Opportunistic Deployments: Challenges and Opportunities of Conducting Public Display Research at an Airport

Florian Alt and Julia Vehns
Media Informatics Group – LMU Munich
Amalienstrasse 17, 80333 München, Germany
Contact: florian.alt@ifi.lmu.de

Figure 1. Example of an Opportunistic Deployment: We deployed an interactive food station (left) at a major European Airport. The station allows passengers to purchase food packages through (a) a display directly at the station (left) or (b) by using one of seven tablets (right) distributed in the baggage claim area. After purchase, participants can pick up the food package from one of the station's compartments (middle).

ABSTRACT

In this paper, we report on the design, development, and deployment of an interactive shopping display at a major European airport. The ability to manufacture displays in arbitrary size and form factors as well as their networking capabilities allow public displays to be deployed in almost any location and target a huge variety of audiences. At the same time, this makes it difficult for researchers to gather generalizable insights on audience behavior. Rather, findings are often very specific to a particular deployment. We argue that in order to develop a comprehensive understanding of how successful interactive display installations can be created, researchers need to explore an as large variety of situations as possible. We contribute to this understanding by providing insights from a deployment in a security critical environment and involving multiple stakeholders where the audience is encountered in different situations (waiting, passing-by). Our insights are valuable for both researchers and practitioners, operating interactive display deployments.

Author Keywords

public displays, audience behavior, shopping, interaction, deployment-based research

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation: User Interfaces—*Input devices and strategies*;

PerDis'16, June 20 - 22, 2016, Oulu, Finland

ACM 978-1-4503-4366-4/16/06...$15.0
DOI: http://dx.doi.org/10.1145/2914920.2915020

INTRODUCTION

Today, interactive public displays can be manufactured in arbitrary size and form factors, hence allowing them to be deployed and studied in a large variety of locations and contexts, including deployments in shopping centers [25], public squares [2, 23, 30], libraries [2, 14, 23, 30], universities [16, 17, 18, 20, 40], super markets [14], retailers [28, 32], and cafes [33, 37]. This diversity poses a major challenge to display research, since generalizable insights are difficult to obtain. For example, a display application being successful in one location may be ignored by the audience in another location. Also for the same deployment, usage patterns and audiences may strongly differ. For example, a display may be encountered by school children in the morning, employees at lunch, commuters in the afternoon, and shoppers at night.

We argue that the only way to address this is by adding to the rich body of research on public displays, focussing on the peculiarities of a particular deployment on one side, as well as on similarities with other deployments on the other side. Thus, an enhanced understanding of deployment-dependent and deployment-independent aspects can be obtained.

In this paper, we report on the deployment of interactive displays in an airport environment. In particular, the display allows food packages to be purchased and picked up at a food station in the baggage claim area. At the focus of our research is the design and development process of the installation. We shed light on the interplay of the different stakeholders (the place owner, the display provider, the supplier, the consumers), report on how the design of the station was informed through market research, and provide insights on the development process. Our research is complemented by both a qualitative and quantitative evaluation of the deployment.

Findings from our research are interesting for researchers who plan to conduct work in a security-critical environment with many stakeholders involved. At the same time, our research is also valuable for display researchers in general, since the deployment allowed us insights to be obtained on a very diverse audience encountered in different situations.

INTRODUCTION TO DEPLOYMENT-BASED RESEARCH

At the outset of this research we provide an introduction to deployment-based research in general as well as to different forms of deployment-based research in particular.

Definition

Today, there is a lot of confusion – even within the research community – as to what deployment-based research is. Krüger et al. describe deployment-based research as follows:

> "Deployment-based research aims at gaining both technical insights as well as insight from users. This approach involves a cycle where theoretical issues and knowledge developed via reflection on empirical observations are used to design systems that are subsequently deployed to test and explore the theories in question. Such deployed systems then create new contexts in which to observe user behavior, thus leading to new insights, discoveries and a further refinement of the theoretical understanding." [21]

What is important to note is, firstly, that deployment-based research describes a form of study where an artefact is introduced into everyday life without users being made aware of this. This is in contrast to field studies, where investigations are conducted in a real environment, but users are aware of them being subject to an investigation. For a detailed description of different study paradigms we refer to the work of Alt et al. on the evaluation of public displays [5].

Furthermore, this description suggests a cycle where – based on the findings – the subject of investigation is iteratively refined and re-deployed. Such refinements can be rather subtle (for example, changing certain elements of a system's user interface) or be more fundamental (for example, changing the deployment location). A good example is Looking Glass [28] where the authors describe how their deployment was refined in multiple steps. Prior to the deployment in the shop windows of a retailer, the authors investigated passersby's attention towards each window. They found the shop windows to receive different amounts of attention due to a nearby traffic light. Subsequently the display was placed in a high-attention window. A few days into the study they noticed that their way of communicating interactivity created a landing effect, where people only noticed the interactive deployment as they had already passed it. While some people returned, many continued their way. To address this, the authors decided to place a second display in another shop window along the trajectory of users, which in turn led to additional interactions.

Deployment-based research may also eliminate the *novelty effect*, that is prevalent for other study paradigms (lab or field studies). Hence, findings from deployment-based research are usually of very high ecologic validity.

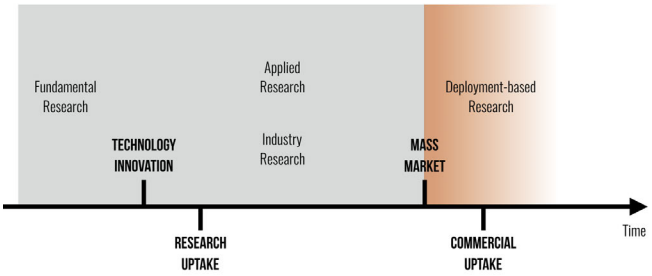


Figure 2. Opportunities for deployment-based research: As technologies become available for the mass market, deployment-based research becomes feasible. Wide commercial uptake further supports this, enabling opportunistic deployments.

Finally, there are research questions that can only be investigated using deployment-based research, since only here users are not aware of the subject under investigation. This includes, among others, studying attention towards displays, audience behavior, social impact, as well as privacy concerns.

Note, that 'deployment-based research' is not equivalent to 'research in-the-wild' [10]. In our view, 'deployment-based research' is just one possible form of conducting research in-the-wild among others, as is field studies.

