Multipurpose Interactive Public Displays in the Wild: Three Years Later

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Extended research on interactive public displays deployed in a city center reveals differences between the public's stated information needs and their actual information behavior and highlights effects that an artificial environment cannot duplicate.

Studies of interactive public displays are often criticized because their evaluation typically takes place in unrealistic lab environments, for short periods, with handpicked test users, predefined tasks, and limited content or services through a single prototype. Such focused usability evaluations provide excellent material for research papers, but whether they test anything of much practical interest is debatable.

To gain more in-depth knowledge about the real-world use of interactive public displays, as part of our Urban Interactions (UBI) Research program, we deployed 12 multipurpose interactive displays in 2009 at six outdoor and six indoor locations around downtown Oulu, Finland. Each display, or UBI hotspot, consists of a 57-inch high-definition LCD panel with a capacitive touchscreen foil, two cameras, a near-field code and radio frequency ID (NFC/RFID) reader, a loudspeaker, Wi-Fi and Bluetooth access points, and high-speed Internet access.[1]

Our objective in deploying these displays was to understand how users derive value from interactive public displays that provide real services based on real content over an extended period. The hotspots offer 25 distinct interactive services, provided by us, the City of Oulu, private businesses and nongovernment organizations, and creative communities. In 2010, we deployed a seventh indoor display, and we plan to add four indoor displays in the near future. Our current 13 hotspots represent the world's largest deployment of interactive public displays for research in a city center. As of April 2012, thousands of users have accessed our hotspots, yielding rich research data on human-display interaction.

We believe that this type of long-term test gauges the value of any system for real users in a much more concrete way than short-term studies with predefined tasks and handpicked test participants. By deploying this many hotspots for this long, we can establish technical and cultural readiness and a critical mass of users needed to reliably evaluate the degree to which our hotspots succeeded as an interactive public display system.[2]

For example, we have already discovered that the public's stated information needs differ from how they actually use the hotspots. We have also identified several discrepancies between a laboratory and real-world environment that have strong implications for future studies of interactive public displays. Finally, our deployment has crystallized several design challenges, such as how to combat interaction blindness—when people fail to interact with a display simply because they don't realize that they can.

UBI HOTSPOTS

As Figure 1 shows, our outdoor hotspots are double-sided displays along walkways in the heart of the city and in the market area. The six indoor hotspots are single-sided

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Figure 1. Outdoor UBI hotspots (a) along a walkway, where a user is interacting with version 2 of the UBI portal and (b) in the market area of downtown Oulu. Each outdoor hotspot is a double-sided display accessible 24/7.

displays in popular municipal buildings such as the main library, the youth and culture center, and the swimming hall. The public can access these hotspots only when the buildings are open.

Interaction modes

A hotspot is in either passive broadcast (digital signage) or interactive mode. In passive broadcast mode, the screen is dedicated to a UBI channel—a customizable playlist of video, animation, and still photographs (both nonprofit and commercial). The playlist's composition is tailorable across hotspots.

When the cameras detect a face or someone touches the screen, the hotspot changes to an interactive mode, which splits between the UBI channel and a customizable UBI portal. Figure 2 shows a screen in this mode.

We implemented the UBI portal using the Web paradigm, comprising a set of webpages rendered by the corresponding webserver processes and managed by our in-house screen real estate management system.[3] The services are referenced by their URLs and can reside anywhere on the Internet. The portal is tailorable for each hotspot.

Figure 2. Version 3 of a hotspot in interactive mode. The screen is split between the UBI channel (top left), a customizable multimedia playlist; the quick-launch menu providing one-touch access to selected services (bottom left); and the UBI portal (right) through which users can access 25 services in seven categories, as well as a help and survey category.

Some services involve interaction with a personal mobile phone, for example, content upload or download to or from a mobile phone, or coupling the personal mobile phone's user interface with the hotspot's public user interface into a distributed/hybrid user interface.[4] We have used NFC/RFID tags, QR codes, Bluetooth, and SMS to enable mobile phone and portal service pairing.

