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CommunityMirrors – Semi-Public Information Radiators for Knowledge Workers

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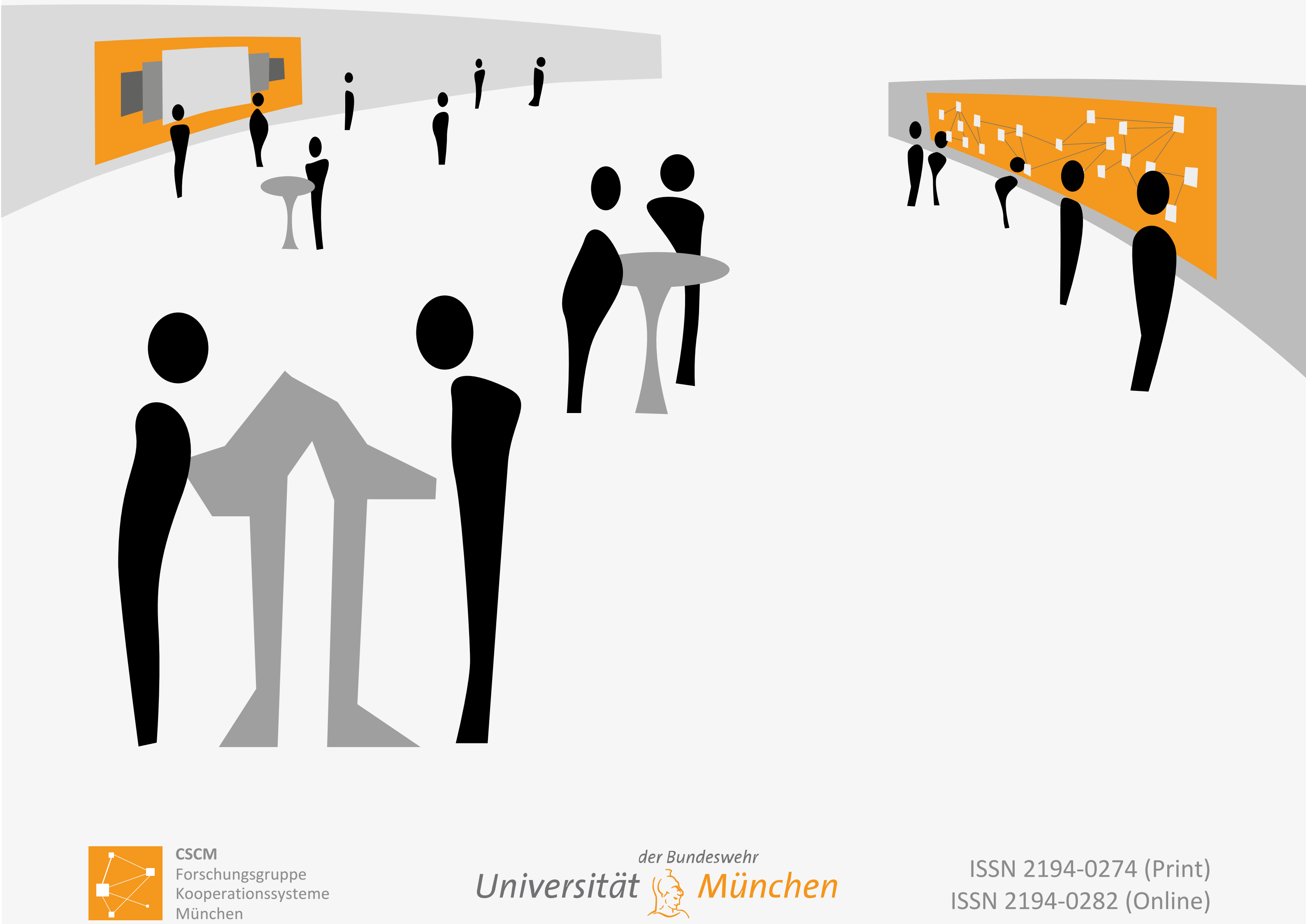

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CommunityMirrors – Semi-Public Information Radiators for Knowledge Workers

Michael Koch

Abstract

Our daily work in the information society relies on creating, editing and collecting different information objects. Without additional presentation mechanisms these activities of particular knowledge workers remain hidden in the underlying IT systems. The resulting lack of awareness can lead to inefficient coordination as well as to the duplication of work in the worst case. Information Radiators are large displays providing context-specific pieces of information in a semi-public setting where people can see it while working or passing-by. They have a long history originating from simple printed posters for agile project management and software development, over interactive versions on large touch displays in the early 2000s to complex situated sociotechnically integrated multi-user multi-device interaction spaces for knowledge workers in recent years. By augmenting the physical working environment with peripherally recognizable digital content Interactive Information Radiators (IIRs) can simplify information sharing "out-of-the-box", foster awareness and socialization, create serendipity and enhance collaboration. In this report we present CommunityMirrors as one potential solution to this problem. CommunityMirrors are an example for information radiators and discussed in detail within this work. We describe the start of the project and elaborate on the work done in the past 20+ years covering different phases from first experiments to setting up a long-term deployment and providing support for evaluation in this deployment.

Keywords

HCI, challenges, public displays, knowledge management, knowledge worker, information radiators, awareness, evaluation, adaptation, multi-user, walk-up-and-use, joy of use

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1 Introduction

Our daily work in the information society relies on creating, editing and collecting different information objects. Without additional presentation mechanisms these activities of knowledge workers remain hidden in the underlying IT systems. The resulting lack of awareness can lead to inefficient coordination as well as to the duplication of work in the worst case. Activity streams from Social Software offer new ways to increase the awareness, but the desktop-based user interfaces in typical organizational settings currently only utilize a small portion of their full socio-technical potential.

In this chapter we will first briefly review the terms *knowledge worker* and *knowledge work* – and how these can be supported. From the different concepts to support knowledge workers we will particularly cover the concept of information radiators and present the idea of CommunityMirrors as one kind of information radiator.

In the remainder of the report, we will present the CommunityMirror project we set up at University of the Bundeswehr Munich – from the first steps in 2001 to the current deployments and their evaluation.

1.1 Knowledge Economy and Cooperative Knowledge Work

For a long time, economics considered only two relevant factors of production: Labor and capital. It was not until the middle of the 20th century that knowledge was added as a third factor of production (Machlup 1962; Romer 1986). Whereas in the industrial age wealth was gained using machines as a substitute for human labor, in the knowledge age or knowledge economy wealth is primarily gained through the generation and use of knowledge (Drucker 1967, 1999, 2010).

In the course of the discussion of knowledge as a production factor, the term "knowledge worker" has been established, which emphasizes the special relationship of everyday work to one's own knowledge:

> "*The manual worker is 'yesterday' [...]. The basic capital resource, the fundamental investment, but also the cost center of a developed economy, is the knowledge worker who puts to work what he has learned in systematic education, that is, concepts, ideas, and theories, rather than the man who puts to work manual skill or muscle.*" (Drucker 2010), p. 34

In advanced economies, more than 60% of the labor force are knowledge workers, i.e., workers whose primary activity is the manipulation of symbols and the generation and use of knowledge, rather than the manipulation of physical artifacts.

For companies, knowledge has become an essential production factor alongside labor and capital. Knowledge in and for work processes must be created, preserved, changed and used in a targeted manner to promote the direct exchange of knowledge and knowledge-based collaboration among employees. These activities are often subsumed under the term "knowledge management".

If one assumes that knowledge cannot be stored in databases, then the acquisition and sharing of knowledge is per se a cooperative activity.

1.2 Serendipity and Peripheral Information Supply

When searching for information in cooperative knowledge processes (desktop scenario), a user who, according to the prevailing conception of business informatics (Krcmar 1997; Mertens et al. 1997), has a subjective need for information, usually decides on a series of search terms which he fills into a form. If this procedure does not lead to success, it is usually due to one of the following reasons:

- The information searched for does not exist in the system, i.e. it is a case of a lack of information due to "empty" search results.
- The subjective search criteria selected based on personal knowledge do not correspond to the objective criteria that an omniscient observer would have selected, for example. Consequently, the subjective need for information differs from the objective need for information required for a successful search, which in turn leads to an inappropriate demand for information (see Figure 1).

Due to the almost unstoppable growth in the supply of information, the first case is now relatively rare. It is more likely that the supply of information resulting from a specific demand for information exceeds the subjective need for information to such an extent that the information sought is "lost" in the mass of available information due to a pseudo-supply.

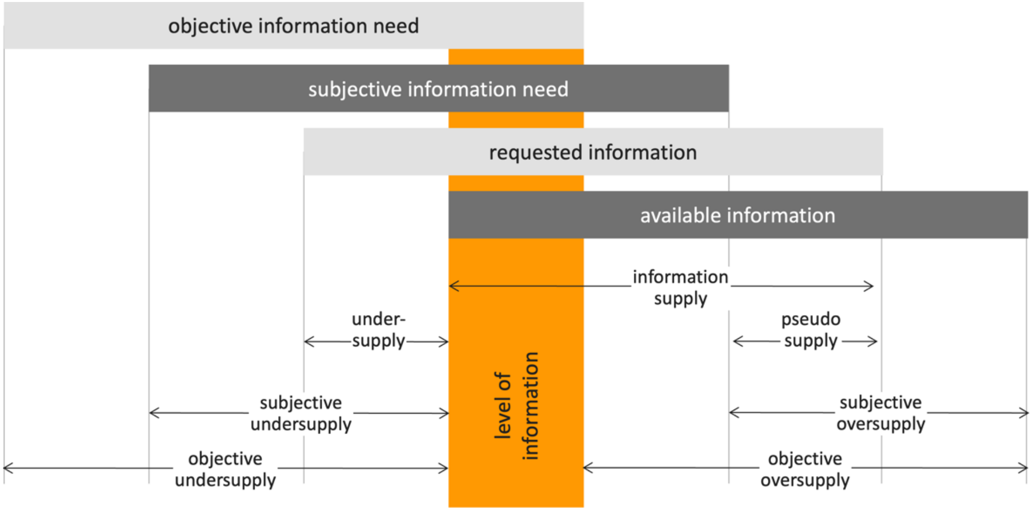

Figure 1: Congruence of information need, supply and demand (inspired by Strauch 2022)

Ubiquitous user interfaces now offer the possibility of making content and the relationships between the information providers and the information provided, which were previously usually completely hidden in the systems, "ubiquitously" visible to potential information consumers. In principle, the use of additional information emitters harbors the risk of further increasing the information overload through an additional channel. In return, however, the proactive and peripherally perceptible information offer that arises without the need for a specific information request can increase the potential of randomly finding relevant information (instead of targeted searching) known from Web 2.0, which is also commonly expressed with the term "serendipity" (Busch 2024; Hannan 2006; Roberts 1989).

Especially in systems with innovative or disruptive content, such as innovation management solutions or other systems that support highly interpersonal or creative processes, serendipity can provide decisive added value to improve the supply of information. As shown in Figure 2, this can contribute to an (objectively) better level of information and ultimately to higher information quality (see also (Koch & Ott 2008; Ott et al. 2009; Ott et al. 2010)).

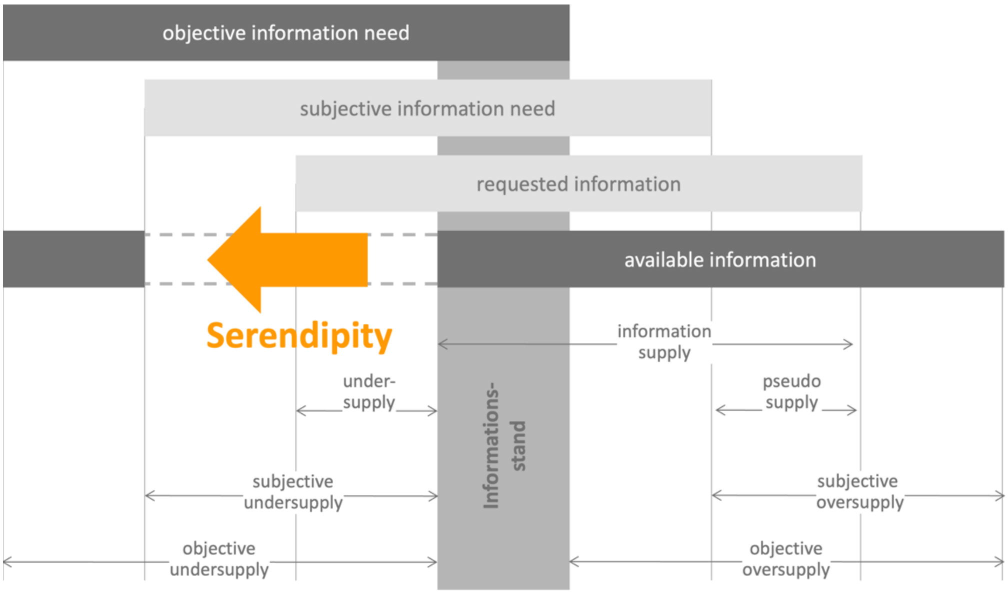

Figure 2: Change in information supply by serendipity

In practice, such an effect could be generated for innovation management by displaying a selection of available ideas in a highly frequented, shared location, such as a coffee corner. The same applies to the presentation of current projects and assigned employees based on an internal social networking service for cooperative knowledge processes. Here, too, great added value can be created if someone "accidentally" (in passing) discovers that a colleague is currently working on similar issues.

1.3 Awareness (Support)

Supporting informal communication is relevant to both teams and communities because it helps members to establish a common ground that is necessary for conversations and relationships. "Common Ground," as Clark defines it in his book Using Language (Clark 1996), is information that two parties share and are aware that they share. According to Clark:

> "*Everything we do is rooted in information we have about our surroundings, activities, perceptions, emotions, plans, interests. Everything we do jointly with others is also rooted in this information, but only in that part we think they share with us.*" (Clark 1996)

Closely related to the idea of Common Ground is the concept of Awareness, which has already been intensively studied especially in the field of Computer-Supported Cooperative Work (CSCW). Dourish and Belotti define awareness as "*understanding of the activities of others, which provides a context for your own activities*" (Dourish & Belotti, 1992). Context for one's own activities can be different types of information, starting with the availability of colleagues to messages about people or information that may be relevant for one's own work or leisure activities. Schlichter et al. consider the provision of awareness to be the greatest commonality in all types of group support (Schlichter et al. 1998). They evaluate the mediation of contacts and the sharing of knowledge as the main activities in communities that can be supported by awareness. While groupware focuses on workspace awareness, community support focuses on people/presence awareness (due to the lack of a common workspace).

The discussion of Common Ground and Awareness suggests that a detailed and aggregated overview of the community and its activities, a mirror of the community, can support the members of a community in their activities. One can identify different types of information that can be helpful for individual community members: Awareness about community members, about information provided by community members to the community, and about activities in the community space.

Awareness about Community Members

Information about community members already known to a person can help to coordinate activities. This application is already widely discussed in the context of awareness in groupware. For previously unknown members of the community such information can help to establish a contact. In addition to information about individual members of the community, aggregated information about the members can help insiders and outsiders to assess the potential and the expected help from the community.

Awareness of Information provided by Community Members

Communities group together people with similar interests. Consequently, information provided by community members in the context of the community is also potentially interesting for other members. This information also provides clues to the interests and expertise of the publishing users and thus supports the identification of communication partners.

Awareness about Activities in the Community Space

One specific type of information that community members implicitly provide is activities they perform on the community platform. These events, again detailed or aggregated, can help other community members identify information or people they can approach to find solutions to problems.

1.4 Information Radiators

The term “information radiator” has first been coined by Alistair Cockburn for frequently updated posters showing the current state in software development processes in a high traffic hallway (Cockburn 2001, 2008). The idea behind information radiators is to represent relevant information in a way that is easily accessible to all team members or stakeholders and can be understood at a glance in order to promote communication and understanding within the team and ensure everyone is on the same level of knowledge. Early non-digital examples of information radiators are Task boards, Burn-Down-Charts, Kanban Boards traditionally printed as posters and hung up in semi-public places where all team members could see them while working on their artifacts.

The main goal of digital information radiators is to provide pieces of information or in other words visual representations of information objects stored in the underlying data sources in a way that makes them consumable peripherally. In contrast to most other IT systems which only show information after a certain user interaction (e.g. a search) information radiators proactively distribute their “info particles” independently from any user to generate appreciation for the contributors and thereby motivate them for further participation and sharing (Ott & Koch 2012).

In the following two subsections we give a brief overview of important potentials of (semi-)public displays as information radiators for knowledge work. See for example (Ott & Koch 2012) for more information on this. Another analysis that comes to quite similar results can be found in (Khan et al. 2014).

1.4.1 Information Out-of-the-Box, Serendipity, Awareness

One key feature of information radiators is that they provide proactive and opportunistic information supply for knowledge workers with pieces of information that are otherwise hidden in IT systems. In (Ott & Koch 2012) the authors describe the following three things that can be taken out-of-the-box by information radiators:

1. Information objects out of the different hidden data silos where they are stored
2. Knowledge workers out of their restricted desktop-based working environment
3. Interconnections between the virtual world of (1) and the real world of (2) out of activity streams in Social Software.

Of course, this out-of-the-box effect cannot be applied for all kinds of data sources in equal manner. The approach can be especially helpful for information objects that are not searched deliberately but profit a lot from being displayed and consumed peripherally, like e.g. activity streams and other awareness information.

Figure 3: Semi-public information radiators in co-located office environment (Ott & Koch 2012)

As amendments to classic desktops (not replacements!) the interfaces can help to create visibility about what is going on in the organization (awareness). Thereby, the additional interfaces can help to efficiently generate a better common ground (for successful collaboration). Awareness is meanwhile widely spread in cooperation systems. The concept has been discussed for many decades in CSCW literature and can be seen as both enabler and facilitator for successful collaboration between knowledge workers (Gross 2013). The value of awareness comes from lowering coordination costs by enabling implicit coordination as well as from supporting different forms of intrinsic motivation (Schlichter et al. 1997). This appreciation through awareness is especially important for knowledge work as the incitement of many people relies on their contribution being seen and recognized. By the extension of user interfaces beyond the desktop this potential can be extended to social situations allowing not only individuals to separately consume awareness information, but also groups of people to jointly watch and talk about activities of others. This in turn can help to foster mutual knowledge (Schiffer 1972; Power 1984) through consequential communication.

1.4.2 Situated Social Place for Informal Communication

IRs can be part of a complex Ubiquitous Display Environment and create a public space with various situated displays. The purpose of these displays is to provide relevant information to the people in their surroundings, directed to the regulars and visitors of the space (Kuflik 2012). The term “display” in this context is not restricted to typical flat wall mounted large screens or respective projections but also includes various other form factors like horizontal (touch) tables (e.g. Shen et al. 2003), curved, tubular, spherical or flex displays (e.g. Wimmer et al. 2010; Beyer et al. 2013; Benko et al. 2008; Steimle et al. 2013) or (interactive) floors (e.g. Bränzel et al. 2013).

Envisioning a combination of multiple displays with different form factors in a semi-public collaboration space for knowledge workers in modern office environments such a ubiquitous (multi-)display environment integrated into a corporate coffee corner could look like Figure 4 (adapted from the project described in (Ott & Koch 2019)).

