

Understanding Future Challenges for Networked Public Display Systems in Community Settings

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ABSTRACT

Networked public displays are envisioned as a communication medium for the 21st century, and as such they have a great potential to address place-based communities. This area has seen an increasing numbers of investigations of networked public displays effects on communities and the way they impact interactions between community members. However, most of this research stands alone in isolation, with little work looking into synthesizing the systems, processes, research questions, and evaluation procedures and effects they produce. In this paper we look at seminal works in the area, i.e., the Wray Photo Display, the Plasma Poster Network, CoCollage, and UBI-Hotspots, and analyze the systems themselves, settings in which they were deployed and respective communities, the processes leading to building up the system, the research questions that were examined, and the effects of the networked public display systems on the community. We discuss the similarities and differences in these works and provide insights for the designers and developers of similar future systems, with a goal to present open challenges for the future work.

Author Keywords

Networked public displays, community interaction, place-based deployments

ACM Classification Keywords

H.4.3. [Communications Applications]: Bulletin boards; H.5.3. [Group and Organization Interfaces]: Theory and Models; H.5.1 Multimedia Information Systems;

1. INTRODUCTION

With significant priced drops of large displays and LCD panels public displays are becoming a common element of the urban landscape and are “painting” the urban environment [18]. Networked over the Internet they are envisioned as a new communication medium for the 21st century [9], one moving from showing advertisement in the form of still images, videos, or Power Point presentations, into a one where there are multiple

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applications running on a display and across displays as well. This new medium has a great potential to enhance place-based communities and stimulate community interaction – interaction between community members residing within and across public spaces, by enhancing already existing processes happening within public space [25].

In recent years there has been a growing number of interest in the area of networked public displays and communities [2, 5, 6, 10, 15, 16,17, 20, 23, 26, 27, 28, 29, 30, 34, 36 , 39,, 44]. Most of these works investigated different settings, e.g., communities in rural villages [16, 40], third places such as cafes and bars [17, 20], or urban public areas [2, 23, 39]. There were different processes that lead to the design of the systems, from full and immersive participatory design [40] to the more distant ones where the infrastructure was simply put into the setting [36]. Also these systems had varying applications running on them, e.g., photo booth like applications that allowed passers-by to take the photos [23], digital public notice boards that allowed information exchange between community members [2], or applications that allowed passers-by to post opinions in the form of text messages about locally relevant topics [39]. Also, these applications have investigated different research questions and have examined different effects on community and community interaction, e.g., from their ability to stimulate civic engagement [39], their ability to stimulate social interaction around a display [26], or how they allow community members to express their membership explicitly in different forms, e.g., pins and posters [17]. Despite the wealth of research in the area there has been very little effort to look into synthesizing the work across different settings and “in the wild” deployments.

In order to inform future researchers, designers, and developers that are looking to work in the area of networked public displays for communities we examine four seminal works, i.e., the Wray Photo Display [40], the Plasma Poster Network [6], CoCollage [20], and the work around UBI-Hotspots [36]. Our goal with this analysis is to synthesize their work and present similarities and differences in the way they were designed and built, the main research questions that were examined, as well as the effects they have produced on communities where they were deployed, allowing to determine what was done and what are the future challenges in this area. The contribution of this paper lies in structuring previous work around four fundamental topics, as well as discussing the works and informing future researchers of the challenges and opportunities that lie within this area.

After presenting related work we will summarize the four systems and the respective settings and communities where they were deployed. After that we will discuss the similarities and

differences between them and will present open challenges for future research. Finally we will present our concluding remarks.

2. RELATED WORK

Even since the early works on public displays there has been a strong connection between them and their use as a medium that connects place-based communities. For example, in the early 80's the Hole in Space project [12] connected two public spaces in New York and Los Angeles via a simple video link. While this project examined how public displays can connect places and communities in urban settings, Houde et al. [15] examined how they can stimulate sense of connectedness between office workers. In their work they have investigated how community-created newspaper in form of a website that is projected in a shared office space stimulates interaction between coworkers. Their work shed early insights into the importance of participation with members of place-based communities.

More recent works have examined new ways of stimulating community interaction. For example, Alt et al.'s Digifeds [2] provide a digital version of a more traditional paper based public notice areas [3]. Their system allows posting and viewing of classifieds on a public display network, while at the same time preserving locality and local nature of postings. Memarovic et al.'s investigation has looked into how networked public displays can be integrated within existing ICTs such as Facebook and Twitter [23, 29]. Their research pointed out the potential of situated snapshots – pictures taken through display attached camera that are later available for viewing on a display network [23] or somewhere on the web, e.g., Facebook [22]. Their findings show how situated snapshots stimulate social interaction around a display and how they stimulate community interaction and awareness, by allowing people to see who is around and who are the people that interact with a display.

