Private Public Screens – Detached Multi-User Interaction with Large Displays through Mobile Augmented Reality

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ABSTRACT

As everyday companions, smartphones are well-suited tools for controlling interactive applications on large public displays. To allow concurrent interaction by multiple users beyond traditional collaborative scenarios we introduce the idea of virtually augmented public screens for creating personalized views and thus literally enabling "private public screens". We present a fully functional research prototype in form of a *Video Wall* application and report on first experiences gathered from a comparative user study. The results show that the proposed personalized Augmented Reality approach, which allows each user to have a private view on the public display, is preferred over a purely competitive mode, where the public display is shared between the users. Further, our study shows that social activity indicators informing about the activities of other users are well appreciated.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces: Evaluation/methodology, Input devices and strategies, Interaction Styles, Prototyping

General Terms

Design, Human Factors

Keywords

Augmented reality, public screen, multi-user

1. INTRODUCTION

Large public displays and entire media facades have become ubiquitous in urban environments over the last years and are nowadays shaping the appearance of town squares, subway stations, shopping malls, and other public places. According to recent market studies [1] their proliferation will further continue with the global market for digital signage tripling between 2010 and 2016 up to almost $4.5 billion.

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To enable compelling end-user applications beyond static information and advertisement displays and allow for everyone's interaction with traditional, formerly non-interactive screens, handheld devices have been heavily investigated as remote controls. According to Paek et al. [11], the resulting interactive shared displays are most suited for certain types of applications including "collaborative tools allowing multiple people to contribute to a single goal" and "arena applications involving competitive interaction".

In this paper, we address a novel, so far neglected type of multi-user screen application beyond typical collaborative and competitive scenarios. Since interaction with public screens installed at busy urban localities is typically characterized by short interaction times and high user fluctuation we are interested in approaches allowing for the concurrent but detached handheld interaction with such a screen by multiple users. The novel technique introduced in this paper enables individual interaction and views on a public screen using a mobile Augmented Reality (AR) approach, thereby literally enabling "private" public displays. Facilitating detached remote interaction by concurrent users with one display raises a couple of novel research questions such as the relevance of communicating concurrent activities of other users and the role of group interaction. In the following, we describe our fully functional research prototype and report on a comparative user study where we gained first experiences with this novel screen interaction technique.

2. RELATED WORK

Using handheld devices to enable interaction with distant screens for multiple users has been a very active field of research for several years. Early research on collaborative scenarios includes work of Rekimoto [12] and Greenberg et al. [6] who investigated the usage of handhelds to support data entry, manipulation and sharing on public displays.

In the meanwhile, several generic platforms for realizing cooperative multi-user applications for public screens and handheld-equipped participants have been presented. For example, Paek et al. [11] introduced an interactive shared display supporting input from any mobile device via communication channels such as email or instant messaging conversation, Anzures et al. [2] exploited mobile devices as game pads for controlling multi-user applications on public screens, Hosio et al. [7] investigated distributed application user interfaces on interactive large public screens and personal mobile devices. Examples for multi-user applications on public screens or media facades utilizing smartphones include a voting system for video clips shown on the large display by

(a) Live video interaction (b) AR-based private feedback (c) Final screen design (with social features)

Figure 1: Real-time interaction through the mobile camera with our Video Wall application shown on a public screen.

Scheible and Ojala [13], a strategy game by Leikas et al. [8], and a drawing application by Boring et al. [5].

Less work has been concerned with approaches enabling personalized or private presentations for multiple viewers using only one public screen and several mobile devices. For example, Olivier et al. [9] applied fixed time cycles to show different navigation instructions on a public projection and used cues on mobile phones such as vibrations to indicate which cycle is relevant to user. Most related to the work presented in this paper is the idea of "visual multiplexing" introduced by Ostkamp and Bauer [10]: up to three texts or pictures in primary colors are multiplexed into one image which is then shown on the public display. The corresponding smartphone application applies suitable color filters and makes the information visible. So far, existing work for enabling private views on public displays is either limited to simple information displays on the handheld or results in distorted screen content on public displays.

3. RESEARCH PROTOTYPE

We implemented a fully functional prototype to experiment with virtually augmented public displays. Our *Video Wall* application allows multiple concurrent users to select videos at a public display and features different modes of playback for conducting comparative user studies.

3.1 Concept

For intuitively controlling the application through mobile devices and fitting our AR approach we applied a live video interaction technique (cf. Boring et al. [4] and Baldauf et al. [3]): users target their mobile devices at the screen and while watching the screen via the mobile camera are able to directly touch buttons visible on the remote screen (Figure 1a). The video is then displayed on the mobile devices directly superimposed on the screen conveying the impression of a private view (Figure 1b).

