Storyboards

This section aims at depicting a story where real users are involved in with the purpose of providing the reader with a better understanding of the interactions that exist between those users and the system. Firstly it is provided a brief description of the actors participating in the event then general information about the event such as the different kinds of data captured during its duration. Secondly it is depicted how the users responsible for the reflective process retrace the important facts happened during the event highlighting the usage of the system to accomplish their tasks.
Pictures used to describe the event are provided by courtesy of "i-maginary"[1].

4.1 Personas

In system design is common to describe the interactions between the user and the system using the metaphor of *"actors"*. However referring to that modeling construct could be too general and for each role identified there can be several different types of users [31]. For example users can be differ in

[1] http://www.i-maginary.it/

their knowledge, skills and the like. Recently it has been introduced the use of *personas* within the scenarios to overcome the limit of the actor construct previously mentioned. This design technique use fictional people to represent specific users which have names, occupations, skills, abilities and so forth. The advantage to use personas is that they are used as a mean to reason about a solution. Indeed they can be directly referred by name when discussing a scenario making easier, for example, think if a function could be used by "John" than all the users represented by a role.

In this work the personas defined are two Civil Defence coordinators. Even if more kinds of actor such as volunteers or disaster managers play an important role within the scenario the focus is on the debriefing and reflection phase that is made mainly by coordinators.

4.1.1 Mario - Coordinator

Mario is an Italian Civil Defense coordinator of 65 years old. He does not have an high-school education, indeed when he was child his father died and, as the oldest of his two brother, he has to take care of his family thereby left the school at the age of 13. After a long career as a member of the Italian alpine rescue team he went to retirement five years ago and by this time he decided to involve himself with social services because he loves to help people, that is what he has done for his entire life. Therefore he joined the Italian Civil Defense and after some years of practice as a volunteer he was promoted to coordinator two years ago. Things are now different than he was a volunteer. Indeed as a coordinator he has more responsibilities included dealing with bureaucracy problems and he has to do with computers, mobile devices and the like that make him feel uncomfortable. Indeed one of his major worries is others' opinion on his work due to his low skill in using those devices that appear very easy to work with for the younger fellows.

4.1.2 Stefano - Coordinator

Stefano is an university student worker of 30 years old. He studies Project Management and at the same time he works as a bartender in a friend's of him club to pay his studies and to avoid to burden on his family. He started his voluntary work at the Italian Civil Defense as a joke to please his grandfather already member since long time. Even he liked this job he had some moments of hesitation due to the lack of time to devote to it. An hesitation that disappear when he knew a nice and pretty girl during an event and he discovered that she is a member of the Italian Civil Defense since some years. It was love at the first sight so he decided to continue with his job with the hope to conquer her heart. He is not very experienced, indeed he was promoted to coordinator after just one year as a volunteer for his abilities. Stefano's personality is characterized by a great passion for people and life while sports, music and computers are his interests.

4.2 The Event

As previously stated, this work wants to support reflection on *important events*, that is events that are particularly complex to organize in terms of security, mobility, health care and so forth and in particular it focus on a scenario of crowd management. Information about the scenario are based on observations that have been collected during a big event in a big Italian city.

Different organizations such as Italian Civil Defense *("Protezione Civile Italiana")*, local police *("Polizia Municipale")*, Italian red cross *("Croce Rossa Italiana")* and so on cooperate during the event to ensure people's safety for the entire progress of it. Everything must be planned down to the smallest details in order to avoid unpleasant and dangerous situations. In the planning phase, coordinators of Italian Civil Defense are provided with the risky zones that must be be monitored (Fig. 4.1). The coordinators are responsible to assign the resources to the zones to monitor; each of them coordinates about twenty volunteers organized in groups of two (Fig. 4.2). By this time the task of the coordinator is to decide where to place the volunteers and who to pair up with whom based on their features such as experience, personality and so on.

Figure 4.1: Example of Zone to be Monitored

Figure 4.2: Italian Civil Defense Volunteers

4.3 Storyboards

Each storyboard is described by a short story that depict what is happening in the storyboard frame. For storyboards related to the reflection session GUI mockups of the application are also provided. Table 4.1 outlines how storyboards are described in a formal way using a template defined within MIRROR[2] project. Each storyboard is named in the following way:
<ScenarioName>_Storyboard_<StoryboardName>.
The uppermost part of the table categorizes the storyboard.

- *Process:* Specifies if the process is individual or collaborative.

- *Scope:* Specifies the scope to be individual work, teamwork or management / organizational learning. This field is relevant only for the reflection session.

[2] http://www.mirror-project.eu/

- *Content:* Specifies the content to be own experience, other's experience and/or best practices / formal work process. This field is relevant only for the reflection session.

Furthermore requirements to accomplish the task are specified as well as the type of the requirements. Assumptions about the domain have also to be stated.

Table 4.1: ScenarioName_Storyboard_StoryboardName

Please put 'X' in tags that appear in this slide		**X**
Process	Individual	
	Collaborative	
Scope	Individual Work	
	Teamwork	
	Management / Organizational Learning	
Content	Own Experience	
	Others' Experience	
	Best practice / Formal work process	

Requirements	**Req. Type**
Requirement needed in order to accomplish the task.	Type of Requirement

Assumptions
Assumptions to consider in order to accomplish the task.

4.3.1 Storyboard 1 - Data Capture

Stefano and Mario together with other members of the Italian Civil Defence monitor the risky zones as planned in the briefing phase of the event. During the event information is continuously exchanged in order to coordinate activities and to assure the safety of people. Information is acquired by different tools (Fig. 4.5(b)). Civil Defense staff and participants in the event can report unpleasant and dangerous situation sending different kinds of information to the system from their handheld device. This information can consist of textual messages or pictures with an associated meaningful string. In addition the Civil Defense staff can send their GPS location to help the personnel in charge of the debriefing and reflection phase to keep track of their position when an event happened. Furthermore the system is able to capture data from environmental sensors such as noise level sensors and camera feeds (Fig. 4.4) from mobile and static checkpoints (Fig. 4.3.1).

(a) Radio (b) Handheld Device

Figure 4.3: Third Party Tools

Figure 4.4: Camera Feeds from Third Party Tools

(a) Mobile Checkpoint

(b) Static Checkpoint

Figure 4.5: Mobile and Static Checkpoints

Table 4.2: CrowdManagement_Storyboard_DataCapture

Please put 'X' in tags that appear in this slide		**X**
Process	Individual	
	Collaborative	X
Scope	Individual Work	
	Teamwork	
	Management / Organizational Learning	
Content	Own Experience	
	Others' Experience	
	Best practice / Formal work process	

Requirements	**Req. Type**
Client application must run on handheld devices.	**Portability**
User must be able to send text messages to the Application Server.	**Functional**
User must be able to log in the handheld application.	**Functional**
User must be able to send pictures with an associated meaningful string to the Application Server.	**Functional**
User, if Civil Defense staff, must be able to send his/her GPS location to the App. Server.	**Functional**
User must be able to send data in a easy way to the Application Server.	**Usability**
User must be able to send data in a quick way to the Application Server.	**Performance**
System should be able to capture data from sensors and third party systems.	**Functional**
System must not be able to capture personal information from the participants in the event.	**Security**

Assumptions
User has installed the client application.
User has started the client application.
User has logged in.

4.4 The Reflective Process

4.4.1 Storyboard 2 - Navigation

The day after, Mario and Stefano, the coordinators in charge to reflect upon the event, go to the place where it occurred. Stefano starts the reflection session choosing to navigate through the *Tweets* left the previous day by individuals and other Civil Defense members participating in the event. Among these tweets he decides to reflect on those described by the keyword *Overcrowding*. Therefore the system suggests Stefano where this kind of information is located in the space. Stefano moves toward these Tweets.

Stefano navigates through the tweets located in the space and reflect on them to understand what generated that unpleasant and dangerous situation. If the tweets only are not useful to understand what led to that situation he can choose to visualize pieces of information acquired from other source such as camera feeds, to have a better understanding (Figure 4.6). If this attempt is not useful he can move to an other zone suggested by the system where is present the same kind of information. Moreover he can leave a comment on or rate the information to make aware his colleagues (Figure 4.7).

Stefano in addition wants to reflect on how the situation evolved over time. In particular he wants to understand how people moved in relation to that situation, check if after a certain time the situation is solved and where the personnel in charge of supervise that zone were located. Then he selects the time desired on a timeline on the screen (Figure 4.8).