North et al. [34] and Motta et al. [30] report on the processes involved in developing a public display network with multiple stakeholders across multiple settings, and on the process of co-creating the content for it with a local community. Their works are important as they show what North et al. call tension-space, i.e., challenges involved in multi-stakeholder collaboration, and also point out the importance of involving the local community in the process of co-creating the content (similarly to Houde et al. mentioned above). Within the deployments in urban public spaces Schroeter [39] has investigated how posting Tweets and SMS messages on local public displays can engage locals into voting their opinions about locally relevant topics, i.e., how it can stimulate their civic engagement. Similar investigation has been made by Wouters et al. [44], who have investigated open use of text messages posted to displays attached to residential households. Their findings show how such messages can spark intrigue and curiosity from the passers-by, as well as stimulate sense of connectedness.

While the above-works investigated the effects of networked public displays in urban environments, Churchill et al. [7] and Jose et al. [17] have made their deployments in third places such as cafes. Churchil et al. have investigated how simple scribbling on a public display can be used to connect people that stop by at the café. Their short-term evaluation has showed the success of such an application in stimulating interest between the members of the café community. Complementing their work, Jose et al. have investigated how familiar paradigms such as badge pins and posters can be adapted to networked public displays. In their investigation of the use of pins and poster posted to a display

network over a 6-month period across 10 different locations they have focused on describing the use-practices, showing how this simple type of communication can stimulate sense of community in third places.

In working environments McCarthy et al. have investigated the use of three displays that they call Unicast – peripheral display showing relevant information for a person, Outcast – a display installed in front of a person's office showing interesting information about them, and Groupcast – a display installed in a common area with a goal to spark informal interaction between co-workers standing next to a display by showing their interests. In their work they have been focusing mainly on the system design and describing the initial user experience. More recently, Munson et al. [32] have investigated the use of two different public displays that showed text messages – one allowed unconstrained posting of Tweets to a display, while the other showed thank you messages and greetings. Their findings show that displays with a dedicated and clear use, e.g., for posting thank you messages, have a more clear purpose and are understood better than the ones without it.

Lastly, researchers have also explored the effects of public displays in rural villages. In their work Jones et al. [16] have investigated how public displays can be used to preserve local knowledge and history and how different interaction techniques can be adapted to make displays that have a more natural and familiar interaction with the users. Also, their work shows participatory processes involved when working with rural communities.

All the above-mentioned work focused on describing singular experiences within a particular setting and a particular research question. Recently there have been works that tried to synthesize lessons learned from multiple deployments. In their work Müller et al. [31] have described the requirements and design space for general public display applications and experiences. Similarly, Ojala et al. [35, 36] have reflected on their multi-year experience with the UBI-Hotspots and have described the challenges involved in continuously running and maintaining, as well as evaluating networked public displays in urban settings. The general procedures, methods, and tools used in the public display research has been described by Alt et al. [4]. When it comes to networked public displays for communities, Memarovic et al. [27] have analyzed previous research and have described general implications of having the input and output of networked public displays tethered to a display, or “free to roam” allowing remote posting and viewing of the display content. Also, they have described the overall challenges in designing, developing, deploying and evaluating display systems within community settings, exemplified through the three public displays systems researchers were involved in [28]. Similarly, Taylor et al. [41] have summarized their lessons learned in making sustainable deployments that can be left “in the wild” and run by community members. Their findings are based on 2 such systems.

The work described in this paper complements the above-mentioned ones by examining four prominent networked public display deployments and describing the design processes, research questions examined, and the effects of the systems on community members. We use them to drive a discussion that shows similarities and differences across the settings and communities. Also these questions/themes were not part of the similar prior work.

3. EXEMPLARY WORKS OF NETWORKED PUBLIC DISPLAY SYSTEMS

The four networked public display systems represent exemplary works and were chosen based on their significance and impact within the networked public displays community. Also, they were deployed in different settings, i.e., rural village, workspace, café, and urban public spaces. We want to note here and make it clear that other similar systems could have been analyzed as well and the four do not necessarily represent the “best” by some rigorous standard, but rather by the systems’ properties and the way they were designed and evaluated. In the sections below we will describe the Wray Photo Display [40], the Plasma Poster Network [6], the CoCollage [20], and the UBI-Hotspots [36]. For each system we will first describe its functionality, followed by the description of the setting and community, system design process, research questions, as well as evaluation procedure and documented effects.