We have released three distinct portal versions: version 1 in June 2009,[1] version 2 in June 2010, and version 3 in June 2011. Versions 2 and 3 contain a quick-launch menu for promoting particular services that users can launch from the menu with a single touch. To entice interaction, we introduced a simple proximity-based visual cue in version 2 so that, in full screen mode, when the camera detects a face, the system animates the upper right-hand corner of the UBI channel to open like a book page displaying "Touch me!"

Services

As of April 2012, version 3 of the portal contains 25 distinct services in seven categories: News (3), Services (3),

Figure 3. Researchers conducting interviews with a mockup display. The whiteboard drew attention to the researchers and made it easier for people to draw their ideas in realistic proportions.

City (3), Third Party (4), Fun & Games (5), Multimedia (3), and New Cool Stuff (four services developed by the four finalists in the 1st International UBI Challenge). Of the 25 services, 16 depend on content that third parties provide and that is therefore beyond our administrative control. This kind of distributed service provisioning is a must for a cost-efficient and sustainable realization of our multipurpose hotspots, and the Web paradigm has proven very suitable for implementing it. We can quickly include new services residing on any webserver in the Internet, as long as they conform to certain minimal design guidelines.

We are contemplating allowing external research groups to remotely deploy their services in our hotspots to provide them with an opportunity to try out their services in the wild. Others are also welcome to use our services in their deployments, since all our hotspot software is publicly available as open source. For example, Lancaster University recently deployed an adaptation of our Ubinion service,[5] which uses hotspots as a feedback channel to the City of Oulu Center of Youth Affairs, to give teenagers at a local school more of a say in community life through interactive public displays.

Although all services are usable without any authentication or login mechanism, a user can also create a personal hotspot account. Upon creating their accounts, users can personalize the hotspot and couple the account with their Facebook account, enabling them to post game scores on their Facebook wall, for example. This functionality is part of our long-term exploration of ways to couple interactive public displays with social networking services to bridge the divide between virtual and physical.[6]

In version 1, users coupled an account with a UBI key (NFC/RFID tag) that we distributed. In versions 2 and 3, users couple the account with their mobile phone's Bluetooth ID and a PIN, allowing them to create an account instantly at any hotspot without hardware other than the mobile phone. The user can also fill in an online questionnaire and give a thumbs up or down vote for each view in the portal.

Commercial use

To cover the hotspots' operational expenses, such as Internet use, electricity, cleaning, and insurance, we sell the capacity of the UBI channel and UBI portal for commercial use. The revenue for the first 24 months was roughly 200,000 euros (90 percent from the UBI channel, and 10 percent from the UBI portal). Commercial use imposes obvious and regrettable limitations on research use. We must deliver the capacity sold, thus the UBI channel must be always visible, reducing the dynamic range of the interactive mode and hotspot use in general.

INFORMATION NEEDS AND BEHAVIOR

Before deploying the hotspots, we conducted extensive activities to elicit requirements. These activities included brainstorming workshops with municipal, industrial, and academic experts; observations and interviews of Oulu citizens; and a study with a crude mockup to convey the idea of a large public display. As Figure 3 shows, the mockup was basically a whiteboard on a stand with wheels. Our researchers conducted 74 open-ended interviews with the display mockup in four candidate locations, which we subsequently selected on the basis of the collected feedback.

From a strictly methodological view, the mockup display was a valuable tool in our initial user studies. It attracted attention and made it easier for researchers to elicit information from passersby. The whiteboard's casual and familiar nature made it more comfortable for people to sketch their ideas about interacting with services using realistically sized drawings.

Nearly all the participants were quite positive about the hotspots, and most felt that the displays would enhance daily activities. In a follow-up poll, most respondents claimed that the hotspots were a good fit for the city and natural to use in a public setting.

Gender differences

Our work to elicit requirements highlighted several gender and age differences in stated preferences.

Females rated commercial services higher, such as offers from shops and suggestions about where to buy items. This rating is not surprising, since many shops in the city center target female customers, who do most of the shopping for their household's daily needs. In addition, females had a stronger preference for weather services,

which might be because of their need to know if adverse weather will affect their shopping.

