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CroMAR: Mobile augmented reality for supporting reflection on crowd management

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Abstract - *In this paper we discuss the usage of Mobile Augmented Reality (MAR) to support reflection on past events, using reflection on crowd management as scenario. Computer based support to reflection generally relies on the visualization of information connected to the experience one is reflecting upon. Different metaphors have been adopted to support easy access to relevant information within the reflection process, e.g. timelines and word clouds. In this context, MAR represents an interesting alternative because it can be used to promote reflection in the specific location of the event by augmenting it with relevant information. In this way, we can expect the reflection process to be grounded in a context that helps to make sense of the information and reflect on alternative paths of action. The paper presents the scenario of usage, together with the design, development, and evaluation of the prototype, CroMAR. Based on this experience, we identify challenges connected to the usage of Mobile Augmented Reality in terms of support for reflection, interaction, and design methodology.*

Keywords: Mobile Augmented Reality, reflection, collaboration, tablet, crowd management

INTRODUCTION

Augmented Reality (AR) enriches the physical world with virtual elements, enhancing users perception of their surroundings by exploiting visual, audio and haptic feedbacks (Mallem, 2010). Although the term "Augmented Reality" was introduced in the 1990s (Caudell & Mizell, 1992), prior experiments with AR were made in the 1960s by Sutherland (Sutherland, 1968), with head-mounted displays (HMD) able to show computer graphics mixed with real world objects. More recently, HMD technology has been proposed, e.g., for military applications (Kalawsky, 1993) and to support collaboration among rescue forces for crisis management (Nilsson, Johansson, & Jonsson, 2009). However, the mass adoption of HMD technology is made difficult by high costs, limited mobility; moreover, wearing a HMD in public might affect dexterity (Wagner & D Schmalstieg, 2003).
The recent widespread adoption of handled devices, such as smartphones and tablets, is opening new possibilities, but it also brings along numerous design and deployment challenges, as discussed at MobileHCI2011 during the first workshop on Mobile Augmented Reality[i].

In this paper we are interested in exploring the possibilities offered by Mobile Augmented Reality to enrich the physical space where human activities with a strong physical element take place. In this perspective, it is important to look at this technology in relation to the discussion on space and place. According to Harrison and Dourish "Space is the opportunity, place is the understood reality" (Harrison & Dourish, 1996). While *space* is the three-dimensional structure of the real world where we live, a *place* is *space* (either real or virtual) enriched with values and meanings. Examples of elements a place is built of are people's experience and activities (Malpas, 1999) as well as meaning and values related with them (Cresswell, 2004). Although the notions of *space* and *place* have different interpretations and often the two terms have been used to refer to the same concept (Ciolfi, Fitzpatrick, & Bannon, 2008), several frameworks have been introduced to characterize the information that is embedded in a place. For example, in 1996 Casey (Casey, 1996) proposed a notion of how people sense places and attribute meanings to them. Building on Casey's work, Rossitto (Rossitto, 2009) describes a place as arising from people's *experiences* along four interrelated dimensions: (i) a psychological dimension, including individuals' memories, values and thoughts; (ii) a physical dimension, that is the geometrical structure of a space; (iii) an historical dimension, encompassing the past of a place and the memories of it; (iv) a social dimension, presence of other peoples, and their cultural aspects. Also other works suggests that experiences are important factors for the definition of a *place* (Tuan, 1975)(Lentini & Decortis, 2010).

In this paper we investigate the usage of Mobile Augmented Reality to support debriefing and reflection on work practices that rely on deployment and management of resources in space and that have therefore a strong spatial dimension. More specifically, we aim to promote reflection among workers who have been deployed on the field to operate as crowd managers during a planned outdoor event (e.g. concerts, sport games, demonstrations). With minor changes, the system could also be adopted to reflect on emergencies on a local territory.

