ChalkboARd: Exploring Augmented Reality for Public Displays

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ABSTRACT

Augmented Reality (AR) devices and applications are gaining in popularity, and – with recent trends such as Pokemon Go – are venturing into public spaces where they become more and more pervasive. In consequence, public AR displays might soon be part of our cityscapes and may impact on our everyday view of the world. In this work, we present *ChalkboARd*, a prototype of an AR-enabled public display that seamlessly integrates into its environment. We investigate the influence of our system on the attention of bystanders in a field study (N=20). The field deployment of *ChalkboARd* provides evidence that AR for public displays needs to be interactive and adaptive to their surroundings, while at the same time taking privacy issues into account. Nevertheless, *ChalkboARd* was received positively by the participants, which points out the (hidden) potential of public AR displays.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; *Empirical studies in HCI*.

KEYWORDS

augmented reality, pervasive displays, attention shift

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Figure 1: *ChalkboARd* is a prototypical public AR display (left) that seamlessly integrates into its surroundings by leveraging form factors that users would expect in this environment (here: chalkboard, right).

1 INTRODUCTION

In the last decades, public displays have become more and more ubiquitous in everyday life. Nowadays, these displays have found their way into most of our public spaces, such as urban environments, shopping malls, or airports [7]. In contrast to private displays, public displays address a wider audience and are shared with multiple users. Therefore, public displays must compete for the audience's attention [20]. Without arousing the attention of bystanders, a public display cannot engage them in their content and motivate them to become a user of the system [18]. In previous work, two strategies have been suggested for how attention of bystanders should be attracted. The first strategy suggests that public displays should remain calm and allow an observer to disengage by shifting them into the periphery [31]. The second strategy suggests that the display actively engage bystanders in its content [24]. We understand these two strategies as poles of a continuum, allowing any sort of variation in between. The perfect public display would lie on a sweet spot on this continuum: active enough to engage bystanders in its content, while still allowing them to disengage if wanted. Such a display would not only arouse the attention of bystanders, but would transform this interest into motivation to use the public display and to engage with the content.

In the past, various form factors of public displays have been suggested. These have ranged from using available displays [22] to

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turning existing everyday objects into public displays such as flowers [9] or street signs [16]. Using existing objects is advantageous in that such objects fit in perfectly with the environment, causing them to be perceived as calm and less salient by bystanders. Further, they may already have a purpose, making it easy for people to understand what kind of information they provide (e.g., street signs [16]). However, the possibilities of such public displays are limited by the attributes of the used object (e.g., how fast flowers can open and close when manipulated and used as public displays [9]). A few years ago, the Pepsi company demonstrated an Augmented Reality (AR) experience in the form of a public display at a bus shelter in London[1]. They used video see-through AR to create a window effect (also called magic lens metaphor) [4, 32] for the bus shelter display and showed 'unbelievable' scenes happening around the bus shelter (e.g., aliens that kidnap people, monsters attacking pedestrians etc.). Although this was a commercial advertisement, the underlying idea of augmenting the environment shows great potential for public displays in the future.

In this paper, we explore the idea of using Augmented Reality for public displays to arouse the attention of bystanders and to engage them in the presented content. Therefore, we developed our *ChalkboARd* system which turns a regular chalkboard into a video see-through AR system by replacing the board with a display and adding a smartphone to capture the scene behind the setup (see Figure 1). Additionally, we created an animated chalk figure that jumps from the *ChalkboARd* display into the captured environment using a toy playground as an AR marker. In a field study, we observed the reactions of bystanders to that public display and interviewed them about their experiences afterwards.

2 RELATED WORK

Our work relates to prior work on (1) visual attention and (2) public displays and Augmented Reality, which we outline and link to the contribution of our work.

2.1 Visual Attention

While the human eye tends too see many things at once in a single instant, only few are consciously perceived and draw the spectators attention (cp. [14]). However, visual attention can be deliberately drawn and manipulated through visual cues. Posner and Petersen [23] divide the shift the attention of a user in three phases: (1) disengage the current target, (2) shift attention between stimuli, and (3) engage new target. To understand how a user's attention shift can be induced effectively, understanding of how attention is naturally directed is required. The human brain processes all available information pre-attentively [28] and then filters out important information. To identify what is important, our brain searches for salient information [15] and at the same time considers the current context [13] (e.g., intentions and goals). Both salience and context can be manipulated to shift a user's attention [26, 27]. For public displays, we mostly know the contexts of users and we can use that information to optimize display placement (e.g., show information of bus departures inside the bus shelter where we expect people to wait for the bus). However, we can also manipulate the saliency of information to influence visual attention, especially when the information is located in the periphery of the user (e.g., adding motion to information or changing the brightness level) [1, 12]. Similar effects can be achieved with Augmented Reality [29]. In our work, we will use motion in the form of animated AR content to arouse the attention of bystanders.