Figure 4: Natural Open Collaboration Spaces (NOCS) as situated social place for knowledge workers (Ott & Koch 2012)

Hybrid work settings inherently cause original inter-human communication to be artificially digitalized by using computer systems. However, knowledge sharing is a social process in which people share information in networks and communities. In this context public displays can go beyond physical barriers of single user desktops (left side in Figure 4). The displays can be installed in different semi-public places, like beside the elevator, in the coffee corner or other social areas where people come together. The re-integration of information objects into their social surrounding enables people to directly talk about the discovered information without computer mediation.

From this perspective the following things are important for the sociotechnical integration of collaborative knowledge processes (Ott & Koch 2012):

- Open physical spaces where people can come together and talk to each other willing to share their individual knowledge.

- Semi-public user interfaces in these natural open collaboration spaces facilitating the access to relevant enterprise data sources.
- Visualizations linking the virtual and the (real) physical world and allow ice breaking between people standing in front of the screens to motivate them for ad-hoc knowledge sharing.
- New interaction paradigms that enable real social multi-user interactions for joint in-formation discovery and joyful collaborative browsing in information spaces.

Based on these assumptions, information radiators can be seen not only as an additional user interface for knowledge workers, but rather as a socio-architectural situated space with different semi-public user interfaces in which both interaction with the displayed information as well as informal communication and interaction around the displayed information takes place. Exactly this situated social place is in most of the cases missing in hybrid interaction scenarios today.

In summary, (interactive) information radiators (IIRs) can support (collaborative) knowledge work by providing awareness, simplifying serendipitous information discovery and building a situated social place for matchmaking and informal communication.

1.5 Communities and Community Support

In the previous sections we have mentioned the term “community” several times. A community is a group of people who share an interest, identify with a common idea, or more generally belong to a common context. Communities can consequently be seen as descriptive identities for a number of people (Mynatt et al. 1997). In addition to the requirement of a common communication medium, common (communication) protocols, and an awareness of the existence and membership in the community, characterizations of the concept of community often emphasize the need for mutual cooperation in the community, e.g., the willingness to share information or to help each other (Ishida 1998). Thus, a community should be seen not only as a group of people who have something in common and can communicate about it, but as its group of people who are willing to help each other and who cooperate for the benefit of all.

Summarizing different definitions one can characterize communities as groups of people who share values, interests and collaborate or help each other in the context of the common interests (Mynatt et al. 1997). Most characterizations also ask for a common physical or geographical place, the same city, a village or a building. This meeting place can also be a virtual one – an electronic communication channel (provided by a community (support) platform).

The use of networked computers to support communities can be traced back to the early days of the Internet: The second service of the original Internet, the File Transfer Service, was "abused" soon after its introduction to exchange messages between people - e-mail was invented (Hafner & Lyon 1996). Mailing lists and newsgroup services quickly followed, both on the Internet (Arpanet) and on alternative networks formed by loosely coupled computers (e.g., FidoNet). These first community support services on the Internet still exist today. In addition, numerous (web-based) platforms have emerged in recent years that provide virtual places for communities.

At the same time, community support did not begin with networked computers. In addition to computer-based approaches such as electronic bulletin boards, MUDs, and MOOs, there have always been traditional approaches to community support such as letters, journals, shared spaces with notice boards and bulletin boards, and special radio and television programs. Both types of support provide a medium that can be used for communication and interaction among community members. And both types have their advantages and disadvantages. For traditional media, the advantages are availability, familiarity, and ease of use. For electronic media, the advantages are the reach, the possibility of personalization and the possibility of easy replication.

When generalizing the functionalities of different (online and offline) community support systems, one finds support functions for the basic activities in communities mentioned before:

- Providing a medium for direct communication and indirect exchange of content and comments within the common topic area of the community.
- Provision of information about other members and support in finding potential communication partners.

In order to combine the advantages of classical and electronic support, these functionalities should be offered as simply and ubiquitously as possible in community support systems.

A special type of communities are the so-called communities of practice (Lave & Wenger 1991). A community of practice is organized around a knowledge area. Members of the community work on similar tasks and support each other by combining resources or sharing and adapting knowledge. Knowledge is exchanged through direct and indirect communication. In large communities, where not everyone knows everyone else, direct communication is usually preceded by finding and getting to know an interaction partner.

This also demonstrates the close link between community support and knowledge management. Since knowledge management is essentially the direct and indirect bringing together of knowledge carriers, it represents nothing other than the support of direct and indirect communication in the communities of practice in which the sought-after knowledge is available. This insight is also the origin of the currently observed reorientation from a database-centered approach to knowledge management with a focus on externalization and storage of knowledge to a communication-centered approach to knowledge management with a focus on various community support functionalities.

1.6 CommunityMirror Concept

In Section 1.4 we already have presented how Interactive Information Radiators (IIRs) should look like and how they can provide benefit to users. In our project we labeled such devices "CommunityMirrors". The name highlights, that the main task of the devices is to mirror back the community of people and what they do to the people.

The term "Community Mirror" was first used in a study researching "Social Group Awareness" (Borovy et al. 1998). It was explored how "Meme Tags" could help information exchange between conference-goers. The tags allowed the conference participants to exchange memes with each other. The memes could contain ideas or opinions. A server system collected information about the exchanges and reflected them back in "Community Mirrors". These large, public video displays presented the community dynamics in real-time.

"Our" CommunityMirrors should be public, shared, interactive, and personalized:

- Public: The CommunityMirror is located in a public space accessible to all community members (and possibly non-members) and can be used by anyone who has access to the space
- Shared: The CommunityMirror can be viewed or used by more than one person at a time.
- Interactive: users can interact with the CommunityMirror.
- Proactive/Personalized: The CommunityMirror can respond to the user (without the user interacting directly with the CommunityMirror), e.g., by detecting users and adapting the display to the detected users.

In our initial work we focused on semi-public, shared displays, i.e. displays that are placed in a (semi-)public space where members of a community meet. Special emphasis was put on supporting shared use, e.g. also by offering the possibility to observe or peripherally perceive other users and thereby become aware of them.

See the following chapters for more information on the CommunityMirrors project.

2 Project History - How it all began

The foundation of the concept of CommunityMirrors and the first prototypes of CommunityMirrors can be traced back to work on Community Support in general (*Project Campiello* at XRCE, *Project CoBricks* at TUM) – and two activities designing artefacts (for community support) at the edge of the 21st century.

The first design activity was work with design students from all over Europe in the atelier workshop “Identity Management and Privacy” which took place at the i3 summer school in Ivrea, Italy, in September 2001. In the atelier we started with the challenge of how to support identity management at physical meetings and developed concepts for advanced (paper) badges but also for a “*Community Pillar*”.

The second activity was work with art and design students from Germany. The idea was to design an application for showing information that is usually hidden in the closed systems inside a university library – the “*Library Mirror*”.

Main publications to look for more information:

Grasso, A., Koch, M., & Snowdon, D. (1998): Campiello - New User Interface Approaches for Community Networks. In D. Schuler (Ed.), Proc. Workshop Designing Across Borders: The Community Design of Community Networks.

Koch, M. (1998): Knowledge Management and Knowledge Agents in Campiello. In B. Lees, H. J. Müller, & C. Branki (Eds.), Proc. Workshop on Intelligent Agents in CSCW (pp. 44–52).

Koch, M., Rancati, A., Grasso, A., & Snowdon, D. (1999): Paper User-Interfaces for Local Community Support. In J. Ziegler & H.-J. Bullinger (Eds.), Proc. Eighth International Conference on Human Computer Interaction (HCI), Vol.2 (pp. 417–421). Lawrence Erlbaum Publishers.

Agostini, A., Giannella, V., Grasso, A., Koch, M., Snowdon, D., & Valpiani, A. (2000): Reinforcing and Opening Communities Through Innovative Technologies. In M. Gurstein (Ed.), Community Informatics. Idea Group Publishing.

Koch, M. (2002a): Requirements for Community Support Systems - Modularization, Integration and Ubiquitous User Interfaces. Journal of Behaviour and Information Technology, 21(5), 327–332.

Koch, M. (2002b): An Architecture for Community Support Platforms – Modularization and Integration. In H. Luczak, A. E. Cakir, & G. Cakir (Eds.), Proc. Sixth International Scientific Conference on Work with Display Units (WWDU 2002 – World Wide Work) (Issue May, pp. 533–535). ERGONOMIC Institut für Arbeits- und Sozialforschung Forschungsgesellschaft mbH.

Koch, M. (2003): Designing Communication and Matchmaking Support for Physical Places of Exchange. Proc. Workshop Moving from Analysis to Design: Social Networks in the CSCW Context (at European Conference on Computer-Supported Cooperative Work 2003).

Koch, M., Monaci, S., Botero Cabrera, A., Huis in't Veld, M., & Andronico, P. (2004): Communication and Matchmaking Support for Physical Places of Exchange. Proc. Intl. Conf. on Web Based Communities (WBC 2004), 2–10.

2.1 Inspirations and First Ideas

First ideas for the CommunityMirrors go back to work on the project Campiello (1997 – 2000, Esprit Long Term Research #25572).

The aim of Campiello was to promote and sustain the meeting of inhabitants and tourists in historical cities of art and culture (Agostini et al. 2000). This should be achieved by dynamic exchange of information and experiences between the communities of people who live in historical art cities and external visitors.

The information space of Campiello consisted in a set of items: physical places, events plus more abstract topics of interest. Another categorization: contents, items, people, traces.

On the technical side, Campiello tried to implement

- Collaborative filtering of information (Knowledge Pump)
- Complementing personal computers with large screen and paper input possibilities (CommunityWall)

The idea was to use paper sheets for the community members to contribute content and comments – minimizing the digital gap by scanning the paper input using modern copying machines and first versions of 2D barcodes on the paper – and have large (non-interactive) screens for displaying the content for the community to consume.

Based on the work in Campiello the idea emerged to go for a modular solution. Instead of isolated applications that implement the collection, distribution and visualization of information, applications for visualizing and exploring the information should be connected to existing community platforms.

To realize such hybrid systems, different applications have to be integrated. Based on this requirement we have developed Cobricks, a modular framework for building community platforms that can easily interoperate with other platforms and external applications such as CommunityMirrors.

One central part of Cobricks was a data model for community support platforms – with user objects as a central data class – and additional data classes for items (content) and categories (organizations, communities).

On the user interface side part of Cobricks is the CMirror application framework. Using this framework, community mirror applications can be created

In summary, the following basic support concepts were derived:

- Providing a medium or channel for direct communication and for indirect exchange of information objects or comments on objects within the common scope (the information space) of the community. The information channel can be enhanced with features that use information about the community member to do (semi-)automatic filtering and personalization.
- Providing awareness of other members and helping to discover relationships (e.g. by visualizing them). This can help to find possible cooperation partners for direct interaction (matchmaking, expert finding).

2.2 Supporting Communities at Physical Meetings - MeetingMirror v0

In September 2001 the atelier workshop "Identity Management and Privacy" took place at the i3 summer school in Ivrea, Italy. The students participating in the atelier were Sara Monaci, Andrea Botero Cabrera, Patrizia Andronico, Mirjam Huis in´t Veld, Yanguo Jing, Leonid Pesin, Lynne Bailie, Richard Boardman, and Liisa Ilomäki – the atelier workshop was led by Michael Koch.

In the atelier the group addressed the challenge of how to support identity management at physical meetings.

2.2.1 Supporting Communities at Physical Meetings

An important activity in communities of practice is to participate in (physical) community meetings, i.e. events during which members of the community come together for communication and for exchanging information.

Support for awareness and matchmaking during such physical events currently is limited to simple badges and (printed) participant lists. These tools usually cannot be influenced a lot by the community members whose information is distributed through them.

We took these observations as a starting point to look closer into possibilities to support community meetings. To start the design process, we first asked ourselves the question of "How do people get in contact with each other and what do they need for that?".

To introduce the participants to each other usually simple badges that show the name and affiliation are used. These devices help to identify possible communication partners and to start conversations. However, the possibilities classical name tags offer to introduce oneself to the community are very limited.

While presenting individuals to the community is something happening in face-to-face encounters, there also has to be a possibility for a member to get an overview of the community as a whole. It should be possible to get information about all participants to quickly identify possible contacts.

The participant lists that fulfill this task today are very inflexible and do not cover all possibilities of this function. Later in the paper we present the concept of a Community Pillar as a medium that is accessible for the whole group and that allows to get an overview of the group.

2.2.2 Making up our First Device: A Connected Badge

After defining the basic conditions, we started working with scenarios trying to think about possible situations where a user should need to introduce himself. In the design practice, scenarios are a quite common way of approaching projects, and it is an effective technique to push teamwork to generate new solutions (Carroll 1995). In our discussion we deliberately concentrated on the design process, which often is neglected in technology driven work on user interfaces. As a result, our work is not a technological design description but wizard-of-oz prototypes and mock-ups, scenarios that present our design ideas and that can inspire future user interface developments.

Starting point of the scenarios was the name tag or badge. Usually, every participant of a meeting gets such a badge when arriving at the meeting. This device solves some basic needs:

- It gives essential information about the user: name, surname, university of affiliation, country.
- It is easy to wear and to bring around.
- It can be stored after the event as a souvenir of the meeting.

Nevertheless, this traditional tool has some evident limits and defeats: even if it presents information to other people, it does not give the user means to say something more about his personal identity. The presented information does not include any of the features involved in someone's likes and dislikes and personal attitudes. The traditional badge, besides, can hardly be modified or customized by the user himself: its structure is quite limited and usually corresponds to a predefined schema. That adapting and extending the information on badges is a real need shows in the fact that during meetings you often can see examples where participants try to correct or modify data on the badge - sometimes details are wrong or misspelled. So, if people could interact with a dynamic badge and directly update it without intermediaries, it would be much easier to change and add personal information even during the event. In this way the tool could be a distinctive sign of the individual and it could increase the general awareness of the community.

An ideal badge should give information about the person wearing it and be easily customizable by the owner herself. With these requirements in mind, we tried to focus on different mock-ups using raw materials like colored paper, pencils, bend etc. and we worked out some examples (see Figure 5).

Figure 5: Building prototypes for badges (Koch et al. 2004)

The first examples were paper based only, and allowed to add personal information in different ways and to update the information when needed (by reprinting the badge or by adding paper stickers). Upon these first quite basic prototype we started to create scenarios with digital badges with a chip memory integrated in a square card, light and easy to carry around, but we settled down for the less technologically driven paper-based solution in the end. The event organizers distribute paper-based badges but allow the users to control the information on their badges through the identity management application. The participants can customize their profile information prior to the event. During the event they can correct and enhance information by reprinting the badge. Additionally, stickers and post-its are provided to add dynamic requests to the badge.

As "personal device" that is used to exchange information between people who are close to each other, the badge is not a tool for getting an overview of a community and its members. Trying to think about a device which could support this we have been starting to imagine the Community Pillar we are going to describe in the following section.

2.2.3 The Pillar: Staging Interaction

The Community Pillar is the most important component of our concept for supporting matchmaking and awareness during physical meetings. Basically, the Pillar is a large cylindrical digital display that is installed at a highly frequented space at the community meeting. The cylindrical shape makes the Pillar accessible through all sides and invites people to surround it. The Pillar, as part of the community support system, has access to information given by all the members of the community through the Web interface before and during the meeting. Through queries using the touch sensitive screen the information can be presented on the Pillar with visual animation.

The Pillar located in a public area, constantly displays icons (images) of all the participants. These icons can be specified by the participants prior to the event or during the event using the Web based identity management application. A participant standing in front of the Pillar can select a question to the database from a set of queries, like "Who comes from Spain?" The Pillar will "move" the icons that correspond to the query and make them gather around the point where the query was made. The result as seen by the person asking the question, is a visual collection of icons that can give a "general" image of the kinds of people that matched the query. The person if interested, can go deeper into each participant's information by touching the respective icons to find out about the person or add another query on top of it. If the objective was to know only an approximate number, the collection of icons gathered will be sufficient.

Figure 6: Interaction with the Community Pillar (Koch et al. 2004)

Since the icons move (through animation) around the Pillar when the query is done, passers-by can discover their icons moving around and might feel tempted to inquire who and what has been asked for. Also, other persons around the Pillar can have a "feeling" of what is going on. In this way the questions been asked to the database remain visible for the whole group and need not to give very specific details in the first instance. It is important to note that every person remains free to decide the level and amount of information that gets accessible through the Pillar and can change those settings during the whole event by using the web interface.

In addition to queries for (static) attributes of the participants the Pillar also allows to display dynamic announcements and to search for the association of members with these announcements. For example, a spontaneous trip to the local pub or a tango session by an enthusiast participant can be announced. Members of the community, in search for activities, can check for a general idea of who is going and decide to join. These specific announcements are visualized in the upper part of the Pillar to distinguish them from the other regular queries about the composition of the community.

The results of the project did not go beyond paper prototypes (for the badges) and concept images (for the Pilar) – but were taken up when we build the first CommunityMirror prototypes.

2.3 LibraryMirror

In 1999 Technische Universität München (TUM) started to rebuild the university library on the main campus in Munich. In the context of this activity TUM and Akademie der Bildenden Künste held a competition to create a piece of art to be installed in the new library ("Kunst am Bau").

Winner of the competition were the students Sandra Filic and Susanne Wagner from Akademie der Bildenden Künste in Munich. The winning project "Engramm" took search terms used in the search form of the web-based library search engine and projected theses on a large white wall in the foyer of the library.

"Engramm" was envisioned as video installation. But we worked together with the students to make the installation dynamic – i.e. to tap into the real data from the library search engine and use this data to build animated views to show both live data and historic data. The installation was implemented by Minh Ngo in his master thesis at TUM (Ngo 2004).[1]

[1] See https://idw-online.de/en/news?id=82131 from 21st Juni 2004

Figure 7: Different views of the LibraryMirror with live data

On June 23rd 2004 the re-opening of the library was celebrated and the installation was presented – and operated for several years as a “LibraryMirror” (see Figure 8).

Figure 8: "Engramm" installation in the foyer of the TUM university library on the main campus at the official re-opening of the library at 23.6.2004

The installation was nice to view – showed a view into the otherwise hidden data (out-of-the-box) and generated additional value. We did not do a formal evaluation of the installation but just performed informal observations and ad-hoc interviews. In these interviews we found an appreciation of what information is available in the library. Viewers found stimulation for what to look for in the library. Viewers also found that there seem to be people on campus sharing their interests by searching for such work. While the display did not provide information about who is searching for what, already the information that there is somebody searching for a particular topic helped to search for and identify this person via other research possibilities. So, several of the ideas presented in the previous chapter showed up.

3 Iteration through different Prototypes

Based on the ideas from Chapter 1 and the first activities presented in Chapter 2, we have designed and deployed several CommunityMirror applications. From the first starters described in the previous chapter we continued to explore the field of CommunityMirrors by building and using prototypes. This exploratory approach led to learnings about different issues – from how to design CommunityMirrors, how to collect information, where to deploy the devices, how to motivate potential information contributors and users (viewers) etc.