Reflecting on action is critical to learn from past experiences and performing better in the future (Boud, Keogh, & Walker, 1985),(Schön, 1983). Different tools have been developed to support reflection, as an individual or collaborative activity. Generally, these tools provide access to information about past events. This information is important to support reflection not only to complement human memory, but also to allow bringing in multiple perspectives on collaborative processes (Krogstie & Divitini, 2010). Different metaphors have been proposed to organize this information, e.g. timelines (Kristiansen & Storlien, 2011) and tag clouds (Glahn, Specht, & Koper, 2009). To take advantage of the strong physical component of the work, in this paper we want to investigate the possibility to augment the space where the event unfolded with the information needed for reflection, letting users explore the *place* while in the *space*. In this perspective, following Casey's conceptualization of places as dynamic, the augmentation of reality has to take into account the need to change dynamically for each individual, depending on past and ongoing activities, users' needs and situations. Information presented to augment reality is not therefore defined a priori, but emerges from the activities and experiences of people "who" live in *place*, through *space* and *time*. This implies that different experiences (the event as experienced by different individuals) need to be captured to provide a meaningful representation of the place.

The paper is organized as following. Next section presents related work. The following section introduces the scenario for the application that we have developed, CroMAR (Crowd MAnagement Reflection). The scenario is inspired by fieldwork with the Italian Civil Protection in one of the largest Italian cities. After the scenario, we present the design, development, and evaluation of the first prototype. The last section concludes the paper and identifies directions for future work.

RELATED WORK

Nowadays, ubiquitous computing technologies allow enriching *spaces* with devices such as sensors and actuators (the so-called smart environments), and to review and interact with information generated in those environments. Several approaches are available to interact with place-based information, for example: 2d maps, virtual reality and augmented reality.

Since the release of public API for several web-based map providers like Google Maps[ii] and OpenStreetMap[iii], 2D-maps have become a popular tool for displaying geo-tagged information; allowing mashing-up information (e.g. photos, news, sensor data) with a map. However, when a huge amount of contents is displayed on a mobile device, due to its screen size, browsing and searching relevant information on a map might become a frustrating experience (Chittaro, 2006). Moreover, the user interface might hinder the real exploration of the space keeping the user focused on the device screen.

Another approach to place visualization is to use Virtual Reality (VR)-based environments like 3D Social Virtual Worlds (SVW). One example of SVW is Second Life[iv]. SVWs can reproduce physical spaces and represent pieces of information adding virtual objects to the reproduced environment. For example, in (Fominykh, Prasolova-Førland, & Divitini, 2011) a university campus is reproduced and augmented with different features to promote collaborative creativity. Though this approach allows exploring remote places, the VR-based interaction lacks of the sensorial perceptions that are proper of a real world exploration, perceptions that might turn out to be important triggers for reflection. Moreover, implementing VR techniques usually demands computational power not yet available on mobile devices.

Whereas VR aims to create computer-generated worlds, Mobile Augmented Reality (MAR) steps towards augmenting the existing physical world with virtual elements. Among MAR applications, popular are those that run on consumer devices, like smartphones or tablets. A number of works have investigated smartphone-based MAR applications in different fields, including: support to pedestrian navigation, either indoor (Mulloni, Seichter, & Dieter Schmalstieg, 2011a) or outdoor (Mulloni, Seichter, & Dieter Schmalstieg, 2011b); platforms enabling user-generation of geo-tagged contents (Júnior & Teixeira, 2011); support for note-taking onto physical objects (Liu, Diehl, Huot, & Borchers, 2011); exploration of hybrid location/computer-vision based AR for performing Foursquare[v] check-ins (Büttner, Cai, Cramer, Rost, & Holmquist, 2011). The recent introduction of a new generation of tablet-PCs (most of them featuring cameras and GPS, starting with the release of the Apple iPad[vi] in 2010), has opened new possibilities for MAR applications, mostly not yet explored. Such applications can explore new domains where the increased screen size and computational power provided by tablets might be winning against the higher portability and easy-of-handling offered by smartphones. Examples of these domains are language learning, as showcased by the WorldLens[vii] iPad application and place-based information browsing as seen in the Wikitude[viii] application.

