

Body Proximate Displays

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1. ABSTRACT

Due to the affordability of consumer-oriented smart devices, many users are able to use different devices simultaneously during their daily life. The usage of different smart devices enables people to show digital content across multiple display types. In the future these new display environments enable the user to work more efficiently. In the following paper we summarize many ideas and concepts which are introduced in academic research area about **Body Proximate Display** environments.

Keywords

Head-worn Display, Hand-held Display, Head-worn Display, Head-mounted Display, See-through Display, Augmented Reality, Multi Display Environments, Multiple Displays, Graphical User Interfaces, Information Spaces, Mixed Reality, Ubiquitous Computing, Gesture Interaction

2. INTRODUCTION

Body proximate displays arise from the combination of different hand-held, head-mounted, wrist-worn devices or other displays [11]. People can use these devices for example as information displays to complete tasks in their daily life. Thereby many problems arise by tasks that span across multiple devices [7]. For example if the user wants to navigate and discover a new city. In this situation the user has to switch between multiple information displays, where one display shows the map and the other buildings around his body. The combination of different body proximate displays increases the complexity of the interaction space.

In study [7] was shown, that technical users use in average about 6 devices in their daily life. The collection of different types of devices varied from a minimum of 3 and a maximum of 11 devices. In these shared environments, displays of smart device can be combined with fixed displays like computer monitors or projectors.

In the paper many different new aspects for body proximate displays are summarized, especially new interaction techniques that combine multiple devices and useful application scenarios for the user. At the end of this paper the challenges and opportunities for future research are discussed.

3. MOBILE AND WEARABLE DISPLAYS

The mobility of hand-held touch-based displays expand the interaction space by using the movements of the device around the body. The users can for example perform mid-air gestures to switch the context of the application or attach

virtual objects to their body. In the following chapter we introduce mobile and wearable displays for body proximate display environments.



Figure 1: Hand-Held Touch-Based Displays, Body-Centric Interaction [6]

3.1 Hand-Held and Touch-Based Displays

In the "**Body-Centric Interaction**" framework of Chen et al. users can manipulate and access content by positioning a display around his body (see Figure 1) [6]. The system generates a relative spatial model of the user by attaching reflective markers to the device and their body. The spatial relationship between the body and the device is used for navigating on-screen content. With this technique people can manage tabs, bookmarks and websites in mobile web browsing. If a user moves his display closer to his head the "retrieving layer" is shown. In this context position websites are rendered on the display. Moving the display further away from his head, the context is switching to the "placing layer". The "placing layer" is used for managing and storing bookmarks. Users are able to retrieve digital content, by anchoring it to body parts. Each part of the body can be assigned to trigger programmable actions. This feature can be used as a shortcut to open frequently used apps. Chen et al. suggest a scenario for opening the phone app when the user is holding his devices close to his ear [6]. After the phone call the user can attach his device to the upper arm. This action can switch the currently used app to a music player. Similar to the anchoring of digital content the control of a running app can switch by moving the device over different body parts. Chen et al. also introduces a usage scenario with a wristwatch, where a user can move his arm to switch between upcoming events in his schedule [6].

3.2 Multiple Touch-Based Displays

New interaction techniques can be created by the combination of multiple touch-based displays.

Hinckley et al. introduces the synchronous gesture technique "**Display Tiling**" [15]. The user can join two touch-based displays to a bigger one by bumping two tablet device to-

gether. The tablet devices can for example lie on a table or be held by the user in mid-air. The system synchronizes all sensor data through a wireless network connection. The framework simultaneously tracks all sensor data gathered by the acceleration sensor in the devices. With the bumping gesture the user can transmit data between the two tablet devices. The data is copied from the system clipboard to the other tablet. Hinckley et al. also provide the user a functionality to display photos on two connected tablet devices [15]. In the photo application the left tablet shows an overview over all possible stored images in a small version. On the right tablet a large version of the image is shown to the user. The bumping gestures also provide a digital version of exchanging contact information. If two users bump their tablet devices together the personal website of the user is shown on the opposite web browser.

