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IMPROVING THE USER EXPERIENCE IN CULTURAL HERITAGE SITES

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To my family

Sommario

"Improving the User Experience in Cultural Heritage Sites" analizza gli aspetti che contribuiscono ad arricchire la fruizione dei Beni Culturali. Il patrimonio culturale comprende tutte le tracce di attività umana presenti in un ambiente fisico, tra cui monumenti storici, siti archeologici, tradizioni, cibo, opere d'arte.

La tesi sviluppa tre diversi contributi riguardanti il miglioramento della fruizione dei beni culturali.

Nella prima parte ci si concentra sul ruolo centrale che l'informazione contestualizzata può avere nel fornire esperienze sempre più immersive e coinvolgenti. Tale tipologia di informazione è oggi resa possibile dai dispositivi mobili di ultima generazione, costantemente connessi alla rete internet, e dotati di una grande moltitudine di sensori. L'obiettivo è quello del miglioramento dell'esperienza dell'utente, che si concretizza in un maggiore coinvolgimento e intrattenimento, grazie ad una tecnologia non invasiva, con cui interagire nel modo più naturale possibile. Per raggiungere tale obiettivo sono state esplorate di diverse tecnologie, tra cui Realtà Virtuale e Realtà Aumentata, e l'accesso a dati sensoriali provenienti da gps, bussola e giroscopio. Per ogni tecnologia utilizzata sono stati analizzati vantaggi e svantaggi e sono stati proposti i domini applicativi di maggiore interesse. Per effettuare i vari esperimenti è stata progettata un'architettura che semplifica l'integrazione di tecnologie dipendenti dal contesto all'interno di prodotti software pre-esistenti.

Nella seconda parte della tesi ci si concentra su come fruire al meglio grandi spazi espositivi, quali musei. E' stato quindi co-progettato il sistema QRouteMe, che sfrutta i QR Code per l'accesso veloce a contenuti informativi contestualizzati.

Nella terza parte della tesi si è definito un modo alternativo di rispondere alle aspettative dell'utente per quanto riguarda la fruizione dei Beni Culturali coinvolgendolo fin dalle prime fasi di progettazione dei nuovi prodotti o servizi. A tal scopo è stato progettato il sistema Crowdboard, un sistema di brainstorming collaborativo, creato con lo scopo di coinvolgere l'utente finale nella co-progettazione di un prodotto/servizio. La tesi presenta una discussione conclusiva su possibili sviluppi del lavoro presentato nella tesi e delle tecnologie per la progettazione collaborativa.

Abstract

"Improving the User Experience in Cultural Heritage Sites" analyzes the aspects which contribute to give a better experience when exploring cultural heritage. Cultural Heritage is a wide concept including tangible goods (monuments, architecture, museums, exhibits) and intangible heritage like languages, folklore, music, dances, festivities, life styles or food habits. The thesis provides three main contributions.

In the first part of the work we explore how to use context-aware technology to provide immersive and engaging experiences. This kind of information is today available in every pocket through last generation smartphone, always connected to the internet, and provided with a lot of sensors. To reach our goal we investigate the use of Augmented Reality, Virtual Reality, and other technologies based on context-related data, gathered through the sensors. For each technology we analyse the main advantages and drawbacks, and propose the more suitable application domains.

In the second part of the thesis we address the problem of improving the user experience in large indoor exhibition spaces, such as museums. We co-designed the QRouteMe information system, that uses QR Codes for a quick access to context-aware information.

In the third part of the thesis we propose an alternative approach to address users' needs and expections related to their experience in a cultural heritage site. We present Crowdboard to engage potential users in co-design activities, involving them since the very beginning of the design process of a product/service.

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Glossary

AMT	Amazon Mechanical Turk
API	Application Programming Interface
DB	Data Base
GPS	Global Positioning System
HIT	Human Intelligence Task
IR	InfraRed
POI	Point of Interest
QR	Quick Response
RFId	Radio Frequency Identification

Chapter 1

Introduction

Cultural heritage is a wide concept including tangible goods (monuments, architecture, museums, exhibits) and intangible heritage like languages, folklore, music, dances, festivities, life styles or food habits. As an example the UNESCO in 2010 inscribed the Mediterranean diet on the Representative List of the Intangible Cultural Heritage of Humanity [42].

This thesis introduces tools and technologies aimed to provide a better user experience when visiting a cultural heritage sites, as well as methodologies to be followed when designing such tools.

This research starts by following the typical approach of user-centered design. First it was decided to take advantage of the access to context-aware information that smart mobile devices provide, to design many mobile guides for enjoying cultural heritage in Sicily. Among them iPalatina®, a mobile guide for the Palatine Chapel in Palermo, iMussomeli®, a virtual guide to the Mussomeli's castel, and streating®, the guide to the street food in Palermo. We argue that the most important context-aware information is the user location. Many places of cultural interest such as museums cannot take advantage of this kind of information due to the lack of access to gps data in indoor enviroments. To address this problem it was co-designed the QRouteMe system, a platform that uses QR Codes to access information in large indoor places such as museums or exhibits. QRouteMe was designed to be used in kiosks and mobile devices. This thesis present the design and implementation of the mobile aspect of the system.

In the last part of the work we decide to involve potential users into the design process. The idea is that involving the users since the early stage of the design process can help accounting for diverse viewpoints while not missing important opportunities.

Crowdboard is a whiteboard augmented with comments coming in real-time from an online community of participants.

1.1 Motivations and Goals

Cultural tourism is currently one of the main driving forces of the tourist phenomena, accounting for a significant part of the world's tourist flows. Cultural heritage and historical sites, dance, music and theatre performances, art galleries, museums and exhibitions, religious sites and ethnic traditions are the main attractions for tourists [56]. Technology can add value to cultural heritage site by making sure the user is provided with relevant information. The access to context-aware data provided by last generation mobile devices can play a relevant role in reaching this goal, because it provides a way to anticipate users' needs. Another important aspect is the user acceptance of technology. Traditional user-centered design approaches make sure the users' needs are taken into account by having the users test a prototype and then address their main concerns. However the users ideas may not get heard soon enough to influence the design concept. Involving potential user since the early stage of the design process could help a design team not missing important opportunities, as well as leading to a better user experience and a better user acceptance.

1.2 Contributions

The main contributions of the work presented in this dissertation are:

- The design and development of several mobile virtual guides to enjoy Cultural Heritage Sites.
- The design of a design pattern to include a new context-aware technology into a pre-existing application.
- The co-design of QRouteMe, an infrastructure to improve the user experience in large indoor spaces related to cultural heritage, such as museums.
- The development of the mobile aspect of the QRouteMe system
- The design and development of Crowdboard to involve potential users into the co-design of Cultural Heritage applications.
- The evaluation of Crowdboard to understand if and under which circumstances the crowd input can positively affect a design conversation and to understand the design principles needed for a good crowd-designer interaction.

1.3 Dissertation Outline

The remainder of the dissertation is organized as follows.

Chapter 2 is an overview of the related work. It start by describing some relevant research regarding the technologies applied to Cultural Heritage. Then it explain what participatory design is and how it has been applied to Cultural Heritage. The chapter continues by describing other concepts used later in the thesis, such as crowdsourcing and the problem of involving people with diverse backgrounds (the crowd) in creative activities.

Chapter 3 describe how the mobile access to context-aware data was exploited to create mobile virtual guides such as iPalatina, iMussomeli, strEATing, MDMArtidec.

Chapter 4 describe the QRouteMe system and the implementation of its mobile aspect. QRouteMe uses QR Codes to provide context-aware information in large indoor spaces such as museums.

Chapter 5 describe the Crowdboard system, its implementation and its evaluation. Crowdboard involve potential users into the design process of products/services related to Cultural Heritage.

1.4 Publications

Parts of the work in this thesis have been published in several referred conference proceedings and journals:

- S. Andolina, D. Lee and S. Dow. “Crowdboard: An augmented whiteboard to support large-scale co-design”. In Adjunct proceedings of the *26th annual ACM symposium on User interface software and technology*, UIST Adjunct Proceedings ’13, ACM (New York, NY, USA, 2013).
- S. Andolina, D. Pirrone, G. Russo, S. Sorce and A. Gentile. “Exploitation of Mobile Access to Context-Based Information in Cultural Heritage Fruition”. In Proc. of the *2012 International Conference on Broadband and Wireless Computing, Communication and Applications (BWCCA)*, Nov. 2012.
- D. Pirrone, S. Andolina, A. Santangelo, A. Gentile and M. Takizava. “Platforms for Human-Human Interaction in Large Social Events”. In Proc. of the *2012 International Conference on Broadband and Wireless Computing, Communication and Applications (BWCCA)*, Nov. 2012.
- A. Gentile, S. Andolina, A. Massara, D. Pirrone, G. Russo, A. Santangelo, E. Trumello and S. Sorce. “A Multichannel Information System to Build

and Deliver Rich User-Experiences in Exhibits and Museums". In Proc. of the *2011 International Conference on Broadband and Wireless Computing, Communication and Applications (BWCCA)*, pp.57-64, 26-28 Oct. 2011.

- A. Gentile, S. Andolina, A. Massara, D. Pirrone, G. Russo, A. Santangelo, S. Sorce and E. Trumello, "QRouteMe: A Multichannel Information System to Ensure Rich User-Experience in Exhibits and Museums", *Journal of Telecommunications and Information Technology*, 1/2012, 58-66.

Chapter 2

Related work

2.1 Technologies applied to Cultural Heritage

Improving the User Experience (UX) in a cultural heritage site is a complex problem with many facets. To provide engaging and exciting UX, researchers have typically tried to answer the following simple questions:

- *Where is the user located or how is it possible to track her/his route?*
- *Which are the more appropriate contents to provide her/him?*
- *What are the possible interactions between users and infrastructure?*
- *How does the presentation of contents affect the user experience?*

Some of the issues above are strictly related to technologies and their improvements such as tracking and localization either indoor or outdoor while other are related to psychological or sociological aspects of interaction. Usually the definition of information in cultural heritage fruition starts from the definition of a possible path inside the site, which is the display organization inside an exhibit, or a proper path for an outdoor location. This path organization is usually the “fil rouge” of the fruition and the contents reflect this organization. This pre-ordered fruition of contents has two major drawbacks: the users could be not involved in the narrative and the level of deepening could not be appropriate for the user. Some works try to address the presented issues as a whole while others try to solve specific problems. In the first category some important frameworks have been proposed and financed at European level to support the development of cultural heritage. One of the first projects was AGAMENNON [2]. The project was indented to organize historical and cultural information about archaeological sites in an intuitive and innovative way, using third-generation mobile phones, to provide the users with a guide presenting their preferred topics respecting the time scheduled for the visit. Another important aspect is the preservation of cultural heritage: the Mosaica [9] project uses web 2.0 and semantic web technologies to achieve such result. Lastly, resorting to Augmented Reality [29, 20] allows to reach a deeper level of user's engagement. Context awareness plays as well an important role in designing mobile applications, especially when focused on cultural heritage related projects. A good definition of context is given in [22]: "any information that can be used to characterize the situation of entities (i.e., whether a person, place, or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves". This conceptual definition includes all the aspects related to context but from an operative point of view is important to define what are the sources of information in the environment (e.g. sensors, people, points of interest, objects) and how the computational model and the architecture of the overall system are organized. Starting from the sensors, mobile access can be advantaged from the new categories of sensors like GPS (Global Positioning System). A recent Gartner's research has estimated in 526 million worldwide the number of users owning devices equipped with location based systems (LBS), significantly increased from the 100 million in 2009. Location based systems are essentially outdoor and indoor. Outdoor LBS are mostly based on GPS (Global Positioning System) satellite infrastructure. The level of accuracy available is in the order of a few meters and it is generally adequate for location-based information providing. Indoor positioning suffers of the degrading reception of GPS-based systems. Rather than relying on position accuracy it is often more important to offer capabilities such as recognizing boundaries and positioning a person using symbolic locations (e.g. "in the hall" or in "near the building").