Males, in contrast, had a stronger preference for multimedia and upload-driven services, which could be due to the perceived technical complexities of using such services. Upload-driven services require users to pair their personal devices with the display—a task that might come across as the kind of gadget-oriented challenge, traditionally attractive to males.

Service needs versus actual use

To gain insight into what services users might prefer, we analyzed information needs from the user studies. Our analysis revealed a priori information-seeking strategies related to transportation, exploration, consumer needs, and entertainment and news. We subsequently implemented and deployed most of the desired services on the hotspots and have logged their use.

The 13 hotspots total about 500 service launches on an average day, but daily variations can be substantial. The hotspots have at times suffered from various technical problems that have reduced their availability and use. Unresponsive touchscreen foils have been the most harmful malfunction that has proven very costly for our deployment in many respects.

The hotspots also automatically count faces detected from the video feeds of the overhead cameras, which collectively can be more than 100,000 in a single day (112,498 detections on 2 April 2012), although multiple detections of the same face are possible. The system counts two detections, for example, if someone looks at a hotspot for a sufficiently long time, then looks away for a brief moment, and then looks back at the hotspot.

A major challenge for our data collection has been the shortage of identified users—people who collected the UBI key (version 1) or have created a hotspot account coupled with their personal mobile phones (versions 2 and 3). Obviously, when all portal services are usable without an account, users perceive the account's added value as low. Thus, a large anonymous group accounts for most of the hotspots' use. Some services involve mobile interactions over Bluetooth, which allows us to identify users' phones from their Bluetooth IDs and subsequently analyze their behavioral patterns.[7]

Our analysis of the service use logs revealed a posteriori information-seeking strategies related to entertainment, exploration and catching up with news, consumer needs, and planning. Overall, we found that people were somewhat inaccurate at predicting which services they would find useful. Except for maps and commercial and consumer services, most services were either unexpectedly popular (such as simple games) or unexpectedly unpopular (such as municipal information and an event calendar).[8]

LABORATORY VERSUS THE REAL WORLD

One of the most valuable lessons we have learned from our deployment is the degree of difference between laboratory and real-world settings. What works with recruited test users in a laboratory is not necessarily representative of what works with a large population of independent users accessing the display at will in a real-world setting.

The findings from our work underline issues such as curiosity and novelty, location, social context, and weather—concerns that laboratory studies often ignore because of limitations in experimental settings and user sampling. Nonetheless, the effects of these issues are real phenomena that manifest themselves in longitudinal real-world deployments.[7]

Curiosity and novelty

A crucial aspect of hotspot use is the curiosity factor, which is difficult to replicate in a laboratory study. We have observed a direct, nonlinear effect on the number of touches required to access a service and its popularity. Users will readily access some services with multiple touches, even when the service is not on the quick-launch menu. On the other hand, some services are popular while they are on the menu, but their use drops to near zero when we remove them from the quick-launch menu.

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We have also observed the novelty factor when we introduce new system features or release a major system upgrade. In both cases, use spikes but then gradually decreases. The effects of novelty vary across instances, but we have consistently observed its impact to some degree.

Our analysis of service use has led us to attribute a substantial amount of hotspot use to curiosity. Passersby are curious about something on the screen, either because it is new or simply because they have never noticed it before. Curiosity motivates them to touch the display at least once to observe its response. Only a few users like a service enough to touch the screen multiple times to launch it.

Location

We have discovered that location is central to the way people use the hotspots. Although we simultaneously deployed identical hotspots at multiple locations, hotspot use has varied dramatically, as have users' service

Figure 4. Using a hotspot to create a UBI postcard. In certain environments, like the swimming hall, users interact with the hotspot in pairs or small groups, underlining the importance of social context in display use. As of 2 April 2012, users have sent more than 14,000 postcards.

preferences. The hotspot in the swimming hall lobby had 47 times more touches than an identical hotspot in the lobby of a municipal service center. Patrons in the swimming hall are generally relaxed and unhurried, with the user population being mostly children and teens keen to play games. This environment proved more beneficial for hotspot use than the business-like, almost clinical municipal service center.