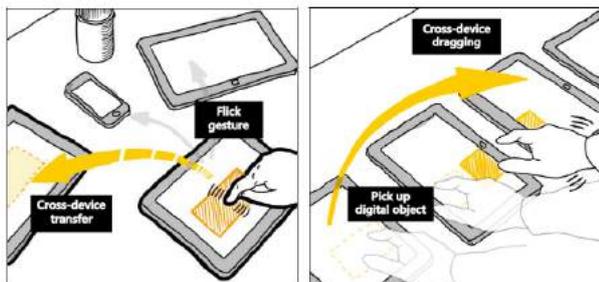


Figure 2: Multiple Touch-Based Displays, HuddleLamp [22]

HuddleLamp uses an RGB and depth camera for tracking multiple touch-based displays on the table (see Figure 2) [22]. Every display on the desk can be freely moved or rearranged to another position and removed from the system. HuddleLamp is able to track the position and movement of different hands. With this tracking method users can move content from one device to another registered device. Cross device file transfers are implemented with a "pick, drag and drop" gesture. "Touch and flicking" gestures allow the user to temporarily move objects from one display to another one. The user can also combine two or more displays side-by-side on the table to create a bigger virtual display. With this feature the user can for example rotate, zoom and pan large images. HuddleLamp also introduces spatially-aware modes where the user can rotate one of his displays to change the context of the application. After the display was rotated the device is changing to a "note taking mode" in which the user can annotate content.

Inspired by Rekimoto [23] **StichMaster** combines two close tablet devices with a new pen gesture called "stitching" [16]. With the "stitching" gesture the user can move a pen stroke starting on one display to another one. Each tablet has to be within arm's reach of the user, it is not required that the devices have to be in direct contact. Each device is connected by a wireless network connection. The synchronization algorithm combines all pen strokes to one virtual path. Users share images by pointing and moving them with the pen to another tablet. StichMaster also provides a functionality for selecting multiple images on a display and presenting them in a gallery to another display. The "Stitching" gesture extends the "pick and drop" gesture for sharing virtual objects

with a pen on different devices [23].

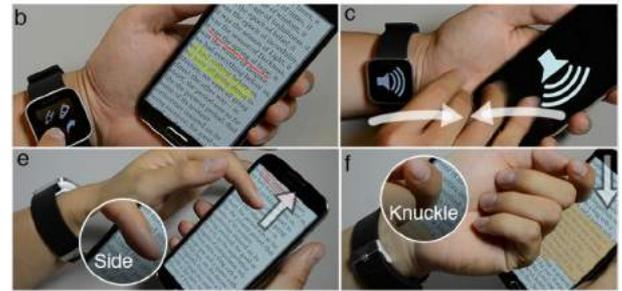


Figure 3: Multiple Touch-Based Displays, Duet [5]

The framework **Duet** uses joint interactions with a smartphone and a smartwatch (see Figure 3) [5]. The smartwatch is used as an active element that enables freehand gestures in mid-air. The combination of both devices enhances the range of multi device gestures. The spatial model constantly monitors the relative orientation between the watch and the phone. The watch is worn on the left wrist, while the phone can be held with both hands. The first gesture allows the user to unlock his phone. The user holds the phone with the left hand and simultaneously flips it with the smartwatch. With a "knuckle touch" the user can arrange apps on his home screen. The user can also quickly switch between opened apps by pressing on an icon grid in the touch screen display of the smartwatch. The "stitching gesture" from the phone to the smartwatch moves all app notifications from the phone to the watch. The user is now able to change the display where the notifications of an application are displayed. With the "double bump" gesture he can zoom out in a map application. The "double bump" gesture is activated by bumping the phone on top of the smartwatch. The overview over the map is displayed on the phone screen. In the map application the display of the watch is used for showing the zoomed-in area of a map. Chen et al. also introduce this feature for selecting small targets on the map [5]. In the map application scenario the user can perform a swipe gesture on the watch's screen to switch between normal and satellite view.

The "flip and tap" gesture enables the user to open an advanced application menu. This gesture is performed by first flipping the smartwatch around the wrist and tapping the touchscreen of the phone. Here the display of the smartwatch is used for showing pieces of text which were marked by the phone's default "copy and paste" functions. Additionally the screen of the watch can show a tool palette by positioning the watch to the inner side of the wrist. Duet also provides a feature, to switch between frequently used apps during a phone call [5]. The user can also switch between apps by swiping to the left or right on the display of the smartwatch.

