Types of Public Interactive Display Technologies and How to Motivate Users to Interact

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Abstract— Currently several different forms of public interactive displays are being researched. The two main categories are ”public displays in combination with mobile devices” and ”standalone displays”. Looking at all these types of displays, the most important design aspects for public interaction displays can be extracted: Non-distracting display of information, comprehension, notification, short-duration fluid interaction, immediate usability, shared use, combining public and personal information and privacy.
All public displays have a problem of acceptance: users have an aversion to use them as they are fearful of unfamiliar technology, but the bigger barrier is fear of social embarrassment. When using a public interaction display, users are aware that they are being watched. To motivate users to interact with the devices the devices have to be ”easy-to-use” and support ”natural” gestures. The user must have a positive tendency towards the device - there must be a benefit in some way by interacting with the device. This can be accomplished, for example, by rewarding the user for interacting with the device.
It has been shown that when a helper or another user introduces a new user to the public screen, the new user is more comfortable using the screen. When the display is in use, it automatically attracts more people. Most users learn how to operate the display by watching other users. Usually an individual from a group interacts with the public display while receiving comments from the group.

Index Terms—social factors, large displays, mobile device,interaction displays, input device, interaction techniques, multi-touch, augmented reality, multi-display environments, situated public displays, urban environments, multi-user interfaces, ubiquitous computing

1 Introduction

Currently more and more types of industry are starting to use various forms of digital signage. Most commonly large LCD screens are used for digital signage. Public displays allow the presentation of information in a more compelling fashion than ever before. Instead of having a single static content, the display can easily be adapted to dynamically display information. Current displays connect to a content management server to determine what information to display [1].

The next evolutionary step of this technology is to enable users to interact with these displays. Several prototypes of public interaction displays have been proposed. When the prototypes were evaluated, researchers discovered that a fear of social embarassement has to be overcome by users before they start using the display. The question remains how to design an ideal public interactive display and how to motivate users to activly interact with the device by helping them overcome their fears.

This paper covers three aspects of interative display technologies. It starts with the different interaction phases that were observed with many public interaction displays. Then it describes several different forms of public interaction displays. The paper continues with addressing general design aspects for creating a successful public interaction display, and with ways on how to encourage users to use these devices.

2 Interaction Phases with Public Interactive Displays

Several researchers have discovered that users react differently towards the display depending on the physical distance of the user to the display. They discovered four distinct phases of interaction [26] *(see figure 1)*.

Ambient Display Phase: The user passes by the display from a distance and does not interact with the device. All other types of interaction should not obscure this main interaction phase. Users should be able to process the displayed information at a quick glance.

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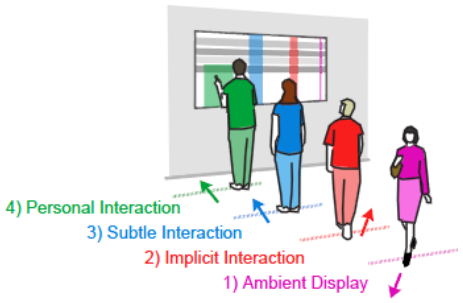

Fig. 1. The different types of interaction phases [27].

Implicit Interaction Phase: The display should be able to detect the position and orientation of the users body. If the user is moving towards the display or stops to watch the display, he is signalling that he is open to receive more information.

In this phase the user can be subtly notified and encouraged to come closer to the display. General notifications should be displayed. If there is a possibility to identify each user individually, personal notifications could be displayed. The user should have the possibility to signal to the display that he is not interested in interacting with it.

Subtle Interaction Phase: The user is moving towards the display. The display could expand the notifications and display more details. The user is approximately an arm’s length away from the display. This is the ideal position to interact with the device directly by simple hand gestures, for example, to select items of interest. A single user at this position does not obscure the device, allowing multiple users to share the screen and simultaneously operate the screen. In this phase highly personal data should not be displayed.

Personal Interaction: The user can move in even closer to the display and, in addition to the hand gestures, is able to touch the display for interaction. The user can accurately interact with the device and interact precisely with the provided information. The user is also now standing very close to the display, so the user’s body helps to occlude the view of other users. Still, very sensitive personal information is not protected and should not be displayed.

The users should be able to transition between these phases seamlessly [27]. ”Users initially signal a phase change using implicit inter-

action, such as body movement, body location, and head orientation, then gradually become more explicit with gestures and touch" [12].

3 Types of Interactive Public Displays

Currently several types of public displays are being researched. They can be categorized into two groups: "public displays in combination with mobile devices" and "standalone public displays".