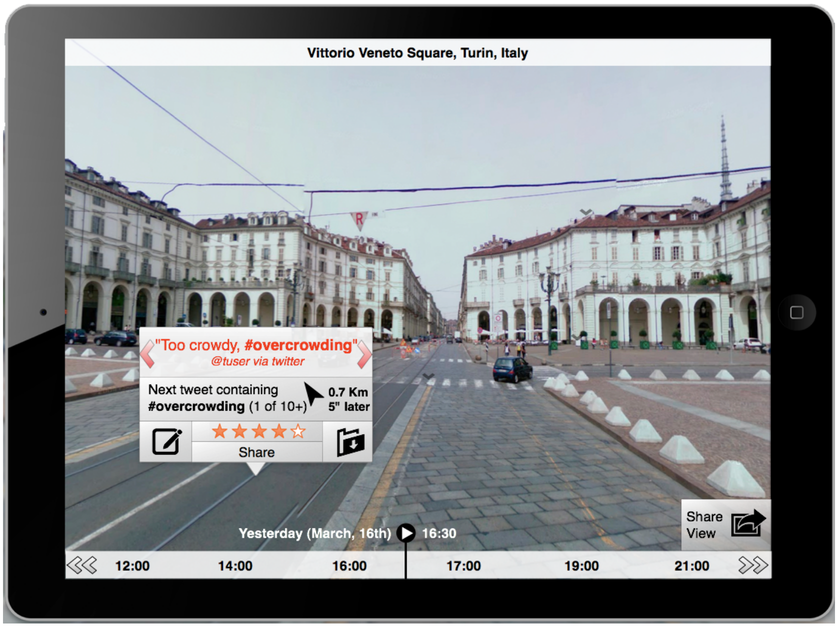


Figure 4.6: Storyboard 2 - Navigation - Tweet

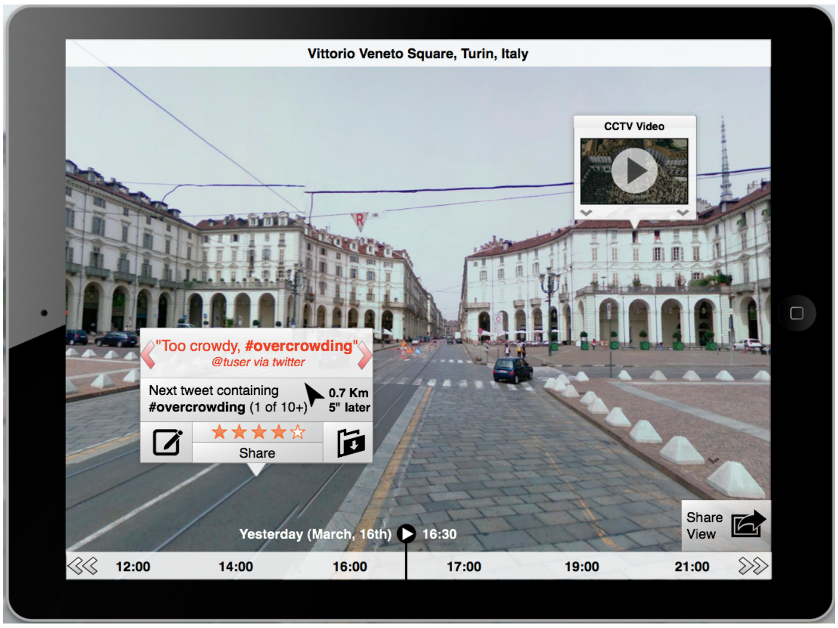


Figure 4.7: Storyboard 2 - Navigation - Camera Feed

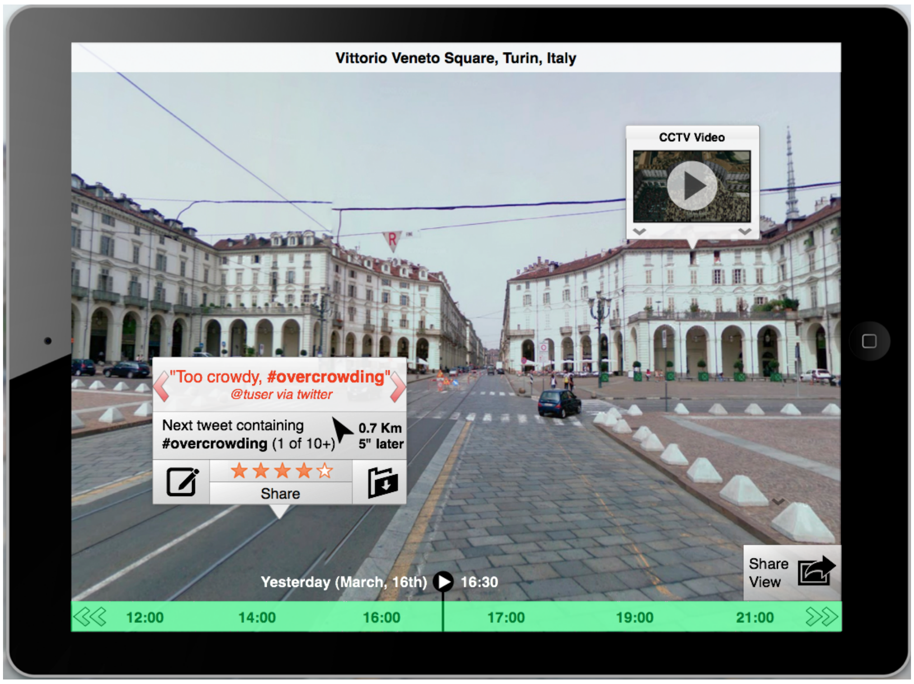


Figure 4.8: Storyboard 2 - Navigation - Timeline

Table 4.3: CrowdManagement_Storyboard_Navigate_by_Tags

Please put 'X' in tags that appear in this slide		**X**
Process	Individual	X
	Collaborative	
Scope	Individual Work	
	Teamwork	X
	Management / Organizational Learning	
Content	Own Experience	X
	Others' Experience	X
	Best practice / Formal work process	

Requirements	**Req. Type**
Client application must run on handheld devices.	**Portability**
The user should be able to carry around the device easily.	**Portability**
User must be able to visualize pieces of information selecting the desired type.	**Functional**
User should be able to visualize different types of information at the same time.	**Functional**
User should be able to visualize pieces of information based on their time of acquisition.	**Functional**
User should be able to visualize pieces of information based on their rating.	**Functional**
User must be able to easily select the type of information desired.	**Usability**
Participants in the event must not be able to retrieve data from the Application Server	**Security**
System should be able to suggest the user where the desired type of information is located.	**Functional**

Assumptions
User has started the client application and has logged in.
User has retrieved the information for the event.

4.4.2 Storyboard 3 - Leave Comment to Info

Stefano finds an interesting tweets left by a participants in the event that it is helpful to understand the situation and decides to leave a comment in order to make Mario reflect on it.

Table 4.4: CrowdManagement_Storyboard_LeaveCommentToInfo

Please put 'X' in tags that appear in this slide		**X**
Process	Individual	
	Collaborative	X
Scope	Individual Work	
	Teamwork	X
	Management / Organizational Learning	
Content	Own Experience	
	Others' Experience	X
	Best practice / Formal work process	

Requirements	**Req. Type**
Client application must run on handheld devices.	**Portability**
The user should be able to carry around the device easily.	**Portability**
User must be able to leave comments on pieces of information.	**Functional**
User must be able to leave comments in a easy way.	**Usability**
System should notify users when someone leave a comment on a piece of information.	**Functional**

Assumptions
User has started the client application and has logged in.
User has retrieved the information for the event.

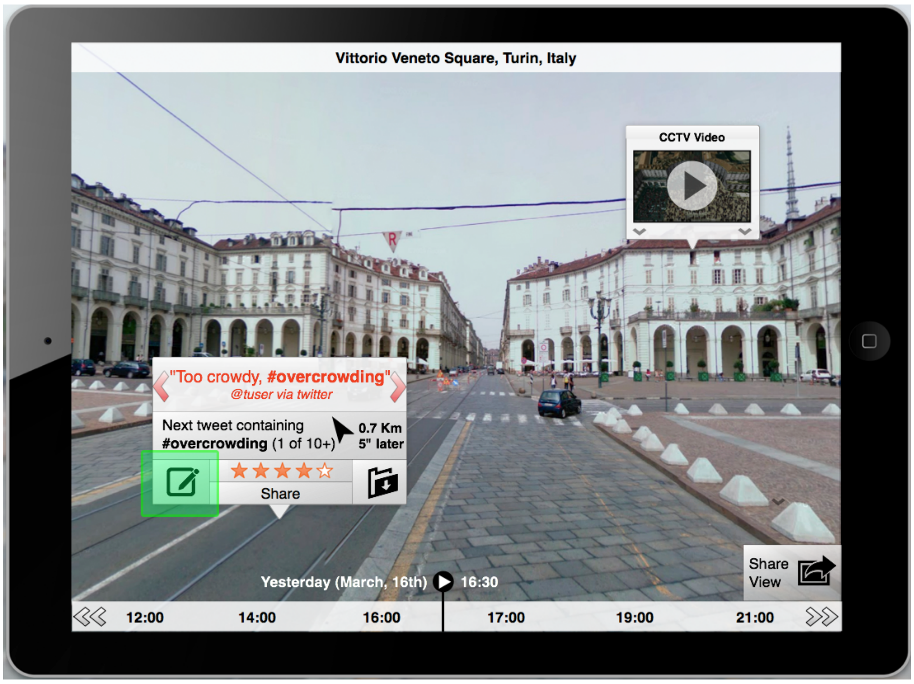


Figure 4.9: Storyboard 3 - Leave Comment to Info

4.4.3 Storyboard 4 - Rate Info

Stefano finds a tweet quite relevant to understand what happened the night before so he decides to rate it. On a scale to one to five he assigns four stars "*" to the tweet.

Table 4.5: CrowdManagement_Storyboard_RateInfo

Please put 'X' in tags that appear in this slide		**X**
Process	Individual	
	Collaborative	X
Scope	Individual Work	
	Teamwork	X
	Management / Organizational Learning	
Content	Own Experience	
	Others' Experience	X
	Best practice / Formal work process	

Requirements	**Req. Type**
Client application must run on handheld devices.	**Portability**
The user should be able to carry around the device easily.	**Portability**
User must be able to rate pieces of information.	**Functional**
User must be able to rate pieces of information in a easy way.	**Usability**
System should notify users when someone rate a piece of information.	**Functional**

Assumptions
User has installed the client application.
User has started the client application.
User has logged in.
User is located in the place where the event happened.

Figure 4.10: Storyboard 4 - Rate Info

4.4.4 Storyboard 5 - Sharing a View

During the reflection session, Stefano notice a puzzle of information that makes him think that such situation happened due to variables not foreseen in the planning phase of the event. Therefore he decides to share the snapshot of this information together with his GPS location with the disaster manager in order to make him reflect about the risky points not covered.

Table 4.6: CrowdManagement_Storyboard_Share_Views

Please put 'X' in tags that appear in this slide		**X**
Process	Individual	
	Collaborative	X
Scope	Individual Work	
	Teamwork	X
	Management / Organizational Learning	
Content	Own Experience	X
	Others' Experience	X
	Best practice / Formal work process	

Requirements	**Req. Type**
Client application must run on handheld devices.	**Portability**
The user should be able to carry around the device easily.	**Portability**
User should be able to visualize different types of information at the same time.	**Functional**
User must be able to easily share a snapshot of the view.	**Usability**
Participants in the event must not be able to retrieve data from the Application Server.	**Security**

Assumptions
User has started the client application.
User has logged in.
User has retrieved the information for the event.

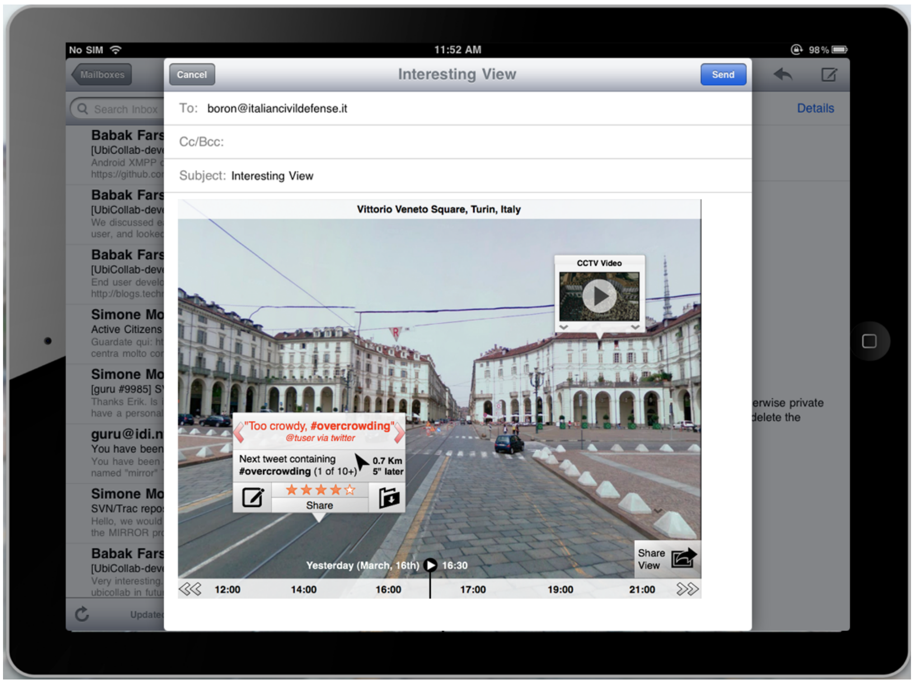


Figure 4.11: Storyboard 5 - Share View

Chapter 5

Solution Proposal and Implementation

Purpose of this chapter is to give a description of the solution proposal and its implementation details. Chapter starts describing the system overall architecture both for the acquisition and reflection phases in section 5.1. The rest of the chapter is focused on the implementation of the solution proposal and it is organized as following:
Section 5.2 describes tools and technologies used in the course of this project.
Section 5.3 provides the design of the system.
Section 5.4 provides the overall functionalities of the application. Each function is described in a detailed way and related screenshots are provided.