3.3 Head-Mounted and Touch-based Displays

Head-mounted displays can show virtual information spaces around the user. The user can manage information by attaching or annotating virtual objects to the physical environment.

EtherealPlanes describes a design framework for projecting 2D information spaces in 3D environments [8]. The user can pin virtual objects around multiple virtual windows that float around the body. Each virtual window can be fixed in relation to the body of the user or mapped to an existing surface in the room. By using pinching gestures the user can re-size or move windows around his body. If the user drops an application icon from an existing window in mid-air a new application window is shown to him. Data objects are moved by a pinching gesture between two different windows. The user can control each application window by pointing with his fingertips inside the virtual windows and moving the cursor to the desired location.



Figure 4: Head-Mounted and Touch-Based Displays, MultiFi [10]

The framework **MultiFi** enables the user to interact with displays on and around the body (see Figure 4) [10]. The system combines head-mounted, hand-held and wrist-worn devices to perform efficient mobile interaction techniques. MultiFi uses the head-worn display as an additional information layer [10]. Depending on the current device and application used additional information is shown to the user on his head-worn display. When he navigates through lists or menus on his smartphone or smartwatch the head worn display can show additional nearby items. Grubert et al. also suggest a method for an efficiently navigating on large maps [10]. In this usage scenario the map is displayed in relation to the upper body of the user. The touch display of the smartwatch or smartphone can be used for zoom operations.

Similar to Chen's body-centric interaction framework [6], MultiFi provides the user a mechanism to store digital information on the body. This feature enables the user to list items on his lower arm when scrolling through lists on his smartwatch. Through head pointing the user can retrieve stored virtual items on his body. The text widget feature allows the user to type text messages with a soft keyboard on his hand-held touch device. The text output is redirected to the display of the head-mounted device. The larger keyboard can speed up the writing process of the user, while the typed text is not visible to other people.

In their study Budhiraja et al. compare different techniques for selecting **Virtual Content** around the user [2]. The content was shown on the head-mounted display while the selecting process had to be triggered on a mobile touch display. In the first "Sticky Finger" method, the user can move the cursor of the head-mounted display by moving his finger on the touch display. In the second method, the "Head Crusher", two fingers are used to select virtual objects on the touch display. In this case two cursors are displayed on the

head-mounted display. In the gesture "Tab Again", the user can select virtual objects by placing the cursor to the object and lifting his finger up. In the last "Pinch Gesture" method, users select content by pinching inwards over the object on the touch display. The user study also measured the average completion time and the error-rate of all participants. The lowest error-rate was produced by the technique "Sticky Finger", while the "Tab Again" gesture also performed well in the average completion time. Many users of the study stated that "Tab Again" is more useful and intuitive than the "Pinch Gesture". 66% of the users preferred the "Tab Again" for selecting virtual objects. Combining all results the users preferred more on-screen touch gestures than gestures with two cursors.

4. MOBILE AND STATIONARY DISPLAYS

Mobile devices allow the user to move between rooms in the working office. This mobility feature enables the user to share digital content on stationary displays in public space.

4.1 Hand-Held and Stationary Displays

The combination of hand-held and stationary displays enables the user to pick up personal information on his hand-held device and share public information on global stationary displays.

Grubert et al. introduce a design framework for combining hand-held devices with printed **Street Posters** [9]. In this approach users can see additional virtual content through a smartphone which is not printed on the poster. The system can assign each graphic and text element further digital information for example live videos or images from an event. If the smartphone is switched from the horizontal position to a vertical one a "zoomable view" of the poster is shown to the user. This extended view possibility allows the user to zoom or navigate through the digital representation of the poster. After moving away from the poster the system automatically stores a digital representation of the printed event poster on the smartphone. With this feature the user can move through the city without information loss. Grubert et al. also suggest a usage scenario of playing virtual reality games on printed street posters [9]. In this scenario the user has to find and select special apples whenever a worm appears. With a short hand movement the user can discover different locations of the apple tree to find the new locations of the worm. The user can select an apple by pressing three times on the touch screen over the apple icon.