When to Conduct Deployment-based Research

In contrast to much of the research we see being conducted in HCI, deployment-based research depends on technology being available to the mass market. As can be seen from Figure 2, fundamental research leads to *technology innovation* first (an example is the invention of eye trackers in the early 20th century[1]). At some point, *research* may *take up* on this technology and further explore it in the laboratory, leading to what is commonly referred to as applied research and industry research. For example, the 1970s witnessed a lot of applied research on eye tracking in the scientific community [19]. At the same time, eye tracking was applied in industry, for example in the context of marketing research. It was then in the 2010s that eye tracking started to enter the mass market, driven by startups, such as Eye Tribe[2] or Pupil Labs[3] who started producing eye trackers for a consumer *mass market*. At the same time, also established eye tracking companies started to sell low cost versions of their tracking hardware for a wide audience (for example, the Tobii EyeX[4]). In a next step, as a result of *commercial uptake*, eye trackers may find their way into laptops, cars, and TVs. As a result a lot of deployment-based research can be expected to happen in this area in the years to come.

A similar development could be observed for large displays. As a result of falling prices in the 2000s due to the emergence of a mass market, not only large outdoor advertisers could afford the deployment of large screens, but also malls, airports, libraries, municipalities, and retailers started to deploy their own displays or built up entire display networks.

[1]Eye Tracking History: `http://eyesee-research.com/news/eye-ttacking-through-history/`
[2]EyeTribe: `https://theeyetribe.com`
[3]Pupil Labs: `https://pupil-labs.com`
[4]Tobii EyeX: `http://www.tobii.com/xperience/`

Research-driven vs. Opportunistic Deployments

Today, there seems to be a continuum spanning from research-driven to opportunistic deployments. While, in general, the former is a result of researchers trying to answer a particular research question in the first place, the latter is usually the result of commercial interest. For example, a shopping mall may decide to deploy a display network with the aim to better advertise products to customers or provide interactive store finders. As researchers get access to such deployments, interesting opportunities arise. In the following we describe the characteristics of both types of deployments.

Characteristics of Research-Driven Deployments

As researchers set out to answer a particular research question, a first step is to *find an appropriate location* for the deployment. This usually creates a need to *identify the responsible stakeholders*, most importantly the owner of a place. Much of the research-driven deployments in recent years where conducted on University premises (close to cafeterias [18, 26, 40], in front of lecture halls [41], or in the entrance area of university buildings [1]). Since there is often no (strong) commercial interests involved, stakeholders (University administration, cafeteria tenants, etc.) are in general open to such deployments, since they create little effort on their side but are expected to increase the value of a place.

At the same time, there may be a need to *deal with ethics and privacy* [22]. For example, if a display is deployed in the entrance area of a building and a camera is used to enable interaction, it is in general possible to find find out when employees (professors, research associates, janitors, etc.) come to or leave from work. In such cases it usually needs to be ensured that no data is stored or that it is being anonymized (for example, recording a depth video only).

A particular challenge in research-driven deployments is that often there is *little knowledge about the audience and their behavior*. This creates a need for researchers to first observe the place, for example to identify trajectories, times were a location is well frequented and who the audience is [28].

Finally, as the deployment is in place, there is usually a *high effort in terms of maintenance* since researchers are self-responsible to keep the deployment running and to check for problems. This includes, for example, making sure that the software is running robustly and researchers need to think about how to access log data [24]. Furthermore, researchers may struggle with issues such as people unplugging the display, detaching sensors, or even vandalism.

Characteristics of Opportunistic Deployments

In opportunistic deployments, the owners of spaces or displays (for example, airports, shopping malls, retail stores, libraries, etc.) may provide researchers access to their infrastructure. A major advantage is the *high degree of realism* in such deployments due to a very diverse audience that considers the deployment as permanent part of the environment. As a result, such deployment often lead to insights with very high ecologic validity. Unlike in university settings, where a deployment may still be considered a research project and where people are in general very curious, in opportunistic setting, people may not approach the display at all if it fails to provide a sufficiently large benefit.

At the same time there are also challenges. There is often a *commercial interest* (for example, using wayfinding signage to replace information desks, drawing people's interest towards a shop, making sure people find a particular retailer in a large mall, etc.) and there are usually *many stakeholders* involved whose interests need to be considered [3]. Furthermore, there may be strong *requirements with regard to the application / content*. This may include the need to adhere to a corporate identity as well as application developers being constrained to certain platforms and programming languages. Finally, researchers need to come up with suitable *hypotheses* that can be assessed given the constraints of the deployment.

Note, that this classification into opportunistic and research-driven deployments is rather a continuum. There are examples of deployments that, despite being very opportunistic, still allowed for a strong research focus.

BACKGROUND AND RELATED WORK

Since large screens became commercially available, a lot of deployment-based research on public displays has been conducted. Table 1 summarizes examples from the past 15 years.

In the early 2000s, deployments were mainly conducted in office spaces and research labs, due to the fact that display hardware was still expensive and not ready for use outside the lab [15]. At the focus of research were door displays as well as displays that aimed to increase workplace awareness and the sense of community in workplaces. Popular examples were the Hermes Door displays [11] at Lancaster University or the Plasma Poster Network [12].

In the mid 2000s, display research finally left lab spaces and the research focus shifted towards promoting social interaction and supporting communities. An example was AwareMedia, a public display deployed in a hospital setting with the goal to support a highly cooperative workflow [6]. Another example, the Opinionizer system, allowed people to publicly share views and opinions and allowed others to observe and comment on them [9].

Finally, in the late 2000s, long-lived deployments emerged, both on research campuses (for example the eCampus system [35]) as well as in city centers (for example the UbiOulu network [30]). Those networks allowed a myriad of different applications to be deployed and tested. Of particular interest is the UbiChallenge, a research contest organized by the University of Oulu that allows researchers from all over the world to deploy and test their display applications [29].

Apart, researchers conducted shorter deployments (1-4 weeks), mainly in University setting, with the goal to better understand user behavior. In particular, a lot of research was conducted on gesture-based interaction, looking for example at how interactivity can be conveyed [28], how gestures can be communicated [40], and how gestures can be used to create engaging applications that make users actively participate in urban polling [39].