A number of methods have been proposed in recent literature to design indoor LBS using different classes of sensors like infrared beacons [17, 33], radio signals from wireless LAN [8, 40], RFID technology [16] or cameras and microphones [14] to detect user location, or combinations of them. An alternative to employing dedicated infrastructure embedded into the environment is to use passive approach. In this case, users are not continuously tracked but information about their position can be discretely provided on demand using fiduciary markers. Following this idea, in [47] a system used as a location-based conference guide is presented. The system can be used in large-scale events with no further costs due to other equipment. Another way to achieve the same functionality is through the detection of the position by comparing a set of floorplans with an image taken from the cell-phone camera [35]. This method has a major disadvantage because it requires a priori the processing of all the floorplans for a particular building.

Besides user's location, additional challenges in the design of information systems for cultural heritage are related to content organization and the growing importance of the social dimension of their use. The first aspect has been addressed in many works. An early work is the definition of a set of different prototypes for both for indoor and outdoor guides called Cyberguide [43]. Other relevant systems are the Hippie/HIPS project [48] that is focused on development of an exhibition guide. The possibility to automatically define related information for a guide has been exploited in many projects such as the PEACH project [59] where the generation of some position related contents and post-visit reports are automatically performed. The CHIP project [7] tries to combine Semantic Web techniques to provide personalized access to digital museum collections both online and in the physical museum.

Another point of view to build a museum guide is to target not just a single user but also a group. The Sotto Voce [5] system is designed specifically with this goal providing a communication mechanism to support interaction.

2.2 Participatory design in Cultural heritage

Research in co-design explores how to involve non-designers into the design process. By "non-designers" we refer to potential users, external stakeholders or people of the same team with no skills in design [54]. Research in co-design, also referred to as participatory design, has grown rapidly in the last 30 years, following some pioneering work, reported for example in [30] and [55]. This early work focused more on involving future users into the design process of ICT systems. However, today co-design practices have been developed for different purposes.

Among the other fields, co-design has been investigated a lot in the domain of Cultural Heritage. In [23] the everyday engagement of children is used as point of departure for designing interactive museum exhibitions. The goal is reached in three stages. First the children are invited to discuss the qualities of a chosen computer game or online community. Then they are asked to create a physical addition or feature to the chosen computer game or online community. Finally the children are assigned the task of creating a new exhibition space in a museum.

Another relevant work is this field is illustrated in [52]. Here social media is used as a platform for co-designing a new mobile application for cultural heritage, with the goal of stimulating the local public to participate actively in preserving, distributing, and developing heritage photos.

Another example of co-design in Cultural Heritage is [61], where Archaeologists and Computer Science created the T.Arc.H.N.A. system, a conceptual architecture, context oriented, open and participatory, where different actors cooperate to create and disseminate knowledge.

An alternative approach to user involvement, similar to participatory design is "open innovation", which urges firms to abandon the so-called "closed innovation" within their own R&D and marketing departments, and instead open up, to include

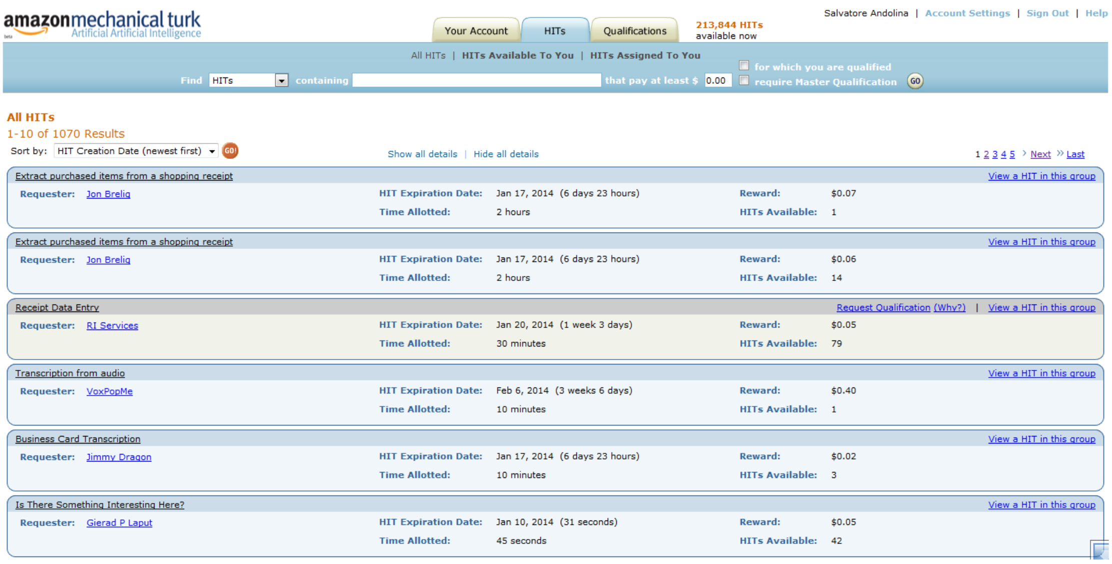


Figure 2.1: Amazon Mechanical Turk. List of tasks with associated rewards.

external knowledge and ideas [19].

In Chapter 5 we explore the use of co-design to improve the user experience in cultural heritage sites. We designed Crowdboard, a tool that helps a design team and a crowd of online participants to work together to design a product or service related to cultural heritage. The system explicitly focuses on taking advantage of the physicality of a traditional whiteboard along with the power of a distributed web applications. Crowdboard uses crowdsourcing (see section 2.3) to leverage people all over the world in order to account for many diverse viewpoints.

2.3 Crowdsourcing

Crowdsourcing refers to the activity of engaging a geographically distributed workforce to complete complex tasks on demand and at scale [37]. Crowd work can be either performed by volunteers and by paid crowd.

Paid crowdsourcing markets typically present a list of tasks and monetary rewards for each task (Figure 2.1). Workers browse these lists to choose a task. Depending on the platform, workers will complete the task immediately and submit it for review, or bid on the task and wait for the requester to choose them for the work. Again depending on the platform, requesters may pay everyone who participates, reject unsatisfactory work, and/or only pay for the best submission [11]. A well known platform for paid crowdsourcing is Amazon Mechanical Turk (AMT). By using such a platform anyone with access to the Internet can perform *micro-tasks*. Examples of micro-tasks include business card transcription, voice transcription, image labeling.

Platforms for paid crowdsourcing such as AMT have been successfully used for gathering labeled data, used later to train machine learning systems. For example crowd has been used for word sense disambiguation [57] with performace as good as professionals. Crowd has also be leveraged to generate large speech corpuses for spoken language research [18].

Real-time crowdsourcing has also been explored. VizWiz [15], for example, helps blind people solve general visual search problems. In [41] real time crowdsourcing is used to control existing interfaces. Examples of other real-time crowd powered systems are Adrenaline [12], a crowd-powered camera where workers quickly filter a short video down to the best single moment for a photo, and Puppeteer [12], which focuses on large-scale creative generation tasks, allowing a graphic artist or designer to fill a page with a large collection of crowd-posed figures.

Crowdsourcing has been investigated as a platform for idea generation tasks. In Ideas2Ideas [39] for example, ideas are shown as PostIt notes on a virtual whiteboard, with a direct manipulation interface for adding to existing ideas.

In Chapter 5 we will involve the crowd in idea generation activities. However we will provide the crowd with a more immersive experience by giving the option to annotate a physical whiteboard and to actively partecipate to a design session held in a physical design studio.

Chapter 3

Mobile and context-awareness

3.1 Introduction

In recent years there has been an increasing use of personal mobile devices (smartphones, PDAs, tablets), so that they are widely available among people of all ages. They are almost in everyone's pocket and can be used almost anywhere. This wide acceptance is due to the even more intuitive interaction interfaces (touch screens, graphical user interfaces), as well as the different available wireless technologies, both for short and long distance communications (RFID, Bluetooth, WiFi, ZigBee, UMTS, HSDPA, and the like). Such diffusion is also driven by the introduction of various types of sensors and multi-programmed operating systems, that actually creates a positive trend (more than one billion smartphone users are estimated by 2014 - Gartner's studies). This justifies the common interest in the study of new ways of service provision (and brand-new services too) according to the features and capabilities of mobile devices [10, 27]. Thanks to all these features, users are allowed to install all the applications they consider interesting or useful, thus making personal devices an indispensable companion for either business or leisure tasks. This opportunity has paved new ways to new business models for all those entities, ranging from single individual programmers to large well-organized software houses, working on developing applications for these devices. The great connectivity, the easiness of interaction and the possibility to be programmed to perform many different tasks, give personal mobile devices a chance to widely become "intelligent terminals" to access any information system appropriately designed in a personalized and context-dependent way.

For all these reasons, one of the most popular uses of such devices is the access to personalized and on-demand information wherever it is needed. Personal mobile devices are thus successfully exploited for human-environment interaction purposes within pervasive systems. As a matter of fact, it has to be considered that such interaction should not be the same for all, since differences in needs and skills of people have to be taken into account to avoid heavy compromises, which could not satisfy anyone. Due to their programmability and wide popularity, mobile devices can be made suitable to operate as remote controllers, or personal adaptive I/O interfaces, for applications remotely running. Needed services can therefore be accessed by means of a well-known device, with no need to learn how to use new kind of interface [44]. There is a large variety of application fields where services can be pervasively accessed by mobile devices, such as context-aware information provision within university campuses [26], augmented reality objects assembly in mobility [34], healthcare systems [49, 63]. One of the fields in which mobile access to information and services is widely exploited is the provision of interactive user profile-based guides in cultural heritage sites.

In such field there are several works, focused both on the research and on the application point of view, aimed at the definition of systems or even parts of them (indoor and outdoor positioning, human-environment interaction, user profiling, information retrieval, intelligent behavior, ecc.) [62, 51, 25, 53]. Cultural heritage applications pose several challenges to designers under different aspects. First, because of the large variety of visitors they have to deal with, each with specific needs and expectations about the visit. Second, no two sites are the same, and probably you need a brand new installation for each site, given its characteristics (indoor versus outdoor, distributed versus centralized, individual centered versus group centered, etc.). Lastly, the technologies involved must be robust to failures, redundant and, above all, easy and intuitive to use.

This thesis presents several mobile apps where context-based technologies are used to reach different goals in user experience. We designed and developed iPalatina®, iMussomeli®, strEATing®and MDMartidec®. For each app we chose the context-aware technologies most suitable for the particular experience we wanted to provide. Each app follows the same design patter as explained in section 3.5.

3.2 Gps, compass and accelerometers

Streating is the mobile guide for Palermo enogastronomy we have developed. The app helps to discover Palermo's world of street food, a unique centuries-old culture that has to be explored to actually enjoy the city. Streating takes advantage of data gathered from GPS, compass and accelerometers to build an Augmented Reality view (see Figure 3.1) that shows the points of interest around the user. The combination of this information gives users the possibility to route their path in the city just pointing the device to a particular direction. In this way they can have information about the nearest place to find a particular kind of food. Users

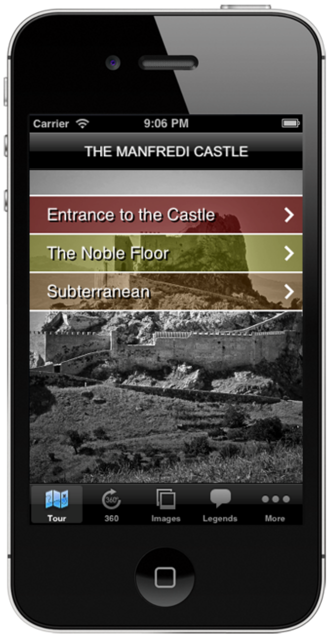
Figure 3.1: Streating AR View [4]

can also have a categorized vision of the possible places according to four food categories. Users can interact with this augmented reality view simply enabling the augmented reality browser with a touch of the interface. For users that are not used to this type of information browsing, it is possible to use a complementary graphic interface showing the information in a more usual way.