The virtual reality game was also evaluated in different public spaces in Austria [12, 14]. The studies compared two different settings for performing a find and select game. In this scenario the user was able to choose between the virtual reality setting "Magic Lens" and the normal game setting "static peephole". In the "static peephole" setting the user played the game on a smartphone display. The study [12] showed that most users on a big public square preferred playing the game with the virtual reality setting. Grubert et al. repeated the same study on at a different location [14]. In public transportation center the users preferred the hand-held setting for playing the game. The study also showed the average task completion time was equal in the game levels when performing the game inside the laboratory compared to outside conditions. Grubert et al. also showed that

the users switched from the virtual game setting to normal tracking when tracking errors occurred. A similar study was conducted in a touristic context [13]. Oberhofer et al. investigated how web-based techniques could be used for tracking print media [20].

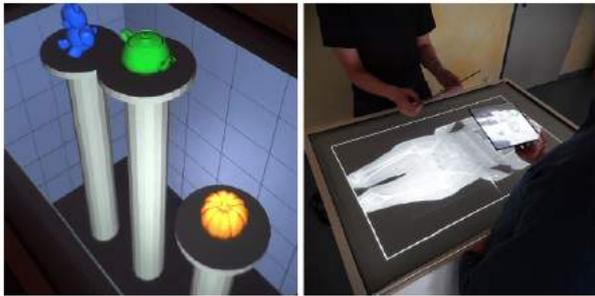


Figure 5: Hand-Held and Stationary Displays, TangibleWindows [26]

The design framework **TangibleWindows** enables the user to interact with virtual 3D information spaces (see Figure 5) [26]. **TangibleWindows** allows multiple users to explore and manipulate a global virtual 3D scene which is aligned to a physical room. The user can wear and look through light weight paper based displays. These local displays act like physical peepholes into a virtual 3D world. The global display which is located on the tabletop of the room acts like a virtual overview over the 3D information space. In this approach the users don't wear head-mounted displays to access the information space. The positions of the user's head and display are tracked by the system to render a correct perspective view on the local display. The fixed cursor of the user interaction is located in the middle of the local window. By pressing the touch display of the local window the user can pick up objects and move them around the scene.

In **TangibleWindows** the user can also manipulate the 3D information space by copying, deleting or rotating virtual objects [26]. To delete an object the user simply drops objects into the physical area beside the table top. For an advanced object inspection the user can flip objects by pressing and holding a button on the local display. Similar to the local object manipulation techniques the user can also drag objects on the global tabletop display. An application scenario of **TangibleWindows** is the virtual 3D representation of a patient's body for planning surgeries. The system can also be used by Interior or Game Designers. In this usage scenario designers or architects can move virtual models of furnitures or walls in different rooms.

Rekimoto introduces a "**Pick and Drop**" gesture for sharing virtual objects with a pen between desktop-screens, palm-sized and wall-sized computers [23]. The gesture is inspired by the "Drag and Drop" technique for moving objects on the desktop computer. The user can copy files between the hand-held devices to share virtual objects to other persons. To perform a "Pick and Drop" gesture, the user first has to select a file by pressing the pen to the touch display. After the selection process the user can move with his pen to another display and release the object. For synchronizing the gesture between different devices, all devices are connected

to a wireless network. Rekimoto suggests an additional usage scenario where the user can pick up URL information in public displays [23]. The public information displays can for example store ads or job announcements. The gesture can also be used for changing the color for drawing on whiteboard-sized display interfaces. "Pick and Drop" gesture can be also used for sharing short text segments like URLs or copied document fragments.

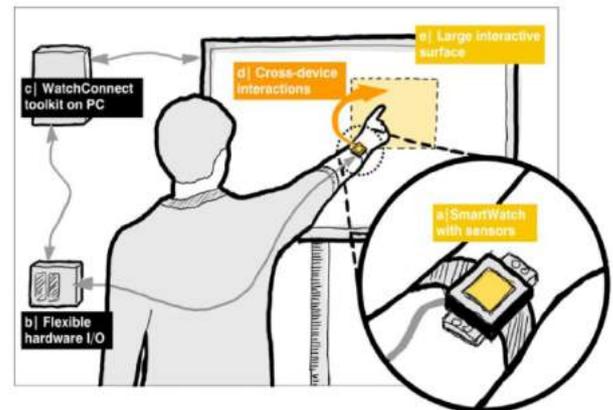


Figure 6: Hand-Held and Stationary Displays, WatchConnect [17]