The two groups of displays and existing applications are introduced in the subsequent chapters.

3.1 Public Displays in Combination with Mobile Devices

Large displays and mobile devices have become ubiquitous. Combining both technologies allow users to interact with the display with their mobile phones. Many screens would only need a minor upgrade to support interaction. But the major limitation of all these types of displays is that no system can efficiently support every type of mobile device and users must have a supported device to actively interact with the display. These displays are designed to work in the "Ambient Display Phase".

Interaction techniques can be categorized into three groups [21]:

1. *Extended input device*: The mobile device acts as a simple upload client that can provide text, image, and video input for the pubic display.

2. *Pointing device*: A cursor on the screen is controlled by the mobile device.

3. *Integral part of the interaction*: The mobile device serves as an extension of the display and allows with an additional interface to control various features of the display.

3.1.1 USIAlumni Faces

The USIAlumni Faces is a virtual yearbook application; the application was projected onto a large public screen. For all interaction with the screen, a customized Nintendo Wii remote control combined with an infrared pen built into a toy torch casing was used ("Interactive Artifact") *(see figure 2)*.

Fig. 2. A user interacting with the Alumni Application [19]

The screen was designed to enhance events like homecoming and alumni events. The artifact controlled the virtual yearbook application (photos of the alumni organized by year and faculty). Specific hand gestures controlled, for example, the flipping of pages.

The application was tested during a real life alumni event. Instead of explaining to the users how to operate the screen, the researcher simply informed the participants of the main function of the screen. This allowed to research social interaction around public displays as well as researching how gesture interfaces are expected to work. The interactions with the screen were videotaped and analyzed.

Users mainly learned how to use the application by observing others in a process of imitative learning. Some users played around with the artifact, while others watched them and tried to reproduce the same gestures to produce similar results.

Usually groups of people (from 2 to 8 people) used the display together; individual interaction was rather rare. While groups used the screen, one individual operated the screen, while the group suggested which information should be displayed.

The display stimulated social interaction. People, who met while interacting with the display, continued to talk with each other even when they stopped interacting with the screen. The display was used as an ice-breaker and allowed people that had never met before to start a conversation[19].

3.1.2 MobiLenin System

With the MobiLenin System users can use their mobile phones to interact with interactive video on large public displays. The system was specifically designed to allow multiple users to vote, which video would be next, and to allow collaborative and competitive interaction. The mobile phone has a specialized Symbian client installed to display the current video choices and to input a vote. The main server processes the votes, shows the result of the poll, and switches the video accordingly [22].

The MobiLenin system was evaluated in a real world setting in a restaurant in Oulu, Finland. The general feedback was that the system was "easy to use" and enhanced the social experience [22].

Users can only interact indirectly with the display and actually do not need to see the display. It seems that the large display is unnecessary and the results could as well be just displayed on the mobile devices.

3.1.3 Touch Projector

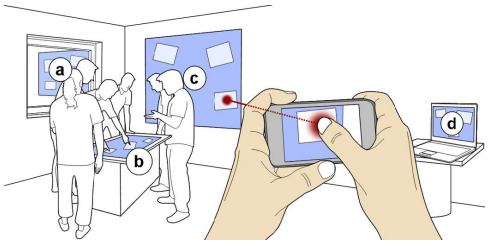

Fig. 3. "Touch Projector allows users to manipulate content on distant displays that are unreachable, such as (a) displays outside a window, or (b) a tabletop system. It allows users to manipulate devices that are incapable of touch interaction, such as (c) a wall projection or (d) a laptop. Users point the device at the respective display and manipulate its content by touching and dragging objects in live video. The device projects the touch input onto the target display, which acts as if it had occurred on itself" [3]

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The touch projector system is based on the vision that users could remotely interact with devices via live video [25]. The basic functionality of the touch projector enables screens without touch capability to receive touch capability through the smartphone *(see figure 3)*. The system uses a smartphone (Apple iPhone) and a dedicated computer connected to the screens. The camera of the smartphone identifies screens by analyzing the objects currently displayed on the screen. In addition to directly interacting with a single screen, objects could be moved from one screen to another screen [3].

Interaction through live video is not limited to traditional display technology. The Touch Projector system was enhanced to control a media facade at the ARS Electronica Festival in Linz. The new system also allowed multiple users to interact simultaneously with the same facade *(see figure 4)* [4].

3.2 Standalone Public Displays

With standalone displays, no additional device is required to interact with the screen. This allows users to interact with the display in the implicit, subtle, and personal interaction phases. Most systems presented work best in the personal interaction phase.