SCENARIO AND DESIGN

A complete description of the work of the Civil Protection is beyond the scope of the paper. Here we simply present a scenario for outlining how Mobile Augmented Reality could be adopted. During an emergency or an event involving a large number of people, different personnel is deployed in the field with the aim of managing the crowd. Volunteers with varied levels of competencies are often involved, together with trained professionals. People work alone, but more often are grouped under the supervision of a coordinator. Different hierarchical levels are generally identifiable. The work is distributed on a territory that might vary in size, as for example a stadium where a sport event is taking place or a city where a number of cultural events are taking place synchronously (this last one being the situation that we followed in our field study). Some events are limited in time, lasting a few hours, while others might last longer. Though clear protocols are identified for recurrent situations or identified possible risks, each event is highly dynamic and unique, requiring adaptation and quick decision-making capabilities. It is therefore important to reflect on an event after it has taken place to learn, at the individual, team, and organizational level. Given the highly distributed nature of the work, it is impossible for any of the involved person to get a complete overview of the event that has happened, because it involves multiple, sometimes contradicting, perspectives. In this situation, it is possible to support reflection by providing access to different information about the events. After the event, we therefore envision enriching the current practices of debriefing and reflection by introducing a tablet-based augmented reality viewer that shows information collected during the event (Figure 1). The system must be able to support navigation of the information and promote sharing among co-workers. Reflection is expected to happen at the same physical location of the event. Mobile Augmented Reality can help to layer information about the event and access spatial information that might be relevant to re-think the event. For example, comparing a photo of a square during an event with the real space under normal conditions might help to reconsider actions that have been taken and possible alternatives, e.g. alternative escape routes. Or, looking at the space in normal conditions might help a worker to re-assess more critically his level of stress during the event. With Mobile Augmented Reality, while being in a *space*, the user can explore the *place* of the event, accounting for multiple experiences that have shaped it.

Figure 1: The first mock-up of the Mobile Augmented Reality system

Sources of information

During an event, information is continuously exchanged to coordinate activities, often with the mediation of different tools; sensor and camera feeds from mobile and static checkpoints are recorded. Event's attendees might distribute related user-generated content though social media (e.g., Twitter and Facebook). When developing the system, one of the first design decisions is about the type of information that should be presented. Given the dynamic nature of the work and reflection process, combined with the variety of information sources, we expect that is not possible to define a priori for any situation the type of information that can and should be collected and then presented to users. It is therefore important to have a system that can be tailored to specific informational needs. In choosing information sources it is important to capture relevant traces of the multiple experiences that have shaped the place. Information can come from different sources, e.g.:

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

When choosing the relevant sources, it is important to take into account that to support reflection, it is important to shed light on different aspects of the experience, including ideas, behaviors, and feeling (Boud et al., 1985). The sources of information should therefore be selected to shed light on the aspects that are deemed more relevant for the specific situation:

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

In the mockup in Figure 1, we present a tweet and a MMS by participants (on the left side); videos captured by a support unit of the Civil Protection (upper right side); the noise level from a dedicated sensor (middle right side); excerpt from the radio communication of the volunteers (lower right side). This allows capturing both the behavior of different actors and some feelings (tweet and radio communication).

Navigation

The large amount of information collected during an event and the fact that the information will be visualized on a tablet-device screen make the support for navigation of the information critical. Each user should be enabled to visualize different kinds of information depending on what she wants to reflect upon.

In an initial phase of the prototype, we have considered the possibility to layer the information based on existing conceptualization of places, considering e.g. the historical, psychological, and social dimension of a place, building on frameworks reviewed in the introduction section. However, this direct mapping does not seem suitable to capture the needed flexibility and we have therefore decided to support different modality of navigation, rather than organizing the information in predefined layers (Figure 2).

The main form of navigation is *space*. Users can get new information by moving the device and framing different parts of the space. The system will accordingly modify the information that is visualized based on its associated geographical information.

In addition to the spatial dimension, *time* also plays an important role in the shaping of a place, given its dynamic nature. It is therefore important to be able to capture and present the temporal evolution of a place. In our prototype, we envision supporting temporal navigation by visualizing all the information in a portion of location that has been submitted in a certain period of time (see timeline at the bottom of the display in Figure 2). Finally, we want to support navigation by *keywords* trying to capture possible semantic connections among the information (e.g., the usage of similar tags).

Figure 2: Navigation modalities

Cooperation

Crowd management involves a number of actors with different roles. We therefore look at the related reflection on the event as necessarily cooperative. Even when the reflection is individual, it is necessarily relying on information provided by others, to be able to capture multiple perspectives.