The toolkit **WatchConnect** provides developers to create cross-device applications and interaction techniques with smartphones on large interactive surfaces (see Figure 6) [17]. With this framework the user can move virtual objects from his smartwatch to other touch displays. When the user touches the display a connection between the smartwatch and the display is established. If he performs a "left to right swipe" with his smartwatch all selected virtual objects are sent to the display. The user can manually select objects by touching and scrolling on an item list on his smartwatch. If he wants to copy objects to his smartwatch, he has to select all of them on the touch display and perform a "right to left swipe". The toolkit also enables the user to enter or correct a password field on a website. In this scenario the smartwatch is used as an authentication method for showing the entered password in the input form.

WatchConnect also provides a functionality of modifying, viewing and finding locations on a large map [17]. In this application the display of the smartwatch has a default zoom level twice the main map. The user can zoom or switch between different map layers by touching the bevel of the watch. The display of the smartwatch shows a detailed overview of the cursor position of the map. The framework also facilitates a functionality for beaming a user interface from the smartwatch to another display. With this feature the user can open applications like Skype and send the output to a bigger display. After this step all incoming phone calls are shown and redirected to the bigger display.

4.2 Head-Mounted and Stationary Displays

Head-mounted devices can expand the functionality in distributed display environments. Head-worn displays have the advantage that the user can move his virtual objects across multiple rooms in his working environment.

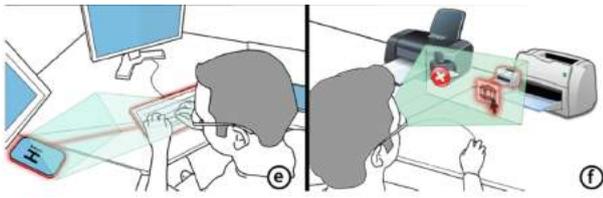


Figure 7: Head-Mounted and Stationary Displays, Gluey [25]

The framework **Gluey** allows the user to migrate digital content across multiple displays. The embedded cameras and spatial sensors in the head-worn display track multiple devices around the user (see Figure 7) [25]. The head-orientation is used for determining the current display in the working environment. After the registration of all devices in the spatial model the user can control data on multiple displays with a single input device. Gluey provides a clipboard mechanism that gives the user an overview over all virtual objects. Every object is shown on the head-worn display. With this technique the user can copy files on his head-worn clipboard and print them in another room. Gluey also provides a mechanism for pairing input devices like a desktop computer with other device like a smartphone [25]. After the pairing the user can for example write messages with the keyboard on his smartphone or use his mouse to control any other device. Additionally the user can capture the physical environment in images and pick colors by pointing in front of his head-worn display.

5. PROJECTED DISPLAYS

Projection based displays enable the user to enlarge the display space of hand-held or head-worn devices. In this scenario each smooth surface for example walls can be used as a projection screen.

5.1 Stationary Projected Displays

Stationary projected displays can be used for expanding the interaction space. Projection based displays can enrich the capabilities of hand-held or head-mounted displays and the way in which the user interacts with the room. In this scenario of "projected displays" every smooth surface of the room can be seen as virtual interactive touch display.

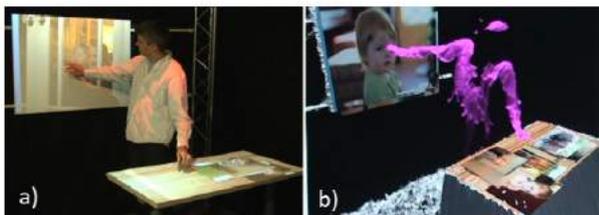


Figure 8: Stationary Projected Displays, LightSpace [27]