3.3 Compass and accelerometers

When the site is indoor, the GPS is not useful and local embedded sensors, such as compass and accelerometers, can be enough to give the context information needed to enrich the visit. We managed this situation in the app iPalatina, the guide to the Palatine Chapel in Palermo. The Palatine Chapel is the best example in the world of the so-called Arab-Norman-Byzantine style. It is filled with mosaics of great elegance as concerns elongated proportions and streaming draperies of figures. In iPalatina the users can take an audio tour of the Chapel, following the sequence of steps provided by the app. Furthermore they can enjoy the Virtual Reality tour, in which they can navigate a panoramic view of the chapel, centered at the heart of the main nave. The panoramic view is annotated with buttons that play spoken description of the points of interest next to the corresponding button. Users can automatically align the point-of-view of the panoramic view with their own point-of-view simply tapping on the compass button. The alignment is calculated using data from compass and accelerometers. With this technology the users can easily find the information associated with the particular detail they are watching. In such a situation, Virtual Reality has some advantages over Augmented Reality. The first is that the users can take a tour of the Chapel, before actually entering in the Chapel. In this way they can be encouraged to visit the Chapel. The second advantage is that even while they are on site, they can enjoy some details that

(a) A. The iPalatina panoramic view.



(b) B. The iMussomeli tour.

Figure 3.2: iPalatina and iMussomeli. [4]

cannot be observed with the naked eye. A typical example is the ceiling of the chapel, which is 14 meters (42 feet) high above the floor.

Virtual reality can also be used for outdoor guides, so we used the same functionalities in the iMussomeli app. It enables users to visit and learn stories about the Manfredi's castle in Mussomeli (Sicily, Italy), also known as the "eagle's nest" for its particular location. In this app users are able to visit the castle with the support of our guide. The chosen POIs are organized in a path with three main groups according to the place layout (see Figure 3.2(b)). A first group is related to outdoor POIs, the second to the main corpus of the castle also known as the "noble floor", and the third to the subterranean. The guide has also a specific section for the castle's legends that are professionally narrated. The guide is used to support a business model where users can rent on site dedicated devices with the installed guide, or alternatively download their own guide on a personal device.

3.4 QR Code

When the points of interest are within an indoor site, one of the most cost-effective and powerful technologies to detect the user's context and to infer user interests is the QR Code. The developed application named MDMartidec presents the exhibition known as "Sicilia ritrovata. Arti decorative dai Musei Vaticani e dalla Santa Casa di Loreto". The app is a support to discover the pieces in the exhibit, which are mostly unique productions of the Sicilian school from 1530 to 1670. The main aspect of this app is the fact that it focuses on the detailed description of a small set of exhibits. For each exhibit the app shows some annotated high resolution images. The annotation's goal is to give relevant information about the neighboring details. As users use the app, they navigate through the annotated details by means of animations zooming a detail of the object. At the end of every animation an audio recording of the corresponding annotation is played (see Figure 3.3). MDMartidec uses QR Code for fast selection of the content of interest. If users want to take a random tour of the exhibit, they are not requested to go back to main screen and select the exhibit of interest every time. In this way we have reduced the interaction needed to reach a point of interest.

Figure 3.3: MDMartidec [4]

3.5 Context-awareness integration

All the apps presented in this work follow the well-known Model-View-Controller design pattern as displayed in Figure 3.4. Every time we are going to add a location-based service to an existing app we execute the following procedure:

- Create a Context Model to represent the particular data (i.e. *GPSData* class).
- Create a Sensor Controller, responsible for gathering data from the sensor and store them in the Context Model. (i.e. *GPSController* class). This module is also responsible for sending a new notification every time new data is sensed.
- Create a specific View, i.e. the graphical user interface with which the user interact (i.e. *GPSView* class).
- Create the corresponding View Controller that manages the whole logic and the interaction events related with the new technology added(i.e. *GPSViewController* class). This module must register to receive the particular notification sent by the Sensor Controller.

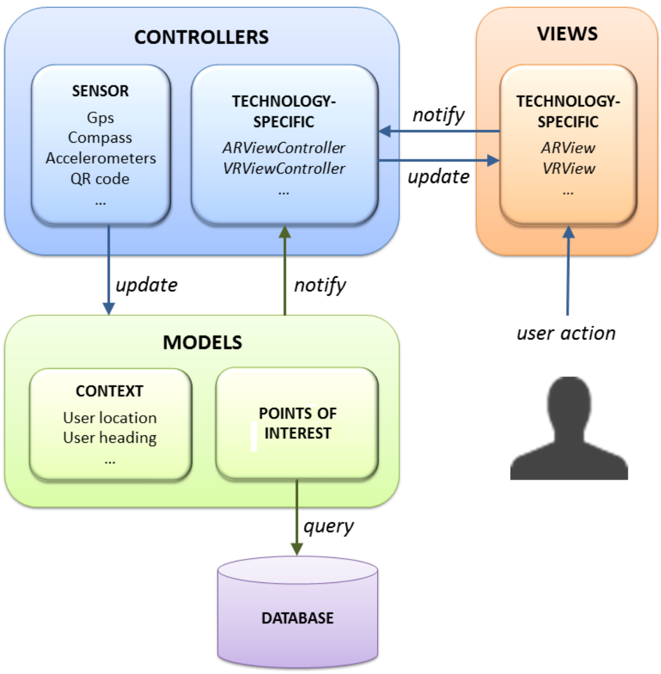


Figure 3.4: Context-aware mobile virtual guides' architecture [4]

The notification strategy is the core of this approach because it represents a convenient way of decoupling the logic needed to manage the sensors from the normal logic of the application. Among the advantages of using such a modular architecture there are: a) rapid prototyping and debugging and b) easy integration in pre-existing software. In fact once the Sensor Controller and the Context Model are designed, they can be easily imported in other projects. Thus, taking advantage of the new context-related data would be as easy as registering the appropriate View Controller to receive the correct notification.

3.6 Discussion

In this capter we presented four mobile apps which provided useful information in cultural heritage sites. Here we give a classification of the technologies we believe are more suitable for different situations.

Outdoor large spaces In this case the GPS it's the main tool to rely on, as we do in strEATing. By using GPS along with compass and accelerometers it is also possible to provide an augmented reality view.

Small enviroment When the enviroment is very small, by just knowing the direction of the user's gaze we know which artworks are in her/his field of view. Thus using compass and accelerometers may be enough to predict the information the user is looking for. This is for example the case of iPalatina. However, when it is possible to introduce some external equipment the use of QR code to access information is another option, as in MDMArtidec.

Point of interest not accessible or not visible In some cases it is possible that the object of interest no longer exist or is not easily accessible. Another possibility is that it is not visible with the naked eye. An example is the ceiling of the Palatine Chapel, which is 14 meters (42 feet) high above the floor. The ceiling is decorated with beautiful paintings, but because of the distance they are not visible. Another example is the Mussomeli's castel, with many rooms not easily accessible. In those cases Virtual Reality has some advantages over Augmented Reality as it allows to explore places not accessible and to enjoy hidden aspects of the site.

The proposed apps were published on the Apple Store [6]. iMussomeli was also made available on site. Thanks to an agreement with the Municipality of Mussomeli, we tracked the behavior of visitors at the Mussomeli's Castle while using our iMussomeli guide.

During our observations and surveys, we noticed that people really appreciated the possibility to listen to narrations, while seeing correlated pictures and videos right on the spot, using the mobile devices provided. Great appreciation was showed from people with disabilities, who once on the spot were disappointed to realize that the place was not accessible. In that case the virtual visit through iMussomeli gave them a good option to enjoy the place.

We also got some useful feedback from the users' reviews on the Apple Store. One of the lessons learnt about this work was that an app for enjoying artworks, must be an artwork itself. For this reason, professionals should be hired for the creation of the multimedia content, for the translation in different languages, and for giving the voice to the narrations. Also the app should be well designed from a technical point of view and the smoothness and responsiveness of the interaction should be an important aspect of the experience to be provided. We applied those principles to our apps and the qualitative feedback we got suggests this approach actually make sense. For example here are some users' reviews regarding iPalatina:

> *... The 360 view is amazing and this app really makes you feel like you are at the Palatine Chapel...*

> *... The 360 and zoom really give a sense of scope and space of the chapel. 360 view is surprisingly responsive, rendering faster and smoother then similar apps I've seen...*

> *... Overall, a beautiful design and a flawless technical experience...*

> *... My wife and I want to visit this part of Italy and this experience has made the Palatine Chapel a target for us...*

Those and other comments show the appreciation for the app as a guide, but also as an artwork itself. They also show that people expected to experience frustration due to technical issues or unresponsiveness and they were positively surprised when this didn't happen. From the feedback received both from people visiting the Mussomeli's castel and people all over the world, reviewing the app on the Apple Store we can conclude we reached the goal of providing a better user experience. Based on users' reviews on the Apple Store and interviews with the Cultural Heritage sites' managers we can also state that the problem of encouraging the on-site visit was positively addressed.

Chapter 4

Improving the user experience in large spaces

The definition of systems able to support users in indoor environments like an exhibit or a museum is an active and multidisciplinary research field with different research areas. The main aspects are related to the process of contents definition and organization and to the customization for different users. In addition to this, many related problems have been investigated such as the localization of users for indoor environments.

One of the first works in this field is the Cyberguide project [43]. The main purpose was the definition of a set of different prototypes both for indoor and outdoor guides designed as a combination of four main components: a cartographer component including the map (or maps) of the physical environments, a librarian component, the information repository containing all the information to be presented, a navigator component used to keep track of the users' positions in the environment and a messenger component used to record and exchange messages to/from users and system.

Other relevant systems are the Hippie/HIPS project [48] that is focused on development of an exhibition guide, providing guidance and information services. From the observations about the visitor's movements through the exhibition, the systems create a user profile and suggest other interesting exhibits or paths inside the current exhibits. The TellMaris [38] system is an example of a mobile tourist guide developed combining both two and three-dimensional graphics running in a mobile phone. The possibility to automatically define related information for a guide has been exploited in many projects such as the PEACH project [59] where the generation of some position related contents and post-visit reports are automatically performed. The CHIP project [7] tries to combine different Semantic Web techniques to provide personalized access to digital museum collections both online and in the physical museum. Most of the works in this area are focused on an explicit definition of a knowledge base while some works tries to implicitly define a user model. The user model definition is mostly based on statistical models rather than recommendation techniques [1].

Another point of view to build a museum guide is to target not just a single user but a group visiting a museum. The Sotto Voce [5] system is designed specifically with this goal providing a communication mechanism to support interaction. From an architectural organization a complex system able to produce and adapt contents for different media has been organized mainly as a client server architecture or as a multi-agent system. The drawbacks of the two approaches are well known. In the first case the server machine is obviously a point of failure and also the communication through the network can be critical while an explicit message passing mechanism has to be implemented for an agent-based system together with a knowledge base used to define the communication ontology for the agents.

Regarding the theme of users' localization there are essentially two types of location technologies: the indoor positioning and the outdoor positioning. The second class of problems has been solved using satellite infrastructure with GPS (Global Positioning System). The reached level of accuracy is in the order of some meters and generally has a good accuracy for outdoor-based information applications. The indoor location suffers of the degrading reception of GPS-based systems. Furthermore the accuracy is not so important while in many cases the users needs a system able to recognize boundaries and able to position a person through a symbolic location (e.g. "in the main hall" or in "the first room"). Several methods have been proposed to solve the problem using different media like infrared beacons [17, 33] or radio signals from wireless LAN [8, 40], RFID technology [16] or cameras and microphones [14] to detect user location. One of the main drawbacks of the proposed approaches is related to the initial cost to organize a large-scale event like an exhibit. Another way to achieve the same functionality is through the detection of the position by comparison between a set of floorplans and an image taken from the cell-phone camera [35]. This method has a major disadvantage because it requires all the floorplans for a particular building to be known in advance. All the proposed methods require an electronic infrastructure to facilitate measurements with all the necessary sensor/actuator devices. In this case a good compromise in a costs/benefits tradeoff can be an approach able to give to users not continuous information of their position but discrete information. We are looking to provide an inexpensive, building-wide infrastructure to be used in a large-scale type of events with a number of users that can be measured in thousands of people. So the utilization of a fiduciary marker able to be easily recognized from users is a natural solution for this type of problems. In this way the user localization shifts from a continuous to a discrete problem. Some similar approaches have been recently used to solve this problem. In [47] a system used as a location-based conference guide called Signpost is presented. The system works only with Windows Mobile phones but it can be used in large-scale events with no further costs due to other equipment.