In our scenario, fragments of information come from actors operating in different contexts to achieve different goals. They are pieces of a puzzle that must come with an embedded context (e.g. geotags, timestamps, comments ...) which allow setting them together in time and space to be compared, clustered, layered, shared and re-used across multiple representations. Information should not be seen in isolation, but as part of a Common Information Space (Bannon & Bødker, 1997) that supports reflection on the practice. In this perspective, the system should be able to support sense-making processes to allow meaningful action. Also, it is important to provide the right level of sharing – depending on roles and respecting privacy issues. We plan to support asynchronous collaboration through the annotation and rating of specific pieces of information; the sharing of a specific type of information; the sharing of a specific view, i.e. a picture of the location and the specific information that one is looking at in the moment the view is captured (Figure 3). Synchronous cooperation will be enabled by video conferencing. For example, a worker doing reflection on site might want to discuss some issues with his supervisor or colleagues who were at the site during the event.

Figure 3: Supporting cooperation

CroMAR PROTOTYPE

The current prototype runs on Apple iPad 2. Despite most of the Augmented Reality applications are developed for smartphones, the amount of information the user has to be provided with led us to exploit a tablet due to its larger screen size. In fact, the difficulty to navigate information grows with the amount of information presented (Chittaro, 2006).

Figure 4 shows the high-level architecture of CroMAR. CroMAR consists of an AR Engine and Viewer, mechanisms for supporting synchronous and asynchronous cooperation, mechanisms for supporting navigation, and a generic REST interface used to communicate with third-party services such as Twitter[ix] and Pachube[x]. Each component of the system is briefly explained to provide an overview of how the system works. More information is available in (Boron, 2011).

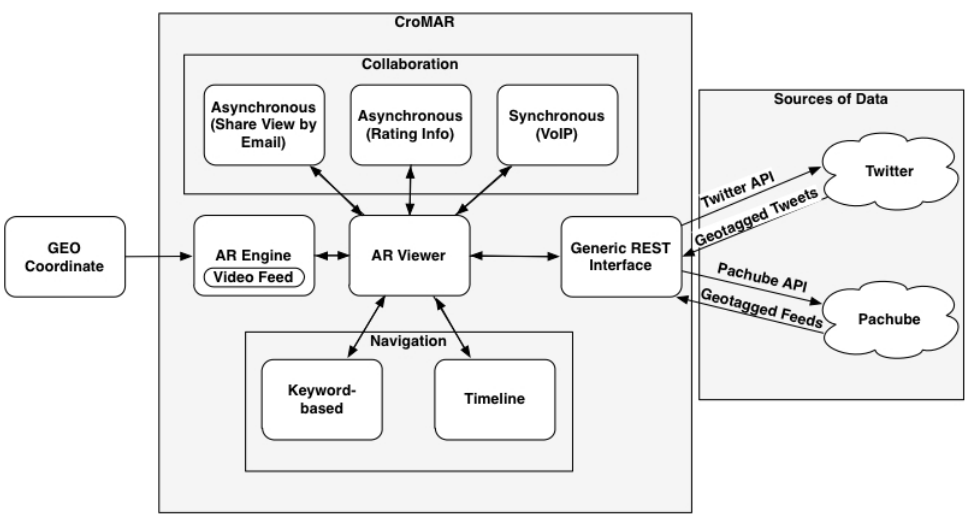

Figure 4: CroMAR overall architecture

AR and Viewer

The AR engine and viewer are based on the Augmented Reality toolkit proposed by Alasdair Allan in the book "iOS Sensor Programming" (Allan, 2010). They are responsible to superimpose information on the video feed based on the position of the user and of the information to be visualized. The engine is responsible to calculate whether a certain piece of information is within the field of view of the user, while the viewer is responsible for the actual visualization. The calculation is based on the geo coordinates of the user, the compass of the device, and the geo-tagging of the information as provided by third party services.

Generic REST Interface

CroMAR has been integrated with different third-party services, such as Twitter and Pachube in order to retrieve information that might trigger reflection. Twitter is used to retrieve user-generated content, while Pachube is used to retrieve data from sensors deployed on the field. To assure the future usage of other services, a generic interface for third-party services has been implemented. When the application starts a request to a third party service, the request is put in a queue of operations and performed. Both the request and the answer are formatted using the JSON format and sent over the representational state transfer (REST) protocol. JSON has been chosen as data exchange format because it is more efficient than XML in terms of time synchronization, parsing on server side, and battery management. These are crucial parameters that have to be taken into account in mobile development due to the limitations of mobile devices (Gil & Trezentos, 2011). To parse the answer sent by the server, the SBJson[xi] library has been used. Using a queue of operations allows keeping the interface generic. To integrate the application with other services, it is necessary to create the request for the service, put it in the queue of operations to perform, and create the methods to handle the request independently by the other requests.

