Tackling Challenges of Interactive Public Displays using Gaze

Mohamed Khamis
Media Informatics Group
University of Munich
Munich, Germany
mohamed.khamis@ifi.lmu.de

Andreas Bulling
Perceptual User Interfaces Group
Max Planck Institute for Informatics
Saarbrucken, Germany
bulling@mpi-inf.mpg.de

Florian Alt
Media Informatics Group
University of Munich
Munich, Germany
florian.alt@ifi.lmu.de

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from Permissions@acm.org.
Ubicomp/ISWC'15 Adjunct, September 07-11, 2015, Osaka, Japan.
© 2015 ACM. ISBN 978-1-4503-3575-1/15/09...$15.00
DOI: http://dx.doi.org/10.1145/2800835.2807951

Abstract
Falling hardware prices led to a widespread use of public displays. Common interaction techniques for such displays currently include touch, mid-air, or smartphone-based interaction. While these techniques are well understood from a technical perspective, several remaining challenges hinder the uptake of interactive displays among passersby. In this paper we propose addressing major public display challenges through gaze as a novel interaction modality. We discuss why gaze-based interaction can tackle these challenges effectively and discuss how solutions can be technically realized. Furthermore, we summarize state-of-the-art eye tracking techniques that show particular promise in the area of public displays.

Author Keywords
Gaze; gaze-based interaction; public displays; pervasive displays; digital signage

Introduction
Public displays have become ubiquitous in public spaces, such as shopping malls or transit areas in airports and train stations. Equipped with an increasing number of sensors, their interactive capabilities promise informative, entertaining and engaging applications that provide tangible benefits to users. Such sensors include, for example, touch screens, cameras, and depth sensors, thereby enabling interaction

based on touch, mid-air gestures, smartphones, and recently also gaze. Nevertheless, the uptake of interactive public displays has been slowed due to many challenges.

This work suggests using gaze to tackle core challenges of display interaction. Gaze-based interaction has numerous advantages: gaze is intuitive [21], natural to use [22], indicates visual attention and usually precedes action [13].

Eye Tracking Techniques for Public Displays

Classical eye tracking techniques require performing time-consuming and cumbersome calibration [13]. This prerequisite has slowed the adoption of gaze for public displays. Previous work overcame this by estimating gaze with low accuracy based on head tracking and face detection [5].

More sophisticated calibration-free eye tracking methods, that show promise in the domain of public displays, were recently introduced. Examples include the work by Zhang et al. [23] that relies on relative eye-movements (e.g. distance between the pupil and eye corner). Vidal et al. [22] proposed leveraging the smooth pursuit eye movement to enable spontaneous gaze-based interaction. Pursuits has been evaluated on a public display and was shown to be well-perceived by passersby [11]. The method has also been used for flexible calibration [18]. Nagamatsu et al. [17] enabled calibration-free eye tracking using a sophisticated hardware setup (2 cameras and 8 LEDs).

With our work we aim to identify which of the techniques are suitable for particular applications and situations.

Addressing PD challenges using Gaze

Gaze can be used both implicitly and explicitly to enhance the user experience with public displays. By looking into existing work, six main challenges that hinder the uptake of interactive public displays have been identified, in this section we shed light on why and how gaze can be superior over existing techniques in addressing these challenges.

Detecting the user's attention
Attracting and detecting the user's attention are core challenges at the outset of the interaction process with public displays [7]. Previous work presented readily interactive displays and tried to attract the passersby's attention using physical objects [10] or user representations such as mirrored silhouettes [16]. Although inferring "attention" to a display is complicated, the passerby's gaze indicates overt visual attention and in many cases precedes action [13]. Recent research used wearable eye trackers to detect visual attention to displays [6]. Also remote eye trackers can be used to detect a user's gaze, which can be a plausible indication of his/her attention to the display, particularly when combined with head orientation and body posture.