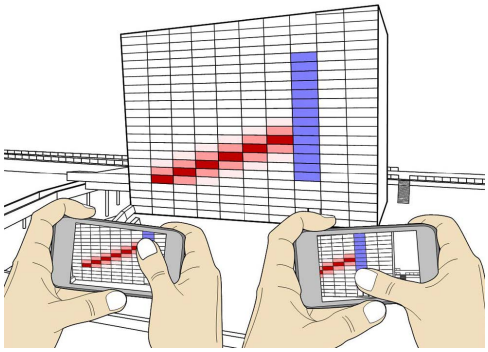

Fig. 4. "Interacting through live video allows multiple users to manipulate a media facade. Changes (also those of other users) are shown immediately on the facade and the mobile device. Colors denote actions from other users" [4]

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3.2.1 Everywhere Display Projector

To enable dynamically projecting images and text everywhere around the projector, the Everywhere Display Projector was built. The LCD-projector is combined with a computer-controlled pan/tilt mirror. This particular projection system compensates for distortions that occur when changing the position of the mirror [16]. With the addition of an independent camera system, the system tries to track and identify hand motions. This is accomplished by analyzing frames to discover fingertips and their changing position between video frames. A touch sensing widget is also implemented in the device, enabling users to touch projected images and interact with sliders and buttons [23].

The system was created to provide additional information in an retail environment. Two types of interaction were implemented with this technology:

- *Interactive Clothing Bins:* The clothing bins are assembled in a checkerboard pattern of alternating merchandise and displayable space. Reaching into a clothing bin triggers to highlight the current bin and the displayable space to display information about the content of the bin. In addition, a touch interface enables to see further information for sizes, available stock, and customer service *(see figure 5)*.

- *Mixed-Media Products Table:* A round table with items placed on it, but leaving a 6 inch "'margin"' of table space as display space. The table displays keywords and highlights which items have the same keyword in common. When the user walks around the table, depending on his position, the display shows other keywords *(see figure 6)*.

The design was tested in a replicated 16x11 foot (5x3.3m) retail space in an laboratory. Users could use the "interactive clothing bins" filled with various types of pants and display detailed information about the pants. "The mixed-media products table" was stacked with Halloween-themed CDs, DVDs, and books. Keywords like "Ghosts", "Witches" etc. were used to describe the items.

During the evaluation of both systems several observations were made. Users did not know that their position was influencing the displayed information, leading to only unaware interaction with the system. Users simply assumed they were in an environment where information could change at any time.

Also, users initially were hesitant to touch projected images. After a short time of getting used to the system, users were comfortable using the touch interface [23].

3.2.2 City Wall

The City Wall interaction screen uses a rear view projection system. The screen can simultaneously track multiple hands and gestures. The interface was designed specifically to handle different media content, especially images. This system is ideal for placing a screen into an urban environment because of its multiple user support *(see figure 7)*. It is 2.5 meters wide and, during testing, up to 7 users used the display in parallel.

Fig. 5. A user interacting with the Interactive Clothing Bins [23]

Fig. 6. The mixed-media products table [23]

4 Design Considerations for Public Displays

Most humans are intimidated by new technology and are hesitant to adapt to new technologies. Public displays have additional social barriers, because of the fact that they are public, and that users are afraid to be publicly humiliated when using such an device. So besides the technical design challenges to be addressed, one must also address social acceptance issues.

4.1 Interesting Public Displays

When users pass a public display, the display must attract the attention of the user. People want to determin very fast, if something is interesting or not. The correct size and placement of the public display is key to attract users.

"Assume that viewers are not willing to spend more than a few seconds to determine whether a display is of interest. If the intent of the content is to be informative, present it in such a way that the most important information be determined in 2-3 seconds and avoid using more than minimal text [11]."

The display should be on eye level with the users to encourage them to glance at the display. The presented content should be updated dy-

Fig. 7. The City Wall used by two users [2].

namically to raise interest. The content should not abruptly shift to new content to encourage longer viewing of the display.

The placement of the display should be supported by its surroundings. The display should be the most interesting object to see and not be distracted by other information, for example, by posters or flyers. If it is possible, the display should be in the direction of the people's movement. Another possibility is that other objects draw attention to the display [11].

The size of the display is important for how the user perceives the experience. External factors play an important role, like how the user is exposed in public, or how much privacy is required. It is very important that the user is comfortable when using a public display. It may be beneficial to use multiple different screen sizes to comfort different types of users.