4.1 QRouteMe

QRouteMe is a complex, multichannel information system to build and deliver rich user-experiences in museums and exhibits.

The system is able to personalize contents and to deliv them in different types of media. We use both stationary (totem/kiosk) media handlers based on surface computing to allow users a simple gesture-based interaction process, and mobile (smartphones, tablet) ones to allow adaptation in contents fruition. The purpose is to build a more personalized user experience.

An important characteristic of the system is his adaptivity. This is a key feature for systems that present limitations related to technical resources such as screen sizes, battery consumption, ergonomics, connectivity.

The aspect of contents organization related to adaptation has been observed in several related studies. A first important classification is presented in [64] where three types of adaptive strategies are described. The first, defined as “adapted strategy”, induces pre-optimization of contents and resources from the awareness of limitations. The second type is an “adaptive strategy”, where the system reacts to external changes in a sort of parameterized way and “adapting strategies” where is possible to handle different strategies according to environmental inputs. The adopted solutions for the QRouteMe system are essentially of the second type. We have observed a series of environmental limitations and produced a set of strategies related to each of the initial constraints. A typical example is the visualization of information in smartphones with different screens. The produced output is able to adjust the content organization according to screen size without any additional processing. Another important feature in terms of adaptation is related to the positioning capabilities. In particular, the system is able to determine the users’ position inside an indoor environment by scanning fiduciary markers or by interacting with the kiosks. Current smartphones localization system such GPS have a resolution for indoor environments that is approximately of 10 meters. This precision is inadequate in many situations, such as fairs and museum exhibits where a considerable amount of information can be located in a 10 meters radius.

An important feature of QRouteMe is its low deployment cost. In fact the system doesn’t need an expensive infrastructure to produce a rich user experience. The infrastructure organization is a typical client-server solution. A wireless network enables mobile devices to exchange information and to connect clients to servers. The activity of locating users does not require any additional sensor/actuator device.

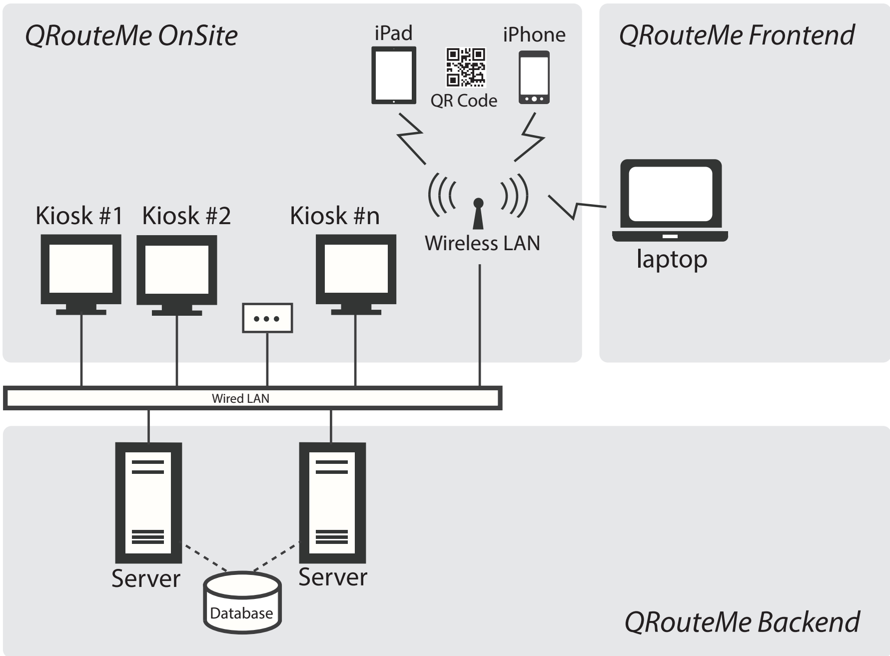


Figure 4.1: QRouteMe Infrastructure.

The main focus of the system is the interaction process. To such purpose the utilization of new technologies, such as surface computing has been proven to be effective. Some important aspects of using QRouteMe is that it provides a pervasive experience by using everyday life devices, such as mobile phones, and by providing the information in an adaptive way that takes into account the devices' contraints. From a technical point of view, an advantage of making extensive use of personal mobile devices is that their computing capabilities shift some of the computational load to the client side of the system, making it easier for the server to handle a huge load of traffic.

4.2 System architecture

The main goal of the QRouteMe system is to provide users with domain information, according to their actual needs and to the context they are currently part of. To reach this goal we decided to design the system infrastructure according to the client-server paradigm. This choice allowed us to obtain an easy-to-implement, easy-to-scale and easy-to-manage framework of components, which can be suitably used to reach our intended goal.

The QRouteMe is composed of three main components:

- *QRouteMe Backend;*

- *QRouteMe Administration Frontend;*
- *QRouteMe OnSite;*

The first one operates at the server side, whereas the second and third components operate at the client side. Figure 4.2 shows the three main components and their modules and the overall data flow among them. In the following sub-sections we will give an overview of each component.

4.2.1 QRouteMe Backend

On the server side, the QRouteMe Platform component main activities are data related: management, processing and storage. This component carries out most of the processing tasks of the whole system, and it is composed by four different modules (see Figure 4.2):

- Kiosk;
- Mobile;
- Statistics;
- Data Management.

All of them interact, whether directly or not, with a relational database. Its schema has been defined in order to be easily adapted to the changing data domains and to the kind of service users have to be provided with. The database can be populated by the administrators by using the QRouteMe Front End component. This feature gives the administrators the possibility to keep the system up-to-date at any time, and to keep the full control on data integrity and correctness. The Kiosk and the Mobile modules manage the users' requests according to the device they are actually using. These modules extract the useful data from the database, and compose the consequent information taking into account which channel the user is currently using to interact with the system. The Statistics module traces the users as they surf the information whilst completely preserving their anonymity and protecting their privacy. By monitoring a great number of parameters, it can provide administrators with a wide range of useful information about the user behavior. Administrators may monitor how many users accessed the application, which and how many pages they were viewing, and so on, according to their needs. This way, they could fine tune the interaction to improve the final user experience, or they could simply evaluate the system effectiveness. Of course, the information provided by the module can go through different levels of detail. It can carry on the overall system evaluation, the separate kiosk and mobile

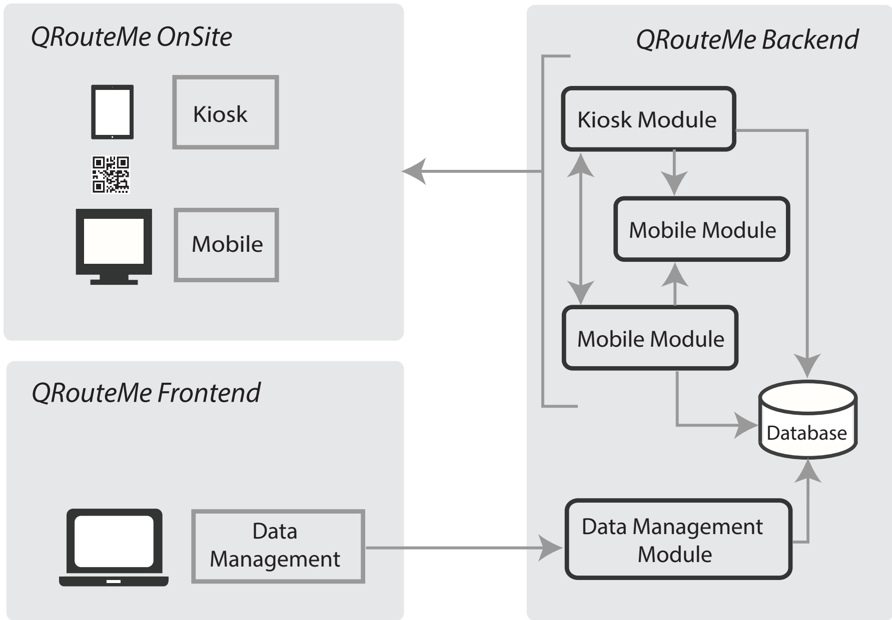


Figure 4.2: QRouteMe Architecture.

evaluation, or the evaluation of each device involved in the interaction. The Data Management module handles the interaction between the Backend component and the applications running on the Frontend component.

4.2.2 QRouteMe Frontend

The QRouteMe Frontend component consists of ad-hoc tools made available to the administrators and implemented according to their needs. The main goal of these tools is to allow administrators to create, read, update and delete data, either directly or by giving data owners the possibility to do it by themselves. This component interacts directly with the Data Management module within the Backend. This ensures that all its activities can be carried out by keeping data integrity and correctness, while avoiding possible conflicts. Furthermore this component improve the system adaptability to the application domain changes, as well as the preservation of data privacy, making it easy to use even for not technical people.

4.2.3 QRouteMe OnSite

The QRouteMe OnSite component represents the system interface with the kiosks' users and mobile devices' users. Concerning the mobile devices in particular, applications can be natively designed and implemented for the most common operating systems (Android, iOS, Windows Mobile and Symbian), thus exploiting all

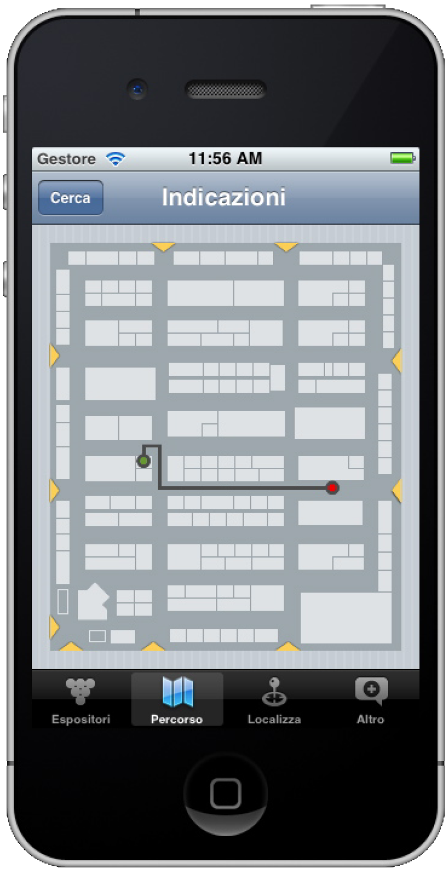


Figure 4.3: Path displayed in the iOS app for Vinitaly 2011 [28].

software and hardware features. Nevertheless, if there is no need to use specific hardware features (such as accelerometers, cameras, positioning systems), a cross-platform web-based solution can be used, in order to have a better portability and a faster development. This component also links both kiosk- and mobile-based information access ways by means of QR codes. People can search for information on a kiosk and then transfer the desired output on their mobile, or people can directly access pieces of information by shooting at QR codes, provided that their mobile device is equipped with a QR reader. By using the app a visitor can get information about the exhibitors and their products. It is also possible to get localized and to find the path from an exhibitor to the other (Figure 4.3).

4.3 Case studies

QRouteMe was used in large fairs such as

- Vinitaly 2011 in Verona, Italy
- London International Wine Fair 2011 in London, UK
- Fruit Logistica 2012 in Berlin, Germany
- ProWein 2012 in Düsseldorf, Germany
- Vinitaly 2012 in Verona, Italy

Although the nature of the events was pretty commercial, they presented similar features, similar users' behavior and similar issues as in cultural heritage indoor locations.