2.2 Public Displays and Augmented Reality

In the last decade, public displays experienced a shift from traditional information displays to digital interfaces that allow for new forms of interaction and user experiences. However, compared to private displays, interaction with public displays is much more challenging, and attracting, engaging, and motivating users is crucial to successful design of public displays [20]. In the past, different kinds of public displays have been developed that allow different kinds of interaction, ranging from implicit interaction (e.g., presence) to explicit interaction (e.g., touch) [20]. However, not only the way of interacting with these displays can differ, but also the form, shape and appearance can come in different manifestations. For example, existing technology such as robot arms that perform spatial and temporal rhythms can be understood as public displays [8], but also several flowers combined in a matrix can be transformed into a public display [9] or street signs may be augmented to display more information than just the name of the street [16]. Nevertheless, public displays can also be understood in a more classical sense [19, 22].

With recent trends in Augmented Reality, the technology becomes part of public space and is increasingly pervasive. However, pervasive AR is often interpreted as body-worn technology that is context-aware [10]. Location-based gaming in particular (e.g., Pokemon Go) brings AR into public spaces [5, 17]. Here, the digital content is publicly shared with multiple users, but the involved displays remain private. The use of private displays can also be observed when AR is combined with public displays (e.g., to give another perspective on the content [11], to allow multi-user interaction [2], or to display private information [3, 21]). However, AR content can also be displayed on the public display itself. An early approach has been suggested by Schnädelbach et al. [25] to enable the public to explore a medieval castle from the site of its modern replacement. Further, Colley et al. [6] showed that more people notice a public display when see-through AR is used to present content. Similar approaches can be found in commercial applications such as Lego's AR Kiosk[2] or the AR Sandbox[3].

2.3 Contribution

So far, pervasive AR is mostly investigated in the form of private displays that augment our existing environment. While this can be a useful approach to advance and personalize information presentation (e.g., on public displays), it does not explore the potential of pervasive AR on public displays. With commercial applications such as the Pepsi ad, the strength of AR on public displays becomes clear. However, little is known about the user experience and behavior when AR is used on a public display. In this work, we want to start filling that research gap by exploring AR for public displays in a realistic setting.

[1] https://www.youtube.com/watch?v=Go9rf9GmYpM, last retrieved May 6, 2019

[2] https://www.youtube.com/watch?v=CNkilCYnmoY, last retrieved May 6, 2019

[3] https://arsandbox.ucdavis.edu, last retrieved May 6, 2019

3 CHALKBOARD

To explore the use of Augmented Reality for public displays, we developed our *ChalkboARd* system (see Figure 1). It is based on the mental model of windows described by Muller et al. [20] and implements a window effect [4, 32] with video see-through AR. Thereby, bystanders can look "through" the display into the captured scene behind the *ChalkboARd* while we can add virtual objects to augmented the scene. Here, we created a 3D model of a chalk figure and set up an animation in which the figure interacts with the real environment of the system. In a field study, we observed the behavior of bystanders in the system and interviewed them for more detailed insights afterwards.

3.1 Implementation

The *ChalkboARd* system consists of a self-constructed wooden frame, a 24-inch LCD monitor, and a Samsung Galaxy S8 Android smartphone that is connected to the monitor via USB-C (see Figure 2). The system is easy to build and detailed instructions for replicating the setup can be found on Github[4]. We developed our software with Unity3D[5], a game engine that supports different platforms (including Android and iOS). For our AR implementation we tested three different AR libraries (Wikitude, ARCore and Vuforia). Due to the static position of the smartphone in the setup, we decided to use marker-based tracking (detecting surfaces requires the smartphone to be moved). In the end, we decided to use Vuforia[6] because it is platform independent (can be used on Android and iOS). To set up the window effect [4, 32] and to control the animation, we used a Bluetooth remote control that was connected to the smartphone. Thereby, we could adjust the position and scale of the camera capture on the screen to create the window effect. To avoid privacy issues, we did not connect the smartphone to the internet or store any of the captured images on the smartphone. The modelling and animation of the chalk figure (cp. Figure 3) were done in Blender[7], an open source software for 3D modelling. During our implementation, we discovered that the smartphone turned off after 25 minutes due to overheating. After some investigating, we figured out that the reason for this was the connection of an external monitor via USB-C and the permanently looped camera image on the screen (e.g., just opening the camera app while being connected to the monitor also resulted in a shutdown after approximately 25 minutes). We were able to fix these issues by adding cool-packs to the smartphone (for a permanent installation of our setup a passive cooling system might be required).