Project Name	Location	Description
Plasma Poster Network [12]	Office space (corridor, foyer, kitchen)	Investigated content sharing between colleagues with the aim to increase social interaction
Hermes Photo Display [11]	Office space	Investigated interaction with public displays using mobile phones
AwareMedia [6]	Hospital	Supported people in coordinating highly cooperative work in a critical setting
Opinionizer [9]	Book Launch Party / Welcome Party	Allowed people to share their views and opinions in a way such that others could observe and comment on them
CityWall [31]	Shop window in a city center	Looked at how people collaboratively interact with a large multi-touch display, focusing on teamwork, negotiation of handovers, and conflict management
Wray Photo Display [37]	Village shop, community center, cafe	Investigated how a public display can support a village community
Nnub [32]	General store	Investigated how a public display can support local place-based community communications
MobiDiC [27]	Signage integrated with phone booths in a city center	Investigated a prototype that allowed content to be tailored to the display context as well as to track people as they retrieved coupons from the display and redeemed them in local stores
Digifieds [2]	Public Square and Library	Investigated how people use a digital public notice area in the wild, comparing different interaction techniques for content retrieval
FunSquare [23]	Public Square and Library	introduced the concept of autopoiesic content and investigates social behavior of passersby
Looking Glass [28]	Retail store	Investigated how interactivity of an interactive display can be conveyed to the audience
Chained Displays [38]	University cafeteria	Investigation of how different display configurations impact on audience behavior
Strike-A-Pose [40]	Entrance area of a University cafeteria	Compared different ways of embedding gestural cues into an interactive game
Moment Machine [24]	Two Shop Windows	Investigated how posting situated snapshots on public displays impact on communities
Squaring the Circle [8]	University building	Investigated how frames on a display impacts on how people position themselves while interacting
Gaze Horizon [41]	University building	First in-the-wild investigation of a public display employing gaze interaction
Communiplay [26]	University cafeteria	Investigated audience behavior as displays enable interaction across multiple displays in a network, showing a representation of remote players
UniDisplay [4, 18]	University building, cateferia	Investigated the influence of delays through content moderation on displays that support user-generated content
MyPosition [39]	Cultural event center, University cafeteria	Investigated how an engaging public display can effectively engage passersby to participate in public discussions
Puppeteer Display [7]	Street-facing window of a University building	Investigated ways of guiding multiple users interacting with a wide public display
GravitySpot [1]	Entrance area of a University building	Investigated how visual cues on a display can be used to guide people to a sweet spot in front of the display
AR See-Through Displays [14]	Supermarket & Public Library	Introduced a public augmented see-through reality display and compared different visualizations with regard to attention

Table 1. Examples of deployment-based research within the pervasive display community. The vast majority of research has been conducted in university settings or urban public spaces. At the same time, little research focused on specific environments (train stations, airports, etc.).

What is striking, though, is that – with the exception of public squares and libraries – only few projects investigated areas, such as shopping malls, train and bus stations [34], as well as airports [13, 36]. We believe such environments to see a lot of interactive display deployments in the future. At the same time, little knowledge exists about the challenges and opportunities offered by such spaces. We believe a reason for this to be that it is usually difficult for researchers to get access to such environments.

This paper contributes to close this gap by presenting a case study on a deployment at a major European airport. We report on the requirements analysis, implementation, deployment, and evaluation of an interactive food station. This deployment allowed us valuable insights to be gathered that we hope to be useful for researchers as well as practitioners who seek to deploy interactive displays in similar environments.

EMMASBOX – AN INTERACTIVE FOOD STATION

Having experience with public display deployments for many years, we were approached by a company who manufactures food stations. These cooled and automated delivery stations allow customers to purchase food product through an online store which are then delivered to the stations through a supermarket. Seeking for future markets, the company initiated a collaboration with the Airport of Munich (Germany) with the goal of deploying a food station, allowing passengers to make purchases as they arrived at the airport. The idea was motivated by the assumptions that people coming back from medium to long-term trips might be interested in immediate food consumption or stocking up their fridge.

What is important to know in this context is that the state of Bavaria enforces a strict store hour law that forbids any sales activity after 8pm and on Sundays.

Requirements Analysis

At the outset of the project, a requirements analysis was conducted through the Airport of Munich with the goal to investigate the potential of sales in the baggage claim area through an interactive food station. To this end, 520 people were recruited in the arrival area of the airport to fill in a survey assessing their interest in a 'virtual supermarket'. In particular, people were asked for gender, their purpose of travel, their willingness to make purchase while they waited for of after they collected their luggage, which articles they would be interested in, and how much money they would spend.

Overall, 520 people participated in the survey (227 female, 293 male). Out of all participants, 65% traveled for private reasons and 35% were business travellers.

According to the answers, 54% of passengers would be interested in making purchases while waiting for their luggage. The vast majority (56%) was interested in food, while other products included drugstore items (12%), printmedia (10%), and cosmetic products (8%) (Figure 3). To spend the waiting time for the luggage usefully, the persons indicated that they would like to purchase main courses costing up to € 10.

Based on the results, the decision was made to offer food packages in the baggage claim area. Note that for logistic reasons, the purchase of customer-defined packages (as offered for the publicly deployed food stations) was not feasible.

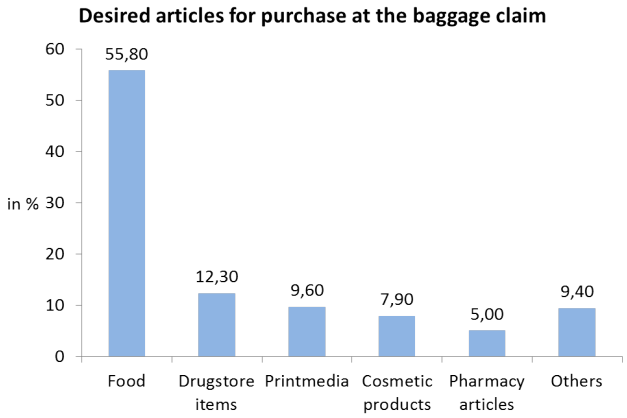


Figure 3. Survey results: Passengers were mainly interested in the purchase of food as they arrived at the baggage claim area.

Stakeholders

Different stakeholders were involved in the deployment. In the following we briefly describe their responsibilities, needs, and the interplay between the stakeholders.

Place Owner Being the owner of the place, the main motivation of the Munich Airport GmbH was to make travelling more comfortable for the passengers (seamless travel). Their responsibility included making the final decision with regard to the location of the deployment.

Station and Software Provider The manufacturer of the station and provider of the software was the open ideas GmbH. Their responsibility was to provide the hardware and to develop the software needed to run the installation. This included the backend, user interface and means to enable payment at the station.

Supplier The station was supplied by a large German supermarket chain that operates two supermarkets at the airport. Their responsibility also included the selection of the food packages offered at the station.

Passengers The passengers arriving at the baggage claim are the potential customers of the food station. On average, 44.000 pass the baggage claim area daily. Given the results of the survey, the potential number of customers amounts to 4.8 million people per year.

Other Stakeholders Further stakeholders playing a role during the project include customs and store owners (particularly those located close to the exit of the baggage claim).