4.3.1 Vinitaly 2011

QRouteMe was implemented for the first time at the wine fair called Vinitaly, held in Verona, Italy, in 2011. That instance was named "Sicilia@Vinitaly2011", and was used to provide information about the Sicilian wineries and their wines. The location was a pavilion of 8,000 square meters. The infrastructure is shown in Figure 4.1. We installed 14 kiosks and also provided a mobile app for the iOS operating system and a mobile website for the other smartphones. Sicilia@Vinitaly2011 recorded, during the five-day of fair, around 40,000 page view, 5,000 Wifi access, 500 iPhone app downloaded. This app is still available on the Apple Store and with more than 2,000 downloads to date.

4.3.2 London International Wine Fair

This was a big international wine fair. An area of 400 sq. mt. in which 25 Sicilian wineries exposed their product, in which we deployed 3 touch screen kiosk. This was a small implementation of Sicilia@Vinitaly2011 that represents a simplification of the QRouteMe system. In this implementation the user could navigate the information about the Sicilian wine that she/he could taste at the tasting desk.

4.3.3 Fruit Logistica 2012

Another application of QRouteMe was implemented in Berlin in February 2012 at Fruit Logistica 2012. This is the world's leading trade fair for the fresh fruit and vegetable business to which 20 Sicilian agricultural producers exposed their own product. In this occasion, inside an area of 400 sq. mt., the users had access to information, by using 2 kiosks and 10 iPads (tablet PCs), placed next to the exhibitors booths.

The exhibitors information data have been made available directly, using QR codes assigned to each exhibitor, and integrated with the printed graphics of each booth. In addition, a video trailer (duration 1 minute) was created and installed on the 2 kiosks to indicate its interactivity. In this implementation the use of system was more focused on the iPad app than on the kiosks, because the producers used the tablets like a tool for their product promotion to the fair's visitors. This app is still available on the Apple Store and it has been downloaded about 2,000 times from all around the world so far.

4.3.4 ProWein 2012 in Düsseldorf

Prowein 2012 is considered the world leading trade fair for the wine and spirits industry. Similarly to the London International Wine Fair, this was a small instance of Sicilia@Vinitaly2011, with three fixed information kiosks within an area of about 400 sq. mt. and 30 Sicilian exhibitors participating to the event.

4.3.5 Vinitaly 2012

For Vinitaly 2012 a similar installation as for Vinitaly 2011 was made. This time the QRouteMe instance was part of a bigger project named SiciliaWineCloud. Similarly to Sicilia@Vinitaly2011, the SiciliaWineCloud application for Vinitaly 2012 consisted of 14 information points (touch screen kiosks), fixed inside a pavilion of 8,000 sm., with ad-hoc software for the information fruition, 187 exhibitors for which he was created a QR for direct access to information in context, free WiFi, a website formatted for presentation of content on mobile devices, an app for iOS mobile devices, and a front-end to manage both the information about the wineries and the promotional advises that was displayed inside screen.

Compared to other QRouteMe applications, SiciliaWineCloud introduced some innovations. The first was the creation of an interactive social game, called "My Top Wine", that provided the possibility to rate the wines tasted by mobile users. During the four days of exhibit, the system rewards the best wine and one of users who voted for him. The second innovation consisted of a real-time "infographic" dashboard projected in the Business Area, that showed the real time kiosk usage and wines votes.

The introduction of a social aspect has increased the usage statistics of the system compared to those recorded the previous year to the same event (see Tables 4.1 and 4.2).

Table 4.1: Results from Vinitaly 2012. Number of accesses from mobile

Date	Number of accesses
25/3/2012 DAY 1	1031
26/3/2012 DAY 2	648
27/3/2012 DAY 3	697
28/3/2012 DAY 4	484
Total	2860

Table 4.2: Results from Vinitaly 2012. Number of accesses from kiosks

Date	Accesses to kiosks	Producers information pages	Wines information pages	Queries for wine variety	Queries for wine type
25/03/12	70035	5731	1336	689	404
26/03/12	79917	5124	1265	609	254
27/03/12	61051	4995	1172	505	249
28/03/12	37953	3435	774	386	207
Total	248956	19285	4547	2189	1114

4.4 Discussion

One of the lessons we learnt after the deployment of several versions of QRouteMe is that the main focus must always be on the actual goal the deployed system is aimed at, according to the target users, forgetting about all the astonishing media (if useless, of course). As previously described, we proposed different solutions to provide people with multimodal access to the available services: a traditional point-and-click interface shown on a touch screen placed on the top of a totem-style case; a personal interface made available through an app to be installed on people's own smartphones; a short range, self-positioning framework based on QR codes to quickly access information related to people's current position.

We tracked both the system usage and the people behavior while searching for information, and we observed that the traditional point-and-click interaction mode was largely the most used one, with a ratio of 100:1 for the whole event over the personal interface (compare Tables 4.1 and 4.2). This was mainly due to the main goal of the system, set up according to the visitors needs: to quickly find the preferred wine or producer, and locate it on the map with respect to their own position. In this case, despite the mobile access could have given users more features, both for utility and leisure, users have preferred to search for the needed information in the fastest way they can. To exploit the mobile access, users had to register to the wireless network, then download the app, and finally use it. Apparently users considered this process too long and not effective, probably due to the mean age of the users and to their actual needs and skills.

As a consequence of this analysis, we are reconsidering the opportunity to include some advanced features based on next-generation technologies, such as gesture-based interfaces, in the design of possible future deployments of the system in similar contexts. The expected results in terms of useful improvement could not be worth the needed efforts in terms of research and development, both in the Human-Environment Interaction and hardware/software fields. An important indicator for us is the ratio between the interactions (281400) and the accesses (248956) to kiosks that is equal to 1.13 meaning that people were able to quickly find the needed information and leave the kiosk. In other words, situations in which there is no need (or not so much possibility, such as the wine fairs) of personalized information provision, traditional interaction seems to be more attractive to users.

Of course, there are circumstances in which the personalization of information provision is desirable or mandatory, such as the fruition of cultural heritage sites. In those cases, the level of details, the presentation media, and the contents composition should be made according to the users profile (skills, age, expectations and goals). In such situations the use of innovative interaction modes (such as voice or gestures) might add some value, as well as the use of mobile devices as terminals for a personalized interaction.

Chapter 5

Crowdboard: Engaging end-users in the design process

5.1 Introduction

Research in co-design [21] explores the process of involving communities of potential users in the design process. Designers with this co-design perspective can leverage Open Innovation platforms [19] to gather many diverse ideas. In those platforms the interactions are often asynchronous and the crowd viewpoints might not get heard or may not get heard soon enough to influence the design concept. Potential domains for large scale co-design include community projects, university planning, and industrial design for consumer products.

We designed the Crowdboard system [3] to allow a co-located design team to gather real-time input from online participants while sketching concepts on a whiteboard. We augment a studio space with Web cameras to capture and broadcast whiteboard activity to online participants (see Figure 1). Community members can annotate the conversation by placing new comments at X-Y locations or adding to an existing thread. These online conversations appear projected onto the physical whiteboard as red dots that the team can expand to see details.

Crowdboard fills the gap between the digital and the physical world, allowing a design team to take advantage of the technology, while using one of its favorite tools, the whiteboard. Crowdboard takes advantage of the crowd input during the creative process in a more direct way. While related work has shown the benefit of crowd input in the innovation process [24], the interaction doesn't happen in real-time.

The use of real-time crowds has been demonstrated for applications such as cognitive aids for visually impaired users [15] and for photo-editing tasks [13]. In contrast, with Crowdboard, we attempt to leverage the crowd's creative abilities.

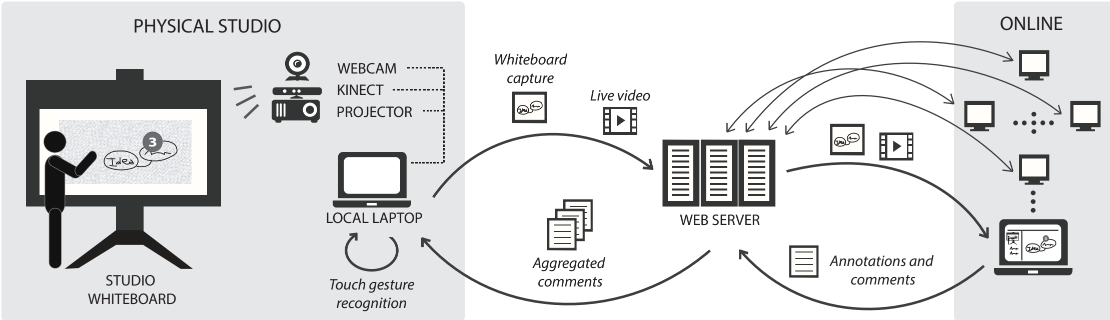


Figure 5.1: System architecture and information flow.

Other groupware systems seek to support small group design activities using new technologies, such as digital whiteboards [32]. Similarly, IllumiShare uses a real-time video connection between two people to enable novel interactions on a traditional sheet of paper [36]. Crowdboard explicitly focuses on leveraging the physicality of traditional whiteboards combined with potentially large numbers of remote participants.

5.2 Design

Crowdboard augments a whiteboard with annotation coming in real-time from an online crowd. Team members draw on the whiteboard with regular markers and interact with the projected crowd comments using touch gestures. The crowd-generated discussions are positioned at X-Y coordinates on the whiteboard, allowing the conversations to specifically refer to something drawn on the board. Each discussion thread has a title and one or multiple comments from different participants. Team members can expand or collapse the discussions using a tap gesture and move them around the whiteboard by tapping and dragging the discussion markers.

The architecture of the system is shown in Figure 5.1. The Crowdboard system is comprised of a traditional whiteboard, a webcam, a projector, a Microsoft Kinect, and a laptop. The system broadcasts video of meetings using UStream [60]. In the physical studio, the live video of the meeting and screenshots of the whiteboard are captured and sent to the server. Online participants get the video and the screenshots and send annotations. The server send the aggregated annotations from all the online participants back to the studio. In the studio the annotations get projected on the whiteboard.

Figure 5.2: CrowdBoard's Web interface where remote participants see a live broadcast of the design conversation (upper left) and whiteboard activity (right). They can leave comments that get projected as virtual markers on the actual board.

5.3 Implementation

5.3.1 Real-time large-scale input from a crowd

One of the goals of Crowdboard is to enable many remote participants to provide diverse input in real-time. The main module that makes this feature possible is the web-server shown in the central part of Figure 5.1. It is written in Node.js and it is responsible for storing the status of the system and keeping the clients synchronized. It has been shown [31] that Node.js is particularly suitable for data-intensive real-time applications that run across distributed devices. To enable the communication back and forth between the client and the server we used *socket.io* [58].

5.3.2 Integration with Physical Design Studio

Another goal of Crowdboard is to allow the team to leverage the creative crowd input while working into a physical studio. To implement this feature we designed two modules: the WhiteboardCapture module and the TouchDetection module. Both run on the local laptop (see Figure 5.1, left).

The WhiteboardCapture module is written in Matlab and is responsible for capturing and uploading whiteboard screenshots to the server. It deals with the calibration needed between the webcam and the projector, to make sure the crowd's contribution is projected on the right place on the whiteboard. To do so, it takes a screenshot of the whiteboard and asks the user to select the four corners of the projected interactive area. The module uses those points to calculate the projective transformation needed to calibrate the webcam and the projector (Figure 5.3). After this one-time calibration, the module enters in a loop performing the following operations: take the screenshot, apply the transformation matrix previously calculated and send the rectified image to the node.js server.

The TouchDetection module is written in C# and its goal is to read the depth-data from the Kinect and to calculate where the user touches the whiteboard. This is achieved using a background subtraction technique and a noise removal algorithm, as in [65]. As in the previous module, a one-time four corners calibration phase is needed to map the depth-camera coordinate system to the world-space system.

5.3.3 Interactions among the remote participants

Online participants interact with the team by using a web interface (Figure 5.2). The left panel contains the live video broadcast of the meeting from the web camera, a group chat window and the list of online participants. The right panel

(a) A. Picture taken from the ceiling. (b) B. Rectified picture sent to the server.