5.1 System Overall Architecture

This section describes a high-level architecture for the system studied. The purpose of this section is to give an overview of how the system works. Despite the focus of the thesis is on the visualization of collected data an architectural overview of the acquisition phase is also given. As previously explained, during the event information is collected by different users and sometimes it is mediated by different tools. Figure 5.1 shows the high-level architecture for the phase of data acquisition.

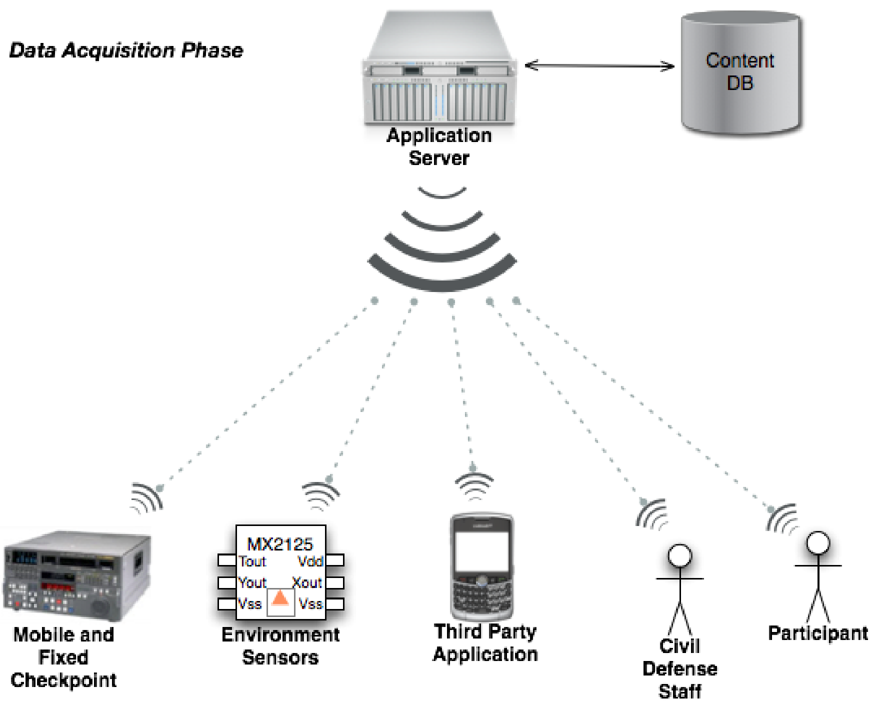


Figure 5.1: System Overall Architecture - Data Acquisition Phase

During the event data are collaboratively collected and are sent to the Application Server. Data are collected by individuals and other tools such as environment sensors and applications to support the work. Afterwards the information is pre-processed in order to remove misleading information and to cluster similar one. At this point information is ready to be fetched by users engaged in the reflection session.

The architectural diagram in Figure 5.2 shows how the system works during the reflection session. This phase starts when members of the Italian Civil Defense, being located in the place where the event occurred, run the Augmented Reality application later on explained. When the application is started, data are fetched from the content DB and sent by the application server to the users. Based on user's location, information is shown on the tablet-device screen.

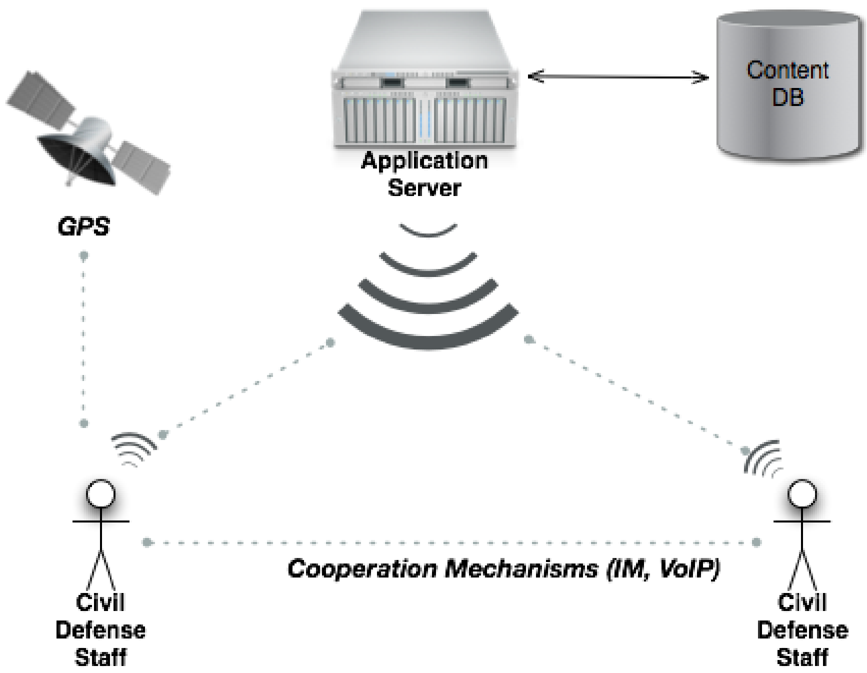


Figure 5.2: System Overall Architecture - Reflection Phase

It is very important to support collaboration among users during the reflection session. The dotted line between the users in the diagram shows how users are supported by cooperation mechanisms such as VoIP calls, instant messaging and the like.

5.2 Tools and Technologies

This section will present tools and technologies used during the project for the implementation of the prototype. Since the application will be developed for the iPad 2[1] device it will be explained its operating system, the programming language and the designed patterns used to develop the application.

5.2.1 iOS

iOS is the operating system of the iPad, iPhone and iPod touch devices. The operating system acts as a layer between the hardware and the applications that run on the device. This abstraction enable developers to write applications that works on devices with very different hardware capabilities. Indeed applications do not communicate directly with the hardware but the communication is achieved using a set of system interfaces that enable developers to not care about hardware changes [2].

iOS technologies implementation can be logically layered as following:

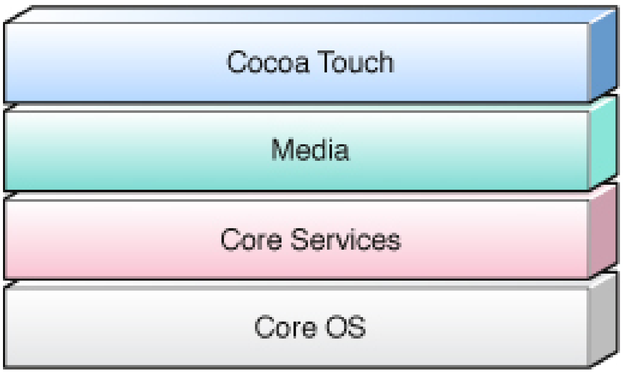


Figure 5.3: iOS Technologies Implementation

At the bottom of the stack there are technologies and services closer to

[1] http://www.apple.com/ipad/specs/

the hardware while those at the top are closer to the end-user. For example at the lower layers there are services and technologies on which most of the applications rely on, such as interfaces for accessing files, low-level data types, network sockets, support for multithreading, location services and the like. Most of these interfaces are C-based. The upper layers contain sophisticated technologies and services whose interfaces are based both on C and Objective-C. Media layer for example contains services and technologies to support audio and video, 2D and 3D drawing like OpenGL ES[2], Quartz[3] and so forth.

Cocoa Touch is the fundamental layer used by the application to be developed and most of the technologies in this layer are written in Objective-C. Here fall services and technologies that provide object-oriented support for network operations, collections and the visual infrastructure for the application such as windows, views, buttons, controls and controllers to deal with those objects. Frameworks to deal with device sensors such as accelerometer or with user's contacts are provided in this layer.

iOS furnishes a software development kit (SDK) that provides all the developer needs to develop, test and install native applications. Native applications are written using iOS frameworks and Objective-C programming language.

5.2.2 Objective-C

Objective-C is the native language for building Mac OS/iOS based applications. The Objective-C language extends the standard ANSI C language

[2] http://www.khronos.org/opengles/

[3] http://developer.apple.com/technologies/ios/graphics-and-animation.html

by adding the concept of object-oriented programming. It is a simple and powerful computer language that allows developers to write sophisticated applications. Objective-C language does not create a new language but it is a small set of extension of the C language [12]. These extensions are mostly based on one of the first object-oriented programming languages, Smalltalk [5].

5.2.3 Xcode

Xcode is a set of tools that enable developers to create applications for Mac, iPhone and iPad. Xcode provides an integrated development environment (IDE) that assists developers in writing and debug source code. Among its tools it integrates *Interface Builder* to design user interface components, *Instruments* a tool to analyze in a visual way application performance and tools for supporting source code versioning through Git and Subversion [6].

5.2.4 MVC Pattern

The Model-View-Controller (MVC) is a design pattern used for designing Cocoa applications. MVC provides a way to divide in a logical way the source code of graphical user interface (GUI) applications [33]. It consists of three main elements:

- *Model:* Classes that hold data of the application.
- *View:* It represents the screen view. Windows, controls, graphical user interface components which the user can interact with.
- *Controller:* It represents the application logic. It decides how to handle user's input and bind together the model and the view.

Purpose of the MVC pattern is to increase flexibility and reuse by decoupling the user interface from the model and the controller. In this perspective an object that implements a button should not contain the logic to process data when the button is pressed. In this way it is possible to create generic objects that can be used in different applications.