In addition to the aforementioned stakeholders, two researchers with expertise in interactive public displays were involved in the project. They took the role of consultants and passive observers who joined several meetings between the other stakeholders and provided advice on various aspects of the deployment.

Display Location

The next step was to decide on the location of the station. This turned out to be a major challenge due to the needs and interests of the different stakeholders.

At the beginning of the discussion, the idea was to place the station close to the exit of the baggage claim where all passengers need to pass by as they collect their luggage and leave the area. However, this turned out to be not feasible since customs is required to have a clear view of the area and passengers approaching the exit. As an alternative, the opportunity of deploying the station in front of the exit of the baggage claim area was considered. The challenge here was, that due to its size, the station would have occluded the view of passengers towards the stores located just outside the exit. This may have had a negative influence on the number of customers of these stores. In addition, it was not clear, whether people would have still been motivated to approach the station at this point, given that they would have already been on their way to public transport or their car. Finally, since the station was too large to fit in between the baggage carousels, the decision was made to deploy it close to the stairway from which passengers entered the area. To additionally approach passengers directly at the baggage carousels, an idea was to place six tablets in the baggage claim area that would allow passengers to browse the available food packages as well as to make reservations for later pickup at the station while they waited for their luggage. The final deployment location of the station and tablets is depicted in Figure 8.

IMPLEMENTATION

Next, we describe the technical implementation. To clarify the interaction process, we first introduce a short purchase scenario. Afterwards, we describe the system architecture as well as the different components of the system.

Purchase Scenarios

Purchase of food packages is possible directly at the station. Therefore, the customer walks up to the station which is equipped with a public display. Using the touchscreen monitor, the customer can browse 7 different food packages. As the customer made the decision for a particular package and placed it in the shopping cart it is possible to proceed to the checkout. The customer pays the food package(s) through a payment terminal. After that, the customer can pickup his food package from one of the station's 63 compartments.

In an alternative scenario, a customer approaches one of the tablets at the baggage claim and browses the available food packages using the same interface as at the station. Again, packages can be stored in a shopping cart. Instead of the checkout, customers using the tablet are provided a reservation code and the food package is reserved at the station for a duration of 30 minutes. The customer may then proceed to the station and enter the reservation code. The food package is loaded into the shopping cart of the station and the interface continues to checkout. Then, the customer can, similar to the first scenario, make the purchase through the payment temrinal and pickup the package.

System Architecture

Figure 4 depicts the system architecture and its different components. The *food station* consists of a local database, containing information on the compartments of the station as well

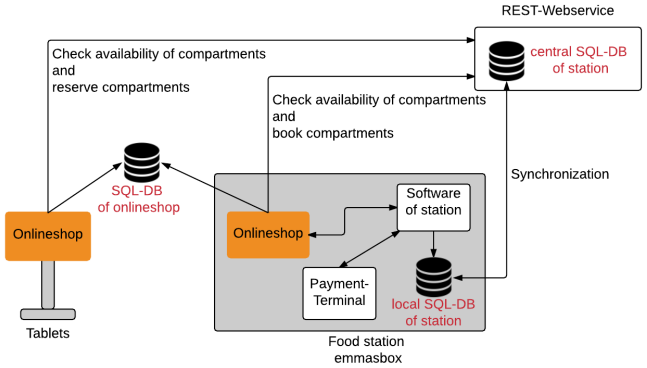
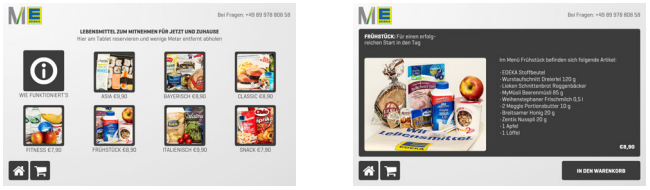


Figure 4. System Architecture: A central database connects the station and the tablets. Both station and tablets employ a so-called online shop, allowing customers to browse and select available food packages. Communication is realized through a REST web service.



(a) (b)

Figure 5. Overview and detailed view of a offered food package, as presented on the station and tablets.

as on the purchase and interaction history. The station software is responsible for controlling the compartments. It is connected (a) to the payment terminal as well as (b) to the user interface that allows the food packages to be browsed and put into the shopping cart (referred to as 'online shop' in Figure 4). The same online shop is running on the *tablets*, the only difference being the reservation feature. The tablet is connected to a SQL database storing interaction data. A *central station database* complements the architecture. The database syncs with all food stations (in our case there is only one food station) and contains all available content. Both the online shop on the station as well as the tablets query this database to check whether a particular food package is available and to make a reservation of the respective compartment.

The local database of the station is synchronized with the help of a REST web service. This makes it possible for the online shop to request, for instance, occupied compartments.

System Components

In the following we provide additional details on the different system components.

online shop

The online shop is the main contact point for customers. It shows an overview of the offered food packages and a detailed view of their contents (see Figures 5a and 5b).

The user interface was built for both, the station and the tablets, but, as previously mentioned, with slightly different functions. The customer could select an arbitrary number of packages – given that the packages are still available – and

(a) (b)

Figure 6. Video clip: To attract the attention of passersby and communicate the purpose of the tablets, we created a short video clip. It focused on communicating the concept of the food station as well as the required steps to make a reservation and pick up the package at the station.

put them into a shopping basket view. Whether a package is available is checked through a request to the REST web service. The web service responds with a list of occupied compartments of the station and the online shop looks up which food packages are stored in these compartments in its own database. Customers at the tablets can reserve the packages afterwards upon availability. Customers who are directly at the station are redirected to the pickup user interface of the station software.

Payment Terminal

With the help of an interface from the station to a payment terminal users are able to pay selected menus with EC or credit card directly at the station.

Station Compartments

Following payment, the station opens the compartment(s) with the bought package(s). Due to the modular construction, the station software is able to communicate with all components. In addition, the station is responsible for controlling the temperature and the mechanism for opening and closing the compartments. A local database is used for saving the occupancy of the compartments.

Video Clip

To attract the passersby's attention, raise curiosity, and communicate the purpose of the tablets, a short video clip was produced and deployed as a screensaver at the tablets. The video shows an aircraft landing, passengers getting off and waiting at the baggage claim for their luggage (see Figure 6a). Then, a passenger notices the tablet standing next to the baggage carousel, gets curious and interacts with the display. In the following scene it is shown how to select and reserve a food package in the online shop (see Figure 6b). After the person picked up his luggage, he proceeds to the food station, pays the already reserved food package and the compartment of the station opens.