Figure 5.3: WhiteboardCapture image processing.

contains a synchronously updated view of the studio whiteboard. Online participants can create a new discussion in a particular (x,y) position on the screenshot with a simple double click. They can also expand and add to an existing discussion. Under the whiteboard view, online participants can manipulate a timeline interface; the videocast, the whiteboard state, and the comment threads will update appropriately.

The web interface is built in Backone.js, an MVC-like javascript framework. Backone.js binds a model with all the views that use it, so that when an attribute of the model changes, all the related views automatically update themselves.

5.4 Evaluation

We evaluated Crowdboard to find out whether a real-time input from a crowd could positively affect an early-stage design session and to learn about possible issues concerning the designer-crowd interaction. We conducted six user studies. After every study we use the knowledge gained to make design changes to the web interface in order to take into account the users' feedback.

5.4.1 Session 1

Crowdboard 1.0

In the first user study we used the web interface showed in Figure 5.2.

Participants: design students

To evaluate Crowdboard, we used social-media to recruit three people to be the local design team and eight online participants to be the crowd. The online participants were either design students or architects with skills in design.

Procedure

The design brief asked the participants to conduct two brainstorming sessions, lasting 20 and 25 minutes respectively. For the first brainstorm, we asked the team to the discuss and create a concept map for the idea of traveling to a foreign country, creating a map of all the issues, opportunities, and knowledge they have on traveling in foreign countries. For the second brainstorm, we asked the team to create a mobile app for travelers. The idea was to draw upon the previous discussion, but to focus more on UI components, ideal technology, human factors, usage scenarios, and even branding.

Results

The team started discussing the functionality of the system and highlighted some of the key issues as a mindmap. Meanwhile online participants followed the conversation and clicked on top of the whiteboard view to add comments. Back in the physical studio, the team noticed the new conversation annotation icons and saw the issues raised by the online participants. The design team and the crowd continued work together to fill the whiteboard with comments, ideas, and potential solutions.

Overall the team's impression about the system was quite positive: *"I thought, overall, [the crowd input] was pretty beneficial."* The crowd felt satisfied from the experience as well:

> *"The session was engaging, I felt the team spirit despite the distance"*

> *"It worked great and the team was very responsive to the feedback"*

Remote Participants Influenced the Conversation. The study showed clear signs of the positive outcomes of real-time crowd input. After the first brainstorm into the issues of "traveling to foreign countries" the team was eager to start drawing out the details of the application. Hoping to take all their ideas formulated from the first session, they quickly started mocking up wireframes. The team stopped after only a couple minutes of drawing. A crowd member quickly realized they had forgotten to take the diligent step of making a site-map. The crowd member quickly sent the advice to create a site-map. The team erased their

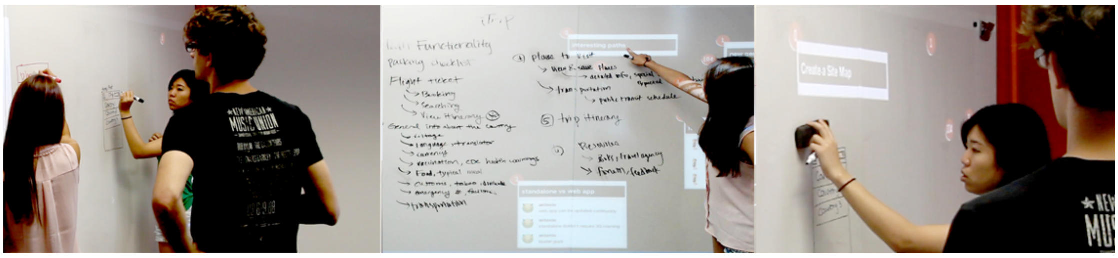


Figure 5.4: Scenes from the case study. (Left) The team gathers to discuss issues for a mobile application geared around travel. (Middle) The remote crowd adds comments as the team continues to design. (Right) The team sees a suggestion to Create a Site map and then decides to do just that.

previous wireframes. The team remained productive for the second session focusing on the framework of the application versus the unneeded details of final design (Figure 5.4).

> *"We were thinking creating a wireframing for the iphone app and someone suggested creating a site map instead... we weren't really sure what the app would look like, because we couldn't organize the hierarchy of the site at that time, so I guess the [crowd] suggestion to make a site map was really useful" (local team member)*

Awareness support needed. During the session, the online participants could make two possible actions: creating a discussion thread or contributing to an existing discussion thread. Analyzing the session, we noticed about the 80% of the discussion threads contained contributions from just one participant, i.e. crowd participants tended to contribute mainly to their own discussion thread. This suggests the need of mechanisms to make the crowd participants more aware of each other's contribution.

Also both the crowd and team felt there was no consistency in input and response. One Crowd member felt he/she inserted a productive comment to the board, but the contribution went unnoticed for a while. This delay takes away from the voice of the crowd and produces disjoint conversations, as explained by one team member:

> *"Sometimes I felt we didn't recognize the upcoming comments immediately"*

Request for a more direct interaction. After synthesizing the final surveys and interviews with the team, the data showed the participants' desire for more direct communication.

The team felt the remote participants often felt invisible and muted: *"The crowd did not have so much presence..., maybe adding voice..."*

When asked how to fix this problem, both team and crowd would like to give the crowd voice/audio: *"[I would add] a system of video chatting to make the conversation actually bilateral."* This is interesting, but it raises questions about how to facilitate such interactions when there are tens or hundreds of simultaneous remote participants.

Lesson learnt

The research reveals some design implications. During the design session, the crowd was not really sure whether the team had noticed their contribution in time. That was confirmed by team members who sometimes felt like the crowd was commenting on a problem already discussed. While appreciating the possibility to refer to something on the board at a certain (x,y) location, both the team and the crowd preferred to move the annotations to the board's edges once read.

These considerations imply the need for a more prominent notification system coupled with a different way to show information on the board.

Another finding involves the request for a stronger designer-crowd interaction. While it was predictable that the crowd wanted to feel like their voice had been heard, and to feel part of the team, we were surprised to find that the team felt the same way. The team appreciated the crowd contribution and considered it beneficial. However they would have appreciated it more to feel the crowd's presence, and to work more like they were part of the same team. Both the team and the crowd suggested the introduction of tools to actually engage in a bi-directional conversation, such as video-conferencing tools. While that could have been useful in a particular case study where the size of the crowd involved is small, we believe that this solution would not be suitable when a larger number of people is involved. Adding a feature like posting audio/video clips seems a good tradeoff to address the issues raised, without preventing the capability to scale. However additional studies are required to understand if the same issues will be raised in other settings involving different crowds and different number of involved participants.

5.4.2 Session 2

Crowdboard 1.2

Before running this pilot we made some modifications to the Crowdboard web interface. As shown in Figure 5.5 we added the list of all the conversations in the left panel, in order to show all the conversations' titles at a glance. Looking the

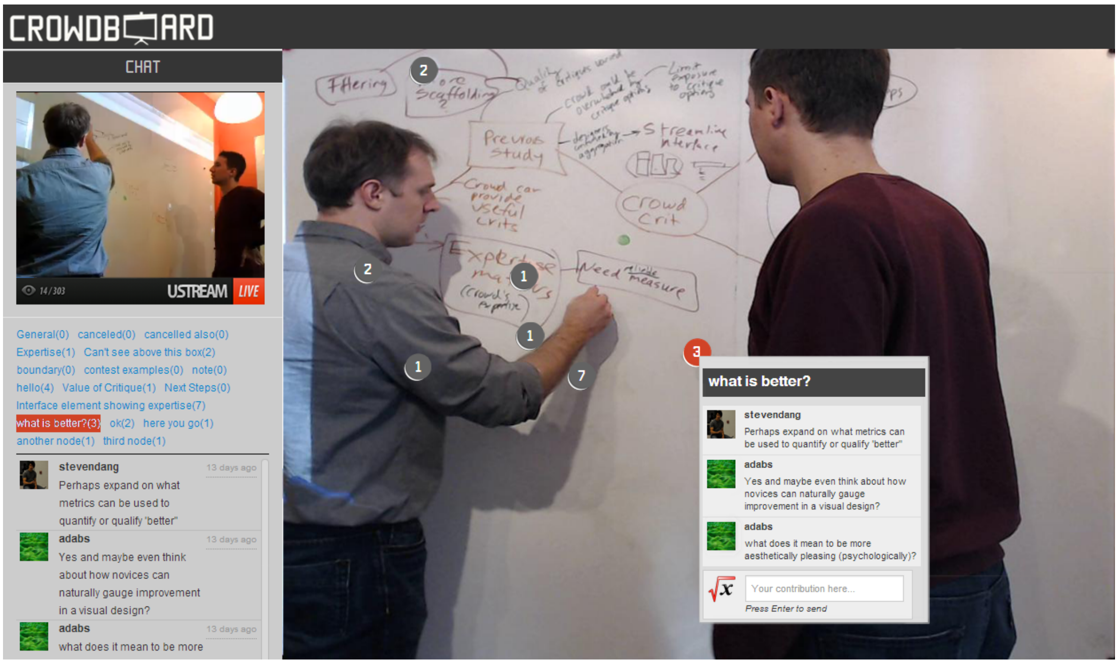


Figure 5.5: CrowdBoard's Web interface version 1.2.

content of a discussion thread was thus possible either by clicking a circle on the whiteboard or by clicking on a discussion thread.

Participants: researchers

To test Crowdboard 1.2 we used word of mouth to recruit two researcher to be the local design team and five researchers to be the online participants. During the experiment the online participants were in different rooms.

Procedure

The brainstorming theme was proposed by one of the team members and was about how to have the crowd performing design critics. The session lasted 30 minutes. The session was followed by an informal interview to the team members and the "crowd".

Results

Both the team members and the crowd concerns were about the usability of the system. Like the previous study there was a general demand for a stronger notification system. The crowd pointed out that a big effort was needed to remember the

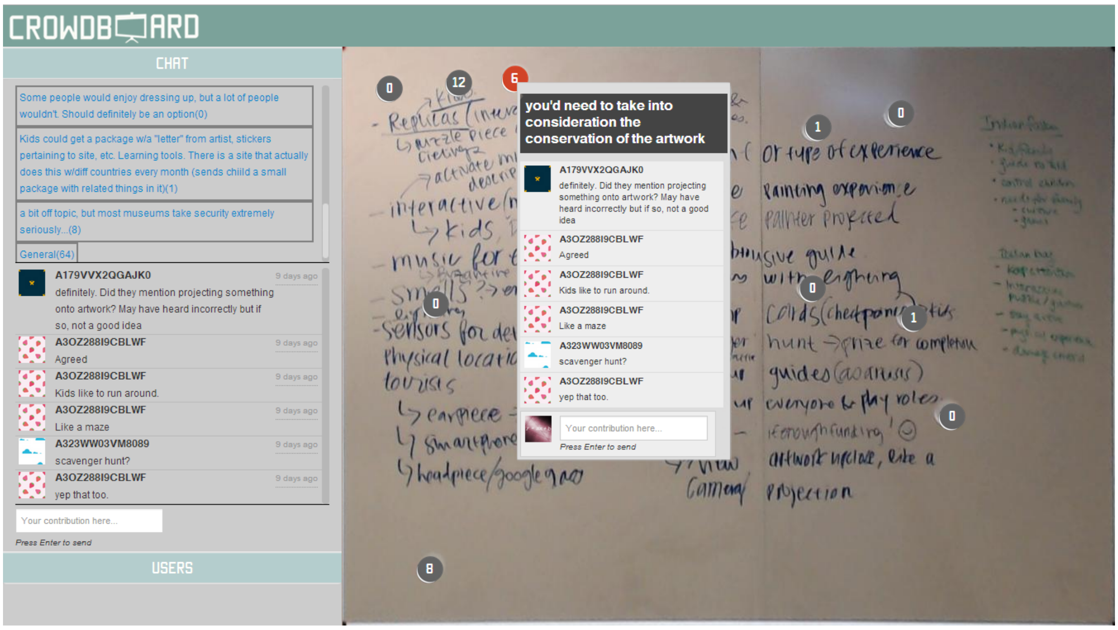


Figure 5.6: CrowdBoard's Web interface version 1.3. Chat View.

status of each discussion thread and to get aware of a new coming comment. Another results of this pilot was the fact that two crowd members did not contribute to the conversation.