Main sources for more information on this:

Ott, F. (2018): CommunityMirrors: Interaktive Großbildschirme als ubiquitäre Natural User Interfaces für Kooperationssysteme, PhD Thesis, Universität der Bundeswehr München, Fakultät für Informatik. https://doi.org/10.18726/2018_1

Nutsi, A. (2018): Gestaltungsempfehlungen für mehrbenutzerfähige Informationsanwendungen auf interaktiven Wandbildschirmen im (halb-)öffentlichen Raum, PhD Thesis, Universität der Bundeswehr München, Fakultät für Informatik. https://athene-forschung.unibw.de/126792

Koch, M., Fietkau, J., Stojko, L., & Buck, A., (2021): Designing Smart Urban Objects – Adaptation, Multi-user Usage, Walk-up-and-use and Joy of Use (Schriften zur Soziotechnischen Integration, Volume 8). https://doi.org/10.18726/2021_1

Lösch, E., Alt, F., & Koch, M. (2017): Mirror, Mirror on the Wall: Attracting Passers-by to Public Touch Displays With User Representations. Proc. 2017 ACM International Conference on Interactive Surfaces and Spaces, 22–31. https://doi.org/10.1145/3132272.3134129

Ott, F., Nutsi, A., & Lachenmaier, P. (2014): Information Ergonomics Guidelines for Multi-User Readability on Semi-Public Large Interactive Screens. Proc. Workshop on Information Ergonomics: Leveraging Productivity by Aligning Human-Information Ecologies, 14th International Conference on Knowledge Management and Knowledge Technologies (i-KNOW'14).

3.1 CommunityMirror Core Concept

In Chapter 1 we already presented the first ideas that lead to the development of the CommunityMirror concept.

The main goal of CommunityMirrors was to provide pieces of information or in other words visual representations of information objects stored in hidden data sources in a way that makes them consumable peripherally (information out-of-the-box, serendipity). In contrast to most other IT solutions which only show information after a certain user interaction (e.g. a query) CommunityMirrors proactively distribute their Info Particles (IP) independently from any user. So, there is no direct need to interact with CommunityMirrors - however the possibility to interact with them might support its function.

Regarding the input/output-modalities we focused on large interactive screens that allow for potential multi-user interaction with different interaction zones (see Figure 9). The theory of the interaction zones is mainly derived from (Prante et al. 2003, Vogel & Balakrishnan 2004) and was adapted to the given context. Beside a semi-public Interaction Zone as well as potentially available Private Zones we identified three interesting areas:

- The Communication Zone, in which users actively monitor other people or talk to them while they are interaction with the system.
- The Notification Zone, in which users' attention can quickly be caught by certain attractors on the screen.
- The Ambient Zone, which mainly supports the submission of peripherally recognizable awareness information ("information radiation").

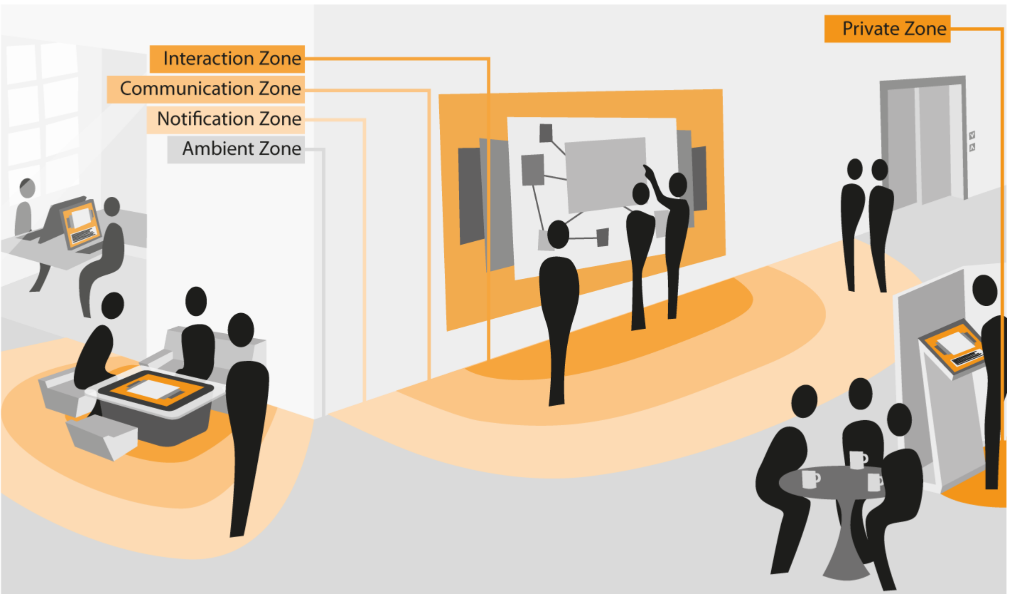

Figure 9: Different interaction zones of CommunityMirrors

The different zones distinguish themselves especially by different levels of attention the respective users pay to the application. This can be visualized with regard to the view direction of the corresponding users as shown in Figure 10.

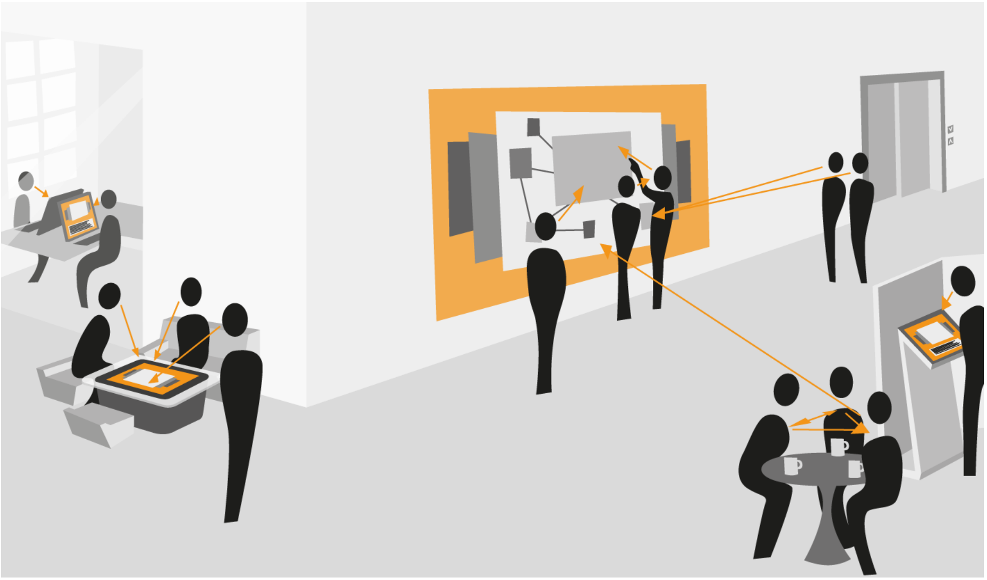

Figure 10: View directions of the different users in the social surrounding

With the use of Social Software as additional data source for CommunityMirrors we are confronted with another level of intensity: the intensity of the user interaction with the Activity Stream. In Social Networks there are typically certain power users with a very strong presence that frequently comment on posts (dominators). In contrast to that, there are many users that do not interact at all and just watch what is happening in the stream (observers). This spectrum is also valid for semi-public interaction with Social Software beyond the desktop. Based on our experiences we differentiate the following interaction levels beside the ground level "(0) Not Involved":

(1) Awareness: The first level; users of this level are in most cases just passing by in the ambient or notification zone in Figure 9. This level is also very present in the communication zone. Here even twice, once as awareness of what is shown on the screen and once as awareness of what other users are talking about while using the system. Users that have reached this first level can be attracted very easily to "higher" interaction levels when they see something they are interested in personally.

(2) Discovery: The second interaction level is reached as soon as a user becomes somehow active in the interaction zone of Figure 9, e.g. he wants to display more details about a seen info particle. The typical behavior in this level is browsing around for a while in the information space. The duration of this discovery phase depends very much on whether the users can easily find more information that they are personally interested in as well as of their personal involvement in the information they see.

(3) Engagement: This third level is very specific for Social Software and depends much on the personal identification of the users with the content he has discovered. Depending on the individual involvement he will show his appreciation for some of

the displayed info particles. The best-known mechanism Social Software offers for that is the Like-Button known from Facebook. But also, other engagement mechanisms like e.g. a star are accepted.

(4) Collaboration: This last and highest interaction level is reached as soon as a user decides not only to consume information or engage for it, but to really contribute to the joint information space. The easiest way of doing that is leaving a comment to a certain info particle.

With the use of CommunityMirrors with data from Social Software especially engagement and simple ways of collaboration become more important. By implementing these mechanisms in the user interface and especially by transferring the results back to the source systems CommunityMirrors can help to foster participation and generating more appreciation for contributors. One main challenge for the interaction levels 3 and 4 is the required identification of the respective user. This is quite simple in single-user desktop scenarios, but at least somehow challenging in the semi-public multi-user touchscreen setting. Here, the input of username and password while other people are watching is not desirable. We are currently experimenting with different technical approaches together with industry partners to find better solutions for identification as well as for authentication.

3.2 Technology Probes and Experiments from 2004 to 2024

For exploring the design space of CommunityMirrors, we followed the approach of "technology probes" to assess the usefulness of the design by situating it in real contexts and watch what happens. Technology probes have been first discussed by (Hutchinson et al. 2003): "*deploy a prototype into a context, allowing designers to research how the prototype has changed their practices through interviews, logging, and other types of data collections*".

The following list shows the major technology probes in the past twenty years. More details on the probes from 2008 to 2014 can be found in (Ott 2018, p. 413ff).

- Conference Mensch und Computer 2004, Paderborn (Koch et al. 2004)
- Several small national and international meetings between 2004 and 2007
- SAP University Meeting at TUM (2007)
- SAP EMEA User Group Meeting, Walldorf (2008)
- Trade Fair SYSTEMS, Munich (2008)
- BMBF Zukunftsforum, Berlin (2009)

- Webinale , Berlin (2009)
- gate ideation competition, Garching (2009) – see (Blohm et al. 2010)
- Zukunftsschiff MS Wissenschaft, different locations (2009)
- Bundeswehr Fernausbildungskongress, WikiBw, Hamburg (2009)
- Jahresausstellung der UniBwM, Neubiberg (2009 - 2010)
- Holistic Innovation Center / SkiBaserl Mirror, München (2010) – see (Moritz et al. 2010)
- UniBwM Tag der offenen Tür, Neubiberg (2010)
- HYVE Office Innovation Contest, Munich (2011)
- 3M Headquarter Community, St. Paul (Minnesota) (2011-2013) – see (Ott & Koch 2014, Ott & Koch 2019)
- Conference Mensch und Computer, Munich (2014)
- Alumni Mirror at UniBwM (2014-2020)
- UrbanLife+, Mönchengladbach (2016-2021) – see (Fietkau 2023b; Fietkau & Stojko 2021; Koch et al. 2021; Koch et al. 2017; Kötteritzsch et al. 2016)
- Community Mirror Network (2016 – now) (see Chapter 4 and various publications – e.g. (Koch et al. 2023)

More short-term prototypes for experiments have been built and used in the following PhD Theses:

- *Nutsi, A. (2018): Gestaltungsempfehlungen für mehrbenutzerfähige Informationsanwendungen auf interaktiven Wandbildschirmen im (halb-)öffentlichen Raum, PhD Thesis, Universität der Bundeswehr München, Fakultät für Informatik. https://athene-forschung.unibw.de/126792*
- *Lösch, E. (2020): Unterstützung der Exploration von mehrbenutzerfähigen interaktiven Informationstafeln im (halb) öffentlichen Raum, PhD Thesis, Universität der Bundeswehr München, Fakultät für Informatik. https://athene-forschung.unibw.de/131737*
- *Stojko, L. (2025): Personalizing User Interfaces of Large Interactive Displays for Intercultural Groups in Semi-Public Areas, PhD Thesis, Universität der Bundeswehr München, Fakultät für Informatik, to be published*

3.3 Learnings from the Technology Probes

An in-depth discussion of the learnings from the technology probes can be found in different publications throughout the years - a large number of summarized learnings in (Ott 2018) and (Nutsi 2018).

In this and the following section we try to summarize some of the learnings in the form of a list of design areas and single design parameters.

3.3.1 Benefit - What Information to provide

In the technology probes we learned that we have to look into the benefit of the installation for the potential users from the very beginning. Only an installation that provides benefit has a chance to be used and to be worth the effort of maintaining it – or to collect enough motivation for crowd sourcing the content acquisition.

We started with the hypothesis that “classical” workspace awareness information is most suited for providing benefit – i.e. information about changes to objects in the workspace and about interactions or relationships of people with these objects.

In the long-term installations, we found this hypothesis confirmed – but also extended. People were asking for short term benefit like

- Current time
- Canteen menu
- Weather forecast
- Maps
- Stock prices (other performance information for the company or department)
- Public transport schedules

Additionally, a relation of information to people proved to be important - not just “dry” information. So, when displaying announcements or information about new publications, the people related to this information should be highlighted – there should be a possibility to navigate to information about these people and to more information provided by these people.

Some learnings were about the display of the information: it should be easy to catch – i.e. short and catchy headlines, images.

For an information display to be of interest for users the novelty effect proved to be important (Koch et al. 2018). There should be new information and new functionality regularly. And it is beneficial to draw the attention to this new information – the newness of the information. As documented in (Koch et al. 2018) there was no fixed timeframe how often the information should be updated – the time was related to how often the information screens have been frequented by the users. If users pass by several times a day, there should be new information every day. Since not the whole information set is replaced every day, it has shown beneficial to indicate which information is new.

In addition to provide potential benefit, it has become clear that sometimes the potential users have to be made aware of this benefit. This is not new to the introduction of technical solutions – e.g. in the field of Enterprise 2.0 platforms have been introduced that offered beneficial possibilities to potential users – but users have not seen these. People had to be made aware of the benefit – not only the functionality, but how this functionality could be beneficial.

3.3.2 Acquisition and Preparation of Information (Data Sources)

Ideally, the information for the information screens is collected and curated manually for this application – however this does not work in practice – After an initial phase, where the organization and the people running the project were willing to provide resources to do this, this willingness more and more vanished and finally, no more (new) information was provided.

So, one has to tap into sources of information that are filled with other processes / motivations. We have identified two ways to do this:

- Automatic acquisition / automatic curation: Using a mashup service we developed in parallel to the CommunityMirrors project (Lachenmaier et al. 2011, 2013) we made it easy to import information from other sources providing a (REST) API or just a more or less stable Web UI. So, for example we were able to import announcements from RSS/Atom feeds, information about people from company directories, information about publications and projects from publication databases. As commented before, this information often lacked some attributes needed for successful usage in CommunityMirrors like short headlines or images. We found that this could (and should) be addressed by automatically augmenting the information objects, e.g. by searching for images or by generating matching images.
- Crowdsourcing: Another possibility to get information was to make it beneficial (and easy) to people to provide this information. E.g. by creating announcement services that feed into the data base. One very successful example for this was building a Web service for managing potential topics for student theses – that could be used on departmental web pages – but also our CommunityMirrors.

3.3.3 Selection of Information

Now we have information in the system – available for showing or browsing. The question remains what information to display as an entry point (when nobody is interacting with the display). We found that filtering based on context parameters is preferable to pure random selection.

Potential context parameters are:

- Location of screen – this mainly grew into looking at the (needs of the) potential user groups frequenting the screens
- Time of day – e.g. not presenting information about menus in the cafeteria after lunchtime … highlighting the bus schedule at the end of the workday, …

Selection of information and of different designs for how to display information can also be based on the cultural background of the potential user (again based on the location of screen and time of day) – see (Stojko 2020; Stojko 2022) for more information on this.

In the experiments we found that users prefer a mix of content types (if available). Even if there is more content about people than about events, the people objects should not dominate the display. How exactly the ratio between different content types should be, may again depend on the cultural background of the users (Stojko 2020).

What we did not check up to now is, if preferably presenting information that has raised interest in the past is helping. There are arguments pro and contra here.

From the literature we additionally can take the advice to counter filter bubble effects by mixing in some randomly selected information into any selection based on context – e.g. mix in information from Organization 2 on a display that is located in Organization 1 and mainly presents information from there.

Filtering by context parameters is a kind of "personalization" of the information selection. We did not elaborate this much further since our setup does not allow for identifying individual users and do "real" personalization. The only approaches we have followed here were the adaptation based on potential cultural preferences of the users (based on location of display) – see (Stojko 2020, 2022, 2024) –, and a glimpse into what we could do by recognizing the emotions of the (anonymous) users (detected with a camera on top of the display) (Stojko & Koch 2023).

3.3.4 Display of Information

The most important factor to take into account when designing the display of information is that we are looking at a multi-user setup – several users in several interaction zones at the same time (see the interaction zone model in Figure 9 on page 22 – based on (Prante et al. 2003; Vogel & Balakrishan 2004; Michelis & Müller 2011; Ott et al. 2014)).

For the analysis of CommunityMirror deployments we are currently using the following distances:

- Interaction zone (direct): 0.0 - 0.8m
- Communication zone (subtle): 0.8m - 1.5m
- Notification zone (viewing): 1.5m - 2.5m
- Ambient zone (passing-by): from 2.5m – 4.0m

First the screen size has to be matching this setting. For a simultaneous interaction of two or more people the screen should be a minimum of 65''. In public space even larger (people keep more distance) – 80'' – so two interacting users can have a minimum distance of 75cm.

The screen should provide visual objects for users in the different interaction zones. The size of the objects should match the distance – so small and detailed elements in the interaction zone but large objects and short text in the notification zone and perhaps special visualizations to draw attention to the screen for the ambient zone (Ott et al. 2014). We have not yet solved, how to provide objects for the users in the different interaction zones and not confusing users. So, for example we tried objects in different (randomly selected) sizes for the different zones – which led to the question: "Does a larger circle mean it is more important?". So, different sizes are okay, but the size should correspond to some attributes of the objects. Other ideas for solving this problem where to divide the screen horizontally into different areas for the different zones – e.g. large objects for the notification zone on the top.

To determine ideal font sizes for different distances one can look into (Domhardt & Schmidt 2013). Based on a 65-inch 4K screen - beta=20', nav=2160px, ha=833mm, pOS=96ppi=3.78pt/mm, fR=2048, hxt=1117 the calculation results in (Nutsi & Koch 2016):

- 11.5pt (0.5m)
- 34.4pt (1.5m)
- 57.5pt (2.5m)
- 80.5pt (3.5m)

For selecting the ideal font type one can refer (Vinot & Athenes 2012) – who concluded that Verdana will be best.

A dynamic text display is recommended, so that content can be read from a distance even if the display is obscured. The text should be animated horizontally across the screen at a display rate of 100 to 115 words per minute (Nutsi 2018).

One issue that plays a role in this context is the investigation of which directions of text movement on the screen provide the best readability. The use of moving text on the screen is motivated by various findings that animated representations help to attract or increase the attention of users to the screen (e.g. Huang et al. 2008).

Classically, it is assumed that leading - i.e., moving a sequence of words from right to left - is the optimal mode of animation (So & Chan 2009). However, this work does not take into account that 1) the view of the screen may be partially blocked by other users (multi-user scenario), and 2) that users may not stand rigidly in front of the screen but may move while viewing the screen itself. In a laboratory study, we therefore tested these scenarios with different directions of movement for text and determined in each case the variant that provides the best subjective readability (Nutsi & Koch 2016; Nutsi 2018).

Figure 11: Laboratory experiment for determining the optimal animation direction for text (Nutsi 2018)

The result of the previous experiments was that the typical text animation direction (right to left) is not always the best choice. When a user is standing in front of the screen, it has been found optimal to animate the text vertically (from top to bottom). For moving users, it has been found optimal if the text moves with the user (in the direction of movement).