Communicating Interactivity to the Passerby
In order for the passers-by to distinguish interactive displays from static advertising screens, a public display needs to communicate that it is interactive [7]. Existing approaches include flipping an edge of the display [12], using *call-to-action* labels, using signs next to display [14] or assigning someone to invite passersby to interact [9]. Based on gaze-data, it is possible to show a concise *call-to-action* label right where the passerby is looking, at the moment s/he attends to the display. This makes it is less likely to be overlooked compared to existing approaches.

Accessibility and Social Embarrassment
Another challenge is the accessibility of the displays. Touch-based interaction is not always possible due to the display's location (e.g. in many cases the display is behind a glass window or mounted above head-height for visibility and security [7]). Gesture-based interaction is often difficult due to the lack of a generally agreed-upon gesture-to-action map-

pings. Moreover, mid-air gestures were found to be embarrassing for users in public [4], particularly if visible from afar. By using remote eye trackers, interaction via gaze becomes very subtle and can be hardly recognized by others in public; thus overcoming the embarrassment problem, while maintaining the advantage of at-a-distance interaction.

Immediate Usability
When it comes to interaction, there is the requirement of immediate usability [7]. Interaction time with a public display is often short (in seconds) [15]. So far this has been addressed by using interaction concepts that require a low learning curve, and by using *call-to-action* labels [14]. Gaze-based interaction is fast [19] and intuitive [21]. Gaze can also be used alongside other interaction modalities to improve their usability. Combining midair gestures and/or touch interaction with gaze tracking in public displays holds promise by, for example, adapting UIs based on users' visual attention.

Privacy in Public Spaces
As displays become more interactive there is a need to enable personalization and to allow users to input data (e.g. add a post [2]). Consequently, displays need to deal with sensitive data (e.g. passwords), that users will be skeptical to provide in a public environment. This problem is currently mitigated by asking users to exchange sensitive data through their mobile devices [3]. Using gaze-based authentication was shown to be more secure than classical methods [8]. Moreover, previous work has demonstrated the feasibility of content exchange across devices via gaze [20]. This makes content-exchange less prone to observations and less likely to leave exploitable smudge traces.

Gaze as a Performance Indicator
Unlike websites, public displays have no equivalent of a user "click stream", which makes it difficult to track user actions for evaluation purposes [7]. Gaze can offer metrics to quantify the performance of displays. Such metrics include, among others, dwell time and number of fixations; these can be used as indicators of attention, perception, understanding, and interest.

Limitations
Eye tracking could be challenging outdoors as the trackers can be influenced by varying light conditions. Moreover, eye trackers have usually been intended for desktop settings, where a single user interacts at a time from the same distance. However, public displays expect multiple users of different heights to interact from different positions. Recent work suggested guiding passersby to certain positions in front of displays using on-screen visual cues [1].

Conclusion
In this paper we discussed why we believe gaze-based interaction to be a promising modality for tackling many challenges related to interactive public displays and introduced different gaze tracking techniques. In addition we provided pointers for future research in this area.

References

[1] Florian Alt, Andreas Bulling, Gino Gravanis, and Daniel Buschek. GravitySpot: Guiding Users in Front of Public Displays Using On-Screen Visual Cues. In *Proc. UIST '15*. ACM.

[2] Florian Alt, Nemanja Memarovic, Miriam Greis, and Niels Henze. UniDisplay - A Research Prototype to Investigate Expectations Towards Public Display Applications. In *Proc. PD-Apps'14*. IEEE.

[3] Florian Alt, Alireza Sahami Shirazi, Thomas Kubitza, and Albrecht Schmidt. Interaction Techniques for Creating and Exchanging Content with Public Displays. In *Proc. CHI'13*. ACM, 1709–1718.

[4] Harry Brignull and Yvonne Rogers. Enticing people to interact with large public displays in public spaces. In *Proc. INTERACT '03*. 17–24.

[5] Frederik Brudy, David Ledo, Saul Greenberg, and Andreas Butz. Is Anyone Looking? Mitigating Shoulder Surfing on Public Displays Through Awareness and Protection. In *Proc. PerDis '14*. ACM, 1–6.