To identify potential benefits of private public screens and compare them with alternatives the Video Wall application supports the following interaction and playback modes:

Competitive. Having selected a preview image, the corresponding video is shown on the large screen in full screen mode. By touching the mobile display the running video can be stopped by any other user and another video can be started. Hereby, the mobile device only serves as remote control, thus leading to a competitive usage scenario.

Concurrent. When a user selects a preview image the respective video is shown in an AR view overlaying the content of the public screen on her device leaving the presentation on the screen unmodified. Touching the AR video returns to the pure camera view making again visible the Video Wall menu of the distant screen on the mobile device. This mode enables fully concurrent interaction by multiple users. However, it completely isolates users leaving them unaware of actions of other users.

Socially concurrent. We further extended the abovementioned concurrent mode with social features. To reflect current user interactions on the large screen and thus communicate them to other users we introduced an activity indicator in the form of a blinking border around videos which are being currently watched. To also indicate previous user interactions we inserted the popular *like* counter from Facebook to each preview image on the large screen and added the respective thumb button to the mobile AR view.

Showing a selected video in full screen on the mobile device was deliberately excluded since it decouples the content and related interaction from the remote display. We consider this approach suitable for selecting items from a large display for later consumption on the mobile device. In contrast, the present paper focuses on multi-user interaction while preserving the interplay with a remote display.

3.2 Implementation

The described Video Wall system consists of the application executed on the distant screen and a mobile application for the handheld devices connected via WiFi or 3G. The screen application is implemented in C# and integrates the Windows media player for playing back videos in full screen mode. For receiving remote control commands from mobile devices for starting/stopping a video, increasing the like counters etc. as well as for informing the mobile devices about the current playback mode we use TCP sockets. The final user interface design of the application is depicted in Figure 1c: it shows 15 preview images indicating the corresponding 15 high-quality video clips. Switching between the abovementioned three modes is possible by pressing the respective numeric keys 1-3. Potential videos running either on the large screen or the mobile devices are stopped.

The mobile Android application was implemented using the *Vuforia* toolkit by *Qualcomm* to efficiently realize the AR features. A screenshot of the video menu interface was used as target for the overlays. The touch-based live video interaction was realized by directly accessing the calculated transformation matrix. This way, touches on the mobile display can be mapped to screen coordinates sent to the screen application. For prototyping purposes we did not use the remotely stored high quality videos for the AR overlay but prepared tailored versions stored on the SD cards of the mobile devices. We reduced the frame rate of the original

Figure 2: Impressions from the described user study conducted during a public science event.

videos to 10 frames per second and scaled down the frame size to efficiently preload and steadily playback the videos even on mobile devices with limited memory resources.

4. EXPERIMENT AND RESULTS

To collect first feedback, we conducted a user study at a public science event. Its trade fair character with lots of visitors resembled the traditional urban context of a public screen and thus made it a very suitable study environment.

4.1 Setup and Method

At our booth we arranged a flat screen with a diagonal of 47 inch as public screen showing the Video Wall application. Further, we prepared mobile devices (three smartphones, two tablets) to be handed out to visitors. When at least two people gathered in front of the large screen we asked them whether they were willing to participate in a short experiment (see Figure 2). To cope with the very dynamic nature of such an event with people arriving and leaving, and to shorten the test duration we had no dedicated instruction session. Instead, two research assistants explained the three modes during usage. The test operator switched modes after some minutes when each of the participants had interacted with the system several times by themselves.

Throughout the event, which took about five hours, more than 100 visitors used our system in groups of two to five people. During usage, the research assistants observed the users' behavior and took notes. Additionally, we captured the experiment by a camera mounted on top of the large screen for post-hoc analysis. After having tried out the modes, the participants were asked to fill out a questionnaire gathering demographic data and asking for comments. We were interested in the general acceptance, i.e. whether the participants would be prepared to use respective systems (e.g. deployed in subway stations), and asked them to rank the modes with regard to the most fun in the group and their general personal preference.

4.2 Results and Discussion

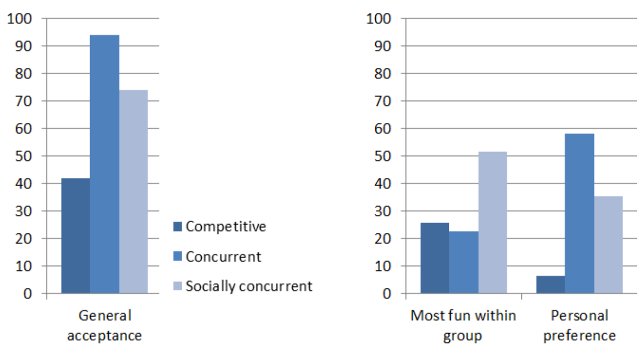
We received questionnaires from 31 participants (15 female, 16 male) aged between 11 and 46 years (mean=23, medium=21). Overall, 77% (24) of the visitors appeared to be young and mostly technology-affine "digital natives".