3.1 The Wray Photo Display

The Wray Photo Display was deployed in the village of Wray, located close to Lancaster. The system allowed community members to upload photos through a website, which were in turn shown on two public displays, located in the town’s Post office and village hall. Images uploaded by the community members were organized in categories, and each category was owned by the person who created it, making her/him also in charge of the moderation. Passers-by could see the photos that were shown in a carousel fashion, and if they were interested in a particular one they could enhance it by simply touching it, as displays were touch enabled. The system also had accompanying website where all the photos could be seen as well.

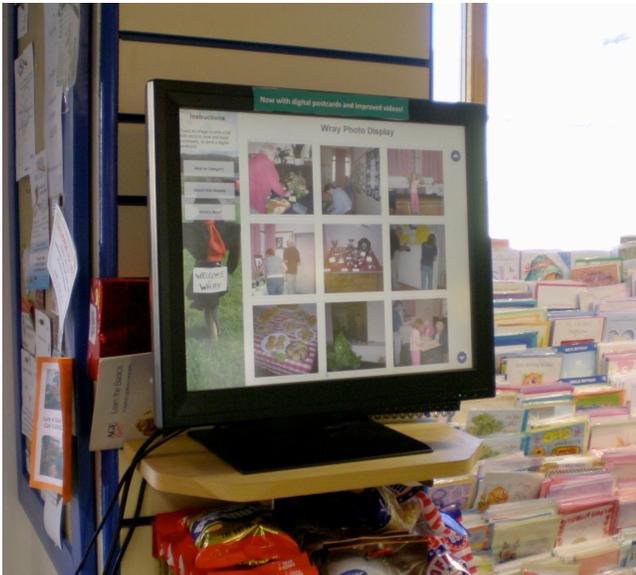


Figure 1 - The Wray Photo Display. Image courtesy of Nick Taylor and Keith Cheverst.

3.1.1 The Setting and Community

The Wray village is a small village located in the North West England and would be a typical place-based community defined by a geographical location [8]. Its population is around five hundred inhabitants. Prominent locations in the village include pubs, town hall, and post office. As documented by Taylor and

Cheverst despite its older population the village has adopted new technology with open arms, as there was a Computer Club as well as an experimental wireless mesh network running in the village.

3.1.2 System Design Process

The system went over an extensive user centered and participatory design process. The lead researchers first conducted preliminary investigations of the setting, and they also had a community champion in the village – person who acted as a mediator between the researchers and the community. Researchers investigated the use of traditional public notice areas when they observed the large number of historical photos that could be noticed in the village. In turn, this sparked their idea that photos could represent a good way of stimulating interaction between community members. The system itself was redesigned several times and was introduced to the village in a probe manner, i.e., the researchers piggy backed on real world events organized by the villagers to introduce their public display system.

3.1.3 Research Questions

The main research questions of the Wray Photo display was how does a community use photos for a social purposes, and how are these then stimulated through a networked public display system. In other words, in the beginning of the study the researchers were open towards understanding the community and their use of media, and the research questions emerged after the researchers investigated the setting, where they uncovered that the Wray community has a collection of historical photos that reminds them of their connections.

3.1.4 Evaluation and Effects

The evaluation of the Wray Photo Display was extensive over the period of 2 years of the deployment and included analysis of the interaction log files to determine the systems overall use, in-depth interviews with the community members as well as reflections and notes from the group meetings. Also, researchers observed how people coordinated and engaged with a display whenever they had the time, e.g., during the community organized events. The most interesting part of the evaluation was a notebook that was attached to the displays, which allowed commenting on the system whenever people wanted. Overall, by the time the authors have documented their work they have received approximately 70 comments. The researchers noted that most of the effects that the application stimulated were due historical nature of the photos, which allowed reminiscence of the past times and also catching up with the missed events.

3.2 The Plasma Poster Network

The Plasma Poster Network is a display network that showed information posted by individuals, as well as information retrieved from a company’s Intranet website. The system supported posting of the content through email and a dedicated webpage for the authenticated community members. Passers-by could browse the content shown on a display, and they could also take it with them by forwarding the desired content to an email address. Interaction with the displays was via a touch interface.

3.2.1 The Setting and Community

Three displays in landscape orientation were deployed in the common kitchen area, foyer, and in a corridor at the FX Paolo Alto Laboratory (FXPAL). At the time of the investigation FXPAL had thirty-four full-time employees that were organized into seven research teams with little or no overlap between the team members. The workspace is located on the first floor of a

two-story building. The community can be seen as a community of practice, defined by a group of people that share the same profession or craft [19].