The video is constantly shown on the tablet. Touching the tablet interrupts the video and the customer sees the home screen of the online shop. In case of no activity for more than 60 seconds, the screensaver automatically starts again. To make the customers understand that they are able to interrupt the video at anytime, the video constantly shows two buttons. To invite interaction, one button is labeled "Select your food package now", while the other button shows the home icon.

Figure 7. Entrance to the baggage claim area. As passengers come down the stairs, the food station is located to their left. However, passengers usually make their way to the right baggage claim first. Only as they are waiting for their luggage they become interested in airport services, such as the food station.

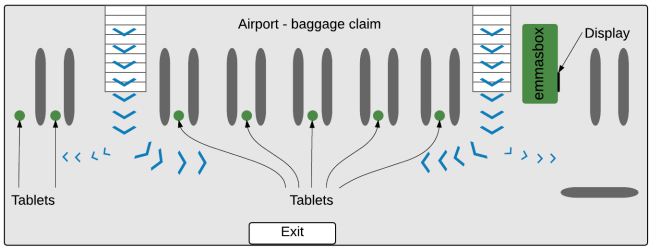


Figure 8. Map of baggage claim area with passenger trajectories. Passengers enter the area via stairs before making their way to the baggage claim area. After luggage pickup, passengers directly make for the exit of the area.

DEPLOYMENT

After the development of the software, both the station and the tablets were deployed in the baggage claim area.

As we previously mentioned, the station was installed next to the stairs at the entrance of the baggage claim area. Passengers passing by could see the back side of the food station (cf. Figure 7).

Seven tablets were spread around in the baggage claim area with the aim to further increase awareness of the presence of the station. The tablets were located near the baggage carousels where the passengers were met while waiting for their luggage. A map of the baggage claim area and the passenger trajectories can be seen in Figure 8.

Our installation was available to the passengers for six month. Research, including logging, interviews and observations, were conducted in a period of four weeks (24.08.2015 – 13.09.2015 and 17.09.2015 – 24.09.2015). The observations and interviews took place on four selected days. This was a results of the limited access to the baggage claim area because of the security critical environment. The interviews were semi-structured in order to gather new insights in the perception and usage of public displays.

All user interactions at the station and at the seven tablets were logged and stored in a local database.

It is worth to note that the tablets had no open power sockets and thus had to be regularly recharged by the airport staff. As a consequence, tablets were occasionally running out of battery and hence did not run during the whole deployment. In contrast the station was available 24/7.

RESULTS

In the following we provide a brief summary of findings from the deployment, including both qualitative and quantitative results. From a research perspective, we were mainly interested to (1) find out how many people interacted with station and tablet, (2) see whether the second screens (the tablets) could serve as an attractor to the main display (station), and (3) to understand people's behavior and identify behavior patterns in the waiting situation around the baggage carousel,.

Data Recording and Analysis

We collected interaction logs during 28 days of deployment. Every touch event was recorded and timestamped. While the station was available 24 hours per day and 7 days per week, tablets were active on average for 14 days.

To obtain an estimate on the number of people who used both stations of tablets as well as their interaction times, we grouped all clicks with less than 60 seconds in between, assuming that after 60 seconds of inactivity, a new user started to interact. For each group, we then calculated the time difference between the first and last click.

Qualitative data were gathered during four sessions on four different days while the deployment was active. In the first session we exclusively focused on the station. During the other sessions, we focused on the tablets and their vicinity. We conducted observations and ran semi-structured interviews with passengers who (a) did not notice the display, (b) noticed the display and (c) interacted with the display.

Quantitative Findings

As pointed out before, on average 44.000 passengers pass through the baggage claim area every day.

The *station* was active for 672h and a total of 1397 persons interacted during that time. This amounts to about 50 passengers per day. People interacted on average for 24 seconds and made 4 clicks. The number of interactions varied between the weekdays. We saw peaks on the weekend, confirming our assumption that most people would be interested in the service on days where shops were likely to be closed. This is also reflected by the distribution of menus sold. From 53 menus, 22 were sold on Saturdays and Sundays.

The *tablets* were active for 1535h and in total 899 passengers interacted. The average interaction duration was 69 seconds. 103 reservations were made, but none of them was picked up.

Qualitative Findings

From our observations we found that many people did not notice the station and tablets as they entered the baggage claim area. We believe this to be a result of people being very focused on finding their baggage carousel in the first place.

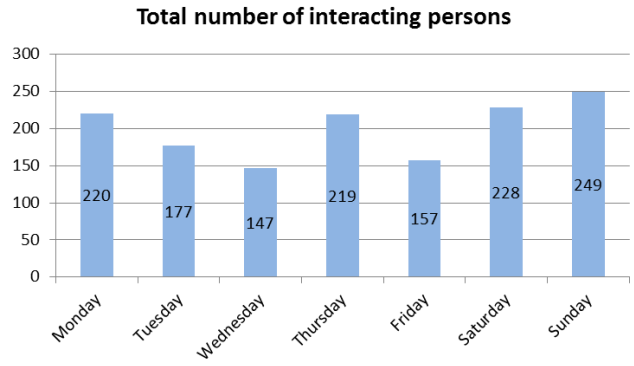


Figure 9. Number of passengers interacting: most interaction occurred on the weekend as shops outside the airport were more likely closed.

Once people arrived at the correct carousel, they were more likely to approach the tablets, in particular if baggage delivery was delayed. While this partially confirmed our assumption that people could be easily targeted in a waiting situation, there was also a significant number of people whose focus remained on the baggage carousel as they waited. From this we learn that it would be crucial to direct people's attention away from the baggage carousel, for example through another display or signage positioned on the belt. While additional signage was located on the carousel, it could not be used for this purpose since it was rent out exclusively to an advertiser.

In addition, we observed a strong honeypot effect, i.e., as people started interacting with the tablet, this also raised the curiosity of other travellers, many of which eventually approached the tablet as other passengers left.

Interestingly, we observed some occasions where no interactions occurred any more as the space around the carousel filled with people. Such a situation is depicted in Figure 10. A reason for this might have been people being afraid of others picking up their luggage once delivery started and they hence stayed focused on the carousel. Or they may have been afraid of social embarrassment in case they started interacting with the tablet and being exposed to onlookers.

We found that once the baggage carousel started moving – independent of whether or not luggage was delivered – the tablets received no attention at all any more. This suggest that in order to maximize the opportunity for interaction, conveyor belts should only be turned on shortly before delivery.

Of those people who started interacting with the tablet, we found the majority to browse through the menus and occasionally put them into the shopping cart. There were instances where people repeatedly clicked the home button. We believe they tried restarting the video, which was not possible but happened automatically after 60 seconds of idle time.