4.2.1 Questionnaire

Figure 3 shows the results gathered from the questionnaire. Concerning the general acceptance, competitive mode would be used by 42% (13) of the participants, concurrent mode by 94% (29), and the socially concurrent mode by 74% (23). For the rankings, the latter mode was named as the one engendering the most fun within the user group by 52% (16), the competitive and the concurrent mode were only ranked first by 26% (8) and 22% (7), respectively. Concerning the personal preference, the concurrent mode is ranked best by 58% (18), the socially extended one by 35% (11), and the competitive mode only by 7% (2). For the socially-enriched mode, 23% (7) stated that the *like* counter influenced their video choice, 13% (4) said so for the highlighting.

Most of the participants did not like the competitive mode due to its interruptions with every user being able to start and stop the video on the public screen and thus would reject to use it. 6 participants explicitly disliked that others are able to see what they watch. However, a closer look at the verbal comments unveiled that this competitive aspect makes for the most fun for a smaller part of the participants. This reason combined with the better quality and experience watching the videos on the large screen was decisive for 2 visitors to even select it as their favorite technique. However, either one or both "private" view alternatives always outperform the public screen technique in the investigated aspects. While the socially concurrent mode turns out to engender the most fun within the interacting user group, it is dominated by the non-social concurrent alternative concerning the general acceptance and personal preference. 8 participants explicitly reported that they prefer the indicator to get an impression what others are currently watching. While the indicator obviously enhanced the group experience, it had a negligible impact on the actual choice of videos.

Analyzing the comments, the *like* button turned out to be a very controversial element: 6 participants explicitly dis-



(a) Ratings (b) Rankings

Figure 3: (a) shows the general acceptances in percent, (b) shows how often each technique was ranked first in percent.

liked the technique with statements such as "this like feature appears everywhere" and "it's on every website, I don't want to see it on a public screen". Two participants associated it with marketing purposes and clearly stated their fear concerning misuse. For 5 participants the *like* counter even had converse impact: they deliberately ignored this user voting with utterances such as "I have a mind of my own" and "I am not interested what others do or like". Demonstrating individuality when using applications on public screens seemed to be a relevant issue for the participators.

4.2.2 Observations

In many cases, the competitive mode led to irritations since it was unclear for participants who switched the video. Only very few visitors were entertained by this competitive and "random" element. The competitive mode also unveiled barriers for multi-user screen applications: several participants did not dare to change a video started by others. They needed the clear instruction by the test operators to try it out. This "virtual ownership" effect is obviously an impediment for newly arriving users.

The AR views were described as very easy to use and impressive by most of the visitors. After this first "wow effect" some technology-affine users tried to explore the limitations of the technology and to break the AR overlay by waving their hand in front of the camera. The direct touch-based interaction approach via the camera made several users very focused on the mobile device, so that it took some time until they realized that they have their separate view and others watch different videos. Further, we observed the natural curiosity to know what others are watching, especially if the visitors obviously knew each other, e.g. kids with their parents. Generally, "shoulder surfing" by passersby and participants (as seen on Figure 2) was a very common phenomenon clearly highlighting the relevance of activity indicators.

5. CONCLUSIONS AND FUTURE WORK

We introduced the idea of "private public screens", public screens virtually overlaid by means of AR to enable detached handheld interaction by several concurrent users with one large display. We illustrated the concept with the *Video Wall* application and presented experiences from a first user study. The results show that an activity indicator communicating current actions by other users is well appreciated in case of such separate views. Further, expressing individuality when interacting with a public screen turned out to be a relevant aspect that should be considered by application designers, e.g. by integrating extensive feedback features. Reusing the popular *like* concept was not as successful as expected and unveiled users' privacy concerns (which may even increase when using an own device with personal information). Thus, when designing applications for public screens, the integration of symbols with connotations and respective services need to be carefully considered. Overall, interactive AR visualizations on a public screen were proven to be a very impressive and entertaining feature.

Future research should deeper investigate techniques for indicating remote activity in a clear, non-disturbing manner and should explore alternative techniques for recommending items at public places. Further, we plan to conduct more systematic evaluations to address limitations of the presented study such as the skewness towards digital natives, e.g. by orderly covering different user groups.

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