3.3.5 Interaction (Concepts)

Traditionally, information displays are non-interactive. Reasons for this range from costs for interaction technology and maintenance (including costs for regularly cleaning the touch displays) to unclear or missing benefits from including possibilities for interaction.

Making information displays interactive raises several problems with intuitiveness and usability that have to be solved to make walk-up-and-use possible. In the following we list some of these problems which we discovered to be particularly important for interactive information displays.

First the question has been, what to make interactive. Following the thought of improving benefit, we came up with the following ideas in the context of information displays:

- browse the information space – beginning with information you see (show related information, browse the information graph)
- take information with you (copy it to a personal device, into a personal account)
- search by information attributes
- show information not yet shown on screen

Several usability problems had to do with what other authors already titled “interaction blindness” (Houben & Weichel 2013; Memarovic et al. 2015): Potential users do not know that the screen is interactive, what screen components can be interacted with, what interaction results in.

Some other design recommendations regarding usability (in part from Nutsi 2018):

- The application should be intuitively controllable, which can reduce the risk of embarrassing mistakes in public (Hespanhol & Tomitsch 2015).
- Control functionalities should be available at different positions, and should only affect the space near the location users have interacted with. Global effects to the whole screen should be avoided.
- The control functionalities should be called up using a touch-and-hold gesture that can be executed as often as required and can also be called up simultaneously by several users in different areas of the wall screen.
- An action should be able to be canceled by a user at any point in time (Kristoffersen & Bratteberg 2008).
- Multi-user applications should not be modal, i.e. all functionalities should be available to all users at all times. Apted et al. (2009) recommends avoiding modal behavior as it interferes with the use of the interaction space.
- Feedback must be immediate, and it must be clear which user has triggered feedback. In the case of multi-user interactions, it also serves to raise awareness and should convey who controls which part of the application at which time.

In addition to “standard” usability problems there are some deeper problems with interaction that have to be addressed on a deeper (sociotechnical) level:

- People feared embarrassing mistakes in public.

- People were unsure if it was okay for their superiors if they spend time (interacting) in front of screens.
- Interacting by touch resulted in the screens getting dirty – and reducing the willingness to interact (Ott & Koch 2019; Mäkelä et al. 2022).

So, providing interactivity poses some problems. Are there gains?

Our hypotheses for gains of providing interactivity were:

- New possibilities (explore information)
- Better information intake
- Better motivation

In (Veenstra et al. 2015) the authors present a comparative case study that aimed to uncover the quantifiable difference between non-interactive and interactive public displays. In public space, content loop or physical pushbuttons for content selection and gaming. Result: interaction helps to engage viewers. The same came up in our own study with information radiators (Nutsi & Koch 2020). Another piece of related work is (Xu & Sundar 2016) where the authors conclude that higher interactivity enhances recognition as well as recall memory of interactive content but diminishes the recognition and recall memory of non-interactive content part of the interface.

3.3.6 User Attraction

Since using information radiators is a voluntary task, one can and should reflect about user attraction. In the previous sections we already discussed some of the design recommendations with user attraction:

- Animation
- Images, short titles
- Ergonomic issues (font size)
- New information (novelty effect of information)
- Social effects (group dynamics, honeypot effect)

More information on how this and other effects (e.g. adding user representations to the display) can increase user attraction can be found in (Lösch et al. 2015; Lösch et al. 2017; Lösch 2020).

3.3.7 Location of Installation

The location of a screen influences duration and type of interaction. An exposed location can inhibit or even prevent interaction.

In the different experiments we have done, we learned that installation in highly exposed locations should be avoided (people avoid exposing themselves too much). On the other hand, places where people frequently pass-by and wait are ideal. The application should be intuitively controllable and convey that the risk of social embarrassment is low.

For example, in one study (Blohm et al. 2010) we compared placing the display in the cafeteria of a company to placing it next to the elevators. The location next to the elevators clearly won. In the cafeteria people usually went for speaking with people and not for interacting with information radiator displays.

3.4 Generic Lessons for Design

In the various deployments, we were able to identify a wide range of design parameters for CommunityMirrors and, in some cases, to propose solutions. An overview of this has been presented in the previous section (see also Chapter 4 for what we have done in the CommunityMirror Network installation). Now we will present three more generic MCI cross-cutting issues we derived in the work on CommunityMirrors – as a kind of generic lessons for design:

- multi-user capability,
- walk-up-and-use capability, and
- joy-of-use.

3.4.1 Multi-user Capability

As mentioned earlier, large wall displays enable simultaneous use by more than one user. The use does not have to be coordinated at all. Even direct interaction with the screen by one user and simultaneous viewing of an information item on the screen by another user further back represents a multi-user scenario that must be considered in the design. In the scenario mentioned, for example, it is necessary both to allow direct interaction directly in front of the screen and to display additional information particles (e.g., in sufficient size) so that they can be easily perceived from further back.

To describe and analyze such multi-user scenarios, various interaction zone models for large wall screens have been defined and considered in the literature. Figure 12 (left) shows such a representation of interaction zones: In the active zone or interaction zone, people can interact directly with the screen, people in the attention zone focus their full attention on the contents of the screen or the activities of the people in the active zone, and people in the perception zone perceive contents or activities on the screen (peripherally) in order to then switch to the attention zone or active zone based on this.

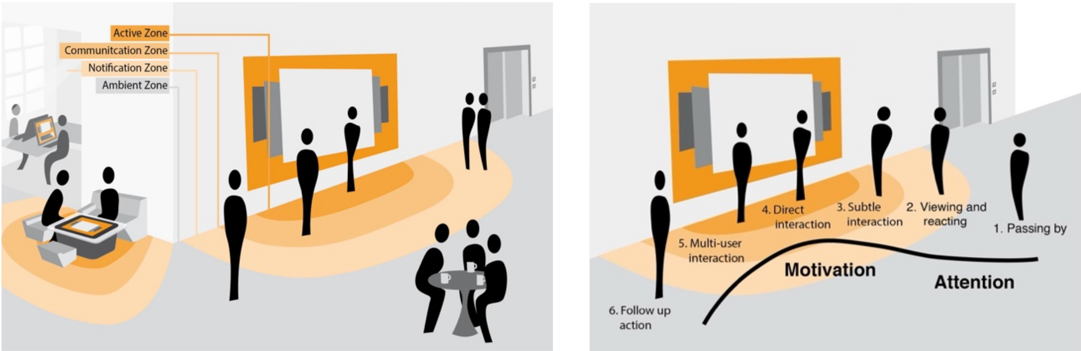

Figure 12: Spatial and temporal interaction models: While spatial models (left, according to (Vogel & Balakrishnan 2004)) divide the area in front of public displays into interaction zones, temporal models model the interaction process (right, according to (Michelis & Müller 2011; Müller et al. 2010)). Users move through different phases - from passers-by to active users.

3.4.2 Walk-up-and-use Capability

Since the use of CommunityMirrors will be spontaneous and without prior reading of a user manual, intuitive usability - or walk-up-and-use capability - is required in addition to multi-user capability.

Intuitive usability has been defined, for example, as: "*A technical system is intuitively usable if it leads to effective interaction through nonconscious application of prior knowledge by the user*" (Mohs et al 2006). Even earlier, Raskin discusses the relationship between intuitiveness and familiarity (Raskin 1994). However, the notion of intuitiveness of user interfaces has not been finally clarified (Herczeg 2009).

In the context of CommunityMirrors, we now specifically address the question of how anyone walking past the screens can

- 1) be made aware of the screen and the interactivity of the screen,
- 2) be motivated to approach the screen, and
- 3) be motivated and enabled to perform beneficial touch interactions with the screen.

From the model we orient ourselves thereby at the temporal interaction zones represented in Figure 12 right.

This immediately comprehensible and expectation-compliant use (or "intuitive" use) is again not a pure product characteristic. It describes rather relations between product, user and context. Intuitiveness reduces the “conscious part” of cognitive processing. Attention is then available to a greater extent for the primary task.

For the development of a solution, we currently rely on construction-oriented research (i.e. we build prototypes according to the determined requirements and with findings researched in the literature) supported by individual laboratory and field experiments with the built prototypes for the clarification of optimal design variants (Lösch et al. 2015).

The basic idea of the emerging solution is to start the communication with the passers-by at an early stage - i.e. when entering the outer interaction zones - and then to guide the users step by step through the different zones and into active interaction with the system. The system addresses the users by displaying motion-synchronized mirror images of the users on the screen, supplemented by short text instructions and other visual elements. The users recognize themselves in their mirror images and thus understand from a distance that the screen is reacting to them - in other words, that it is interactive. Text messages placed around the mirror image can also be easily assigned to the associated persons in a multi-user scenario, so that individual support for each user is possible.

In this way, users are playfully encouraged to stop in front of the screen (1), move closer to the screen (2), and finally engage in an initial touch interaction. Through the interplay between users' actions and the system's feedback, users receive an impulse in the direction of the desired behavior in each situation. In this way, the successful execution of user actions can be supported while maintaining user motivation to engage with the system.

During this user approach to the system, the attention of passersby is attracted and the modality of interaction with the system (in this case, touch interaction) is conveyed, ultimately motivating independent and beneficial touch interaction with the system.

3.4.3 Joy-of-use(-Ability)

Since the use of interactive information emitters is voluntary, the application must also take care to make it attractive for potential users to use them. This is where the concept of joy-of-use plays a crucial role.

Joy-of-use roughly describes the degree to which interaction with a technical system can trigger emotional impressions such as joy, happiness, or fun in users (Hasenzahl et al. 2001; Hatscher 2000). Closely related to the concept are, for example, gamification or funology (Reeps 2004).

4 The CommunityMirror Network

Based on the results from the technology probes we started to create and operate a CommunityMirror setting that allowed us to further dig into the evaluation of the phenomena around such displays.

As described elsewhere (e.g. Alt et al. 2012), it is important to run long-term deployments for addressing some types of research questions. In the CommunityMirror project we have been working with several shorter deployments for years (the technology probes) - but always had to deal with the novelty effect (Koch et al. 2018) and problems with the non-professionalism of the (research) deployments. The only professional deployment we had closer access to was (Ott & Koch 2019) which showed the problems with limited access and influence on outside deployments.

So, we decided to invest in setting up and managing a long-term, in-the-wild, real-world deployment of an interactive large information screen solution at our university. We started operating the first two screens in 2018 and added two more in 2019, then paused due to the COVID-19 pandemic, and restarted operating the screens in mid 2022 - now with additional capturing of body tracking data (Fietkau 2023a) at two of the screens.

The goals of the setup were to research different factors in context without the novelty effect dominating the results - and to research aspects of operating such a setup for a longer term.

In this chapter we will briefly report on the setup of the CommunityMirror Network.

Main source for information on this:

Koch, M., Fietkau, J., & Stojko, L. (2023): Setting up a Long-Term Evaluation Environment for interactive semi-public Information Displays. Mensch und Computer 2023 - Workshop-Proceedings. https://doi.org/10.18420/muc2023-mci-ws13-356

4.1 Basic Functionality

Following the ideas of CommunityMirrors listed in the previous section we planned to set up an installation that presents relevant and valuable information to the community: the people working, studying, and visiting the Department of Informatics at the University of the Bundeswehr Munich. In the following subsections, we briefly describe what decisions we have made regarding data and data collection, user interface, and operation based on our experiences from former short-term deployments.

4.1.1 Data and Data Collection

When researching what information might be of interest to all interest groups – co-workers, students, and visitors – we came to three different types of information

- (1) People: information about people working in the Informatics Department, around the area of the installations.
- (2) Organizations: information about (sub-)organizations within the department, as part of the university, and in general.
- (3) Content: information about what the people in our department are working on, what is taking place (e.g. announcements (of events or other), reports or news, new publications, active (research) projects, announcements of topics for student theses, …).

In addition to the “serious” information, we added some non-serious content: photos from department events and comics, funny images and texts.

All these information items consist of a catchy title, an image (wherever possible), and a short abstract with links to further information on the Web. Additionally, all the information items are linked to other information items to create an information graph for browsing (see Figure 14).

As we learned in earlier deployments, this information has to be current and updated quite often to keep interest, and to sustain the usefulness of the screen (Ott & Koch 2019). So, we fell back to a data solution already used for shorter deployments before, the CommunityMashup (Lachenmaier et al. 2011; Lachenmaier & Ott 2012). The CommunityMashup collects information from different sources and makes it available in a common format - based on the data types of users, organizations, and content.

4.1.2 Data Display and Interaction Possibilities

The screens in our network access data from the same CommunityMashup data store, display the data, and allow interaction with it. To display user-centric data, each CommunityMirror uses selection strategies to choose appropriate data items, e.g. according to their location. For instance, the display located in the corridor of the Institute of Theoretical Informatics shows more info particles related to this specific institute. The core element in the user interface is an "information flow" that shows the selected data items as circles, in various sizes, showing the title and the image (see Figure 13). Depending on the data type the circles have a specific color: persons are light blue, organizations are dark blue and content items are green. These flow items move through the screen, from left to right or right to left, until they leave the screen which results in another item being selected and inserted in the flow. There is a maximum number of items displayed in the information flow at one time. To achieve a balance in the displayed data objects, there is an algorithm that always selects a certain percentage of each type of item and steers toward a specified balance.

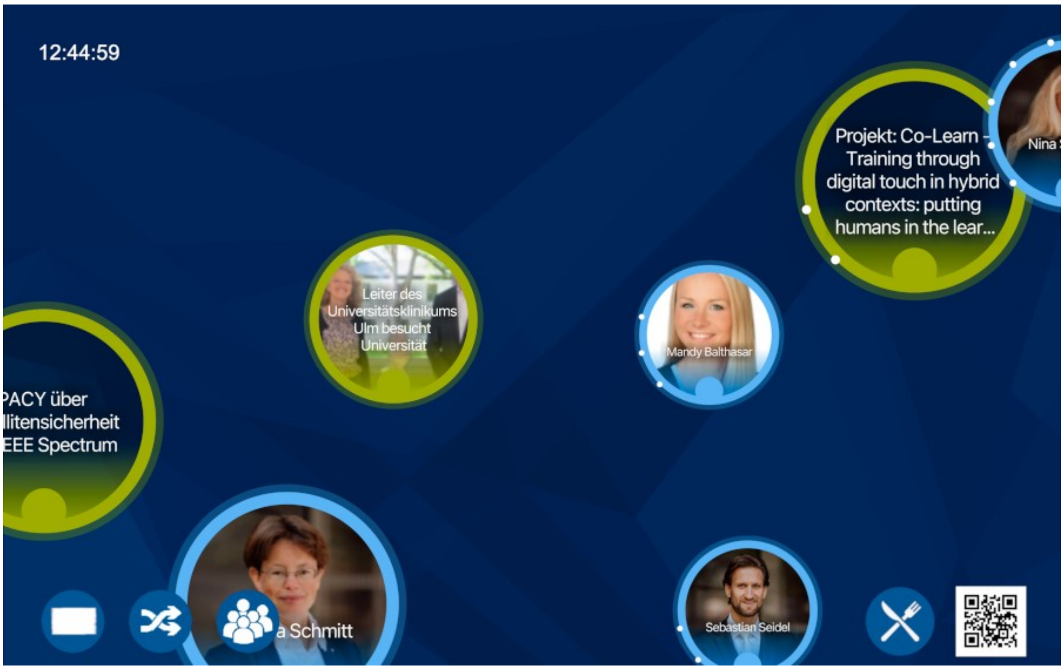

Figure 13: A typical information flow of a CommunityMirror instance showing person particles (blue), and content information (green)

Since we are interested in how often and in which way people interact with the CommunityMirror to explore the displayed information, we added functionality for capturing active and passive usage data - for scientific evaluations and for operation support. Our logging solution is described in more detail elsewhere (Fietkau 2023a; Rohde et al. 2023) and in Chapter 5.

Following a light gamification approach, the users can interact with the flow items -- e.g. stop them, drag them around, even throw them out of the border of the screen to disappear.

When a flow item is touched, the movement of the selected item stops, and a detailed view of the item is displayed showing the abstract (in a scrollable window). After some time without interaction, the item cycles back to the non-detailed view and disappears. The detail view not only shows the selected item but also other items that are related to the selected item as a graph (see Figure 14). This graph can be used to navigate to other information.

Additionally, a QR code is displayed in the detail view that can be used to capture the information on a mobile device for later access (by capturing a link to the CommunityMashup).

Figure 14: Connected information objects that build an information graph for browsing in the CommunityMirror

In earlier deployments, we found that the flow works well and addresses both people directly in front of the screen and people watching from a distance (by displaying the flow items in different sizes), but there was something missing. People in the department asked for large posters as they are displayed on paper-only boards. So, we added "teasers" (see Figure 15), a poster-like display of the items (quarter to half a screen size) that is shown from time to time. Touching the teaser results in opening the item in graph mode for browsing.

Figure 15: The teaser feature of the CommunityMirror (left side) that shows poster-like information randomly from time to time

Finally, we added some more static information that is of special interest for the users (see Figure 16 for some of them):

- a clock in the upper left corner
- a possibility to access the cafeteria menu
- a possibility to access a campus map
- a possibility to see the (live) departure times at the nearby bus station
- a possibility to display weather forecast information – however potential users have not been interested in forecasts for the next days but for forecasts on potential rain in the next hours (rain radar)
- a possibility to access information about the installation
- a possibility to instantly replace the currently shown flow items (refresh information flow)
- a possibility to replace the currently shown teaser
- a possibility to show all the professors or staff members in the context of a screen location – a kind of pre-configured search feature

Figure 16: Overall user interface of the CommunityMirror with information flow (blue and green circles passing through the display), a watch on the upper left corner, bus schedule on the right side, access to the cafeteria menu on the lower right corner next to the QR code with further information about the project, and a button for teaser selection or skipping on the left corner with a reshuffle button of the information flow right next to it.