Laboratory or single-location deployment studies cannot effectively capture the influence of location. Even a campus-wide deployment of several displays is limited, because although context varies slightly, the displays can attract only a limited number of user types.

Social context

Although the hotspots offer mostly single-user services, we often observe people using them in pairs or small groups. Social settings such as the swimming hall foster interaction. In Figure 4, for example, a group is posing for a UBI postcard photo, which they can then send to their friends. The group can retake the photo as many times as they need, ensuring that everyone is satisfied with the outcome.

Our sole multiuser service is the UBI *Mosquitoes* game, in which the objective is to smack mosquitoes and flies while avoiding butterflies. Younger users often play it in groups, since having more players increases the chances of achieving a high score.

We have also identified social settings that inhibit hotspot interaction. In one instance, a large crowd was near a hotspot (which we detected through Bluetooth), but only a few people used it. We concluded that this counterintuitive effect has to do with the nature of nearby events and hotspot placement. The crowd in question was attending a formal dance near one of our indoor hotspots. We expected use to increase as a result of the increased population in proximity to the hotspot, but we deduced that people arriving at the event were mostly in pairs or small groups and anxious to join that event. Consequently, a single person was not likely to hang back to use the hotspot while the others joined the event.

We also concluded that hotspots are not appropriate in crowded events, since users standing in front of the display are likely to block the coming and going of others or get jostled in their attempts to use the display, both of which are annoying. These observations strongly imply that people use the hotspots when they have extra time, which is less likely to occur during structured special events.

Weather

Weather also affects hotspot use, even indoor hotspots. After mapping our logs of average daily temperatures and weather conditions (sunny, cloudy, raining, snowing), we found that sunnier and warmer days correlate with higher hotspot use in terms of screen touches, services launched, and user interaction time. Our correlation analysis attributes about 10 percent of use variation to changes in ambient temperature alone, discarding other variables such as time of day, day of the week, or even location.

Once again, laboratory studies could not capture these patterns, since the test generally takes place indoors with controlled lighting and temperature.

FUTURE CHALLENGES

To move ahead, public display research must find ways to motivate interaction, such as combating interaction blindness and overcoming entrenched inhibitions to using public space technology, and to ease the transition to multipurpose displays.

Combating interaction blindness

Recent advances in display technologies have enabled the proliferation of large displays in public spaces. To date, however, these displays are still used primarily as one-way commercial digital signs. Existing display technologies are opening the opportunity to replace this passive single-purpose broadcasting with dynamic multipurpose interaction.

However, because empowering the public to control the display comes with new research challenges, the design focus is changing. With broadcast displays, the goal is to design for one-way information sharing. With interactive displays, the goal becomes designing for interaction—providing the best mechanism for average users to browse,

navigate, and identify information that the display makes available.

Display blindness (not noticing the display)[9] and interaction enticement[10] are well-known challenges for public displays, but interaction blindness is a relatively new obstacle. From interviews and diary studies of the use of technology in public spaces, we have seen that people in all population demographics do not interact with the hotspots because they simply do not know that they can. Some of our interviewees did not perceive the display as touchable, in large part because only a few large displays *are* touchable. Most common large displays, such as a TV or computer monitor require some additional mechanism such as a remote control or a mouse.

One way to overcome interaction blindness and entice interaction is make the interface more natural. *Proxemic interactions*—in which the display system interprets cues such as body position and adjusts the interface accordingly—are emerging as a potential paradigm for realizing natural interfaces. Several research efforts have produced proof-of-concept laboratory prototypes,[11] but our simple visual proxemic cue (the "Touch me!" animation) did not noticeably increase user interaction.

Our interview results also suggest that people are hesitant to use technology in public. Many interviewees said that they did not use the displays because they were afraid they might break them or compromise their operation. Some people believe that using the display could upset others in the vicinity, analogous to changing the TV settings in a crowded cafe where the fear of displeasing others inhibits a customer who might want to turn up the volume or change the channel. We are finding that people carry these entrenched inhibitions into their hotspot experience, creating a formidable interaction obstacle.