[6] Nicholas S. Dalton, Emily Collins, and Paul Marshall. Display Blindness?: Looking Again at the Visibility of Situated Displays Using Eye-tracking. In *Proc. CHI '15*. ACM, 3889–3898.

[7] Nigel Davies, Sarah Clinch, and Florian Alt. 2014. *Pervasive Displays - Understanding the Future of Digital Signage*. Morgan and Claypool Publishers.

[8] Alexander De Luca, Martin Denzel, and Heinrich Hussmann. 2009. Look into My Eyes!: Can You Guess My Password?. In *Proc. SOUPS '09*. ACM, 7:1–7:12.

[9] Giulio Jacucci, Ann Morrison, Gabriela T. Richard, Jari Kleimola, Peter Peltonen, Lorenza Parisi, and Toni Laitinen. Worlds of Information: Designing for Engagement at a Public Multi-touch Display. In *Proc. CHI'10*. ACM, 2267–2276.

[10] Wendy Ju and David Sirkin. Animate Objects: How Physical Motion Encourages Public Interaction. In *Persuasive Technology*. Springer, 40–51.

[11] Mohamed Khamis, Florian Alt, and Andreas Bulling. A Field Study on Spontaneous Gaze-based Interaction with a Public Display using Pursuits. In *Proc. UbiComp '15 Adjunct*. ACM.

[12] Hannu Kukka, Heidi Oja, Vassilis Kostakos, Jorge Gonçalves, and Timo Ojala. What Makes You Click: Exploring Visual Signals to Entice Interaction on Public Displays. In *Proc. CHI '13*. ACM, 1699–1708.

[13] Päivi Majaranta and Andreas Bulling. 2014. *Eye Tracking and Eye-Based Human-Computer Interaction*. Springer Publishing, 39–65.

[14] Paul Marshall, Richard Morris, Yvonne Rogers, Stefan Kreitmayer, and Matt Davies. Rethinking 'Multi-user': An In-the-wild Study of How Groups Approach a Walk-up-and-use Tabletop Interface. In *Proc. CHI '11*. ACM.

[15] Jörg Müller, Florian Alt, Daniel Michelis, and Albrecht Schmidt. Requirements and Design Space for Interactive Public Displays. In *Proc. MM '10*. ACM, 1285–1294.

[16] Jörg Müller, Robert Walter, Gilles Bailly, Michael Nischt, and Florian Alt. Looking Glass: A Field Study on Noticing Interactivity of a Shop Window. In *Proc. CHI'12*. ACM, 297–306.

[17] Takashi Nagamatsu, Kaoruko Fukuda, and Michiya Yamamoto. Development of Corneal Reflection-based Gaze Tracking System for Public Use. In *Proc. PerDis '14*. ACM, 194–195.

[18] Ken Pfeuffer, Melodie Vidal, Jayson Turner, Andreas Bulling, and Hans Gellersen. Pursuit Calibration: Making Gaze Calibration Less Tedious and More Flexible. In *Proc. UIST '13*. ACM, 261–270.

[19] Linda E. Sibert and Robert J. K. Jacob. Evaluation of Eye Gaze Interaction. In *Proc. CHI '00*. ACM.

[20] Jayson Turner, Andreas Bulling, Jason Alexander, and Hans Gellersen. 2014. Cross-Device Gaze-Supported Point-to-Point Content Transfer. In *Proc. ETRA '14*. 19–26.

[21] Roel Vertegaal. 2003. Attentive user interfaces. *Commun. ACM* 46, 3 (2003), 30–33.

[22] Mélodie Vidal, Andreas Bulling, and Hans Gellersen. 2013. Pursuits: Spontaneous Interaction with Displays Based on Smooth Pursuit Eye Movement and Moving Targets. In *Proc. UbiComp '13*. ACM, 439–448.

[23] Yanxia Zhang, Jörg Müller, Ming Ki Chong, Andreas Bulling, and Hans Gellersen. GazeHorizon: Enabling Passers-by to Interact with Public Displays by Gaze. In *Proc. UbiComp '14*. ACM, 559–563.