Towards Cross-Surface Content Sharing Between Mobile Devices and Large Displays in the Wild

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CHI 2016 Workshop on Interacting with Multi-Device Ecologies "in the Wild", May 7, 2016, San Jose, CA, USA.

Abstract
Large vertical displays are increasingly widespread, and content sharing between them and personal mobile devices is central to many usage scenarios. Research has already led to manifold interaction techniques. In most cases however, they do not lend themselves for realistic, in-the-wild usage. In this paper we present our research towards bridging the gap to real world usage. We address the issues of *awareness & connectivity* as well as *privacy*, which we believe to be two important aspects of BYOD (bring your own device) content sharing between public displays and mobile devices.

Author Keywords
Cross-device interaction; data transfer; privacy; large displays; mobile phones; proxemic interaction

ACM Classification Keywords
H.5.2. [Information Interfaces and Presentation: User Interfaces]: Input devices and strategies, Interaction styles

Introduction & Background
Hardware advances are making very large vertical displays more common in a variety of scenarios, e.g., as public displays. At the same time, personal devices such as mobile phones have become ubiquitous over the last years, as they allow people to conveniently manage their digital identi-

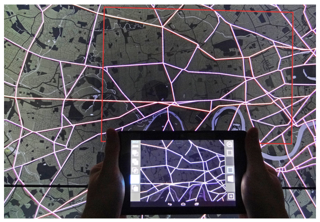

Figure 1: Tango tablet used in combination with a wall-sized display. The position is tracked using the internal sensors only.

ties and content. In combination these two device classes provide the advantages of both settings: among others, personalized interaction, private data storage, and on-demand data sharing. While these issues have been studied extensively in the past, there is a lack of work specifically addressing scenarios where users bring their own devices to share data with large public or semi-public displays outside of typical lab settings. In our research we address two aspects that are often still problematic in real world usage scenarios: (i) *awareness & connectivity* and (ii) *privacy*. In the following we will give a brief overview of the related work before exploring these two aspects in more detail.

For a general introduction to interaction with wall-sized displays, we refer to the overview by Müller et al. on public displays [7]. Additionally, Marquardt et al.'s work on Gradual Engagement [6] provides a design framework for integrating the relative positions of the devices involved in cross-device interaction. A related notion is Greenberg et al.'s Proxemic Interaction (e.g., [4]), in which interactions are based on spatial relationships between people and devices.

Much of the work on cross-device data transfer considers single-item transfer in close proximity. Rekimoto's Pick-and-Drop [8] is early work on cross-device data transfer using a pen as interaction device. More recently, Schmidt et al.'s PhoneTouch associates touches on a large display with a mobile phone by correlating the phone's motion sensor signals, covering both the technology [9] and numerous interaction techniques [10]. In SleeD [14], von Zadow et al. use an arm-worn device; transfer involves touching the large display with the hand the device is strapped on. Alt et al. [1] compare content creation for and exchange with public displays using multiple modalities, while Seifert et al. [12] introduce a number of interaction techniques that allow privately selecting the data to share before performing the actual transfer. In PointerPhone [11], Seifert et al. investigate the interactions possible when remote pointing is combined with interactions on the phone. Dachselt and Buchholz's Throw and Tilt [3] utilizes expressive gestures for data transfer, while Hassan et al.'s Chucking [5] is interesting because it also supports positioning of items on the large screen.

Awareness & Connectivity

A particular challenge for in-the-wild interaction between mobiles and public displays is the issue of *awareness & connectivity*. In this context, both technology and user interface have to be considered, which involves providing standardized protocols (location and services) as well as ui components and interactions.

Concerning the user interface, awareness is the knowledge of the user that there is a public display, that it supports interaction, and that it is ready to accept user input. Known approaches such as Marquardt et al.'s Gradual Engagement Pattern [6] can support this. We believe that in the future a background service on the mobile device could continuously check for available connections in the environment and give appropriate feedback, e.g., status bar messages or vibration to get the user's attention.

Technologically, awareness means that both the mobile can react to public displays, as described above, and the large display can react to the mobile device. However, there are different levels of sensing to this. In fact, they form a whole spectrum between only knowing that a device is in the vicinity and full six DoF tracking. These technical capabilities influence the availability of the following interaction styles:

- In the case where no additional tracking data is available, the mobile device can only be used similar to a TV remote. Data transfer by techniques such as

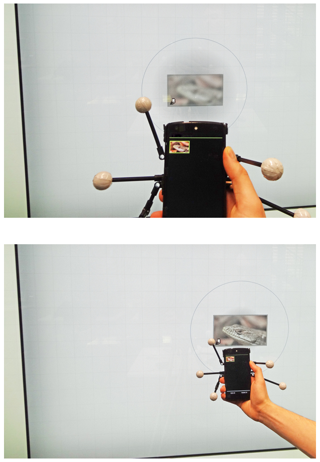

Figure 2: Top: The preview image on the public display is blurred to preserve privacy. Bottom: Blurring can be distance aware. When the user stands near the large display and shoulder surfing is harder, less blurring is applied.