4.2 The Community Mirror Network of 2024

4.2.1 Deployment Locations

Looking into possibilities for setting up CommunityMirror instances on campus we identified several locations (mainly based on availability) in the three-floor building of our faculty and one in a satellite campus location:

- Building 41, ground floor: a location at the entrance to the building where there is a room for workshops with external guests nearby and where there are some bulletin boards for students (showing the results of exams)
- Building 41, first floor: a location in the open staircase between two offices
- Building 41, second floor: a location next to a seminar room, the toilets and coffee kitchen - so, there is traffic by students and staff
- Building CASCADA: a location in the open break room of a research group

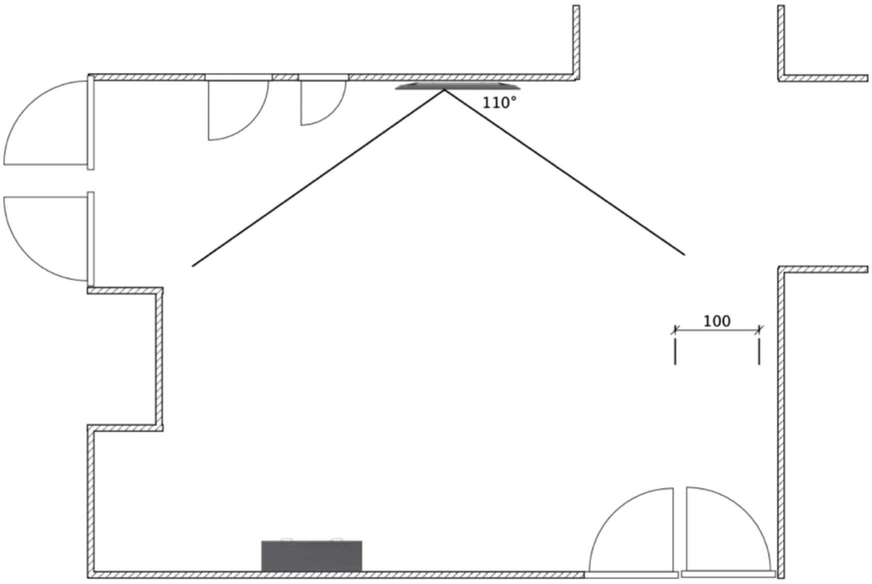

Figure 17: Building 41, ground floor – an entrance area with (paper) bulletin boards relevant for the students in the department – one large workshop room nearby (exit on the top)

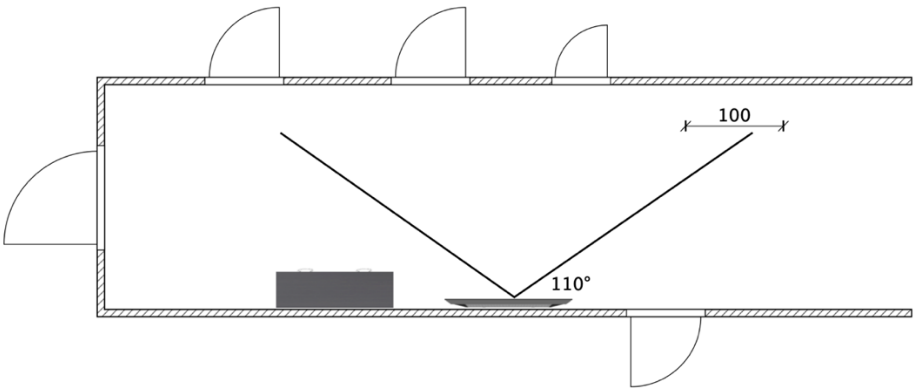

Figure 18: Building 41, second floor – a smaller corridor heading to offices and seminar room of one of the working groups in the Informatics department

4.2.2 Operations Management

The basis of the setup are CommunityMirror applications on different computers that load information objects to display from one CommunityMashup installation and that continuously export activity log data to a logging management solution (Rohde 2023 and Chapter 5).

The runtime of the CommunityMirrors is scheduled between 7 am and 6 pm during the day. Between 6 pm and 7 am the CommunityMirrors turn into sleep mode to save energy, as it is assumed that no or almost no users would use the screen – neither actively nor passively - in the late evening hours or at night.

The first task regarding the management of the network of four (and expandable to more) screens was to set up a deployment script that allows easy updates of the software on the instances without the need to physically visit all of them. Therefore, a git repository was set up that automatically updates itself and the CommunityMirror software (the CommunityMirrorFramework, CMF). To reduce memory-related errors, the computers restart themselves once a day.

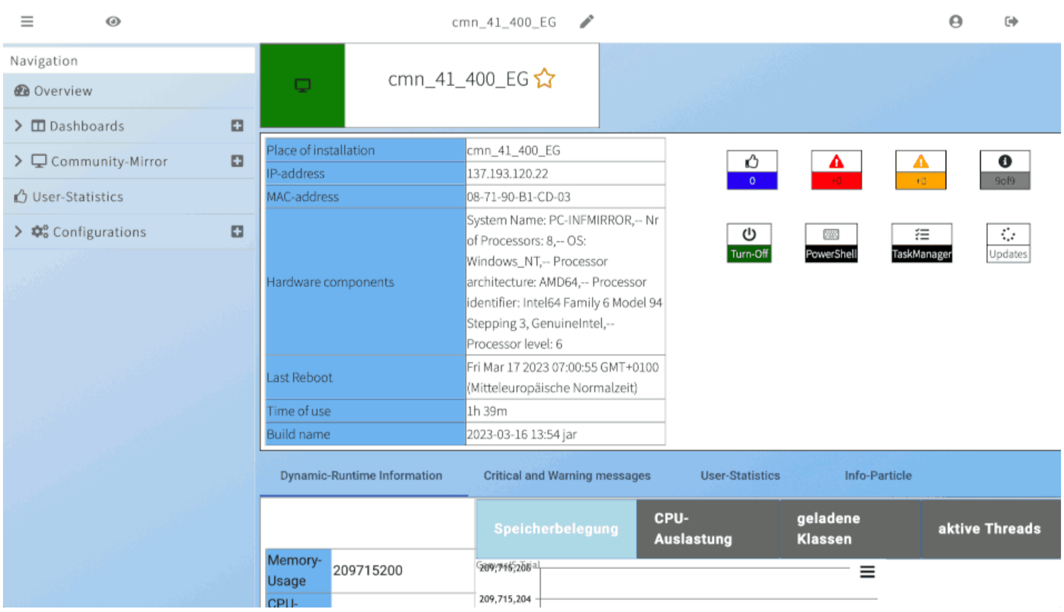

Figure 19: Dashboard for CommunityMirror remote management, with diagnostic information on one particular device currently visible

The second task regarding management was to build a remote management service for the instances and an application to look into the current status of the instances. To that end, the CommunityMirror software was outfitted with an extensible remote interface that allows remote administrators to access diagnostic information and to trigger system actions (such as a reboot). This remote interaction happened over a direct internet connection for initial tests, which was later improved to use current encryption standards and measures against man-in-the-middle attacks.

The remote management interface is accessed through a web-based dashboard (see Figure 19). It shows an overview and an operation manual for regular tasks, e.g. updating people information items, as we did not yet find a good way to automatically import the information from the people directories at the department. The objective of this application is to enable easier operations management as it also shows information about the status of the deployments based on our logging framework and integrates an interface for remote management.

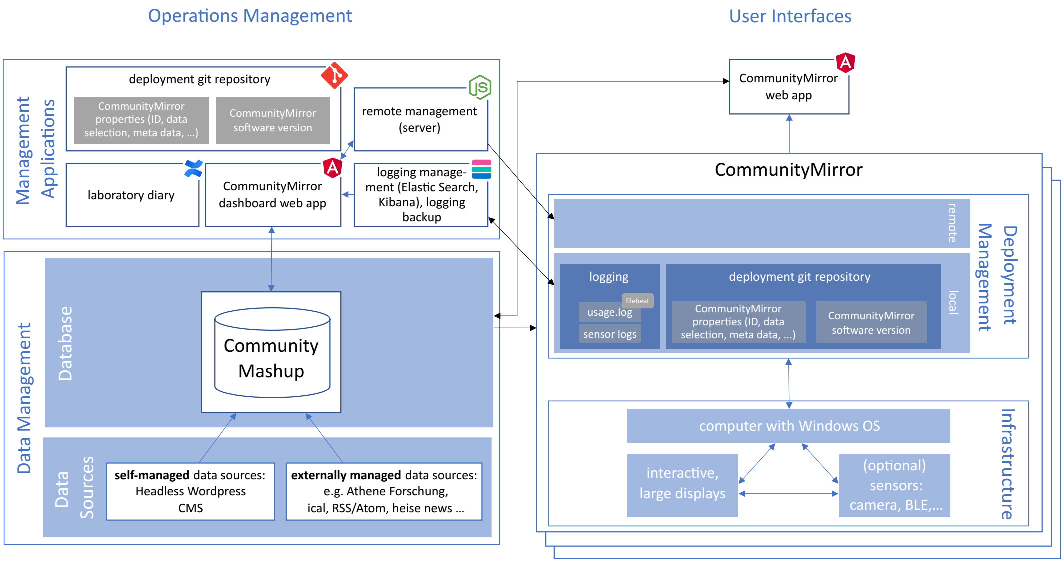

Figure 20: An architecture diagram of the CommunityMirror network showing all relevant components: CommunityMirror instances and their optional hardware add-ons, logging framework, data sources (CommunityMashup), network management dashboard, and remote management

The most important issues in management however had to do with the data. We carefully investigated what data to display (to be useful) and how we can obtain the data without too much additional effort. While the use of the CommunityMashup solution for automatically collecting data was helpful, it did not do all the work needed. There was a need to regularly check if there was enough new information and if it came from enough different sources, and to adapt the import and selection rules or to manually add and update information.

Data management can be divided into two tasks:

- maintenance of existing content
- acquisition of new content

To make maintenance of existing content as easy as possible, we added attributes like an expiration date to the content items and remove them automatically when outdated.

For keeping data like the list of persons and organizations up to date we defined a maintenance process and provided tools to semi-automatically update the information from other information sources (like the faculty person directory).

Adding new content is done mainly via the CommunityMashup. However, we found a need to monitor how much content is available in which categories -- and to allow people to suggest content. For the overview we added regular statistics provided by the CommunityMashup that can be accessed in the dashboard solution mentioned before. For suggesting content and for making it easy to maintain the non-automatically collected content (by a large number of users) we added a functional mailbox and a web-based content management system that allows users to easily create content objects.

In addition to checking for "normal" data operation, management includes maintaining data about the operation -- as entries in an electronic laboratory journal and as annotations / comments in the logging framework. This additional context data is needed to interpret the raw data in the logging framework when doing evaluations.

4.3 Research Questions

After operating the CommunityMirror network for more than two years now, we can conclude that it offers benefits to the users in our department and provides a powerful environment for public display (action) research.

With the solutions for continuously collecting interaction data (Rohde 2023) and body tracking data around the displays (Fietkau 2023a) – see the following chapter, we now have data beyond the novelty effect to work on questions like:

- How do new features, e.g. the employee panel or gamification functionality, influence the interaction with the CommunityMirror?
- What are the information objects users interact with the most - persons, organizations, or content?
- How many people pass by the screen? How do they move between interaction zones? We no longer need to count interactions but can work with conversation rates.

Regarding the effects surrounding the CommunityMirror, we can now have a look at the following questions:

- What are the dynamics between a group of people in front of the screen and how do these groups form (honeypot effect)?
- How can we use body tracking data to observe the honeypot effect? And even further, distinguish between the novelty and honeypot effect and identify a temporal context?

- How can we observe the novelty effect using quantitative logging of body tracking and interaction data?

With our full access solution of a large interactive semi-public information display environment, we have the opportunity to do field studies with full control that allow us to examine these questions, which are interesting for research and operational real world deployment scenarios, e.g. for Computer-Supported Cooperative Work (CSCW).

Additionally, we contribute to "sustainability" of IT research in practice. Research in applied computing today requires researchers to engage deeply with practitioners in order to design innovative information technology artifacts and understand their appropriation. The problem not yet solved is what happens when the research project is over. See for example (Simone 2022) for a broader discussion of this topic.

5 Evaluation – Long-term In-the-wild

When looking at potential research to be done in the field of interactive displays one can find several areas where long-term in-the-wild deployments are needed. While questions about performance (for example of a new interaction technology) can be answered with the help of controlled experiments in laboratory environments, there are more and more questions that can only be meaningfully investigated in the field. These include the behavior of users (e.g. walking paths, moving through different interaction phases), user experience, acceptance (e.g. with regard to privacy protection or data protection) and the social impact of new technologies (Alt et al. 2012). For these, the ecological validity of the validity of the data collected plays an important role, i.e. whether it was collected in a realistic situation.

At the end of the previous chapter, we have listed some (evaluation) goals we wanted to achieve with setting up the CommunityMirror Network as an example of deployment-based research, in which artifacts are embedded in the user's everyday life in such a way that the research context is not recognizable. Users use artifacts of their own free will, which leads to highly valid data.

In this chapter we will present what we have done in the CommunityMirror project to allow for long-term in the wild evaluation – and what questions we already have addressed with this setup.

Main sources for more information on this:

Koch, M. (2019): Towards a Logging Framework for Evaluation and Management of Information Radiators. Mensch und Computer 2019 – Workshop Proceedings. https://doi.org/10.18420/muc2019-ws-566

Koch, M., Fietkau, J., Draheim, S., Schwarzer, J., & von Luck, K. (2023): Methods and Tools for (Semi-)Automated Evaluation in Long-Term In-the-Wild Deployment Studies. Mensch und Computer 2023 – Workshop Proceedings. https://doi.org/10.18420/muc2023-mci-ws13-116

Fietkau, J. (2023): Software Tools for Recording and Viewing Body Tracking Data. Mensch und Computer 2023 – Workshop Proceedings. https://doi.org/10.18420/muc2023-mci-ws13-334

Rohde, C., Koch, M., & Stojko, L. (2023): Using an Elastic Stack as a Base for Logging and Evaluation of Public Displays. Mensch und Computer 2023 - Workshop Proceedings. https://doi.org/10.18420/muc2023-mci-ws13-303

Koch, M., Fietkau, J., & Stojko, L. (2023): Setting up a Long-Term Evaluation Environment for interactive semi-public Information Displays. Mensch und Computer 2023 – Workshop Proceedings. https://doi.org/10.18420/muc2023-mci-ws13-356

Fietkau, J., & Schwarzer, J. (2024): Herausforderungen menschengerechter Forschung mit Body-Tracking-Sensoren in Langzeit-Feldstudien. Mensch und Computer 2024 – Workshop Proceedings. https://doi.org/10.18420/muc2024-mci-ws14-170

Buhl, W., Engel, K.-F., & Buller, V. (2023): Evaluation of a gamification approach for increasing interaction with public displays. Mensch und Computer 2023 – Workshop Proceedings. https://doi.org/10.18420/muc2023-mci-ws13-344

5.1 Interaction and Observation Data

When looking into what information is available in CommunityMirror deployments, and what is used in scientific evaluations of such deployments, three different types of information can be distinguished:

- **Interaction data** – (log) events from interaction behavior of users with the interactive screen – this can be directly captured from the application driving the screens.
- **Observation data** – information about what is happening in the environment of the displays – particularly the (potential) users in front of the displays – to automate capturing this information we have installed 3D cameras above the screens that support body tracking
- **Context data** – information about the context of the screen operation that potentially influences usage – e.g. about what weekday it is, what weather it is, opening hours of the building, holidays, outages of the hardware, events taking place near the screen.

From these three types of information the latter is standing out, because the interesting data is how many users can be expected to potentially interaction with the screen – which is part of the observation data. While there might be a usage for pure context data (e.g. to explain or confirm results from observation data), we will not address this category for the moment and concentrate on automatically captured interaction and observation data.

Collecting interaction data from application logs has been used a lot in HCI studies of interactive displays (e.g. Börner et al. 2013). The use of observation data often is only used for some short observation periods (the whole spectrum from direct participant observation to doing video recordings and surveys). Only with the automation of doing observations (analyzing the observation data) this data finally was available for long-term studies. First examples can be found in (Elhart et al. 2017) and (Mäkela et al. 2018).

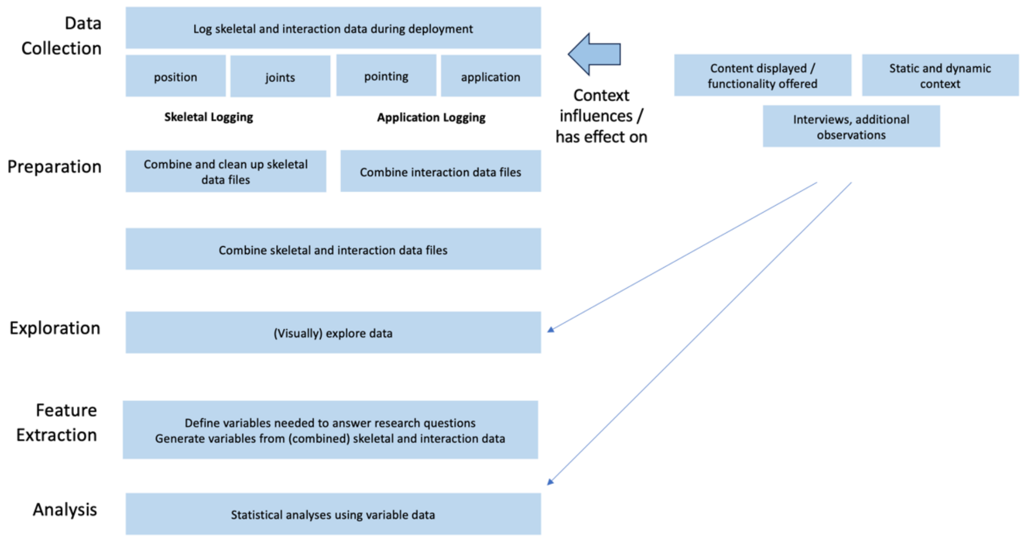

Figure 21: A preliminary methodological blueprint for long-term, semi-automatic, and real-world evaluations of large interactive screens (based on Figure 5 in Mäkelä et al. 2018)

5.1.1 Interaction Data

Regarding interaction data with touch screens the basic data is data about simple touch events – storing a timestamp and the position where the touch occurred on the screen. The touch then should be separated in the two events touch down and touch released. With some processing this easily can be calculated to drag events (if the screen position changed from touch down to touch released).

This is where we started with the CommunityMirrors. We implemented a library for the CommunityMirrorFramework that is called in the code when touch events happen – and that then writes the events to a log file (or other output channels).

The basic (user activity) events captured are:

- TOUCHPRESSED
- TOUCHRELEASED
- TOUCHDRAGGED

We did not yet try to capture gestures – distinguish fingers and capture multi finger gestures. This is for future development.

But we used the knowledge of the application about what information objects were on the interaction positions to add additional information to the events. So, we do not only capture on which screen coordinates the touches occurred, but also what objects have been touched.

For the CommunityMirror Network we distinguish between information objects and other elements on the screen. Information objects are managed in the CommunityMashup service and have a unique identifier to refer to (and to use for retrieving the information later when evaluating the deployment). Information objects on screen are called info particles (or visual information object) and always include a link to the information object they visualize.

As described in Chapter 4, visual information objects (info particles) Info particles can be displayed in different levels of detail – the simplest version providing a micro view (just showing a picture and title) and a detail view (showing details). In the detail view, connections to other info particles (and the corresponding information objects) are shown in the form of a navigable graph.

Other objects on the screen are teasers (which represent a particular info particle), action buttons (on the bottom of the screen) and non-interactive sticky components (bus schedule, clock).

For status changes around the "action objects" in the CommunityMirror Network design we have added additional events (we capture a TOUCH and RELEASE event for every activity – the additional events are logged in addition to the basic events):

- TOUCH_NEXT_VISUAL_STATE_PREVIEW – change info particle from detail view to preview (by touching it)
- TOUCH_NEXT_VISUAL_STATE_DETAIL – change info particle from preview to detail view (by touching it)
- TOUCH_GRAPH_OPENED – open graph view by touching an info particle
- TOUCH_GRAPH_CLOSED – close graph view by touching an info particle in graph view
- TOUCH_GRAPH_NAVIGATED – navigate in the graph by touching – i.e. open a new info particle as center of the graph
- TOUCH_SHOW_MESSHALLPLAN – show the mess hall plan (by touching the corresponding action button)
- TOUCH_SHOW_WEBVIEW – show a web view (like the info window) by touching the corresponding action button
- TOUCH_RESHUFFLE_FLOW – touch the reshuffle flow action button
- TOUCH_RESHUFFLE_TEASER – touch the reshuffle teaser action button
- TOUCH_SHOW_ITEM_PANEL – touch the action button for opening an item panel (e.g. list of professors)

In addition to simple log data entries, it would be beneficial to aggregate log data entries – e.g. to sessions – and to make the information on the sessions available for evaluation (or administration). However, this issue is not trivial. There are different ways to define, what a session is – and it should be possible during evaluation to try different ways to do the aggregation. So, the information about sessions probably should not be stored with the log data entries directly. This question is still open.