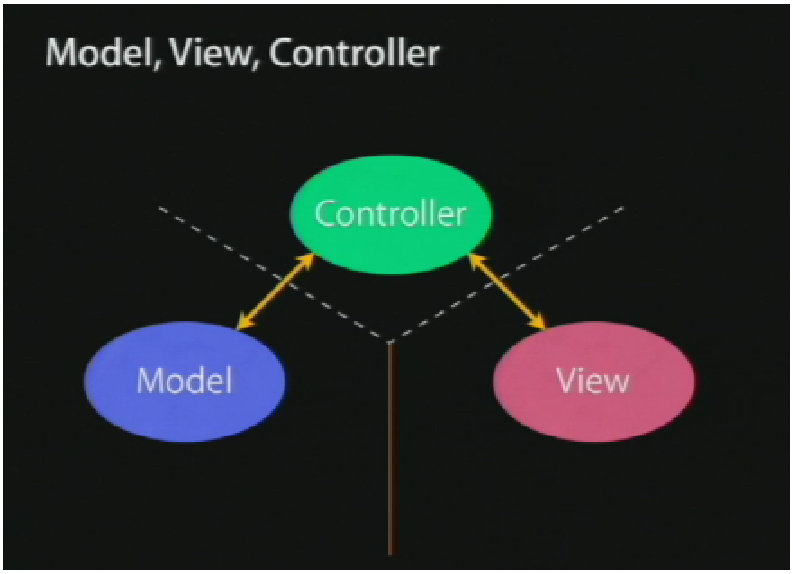


Figure 5.4: Model-View-Controller Design Pattern

Figure 5.4 shows how the pattern works. View and model are decoupled using a subscribe/notify protocol. The content of the view must reflect the state of the model. When data of the model changes, the model notifies the view that depend on it. Then the view updates itself [18].

5.2.5 Delegation Pattern

"A delegate is an object that is given an opportunity to react to changes in another object or influence the behavior of another object" [18]. The idea behind is that two objects cooperate to perform a task (Figure 5.5).

An object exposes its behavior to the outside but in reality it delegates the responsibility of performing that behavior to an other object, the delegate. The object, which has a reference of the delegate object, sends messages to its delegate when needed. The messages can inform the delegate that something happened, in that case the delegate is given the opportunity to perform a task or can request the delegate for critical information.

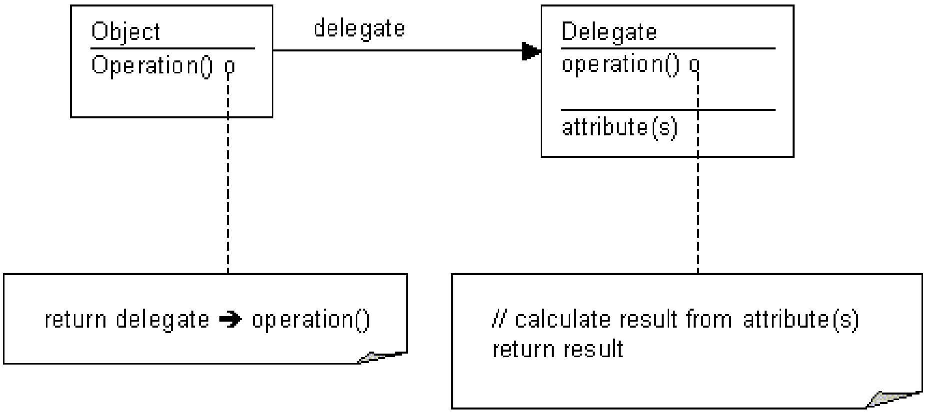


Figure 5.5: Delegation Design Pattern

5.3 AR Application Overview

Purpose of this section is to provide an overview of the Augmented Reality application developed.

5.3.1 AR Application Architecture

The application developed is based on the Augmented Reality toolkit proposed by Allan Alasdair in his book [7]. The contribution of this thesis, indeed, is not related to the Augmented Reality itself as means to visualize information. It deals with exploiting this powerful interface to help users reflect upon information collected by providing mechanisms that facilitate the reflective process. That is why there are no reasons to recoding the wheel. Figure 5.6 shows the architecture of the ARView application proposed by Alasdair on which the architecture of the prototype implemented in this work relies on.

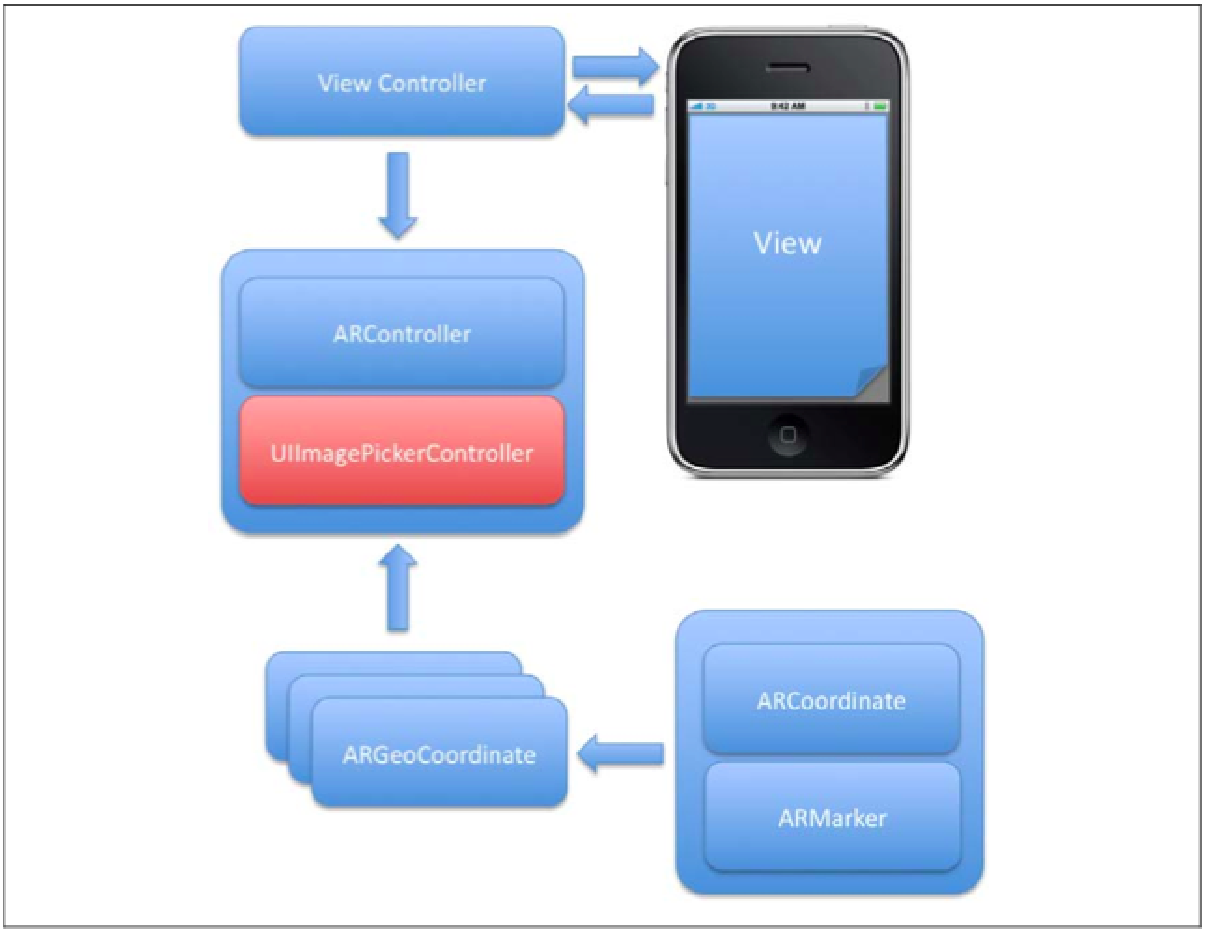


Figure 5.6: The architecture of ARView application

Since the AR engine should be reusable, it should not be tied to a specific view controller. The ARController class uses the UIImagePickerController to capture feeds from the device camera as well as manage and update the virtual information on the overlay view. Virtual information consists of a number of ARMarker objects. ARGeoCoordinate is a sub-class of ARCoordinate and it helps to create ARCoordinate objects using coordinates representations. As the reader can notice the picture reports a device different from the iPad 2. As stated before the iOS operating system provides system interfaces that enable developers to build applications using native code without worrying about the underlie hardware.

5.4 System Functionalities

In this section functionalities implemented in the prototype will be presented. For each function a detailed description is provided. Furthermore screenshots of the application are presented in order to provide the user with a better understanding.

5.4.1 Data Visualization - Tweets

In the prototype implemented, information visualized consists of geotagged Tweets left by users in the physical space. Indeed Twitter[4] is really popular and when something important happens individuals tend to express their feelings with "what are they familiar with and what is close at hand" [1]. When the user starts the application a JSON [3] request is sent to the Twitter server asking for Tweets categorized by the *"trondheimar"* tag. If the response does not contain any error message, the JSON Framework [4] is used to parse the answer and to extract the information needed. Firstly it is checked that Tweets are geotagged. Indeed as emerge from the problem elaboration they are requested to have a specific location in the physical

[4] http://www.twitter.com

space. If so, other information related to the Tweet such as its timestamp, GPS coordinates and text, name of user who posted it and his profile picture are retrieved. If not the tweet is discarded. The information is then created and it is ready to be visualized on the device screen.

5.4.2 Spatial-based Navigation

As an Augmented Reality application the prototype enable the users to explore the physical space augmented with geotagged tweets. GPS, compass and accelerometer are used to determine user's location and user's angle of view thereby the information overlaid on the device screen is calibrated with respect on this factors and then visualized on the screen. Tweet icons are overlaid to the real world as seen through the device camera. Figure 5.4.2 shows a physical space in Trondheim downtown and the same space augmented with tweets. The information visualized is represented by a blue cloud icon with a string that specifies the tag of the Tweet. When the user taps on an icon, a view showing tweet details appears on the screen (Figure 5.8). As the reader can see these details consists of user name who posted the tweet, user profile picture, GPS location of the tweet, its timestamp, tag and text. A mechanism to rate the information is also provided but the implementation of its logic will take place in the future work.

(a) Trondheim Downtown - Space

(b) Trondheim Downtown - Place

Figure 5.7: Trondheim Downtown - On the left the physical space, on the right the same space augmented with Tweets.