Observations have shown that when the same content is displayed on small and large screens, users pay more attention to the small screen, mainly because they feel as if it would be like a more private presentation and they are more comfortable looking at the content [11].

4.2 Design Principles

In 2004, Vogel and Balakrishnan compiled a list of fundamental design principles for public displays.

Non-distracting Display of Information lets users accept the display as a natural object that fits into its surroundings. Public displays should blend completely into their environment. It should fit with the surrounding architectural design and not disturb users in their common activities. Especially, content should assume a similar color palette as the surroundings of the display [7].

When the content of the display changes too fast, it disturbs and distracts users. The precise timing is key and has to be determined individually. A system with a too slow reaction time appears to be unresponsive and discourages users [8].

Comprehension of what the device can do and how to operate the device is important. "An interactive display should reveal meaning and functionality naturally" [27]. The user should not be intimidated by the screen and should be invited to use the display by its "easy-to-use".

Notifications have to be made in a socially acceptable manner. Displays should not forcefully interrupt passing people to attract users. The display has to determine the interruption tolerance of a potential user by analyzing the number, speed, and orientation of potential users [27]. In many cases, no explicit notification is needed, because active users automatically attract more users [15][6].

Short-Duration Fluid Interaction means the display integrates into common activites that take place in the surroundings of the display. The user should not be disturbed in his usual activities. Information should appear as naturally as possible. For example, in a retail environment the primary activity is to look and select merchandise. The display of additional promotional offers and other information should not intrude or distract from this activity [27].

Immediate Usability allows users to operate the devices with commonly known gestures. Visual aids are required to make it clear, if the screen is touchable, or if it is operable with hand gestures. Any form of explicit explanation, before using the device, discourages users to use the device.

Interaction techniques based on the position of the user as well as touchable projected images should be avoided, because users need prior training to operate the display.

If more complex interaction techniques are required, they should be discoverable by experimentation, or suggested while using the display. When the screen is used by multiple users, it is also possible that such knowledge gets passed on by observing other users operate the screen [19].

Shared Use is essential to create a positive experience for users. Many advantages from large public interaction displays come from the possibility that multiple users can share the display "either individually or collaboratively whether interacting implicitly, explicitly, or simply viewing the ambient display" [27] .

Even when a terminal is designed to only handle a single user at a time, the display should still be able to connect to an online social space to provide a possibility for discussion and collaboration [8].

Combining Public and Personal Information is a very delicate topic. Only "harmless" personal information should be displayed on an public screen. "By harmless, we mean information that one is not too concerned about others viewing" [27]. However, every person has to determine individually what he considers "harmless" information. "Information considered totally innocuous to some, is considered personally private to others" [14]. Before using the display with private information, the user should be able to set up the system in a way that he is comfortable with using the display.

Privacy cannot be maintained with large interaction displays, especially because people tend to be more voyeuristic with large displays [24] and, even standing in close proximity, does not occlude enough of the display to discourage eavesdroppers. When handling private information, the user should always have a simple gesture to hide their implicit interaction with the display.

When the display is used in an urban enviroment, the display needs additional qualities to be successful:

Placement of displays influences what kind of user experience gets created. "Public displays are generally deployed in socially active public environments and as such should be linked to the qualities that make such spaces special" [7]. For example, in a coffee house the public display could be part of the coffee table, letting it perfectly blend into the surrounding architecture as well as engaging users in interaction.

Communal and Shared Information is usually preferred over individual information, for example, customer pictures. All content should relate to the community and be created by the community.

Local and Location Dependent Applications on the public display are to encourage users to socialize.

Needing Nurturing : "Interactivity should be founded on repetitive social actions (e.g. participating in discussion, creating friendship links, collaborating in group activities)" [7].

Reward Systems can create loyal customers [5] and encourage usage in such environments. For example, "rewards in a coffee shop can be either a free coffee or an aesthetically pleasant visualization" [7].

Information presented in such community displays focuses on five types of information:

1. *Relations*: Users are mostly interested in continuing interacting with other users in the community. Information about quantity and quality of the current relations between users helps users to connect.

2. *Co-operations*: Overview of cooperate initiatives available and how users are participating in these initiatives. "e.g. voting for the same song in a vote-based music jukebox" [7].

3. *Nurturing actions*: Actions to maintain their participation level in the community.

4. *Visits*: "Information related to duration and rate of visits to the place, where the community display resides" [7].

5. *General*: Local weather information, local news etc.