An important research direction, therefore, is to develop design and interaction patterns that both suggest and entice interaction with public displays. Placing a mouse and keyboard in front of a screen might encourage interaction because of their familiarity in computer use. Buttons and icons on a form or website also suggest that interaction is possible.

Changes in desktop computer design and interaction mechanisms, such as the mouse and screen windows, have enabled serendipitous interaction because of the public's familiarity with these paradigms. Similarly, the recent growth in touchscreen and tablet use means that the public is becoming more comfortable interacting through touch.

Although the research community has actively explored alternative and sometimes exotic interaction designs for public displays,[12] perhaps a more meaningful goal is to identify and develop equivalent standards, metaphors, affordances, and interaction patterns that make interactive public displays more accessible and familiar.

Transitioning to multipurpose displays

Moving from single-application displays to multipurpose hotspots creates new possibilities for display design. Although the line between single-purpose and multipurpose displays can be fuzzy, one distinction is the number of functions. Arguably, a display with multiple information types about a city is a single-purpose display because it has one function—to supply information. In contrast, a multipurpose display provides additional functions, such as browsing, games, galleries, and polls. Thus, functionality, not information type, defines the display.

The transition to multipurpose displays raises a host of new questions:

- What is the best way to present multiple applications to users?
- How can we exploit the competition among applications for user attention?
- How many applications should a display have?
- Should displays present one identical application grouping to all users, or should they adapt and customize their menu structure?
- Should users be able to install their own applications on the displays?

An important research direction is to develop design and interaction patterns that both suggest and entice interaction with public displays.

We anticipate answering these questions in our future work. For now, however, we are concentrating on the tradeoffs in multipurpose displays and their application ecosystems.

Inevitably, some applications will be more popular than others, either because of their design quality, the engagement they offer, the value users perceive, or some combination of these reasons. This inequality leads to some interesting tradeoffs that managers of interactive public displays must consider in selecting which applications to promote.

One tradeoff is whether to keep or remove unpopular applications. Although the quick-launch menu is an effective way to focus attention on a handful of applications, the dozens of applications not on the menu tend to suffer as a result. On the other hand, promoting interesting applications attracts more people to the display. Thus, promoting an unpopular application is likely to make it more popular but will make the display less interesting in general, while promoting popular applications will further erode the use of unpopular applications but will attract more people

to the display. This tradeoff is important to consider in making any decision about application retention.

Mobile interaction and authentication are also issues for multipurpose interactive displays. Despite extensive research on mobile interaction with public displays, we still lack a way to couple a public display with a broad range of personal mobile devices to form a distributed or hybrid interface that the general public would be comfortable using. Although we have experimented with a wide range of technologies for this purpose, such as Bluetooth and QR codes, we have not found a solution that would work well for most of the public, mainly because the mobile device market is so fragmented.

With authentication, a user logs into a public display to gain exclusive personal access, which in turn allows the user to personalize the interface or link to social networks, such as Facebook. Given that a public display has a publicly viewable interface, a question worth investigating is whether or not there is a need for the private use of public displays. If so, there must be an easy-to-use yet reliable authentication mechanism that the public will accept.

After three years of observing our hotspots, we believe that large public displays are not condemned to serve only as one-way digital signs. Rather, although more research is required to unlock the full potential of multipurpose interactive public displays, there are meaningful and sustainable use cases for these systems.

Our deployment has raised some interesting questions and opened creative design options that capitalize on the popularity of mobile technology. For example, we plan to explore how best to link personal mobile phones and wireless pads to interactive public displays.

The main asset of a large interactive public display is its much larger digital screen, so an important question is how to make the most of that feature as an interface to the urban landscape and its associated information space. Fortunately, we still have time to find answers, since our hotspots will remain operational until March 2017, if not longer.

Perhaps our most important finding is that many studies of large interactive public displays ignore the effects of issues such as curiosity and novelty, location, social context, and weather—effects that tend to show up only in long-term real-world deployments in multiple settings. Our results suggest that the limited user sampling characteristic of a laboratory or single-venue usability test might not provide enough information for researchers to use in extrapolating the true impact of such display systems on the user population at large.

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