Design Implications for Interacting with Personalised Public Displays through Mobile Augmented Reality

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ABSTRACT

Due to their situated nature, digital public displays have the potential to provide information and messages to large groups of people. However, in practice, non-customised content typically is not relevant to every passerby, while personalising information tailored to individuals is associated with privacy concerns. Previous research has identified mobile augmented reality as a promising method for keeping digital displays public, yet enabling customised views for interested passersby in a way that retains privacy. By building on this previous work, the aim of this paper is to understand user preferences for interacting with personalised information on digital public displays through their mobile device. The paper reports on a study that was conducted with a prototype augmented reality app and public display system. Findings from the study highlight the need for contextual personalisation based upon user activities and objectives at the time of the interaction. Additionally, interactions should be adaptable between public and covert, depending upon what the user wants to share. Based on these findings the paper presents a series of design implications for personalising public displays.

Author Keywords

Digital Public Displays; Personalisation; Augmented Reality; Interaction Methods; Design Implications

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INTRODUCTION

Digital public displays are increasingly permeating urban spaces, such as bus stops, shopping centres, and train stations. In many cases the content shown on these displays is limited to advertisements [1], that have little relevance to the viewer due to their generic nature [8].

In response to this, the HCI and pervasive displays community is increasingly focusing on issues that go beyond questions about *how* people will interact with public displays in the future, moving towards developing a better understanding about *why*, *where* and for *what* purpose people actually do engage with public displays [13][23]. For example, this involves research on making public displays more relevant and useful to the communities that they are situated in by providing situated, civic interfaces for the general public. This includes opinion polls on issues that affect a community [8, 9, 10] or providing user-generated content consisting of news, current events, and sales [4][9].

Public displays, being in a fixed place may well be broadly relevant to a local community, but they may not necessarily be relevant to every individual. Davies et al. [8] suggests that the "move towards personalised content in the signage industry precisely mirrors the shift towards personalised content that has occurred in the Web". Personalisation on the internet is usually achieved through the creation of user profiles, such as a Google account to make the search engine's results more relevant to their users [15]. Making personalisation operate on a public display could be achieved through a similar approach where the user (or their personal device) is identified and the corresponding profile is loaded. However, this requires displays to either build a profile of the user, which potentially raises privacy concerns [8], or alternatively retrieve a user profile [14], which could potentially be stored on a personal mobile device, such as a smartphone. The profile could then be sent to the display via a communication technology, such as Bluetooth [20].

However, in contrast to personalised web pages, the adaptation of content on a public display raises new privacy concerns. One promising method to enable customised content, while mitigating privacy concerns is to harness mobile augmented reality (MAR). This approach allows passersby to use their camera-equipped mobile devices, such as smartphones or smart glasses, to create personalised views over the display along with private interactions with public displays [3][16].

In this paper, we will expand on previous work in this area by evaluating the effectiveness of AR as a method of enabling personalised interactions with public displays. A study with a prototype MAR public display system was conducted and the results informed a series of design implications for future research.

BACKGROUND AND CHALLENGES

It is envisaged that digital public displays will become more than simply a medium that serves static content [8]. Instead displays will be personalised to meet the needs and interests of passers-by, similar to personalisation on the internet [14], only in the real world. The concept of viewing personalised content in an urban space is not new, it has been portrayed in science fiction movies, such as the "Minority Report", where people wear special contact lenses that allow them to see AR content seamlessly and privately (Figure 1).

Figure 1. Minority Report scene where holographic advertisements on shopping centre screens and billboards targeted the main character, based upon factors such as his history with a certain company (http://www.viralblog.com/wp-content/uploads/2013/01/minority.png).

This section discusses previous work and is structured around four challenges that we identified as associated with personalising digital public displays: (1) social considerations; (2) privacy; (3) interaction; and (4) content. In this section we describe these challenges and the previous work that addresses some of the challenges.

Social Considerations

Social perception can have an impact on whether an individual interacts with a public display. For some people, the fear of social embarrassment if they do something wrong is enough to deter them from interacting [4].

Awareness of onlookers seeing the same content is another factor. If the content is personal, then it may not be appropriate for others to see it. One proposed approach to mitigate this effect, known as "shoulder surfing", is to black out parts of the screen that the user is not looking at to preserve the privacy of the personalised interaction [7]. However, this solution may not be sufficient when there are large crowds surrounding the public display, which may be the case if the interaction is performative and stands out [22]. Furthermore, studies have found that shoulder surfing is still a problem even with mobile device interaction [3].