With regard to the packages we found that only few were popular among passengers. Interviews revealed that food that could be instantly consumed was among the favorites among customers. Furthermore, the most popular food package was the only one to contain something to drink.

Figure 10. The tablets received little attention once the baggage carousel started moving. Also, many people in the vicinity seemed to prevent people from approaching the tablet and starting to interact.

Finally, no passenger who made a reservation picked it up at the station. Interviews revealed that in many cases it was not clear where to pick up the package. While some passengers thought the pickup location to be the supermarket outside the baggage claim area, others were not able to determine the location of the station. Though we do not have any evidence for this, we believe that also many people considered the effort to pickup the package after collecting their luggage to be too high or they may have even forgotten about the reservation by the time they had their luggage.

Post-Deployment Activity

Clearly, the deployment was unsuccessful from a commercial perspective with very low interaction numbers and purchases being made. This was partially a result of the constraints imposed by the need to cater to the needs of the different stakeholders. Over the duration of the deployment, observations and interview led to a better understanding of shortcomings in the deployment. As a result, we developed ideas and strategies as to how the deployment could be improved. Many of them took a significant time to implement, yet led to significant improvements, i.e. an increase in the number of interactions and packages sold.

Firstly, food packages were reconfigured so as to contain drinks and instantly consumable food. This took significant time to realize, since new high-quality images of the packages needed to be produced and the description of packages shown in the onlineshop needed to be changed.

Secondly, additional analog signage in the form of arrows on the floor pointing towards the station were added in the tablet vicinity. Again, this included a tedious process of producing the signage, obtaining permission for deployment (mainly due to fire protection requirements), and installing it.

Thirdly, the location description of the station on the tablets was improved through more concise text and an enhanced map of the area.

LESSONS LEARNED AND RECOMMENDATIONS

We summarize learnings from the deployment. While some of them are unique to the environment, many of them are generally applicable in deployment-based research.

Importance of Location and Required Effort

From previous deployments it is well known that the location of a display plays a crucial role when it comes to interaction [28]. In particular in areas where waiting times occur (for example, in coffee kitchens, at bus stops, etc.) passersby are likely to interact. While this was clearly the case while people waited for their luggage, we did not expect that while waiting for luggage, people would not at all move away from the location of the baggage carousel. Furthermore, as soon as people received their luggage, their aim was to reach the exit as soon as possible. In this situation, the effort for making a detour to pick up the food package seemed to outweigh the expected benefit.

Keeping the effort for users as low as possible is crucial for the success of any deployment. We learned that while using tablets is suitable to increase the awareness of people (for example, on the existence of a particular service), they may not be suitable to convince people to take a detour in order to benefit from the service. Hence, ways need to identified as to how the motivation of people can be increased, for example through discounts based on the distance or by allowing people to make instant purchases (i.e., payment directly at the tablet).

Engagement With Stakeholders and Value Proposition

Another major challenge in the deployment was catering to the needs of many different stakeholders and their commercial interests. In contrast to deployments at universities and in urban areas where the deployment of a display is usually considered as an added value, stakeholders at the airport seemed to be afraid of additional signage attracting away the attention of passersby. Clearly our deployment could have benefited from a different location. To compensate for a decrease of attention towards other stakeholders, the food packages could have contained coupons to be redeemed in nearby stores.

Researchers need to, early in the deployment, identify the needs of different stakeholders. In case of conflicting goals, which are, however, mission critical, ways need to be identified how other stakeholders can be compensated and synergies be utilized.

Getting the Content Right

In most research-driven deployments, content plays a secondary role. There, the primary aim of content is to attract people in the first place, for example through an interactive game. Moreover, in research-driven deployments it is often not even desired to maximize interaction times with the display, since the goal might be to throughput as many users as possible. In opportunistic deployments with stakeholders having a commercial interest, however, content is crucial and needs to ultimately generate revenue. At the same time identifying the right content may be challenging. For example, in the case of this deployment, no prior knowledge existed as to how the composition of the food packages should look like. Hence, the only opportunity is to modify the content until it is of sufficient attractiveness to customers. An interview with an operator of another vending machine selling electronics revealed similar challenges. Indeed it took them about 24 months to select the best selling content for the station.

From a research perspective, the solution to getting the content right is quick iterations. Therefore, the software should be prepared for this, for example, by allowing parts of the content to be exchanged quickly and easily – possibly without requiring programming knowledge.

Concise and Easy-to-Understand Information

Conveying information to the passengers was a major challenge. Despite being in a waiting situation, people seemed to have allocated a lot of their attention towards the baggage carousel, leading to that they did not carefully read the instructions on the tablet. This may be similar in other situations, for example people constantly observing the real-time departure information while waiting for a bus. While using the video we managed to clearly convey the purpose of the display, people missed information on where to pickup the packages. These information were shown in the form of a map and a text description. Other promising solutions could be to show analog signage in the display vicinity to guide the user's way. This however requires that people can easily relate the off-display signage to the content on the display.

From this we learn that information needs to be presented concisely and that it needs to be easy to understand. Longer text descriptions are easily missed, since people may not direct their full attention towards the display in 'split-attention' situations (as was the case at the carousel). Hints could consist of few words and additional hints in the environment could further support people. However, such hints may need to be easy to relate to the display, for example, through an appropriate color coding or images (in our cases of a food package).

Few Iterations

During the deployment, a lot of improvements were identified. Due to the limited access to the area and the need to involve different stakeholders it took not only significant time to implement the improvements but also all of them were deployed almost simultaneously. From a research perspective this is problematic, because it is not possible to trace down what in fact solved an issue. For example, the fact that after the improvements, sales numbers increased could not easily be attributed to improvements of the package content or an enhanced description of the location of the food station.

Need for Flexibility

The overarching challenge we faced during the deployment was the lack of flexibility due to (a) the security-critical environment and (b) the large number of stakeholders and their conflicting goals. This made both initial decisions as well as later changes cumbersome. In general, it is advisable to a-priori try and understand as much about the intended location of the deployment and the behaviour of users as possible – for example through observations. At the same time,

deployments usually change the nature of a place leading to unforeseeable changes in user behavior – or it is simply not possible to predict how people will behave. As a result, researchers need to be prepared to continuously observe the environments, its users, and their behavior. They should try to ensure a high degree of flexibility with the deployment and design for changes and short iteration cycles.

CONCLUSION

In this paper we provided an introduction to deployment-based research. To support researchers in preparing and conducting deployments, we provided a list of deployments that have been conducted in the area of pervasive displays over the past decades. We then reported on the opportunistic deployment of an interactive food station in an airport environment. Evaluation of the deployment over several weeks yielded interesting insights, allowed us to identify challenges, but also revealed opportunities.