Lesson learnt

In this session two main factors played a relevant role: a) the background of the participants and b) the fact that the participants knew each other. Both the team and the crowd were Interaction Designers. That explains why their feedback focused a lot on fine-grained visual details. Another situation we noticed was the evaluation apprehension from the less senior research members of the group who didn't feel like contributing to the discussion. Although some improvements were made with respect to the previous study, the system still needed a better notification system.

5.4.3 Session 3

Crowdboard 1.3

Taking into account the feedback received in the last two studies, we decided to address the problem of occlusion caused by participants standing in front of the camera, by placing the camera on the ceiling. We also modified the Crowdboard

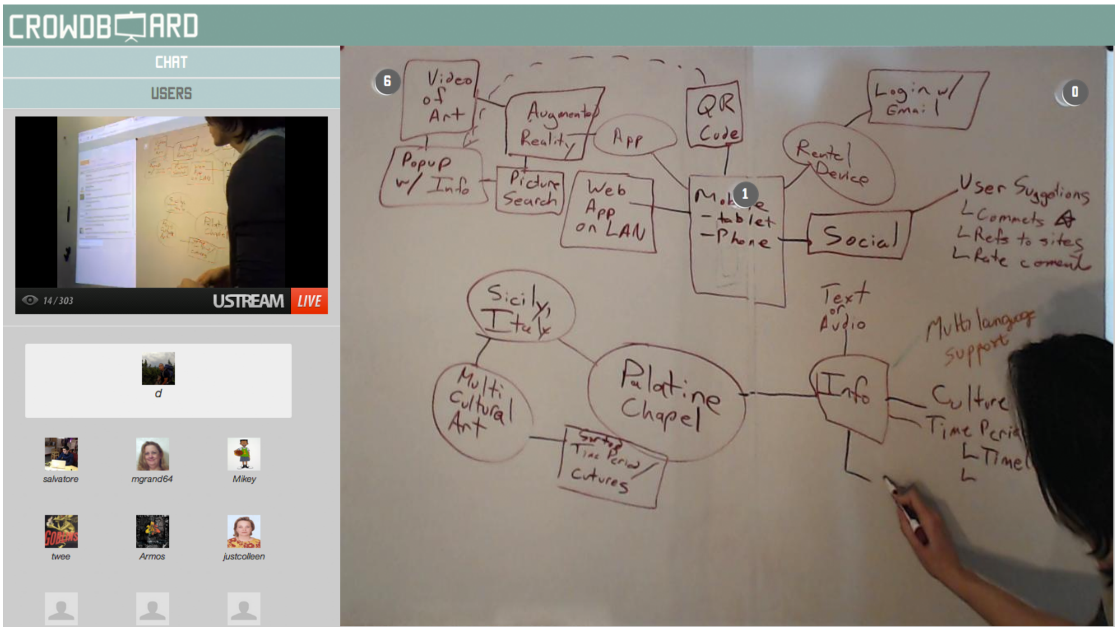


Figure 5.7: CrowdBoard's Web interface version 1.3. Users' View.

web interface as shown in Figure 5.6 and Figure 5.7. Following the users' feedback we realized that the majority of the online participants did not feel useful watching the live video stream on the left panel (Crowdboard 1.2). Regardless of the low frame rate, the main central panel, with the continuosly updated whiteboard capture, was considered enough. For this and for space reasons, we decided to put the video stream in a panel collapsed by default. This way, in Crowdboard 1.3 we gave more room to the threads' titles and contents, while still giving the option to expand the collapsed panel on the left and watch the live video (Figure 5.7). For the users keeping the video in the collapsed panel, the experience corresponded to having only audio.

Participants: paid online crowd

In this experiment we hired three master students in human-computer interaction to play the role of the design team. As for the online participants, we hired 11 people from Amazon Mechanical Turk (see section 2.3). In the crowdsourcing community such people are usually referred to as "Turkers".

Method: synchronous crowdsourcing

The typical task Turkers are used to are asynchronous in their nature. Our experiment presented a peculiar aspect: we needed to have online participants to show up at a certain time (the time the experiment was scheduled) on our platform. Doing so in a platform designed for asynchronous tasks poses several challenges. Furthermore, to be able to use the system, they needed to register to the Crowdboard website. This poses an additional challenge as AMT terms of services explicitly forbids to ask Turkers to register to an external website. One possible solution would be emailing workers and providing instructions, but AMT allows a requester to contact only workers who have completed a task.

We addressed those problems in the following way:

1. We posted a small reward task. The task itself was to accept to be notified by email. Mason and Suri [46] suggests that if one wants to conduct experiments with n subjects simultaneously, that one needs a panel with *3n* subjects in it. Thus we followed this suggestion and we used the small reward task to pre-notify 30 people, with the actual goal of having 10 people show up at the designated time.

2. We paid the Turkers the small reward.

3. We pre-registered each worker to the Crowdboard website and assigned a different default user thumbnail.

4. We notified each worker by email. In the message we explained the nature of the task to be conducted (collaborative brainstorming). We also told them the scheduled time of the experiment and sent them a custom link to the Crowdboard website to be followed at the designated time. We asked to partecipate at least at 30 minutes (out of 60) of the session and to actively participate with at least three relevant ideas/comments.

5. When the experiment was done, we paid the Turkers who followed our requirements and sent them a survey.

6. We paid the Turkers who filled out the survey.

This is a very long process, but the AMT APIs provide a good tool to make part of this automatic.

Procedure

The design brief asked to brainstorm how to improve the user experience in the Palatine Chapel of Palermo. It asked to consider the particular place, but gave also the option to generalize to other Chapels. It also asked to consider two different kind of *Personas* [50], i. e., a specific target audience. The two personas were an indian father, and an italian kid. The task of introducing the place and the problem was given to the design team. After the study we sent surveys to both the team and the crowd.

Results

As expected (see previous explaination of the synchronous crowdsourcing method) just 11 crowd members out of 30 joined the discussion at the designated time, but one left the virtual room after five minutes and thus did not actually take part to the conversation.

Some crowd members experienced technical difficulties. For example a crowd member pointed out:

> *"There was a slight issue with the video feed but that seemed to be resolved quickly"*

We asked the crowd to what extent they felt the conversation led to good results and the average result was 9.125 out of 10.

Regarding the Crowdboard's features, the crowd particularly appreciated the option to refer to something on the whiteboard:

> *"I liked how you could pin to the white board and write your thoughts, it was very interactive"*

> *"I liked that I was able to pin things on white board to reference what people were writing. It made it easier to collaborate because I did not have to type out what I was referencing"*

In general the crowd showed a lot of enthusiasm about the experience:

> *"I really enjoyed the experience, and wouldn't mind doing more work of this sort. I had fun, and felt as if my time was well spent. I'd really like to know what ultimately happens with the project"*

> *"Best HIT I've done on mTurk. I felt as if I was actually in the room and enjoyed contributing to the conversation"*

The team appreciated the tagging option as well, and showed a general appreciation for the crowd input, as pointed out by one team member:

> *"I think the overall conversation was good...People all had good opinions."*

However the team lamented the lack of a good notification system that would have made it easy to understand the presence of new coming comments that needed to be read. Although the crowd feedback seemed to be very interesting, the team didn't look at it on a regular basis. One team member explains the reason that made her losing faith on the crowd attitude:

> *"Sometimes I felt the crowd were having separate conversations"*

Lesson learnt

In this study we learnt that people from AMT can be a good resource to involve in co-design activities of products for cultural heritage sites. The participants had different background, status and age. They immediately understood how to use the system. They also really appreciated the system, especially the feeling that their voices had been heard. The tagging option was considered useful from both the team and the crowd and the discussion was considered to lead to good results. However some issues still happened. The crowd had a very positive attitude and took the experiment very seriously. Just once, because they experienced some technical issues, they talked about that in the chat and as a consequence the team felt they were having separate conversations and lost interest in the crowd's input. The technical issues were caused by the high load on the server side. The real-time streaming of the whiteboard scans stressed a lot the server, which was programmed in a technology, Node.js, that performs well in handling a huge traffic of small size messages, but is not the best option for high loads [31].

Another factor that didn't help in building a good interaction between the team and the crowd was the fact that the names and thumbnails of crowd members were pre-assigned. They were too much similar to each other. As a consequence the team could not distinguish between a crowd member from the other and they felt this influenced negatively the interaction with the crowd.

5.4.4 Session 4

Crowdboard 1.4

Before running this study we decide to handle the high load issue. The web interface here is the same as in Crowdboard 1.3 (see 5.4.3). As previously explained, servers like the Crowdboard's one, written in Node.js, are not the best option to serve heavy files, especially in conditions of heavy traffic. The adopted solution to address this problem was to install *nginx*, a server with good performace in handling huge loads. The new architecture thus used nginx to serve the big files and the initial Node.js server to deliver all the other messages.

Participants: paid online crowd

In this session we hired two master students in human-computer interaction to play the role of the design team and 11 people from Amazon Mechanical Turk to be the crowd.

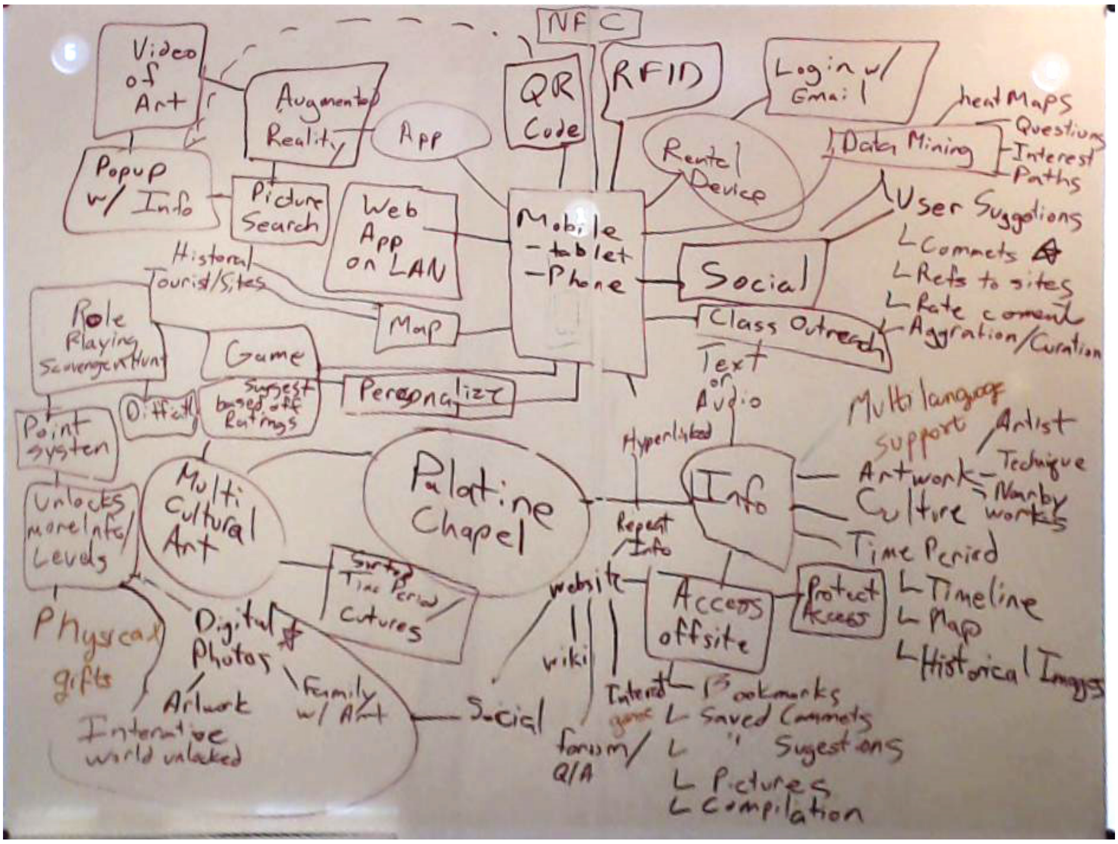


Figure 5.8: Session 4. Improving the user experience in the Palatine Chapel

Method: synchronous crowdsourcing

In this session we used the same procedure as in the previous session. This time we pre-notified 45 people with the goal of getting 15. With respect to the previous study we skipped the step of pre-registering the Turkers to the Crowdboard website. Instead we asked people to register themselves and also encourage them to add a thumbnail.