4.3 Overcoming Social Barriers

Several studies have shown that users are reluctant to use public displays. It has been observed that a major factor is the fear of social embarrassment. An analogy can be drawn with a street performer, "who invites a participant from the audience to help out with their show. Such a person can often be wary of volunteering, not knowing what exactly will be required from them, especially if it entails making them look foolish in the eyes of the on-looking audience" [6].

Users do believe that they do not have the basic skills to operate such a device and they do not have time to learn how to use the device. Other initial barriers are that there is no established social etiquette how users should behave towards the device.

To study these kind of social interactions, the "Opinonizer" system was used [6]. It is a questioning program, running on a laptop, that could be projected onto a large wall. Users had the possibility to input comments on various changing topics. The system was evaluated at two real separate social events: a book presentation and a student welcoming party.

To overcome these initial barriers, a dedicated helper has to motivate and assist users to operate the device. When more users start to interact and actively use the display, bystanders learn how to operate the device through observing others interacting with the display.

In addition, the helper should actively interact with the device and provide initial input to the system. The resistance to inputing information is then lowered, because users see that other people are already participating[6].

Several observations were made:

Honey-Pot Effect describes the observation, when one user finds and uses the device, it attracts more users. Initially, the display is something new. Over time, more and more users overcome their fear of something new and start to participate. This in turn attracts more new users and the number of people in the vicinity increases. This leads to a physical "bottleneck": users have to determine the social practice of, for example, queuing up to use the input device.

Not knowing what social practice is being applied, leads to negative feelings and creates new barriers, thus discouraging users. Positive conceptions, like believing the display is enjoyable or worthy of attention, entice people to participate.

Besides the increased usage of the public display, the people around the display are open for discussion to talk about the display or the current topics, creating a social buzz around the display.

Low Self-consciousness of users prevents them from using the display. If the public display updates in real time, then all spelling mistakes and shaking with the mouse cursor are viewable by all. Users need a high self-confidence to cope with the feeling that other people are watching as well as the pressure of creating a socially accepted comment.

Remote input would remove social awkwardness, but also remove the "honey-pot" effect. "Remote input would reduce pressure on people, it would defeat the purpose of having a public display as a place for encouraging socializing" [].

A simple way to reduce this type of stress would be to remove real time updating of the screen, allowing users to edit and revise their comment before posting it on the display.

Nicknames: or first names were preferred by people when inserting a comment on the display, even though surrounding people could exactly identify who is inserting the comment. It allows people in the immediate vicinity to create social contact, but is at the same time, "vague enough to prevent social embarrassment and identification from a wider, unknown audience." [19]

Other possibilities to overcome the initial barriers are to increase the attractiveness of the display.

Reward Systems based on performance, for example, learning new aspects of the interface. This can be used with every type of display system. The reward itself should be something physical (e.g., discounts, product coupons).

A random lottery based system gives an incentive to use the system. In addition, it gives certain users a very positive feeling when they actually win the lottery. This type of reward system would be best when used in a bar-type environment [22].

Rewards encourage users to overcome their fear of the new as well as give them an attractive reason to continue using the display.

Usefulness of the display is very important for users so they immediately understand that using the display benefits them.

4.4 Multi-user Interaction at Urban Public Displays

The earlier mentioned CityWall project recorded the interaction of its users via webcam. Several observation were made of people interacting at the display with others [15]:

Parallel Use: Several people could interact with the device simultatiously and work parallel next to each other. Users acted as individuals, disregarding all actions of the other users. A different form of parallel interaction was observed when multiple users synchronized to simultaneously use the same interaction to manipulate displayed photos.

Teamwork and Playful Activities: People who came with friends to the display, clearly acted as a team to work towards the same objective. Depending on the social organization, different group interactions took place. In most cases, one individual approaches and uses the device, while the surrounding group comments and gives advice. Teamwork was also observed to overcome physical limitations. When a user held an item in one hand, another user provided a helping hand to perform gestures. Even though the display was only designed to manipulate photos, groups of users created their own games. "For example, people were playing Pong, throwing photos at each other, and soccer, building a goal out of two photos and trying to throw a third one in." [15]

Conflict Management: Conflicts using the display usually occur when users intrude on the territorial boundaries of other users. Such conflicts usually happen by accident, e.g., by extreme large scaling of an image that covers most of the display and disturbs other users in their work space. One way of resolving this conflict is that the group, that has been intruded on, withdraws from the display. Another way is to first look for support in the group, and then confront the intruding group. In some cases, the conflict was resolved by humoring the situation and making a joke like "It is mine, dont touch" [15].