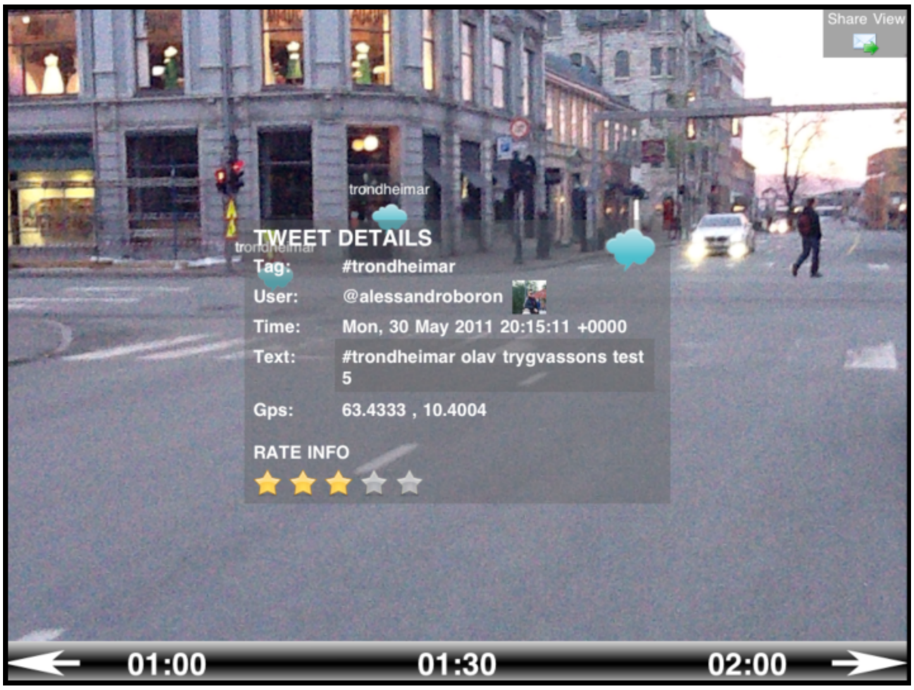


Figure 5.8: Trondheim Downtown - Tweet Details

5.4.3 Time-based Navigation

At the bottom of the device screen is placed a timeline which the user can interact with. Purpose of the timeline is to provide the user with a navigation of the information along the temporal dimension. In this way the user can follow the evolution of the information over time. When the user taps the desired time on the timeline, the tapped label is lighted up while at the top left corner of the screen it is reported the time span related to the information visualized. In response the application shows only information collected within a time span of one hour from the desired time. Figure 5.9 shows information collected from 01:30 to 02:30. As the reader can see there is not any information collected in that time span.

Figure 5.9: Timeline used to perform a temporal navigation of the information

5.4.4 Sharing View

The sharing of the user's view is the only collaborative mechanism implemented in the prototype of the application. When a user finds an interesting composition of information or in case he/she has some doubts about a situation he/she can share what is visualized on the device screen with other colleagues in order to get feedbacks. At the top right corner of the device is placed the *"Sharing View"* button. When the user taps on that button a snapshot of what is visualized on the screen is taken and an email form is presented to the user. The email form reports a geo-referenced snapshot of the user's view (Fig. 5.10).

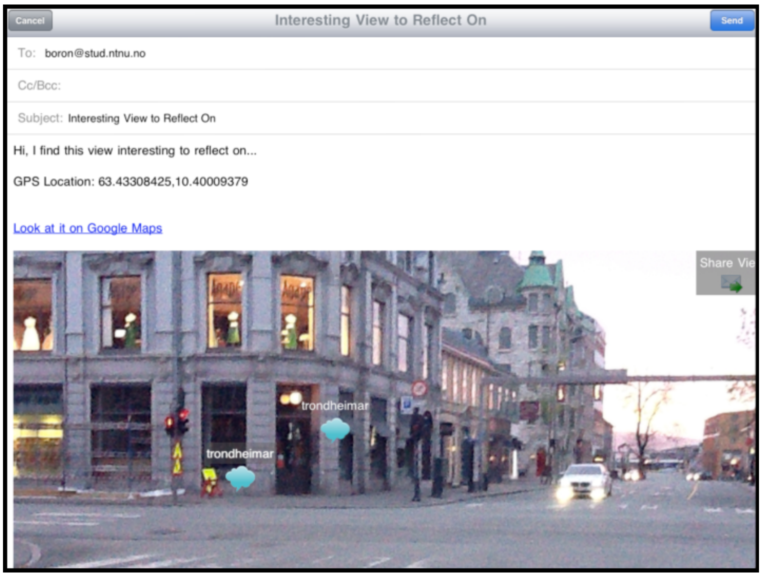


Figure 5.10: Mail form used to share the screen view with other colleagues

As soon as the *"send"* button is tapped the user is notified about the success of the sharing (Fig. 5.11).

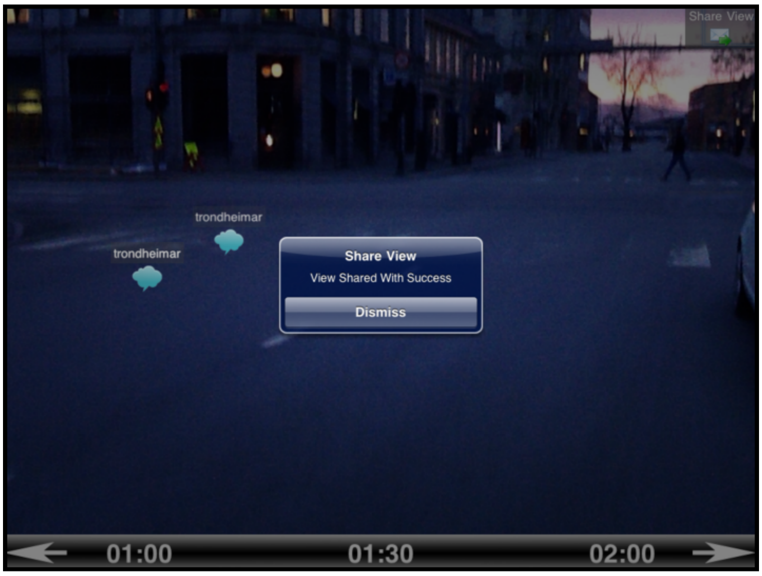
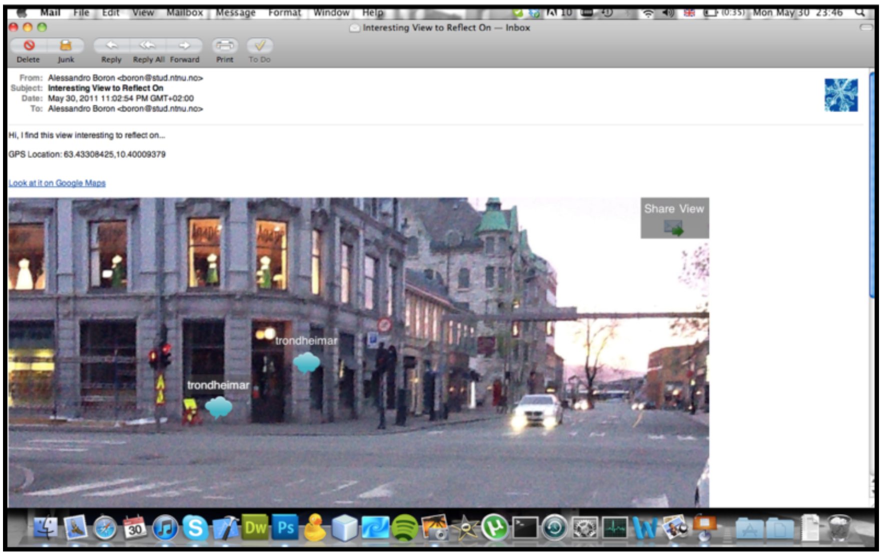
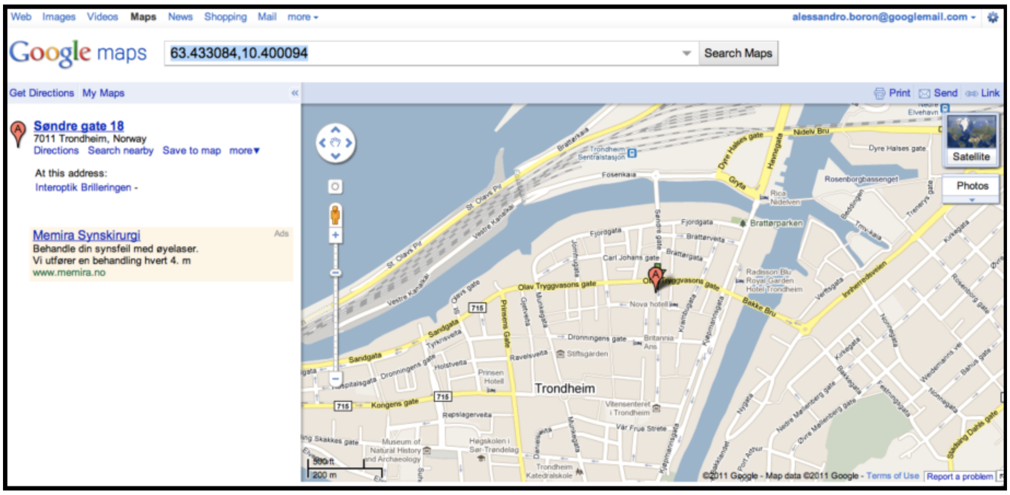


Figure 5.11: Notification that inform the user about the success of the sharing

In this way the fellow who receive the email can reflect on the snapshot view, reply to the sender and look at its location on Google Maps[5] to see where it has been taken (Fig. 5.4.4).



(a) Sharing View - Mail Received



(b) Sharing View - Google Maps

Figure 5.12: View received by the user and visualization of where it has been taken on Google Maps

[5] http://maps.google.com/

Chapter 6

Evaluation

Purpose of this chapter is to evaluate the work done during this project. In particular the evaluation aims at investigating possible applications of the solution proposal in real settings. Experts of the field are presented with the problem definition and its elaboration. Then the prototype implemented is presented and it is followed by a discussion session to get some feedback. Furthermore a questionnaire (Appendix C) is proposed to and answered by the experts. Since the work done in this thesis will be continued through a summer job a usability test will take place in the nearly future in order to evaluate the real use of the system.
In section 6.1 is reported the experts evaluation.
In section 6.2 requirements fulfillment will be evaluated.

6.1 Experts Evaluation

The experts evaluation has been made the 31st of May 2011 through a Skype[1] video conference. Participants in the conference were two consultants of

[1] http://www.skype.com

an italian IT company that provides software solutions for the Italian Civil Defense. Both the experts, referred in this chapter as *Expert1* and *Expert2* are involved in the MIRROR project but were not involved in the design of the system proposed in this work. Furthermore *Expert2*, acts also as volunteer in his spare time. In the video conference took part also my co-advisor, PhD. candidate Simone Mora. The experts skills brought two advantages in terms of feedback. On one hand, being involved in the MIRROR project they are aware of challenges connected to support reflection. Moreover, acting as volunteer *Expert2* has grounded understanding of the problematics and issues related to the work on the field such as planning, mechanisms for communication and cooperation, types of information that are relevant to reflect upon during the debriefing phase and the like. On the other hand, since they are employed in an IT firm the two experts know technologies and devices that are present nowadays. In this perspective, feedback came out both for the main idea of this work, its application in real settings and for technologies used in the solution proposal.