Navigation Mechanisms

The prototype enables navigating through the information along three different dimensions: spatial, temporal, and keyword-based. GPS, compass and accelerometer are combined together to determine the user's location, user's heading and the angle of view of the device. Spatial information is therefore calibrated with respect to these parameters and it is superimposed on the device screen by the AR engine and viewer.

Concerning the temporal dimension, a timeline has been implemented and placed at the bottom of the device screen, which the user can interact with (Figure 5). By tapping a time label, the user can display the information that was collected within a time span of one hour from the specified time. To do this the system compares the timestamp of the information with the selected time. If the difference between the two timestamps is greater than one hour the information is removed from the user's view.
Furthermore, a label reporting the time span related to the visualized information is shown at the top left corner of the screen.

The keyword-based navigation allows the user to specify the information to display based on its tag. For this purpose the application is provided with a settings interface where the user can set the keywords that will be used for the request to the Twitter API. In this way only Tweets tagged with the chosen keywords are retrieved and displayed on the device screen.

The system assists the user in navigating through the information. The information, sorted according to the distance from the user's location, is presented in a table to the user and for each row it is reported the type of content, the distance in kilometers, and an arrow that points to where the information is located. The distance and the arrow direction are updated as soon as the user changes her position and heading.

Figure 5: Timeline-based navigation

Cooperation Mechanisms

CroMAR supports synchronous and asynchronous cooperation. Asynchronous cooperation is supported by sharing a specific view via email. When the user presses the "Sharing View" button (Figure 6) a snapshot of the screen is taken. The user is presented with a precompiled email form reporting the taken screenshot, the GPS coordinates of the user and a link that allows the receiver to look on Google Maps the user's location. Rating information is another form of asynchronous collaboration (visible in the tweet appearing in Figure 5). When the user taps on a landmark on the screen a view with details about that information is shown. Among those, the information is presented with the average of the votes provided by the users. If the user has not already rated the information, she can do it by tapping the selected star "*". If the user has rated the information from before, she can change the vote anytime.

As a mechanism to support synchronous cooperation, the user is provided with VoIP calls through the Apple Facetime[xii] integration. When the user presses the Face Time-button all the contacts from the user's contacts database are retrieved. Specific groups of contacts might also be specified. For this purpose, the iOS AddressBook framework has been used. Facetime does not have public API yet. It means that it is not possible to switch from Facetime to CroMAR once a call ends or the receiver does not answer. This will be possible when Apple releases Facetime API.