Floor and Turn-Taking: By observing the actions of others, people can anticipate when it is appropriate to go and take the floor [20]. Such terminal activity has many different forms. One distinctive example is when users, just before their exit, moved towards the side of the screen without making any meaningful actions. No new items are introduced to the screen and the interaction with the existing objects is minimal.

Expressive and Pondering Gestures: Using expressive and grand gestures allow users to clearly signal other users that they are using the display and need a lot of space. On the other hand, people used a pondering grip while thinking about what they would want to do next with the photo. Both gestures signal to other users that they are busy. When other users want to interact with that user, they have to wait for another more suitable moment.

Concluding Actions: When individuals find interesting photos, they use physical and verbal signals to attract attention. Some users leave a mark before leaving the display,for example, leaving an embarrassing photo on the screen.

4.5 Limitations of Mobile Devices

It is obvious that mobile devices could control all applications from a remote distance. For many applications this can be desirable, for example, adjusting the lighting in a room or regulate the room temperature. But in many cases, where the user has to be present to operate the device like microwaves, DVD players, or ATMs, "it is not advisable to use handhelds as interaction devices in order to replace existing physical user interfaces. In most everyday situations, direct manipulation of the appliance is easier, faster, and more convenient than handheld-mediated interaction." [18]

Handheld devices can benefit user interaction when a special situation occurs. Special situations occur rarely, but usually present several problems at the same time: The user lacks the knowledge which individual steps are required to resolve the issues, and the user interface provides no simple interface for these uncommon tasks. Several examples for such tasks would be [18]:

- Programming an oven to start cooking at a user given time. (Usually the functionality is not used because it is to difficult to operate the user interface)
- Figuring out how to use the special programs of washing machines.
- Cryptic error codes of printers (e.g., F602) is incomprehensible and of little value for a user.

Mobile phones have two ways of interacting with the appliances [18].

1. *Information Provision*: The appliance could notify the mobile device about its current status and provide additional information that cannot be displayed on its own display. The user would be provided with a full instruction set what to do next to resolve the problem.
2. *Provide User Interface*: The mobile device could extend the haptic user interface and allow easy access to rarely used features.

When using a mobile device in combination with an public display the same interaction paradigm applies.

1. *Information Provision*: The display could notify users about new personalized information accessible via the screen. Other features could be that the display communicates with the handheld device to identify users and adjust the screen to the users preferences.
2. *Provide User Interface*: When the user can simply walk up to the display and manipulate it via touch, there is no clear benefit to have an additional user interface on an mobile phone.

   In some cases, when the public display is unreachable or cannot be manipulated by touch, creating interactivity via mobile device is an option.

When utilizing mobile phones as input devices one has to face the fragmentation of the cell phone market[9]. Currently there is no way to create a unified application for all devices. For the smartphone market, Adobe Flex 4.5 enables a unified experience for iOS, Blackberry, and Android devices. Even with such initiatives, some operating systems like Windows Phone 7 are currently unsupported [10].

5 Conclusion

The technical design principals found by Vogel et al. are the basis for public displays. Touchscreen technology, found in consumer products, like the Apple iPad, Apple iPhones, and Android devices, is the most promising technology for public displays. "With these, users can now interact directly with the displayed objects by simply touching the display, creating a sense of immediacy and natural interaction." [17]. Users are familiar with the technology and are comfortable using it.

To further enhance public displays, a Microsoft Kinect motion sensor could be used as proximity sensor and hand gesture tracking device. The Microsoft Kinect is a specialized gaming controller to accurately track multiple players. The system has proven to be very reliable in tracking human motions. Medical facilities are experimenting with Kinect controlled medical displays to assist surgents [13].

Combining a touchscreen and a Microsoft Kinect system is relatively cheap and would be an ideal public interaction screen for widespread usage.

At the current state of development of interaction displays, users perceive this type of technology as something new and unusual. The initial reaction of users will be to try to avoid the displays. In the long term, when interactive displays become more common, public interaction displays are going to find social acceptance. To accelerate this process, the public display has to have a solid intuitive design combined with a reward systems.

My research only focuses on Western culture. It would be very interesting to see if similar usage barriers of public displays exist in other cultures, e.g. the Japanese culture or the Arabic culture. With touch devices and proximity sensors becoming more common, new developments for additional ways of naturally interacting with public displays, evolvement of "easy-to-use" interfaces, and also new ways of mobile phone interaction are to be expected. Most interesting will be how these types of devices will integrate into our daily lives.

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