Privacy

Making content relevant to each user raises the need for protecting their privacy, as the user may not desire for their personalised content to be shown in public [8]. This was the case in London, where rubbish bins with screens used Wi-Fi-collected MAC addresses of passers-by to track their movements, to personalise the content on the screens. The project was eventually shut down due to privacy concerns from the public [17]. These concerns primarily related to the system not gaining consent *before* using this information to drive advertising.

A potential way to tackle privacy concerns associated with the public display of personalised content is through MAR. Baldauf et al. [3] demonstrated that AR can offer a private view in conjunction with a public display. This approach has potential as an effective means for people to interact with public displays as it could reduce the social concerns people may have about interacting in public [16]. However, that research only considered how people would interact with public displays through MAR and did not investigate the potential of this method to provide a private view of personalised data.

Interaction

One of the challenges of providing a means for interaction with public displays is that user privacy may be compromised. Parker et al. [16] identified four common interaction methods with public displays, based on a review of previous literature, each addressing different levels of privacy: remote indirect, kiosk, gestural and mobile. Interaction through a mobile device was found to offer an effective means for interacting with privacy-relevant content, as it is relatively private and enables users to interact from afar. Also it could, potentially, support multi-user interaction, making it a highly flexible approach compared to the others.

Ballagas and Sheridan [5] explored using a mobile phone's camera as a pointing device, allowing users to control a display's cursor by sweeping and pointing a phone through image processing techniques. Their study showed great potential, but was ultimately limited by technological constraints of 2005. A more recent study [2], in 2013, was able to expand upon pointing the camera by using the mobile device's orientation sensors to control remote screens. Although these orientation-aware techniques were considered intuitive, they were outperformed by orientation-agnostic techniques due to problems with accuracy.

Similar work, allowed remote touching of a display using 3D interactions through MAR and was presented as an alternative method to interacting with a large display [3][10][6]. This method enabled people to interact with the public display remotely, using their own device, by touching their device's touchscreen to manipulate objects on the public screen.

Mobile device interaction can also be used to lower the barriers of participation and interaction with public displays. Schroeter et al. [19] developed a system that allowed the general public to voice their opinions on certain issues affecting their community using SMS or Twitter to submit messages, thus lowering the barrier for participation. The messages appeared on a large public display for all to read. This interaction, however, was not private, as the user's name or ID was posted along with their message.

Content

One of the reasons public displays often go unnoticed is that they show content that is irrelevant to some people [11]. As reported in Alt et al. [1], the right content depends on the use-case. For example, a local resident in the area where a public display is situated may have completely different content needs from a tourist. However, an inherit issue with personalising content for public displays is identifying users to determine their content needs without compromising their privacy [14].

PROTOTYPE

The goal of our work is to evaluate the effectiveness of AR at enabling personalised interactions with public displays and whether it can address some of the challenges reviewed in the previous section. To tackle this, we created a prototype consisting of a MAR app and a public display application, in the form of a public bulletin board. The MAR app featured two modes: AR overlay and remote control. The design of these modes was informed by previous research into MAR interaction with public displays [12][13]. In the following sections, the interface and the two modes are discussed in detail.

Interface

The prototype was developed as two separate apps, one for the mobile device and the other for the large 50 inch widescreen public display.

Public Display

The public display app was created as a Google Chrome web app using HTML and JavaScript. It displayed the public content and the tracking image.

Figure 2 shows a user interacting with the public display. At the top of the public display (Figure 2a) is a navigation bar (with a red rectangle around it). It shows the user the available content categories, with the currently selected category in yellow. The available categories that a user can navigate are: News, University News (selected in the figure), Classifieds, and Property Rentals. The tiles in the centre of the screen are the content for this category. To see more information about a particular tile, the user taps it to open a popup window containing a larger version of the image, description, title, and the author.

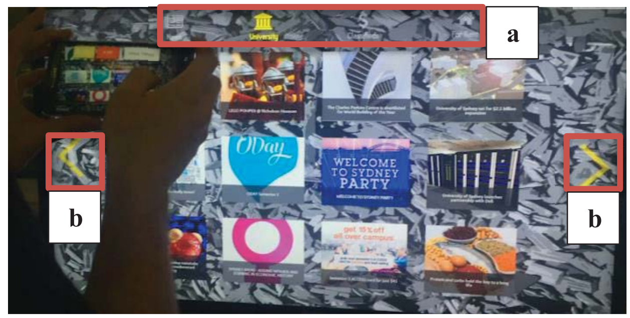

Figure 2. (a) Navigation bar, with the currently selected category, University News, highlighted yellow; (b) Arrows indicate horizontal navigation.