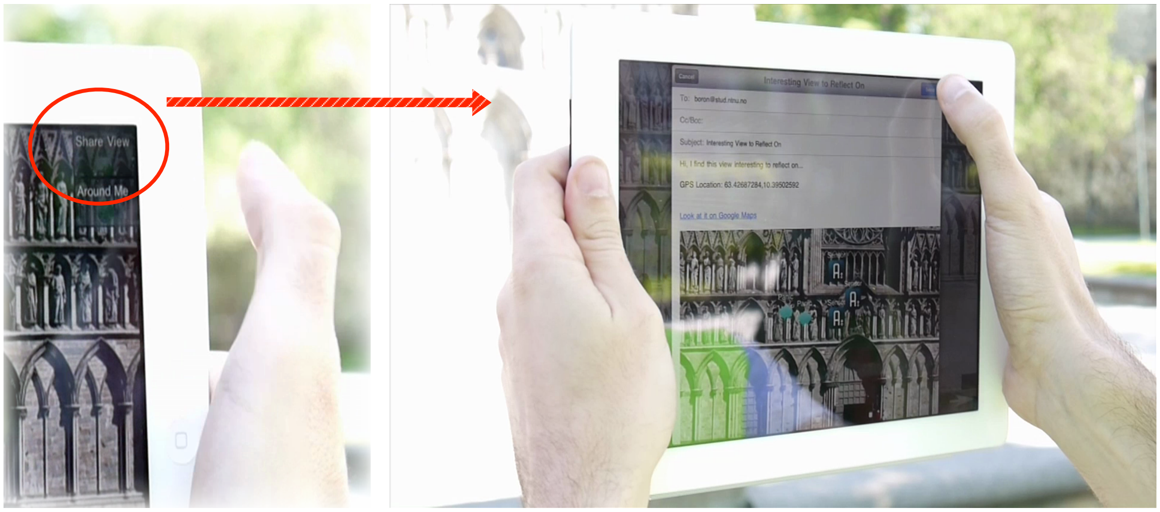

Figure 6: Asynchronous collaboration

Evaluation

CroMAR has been evaluated with the help of two experts. The experts work as consultants of an Italian IT company that provides software solutions for the Italian Civil Protection. Furthermore, one of the two experts also acts as ER volunteer in his spare time. The experts' skills brought two advantages in terms of feedback. On one hand, being a volunteer helps to have a grounded understanding of the problematic and issues related to working on the field such as planning, mechanisms for communication and cooperation, information that is relevant to reflect upon during the debriefing phase. On the other hand, being employed in an IT firm implies knowing technologies and devices as well as needs. Therefore, feedbacks were given on the main idea of the work, its applicability in real settings, and with respect to technologies used in the prototype.

The expert evaluation has taken place on May 31st, 2011 through a videoconference. The evaluation can be divided into three main parts. At the beginning experts were given an overall presentation of the work and its motivation. This included the analysis of the envisioned scenario, with its challenges and core issues. In the second part, experts were presented with some screenshots of the prototype implemented as well as proposal for future work. The last part of the videoconference focused on discussion in order to receive suggestions and feedback and it ended with a questionnaire that has been filled in concert by the two experts.

Experts were asked their opinion about the visualization in situ using Augmented Reality compared with other techniques to be used in an office setting. They both agreed that Mobile Augmented Reality seems promising in triggering reflection. Indeed, in their opinion, reflecting in places different from where the event took place lacks of the context surrounding the information collected.

The experts found different aspects of CroMAR very interesting: the idea to engage people participating in the event in the collaborative process of collecting data, the concept of the timeline to provide an overview of the information over time, and the chance to share with other fellows the user's content view. Moreover they suggested that providing other mechanisms for supporting synchronous cooperation, such as Instant Messaging and VoIP calls, could be useful.

In general the experts confirmed the potential usefulness of the application in real settings connected with the Italian Civil Protection even though the experts expresses some concerns connected to the device used to visualize the information:

"The device used to display the information should be chosen carefully. An iPad is a device too fragile, at the first impact it gets destroyed. Staff involved in this kind of activity tends to use the devices in a crude way."

Short battery life was also pointed out as an issue to consider.

Challenges

The expert evaluation has confirmed the potential of the proposed approach for supporting reflection. Our experience also points out some challenges.

In terms of reflection, it is necessary to identify under which conditions a representation of information that augments a physical space it to be preferred to other approaches and when being in situ represents instead a distraction. It is also important to identify scaffolding mechanisms that make sure that the information that is relevant for a given reflection session is explored, considering also that not all the information can be connected to a specific location. The physical exploration of space is clearly an important scaffolding of the exploration of information, but it is necessary to study when this exploration actually promotes reflection.

Several design challenges have emerged after initial internal testing of the implemented prototype, usability of the future releases may benefit from early analysis of the following issues.

Due to the screen size of the tablet relevance of the contents displayed is critical for providing a satisfactory user experience. In particular, when having to deal with user-generated data from social networks, it's important to develop techniques to infer relevance and reliability of contents provided by the users (e.g. by rating or profiling), also important is to allowing filtering contents (e.g. by extracting keywords from texts and pictures) and have tools to find duplicates that can be hidden to improve interface usability (e.g. photos of the same episode taken from the same perspective). Also the user should be enabled to set the granularity of the information displayed, for example visualizing only information generated within a chosen radius in space (e.g. the user's range of vision).

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

Moreover, we built on the user interaction paradigm successfully exploited by AR application (e.g. Layar, Wikitude) running on smartphones. In short, it involves using the camera on the back of the smartphone to frame the scene we want augmented and tap on landmarks to get additional information.