4 STUDY

To explore how bystanders react to Augmented Reality presented on a public display, we conducted a field study with our *ChalkboARd* system.

4.1 Design and Procedure

We set up our system in the lounge of our research institute (see Figure 1). The lounge contains several seating options, each with three chairs located around a round table. Additionally, the lounge has a play corner that is separated from the seat options by three flower pots. Here, we replaced the middle flower pot with our *ChalkboARd* system (see Figure 1). We adjusted the orientation of our setup to face the seat options with the display while the camera points into the direction of the play corner. For the experiment we prepared a seat option with a table and three chairs next to our *ChalkboARd* system and placed a sign on the table informing bystanders about the experiment. Next to the experiment table, two observers of the scene are pretend to drink coffee and be engaged in a conversation about an unrelated topic. However, their official task is to observe the participants of our experiment and to document their behavior. Directly after each participants took a seat, one of the two observers started the animation with the Bluetooth remote control. The animation consisted of five iterations, each with a duration of 60 seconds. Thereby, we wanted to be able to observe in which iteration the setup arouses the attention of participants. In each iteration, the *ChalkboARd* system pretends to be a regular chalkboard and shows a chalk figure that is not moving for 30 seconds (see Figure 3a). After 30 seconds, the figure falls to the bottom of the display and opens up the background to show the window effect (see Figure 3b). After that, the figure jumps into the world onto the helicopter landing pad on the playground carpet (see Figure 3c). Then the figure starts to dance on the carpet, and leaves the scene after another 30 seconds (see Figure 3d). The chalk figure then comes back in, along with the black plane, to return to the start scene, which looks like a regular chalkboard (see Figure 3a). After five iterations, one of the two observers stops the animation and asks the participants if they are willing to do a short interview with them.

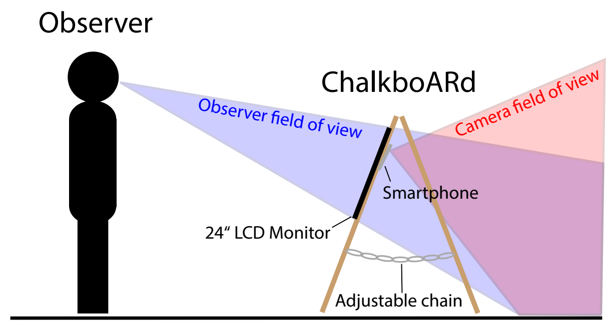
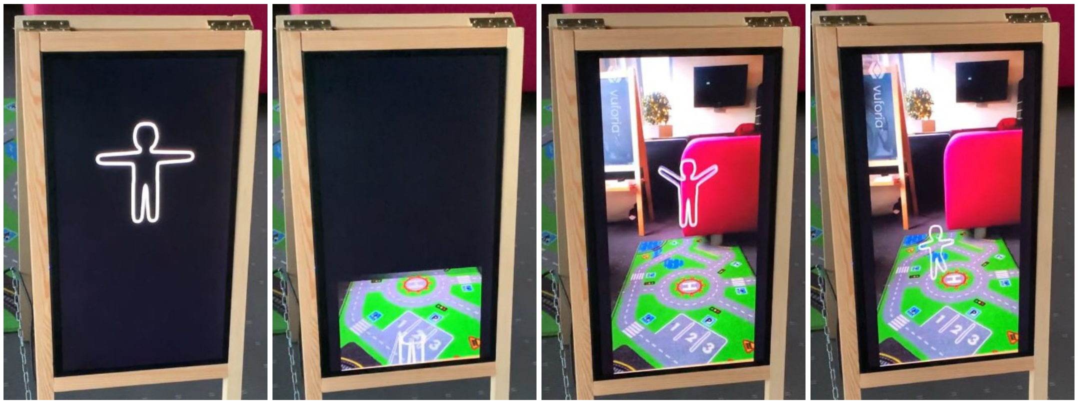


Figure 2: *ChalkboARd* system setup: the observer's view is directed at a video-see through AR display creating the experience of "seeing" through the physical chalkboard.