The arrows (Figure 2b) indicate horizontal navigation of categories. The woodchips background image is a modified example marker from the Vuforia website that the mobile device tracks. It was found to be the most reliably tracked image even with sunlight, reflections and occlusion.

Mobile App

The mobile app was created in C# using the Unity game engine (version 5.0.3) and the Vuforia augmented reality library.

To switch between both the AR overlay and remote control modes, the user needs to press the red interface button labelled "4 me" (Figure 3), which turns green when in the AR overlay mode. The yellow button is used to change pre-loaded user profiles and the white button indicates the tracking status. If tracking is lost during use of the prototype, pressing the white button makes the AR marker appear on the screen with no interface elements occluding it for 3 seconds. This allows for the tracking to be re-established.

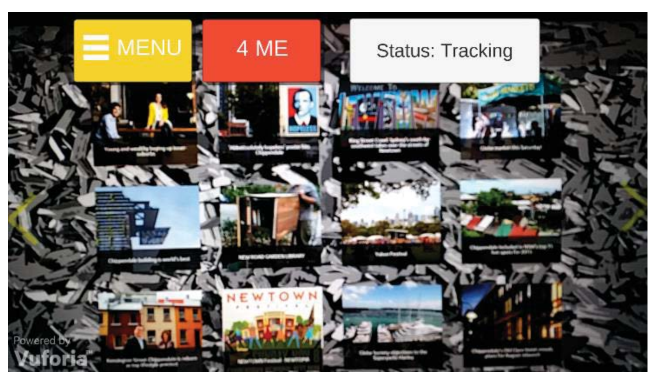

Figure 3. The mobile app interface, with the device's camera pointing at the public display.

One way communication between the two apps is achieved through websockets via the university's Wi-Fi network. The PC connected to the digital public display hosts the websockets server and receives interaction data from the mobile device. The data is generated from either a tap or a swipe (left or right). A tap sets the position in 3D space that it occurred, as the app was created in a 3D game engine. The 3D position is then translated into a 2D coordinate using a 3D projection algorithm. However, if the interaction is a swipe and is performed while pointing the mobile's camera at the screen, the system transitions to the next or previous category, depending on the direction.

AR Overlay

This mode allows users to view their personalised content on their mobile device through a virtual content overlay using AR (Figure 4). They can interact using touch to select a tile and swipe gestures to navigate to different categories of content on their mobile device.

Figure 4. Virtual personalised content that is overlaid over the public display and can only be seen through the mobile device's screen.

Upon the user tapping a tile, a virtual popup will appear, overlaid over the mobile device's camera feed. To close the window, the user needs to tap outside of the popup.

Remote Control

This mode allows users to have full control over the display, similar to a TV remote, using the mobile device (Figure 5). All of the interactions are visible to other people and are performed in the same way as the AR overlay mode, with touches and swipes. If the user taps a tile a popup will appear, similar to the AR overlay mode. However, the popup is shown on the public display.

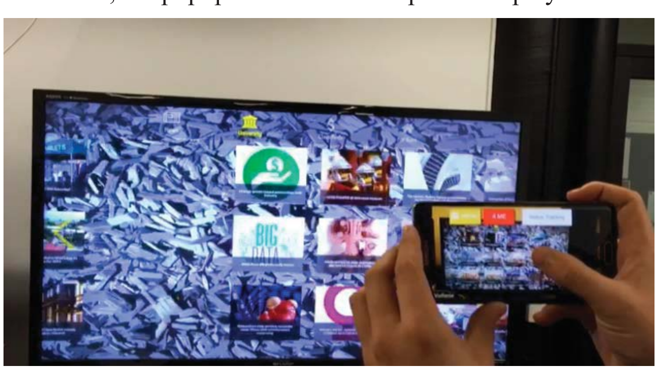

Figure 5. Remotely controlling the public display using touches.

STUDY DESIGN

As discussed in the previous section, the prototype system consists of a MAR app and a public display Chrome app with an AR marker background for tracking.

The personalised content featured on the public display was generated based on a background pre-survey that participants were asked to complete. This asked about their field of study or work, their home suburb, and topics of interest. This information was used, in advance of the interaction session, to manually populate the personalised view of the application, drawing upon information from multiple sources, such as news, classifieds and events to create the personalised display. Non-personalised data was manually gathered in the same way.