While smartphones can usually be operated either tapping on the touch-screen with the thumbs, holding the device with two hands or just holding the device with one hand; the tablet form factor need a two-hands grip in order to steadily frame a portion of space with the tablet back camera. It means that the user can only tap on portions of screen reachable with the thumbs, therefore not allowing designing for interaction outside the area represented in figure 7.

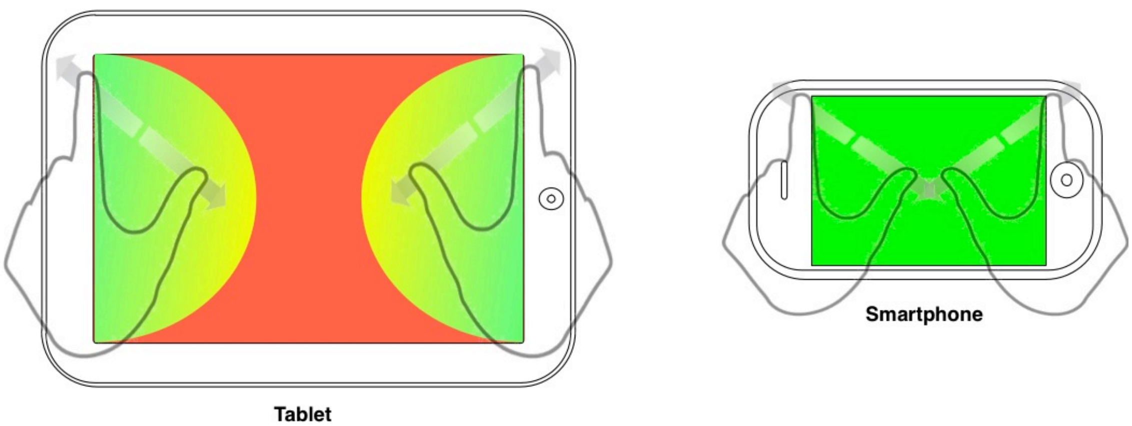

Figure 7: Interaction surface available on Tablet and Smartphone devices in landscape mode

Finally, due to its weight[xiii], the current prototype doesn't allow a confortable handling for more than few minutes; moreover glares deeply affects the screen readability under direct sunlight.

To answer these challenges it is important to conduct extensive user evaluation on the field. It is widely recognized that the evaluation of mobile and ubiquitous technology arises a number of challenges because it has to be conducted in-situ and the results can change significantly based on the context. In our experience, MAR systems presents additional challenges connected to the tight coupling of information and specific geographical location. This makes it difficult to run the evaluation under semi-experimental conditions and to repeat it in multiple locations under similar conditions.

CONCLUSIONS

In this paper we presented a prototype developed to support reflection on crowd management using Mobile Augmented Reality. Reflection is expected to happen at the same physical location of the event. Mobile Augmented Reality is used to layer information about the event and access spatial information that might be relevant to re-think the event. With Mobile Augmented Reality, while being in a *space*, the user can explore the *place* of the event, accounting for multiple experiences that have shaped it. The prototype is running on iPad2 and has been evaluated with the help of two experts. Based on our experience, we discussed challenges connected with the development and deployment

As part of our future work, we plan to develop further the system with special focus on scaffolding the reflection process. We are also planning to evaluate the system with potential users to deepen our understanding of the role of Mobile Augmented Reality in fostering reflection. In particular, we need to compare this approach to alternative organization and visualization of information to support reflection. Finally, we are investigating the possibility to integrate a serious game in our approach.

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[i] See workshop web site: http://www.elizabethchurchill.com/MARWorkshop/index.html
[ii] Google Maps - http://maps.google.com
[iii] Open Street Map - http://www.openstreetmap.org
[iv] Second Life - http://www.secondlife.com
[v] Foursquare - http://www.foursquare.com
[vi] Apple iPad - http://www.apple.com/ipad/
[vii] World Lens Application - http://itunes.apple.com/en/app/word-lens/
[viii] Wikitude - http://www.wikitude.com
[ix] Twitter - http://www.twitter.com
[x] Pachube - http://www.pachube.com
[xi] SBJson - http://stig.github.com/json-framework/
[xii] Apple Face Time - http://www.apple.com/mac/facetime/
[xiii] The iPad2 weights circa 600grams (see http://www.apple.com/ipad/specs/)