The video conference consisted of a presentation of the work done during this project. The presentation can be divided in three main parts. In the first one the main objective of the thesis, its motivation and the problem elaboration were presented. Here falls also the analysis of the scenario envisioned with its challenges and issues (Figure 6.1). In the second part experts were presented with some screenshots of the prototype implemented as well as proposal for future work (Figure 6.1). The last part of the presentation was focused on discussions in order to receive suggestions and feedback and it ended with a questionnaire that has been filled in concert by the two experts.

Here are reported the most important feedback emerged during the evaluation.

During the presentation it was explained the idea to engage people participating in the event in the collaborative process of collecting data. This idea was found very interesting. The two experts were enthusiastic about it and *Expert1* commented *"Oh...that is a great idea."*

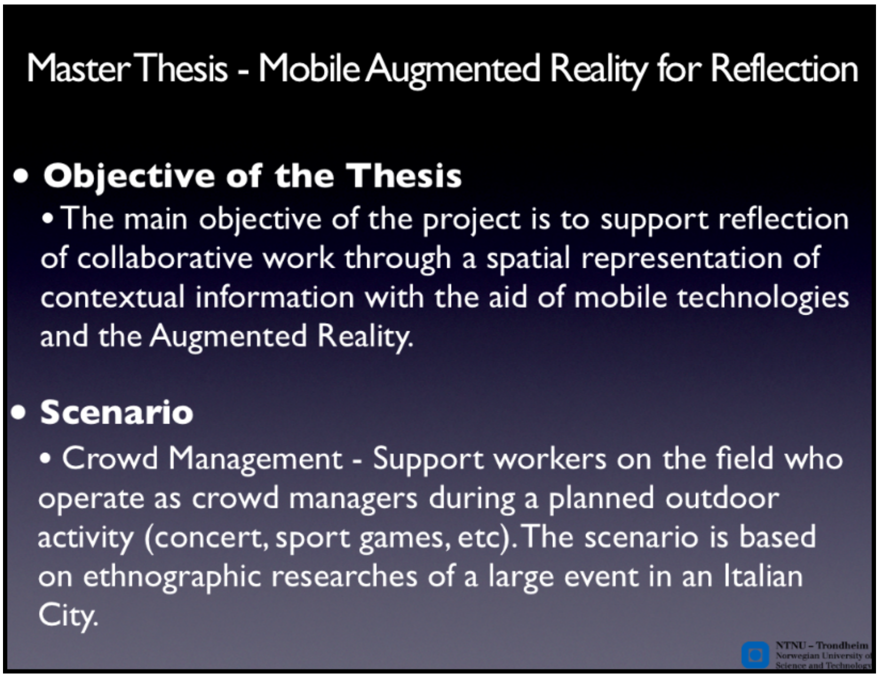
When the discussion focused on the usage of the collected information the experts were asked about their opinion on how and where to use it. In particular it was asked if it could be more useful to visualize the information collected in situ through the Augmented Reality rather than within an office. *Expert2* quickly answered *"According to me with the Augmented Reality"*, *Expert1* in addition said *"It is a really good idea."* From the discussion emerged they both agreed that looking at the information in the same place where it was collected helps in triggering reflection. Indeed reflecting in other places such an office lacks of the context surrounding the information collected.

Before showing the screenshots of the prototype the two experts were presented with some mockups of the application envisioned. It was explained that *time* is one of the dimension the application wants to support for the navigation of the information since it is important for the reflection session seeing the evolution of the information over time. They found this idea really interesting and *Expert1* said *"It is an excellent idea."*

A positive feedback came also out from the possibility to share the screen view with other colleagues in order to provoke them reflect upon the information. During the presentation of the prototype it was shown how the user can share what he/she sees on the device screen with other colleagues and how the receivers can localize the snapshot on google maps since it is geo referenced. The comment of *Expert2* was *"Nice function, it is really nice.."* while *Expert1* said *"I like it."*

During the evaluation, the experts confirmed the potential usefulness of the application in real settings connected with the Italian Civil Defense. Indeed *Expert1* specifically said *"Concerning the Italian Civil Defense I find this application excellent, I am excited about it."*. Two problematics came also out. The first one is related to the device used to visualize the information *"The device used to display the information should be chosen carefully. An iPad is a device too much fragile, at the first impact it gets destroyed. Staff involved in this kind of activity tends to use the devices in a crude way"* stated *Expert1*. The second one relates the battery of the device. Their concern was on the duration of the battery and possible problems to charge the devices. *"Supposing to have an iPad protected with a sort of armor, we should think a way of usage that prevent that the device runs out of battery fast because we cannot imagine how it is possible to charge their batteries on the field unless with the generators of the base camps."* This can be proved true in scenarios such as disaster management where people have to act rapidly without paying attention to the devices, but since we want to support reflection with a certain distance from the event, user needs are different thereby these problematics do not seem very important.

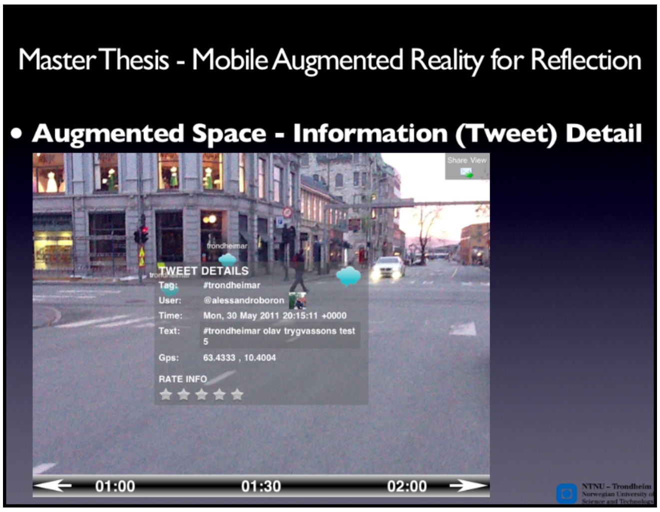
The discussion ended with a positive comment left by the experts on the proof of concept implemented. *"This application is extremely interesting. It could be integrated with streams of data collected by systems already in use. The concept of the timeline is fantastic, it allows you to see again what is happened and to reassess what you have done in a no stress condition. I like it very much if I have to be honest"* commented *Expert2*.



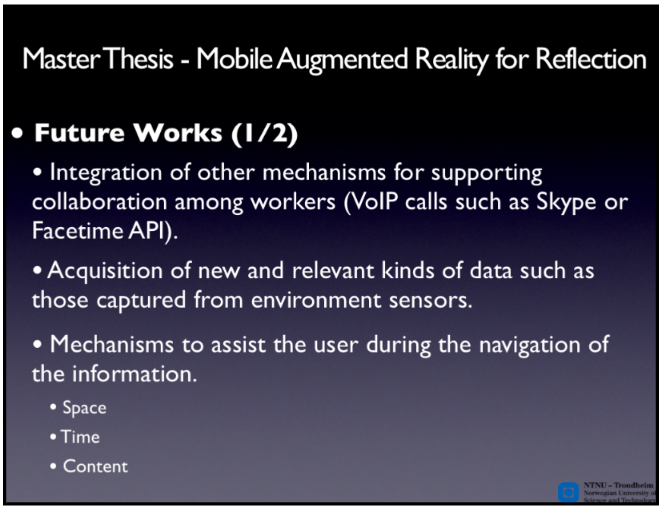
(a)

(b)

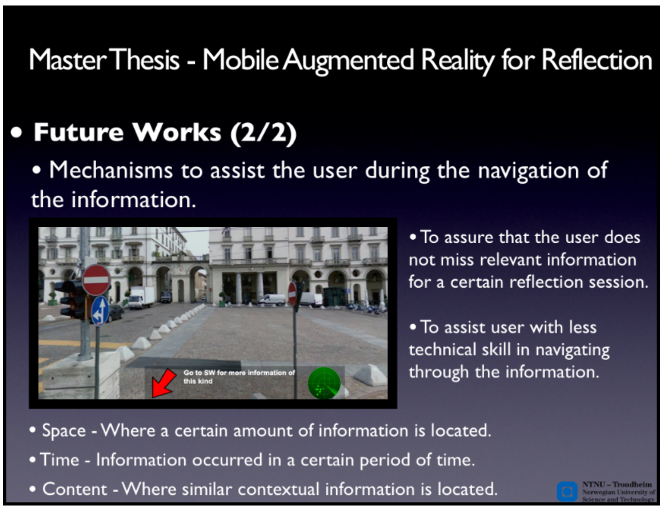
Figure 6.1: Objective of the thesis and the scenario envisioned.



(a)



(b)



(c)

Figure 6.2: Screenshots of the prototype implemented and future work.

6.1.1 Experts Answers

At the end of the evaluation experts were provided with a questionnaire reporting the following questions. The questionnaire was answered in concert by the two experts.

- **Q: What is your technical skill?**

  A: *Technology is my bread and butter.*

- **Q: Moving the debriefing phase from an office to an outdoor setting is not a problem. From 0 (Definitely do not agree) to 5 (Strongly agree).**

  A: *5.*

- **Q: The application showed can be used in a real scenario in which somebody is requested to trigger reflection. From 0 (Definitely do not agree) to 5 (Strongly agree).**

  A: *5.*

- **Q: The application showed can be easily used by members without high technical skills. From 0 (Definitely do not agree) to 5 (Strongly agree).**

  A: *3.*

- **Q: Which of the following mechanisms to support collaboration are relevant to provide?**

  A: *VoIP calls, Instant Messaging, Real-time sharing of screen.*

- **Q: Please describe your first impression.**

  A: *Very useful and adaptable. The software can be used by consumer HW technology, so cheap and easy to "sell"*

- **Q: According to you, are there any advantages in using Augmented Reality to trigger reflection in a real setting? If so, which one?**

  A: *The Augmented Reality makes easier to get/share information, and is a good system for testing with real settings a simulated scenario in a safe environment.*

- **Q: Are the data acquired relevant for the reflection phase? Are there other kinds of data that could be interesting to acquire?**

  A: *yes, will be interesting also collecting information about the people that are in a such way involved with events, can be nice to track the mood of the users. For future implementations would be nice to have the opportunity to track also useful information for the City, E.g. road holes, broken manholes.*

- **Q: Beyond time and content-base navigation do you suggest other kinds of navigation?**

  A: *Role/ group (e.g. some info will be only available to Disaster Manager).*

The answers provided by the two experts highlighted the potential usefulness of the application in the context of the Italian Civil Defense. In particular the prototype implemented seems adaptable to be integrated with existing systems used to capture data during the events. On one hand Augmented Reality proves very powerful for visualizing spatial information and for sharing information with others. On the other hand this user interface could be not immediate to use for people without technical skills thereby training is needed in order to use it. From the questionnaire emerged that it would be interesting to acquire other kinds of data on which reflect on such as mood of people participating in the event while for the navigation of the data could be useful to visualize information based on users' role. Concerning collaborative aspects, the prototype should be improved by providing additional mechanisms to support collaboration among co-workers such as VoIP calls, instant messaging and real time sharing of the screen.