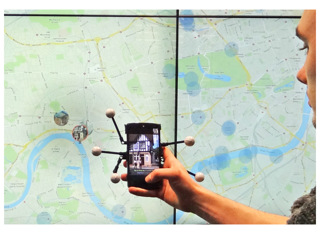

Figure 3: By default, only the position of pictures on a map is shown. Only when directly pointing at them, their preview is revealed.

swiping is possible but lacks positional information. Alternatively, drag gestures on the phone can (relatively) control the movement of a pointer on the large display.

- If the large display allows sensing of contact positions (e.g. it is touch capable or via marker tracking of the phone), precise transfer to the touch position becomes possible when in touching distance (e.g., [9, 14]).
- Relative motion tracking of the mobile device, e.g., using the internal IMU, enables device gestures such as throwing [3].
- Finally, with full 6 DoF tracking available, pointing is available and allows for precisely targeted transfer of digital objects.

Up to now, tracking of mobile devices in front of large vertical displays usually involves instrumentation of the room and in many cases also the device, using marker based tracking systems or depth cameras (e.g., [13]). Lately, devices such as Google's Tango[1] allow non-instrumented, visual motion tracking. We tested Tango in a typical interaction scenario in front of a wall-sized interactive display (Figure 1) and found the tracking precision sufficient for most application cases. Drift, however, can be a problem, especially when the display content changes rapidly.

For meaningful interaction between the devices, not only files transfer has to be considered but also specific, intuitive user interfaces. General file transfer applications, e.g., a file browser, would be applicable to a wide range of situations. However, we believe that carefully crafted interfaces that take the context (display type, application scenario, ...) into consideration could provide a richer experience. Additionally, such interfaces could also integrate not only content sharing but other uses for mobile devices, such as personal tangible magic lenses, as well. Therefore, in our investigations we explore a streaming-based thin-client architecture. The application running on the large display streams user interfaces to the mobile device and collects user input. Our current prototype renders the UI into an h.264 video stream using the Python-based libavg[2] framework. The stream is then decoded and displayed on the mobile device by a small, native application. User input, i.e., touch and motion data, is streamed back via OSC protocol. This allows applications that use a simple and thin client to provide arbitrary, application-specific user interfaces. Depending on the precise details of the usage scenario (e.g., number of clients), we think that this solution could serve as a basis for various settings, because the bandwidth of available network connections increases continuously and todays mobile devices are equipped with efficient decoders.

Privacy

Privacy is a general concern in many multi-user application scenarios. In particular, we believe that this is a major factor to be considered in content sharing applications between public and private devices. There has already been work regarding the presentation of private data on public displays and specific interactions, such as on limiting shoulder surfing [2] and password input [9], respectively. Given that users often store very personal pictures on their phones, they might be hesitant to let others see them unfiltered. To counteract privacy concerns in such cases, we currently explore three different interface strategies: (i) limit what data is displayed at all, (ii) hide information through blurring and other image-based methods, and (iii) show abstract representations of data items, e.g., by only showing metadata.

[1] https://www.google.com/atap/project-tango/

[2] http://libavg.de/

In our investigations, we use a simple two-step process for data sharing activities: First, instead of sharing and displaying all documents at once, the user manually selects them on his or her device, thus filtering them on a smaller, more private display, similarly to [12]. Secondly, when transferring to the public display, we show a heavily blurred version of the content (Figure 2). This allows the user, who knows his or her photos, to cancel the transfer if an undesired picture is shown, while hiding details from the public. For use cases such as geotagged photos on a map, we transfer metadata of items first, allowing the large display to show preview circles at corresponding positions. The photos themselves are not revealed until the pointing cursor is over their position, preserving privacy (Figure 3).

Besides the issue of uploading content, *downloading* from the public display can also lead to privacy concerns: Imagine a public information terminal in a medical center with info flyers on different medical issues or a digital notice board with anonymized publicly available exam results. These are situations in which a user might not want others to see which digital objects he or she copies to their personal device. To this end, we propose the concept of *blind pointing*: During pointing/selection, no visual representation of a selection cursor is shown on the public display. Instead, the user only gets vibrotactile feedback. We believe that proprioception could allow users to reliably select items on a large display solely supported by such unspecific feedback in combination with small, inconspicuous pointing gestures.

Conclusion

In this position paper, we outlined our on-going explorations on content sharing between large displays and mobile devices, focusing on the two important aspects *awareness & connectivity* as well as *privacy*. In the context of BYOD and to consider different device platforms, maximize compatibility, and ease the process of device connections, we explore the usage of non-instrumented devices (i.e., without additional markers) such as Tango and deploy a streaming-solution in which the display application sends the user interface (output) and collects user input. Furthermore, we developed early concepts and prototype implementations addressing the issue of privacy, such as abstracting visual user feedback on large displays or using *blind pointing*.

We believe that, together with various other investigations in this field, our research helps the community to determine underlying principles and enable the development of seamless content sharing between large displays and personal mobile devices in the wild.

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