3.2.2 System Design Process

In order to understand the interaction design requirements for the Plasma Poster Network researchers conducted two thorough studies that informed the system design: a study around traditional public notice areas around Paolo Alto, and a study on information sharing practices of the FXPAL members. The first study investigated the use-practices with public notice areas at three public spaces and also included six interviews with local community members. In addition the study also looked at three closed workplace environments and how public notice areas were used there. In their second study the researchers investigated people's movements through the building as well as their activities. The researchers also conducted a diary study with seventeen participants, asking them to write down their online and offline sharing practices within the organization.

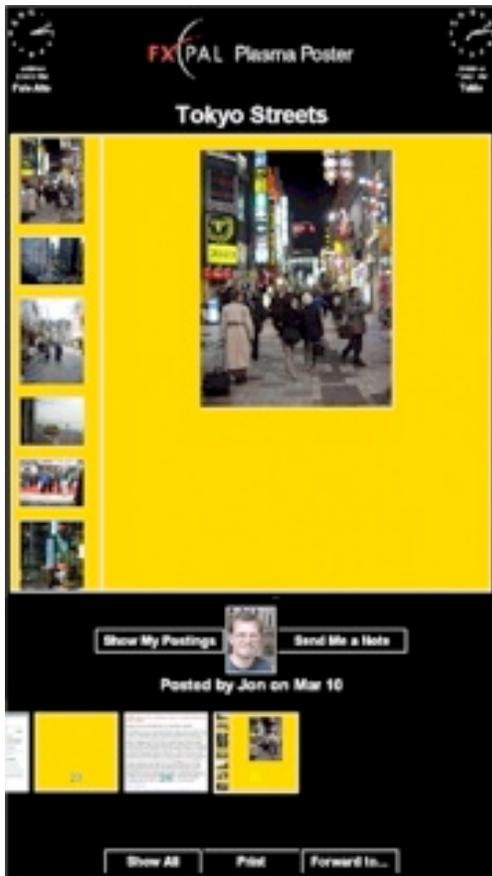


Figure 2 - The Plasma Poster Network. Image courtesy of Elisabeth Churchill.

3.2.3 Research Questions

The overall goal of the research was to stimulate informal social interactions by allowing people to discover shared interests. The underlying research questions were structured around two themes, one involving around the use of the technology, i.e., how people engage in reading and posting of the content on the Plasma Poster Network and if there are any notable use-patterns, and one around its reception and impact, i.e., is a Plasma Poster Network seen as a valuable addition to existing means of content sharing, what are

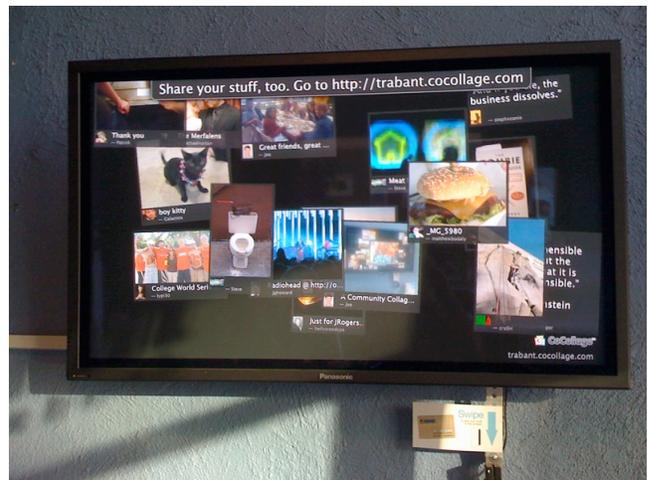
people's reasons for posting content, what are the most popular content types, and does the system fulfill its purpose of starting/cueing informal social interaction.

3.2.4 Evaluation and Effects

The Plasma poster Network was deployed for six months within the FXPAL. Evaluation of the application took the form of analyzing interaction log files and also gaining qualitative insights into the system's use, which were gained through three interview based evaluations (seven, ten, and eight interviewees, twenty five in total) and a survey (with twenty three survey respondents). Their findings show that a smaller subset of people was responsible for the majority of the content – nine people accounted for 88.6% of the content, and also point out that location makes a difference for interaction – 67.9% of the overall interactions happened in the kitchen. Qualitative evaluation showed that the system has reached its goal and was able to foster social interaction, both situated as well as remote when people were not around a display. Survey participants responded that getting informal and serendipitous information about people's lives was one of the better qualities of the system.