6.2 Requirements Fulfillment

In this section it is briefly discussed the satisfaction of system requirements reported in section 3.5 and 4.3. The focus will be on requirements related to the visualization of the information and collaborative aspects. Requirements not satisfied will be implemented in future work.

6.2.1 Functional Requirements Fulfillment

Table 6.1: Functional Requirements Fullfilment

ID	Status	Comments
Data Navigation		
FR-DN1, FR-DN2	Partially Satisfied	User is able to visualize pieces of information. Even if the user cannot choose the type of data to visualize the system supports different kinds of data.
FR-DN3	Satisfied	User can select information based on their time of acquisition using the timeline. The timeline shows information within a time span.
FR-DN4	Not Satisfied	User cannot visualize pieces of information based on their rating. The interface to rate an information is provided but its logic is not implemented.
FR-DN5	Not Satisfied	System is not able to suggest the user where the desired type of information is located. This function is not implemented yet.

Table 6.2: Functional Requirements Fullfilment

ID	Status	Comments
Support for Collaboration		
FR-SC1	Not Satisfied	The user is not able to leave comments on pieces of information. This function is not implemented yet.
FR-SC2	Not Satisfied	System does not notify users when somebody leave a comment on a piece of information since the function is not implemented.
FR-SC3	Partially Satisfied	The system provides the user with the interface to rate an information but its logic is not implemented.
FR-SC4	Not Satisfied	The logic of rating is not implemented yet thereby the system cannot notify users.
FR-SC5	Satisfied	User can share his/her screen view through the appropriate button on the right top corner of the device screen. The sharing is made by sending an email with a geo-referenced snapshot of the user's screen.

6.2.2 Non-Functional Requirements Fulfillment

Table 6.3: Non-Functional Requirements Satisfaction

ID	Status	Comments
Portability		
NFR-PT1	Satisfied	The application implemented runs on the Apple iPad 2 but cannot run on systems that use a different operating systems.
NFR-PT2	Partially Satisfied	As a mobile device the device should be easily carried around. The result is reported as partially satisfied because of the lack of a usability evaluation.
Usability		
NFR-US2	Not Satisfied	User cannot easily select the type of information desired since this functionality is not implemented.
NFR-US3	Not Satisfied	User cannot leave comments in a easy way since this functionality is not implemented.
NFR-US4	Partially Satisfied	User can rate information through a ”star” classification but miss a usability evaluation.
NFR-US5	Partially Satisfied	User can share the device view pressing a button but miss a usability evaluation.
Security		
NFR-SC2	Satisfied	Participants in the event are not able to retrieve data from the Application Server.
Device		
NFR-D1	Satisfied	The device can support Augmented Reality visualization of information.

6.3 Discussion

In this work Augmented Reality is exploited to trigger reflection on place-based information that is collaboratively collected during planned, outdoor activities. Augmented Reality allows individuals to reconstruct experiences being in the same place where they occurred. Indeed individuals can explore spaces as seen through the device camera augmented with virtual information. In this perspective Augmented Reality is a suitable approach for visualizing spatial information.

However there are issues that designers have to take into account in designing systems. The first issue relates with the limitation in terms of screen dimensions of mobile devices. The user should not be overwhelmed with too much information. In this perspective possible approach to reduce similar information for a certain situation/location or to avoid misleading information are investigated. Nevertheless the designer should ensure that different pieces of information collected for a certain location/situation, provided they can have the same GPS coordinates, do not overlap on the device screen. If so, the interaction with the information would be affected.

Location-based Augmented Reality applications need to know users location in order to provide them with information in their surrounding. This implies that applications need an accurate position tracking system to register information with the user's environment. Commonly AR applications use GPS for tracking the user location; its accuracy depends on the line of sight with several satellites. In outdoor settings the GPS has an accuracy between centimeter and meters, depending both on objects such as building in a city or tree in a forest that hinder the reception of satellites and if other tracking techniques are used in addition. In this perspective if the granularity of the information needed must be in the order of centimeters new tracking techniques to use in addition to the GPS must be investigated.

If on one hand Augmented Reality allows to augment the real world with virtual information, on the other hand mechanisms to assist the user in the exploration of the information should be provided. Indeed users can be annoyed to seek for information in their surrounding without any clues about where to find information on which reflect on. Furthermore they could risk to miss relevant information for a certain reflection session.

User interface design is another issue that has to be taken in to account by the designer of the system. In designing the user interface of the prototype I had to choose how to implement the timeline since it is not a GUI components provided by the iOS application programming interface (API). The choice was to place the timeline at the bottom of the device screen and to provide it with buttons at its sides in order to let users use their thumb to scroll it without miss the grip on the device. The button for sharing the view was placed at the top right corner of the device screen not by accident. The reason was to place that button far from the device camera in order to avoid to cover the camera lens while taking the snapshot of the view. Therefore adding new functionalities that require the design of GUI components implies analyzing the user-friendlyness of them.

A usability evaluation will help also to test the issues related to the ergonomics of the device. Indeed a reflection session could take time to be accomplished and being with the arms outstretched for long time to explore a place could be annoying for the users.

Chapter 7

Conclusion and Future Research

7.1 Summary

The objective of this thesis was to support reflection of collaborative work through a spatial representation of information related with work experiences with the aid of mobile technologies and the augmented reality. In particular this work aimed at supporting reflection of workers that operate as crowd managers of the Italian Civil Defense during planned, outdoor events such as concerts, sport games and the like. This work wants to support *reflection-on-action*, reflection that happens with a certain distance from the event. Concerning how place-based information can be exploited to trigger reflection (RQ1), a literature review on reflective learning and augmented reality with a particular attention on mobile AR was done. Particular attention was also given to the analysis of the scenario envisioned. In this perspective previous knowledge about the concept of space and *place* as "space invested with meanings and values" [20] and Augmented Reality as means to layer and visualize place-based information was applied to have a better understanding of the main problem and to find an answer for the RQ1: place-based information is used to represent virtual clues collected during the events and related to physical spaces where events take place on which individuals will reflect upon.

In terms of what advantages Augmented Reality brings in supporting reflection (RQ2) the research resulted in the design and prototyping of an Augmented Reality application for tablet-device to visualize the information collected during the events. A high-level architecture of the overall system is proposed as well as the architecture of the prototype implemented. Furthermore storyboards for the solution proposal were provided.
Then the prototype implemented was evaluated by two IT consultants involved in the MIRROR project[1], that provide software for the Italian Civil Defense. The evaluation aimed at investigating possible applications of the system developed in real settings and it was very helpful in terms of feedback and suggestions.

Furthermore a workshop paper based on the work done in this thesis has been written and approved for for the 1st Workshop on Mobile Augmented Reality at MobileHCI 2011 - Stockholm, Sweden - 30/08 - 02/09 2011[2]. The paper has been written together with my co-advisor PhD candidate Simone Mora and my supervisor Professor Monica Divitini.
The research will continue with a summer job at IDI/NTNU under the supervision of Professor Monica Divitini. Purpose of the research is to improve

[1] http://www.mirror-project.eu/
[2] http://www.elizabethchurchill.com/MARWorkshop/index.html

the prototype implemented by providing new functionalities that help to cooperate and trigger reflection. Suggestions came out during the experts evaluation will be also analyzed.

7.2 Evaluation

The assignment for this thesis was to investigate the usage of mobile Augmented Reality to support reflection-on-action on collaborative, planned outdoor activities. The task entailed investigating different areas related both to theoretical concepts such as reflective learning processes, space and place and definitely technical aspects such as Augmented Reality and iOS programming. The work has been a big challenge for me since I had a theoretical background only on the concept of space and place and its possible relationship with the Augmented Reality. Precious in order to accomplish the task assigned were the scientific approach taught me and feedback received in the course of this project from my supervisor Monica Divitini and my co-adviser Simone Mora.

After evaluating the solution implemented I can state that this work has successfully achieved its goal. A specific case study has been analyzed and an Augmented Reality system to support reflection has been designed, prototyped and evaluated.

Of course the solution implemented should be improved in order to support new functionalities and it should be object of a usability evaluation in order to assess its user-friendliness. This work will be part of my summer job and it will be reported for the MIRROR project.

7.3 Future Work

Here follow some ideas for possible future research. These ideas relate to technical improvements and suggestions emerged during the experts evaluation.

- **Requirements Fulfillment:** First step of future work consists of satisfying system requirements specified in section 3.5. Concerning collaborative aspects requirements not implemented in the prototype relates the possibility to leave comments on and rate the information. The experts evaluation pointed out the need of mechanisms to support synchronous communication such as VoIP calls and instant messages. It would be also useful to provide a real-time sharing of the screen to other colleagues. Regarding the navigation of data, the user will be provided with functionalities to select the type of data he/she wish to visualize. Important is to also provide the user with a mechanism that suggests him where relevant information for a certain reflection session is located.

- **Data Capture:** Since the focus of the thesis was on the visualization of the data collected from users it is important to provide them with applications that allow to collect different types of information. The users should be provided with mechanisms to collect information that is not only composed by tweets and MMS. In this perspective the reader can think about applications to promote events that offer information and discounts in order to foster its usage but at the same time allow users to collect different type of information such as their mood or to track inefficiency such as broken manholes and the like.

- **Usability Evaluation:** Evaluation with users is very important to test the usability of the application. It is crucial that the application is user-friendly to be used. In this perspective evaluating how the user interface supports users in doing their tasks allows to get feedback that will be used to make the user interface more efficient, effective and satisfactory.

- **Porting of the System:** Porting of the application to other platforms is important in order to support different type of devices. In this perspective can be useful to deploy the application on specific devices such as the ones used to support workers deployed on the field. Using this kind of devices that are both shockproof and waterproof would make possible to use the system implemented in different kind of settings.