Procedure

Once again the design brief asked to brainstorm how to improve the user experience in the Palatine Chapel of Palermo. The time given was 60 minutes.

Results

The final output of the session is shown in Figure 5.8. This time only 11 crowd members out of 45 joined the discussion. In the final survey nobody complained about technology issues. For example when asked about the main hurdles encountered during the session, one crowd member said:

> *"I do not believe there were any major hurdles, everything went smoothly."*

Once again the crowd felt their voice had been heard.

> *"...It felt rewarding to get feedback and see our ideas being valued as potentially important"*

The team considered the crowd input very beneficial as pointed out by a crowd member

> *"After few minutes I ran out of ideas...I was relying a lot on the crowd"*

Lesson learnt

The study confirmed the good results of the previous one and showed that the technical issues due to the high load were solved. This study also reveals some useful insights. A very interesting result was the fact that for the first time the team seemed to take full advantage of the crowd input. The key of this success was the behavior of the team who took great care in trying to engage the crowd throughout the entire session, by talking with them instead of just talking to each other. Another key factor was the following: during the discussion the two team members took different roles. This happened naturally and without previous agreement: one team member decided to just monitor the crowd input while the other team member was leading the discussion and took care of adding the crowd ideas on the whiteboard. This method maximized the team productivity and at the same time contributed to engage the crowd who was continuously acknowledged. Another aspect of this study is the small number of participants who showed up at the experiment. We expected 15, but we got only 11. We believe this was due to the sign-up procedure (not required in the previous study) that could possibly have discouraged some people. However in this case, unlike the previous study, the team could remember some crowd's members names, and build an idea of the quality of the input and participation of those crowd members. This was perceived as a good factor that helped social interactions.

5.4.5 Session 5

Crowdboard 1.5

Before this study we made sure that every new coming comment would have been well notified. We did this by choosing different color schemes for different states of a discussion thread. Threads with no comments to be read were highlighted in gray, threads with some comments to be read were highlighted in blue, and threads currently selected were highlighted in red.

Participants: paid online crowd

In this session we hired 33 people from AMT to be the crowd and two design students to be the team.

Method: nearly real-time crowdsourcing

This time we abandoned the pre-notification strategy used in the last two studies. Instead we post a single task aimed at bringing workers to the Crowdboard website at a designated time. We posted the task 20 minutes before the beginning of the brainstorming session. We posted tasks for 60 possible workers, but canceled them after 33 had accepted to join.

Procedure

We asked to design a mobile app for traveling abroad. We allotted only 10 minutes for the entire session. At the end of the session we sent surveys to both the team and the crowd.

Results

This time we got mixed results. Both the team and the crowd felt overwhelmed by the large number of ideas coming in such small amount of time.

Lesson learnt

The great amount of comments coming in such small amount of time influenced negatively the conversation. Furthermore both the team and the crowd didn't get enough time to make themselves comfortable with the system and with the matter of the discussion. Longer studies and new ways of aggregating comments are required for a better interaction.

5.5 Discussion

From the experiments we conducted we understood

- How to gather a crowd of potential stakeholders to co-design products/services for cultural heritage sites.
- Which elements could influence the crowd behavior when involved in co-design activities
- Usability elements to provide a good designer-crowd interaction.
- Some technical solutions to enable a smooth real-time large-scale collaboration
- The team benefits when using Crowdboard
- The crowd benefits when using Crowdboard

The main lesson learnt is that Crowdboard can play a relevant role in engaging crowds in co-design activities.

Feedback from the crowd The system makes the online participants feel like actually being in the physical studio, and this raise their level of engagement. They appreciated the fact that professional design teams are willing to take into account their ideas (see Figure 5.9 and Figure 5.10) regarding projects that are seen as potentially important. Furthermore the crowd appreciated the fact that the system was easy to understand (see Figure 5.11).

Feedback from the team The teams liked the system as well, but took full advantage of it in long sessions and when different roles between team members were introduced.

Design and technical aspects that influence the interaction The factor that could influence most the user experience of the team is being able to localize immediately a new coming comment without getting distracted from their reasoning, while the factors that could affect the crowd most are technical issues. In a system like Crowdboard, with either a high traffic of text messages and a high traffic of heavy resource, using different servers optimized for the two different kinds of traffic represented a good trade-off, at least for a number of participants less than 35. In order to scale to bigger numbers of participants, additional actions may be required.

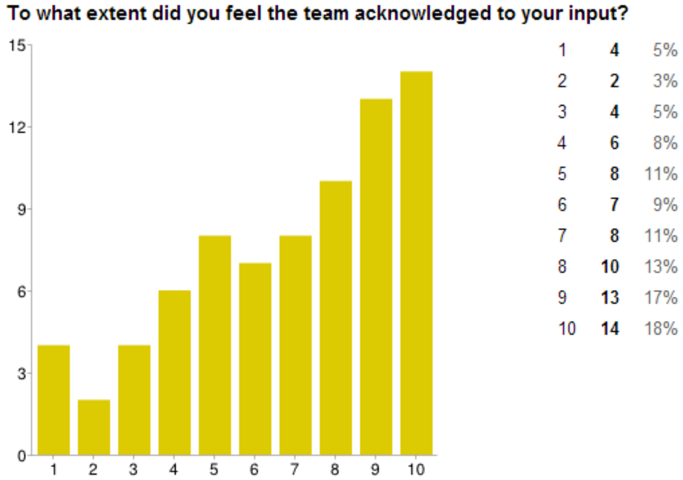


Figure 5.9: Extent to what the crowd felt their input was acknowledged.

Recruiting strategies Participants can be effectively gathered through crowdsourcing platforms like AMT. This is especially true when designing in the field of cultural heritage, because online workers represent a wide range of people, and everyone is a potential tourist. Among the recruiting strategies, the pre-notification system has proved to be reliable in providing the expected number of participants. However workers must feel their privacy is not in danger, so no sign-up phases should be required. Using nearly real-time crowdsourcing can be an effective way to make the recruiting process quicker, but it doesn't garantee to get the desired number of participants.

Other factors The longer studies showed better results. If the crowd is forced to rush, the quality of the conversation can be negatively affected. Also the ideal number of partcipants seemed to be a dozen. Higher numbers led to more confusion, so better strategies are required in order to scale. Adding a voting system coupled with filtering features would allow both the team and the crowd to visualize only the most popular comments. By doing so, confusion will be avoided even with larger numbers of participants.

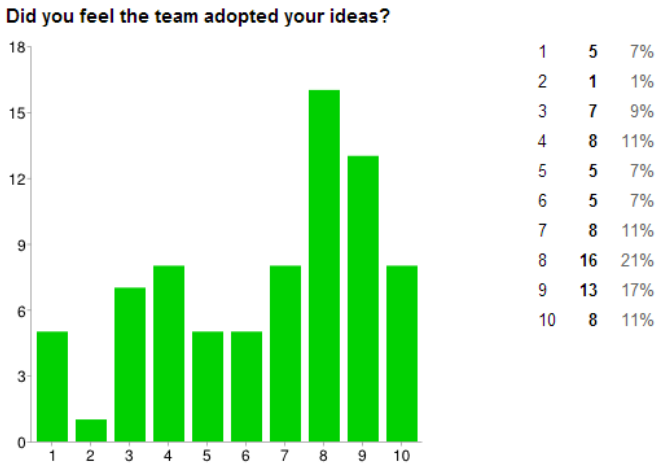


Figure 5.10: Extent to what the crowd felt the team adopted their ideas.

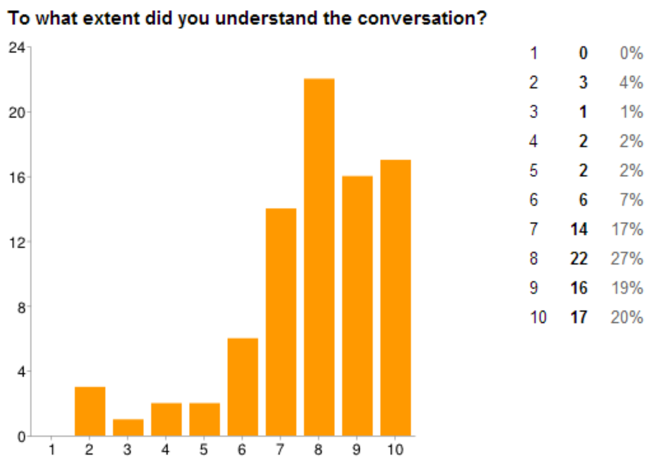


Figure 5.11: Extent to what the crowd understood the conversation.

Chapter 6

Future work

This thesis introduces design methodologies that we believe can be successfully applied to different domains than cultural heritage. We believe Crowdboard can be used in town hall meetings or in educational settings such as a traditional class or a MOOC [45], an online class with thousands of students.

6.1 Envisioned Scenario

To give an idea of possible application fields for Crowdboard, we imagine scenarios where a design team wants to engage the community directly affected by the design. For example, imagine a university who hires consultants to investigate a new fingerprint-based technology to replace the current pay stations across campus.

The consultants promote the upcoming design conversation through social media (e.g., Join the design team on July 11th at 4pm EST). On that day, they start-up Crowdboard and wait for people throughout the university to log on to participate.

The team starts discussing the functionality of the system and highlights some of the key issues as a mindmap. Meanwhile online participants follow the conversation and click on top of the whiteboard view to add comments. For example, at a local dorm, a student named Jack decides to raise the issue of whether the fingerprint system should require additional identification numbers. Back in the physical studio, the team notices the new conversation annotation icon, and expands the list to see the issues raised by the larger community. The design team discusses the tradeoffs of introducing personal id numbers as part of the system.

The design consultants and the online university crowd continue to work together to fill the whiteboard with comments, ideas, and potential solutions. At the end of the session the design team and the University both feel satisfied because the key issues and opportunities have been addressed.

In order to enable the envisioned applications more advanced features are required. Possibilities include adding sound notifications and keeping a list of new entries always visible in the interface. Another idea is adding a system of up-down voting, that may allow the team to see the most important contributions. Possible additional features may include support for sketching and for uploading images.

Conclusions

This work described the design and implementation of interactive systems and methodologies aimed at improving the user experience in Cultural Heritage sites. This goal is achieved in two different ways.

The first one is by taking advantage of context-awareness to provide a pervasive experience when visiting a cultural heritage site. The thesis explores how mobile devices can be used to exploit context-awareness in different situations and proposes a design pattern to facilitate the integration of context in pre-existing systems. iPalatina, iMussomeli, strEATing and MDMartidec are examples of how this pattern was successfully used for different situations. In order to achieve the same goal in large indoor spaces, such as museums and exhibits, the QRouteMe system was co-designed and co-implemented. In this case, the context-aware information is obtained by means of QR Codes.

The other important contribution of this thesis is the study of how potential stakeholders can be involved into the co-design of a product/service related to cultural heritage. We designed and implemented Crowdboard, a traditional whiteboard augmented with comments coming in real-time from an online crowd. This thesis presents several user studies, conducted with the goal of generating ideas on how to improve the user experience in cultural heritage sites. In particular, it considers the case of Palatine Chapel in Palermo. The results show a large number of generated ideas and opportunities. The goal of improving the user experience is reached by designing accounting for many diverse viewpoints in order to meet the needs and expectations of as many stakeholders as possible.

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