4.2 Participants and Ethics

Overall, 20 participants (4 females) participated in our experiment, aged between 21 and 42 (M=29.6, SD=5.4). 10 participants were from our research institute and 10 participants were guests who were visiting the research institute for ongoing collaborations. We allowed different group sizes (from two to three participants) to participate in our experiment. Additionally, we asked the participants to rate their experience with AR on a 5-point Likert-scale

[4]https://github.com/UweGruenefeld/ChalkboARd
[5]http://unity3d.com, last retrieved May 6, 2019
[6]http://vuforia.com, last retrieved May 6, 2019
[7]http://blender.org, last retrieved May 6, 2019



(a) Start scene. **(b) Window scene.** **(c) Jumping scene.** **(d) Dancing scene.**

Figure 3: For the field test, we deployed a simple animated AR scene, consisting of a chalk figure (a) escaping the limits of the 2D chalkboard (b), jumping to the 3D scene on the playground carpet (c), and performing a small dance (d). ***Best viewed in color.***

item (1=no experience and 5=very experienced). 5 participants had no experience with AR, and 11 participants were somewhat familiar with AR (Md=2, IQR=0.25).

Since we did a field study in which we wanted to observe authentic behavior of participants, we could not inform them about the procedure of the experiment beforehand. Instead, we decided to use a sheet of paper that contained the most important information and placed it on the table that was used for the experiment. On the sheet of paper, we explained that having a seat at this table means that you are willing to participate in the experiment. Further, we informed participants that we did not collect any images, videos or audio data, and that participating in the experiment would not cause any harm to them. To avoid any privacy issues, we collected all information during the observations and interviews anonymously.

4.3 Observations

We observed the behavior of the participants throughout the experiment. We observed their reactions to our *ChalkboARd* system. We were especially interested in two aspects: (1) when the setup arouses the attention of participants, and (2) the impact of the setup on their behavior.

Attention In the beginning, all participants were engaged in conversations. However, all participants looked in the direction of the monitor within the first iteration of the animation. Eighteen participants (90%) looked during the fall of the chalk figure to the bottom of the monitor, and 2 participants (10%) looked when the figure jumped into the real world. Interestingly, 13 participants (65%) and therefore, most of the participant followed the animation over all five iterations (five minutes in total). This is surprising, since all five iterations were showed exactly the same animation over and over again. It may be an indication that the animation is not perceived as calm, and therefore, does not allow the observer to disengage from the content. However, not all participants followed the animations until the end. Two participants (10%) stopped observing the *ChalkboARd* system after the first iteration, and 5 participants (25%) stopped observing after the second iteration and continued with their conversations. This is probably because they realized that the same content was being presented in every iteration.

Behavior Eighteen participants (90%) talked about the setup, mainly about how the setup could work from a technical perspective. Only 2 participants (10%) did not specifically mention the setup in their conversation. Interestingly, 9 participants (45%) left their seat and interacted with the system, often while at the same time getting instructions from the other seated participants of what to do with the setup. Four participants (20%) thought that their behavior somehow triggered the start of the animation. Therefore, they tried different gestures in front of and behind the system to start the animation (e.g., they tried to start the animation of the chalk figure by stretching out their arms or dancing in front of the setup). However, when they realized the animation was restarting every 60 seconds, they stopped their efforts. Another 4 participants (20%) wanted to understand the setup better, and held their hands in front of the camera or started to change the direction of the system (e.g., one participant turned the setup 180 degrees to face the other participants and observed the changes to the chalk figure). Two participants (10%) realized that the playground carpet was somewhat involved in the animation (e.g., one participant laid down on the carpet to make the chalk figure jump onto his body and dance there, while another participant lifted up the carpet to see if there was something underneath and, when he found nothing, moved the carpet to a different location). Whenever participants started to interact with the setup, the other participants showed reactions indicating their enjoyment, such as laughing or joking around. Groups of three were especially motivated to try out various things with the setup, while groups of two acted more passively.

4.4 Interviews

After the experiment, we conducted a semi-structured interview with each participant individually. Here, we asked the participants five different questions about the *ChalkboARd* system: (Q1) Did you notice something unusual during your stay in the lounge? (Q2) How do you think how does the system works? (Q3) Did you like the system or do you think the system is problematic? (Q4) If the system would stay in the lounge for the long terms, would that influence your behavior in anyway? (Q5) What would you suggest to change about the system?

(Q1) Overall, most of the participants did notice our setup. Eighteen participants (90%) mentioned noticing the setup or a display next to their seat. Eleven participants (55%) explicitly mentioned that they saw some kind of Augmented Reality technology. Only 2 participants (10%) did not mention the setup, instead they said that fewer people were in the lounge that day. However, after being given a hint, they said that they saw the setup.