3.3 CoCollage

The CoCollage (Community Collage) system is a public display system that allowed people to check-in into a café and show their profile picture and a text or picture message. In order to do so users had to have a CoCollage social networking account and they either had to check-in into a café by swiping a loyalty card through a card reader located below a display, or by clicking an "I'm here" button on the social network, that appears only when a person is connected to a café's WiFi. When located within the café CoCollage users could send messages directly to the CoCollage display. The online social network allowed them to manage their profiles and also have interactions outside the café's premises.



3.4 Figure 3 - The CoCollage display system. Image made by Joe McCarthy and used with the creative commons license (CC BY-NC-SA 2.0)¹ Image courtesy of Joe McCarthy.

3.4.1 The Setting and Community

Before deploying the system the researchers examined their local (University District of Seattle) coffee shops with respect to their size, architecture's suitability for a display, and the overall sense of community generated by the place. The chosen setting for the

¹ <https://creativecommons.org/licenses/by-nc-sa/2.0/>

CoCollage system was a café with estimated four hundred regular customers and a creative flow going on at the café. As the authors note this was exemplified via sketchbooks spread across the café's tables, where people doodled freely, often adding comments or drawings to someone else's work. The community at the café can be seen as a community that inhabits third space where locals from the area come to unwind and chat [37]

3.4.2 System Design Process

The design process behind the CoCollage system is not described in details. The original paper focuses more on describing the user interface and the system components, i.e., possible interactions over the social network, possible interactions via a public display, and the admin interface that was made available to the baristas and café owners.

3.4.3 Research Questions

The primary goal of the CoCollage system was to create an impact on people's community experience at the café and to increase place-attachment over the use of the system. More specifically, the researchers were interested in understanding if the use of the system would increase the number of people café customers know; and if it had an impact on the sense of community as defined by Wilkinson [43] and place attachment as defined by Rosenbaum et al. [38]. The two tools were mixed to create a tool that would allow assessing the patrons commitment in using the café, hers/his dependency on it, how much a person identifies with the self and café, and how much they visited each other's homes.

3.4.4 Evaluation and Effects

The CoCollage system was initially made open for use only for baristas for a week, and after that the deployment lasted for almost four months. The evaluation of the CoCollage was conducted through log file analysis, interviews with café owners made on a weekly basis, and a survey that investigated the impact of the application according to the mixed questionnaire containing elements of sense of connectedness and place-based attachment. Weekly interviews with the café owners mainly served the purpose of understanding how the system was being used and if any changes were necessary. Log file analysis showed general trend in the systems use, e.g., how many users updated their profiles and what types of images were shared online and on the display.

The most interesting part of the evaluation was with respect to the survey that was distributed within a week of first account creation and two months later. The questionnaire examined four factors as mentioned previously, i.e., the number of friends accounted for within a café, the neighboring factor – how often did café patrons visit each others homes, the dependency factor – how much do the café patrons rely on the café to have their needs met, and how much do café patrons identify themselves with a café. Their study results show that the CoCollage was able to increase the sense of neighboring and dependency; however the application had no impact on the overall number of friends and personal identification with a café. The survey also had an open-ended feedback. Participants reported that in general the system did bring up the notion of connectedness, e.g., by getting the overall notion of the place, contributing to the screens content, or by being able to see photos of a known group of people that would in turn serve as a conversation starter. However, the system also had negative effects at the same time: while some people appreciated the overall ambience the system creates other thought that it actually distracts them as the display became the centerpiece of attention;

also while some people felt more connected with the rest of the people in the café others felt more isolated.

3.5 UBI-Hotspots

While the above-mentioned networked public display systems had a single application running on them and everything about them is tethered to it, UBI-Hotspots represent a system that has multiple applications running and is much closer to a traditional desktop/mobile phone system. The UBI-Hotspots run in two modes: passive mode and interactive mode. In the passive mode UBI-Hotspots show advertisement in the form of videos and images; when a passer-by comes close to a display s/he gets an opportunity to press a button that then switches a display into interactive mode. The UBI-Hotspots offer a variety of applications running, from the city of Oulu maps and relevant tourist information, newspaper articles from the local newspapers (Kaleva), to games like Hangman, to photo-booth applications that allow taking situated snapshots and sending them to an email address.



Figure 4 - UBI-Hotspots. Image courtesy of Timo Ojala.