5.1.2 Observation Data

For capturing observation data, we followed the approach from (Elhart et al. 2017) and (Mäkela et al. 2018), mounting a camera on top of the interactive screens to capture what is happening in front of the screens.

We do not capture video but body tracking data. Body tracking can be seen as the process of extracting the spatiotemporal data on people and their movement from sensor hardware such as cameras (Fietkau 2023a). Body tracking data consists of the resulting data points, generally including the positions of people in the sensor's detection area at a specific point in time, as well as the positions and orientations of their limbs at some specific degree of resolution and precision that depends on the hardware and software setup (Fietkau 2023a). In the literature, body tracking data is also called pose data (Vyas et al. 2021) or skeleton data (Song et al. 2017), referring to the relatively coarse resolution of body points represented in the data.

In the CommunityMirror project we have decided to use the ZED 2 camera and mount it directly above the screen (see Figure 22).

Figure 22: Setup of display in 41/400 2OG – with the ZED 2 camera on top of the screen – fixed with a 3D printed mount

The ZED 2 camera datasheet lists the following information [2] :

- 15 frames / sec (for maximum accuracy)
- Field of View: Max. 110°(H) x 70°(V) x 120°(D)
- Depth Range: 0.3 m to 20 m
- Depth Accuracy: <1% up to 3 m; <5% up to 15 m
- 26 data points per skeleton

The result of the body tracking are single frames with the 26 skeletal data points for all persons detected in the detection area of the camera. The frames are written to separate files for sessions beginning with a person entering the observation area of the camera to the last person leaving the observation area. See the following section for the file format and the toolset we use for this.

With this setup we can detect when people pass the screen in different zones, when people change from one activity zone to another, when people change their walking speed.

What is not covered in the core data is how attentive people are towards the screen or if their attention changes. Other hardware sets provide some help here, e.g. the attention value that is automatically calculated by the Microsoft Kinect framework for

[2] See ZED 2 data sheet at https://docs.clearpathrobotics.com/assets/files/clearpath_robotics_023611-TDS1-4397f62e823823822ebb46c234e19834.pdf

every detected person. For the ZED 2 we have to calculate such a value ourselves based on data captured by the sensor as gaze or posture.

For interpreting observation data, it might be important to know which objects have been on the screen at a particular time. As a first step toward this additionally store some information when new objects are displayed on the screen or when objects are removed.

5.2 Tools for Data Storage and Analysis

In the previous section we have presented the basic format for the interaction and observation data we are capturing and storing: log files with interaction events and skeletal data representations in frames for observation sessions.

For combining this data and analyzing the data we have selected or built some tools. In the following sections we will present the current state of this ongoing activity.

5.2.1 Storing Events - ELK

In general, you need a tool to store the log data, a tool to gather the log data, and a tool to visualize/search the log data. So, what we were looking for was a suitable combination of these three tools, that can easily integrate and match our requirements.

The most well-known solution for the task is the Elastic Stack[3]. The Elastic Stack is a popular collection of open-source tools for collecting, storing, searching, analyzing, and visualizing data from various sources in real time. It consists of the components: Elasticsearch as the storage and search engine, Logstash as the data processing pipeline and Kibana as the data exploration and visualization tool. The Elastic Stack has a big developer community and can run on premise.

To integrate the Elastic Stack into the infrastructure of our long-term public display installations in the CommunityMirror project, we have developed a logging framework that helps with the objectives within our research projects and deployments. This framework collects log data from various installations deployed in a real-world environment. We analyze the log data using Elasticsearch's robust search capabilities, leverage Logstash for data transformation and ingestion, and utilize Kibana to create intuitive visualizations, dashboards, and operations support for ongoing research activities.

[3] The Elastic Stack. https://www.elastic.co/elastic-stack/

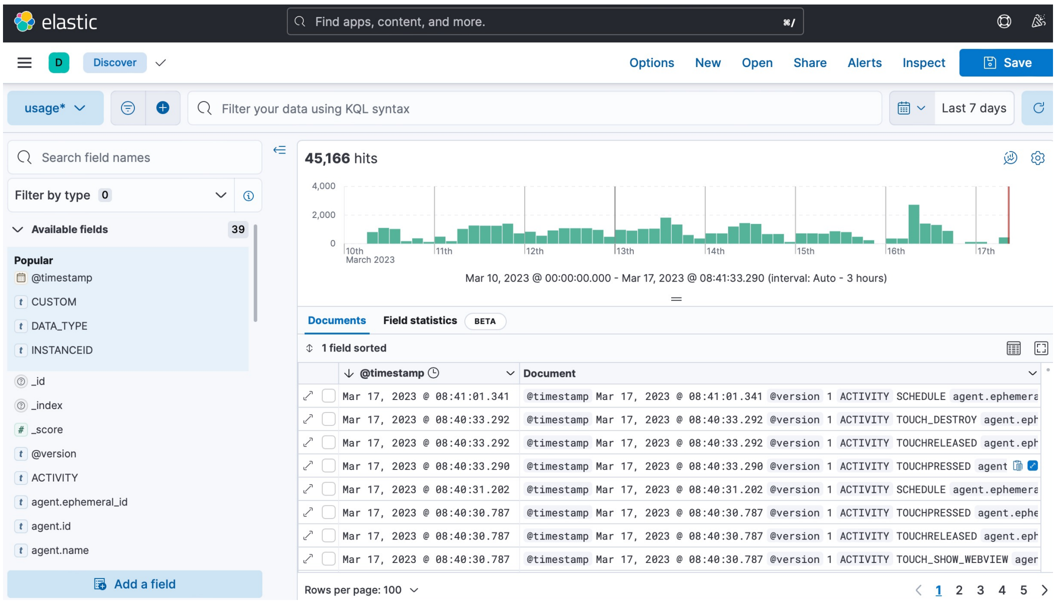

Figure 23: Example of a Kibana diagram showing events (right side) and filtering options (left side)

The current state of the implementation is that the logs from all our four installations in the CommunityMirror Network are collected by the ELK-Tool Logstash in real-time. Annotated with an identifier for the CommunityMirror installation, the data is then stored in the Elastic Search index and can directly been visualized using Kibana. Additionally, scripts can access the index using the Elastic Search API.

While built for scientific evaluation, the real-time features of ELK allow for usage as management tool. For example, we are using the log data in ELK in our dashboard application (see Chapter 4).

5.2.2 Storing, Playback and Analysis of Observations - PoseViz

As described in the previous section, the data that can be retrieved from sensors like the ZED 2 are frame descriptions, representing coordinates for all detected persons.

To allow for a device independent storage of such information we have developed a vendor-neutral extended version of the existing proprietary recording file formats – the PoseViz file format (see Fietkau 2023a). The design of the PoseViz file format was closely inspired by the Wavefront OBJ format for 3D vertex data. It is a text-based format that can be viewed and generally understood in a simple text editor. See Figure 24 for an example what a PoseViz body tracking recording looks like.

```
ts 2022-11-24T11:39:18.796
ct 0.18679 0.34504 0.12434
co -0.30539 -0.03130 -0.01309 0.95162
f 0
p 0 -0.19495 1.34052 3.32204
cf 0.76
ast IDLE
gro -0.01758 0.97214 0.01931 -0.23298
v 0.00000 0.00000 0.00000
k 0 -0.18878 1.29331 3.28806
k 1 -0.18537 1.15794 3.28186
k 2 -0.18196 1.02257 3.27566
k 3 -0.17897 0.88718 3.26986
k 4 -0.14888 0.88851 3.25432
k 5 -0.03154 0.89370 3.19375
(...)
```

Figure 24: Excerpt from a PoseViz body tracking data file showing the beginning of a recording including a timestamp, camera translation and camera rotation, followed by the first frame (time offset zero) containing one person. Partial body tracking data is shown here including the tracking confidence, action state, global root orientation, current velocity, and the first few body key points. (Fietkau 2023a)

The whole toolset for working with body tracking data first includes a tracking server for retrieving the data from the sensors. The second component is a tool for visualization and playback (see Figure 25) – and finally there is a framework for additional tools (scripts) for processing the data for retrieving additional information – e.g. events when people enter or leave activity zones.

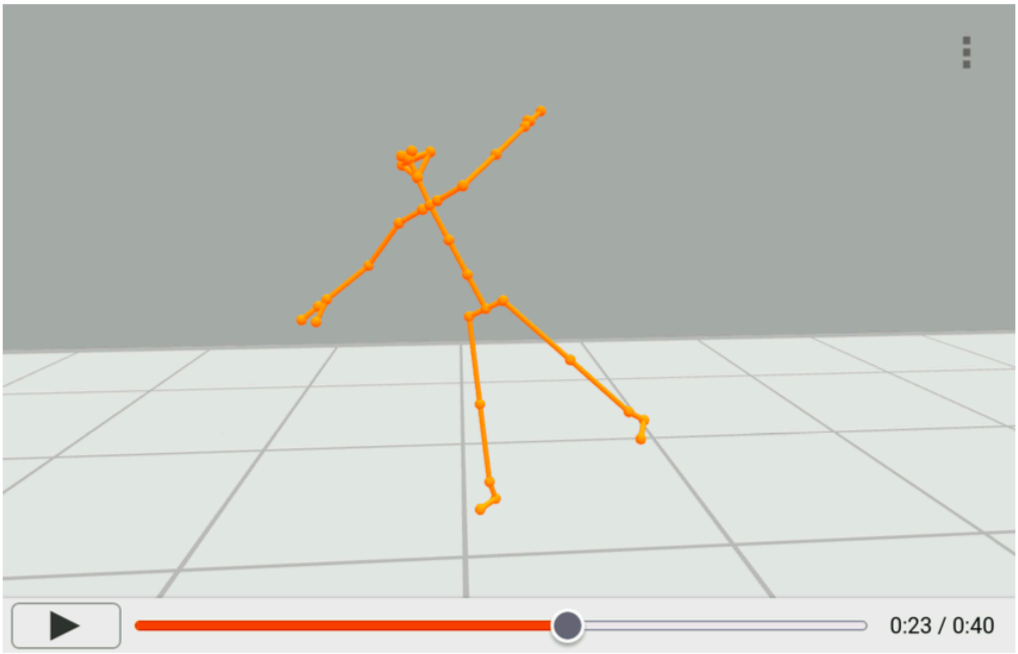

Figure 25: Screenshot of the PoseViz playback software, showing an example body tracking data recording as well as the player UI at the bottom of the screen (play button, progress bar, time stamp) and the settings menu signified by the three dots in the upper right (Fietkau 2023a)

The overall setting for handling observation data is shown in Figure 26. In Figure 27 we show a copy of Figure 21 from page 49 with annotations for the tools and formats we are using in the CommunityMirror project.

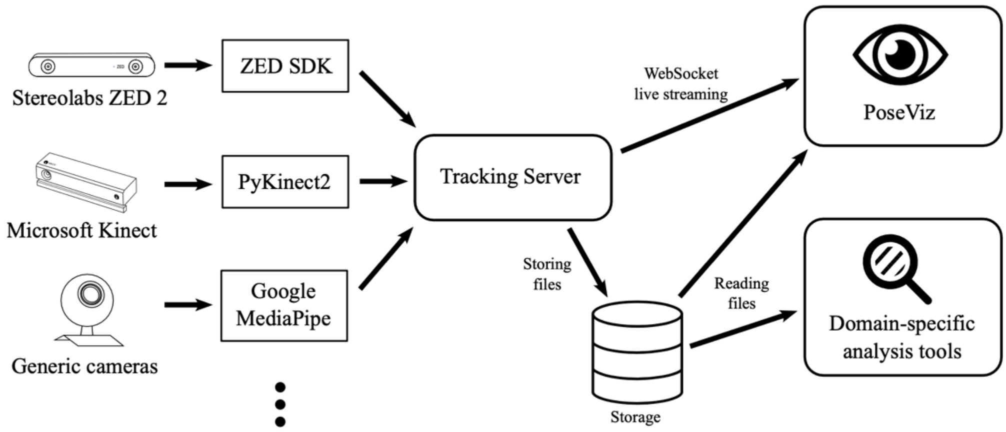

Figure 26: Toolset overview showing the interactions between system components. (Fietkau 2023a)

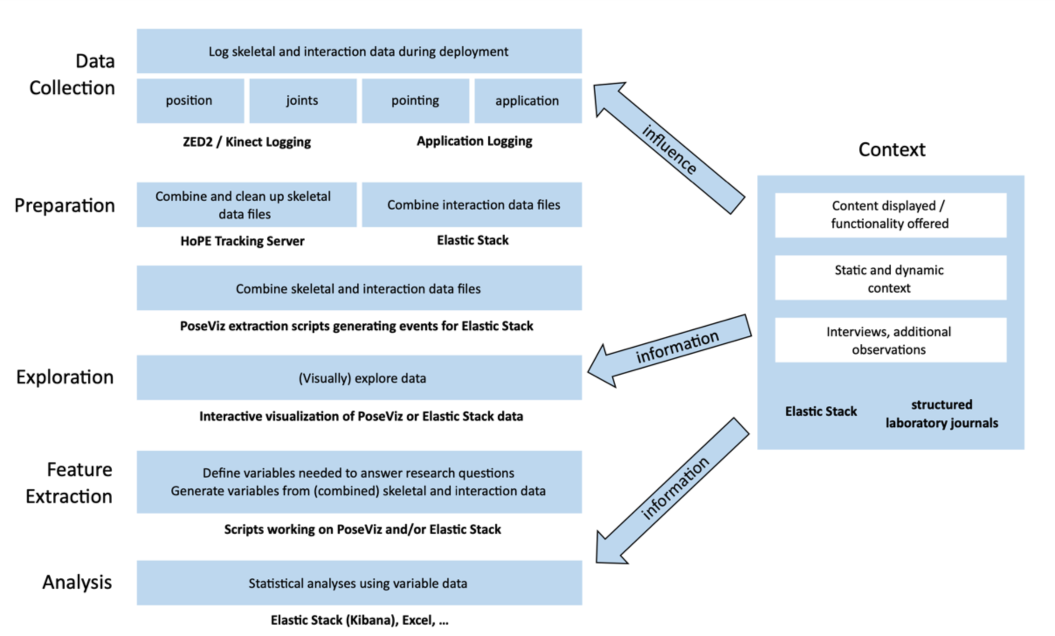

Figure 27: A preliminary methodological blueprint for long-term, semi-automatic, and real-world evaluations of large interactive screens (based on Figure 5 in Mäkelä et al. 2018) – annotated with the tools we are using in the CommunityMirror project

5.3 Examples for Data Analysis

In this section we briefly show how the tools described in the previous section are used, and what we learned about the use of quantitative information in evaluating long-term in-the-wild deployments of public interactive screens.

5.3.1 Comparing different Features

In research on interactive display installations, one often wants to distinguish if the introduction of new features makes a difference – or if there is a difference in user activity for two different features.

One example for this was analyzing the potential of gamification in a student project. See (Buhl et al. 2023) for more details.

For the project one screen in the CommunityMirror network (the one in Building 41/400 ground floor – see Figure 17) was equipped with a new version of the CommunityMirrorFramework software. We added a basketball basket in the button middle of the screen. The users were able to “throw” the floating information bubbles on the display into the basket. See Figure 28 for a photo of this setup.

Figure 28: Screen in CommunityMirror Network with a basketball net to throw the moving particles in (Buhl et al. 2023)

The experiment ran from the 22nd of May 2023 to the 9th of June 2023 which adds up to 19 days in total including the days cut off for the novelty effect. The removal of three days for the novelty effect thus leads to a total of 16 days with data collected.

First, we only counted interactions – which was easy by doing a simple query to our ELK infrastructure. We limited the query to the times from 7 am to 6 pm since the screens are switched off outside this time. We counted basic interaction events only (just the event TOUCHPRESSED).

We did this for four intervals (no gamification, novelty effect, gamification, after gamification) and built daily averages (see Table 1)

	# days	# interactions	# interactions per day
1.3. – 21.5. pre study	82	3199	39,01
22.5. – 24.5. novelty effect	3	210	70,00
25.5. – 9.6. gamification	16	551	34,44
10.6. – 30.6. no more gamification	21	618	29,43

Table 1: interactions per day – include all days

So, when ignoring the novelty effect period, we found no significant effect. The interactions per day even decreased after the gamification element was removed. But this can be due to the study period being at the end of the lecture period.

Next, we tried to remove days with potentially little traffic (derived from contextual data) from the data set – first by removing weekends and holidays and university breaks (including the exam week) (Table 2) – Again no effect. The interactions per day moved closer to the number in the novelty effect period.

	# days	# interactions	# interactions per day
1.3. – 21.5.	49	2993	61,08
22.5. – 24.5.	3	210	70,00
25.5. – 9.6.	9	550	61,11
10.6. – 30.6.	10	500	50,00

Table 2: interactions per day – without weekends, holidays and breaks

When looking into the raw data, one could identify some days with much more interactions than on average other days. This may be due to experimentations or demonstrations at the device. Since this is not part of "normal usage" we then also removed those peek days (days with >= 200 interactions / day) from the data (Table 3). But this again did not change the picture a lot.

	# days	# interactions	# interactions per day
1.3. – 21.5.	46	1769	38,46
22.5. – 24.5.	3	210	70,00
25.5. – 9.6.	8	312	39,00
10.6. – 30.6.	9	500	55,56

Table 3: interactions per day – weekends etc. and peaks >= 200 removed

Altogether one can conclude that in this case the gamification did not change usage significantly. One can also conclude that in the future one should do the evaluation using longer periods of time – since removing weekends etc. resulted in having very few days in the final data set.

5.3.2 Conversion Rate – Adding Observation Data

When using interaction sums per day (as in the experiment described in Section 5.3.1) we have found problems with the context (comparing quite different types of days). We tried to solve the problem by excluding weekends, holidays etc. from the data. But for getting this context information we had to do manual tagging of the dataset. For example, we have not excluded Fridays, which could be considered as "half-days", since lots of people leave the university around lunchtime for the weekend. It would be better to have information about how many people passed the screen and potentially could have interacted.

What we did do to explore this idea was to calculate some data from the PosViz observation data. We took the sessions in the data (periods where there was at least one person in front of the screen) and calculated per day

- Number of persons passing the screen (person count)
- Number of periods with one or more persons in front of the screen (session count)

Then we compared the number of potential users with the number of interactions. See Table 4 for this information for the days where the gamification was enabled.

date		interac-tions	persons	ratio	sessions	ratio
25.5.2023		40	265	0,15	5	8,00
26.5.2023		0	191	0,00	162	0,00
27.5.2023	weekend	0	0		0	
28.5.2023	weekend	0	0		0	
29.5.2023	holiday	0	2	0,00	2	0,00
30.5.2023		0	170	0,00	25	0,00
31.5.2023		18	201	0,09	143	0,13
1.6.2023		194	100	1,94	80	2,43

2.6.2023		28	179	0,16	124	0,23
3.6.2023	weekend	0	7	0,00	4	0,00
4.6.2023	weekend	0	11	0,00	11	0,00
5.6.2023		238	203	1,17	153	1,56
6.6.2023		28	126	0,22	95	0,29
7.6.2023		4	175	0,02	149	0,03
8.6.2023	holiday	0	0		0	
9.6.2023	break	1	147	0,01	37	0,03

Table 4: Comparing number of interactions (interaction data) to number of persons / sessions (observation data) – to test if the ratio is meaningful.