The framework **LightSpace** uses multiple depth cameras and projectors to simulate multiple touch displays (see Figure 8) [27]. The system projects the displays at the wall, on top of the table or on the body. With the data of the depth

camera **LightSpace** is able to facilitate mid-air and multi-touch interactions. The user can pick up virtual objects on the projected surface and drop them to another surface for example from the wall to the table. When the user picks up a virtual object a special marker is projected to his hand. With this marker function the user can move virtual objects around the room. **LightSpace** also introduces "through-body transitions" where the user can move virtual objects through his body by touching the object and then touching the desired location. The system also provides a new mechanism of selecting items from a menu list. Similar to the marker function the menu list is projected on the floor in front of the user. The user can select an item while moving his hand up and down and waiting for two seconds. In this special gesture technique the hand of the user acts like a projected body display.

aFoveAr combines an optical see-through display with a projector to achieve a new hybrid display system [1]. In this display configuration the "Field of View" of the users can be increased up to 100 degrees. The system uses a head tracking system to generate a correct perspective view on the head mounted display. One wall of the room acts like a projection surface for the scene. The 3D models and the content which is displayed on the head-worn display are rendered by a game engine. The system enables the user to look at 3D models or animations with a wide "Field of View" angle. The user can also move around the room to inspect different perspective views of the 3D scene. The prototype of **aFoveAr** also provides the functionality for a 3D life-size telepresence system [1]. This feature allows the user to have conversations with a virtual 3D model of a person.

Similar to the 3D model inspection the user can play virtual augmented reality games in the room. In this game the user has to fight against virtual sock puppets which appear in the 3D scene. The character of the user can run around the surfaces of the room for example on furnitures. With the wide field of view of the projector and the head worn display the user can easily track incoming attackers. The combination of both display types allows the system to highlight objects of the 3D scene. Similar to this feature the user can also add additional light sources to the scene.

5.2 Mobile Projected Displays

Mobile projected displays can originate from hand-held projectors. These projectors can be carried by the user to project virtual information spaces on a surface.

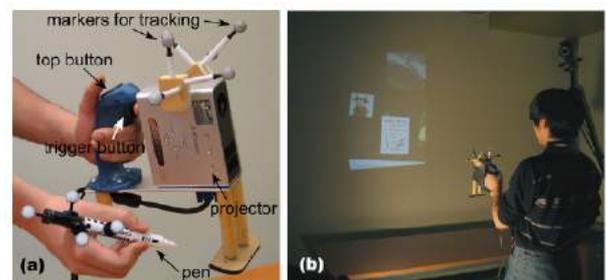


Figure 9: Mobile Projected Displays, Hand-Held Projector [3]

Cao et al. combine a "**Hand-Held Projector**" and a pen

to create a virtual information space in a room as if using a flashlight (see Figure 9) [3]. The system uses a stationary motion tracking system to track the position of the pen and the projector in the physical environment. The hand-held projector stabilizes the projected image by a mechanism to compensate the movements of the user in the room. This technique enables the user to explore a virtual illusion of a stationary information space. Before the user can use his own virtual information space, he can create several virtual displays on the wall. Virtual objects like pictures can be pinned to these displays. With the pen the user can draw additional annotations to virtual objects. They can be moved from one display to another one by holding them at the cursor position, which is located in the middle of the projection image. With the cursor the user can interact with menus like buttons or sliders. The cursor interaction provides an efficient way to move or rearrange virtual objects which are scattered across the room. If the distance from the user to the surface changes, more fine granulated information is displayed to the user. By pressing both buttons of the hand-held projector, a miniature overview of the actual space is projected to the virtual display.

In the framework of Cao et al. a hand based rotation with the projector to the left or right side acts like a shortcut for frequently used menu commands [3]. This feature enables the user to interact with information space without moving the cursor position. The main advantage of hand-held projectors is that each smooth surface can be used as a virtual display. This system also provides a mechanism for a collaborative working environment where different people can do brainstorming or annotate shared virtual objects.

6. TECHNICAL AND SOCIAL CHALLENGES

The usage of body proximate display environments can cause technical or social problems. In this chapter we introduce 5 different challenges and problems which can negatively affect the user experience.

6.1 System Latency

The system latency in HuddleLamp was observed as noticeable delay between the movement of the screen and the reaction of the user interface [22]. This latency was caused by the vision processing, the web socket connection and the rendering performance of the device. In LightSpace the overall system latency was greater than (100ms) [27]. This latency appeared during quick hand movements, when the user picked up a virtual object and carried it to another surface. The latency also caused problems in the Gluey framework [25]. Serrano et al. stated that the latency needs to be reduced to provide a smooth interaction experience. Grubert et al. also described a noticeable delay when the user played a virtual reality game [12]. In this scenario fast hand movements or a short distance to the poster caused tracking errors during the game play, which can lead to a degrading user experience [19].