In total, 10 participants were recruited to take part in the study. All were university students, 7 males and 3 females, aged between 19 and 30. The study was held between 12 noon and 2pm over 3 weeks of the semester. It was located in a busy public cafeteria area, within the university. This is near the main entrance to the building and has a stream of people passing by. We estimate that during each session, at least 20 different people walked past.

Each participant undertook the study in a separate session. The study was structured so that each participant could try both modes: AR and remote control. Each mode displayed non-personalised and personalised content, which was manually changed by the researcher. The initial mode for each participant was dictated by the researcher, to counter-balance the order of the two modes. At the start of each mode, the participants were given a 30-second tutorial to learn the interactions. This was to ensure that participants were familiar with the prototype and the interactions before commencing the experiment, as the focus of the study was not on the system's usability and learnability. Following each tutorial, the participant was free to explore the system with that mode; they were not given any tasks, in line with the likely use of a new display encountered in a public space. Each mode took approximately 5 minutes.

Once the participant had completed both modes, they were given additional free time to explore the system in any mode they desired. We observed each participant's use of the system. This data was later used in the grounded analysis.

After completing use of the prototype, participants were asked to participate in an interview, where the generated data was analysed using grounded theory.

FINDINGS AND DISCUSSION

Findings from our observations and participant questionnaires are categorised into the themes that emerged from our grounded analysis of the qualitative data: Privacy, interaction, social considerations, content, and experience. In this section we discuss each of these themes.

Privacy

Privacy concerns were expressed by 7 of the 10 participants. One felt embarrassed at being in the spotlight and was worried about what others might think of them, *"I was embarrassed. I feel like everyone's eyes are on me when using it"*. Other participants stated *"I would not be happy for people to see content such as text messages from my girlfriend"* and *"if it would go and try and put personal things like the books I read or something like that I wouldn't be comfortable with it"*. Therefore, acceptable content is subjective and users should have the final say on what content is displayed. This was mentioned in a follow-up comment to a question asking what content is acceptable, *"Depends on whether I really want to share or not. If you could share your photo on the big screen, that is really up to you. So I would like to share one. I can make a decision, then it will be fine"*.

To overcome such privacy concerns and make the content more readable, it was suggested that the popup window, which is activated when a tile is selected to display more information, should instead appear in fullscreen on the mobile device.

The remaining 3 participants had no concerns about interacting in public and their personalised content being seen by others. They mentioned that others must perceive them as simply using their phone - *"They were just normal gestures you would use on your phone. So I didn't worry about people around me"* - which is a common sight in first world countries. One of the unconcerned participants commented: *"If I am the only the one that can control the big screen and can share with my friends I will be proud of it. Rather than feel embarrassed"*.

Interaction

The findings from our analysis found three problems raised by participants in relation to interaction: zoom, orientation, and navigation.

Zoom

Zooming in and out with a mobile device's camera is a common gesture that people are familiar with. It is performed using either physical buttons or a pinching gesture [6]. However, this form of zoom was not implemented in our prototype as we thought of the mobile device in our design as a prototype interface for an AR see-through device, which would be worn on the user's head at all times. Therefore, to zoom with our prototype participants had to physically move closer or further away from the public display.

Four participants specifically requested the ability to zoom without physically moving. They stated that this feature would allow them to view content covertly without making it obvious that they are linked with the display and its content and to make it easier to read from a distance, particularly if there were large crowds.

While device zoom may be more convenient and covert, one participant considered physical zoom more natural, stating that if there was device zoom it would be the same experience as simply using a website.

Orientation

Our prototype supported two possible ways of holding the mobile device, either in portrait or landscape orientation. The researcher let the participant select the orientations themselves and during the demonstration, would hold the device in a randomly selected orientation, either portrait or landscape. Three participants voiced complaints about the orientation, mentioning that holding the mobile device in portrait orientation was easier, as their fingers sometimes obstructed the camera lens in landscape orientation. Additionally, as the mobile device had capacitive buttons next to the home button for opening the task manager and going back, participants reported that their thumb kept accidently touching the buttons in landscape orientation.

Landscape orientation was also considered *"clunky and embarrassing"*, possibly due to this being an uncommon way for holding phones in public, which may make it seem like participants were taking a photo or playing a game.

One of the 3 participants who complained about the orientation attributed this to their small hands and suggested that landscape orientation may be appropriate if the mobile device was of a smaller form factor. They were concerned about accidentally dropping the phone as it felt big holding it in landscape orientation.

Navigation

The navigation and arrow elements on the public display did not always behave in the way the participants expected. We observed that every participant tried to quickly access a particular category by tapping on it, instead of cycling through using taps. However, this feature was not implemented in the prototype. Arrow elements on the right and left indicated the fact that there was more content on either side. Participants attempted to tap on these arrows as they thought it was an alternative to swiping for navigation.