The result was not yet satisfying. Identifying weekends and holidays works quite well (by looking at the number of users passing by), but the ratios were too scattered to be of any additional use. Perhaps additional numbers from the observation data can help to better distinguish the situations – e.g. the average or maximum length of sessions, the sum of all sessions, the average or maximum number of users in sessions – or by trying to identify situations that falsify the data – e.g. the 5 sessions with 265 users on the first day – which is probably a measurement error.

5.3.3 Analyzing Walking Paths

Using observation data, we tried to visualize what the sensors have seen and draw walking paths in front of the screen – Figure 29 shows this for the display in the second floor.

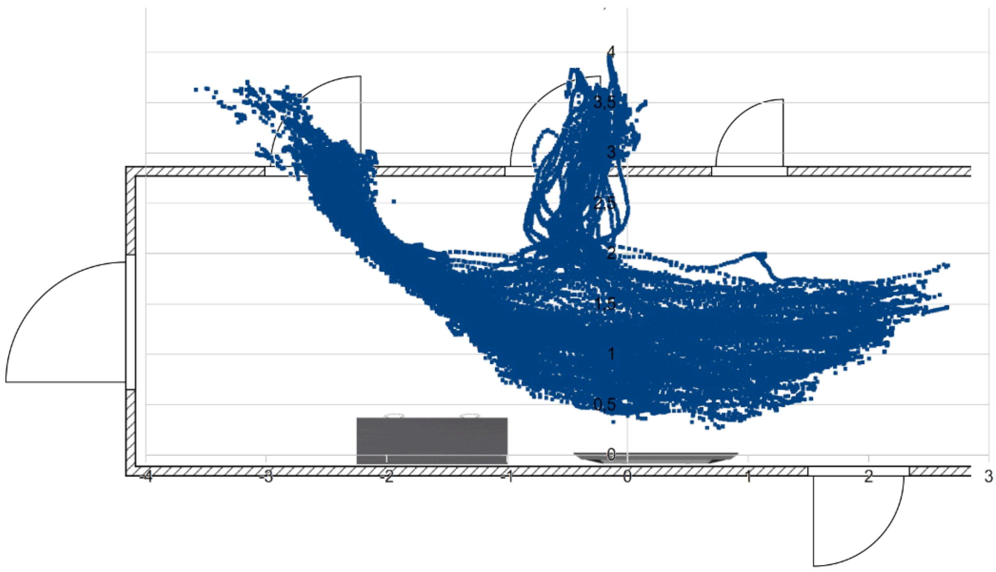

Figure 29: Walking paths in front of the CommunityMirror in 41/400 2.OG

While being interesting in itself and showing limitations of the observation sensor – not all people ended in the break room on the top left, but most continued to the exit to the stairways on the left – the figure also shows that more research is needed on the level of automation during mobility behavior analyses.

In (Schwarzer et al. 2023) we tried to do this. Particularly, we adopted both agglomerative hierarchical clustering and dynamic time warping.

5.3.4 Identifying Honeypot Sessions

As a final example a more complex task from one of our research projects: In this project one goal was to identify in the observation data from several months how often the honeypot effect (Wouters et al. 2016) could be observed – or at least to identify a reasonable small number of potential candidates that than can be checked manually using the PoseViz tools.

To identify features of honeypot situations we could look for, we first have created recordings of artificially created sessions that represent the honeypot effect; and have screened part of the live material for such sessions (Bieschke 2024).

From these recordings we have derived features of such sessions – e.g. presence of persons in the different interaction zones, persons not moving, intersection of gaze direction, … These features then have been implemented in a filtering script.

A short evaluation of script showed that when used on the data of more than 8.000 sessions in October 2023 it has returned four sessions as clearly honeypot session – from the five session we know. There were now false positives.

5.4 Next Steps

In this chapter we have presented our work for enabling automated 24/7 evaluation of long-term in-the-wild deployments. We have reached a state where we can reliably capture interaction and behavior data from several screens and are able to check this data using different tools – from simple visual inspection to writing scripts for more complex calculations and checks.

Our next steps are now to use the evaluation infrastructure for more real evaluations (like the ones presented in Section 5.3).

One step into this direction is to extract events from observation data and store these in the ELK infrastructure to enable easy exploration.

The current concept for this is to create a Python script that automatically extracts the following events from the PoseViz observation data and stores these events in the ELK index:

- User enters observation area (additional information in event: ZED 2 user id, movement vector, velocity, attention status, how many users are already in observation area)
- User enters a particular interaction zone, see the zones in Figure 9 inspired by Michelis et al. (2011) – further detailed in Section 3.3.4: interaction, communication, notification, ambient (additional information as before)
- User leaves observation area (additional information: ZED 2 user id, movement vector, velocity, attention status, how many users are still in observation area)
- User leaves a particular interaction zone (additional information as before)
- User is slowing down below a particular value (additional information: in which interaction zone, distance to display, movement vector, attention status)

6 Related Work

Using and evaluating large screens for community support has been explored in the field of Human-Computer Interaction for quite some time.

An extensive list of projects implementing large screen-based information displays can be found in (Ott 2018). The work lists 264 examples, nicely summarized and annotated in Appendix B.

An interesting insight from this extensive collection of examples: A lot of the prototypes were from the early 2000th – when technology was good enough to build something, but not good enough to build for long-term deployment. So, the studies mostly are short-term exploratory studies. This is quite a common issue in lots of HCI studies. New technology was explored – but not long and thoroughly enough (due to technology restrictions and due to lack of (time) resources for doing long-term studies) to learn something about use and usefulness in real usage scenarios.

Another large list of 33 examples is presented by Lippert (2020) – well analyzed regarding the benefit the authors reported for their projects.

In the following we provide a brief overview of the related work (Section 6.1) and then focus on some selected projects for more details (sections 6.2ff).

6.1 Overview

The use of large (touch-sensitive) screens as user interfaces for information systems dates back to work by Mark Weiser (1991) in the 1970s – as part of his "pads, tabs and boards" metaphor for future computing.

The first prototypes build following Weisers "board" metaphor were focused on supporting direct collaboration in workgroups. One example of this is DynaWall (Geissler 1998). DynaWall is developed at the Fraunhofer Institute IPSI and provides an active screen surface of 4.5 x 1.1 meters and a resolution of 3072x768 pixels. User interaction takes place via hand gestures and stylus input.

An early example in the field of community support is the Silhouettell system (Okamoto et al. 1998). The system uses large screens to display information about people standing in front of the screens. The system can detect the presence of people, can assign them an identity, and can load a profile with the people's interests. Finally, the information resulting from the comparison of the profiles of the people in front of the screen is displayed (to indicate common interests).

Other examples of the use of large screens in supporting communities include the Plasma Poster from Fuji Xerox Palo Alto Laboratory (Churchill et al. 2003), the Magic Wall from Accenture Research (see www.accenture.com), and the CommunityWall (or Cwall) from Xerox Research Lab Europe (Agostini et al. 2000, Snowdon & Grasso 2002; Grasso et al. 2003). In all applications, information from the community information space is displayed and the device provides a meeting place that can be used by several people at the same time. The goal is usually to support knowledge communication in the workplace. A nice compilation of reports about several of these projects can be found in (O'Hara et al. 2003).

Various large wall screens have been designed and deployed outside of research settings. BBCi, for example, has built applications that allow passersby to watch live interviews on large screens and contribute their own questions via SMS. In the Lisbon office of Vodafone, a large display has been built on which passers-by can again use SMS to call up information, short animations and games. Further examples are listed in (Scanlon 2003).

Additional examples of non-interactive information displays can be found in HCI and CSCW research – e.g. in the large body of work on ambient displays (Matthews et al. 2007). One example of an ambient display that acts as information radiator is the Aware Community Portal (Sawhney et al. 2001). The setup consisted of a projected display with an associated camera and server used to display items of relevance to researchers within a laboratory. The display showed live news and weather feeds, an hourly cartoon strip and a periodic clock update as well as a feed from a camera. Other examples can be found in the field of awareness support (Gross 2013) - e.g. by Prinz & Gross (2001) with the TOWER environment showing workspace awareness information in 3D scenes on large screens.

Interactive solutions are less common than passive non-interactive large screens for advertisement, digital signage or awareness. One of the key challenges for those systems is making users "aware" of the offered interaction possibilities in order to entice for interaction. Vogel and Balakrishnan presented an early overview and thoughts about interaction with public ambient displays (Vogel & Balakrishnan 2004).

Some examples of research prototypes exploring the design space of interactive information radiators over the past ten years are CommunityWall (Snowdon & Grasso 2002), Plasma Poster Network (Churchill et al. 2003), Ambient Surfaces (Schwarzer et al. 2013, 2015) and XioScreen (John & Rist 2012). An example of a public deployment with long-term evaluation can be found in the UBI-Hotspots project (Ojala et al. 2010).

The different systems show both the potential of the underlying concept as well as the added value of interactivity. In evaluations of the CommunityWall users considered at least 50% of articles interesting enough to interact with (Snowdon & Grasso 2002). The evaluations also showed that people were willing to contribute to such a system by submitting content. One problem with the evaluations was that the evaluation mainly took place in or near the groups that built the systems, and that the evaluation covered the usage of only some weeks. Rare exceptions like (Schwarzer et al. 2016) briefly report about the usage outside the research setting over more than one year. In most cases, some years after the studies have taken place most of the systems were no longer in operation.

Some meta studies and discussions of particular (methodological) problems in longitudinal evaluations confirm these observations (Alt et al. 2012; Koch et al. 2018; Schwarzer et al. 2019).

6.2 Ambient Agoras (GMD)

Already in 2003 Prante et al. (2003, 2004) report from the EU-funded project *Ambient Agoras* and present prototypes that emerged from the project – including InfoRiver and Hello.Wall.

In the *InfoRiver* system the authors implemented the information river metaphor, representing the flow of information through an office building or an organization. Positioned in public or semi-public areas (like lobbies or corridors), InfoRiver used a stream-like display to convey context-aware information to passersby, such as news, event updates, or community announcements.

The "river" metaphor represented the continuous flow of information and allowed the display to react subtly to people's proximity or movements. For instance, as someone approached, the flow of information might change in speed or shape, gently inviting closer interaction without being intrusive. The InfoRiver aimed to seamlessly integrate information into the environment, creating a sense of place awareness and community connection while enabling non-intrusive information discovery.

The *Hello.Wall* was an experimental interactive installation designed to explore how technology could facilitate subtle social interactions between people in shared spaces. Hello.Wall was a "smart wall" concept, equipped with sensors, displays, and communication technologies to detect and respond to the presence and activities of people nearby.

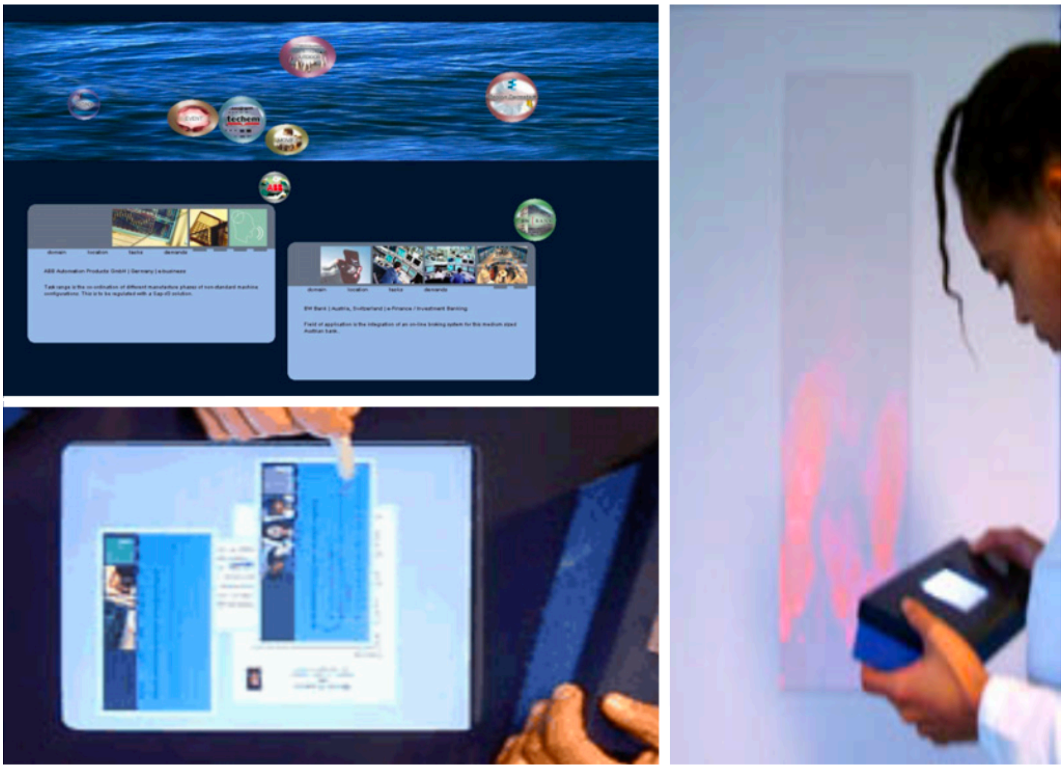

Figure 30: User Interfaces to the InfoRiver system – clockwise from upper left: InforMall, GossiPlace & ViewPort, ConsulTable (Prante et al. 2004)

The wall used different types of ambient lighting and visual feedback to convey information or gently prompt interaction, essentially acting as a mediator for awareness and communication. For example, it could signal when someone was close by, indicate shared interests, or suggest topics based on commonalities among people in the space. The goal was to create a social, ambient display that encouraged interaction in a non-intrusive way, blending seamlessly into the environment rather than demanding attention.

6.3 CommunityWall (Xerox Research Centre Europe)

The *CommunityWall* project was an initiative focused on creating a digital, interactive wall to support community engagement and knowledge sharing within an organization (Snowdon & Grasso 2002). This "community wall" acted as a collaborative, public display where people could post, share, and interact with information, such as project updates, personal interests, and community announcements.

Figure 31: CWall Screen (Grasso et al. 2003)

Using touchscreen and sensing technologies, CommunityWall enabled users to easily post content and interact with others' contributions, encouraging a sense of collective presence and awareness in the workplace. The wall served as a visual and interactive platform for fostering informal communication, community building, and a shared understanding of ongoing projects, helping connect people who might not typically interact face-to-face.

This project was part of XRCE's research into collaborative systems and ambient displays in the project Campiello, exploring how digital tools can create shared, dynamic spaces for knowledge sharing and a more cohesive, connected workplace.

6.4 PlasmaPoster (Fuji Xerox)

Plasma Poster was an innovative digital poster system developed by researcher Elizabeth Churchill and her colleagues (Churchill et al. 2003). The project focused on creating a collaborative display system that allowed people to post, share, and update information in public spaces, much like a digital bulletin board. Using plasma screens in high-traffic areas, the Plasma Poster allowed users to add content via web-based interfaces or directly on the screens, including announcements, event information, and personal notes.

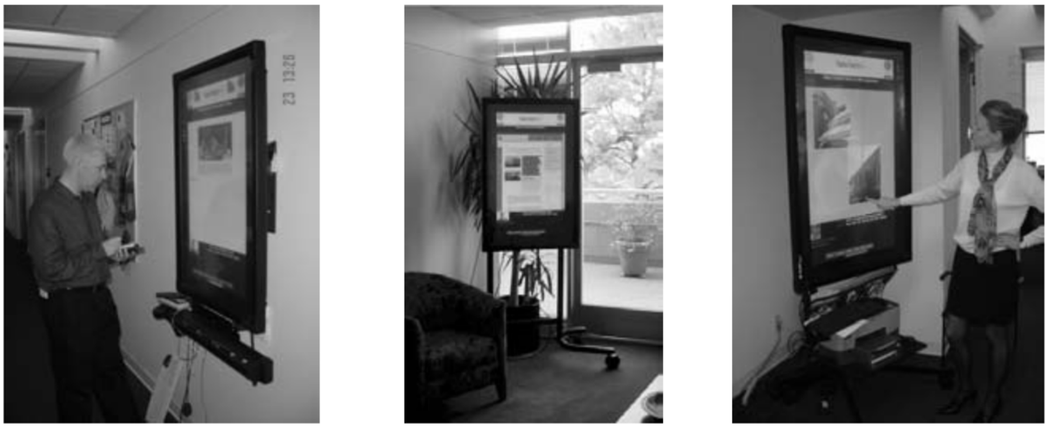

Figure 32: Plasma Posters are located in a corridor (left), a foyer (middle) and the kitchen (right) (Churchill et al. 2003)

The system aimed to facilitate informal communication within organizations and communities by creating a shared display where people could discover relevant information, coordinate activities, and leave messages for others. Unlike traditional bulletin boards, the Plasma Poster could dynamically update content, organize posts by relevance or timing, and even incorporate interactive features to enhance engagement.

This project contributed to research on public display systems, examining how digital interfaces could support community interaction and awareness in shared spaces. It was an early example of "situated displays"—technology embedded in physical environments to enhance social interactions.

6.5 UBI-hotspots (University of Oulu)

The *UBI-Oulu* project (see e.g. Kukka et al. 2013; Ojala et al. 2010 and Ventä-Olkkonen et al. 2016) uses the ubiquitous urban computing infrastructure (Open UBI Oulu) for numerous scientific studies. The following description is essentially based on Ojala et al. (2010). The infrastructure was built in 2009 and consists of 12 interactive 57'' horizontal wall screens at different locations in Oulu, Finland, in indoor (e.g. swimming pool, library) and outdoor areas (e.g. pedestrian zone). Each hotspot is also equipped with Wi-Fi and Bluetooth as well as an NFC reader, a camera for facial recognition and loudspeakers. After initial complaints, however, the sound output had to be switched off in indoor areas (Ventä-Olkkonen et al. 2016). If there is no interaction, the screens show advertising. This mode can be left by touching the screen. This makes the interactive offers on the screen and a menu bar for navigating the content at the bottom of the screen visible. If there is no more interaction for a set period of time, the screen changes to the advertising mode.

Figure 33: Outdoor UBI hotspots (a) along a walkway, where a user is interacting with version 2 of the UBI portal and (b) in the market area of downtown Oulu. Each outdoor hotspot is a double-sided display accessible 24/7 (Ojala et al. 2012)

At the start of the project, potential users were asked about their ideas for useful applications on the screens (Kukka et al. 2013). The majority named map services and information on public transportation, followed by current events and nearby dining options. After the project was implemented, the actual usage figures showed that only the map services were used frequently, while the other three information services were rarely accessed. The usefulness of most services was overestimated. News and games were used most frequently. In observations (ibid.) it was found that people used the screens in equal proportions alone or in company, whereby it became clear in additional surveys that use in small groups is preferred. Accordingly, finding information can be regarded as a social activity. If people are already interacting with a screen, this arouses the curiosity of other people (honey-pot effect). According to Kukka et al. (2013), public screens trigger social behavior and have the potential to stimulate communication with colocated strangers. In a more recent publication on the project (Ventä-Olkkonen et al. 2016), it is described that only one of the screens was used intensively in 2015. It is located in the entrance area of the public swimming pool in Oulu, where people are often waiting, and many children and young people are present. The most common usage scenario was children playing simple games and applications that enable multi-user activities; this screen was hardly ever used to retrieve information. A survey showed that adult users are inhibited in their interaction by the public situation. The awareness of possibly being observed by others means that they do not want to search for information on these screens. Ventä-Olkkonen et al. (2016) also state that public screens nowadays have to compete with smartphones.