3.5.1 The Setting and Community

The city of Oulu has around 196,000 inhabitants² with mainly Finnish people living in the area, spreading on 3 866,2 km². Similarly to the Wray Photo Display's case, the community in Oulu can be defined as a place-based community [8]. The UBI-Hotspots are distributed around the city of Oulu at twelve locations. Most of them (9/12) are located in the downtown area, where the rest are in the Science Center (1), Swimming and Sports Hall (2). All the displays have the same type of content available. The city itself is very tech-oriented and adopts new technology trends, e.g., the whole city is also covered with free panOULU WiFi network.

3.5.2 System Design Process

The research team behind the UBI-Hotspots conducted an open investigation of what applications could be running on the displays. This was done through a mock-up display – a whiteboard on wheels, which served the purpose of soliciting passers-by opinions and ideas. Their study lasted two days and seventy-four people were interviewed in this period. Most of the suggested applications were connected to local information that could be available on traditional public notice areas, e.g., bus schedules,

² <http://www.ouka.fi/oulu/english/oulu-information>

municipal information, information about events in the city etc. In order to further boost the ideation and participation from the local community the research team published an open call for ideas in the local newspaper, but reported on disappointing results. Also, the research team worked on the interaction model with public displays as proposed by Vogel and Balakrishnan [42], which was the latest interaction model when the system was being built.

3.5.3 Research Questions

Some of the research questions regarding the UBI-Hotspots were quite technical, however the ones that related to its impact on the community were mainly oriented towards their use for civic engagement. For example, in one of their studies the research team investigated how can networked public displays be integrated with social media in order to attract young adults and solicit their opinions about the city of Oulu [14]. In a similar study the researchers were interested in soliciting community members' opinions about the ongoing construction works happening in the city [13].

3.5.4 Evaluation and Effects

In cases where evaluation of the UBI-Hotspots was focused on understanding their impact on civic engagement (as in [13, 14]), evaluation took place during scheduled field trials. During those the research team would typically conduct in-situ observations with at least two researchers present (observing how people engage and interact with the application), would distribute a questionnaire to the people who interacted with the application after their interactions, and would analysis of the posted content.

The research around UBI-Hotspots revealed that social situation and users' age impact the way people use the displays, suggesting that younger crowds enjoy playful aspects of the applications, even when they are meant for serious things like civic engagement [14]. One of the interesting findings with respect to civic engagement is that younger people preferred to stay anonymous when they expressed their opinions or gave their feedback about important civic topics. The researchers also report that although public displays would be used for feedback on a very specific topic, they would get very broad and sometimes unrelated feedback. However, they also report that sometimes the amount of feedback received through public displays on civic topics would be very low [13].

4. DISCUSSION

In this section we will discuss the similarities and differences between the four works and respective systems, settings and communities, system design processes, research questions, and evaluation procedures and effects stimulated by networked public displays. At the end of each subsection we will also present open challenges for the future research. All the challenges are summarized in Table 1 at the end of this section.

4.1 The Systems

All four exemplary systems represent some way of more traditional public notice areas that served for exchange of locally relevant information – they Wray Photo Display showed photos posted by community members, the Plasma Poster Network showed interesting information posted by individual members of the community or information from the company's Intranet, the CoCollage showed profile pictures and text or photo messages, and the UBI-Hotspots multipurpose displays had information and applications on public transportation schedules, local news, or events. Three out of four systems (the Wray Photo Display,

Plasma Poster Network, and CoCollage) ran a single application and had the identical interaction paradigm and purpose as traditional public notice areas. Only the UBI-Hotspots had a different paradigm that was much closer to desktop/mobile computers where users can choose the applications they want to interact with. Although these systems were networked and potentially could have connected to different places their primary purpose was to support highly situated and local information needs. This also points out that at the current moment this communication medium primarily acts as a medium for stimulating community interaction in single settings and place-based communities.

4.1.1 Open Challenges

As argued by previous work [25] networked public displays are indeed meant to be a medium for communities, one that connects local members, promotes diversity of different communities within a single public space, connects geographically distributed communities, and also infuses difference in homogenous settings. When we look at the current state of the research we can see that most of its focus lies on connecting local communities. There are strong reasons for that, as at the moment networked public displays are seen mainly as a descendant of traditional public notice boards [2, 6, 9, 32, 39, 40] or as a big desktop and smartphone system [36]. One of the biggest challenges in building networked public display systems is going to be *breaking the paradigm and stimulating networked interactions*. Previous work has shown some ways of how this could be done, but with mixed results. For example, using video links is one way of providing clear paradigm that two or more places are connected, e.g., as in [11, 34]. One of the problems with such direct connections is that it does not provide more than a playful interaction, one where people simply wave or perform other types of gestural interaction.