Social Considerations

Participants commented on concerns about sharing with others who might like to use the display. One stated that they felt *"a little obnoxious using it directly in front and in the middle of the screen"*, further adding *"You are essentially blocking the whole screen from others wanting to use it"*. This could potentially be resolved by users standing further back.

We also was observed that passersby perceived participants as taking a photo and would walk around so as not to obstruct the camera. This phenomenon suggests that the existing social standards translate to a new system like this, similar to people queuing or opening doors for one another. Potentially in a multi-user remote control scenario these standards could translate to people cooperating with each other and negotiating the shared use of the display. This observation also points to opportunities for future research, which could focus on studying shared, co-located interaction with such personalised displays and emergent social behaviours.

Content

An analysis of questionnaire responses indicated that participants were most interested in content relating to properties for rent, classifieds, events happening in the local area, and keen concerns for students. This observation could potentially be linked to the fact that all participants were students, but it also suggests that content which is locally relevant is of more interest to users, which is in line with previous research [1].

Some participants mentioned that the rentals category would be interesting when they were ready to move house.

Another popular class of content related to activities that a particular individual needs to do. Eight participants mentioned they would like to see more specific content related to what they are currently doing and social events on campus. For instance, one of those participants wanted a timetable for the nearby train line, which they were about to catch, their class timetable, or the traffic conditions on the route they regularly take if they were driving. Another suggestion was a student forum, which could create more social connectedness for students in the same building. Examples given included *"today I lost my wallet in room 261"* and *"you saw a girl in a certain classroom and you can't remember her name"*.

Experience

Participant interview responses about the overall experience were mostly positive, with many stating that the system was *"different to other public displays"*. One of the participants described the system as "*thrilling*", stating that *"to be able to interact with this content in a public space gives a feeling of social connectedness and sharing. It is kind of a social media type feeling"*.

The feeling of control over such a large display (50 inch widescreen) was also appreciated with some stating that it felt like they were in a futuristic movie like "Avatar". This is likely a novelty effect.

Interaction was also highlighted by every participant as natural and intuitive for anyone to pick up, as the interactions were based on existing interaction techniques common on typical touchscreen mobile devices.

IMPLICATIONS

The following series of design implications were identified following the grounded theory analysis.

Personalisation should be responsive. To be more relevant, personalisation should be based upon the *current* user activities, such as going to a class or catching a bus. For example, an interactive train timetable, where a user chooses the destination to see a list of events happening in that area, presented below the route map. These events can be matched to the time of day and the user's interests. This could also include showing content that is contextually relevant, linking public displays with the area of contextual computing [9].

Consideration for others. Public visibility is not the only concern users have. They also worry about intrusion into other's personal space or blocking the screen. Therefore, interactions from afar and non-competitive multi-user interactions seem promising.

Familiarity is important. Interaction, using a mobile device, should operate similarly to other apps. An example of this is the zoom. Most of the participants expected zooming through the device rather than physically zooming by walking closer or further away. The reasons include the preference expressed for a more covert device zoom that does not identify the individual as obviously as physically zooming. This also applies to mobile device orientation, as holding the device vertically was seen as more covert than the non-standard landscape orientation, rather than portrait orientation which is the usual way to use the phone.

Covert interactions to protect a user's privacy. Four participants were worried about embarrassment, while others were concerned with other people linking an interaction to them, and so would identify them as the person for whom the content was created and personalised. To address these concerns, MAR interactions with a public screen should be similar to normal phone use, to allow the user to blend in.

CONCLUSION

In this paper we identified four challenges for personalised public displays. To gain insights into how, why, where and for what purpose people would use personalised public displays, we conducted a user study to tackle these challenges, where a public display prototype that can be interacted with through MAR was tested.

For our study, we prepared personalised content based on a pre-study questionnaire. The personalised content included general news, university news, classifieds, and property rentals. Although participants enjoyed the interaction method, perhaps because of its novelty, they commented that the categories of personalised content we created were not entirely relevant to them. Our findings suggest that personalised content needs to carefully take account of what the individual is doing at the time, such as if they are on the way to go grocery shopping, catching a train, or if they are looking for a place to rent while studying at university.

Future research opportunities in this area include the investigation of contextual personalisation and approaches for mitigating shoulder surfing, such as the use of see-through head-mounted displays. Another avenue for future work is to link personalised public displays with contextual computing.

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