6.2 Computation and Synchronizing Costs

The computation of a spatial 3D model of a room with depth cameras can be very expensive, especially when many people interact simultaneously [27, 1]. The user studies with LightSpace showed that two or three users slowed down the image processing speed [27] in a refresh rate of (30Hz) or lower. In Gluey the hardware of the head-worn display was

limited when using "Field of View" tracking techniques [25]. Hinckley et al. describe a scenario where the sensor data synchronization of a large number of devices can overload the CPU and wireless network resources [15]. "Synchronous gestures" over a set of n devices can produce $n \times n$ one-way connections. In the virtual reality game of Grubert et al. the tracking system regularly failed [12, 14, 9]. Therefore many participants had to change their hand poses during the game to reduce the amount of tracking errors. In aFoveAR the powerful hardware set up ensured relatively smooth user experience [1]. With the powerful hardware set up the tracking latency could be reduced to (10ms).

6.3 Spatial Memory Capacity

The memory of a user to retrieve digital content is limited to his spatial memory capacity. This capacity can be overwhelmed by a large number of virtual objects in the information space. A large number of digital objects which are for example attached to the body [6, 10] to the wall [3, 1, 9] or around the body [18, 26] can confuse users. In the frameworks [3, 25, 26] the space for attaching virtual objects was not limited to a specific room or display. This fact makes the retrieving of virtual objects in many locations very difficult. Also the fact that humans have a limited "Field of View" can reduce search tasks for cluttered digital content [21].

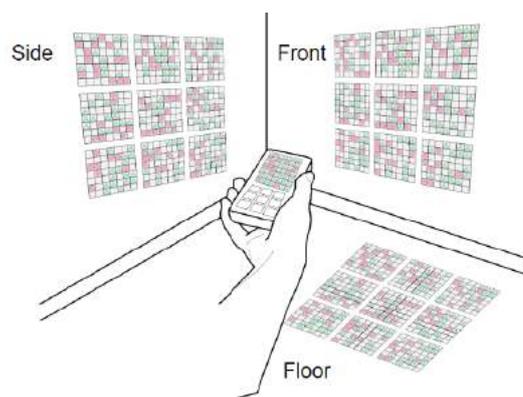


Figure 10: Spatial Memory Capacity, Visual Separation [4]

In study the effects of visual separation between projected displays was illustrated (see Figure 10) [4]. The study compared different room locations (side, front and floor) where the projected display of the phone was shown. The participants had to perform pattern matching search tasks. The user had to find sub-pieces of patterns in the projected display. These sub-pieces were shown on the screen of the phone. The preferred projection position of the user was the floor. In this position the context switches (between the screen and the projected display) were very low compared to the other positions. Because of these results, Cauchard et al. recommend that the default display in multi-display environments should be aligned in the same "Field of View" [4]. Different other solutions were invented to address the problem of the limited spatial memory capacity. Cao et al. introduce a virtual display which gives an overview over all attached virtual objects in the current room [3]. Chen et al. propose a scan mechanism for visually locating all

items (like browser tabs or images) which were assigned to parts of the body [6]. In the framework MultiFi the head-worn display enabled the user to relocate all information assigned to the body [10]. With head pointing the user can retrieve and switch all information. Schmidt et al. suggest "personal clipboards" for reducing the information clutter in shared working environments [24]. The advantages of "personal clipboards" are that the private enclosed information is not permanently shown on public displays.

6.4 Acceptance of new Interaction Methods

In body centric interactions the user can access digital content by making gestures with his arm. In Chen's body-centric interaction framework the digital content was placed on parts of the body or in the surrounded mid-air [6]. These new uncommon interaction methods may be often not appropriate in public spaces. Body centric interactions can look odd to other people standing in the surroundings. This fact can cause problems, especially when the surrounding area is full of people for example in a crowded train. Grubert et al. showed that the user can change the way how to interact with the virtual content when a passer-by intrudes the personal space of the user [14, 12].