Clearly, researchers need to carefully think about whether or not to take the effort required for participating or conducting work in the context of an opportunistic deployment. As has been stressed before, the strength is findings of very high ecologic validity that cannot be obtained otherwise. We hope the lessons learned from the presented deployment to be useful for other researchers as well as practitioners who plan to do deployments in the same or similar settings.

ACKNOWLEDGEMENTS

We would like to thank Rüdiger Weimer, Michael Reichelt, and Oliver Latka from the open ideas GmbH for the opportunity to participate in this project. Furthermore, we thank the staff of Airport of Munich for their support during conducting on-site observations.

REFERENCES

1. Florian Alt, Andreas Bulling, Gino Gravanis, and Daniel Buschek. 2015. GravitySpot: Guiding Users in Front of Public Displays Using On-Screen Visual Cues. In *Proceedings of the 28th ACM Symposium on User Interface Software and Technology* (2015) *(UIST '15)*. ACM, New York, NY, USA.

2. Florian Alt, Thomas Kubitza, Dominik Bial, Firas Zaidan, Markus Ortel, Björn Zurmaar, Tim Lewen, Alireza Sahami Shirazi, and Albrecht Schmidt. 2011a. Digifieds: Insights into Deploying Digital Public Notice Areas in the Wild. In *Proceedings of the 10th International Conference on Mobile and Ubiquitous Multimedia (MUM'11)*. ACM, New York, NY, USA, 165–174.

3. Florian Alt, Nemanja Memarovic, Ivan Elhart, Dominik Bial, Albrecht Schmidt, Marc Langheinrich, Gunnar Harboe, Elaine Huang, and Marcello P. Scipioni. 2011b. Designing Shared Public Display Networks – Implications from Today's Paper-Based Notice Areas. In *Proceedings of the 9th International Conference on Pervasive Computing (Pervasive'11)*. Springer Berlin Heidelberg, Berlin, Heidelberg, 258–275.

4. Florian Alt, Nemanja Memarovic, Miriam Greis, and Niels Henze. 2014. UniDisplay - A Research Prototype to Investigate Expectations Towards Public Display Applications. In *Proceedings of the 1st Workshop on Developing Applications for Pervasive Display Networks (PD-Apps '14)*. IEEE, Budapest, Hungary.

5. Florian Alt, Stefan Schneegaß, Albrecht Schmidt, Jörg Müller, and Nemanja Memarovic. 2012. How to Evaluate Public Displays. In *Proceedings of the 2012 International Symposium on Pervasive Displays (PerDis'12)*. ACM, New York, NY, USA, 171–176.

6. Jakob E. Bardram, Thomas R. Hansen, and Mads Soegaard. 2006. AwareMedia: A Shared Interactive Display Supporting Social, Temporal, and Spatial Awareness in Surgery. In *Proceedings of the 2006 20th Anniversary Conference on Computer Supported Cooperative Work (CSCW '06)*. ACM, New York, NY, USA, 109–118.

7. Gilbert Beyer, Vincent Binder, Nina Jäger, and Andreas Butz. 2014. The Puppeteer Display: Attracting and Actively Shaping the Audience with an Interactive Public Banner Display. In *Proceedings of the 2014 Conference on Designing Interactive Systems (DIS '14)*. ACM, New York, NY, USA, 935–944.

8. Gilbert Beyer, Florian Köttner, Manuel Schiewe, Ivo Haulsen, and Andreas Butz. 2013. Squaring the Circle: How Framing Influences User Behavior Around a Seamless Cylindrical Display. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13)*. ACM, New York, NY, USA, 1729–1738.

9. Harry Brignull and Yvonne Rogers. 2003. Enticing people to interact with large public displays in public spaces. In *Proceedings of the IFIP TC13 International Conference on Human-Computer Interaction (INTERACT '03)*. Springer, Berlin-Heidelberg, 17–24.

10. Alan Chamberlain, Andy Crabtree, Tom Rodden, Matt Jones, and Yvonne Rogers. 2012. Research in the Wild: Understanding 'in the Wild' Approaches to Design and Development. In *Proceedings of the Designing Interactive Systems Conference (DIS '12)*. ACM, New York, NY, USA, 795–796.

11. Keith Cheverst, Alan Dix, Daniel Fitton, Chris Kray, Mark Rouncefield, Corina Sas, George Saslis-Lagoudakis, and Jennifer G. Sheridan. 2005. Exploring Bluetooth Based Mobile Phone Interaction with the Hermes Photo Display. In *Proceedings of the 7th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI '05)*. ACM, New York, NY, USA, 47–54.

12. Elizabeth F. Churchill, Les Nelson, and Laurent Denoue. 2003. *Communities and Technologies*. Kluwer, B.V., Deventer, The Netherlands, The Netherlands, Chapter Multimedia Fliers: Information Sharing with Digital Community Bulletin Boards, 97–117.

13. Luigina Ciolfi, Mikael Fernström, Liam J Bannon, Parag Deshpande, Paul Gallagher, Colm McGettrick, Nicola Quinn, and Stephen Shirley. 2007. The shannon portal installation: Interaction design for public places. *Computer* 7 (2007), 64–71.

14. Ashley Colley, Leena Ventä-Olkkonen, Jonna Häkkilä, and Florian Alt. 2015. Insights from Deploying See-Through Augmented Reality Signage in the Wild. In *Proceedings of the 4th ACM International Symposium on Pervasive Displays (PerDis '15)*. ACM, New York, NY, USA.

15. Nigel Davies, Sarah Clinch, and Florian Alt. 2014. Pervasive displays: understanding the future of digital signage. *Synthesis Lectures on Mobile and Pervasive Computing* 8, 1 (2014), 1–128.

16. Nigel Davies, Adrian Friday, Peter Newman, Sarah Rutlidge, and Oliver Storz. 2009. Using Bluetooth Device Names to Support Interaction in Smart Environments. In *Proceedings of the 7th International Conference on Mobile Systems, Applications, and Services (MobiSys '09)*. ACM, New York, NY, USA, 151–164.

17. Nigel Davies, Marc Langheinrich, Sarah Clinch, Ivan Elhart, Adrian Friday, Thomas Kubitza, and Bholanathsingh Surajbali. 2014. Personalisation and Privacy in Future Pervasive Display Networks. In *Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 2357–2366.

18. Miriam Greis, Florian Alt, Niels Henze, and Nemanja Memarovic. 2014. I Can Wait a Minute: Uncovering the Optimal Delay Time for Pre-Moderated User-Generated Content on Public Displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 10.