Appendix A

List of Acronyms

API Application Programming Interface

AR Augmented Reality

CSCW Computer-Supported Collaborative Work

GPS Global Positioning System

GUI Graphical User Interface

IDE Integrated Development Environment

IM Instant Messaging

IR Information Retrieval

IT Information Technology

MMS Multimedia Messaging Service

MVC Model-View-Controller

PDA Personal Digital Assistant

VoIP Voice Over IP

Appendix B

Scenario

"Different organizations such as Italian Civil Defense (Protezione Civile Italiana), local police (Polizia Municipale), Italian red cross (Croce Rossa Italiana) and so on cooperate during the event to ensure people's safety for the entire progress of it. Everything must be planned down to the smallest details in order to avoid unpleasant and dangerous situations. In the planning phase, coordinators of Italian Civil Defense are provided with the risky zones that must be be monitored. The coordinators are responsible to assign the resources to the zones to monitor; each of them coordinates about twenty volunteers organized in groups of two. By this time the task of the coordinator is to decide where to place the volunteers and who to pair up with whom based on their features such as experience, personality and so on. Stefano and Mario together with other members of the Italian Civil Defense monitor the risky zones as planned in the briefing phase of the event. During the event information is continuously exchanged in order to coordinate activities and to assure the safety of people. Information is acquired by individuals and also mediated by tools. Civil Defense staff and participants in the event can report unpleasant and dangerous situation sending different kinds of in-

formation to the system from their handheld device. This information can consist of textual messages, Tweets and pictures with an associated meaningful string. In addition the Civil Defense staff can send their GPS location to help the personnel in charge of the debriefing and reflection phase to keep track of their position when an event happened. Furthermore the system is able to capture data from environmental sensors such as noise level sensors and camera feeds from mobile and static checkpoints. The day after, Mario and Stefano, the coordinators in charge to reflect upon the event, go to the place where it happened. Stefano starts the reflective process choosing to navigate through the Tweets left the previous day by individuals and other Civil Defense members participating in the event. Among these tweets he decides to reflect on those described by the keyword Overcrowding. Therefore the system suggests Stefano where this kind of information is located in the space. Stefano starts his reflective tour moving toward those Tweets. Stefano navigates through the tweets located in the space and reflect on them to understand what generated that unpleasant and dangerous situation. If the tweets only are not useful to understand what led to that situation he can choose to visualize pieces of information acquired from other source such as camera feeds, to have a better understanding. If this attempt is not useful he can move to an other zone suggested by the system where is present the same kind of information. Moreover he can leave a comment on or rate the information to make aware his colleagues. Stefano in addition wants to reflect on how the situation evolved over time. In particular he wants to understand how people moved in relation to that situation, check if after a certain time the situation is solved and where the personnel in charge of supervise that zone were located. Then he selects the time desired on a timeline on the screen. Stefano finds an interesting Tweets left by a participants in the event that *it is helpful to understand the situation and decides to leave a comment so Mario can read and reflect on it. Stefano finds a tweet quite relevant to understand what happened the night before so he decides to rate it. On a scale to one to five he assigns four stars "*" to the tweet. During the reflection session, Stefano notice a puzzle of information that makes him think that such situation happened due to variables not foreseen in the planning phase of the event. Therefore he decides to share the snapshot of this information together with his GPS location with the disaster manager in order to make him reflect about the risky points not covered.".*

Appendix C

Experts Evaluation Questionnaire

Here follows the questionnaire used for the Experts Evaluation.

Experts Evaluation
Mobile Augmented Reality for Supporting Reflection
Alessandro Boron NTNU

Welcome to the experts evaluation survey with which I can improve my work. Anyway, thank you for filling it all out.

About you

1. **What is your technical skill?**
   - ☐ Technology is my bread and butter.
   - ☐ I have some knowledge about computers and technologies in general.
   - ☐ Computers, smartphone, tablet what is that?!?!.

Please evaluate the following features

2. **Moving the debriefing phase from an office to an outdoor setting is not a problem.**
   Definitely do not agree ☐—☐—☐—☐—☐ Strongly agree
3. **The application showed can be used in a real scenario in which somebody is requested to trigger reflection.**
   Definitely do not agree ☐—☐—☐—☐—☐ Strongly agree
4. **The application showed can be easily used by members without high technical skills.**
   Definitely do not agree ☐—☐—☐—☐—☐ Strongly agree
5. **Which of the following mechanisms to support collaboration are relevant to provide?**
   - ☐ VoIP calls
   - ☐ Instant Messaging.
   - ☐ Real-time sharing of screen.
   - ☐ Asynchronous messages.
6. **Please describe your first impression.**

   ____
   ____
   ____
   ____

7. **According to you, are there any advantages in using Augmented Reality to trigger reflection in a real setting? If so, which one?**

   ____
   ____
   ____
   ____
   ____
   ____

8. **Are the data acquired relevant for the reflection phase? Are there other kinds of data that could be interesting to acquire?**

   ____
   ____
   ____
   ____
   ____
   ____

9. **Beyond time and content-base navigation do you suggest other kinds of navigation?**

Appendix D

Workshop Paper

Here follows the workshop paper that has been written and accepted for the 1st Workshop on Mobile Augmented Reality at MobileHCI 2011 - Stockholm, Sweden - 30/08 - 02/09 2011 [1]. The paper has been written in concert with my supervisor Monica Divitini and my co-advisor Simone Mora.

[1] http://www.elizabethchurchill.com/MARWorkshop/index.html

Mobile augmented reality for supporting reflection

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Abstract
In this paper we discuss the usage of Mobile Augmented Reality to support reflection on past events, using reflection on crowd management as scenario. The paper identifies the main challenges of the scenario to Mobile Augmented Reality in terms of organization and usage of information.

Keywords
Augmented reality, reflection, collaboration

Introduction
Reflecting on action is critical to learn from past experiences and performing better in the future [1, 2]. Different tools have been developed to support reflection, as an individual or collaborative activity. An example is provided by life logging applications, which promote reflection in the context of behavior change, and witness the potential of mobile applications to capture information on the move and use it for reflection.

Information about past events is important to support reflection not only to complement human memory, but also to allow bringing in multiple perspectives on collaborative processes. Different metaphors have been proposed to organize this information, e.g. timelines and tag clouds.

In this paper we investigate the usage of Mobile Augmented Reality to support reflection on work practices that rely on deployment and management of resources in space and that have therefore a strong spatial dimension. The importance of space in collaborative settings has been largely recognized, starting from [3]. Space-based services for storage and interaction with information are widely used both for work (google maps mashups) and for leisure (foursquare, yelp). Augmented Reality is recognized as an interface to show space-based information to support an ongoing activity (e.g. to search for the closest restaurant) in a user-friendly way. In this paper we investigate the usage of Mobile Augmented Reality for supporting reflection and discuss related challenges building on a scenario of crowd management. More specifically, we aim to promote reflection of workers who are deployed on the field to operate as crowd managers during a planned outdoor event (concert, sport game, talks). The scenario is based on observations we have collected during a large event in a large Italian city.

The scenario we envision is the following. During the event information is continuously exchanged to coordinate activities, often mediated by different tools; sensor and camera feeds from mobile and static checkpoints are recorded. We also envision that event's attendees can send media from their smartphones, e.g. about dangerous situations. After the event, we envision enriching the current practices of debriefing and reflection by introducing a tablet-based augmented reality viewer that shows information collected during the event. Information is presented in layers and can be shared among colleagues. The system guides users to different locations where information was generated. Reflection is expected to take place at the same physical location of the event.

We believe that the usage of Mobile Augmented Reality can be beneficial because it allows grounding reflection in the specific place where the event took place. AR can help to layer information about the event and access spatial information that might be relevant to re-think the event. For example, comparing a photo of a square during an event with the real space under normal conditions might help to reconsider actions that have been taken and possible alternatives, e.g. alternative escape routes. Looking at the space in normal conditions might help a worker to re-assess more critically his level of stress during the event.

Visualization of information

The large amount of information collected during an event and the fact that the information will be visualized on a tablet-device screen make the process of layering the information critical. The user should be enabled to visualize different kinds of information depending on what he/she wants to reflect upon. Information can come from different sources, from:

- Context/environment, e.g. a photo captured by a mobile unit or an indicator of noise level
- Participants, e.g. a tweet sent in by a participant to the event to signal something not functioning or from a worker to signal his stress level in certain conditions
- Applications supporting work, e.g. the recording of radio communication during the event or information from the event management system

Another categorization of information can be done based on the semantic of the information, according to Boud's model [1]:

- Ideas , e.g. suggestions by an worker on how to handle a situation differently
- Behavior, e.g. GPS tracks of emergency vehicles
- Feelings, e.g. stress level of workers expressed with textual messages or emoticons

In addition, the layering could take advantages of existing conceptualization of places, considering e.g.

the historical, psychological, and social dimension of a place. In any case, one of the challenges is to select an appropriate set of information to visualize in order to support reflection situated in a specific context. This might require a pre-processing of the information by the system to avoid the visualization of similar information for a certain location/situation. A possible solution could be the use of Information Retrieval (IR) techniques to extracts important keywords from textual messages and picture captions in order to categorize them.

In addition to the spatial dimension, time might also play an important role. It is therefore important to be able to capture and present the temporal evolution of a place.

The right association of information to places and capturing the right level of granularity depending on the context is also a challenge. For example, when one looks at a square, is he interested to the whole area or only to a small sub-area? How to get the right level of granularity? Also, considering that information is sent in by different actors, often under time constraints, how can we capture the right association of the information to a place?

Usage

Crowd management involves a number of actors with different roles. We therefore look at the related reflection on the event as necessarily collaborative. Even when the reflection is done by an individual, it must necessarily be based on information provided by others.

In our scenario, fragments of information come from actors operating in different contexts to achieve different goals. They are pieces of a puzzle that must come with an embedded context (e.g. geotags, timestamps, comments …) which allow setting them together in time and space to be compared, clustered, layered, shared and re-used across multiple representations. Information should not be seen in isolation, but as part of a *Common Information Space* [4] that supports reflection on the practice. In this perspective, the system should be able to support sense making processes to allow meaningful action. Also, it is important to provide the right level of sharing – depending on roles and respecting privacy issues.

One additional challenge is constituted by the need to support exploration and make sure that the information relevant for a certain reflection session is explored. In our mockups we envision supporting navigation and exploration of the information not only using the spatial dimension, but considering also connection among the information (e.g., the usage of similar tags) and the time dimension (e.g. all the information in a location that has been submitted in a certain period of time).

Finally, there is a need to support different forms of collaboration. For the time being, we plan to support indirect collaboration through the annotation and rating of specific pieces of information; the sharing of a specific type of information; the sharing of a specific view, i.e. a picture of the location and the specific information that one is looking at in the moment the view is captured. Additional user studies might help to identify additional forms of cooperation.

Conclusions

In this abstract we have presented challenges connected with the usage of Mobile Augmented Reality to support reflection on collaborative practices with a strong spatial dimension. Some challenges are discussed in relation to visualization of information and its usage. The additional material that we have provided in attachment presents some mock-up of the system to illustrate the main ideas. At the workshop, we expect to present also the results from the initial evaluation of the ideas with users.

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