6.5 Security and Data Privacy

New technical working environments ([25, 16, 3, 22, 23, 15, 26, 1]) allow the user to share virtual objects like pictures or documents in the working office. In shared environments personal information of the user has to be separated from public work displays. The user study of Dearman et al. showed that many users wish a device functionality for separating their digital content into a work and a private information space [7]. Some ideas were proposed to address this problem. Cao et al. introduced a "personal folder" to store private objects for a collaborative usage scenario [3]. All personal objects are saved into the hand-held projector of the user. The user can decide which virtual objects he wants to share. Similar to this approach the framework Gluey proposes mechanism for pinning objects on the head-worn display to carry virtual objects [25]. Dragging objects to the "Glueboard" can be seen as a personal storage functionality. The head-worn display of the framework aFoveAR can also be seen as private information space for the users [1]. Benko et al. also suggest a mechanism for hiding personal cards when the users play a virtual card game [1]. In MultiFi the user can write personal text messages on his head-mounted display [10]. The advantage of this approach is that not all text messages are visible to other people. Hinckley et al. introduced a feature for denying unauthorized tablet connections [16]. Only tablet devices which are close together can be connected to perform the "stitching gesture".

In the user study of Schmidt et al. different kinds of personal clipboards are introduced for organizing private and public information on touch interfaces [24]. Personal clipboards provide the user with individual copy-and-paste operations in multi-user environments. The study [24] compared "Context menu", "Subarea" and "Hand-held" personal clipboard techniques. Each clipboards technique was implemented with a different user authentication method. In "Context menu" clipboards each user had to wear a wristband with a unique identification code. In "Subarea" clipboard each user was assigned to special region on the surface. In these

regions each user can store private virtual objects. The user is identified by his individual hand shape pattern. "Hand-held" clipboards were realized by using the smartphone as a pen to perform touch gestures. The user is identified by simultaneously tracking the touch events of the user's phone and the events of the shared touch display.

7. FUTURE RESEARCH

In this section we propose some new ideas for body proximate display environments. The following scenarios describe common usage patterns in the user behavior and the implementation of these frameworks.

In the previous academic work ([22, 16, 23]) different techniques were proposed to share virtual objects between multiple hand-held displays. Inspired by Hinckley et al. we propose a **SmartPen** where the user can store digital content [16]. This pen acts like an USB stick with a personal clipboard, where the user can move content between different devices in his working office. The user can for example grab files with his pen by touching the virtual object on the touch display. After the grabbing process the user can release the virtual object by pressing a special button on the pen. In this scenario the connection between all devices is established by a wireless network. With this feature the user is able to move files from his smartphone or desktop screen to a printer. In this case the location of the printer is not necessary because the files are stored on the SmartPen. The display of the SmartPen can give the user an overview over all stored objects.

For the second scenario we suggest the **SmartRead** which was inspired by [5, 17, 25]. The framework combines a hand-held device with a head-worn display to enrich the reading experience of the user. In this scenario the user can for example read documents or browse websites on his smartphone. During the reading process all media embedded objects like pictures in the document are shown in the head-worn display. When the user reads a website or a document the system automatically tracks the eye position of the user. The tracked eye position can be used for an automatic scrolling mechanism. With special text selection gestures on the smartphone, the user can save text fragments on his personal clipboard. All copied text fragments are automatically summarized in the personal clipboard of the user. The SmartRead framework can also be controlled by special voice commands. We propose a function allowing the user to search for text patterns in the document or navigate through chapters with easy voice commands.

Benko and Cao [1, 3] introduced some projection based frameworks, where the user was able to interact with room walls. In these approaches each smooth surface was used as a virtual information space. We suggest the framework **SmartBedProjector** that combines a stationary projector with a hand-held device. This projection based framework enables the user to lie on a bed and watch films or slideshows above his head. In this approach the room ceiling is used as a projection surface. The hand-held device can be seen as a remote controller of the projected display. By swiping to the right on the touch display the user can for example switch the TV channel or show the next image during a slideshow. The hand-held display provides the user a

function to see additional meta information of the projected image. We propose a scenario where the hand-held display shows the location where the current picture of the slideshow was taken.

8. REFERENCES

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