4.2 The Setting and Community

The four settings in the example systems represent different environments, i.e., rural village, workplace, café, and urban space. What is quite interesting to note is that for the three of them – the Wray Photo Display, the Plasma Poster Network, and the CoCollage – spaces where the displays were located were similar in size – post office and a town hall, workplace kitchen, foyer and a corridor, and a café – and it was their broader context that made the difference. In contrast to them the setting for the UBI-Hotspots was much broader and covered a wider area, also due a bigger number of displays. While for the three applications their setting was fixed, for the CoCollage researchers first built the system and then went into looking for the potential location where it could be deployed. Their final deployment setting was based on the general feel of the setting and its community.

4.2.1 Open Challenges

The four systems present a dilemma for every researcher: *do you map the application to the setting or vice versa*. This is something that depends on the research questions one wants to address, but also on the opportunity. While for some of the presented systems the setting was quite fixed (the Plasma Poster Network) for others researchers had more freedom in choosing where they want to install the displays (the Wray Photo Display, CoCollage, and UBI-Hotspots). One is not necessarily better than the other, but rather presents a starting point of interest: in the case of choosing the setting first researchers get the opportunity to get to know the setting and the community better before starting to build the system, and at the same time they start gaining trust of the community; on the other hand researchers interested in technology

can focus on system requirements and the overall application vision without any constraints and can later decide which setting would suite their needs.

The general question poses itself, i.e., *how would different networked public display applications operate in different settings*. Most of the research nowadays investigates the impact in a single setting, and although there have been efforts to show the impact of space and context on the use [1] these studies were typically short-term. Of course, this implies more research efforts and resources in order to determine the impact of the applications on multiple settings and their respective communities. A possible solution for this would be to investigate an application within existing test-beds in Lancaster [5], Oulu [36], Minho [17], London and Nottingham [34], or Lugano [22]. Differences between the communities should be considered in this case, e.g., size, values, and existing sense of community (as pointed out by [20]). Borrowing from related work on social networking sites [33], an important factor that could impact the adoption of an application or a whole system across different settings is community structure, which can be seen as the number of weak and strong ties that exist within it. However, other factors should be also considered.

Interesting to note is that recent research pointed out the importance of the setting and the attractors/distractors that compete for passers-by attention [24], e.g., environmental sounds like church bells, visual distractions like graffiti and people moving, or other forms of technology like mobile phones. While these were not reported in prior work future reports would benefit from analyzing the setting in more details and documenting the different properties of the environment and its attractors.

4.3 System Design Process

All but one system (CoCollage) was co-designed with the help of community members. While for some of the systems this collaboration was long-term and involved several redesigns (the Wray Photo Display), for others community members were part of the process only in the user requirements stage (Plasma Poster Network and YBI-Hotspots). In cases of longer collaborations research teams needed a community champion that acted as a mediator between them and the community. Research teams investigated community ethos in order to uncover inspiration for the networked public display applications (Wray Photo Display), solicited their ideas on the possible content and applications through a mockup (UBI-Hotspots), or they investigated community members' practices with current ICTs (the Plasma Poster Network). For two of the system (the Wray Photo Display and the Plasma Poster Network) an investigation of the use of traditional public notice areas informed system design.

4.3.1 Open Challenges

Analyzed works offer the ingredients of networked public displays system design: deciding whether the application is going to be custom made for a single community or it is going to be more general purpose application, understanding current practices with public notice areas and practices with modern ICTs, and deciding for how long community members will be involved in the process, i.e., if the collaboration is going to be short- or long- term. If there is no application on the horizon one can always investigate the community and its ethos in order to find inspiration. However, the burden of designing the system still stays entirely on the research team, as evidenced by the UBI-Hotspots example where researchers came empty-handed when they solicited ideas from the general public. *Although prior work offers the ingredients it does not spit out the magic formula*. This means that designers and

developers of networked public display systems can get informed about the ingredients of the process, but they still have to decide themselves how things progress. An open challenge here is *understanding what processes work best for different communities and situations*. Future work can tackle this challenge by documenting in more details how the system was designed and comparing it with similar works.

4.4 Research Questions

Some of the research questions started with a general theme, e.g., how can networked public displays stimulate social interaction. These would then be more focused around the application itself, e.g., how can they stimulate social interaction around photos, or how can they support the discovery of shared interests (which would lead to social interaction). Similarly, researchers would investigate the application's impact on the general sense of community, but also on a sense of community or place attachment determined by a stronger criteria (CoCollage). The topic of civic engagement was investigated in general. What is interesting to note is that a separate set of questions was used to understand the applications use in general, e.g., did passers-by read or post the content, what were their motivations for doing so etc.