19. RJ Jacob and Keith S Karn. 2003. Eye tracking in human-computer interaction and usability research: Ready to deliver the promises. *Mind* 2, 3 (2003), 4.

20. Mohamed Khamis, Florian Alt, and Andreas Bulling. 2015. A Field Study on Spontaneous Gaze-based Interaction with a Public Display using Pursuits. In *Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (Ubicomp'15)*. ACM, New York, NY, USA.

21. Antonio Krüger, Albrecht Schmidt, and Jörg Müller. 2010. Technological and research perspectives of old-age ubiquitous computing. *GeroPsych* (2010).

22. Marc Langheinrich, Albrecht Schmidt, Nigel Davies, and Rui José. 2013. A Practical Framework for Ethics: The PD-net Approach to Supporting Ethics Compliance in Public Display Studies. In *Proceedings of the 2Nd ACM International Symposium on Pervasive Displays (PerDis '13)*. ACM, New York, NY, USA, 139–143.

23. Nemanja Memarovic, Ivan Elhart, and Marc Langheinrich. 2011. FunSquare: First Experiences with Autopoiesic Content. In *Proceedings of the 10th International Conference on Mobile and Ubiquitous Multimedia (MUM '11)*. ACM, New York, NY, USA, 175–184.

24. Nemanja Memarovic, Ava Fatah gen Schieck, Efstathia Kostopoulou, Moritz Behrens, and Martin Traunmueller. 2013. Moment Machine: Opportunities and Challenges of Posting Situated Snapshots onto Networked Public Displays. In *Proceedings of the 14th IFIP TC 13 International Conference on HumInteraction Interaction (INTERACT'13)*. Springer, Berlin, Heidelberg, 595–602.

25. Alexander Meschtscherjakov, Wolfgang Reitberger, Michael Lankes, and Manfred Tscheligi. 2008. Enhanced Shopping: A Dynamic Map in a Retail Store. In *Proceedings of the 10th International Conference on Ubiquitous Computing (UbiComp '08)*. ACM, New York, NY, USA, 336–339.

26. Jörg Müller, Dieter Eberle, and Konrad Tollmar. 2014. Communiplay: A Field Study of a Public Display Mediaspace. In *Proceedings of the 32Nd Annual ACM Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 1415–1424.

27. Jörg Müller and Antonio Krüger. 2009. MobiDiC: Context Adaptive Digital Signage with Coupons. In *Proceedings of the European Conference on Ambient Intelligence (AmI '09)*. Springer-Verlag, Berlin, Heidelberg, 24–33.

28. Jörg Müller, Robert Walter, Gilles Bailly, Michael Nischt, and Florian Alt. 2012. Looking Glass: A Field Study on Noticing Interactivity of a Shop Window. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. ACM, New York, NY, USA, 297–306.

29. Timo Ojala and Vassilis Kostakos. 2011. UBI Challenge: Research Coopetition on Real-world Urban Computing. In *Proceedings of the 10th International Conference on Mobile and Ubiquitous Multimedia (MUM '11)*. ACM, New York, NY, USA, 205–208.

30. Timo Ojala, Hannu Kukka, Tomas Lindén, Tommi Heikkinen, Marko Jurmu, Simo Hosio, and Fabio Kruger. 2010. UBI-Hotspot 1.0: Large-Scale Long-Term Deployment of Interactive Public Displays in a City Center. In *Proceedings of the 2010 Fifth International Conference on Internet and Web Applications and Services (ICIW '10)*. IEEE Computer Society, Washington, DC, USA, 285–294.

31. Peter Peltonen, Esko Kurvinen, Antti Salovaara, Giulio Jacucci, Tommi Ilmonen, John Evans, Antti Oulasvirta, and Petri Saarikko. 2008. It's Mine, Don't Touch!: Interactions at a Large Multi-touch Display in a City Centre. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '08)*. ACM, New York, NY, USA, 1285–1294.

32. Fiona Redhead and Margot Brereton. 2009. Designing Interaction for Local Communications: An Urban Screen Study. In *Proceedings of the 12th IFIP TC 13 International Conference on Human-Computer Interaction: Part II (INTERACT'09)*. Springer-Verlag, Berlin, Heidelberg, 457–460.

33. Jürgen Scheible and Timo Ojala. 2005. MobiLenin Combining a Multi-track Music Video, Personal Mobile Phones and a Public Display into Multi-user Interactive Entertainment. In *Proceedings of the 13th Annual ACM International Conference on Multimedia (MULTIMEDIA '05)*. ACM, New York, NY, USA, 199–208.

34. Fabius Steinberger, Marcus Foth, and Florian Alt. 2014. Vote With Your Feet: Local Community Polling on Urban Screens. In *Proceedings of The International Symposium on Pervasive Displays (PerDis '14)*. ACM, New York, NY, USA, Article 44, 6 pages.

35. O. Storz, A. Friday, N. Davies, J. Finney, C. Sas, and J Sheridan. 2006. Public Ubiquitous Computing Systems: Lessons from the e-Campus Display Deployments. *IEEE Pervasive Computing* 05, 3 (2006), 40–47.

36. Karolina Szymbor. 2015. *The Interactive Touch Wall at the Copenhagen Airport in Human-Computer Interaction Perspective: Evaluation of The User Experience*. Master Thesis at Aalborg University.

37. Nick Taylor and Keith Cheverst. 2009. Social Interaction Around a Rural Community Photo Display. *Int. J. Hum.-Comput. Stud.* 67, 12 (Dec. 2009), 1037–1047.

38. Maurice Ten Koppel, Gilles Bailly, Jörg Müller, and Robert Walter. 2012. Chained Displays: Configurations of Public Displays Can Be Used to Influence Actor-, Audience-, and Passer-by Behavior. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. ACM, New York, NY, USA, 317–326.

39. Nina Valkanova, Robert Walter, Andrew Vande Moere, and Jörg Müller. 2014. MyPosition: Sparking Civic Discourse by a Public Interactive Poll Visualization. In *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work and Social Computing (CSCW '14)*. ACM, New York, NY, USA, 1323–1332.

40. Robert Walter, Gilles Bailly, and Jörg Müller. 2013. StrikeAPose: Revealing Mid-air Gestures on Public Displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13)*. ACM, New York, NY, USA, 841–850.

41. Yanxia Zhang, Hans Jörg Müller, Ming Ki Chong, Andreas Bulling, and Hans Gellersen. 2014. GazeHorizon: Enabling Passers-by to Interact with Public Displays by Gaze. In *Proc. of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp 2014)* (2014-09-13). 559–563.