(Q2) The technical setup of our *ChalkboARd* system was well understood by participants. All of them mentioned that a display and a camera were involved in the setup. Additionally, 8 participants (40%) mentioned that there was some kind of computing unit required, and 4 participants (20%) explicitly mentioned software in form of an AR software development kit or Unity.

(Q3) The reactions in terms of how the participants felt about the system were mixed. Thirteen participants (65%) said that they liked the setup a lot. They described the idea of using AR for public screens as very interesting. Three participants (15%) said that they were neither in favor of nor against the setup. However, 4 participants (20%) said that they did not understand the use of such a display and therefore were not in favour of it. Two of those 4 participants understood the setup more as an art installation, of which they were generally not in favor of in general. Three participants (15%) mentioned that the system looks like a regular chalkboard and only the animation revealed otherwise.

(Q4) With regard to long term behavior changes, 8 participants (40%) said that the setup would change their behavior, and only 2 participants (10%) said it would not change their behavior and that they would ignore the setup. The other 10 participants said it would change their behavior if the content would change frequently (30%) or the camera would point in a direction that could capture them (20%). In general, all participants that stated it would change their behavior said that this would be due to the camera, and that they had privacy concerns with such a system. Further, 3 participants (15%) said the setup could be distracting when sitting next to it and therefore, they would choose a different seat in the lounge.

(Q5) Participants had different ideas on how to improve our *ChalkboARd* system. Eight participants (40%) asked for more interactivity (e.g., that the system reacts to their behavior or that the chalk figure interacts with different objects in the environment that may also be controlled by bystanders). Three participants (15%) wanted to have more animations and additional content (e.g., could the system could inform bystanders about coffee prices, etc.). Two participants (10%) suggested the system be set up in other locations (e.g., in a waiting room or in places with kids around).

5 DISCUSSION AND RESEARCH VISION

Attention. Use of AR on public displays is well-suited for arousing the attention of bystanders. All bystanders discovered the setup within seconds of the animation starting, and reacted mostly positively to the setup. Since the *ChalkboARd* system looked like a regular chalkboard, we think the unexpected movement is what aroused the attention of the bystanders. One could argue that it was not the AR content that aroused the attention of the participants, but the animation of the chalk figure. Still, many participants reacted positively to the AR content. In our experiment, we controlled the start of the animation. However, in a more realistic scenario, the system would be able to detect when bystanders are nearby and would then start the animation automatically.

Interaction. From our observations and interviews, we saw that bystanders tried to interact with our setup in various ways. For example, they tried to copy the behavior of the chalk figure by stretching their arms out in front of the system. They did this because they thought their behavior would have an influence on the animation shown on the display. Others manipulated the captured camera image by interacting with the playground carpet or changing the direction of the setup. Here, our system offered too few possibilities for interaction and therefore, bystanders lost interest in interacting with the system after some time. However, related work shows that more interaction with public displays can be realized in various ways (e.g., with gestures [30]). To investigate when our system would arouse the attention of bystanders, we showed the same animation in five iterations. However, if the system is used on a daily basis, it should add an informational value and show a wider variety of different animations as AR content.

Privacy. Most of the participants understood the setup from a technical perspective. They were able to identify all relevant components (display, smartphone, camera, playground carpet). However, some participants, especially those with no technical background had privacy concerns. They were unsure whether the camera feed was stored on the phone or not. Therefore, they said they would change their behavior to avoid being filmed by the camera. This is interesting, because participants also expect the system to be more interactive and adaptive to their behavior.

Future work. In the future, we would like to test our system for displaying information in different public places (e.g., in front of a restaurant, in the city center or in a waiting room of a pediatrician). Here, it may also be a good idea to focus more on children as a target group because the chalkboard offers a good opportunity for playful interaction with it. Therefore, we would like to add more interactivity with various motion sensors that can start different kinds of animations and react to users being close to the system (e.g., gesture-based interaction where content can be removed from the display by moving the hand over the display similar to a sponge or touch-based interaction where users can write on the chalkboard with virtual chalk).

6 CONCLUSION

We presented *ChalkboARd* , an Augmented Reality public displays that seamlessly blends with its environment. We illustrate the vision of creating AR content that is well integrated in the environment. In a field study, we explored the influence of our system on bystanders. Our results show that participants have an expectation of interactivity, but at the same time also concerns about. In future work, we would like to test our system integrated in different public places with more interactivity included.

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