4.4.1 Open Challenges

Although there is an increasing body of research that looks into networked public displays and their impact on communities, most of the research questions that were explored can be characterized as having general themes. To a certain extent this can be due lack of synthesis across the research field. Another trend in the questions is that the general impact of the application is looked in isolation from the application's use and its features. What would be great to see in future work is the connection between the two i.e., *what features of the application and its use lead to the sense of connectedness* (or other community oriented questions like their ability to stimulate social interaction or civic engagement). Although one can say that the most used features are the ones who contribute to applications impact the most, this would need further validation. These types of questions would strengthen the knowledge on the use and impact of networked public displays as a communication medium for communities.

4.5 Evaluation and Effects

Most of the systems were evaluated through the analysis of interaction log files, observations of user-engagement with a display, interviews and/or questionnaires. Interaction log files mainly served for the purpose of showing user engagement, while the effects of the application were typically assessed through interviews or questionnaires. In all but one case (CoCollage) evaluation took place in a single point in time, even if that was for a couple of days; or the whole deployment period served for simply collecting the information (the Wray Photo Display). Also, only one evaluation incorporated the work from other fields, e.g., social science and community theory, to understand the impact of the application (CoCollage). When it comes to the reported effects of networked public displays they show their ability to stimulate social interaction, sense of community, or at least some parts of it as defined by Rosenbaum [38], and civic engagement, to a certain extent, as reports show occasional low engagement [13].

4.5.1 Open Challenges

Analyzed systems show one of the biggest challenges for future work when it comes to evaluation, i.e., *at what time it is appropriate to do the evaluation and how often should it be*. As most of the previous work conducted the evaluation in a single

point in time it is really hard to judge what is the best timing to do the evaluation, as well as how often it should be done. For example, a natural order similar to lab-based studies where a stimulus is introduced, e.g., determining the sense of community before the deployment, during the deployment, and after the deployment, could be done. However, this could work only in the cases where the networked public display system is removed from the environment or when an application stops running on the existing infrastructure. Another approach would be to evaluate the impact of the application on some steady frequency, e.g., on a monthly level; or a more proactive approach like experience sampling where users would get the option of filling out a questionnaire while they interact.

Connected to the above-mentioned challenge is *holistic understanding of trends in user engagement and effects produced by the networked public display applications*. While newer research is going in this direction and describes different user types based on their return frequency, demographics, and the overall trend in use during the deployment period [23], there is a real need for more such research in order to fully understand the engagement stimulated by the networked public displays. By describing engagement with different applications – who uses the application and under what circumstances, how often users engage and what are the patterns in engagement, how they experience interactions with the applications, what is the short-term and long-term impact – would help in building up the knowledge of how they operate and what effects they create. In order to further strengthen the evaluation of networked public displays existing works from the fields of community theory or environmental studies could be consulted – this would help in building comprehensive evaluation tools that are grounded in theory.

Continuing, all the evaluations looked at networked public displays and the effects they produce in isolation. Although this provides a good internal validity, a more holistic evaluation would definitely be appreciated. In other words, *the effects of networked public displays could be compared to the effects produced by other media*. At the beginning, this does not have to be a statistical comparison of what media produces more of the effects, but rather a qualitative one that would show how networked public displays fit in within the rest of the media [29].

Category	Open challenges
<i>Settings and Communities</i>	<ul style="list-style-type: none"> - Do you map the application to the setting or vice versa - How would different networked public display applications operate in different settings
<i>System Design Process</i>	- Understanding what processes work best for different communities and situations
<i>Research Questions</i>	- What features of the application and its use lead to the sense of connectedness
<i>Evaluation and effects</i>	<ul style="list-style-type: none"> - At what time it is appropriate to do the evaluation and how often should it be - Holistic understanding of trends in user engagement and experiences produced by the networked public display applications - Comparing the effects of networked public displays to the effects produced by other media

Table 1 - Summary of the open challenges for future research on networked public displays for communities.

5. CONCLUSION

While there has been an increasing body of research around networked public displays and their use as a communication medium that addresses place-based communities, most of this research has been done in isolation and has not looked into methodically assessing the properties of networked public display systems and its applications, the processes used in their design, the research questions that were asked in the studies, nor the evaluation tools/methods and procedures that were used to examine and capture their effects. In this paper we have made a first step in such direction and have presented an analysis of four exemplary systems, making connections in similarities and differences between them. This analysis can help designers and developers of future systems by allowing them to have a quick overview of the different possibilities that lie within this research area. Also, we have presented open challenges for the future work that will ensure better design of the studies as well as better design of the systems.

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