On of the sub-projects of UBI-hotspots was *FunSquare* (Memarovic et al. 2012). This is an example of a scientific field study that used the Open UBI Oulu infrastructure. The application was demonstrated and evaluated on two days at two of the hotspots (marketplace, library). FunSquare displays interesting facts that combine statistical information with dynamic information from the environment of the screen location. Observation showed that the facts were read both from a distance, while standing, in passing, and directly on the screen. The application was used by individuals, couples and groups of people (mostly families). Although individuals read more facts in absolute terms, couples or groups interacted relatively more frequently. The application stimulated social interaction, people talked or laughed about the content or discussed it. People also tried to collaboratively interpret what the application was doing. Memarovic et al. (2012) recommend that users of public screens should be allowed to discover the application step by step, i.e. the features of an application should not be too obvious. The authors also suggest that more explanations could reduce social interaction.

6.6 xioScreen (University Augsburg)

The *xioScreen* project was an experimental initiative aimed at exploring new ways for users to interact with digital content on large, interactive screens (John & Rist 2012). The project focused on developing an intelligent display system that could respond to gestures, touch, and even nearby physical objects, creating a highly interactive experience. By combining multi-touch technology with object recognition and environmental awareness, xioScree*n* sought to make digital interactions more natural, intuitive, and immersive.

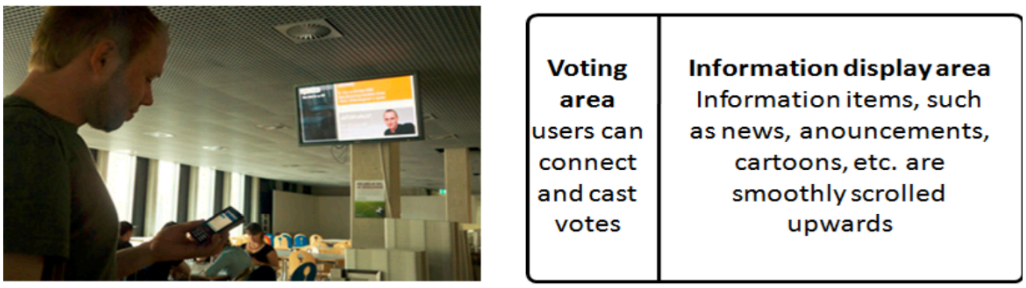

Figure 34: Installation of a xioScreen v2 at HSA Mensa and screen layout scheme (John & Rist 2012)

The goal was to expand the potential of interactive screens beyond simple touch inputs, enabling people to manipulate digital content through a range of physical actions. Users could, for example, place objects on the screen to trigger specific functions, swipe or tap to access information, or make gestures to interact with virtual elements. This created a blend of digital and physical worlds, where the screen became a dynamic, responsive surface, adaptable to different use cases—ranging from collaborative work in offices to educational tools in classrooms.

xioScreen contributed to advancing research on tangible interfaces, interactive surfaces, and augmented reality, helping shape the future of intelligent, responsive screens in everyday environments.

6.7 Ambient Surfaces (HAW Hamburg)

In the project *Ambient Surfaces* interactive large screens in semi-public areas are explored for supporting agile software teams since 2012 (ongoing). During this time, various preliminary in-the-wild deployments have been realized and matured over time (Schwarzer et al. 2013, Schwarzer et al. 2015, Schwarzer et al. 2016).

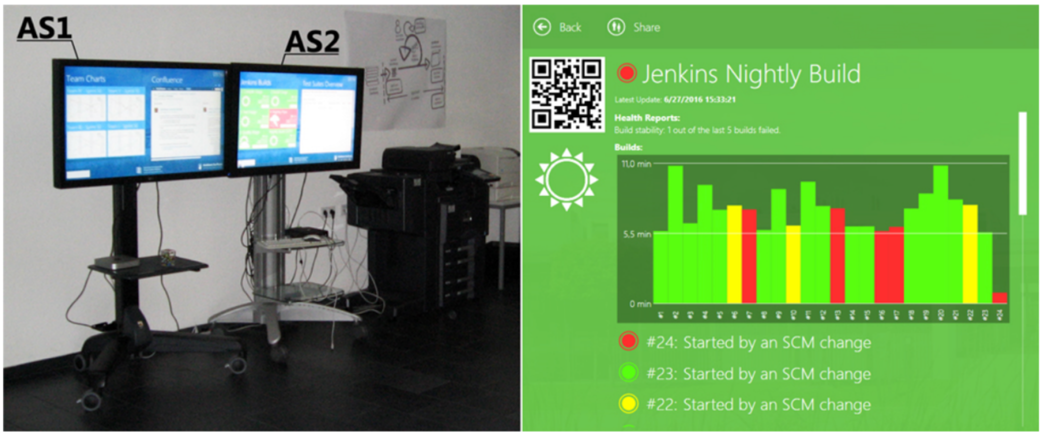

Figure 35: Left: The installation setup of both Ambient Surfaces in a common room on the ground floor; printers, white-boards and the stairway to the upper level are in this area as well. Right: A custom visualization showing a build summary for a specific Jenkins job (Schwarzer et al. 2016)

A first five-year deployment was established back in 2014 in collaboration with a company near Hamburg. Two ambient displays were installed in the spatial environment of the agile software teams.

As a result, the team advanced on fundamental questions concerning the novelty effect (Koch et al. 2018), methodological considerations (Schwarzer et al. 2019), theory development (Schwarzer et al. 2022), audience behavior (Schwarzer et al. 2023; Schwarzer et al. 2016), and automatic analyses (Schwarzer et al. 2016).

7 Summary and Conclusions

In this report we have reported a long-term project “CommunityMirrors” – an effort for exploring the design space of large interactive screens in semi-public environments acting as interactive information radiators.

We have explored several design areas and have derived recommendations for building such solutions. With one of the built solutions, we have done real long-term in-the-wild deployment studies.

One important issue in setting up sustainable solutions has been to tap information silos and information flows already available in the organization – in addition to creating crowdsourcing solutions for content collections. In both cases watching the benefit of the potential users has proven to be critical for success.

For evaluating the settings beyond simple qualitative statements, we have worked on a 24/7 solution for automated evaluation in long-term field deployments. Combining interaction data and observation data showed a lot of potential for scientifically evaluating design options in the future.

While there is still a lot to learn about the usage of large (interactive) screens as information radiators (e.g. the issue of the usefulness of interaction in this setup is still mostly open), there are some ideas of where the user interfaces in the functional setup might develop to. The question we most often hear for example is how the move towards AR solutions in the office space might affect the usefulness of large screen information radiators in the future. Is there still a need for such devices if information can be presented to users directly in the vision in a personalized and context-adapted way? How will the concept of information radiators (in office environments) and the idea of “Out of the Box” develop in the coming decades?

We are trying to address this argumentation and ideas for future solutions in (Koch et al. 2024). The summary was that there will be (collaborative) knowledge work in the future – and therefore there will be a need for Information Radiators to support awareness and matchmaking in and by providing social spaces. With hybrid work extending there will be even more need. However, new user interfaces will contribute to address this need. In addition to large (interactive) screens there will be AR solutions – or in the far future even brain computing interfaces.

Figure 36: Local office in the future vision: Individual work with different interfaces and artefacts, Collaboration with locally present or remote colleagues which are present via screen or as holograms, Information Radiators via AR, holograms or 'classical' screens/wallpapers (next to the elevator) (Koch et al. 2024)

The future of IIRs in our vision will be a dynamic blend of digital and physical experiences, personalized and social. Using the developments in HCI - particularly towards new display possibilities and new interaction possibilities, there will be multimodal interfaces, haptic feedback and integration with the Metaverse. The user interface might move some from real world installations to presentation via AR including a higher grade of personalization.

Due to the increasing hybridity of work, presenting information about co-workers will be more important than it is today and again, different ways will be used to do so, from annotations in AR via avatars on screens up to representations of the people via holograms.

As technology continues to evolve, IIRs will adapt and transform, offering new ways to support knowledge workers in their daily tasks. Among others, IIRs may become central hubs for collaboration.

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Glossary

Ambient displays

"Ambient displays are aesthetically pleasing displays of information which sit on the periphery of a user's attention. They generally support monitoring of non-critical information.", (Mankoff & Dey 2003, p. 169); a challenge of the "information decoration" is particularly: "[…] seeking a balance between esthetic and informational quality.", (Eggen & Van Mensvoort 2009, p. 109).

Augmented Reality

"Augmented Reality is a hybrid experience consisting of context-specific virtual content that is merged into a user's real-time perception of the physical environment through computing devices. AR can further be refined based on the level of local presence, ranging from assisted reality (low) to mixed reality (high)." (Rauschnabel et al. 2022)

Awareness

"[…] awareness is an understanding of the activities of others, which provides a context for your own activity." (Dourish & Bellotti 1992, p. 107) Awareness information reflects the presence, context and activities of other actors and usually is action relevant. – see Section 1.3

Common Ground

"information that two parties share and are aware that they share" (Clark 1996) – see Section 1.3

Community

groups of people who share values, interests and collaborate or help each other in the context of the common interests (Mynatt et al. 1997) – see Section 1.5

CommunityMashup

"The CommunityMashup is a flexible integration solution for data from social services and provides features like application frameworks with offline data access for different platforms. In contrast to existing mashup solutions, we aim to provide unified and aggregated information based on a person-centric data model. One main idea behind the person-centricity of this model is the wish to integrate social data that naturally belongs to a person or an organization but is artificially distributed over different services in the web". (Lachenmaier & Ott 2012)

CommunityMirror

Interactive information radiator, providing information that is individually interesting and important for the context in semi-public places (e.g. entrance areas of companies, coffee corners, next to elevators, etc.). The multi-user ubiquitous user interface enables proactive information provision and peripheral perception (awareness) as well as direct interaction with the information presented (browsing). At the same time, a CommunityMirror promotes interaction between several people from the screens (bystanders).

CommunityMirrorFramework (CMF)

Modular toolkit for the quick and easy creation of various scenario-specific CommunityMirror applications. The toolkit/framework is based on Java with JavaFX for handling the display and animation.

CommunityMirror Network (CMN)

Set of CommunityMirror installations working with the same set of information objects at UniBwM.

Display Avoidance

Consciously moving, possibly purely visual avoidance of a co-present social actor in front of a large screen. Kukka et al. (2013) coined this term for their observation of passers-by noticing situated displays but then "turned their head in the other direction, and then turn back once they had passed the display".

Display Blindness

Subconscious cognitive process by which a social actor "fades out" a large screen and does not perceive the display installation in their environment. (Huang et al. 2008)

ELK (Stack)

Collection of three open-source products: Elasticsearch, Logstash, and Kibana, which are developed, managed and maintained by Elastic. You can use this stack to ingest and visualize data in real time. Elasticsearch is a search and analytics engine.

Gamification

Attempt to enhance systems, services, organizations, and activities by simulating experiences like those experienced when playing games in order to motivate and engage users. (Hamari 2019) This is generally accomplished through the application of game design elements and game principles (dynamics and mechanics) in non-game contexts. (Deterding et al 2011; Robson et al. 2015)

Hybrid Work

Time and location-independent form of work in which part of the work is done in the office and another part from any other location. (Duckert et al. 2023) define the term as: “situations where at least three actors are located at fewer geographical sites than the number of actors, and all actors are mutually dependent in their work.”

Information Object

A self-contained amount of information with a recognizable identity that can be materialized in data form in IT systems, can be displayed as visible information in user interfaces and can become the knowledge of a social actor through subject-specific perception and abstraction.

Information Radiator

Class of displays (not necessarily digital) placed at high-visibility locations that continuously display contextually relevant information so that it can be perceived and understood by passers-by. This distinguishes information radiators from most conventional IT systems, which typically return information only after a specific request (selection, search query, etc.). Information radiators have the ambition to be passively usable. The term was coined by Alistair Cockburn (Cockburn 2001, 2008) in the context of agile software development. – see Section 1.4

InfoParticle

Visual form of representation of a socio-technical information object with a display form optimized for the usage and information context of interactive large screens as well as interaction capability adapted to the existing interaction techniques and concepts.

Interactive Large Screen

"Wall displays, including vertically oriented free-standing, wall-mounted, and wall-projected configurations, foster a combination of interactive use and passive value. Unlike desktop displays, they offer content visibility from a distance and can therefore benefit users through ambient or opportunistic information even when users aren't directly in front of the display or actively interacting with it." (Huang et al. 2006)

Interaction

Reciprocal process between several actors in the form of goal-oriented actions within a common context.

A more HCI-adapted definition can be found in (Saffers 2010, p.4): “An interaction, grossly speaking, is a transaction between two entities, typically an exchange of information, but it can also be an exchange of goods or services. […] It is this sort of exchange that interaction designers try to engender in their work. Interaction designers design for the possibility of interaction. The interaction itself takes place between people, machines, and systems, in a variety of combinations.”. Also see (Hornbæk & Oulasvirta 2017) for a broader discussion.

Interaction Blindness

Inability of the public to recognize the interactive capabilities of user interfaces. (See for example Houben & Weichel 2013)

Joy-of-Use

Positive user experience that the visitor feels when using digital media. This takes the form of psychological stimuli that are intended to appeal to the user emotionally, so that a positive bond with the digital product or company is created. Joy of Use is an extension of usability and adds emotions and aesthetics to it. The goal is to make the website as user-friendly as possible so that the user experiences a positive sense of achievement.

Knowledge Worker

A person, who’s primary (work) activity is the manipulation of symbols and the generation and use of knowledge, rather than the manipulation of physical artifacts. – see Section 1.1

"*The manual worker is 'yesterday' [...]. The basic capital resource, the fundamental investment, but also the cost center of a developed economy, is the knowledge worker who puts to work what he has learned in systematic education, that is, concepts, ideas, and theories, rather than the man who puts to work manual skill or muscle.*" (Drucker 2010, p. 34)

Large Screen

Digital display surface consisting of a single projection (1), a single screen (2), a multi-projector image (3), a screen matrix (4) or any combination of (1) to (4) recognizable as a unit, which is large enough for at least two co-present social actors to interact with the screen in a synchronized and coordinated manner at a personal proxemic distance.926 Large screens can be horizontal, vertical, flat or curved; mixed forms are possible. Embedded in the architecture, they can take the form of tabletops, wall screens or ceiling or floor display surfaces. They differ from other media in that they have a higher resolution (> 20 ppi), which means that text can also be read (to some extent) at close range (< 1 m) of the display surface.

Multi-User

Can be used by more than one user at the same time. For interactive displays this can be one or more active users (interacting directly with the display) and passive users just watching the display or the interaction of the active users for different distances.

Novelty Effect

"The novelty effect, in the context of human performance, is the tendency for performance to initially improve when new technology is instituted, not because of any actual improvement in learning or achievement, but in response to increased interest in the new technology." (Wikipedia - Novelty Effect 2024) For interactive displays the effect can have its rooting in the installation of a display or new interaction technology, in (interactive) features the display offers or even in information available on the display. (Koch et al. 2018)

Pervasive Display

A screen ranging from the size of a television to a media façade, which is embedded in public or semi-public space with the purpose of displaying digital content for multiple (simultaneous) viewers (Clinch et al. 2016).

Public Display / Public Screen

A digital screen used in a public place to convey information, advertising or entertainment content to a wide audience. These displays are usually large in size and are often installed in high traffic areas such as shopping malls, airports, train stations or other public places. Public displays are a specific variant of digital signage displays.

Semi-public

"partially but not entirely open to the public" (Collins English Dictionary). For interactive displays we define locations as semi-public when there are access restrictions (not all people are allowed to enter the space). We mainly look at office environments in organizations. Clearly public are streets, parks, public transport, malls. Semi-public are university campuses, museums, organization buildings without access control, … Non-public are organization buildings and shopfloors with strict access control.

Serendipity

Notion of making (unplanned) surprising and valuable discoveries. The term was coined by Horace Walpole in 1754. Busch (2024) identifies three necessary conditions that differentiate serendipity from related concepts such as luck or targeted innovation: agency, surprise, and value. – see Section 1.2

Social Software

Collective term for software tools that support people in the areas of communication and collaboration, and in general the maintenance of social relationships. The term social software emerged primarily in connection with the term Web 2.0, but not only refers to applications such as wikis or blogs, but also chats, forums, etc.

Sociotechnical System

Purpose-oriented unit of partly digital-virtual or technical, partly real-physical or social components and associated processes that can be delimited from the environment and are inextricably linked by functional dependencies in order to achieve their purpose. (Gross & Koch 2007, p. 15)

Ubiquitous Computing

Practice of embedding information processing and network communication into everyday human environments to continuously provide services, information, and communication. According to Mark Weiser (1991) "technology should create calm" and therefore "the best computer is a quiet, invisible servant".

Walk-Up-And-Use

Describes a system that is so self-explanatory that first-time or one-time users can use the system effectively without any prior introduction or training.

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Prof. Dr. Michael Koch has studied Informatics at TU München and has received a doctorate (PhD) in Informatics from the same university. After some time in industry at the Xerox Research Centre Europe and some post-doctoral work at TU München, University Bremen and University Dortmund he is now working as a full professor for Human Computer Interaction at University of the Bundeswehr Munich where he is leading the Cooperation Systems Center Munich (CSCM). His main interests in research and education are shaping cooperation systems, i.e. bringing collaboration technology to use in teams, communities and networks, and bringing integration and user interface technologies one step further to support this. In this context he is working on using (semi-)public displays as information radiators – and has initiated and lead the CommunityMirror project since 2001. He currently is editor in chief of i-com - Journal of Interactive Media - and member in the steering committees in the special interest area on HCI in the German Computing society (GI) and in the European Society for Socially Embedded Technology (EUSSET).

CommunityMirrors – Semi-Public Information Radiators for Knowledge Workers

Our daily work in the information society relies on creating, editing and collecting different information objects. Without additional presentation mechanisms these activities of particular knowledge workers remain hidden in the underlying IT systems. The resulting lack of awareness can lead to inefficient coordination as well as to the duplication of work in the worst case. Information Radiators are large displays providing context-specific pieces of information in a semi-public setting where people can see it while working or passing-by. They have a long history originating from simple printed posters for agile project management and software development, over interactive versions on large touch displays in the early 2000s to complex situated sociotechnically integrated multi-user multi-device interaction spaces for knowledge workers in recent years. By augmenting the physical working environment with peripherally recognizable digital content Interactive Information Radiators (IIRs) can simplify information sharing "out-of-the-box", foster awareness and socialization, create serendipity and enhance collaboration. In this report we present CommunityMirrors as one potential solution to this problem. CommunityMirrors are an example for information radiators and discussed in detail within this work. We describe the start of the project and elaborate on the work done in the past 20+ years covering different phases from first experiments to setting up a long-term deployment and providing support for evaluation in this deployment.