PowerWall Interactions and Interactive (3D) Visualizations

Abstract
Analyzing large data sets on ordinary computer screens can be very cumbersome as size and resolution of desktop screens are rather limited. As a potential solution, ultra-high-resolution powerwalls extend the researcher’s work space and facilitate the analysis of large data sets. Interacting with such powerwalls requires new techniques beyond keyboard and mouse due to the dimension of the display surface.

In Powerwall Interactions, we look at how people can interact with and collaborate at such powerwalls. As a first step, we will look at gesture interaction on powerwalls and we also look at how collaborating with multiple people on powerwalls and connected devices, in particular tabletop computers, can be realized. This research is embedded into our efforts of investigating interactive visualizations on our 3D-enabled high-resolution powerwall.

Author Keywords
Powerwall; high-resolution displays; tabletop; collaboration; large screen interaction; interactive visualizations

ACM Classification Keywords
H.5.2. [Information Interfaces and Presentation (e.g. HCI)]: User Interfaces
Introduction

A tremendous amount of data is generated and stored every day for various purposes: Prominent examples are scientific measurements or business figures. While storing such data is only the first step, it is even more important to analyze this data in order to take advantage of it. Visualizations are extremely helpful to visually communicate information behind such data. As soon as it comes to analyzing large data sets through a multitude of visualizations and especially if it comes to cooperatively analyzing them, the space of ordinary computer screens quickly limits the viewer’s abilities. Using high-resolution powerwalls, this limit can be overcome: The dimensions of typical powerwalls allows multiple people to look at content at the same time as well as their resolutions allow more visualizations. Due to the physical dimensions of these displays, traditional interaction with mouse and keyboard can be cumbersome as well as they complicate the use by multiple persons at the same time. Therefore, additional modalities and interaction styles to control these powerwalls are necessary. Also, concepts for collaboration on a powerwall itself and with additional devices like tablets, tabletops, and other mobile devices need to be found and evaluated. In our project Powerwall Interactions, we aim at exploring the design space of interacting and collaborating with powerwalls. Using a prototypical powerwall setup as well as one of Europe’s biggest powerwall installations, we want to build and compare different setups, collaboration scenarios, as well as interaction styles, modalities and visualizations. One specific goal is to employ a user-defined approach by looking at how users naturally want to interact in these setups. While we will look at various scenarios, one current focus is the analysis of eye-gaze data collected during eye-tracking experiments. The first prototypical environment consists of a powerwall that can be controlled by gestures using off-the-shelf hardware. Additionally, collaboration is enabled through an off-the-shelf tabletop computer that can also be controlled by tangible objects.

Related Work

For the domain of large displays and powerwall, much work has already been done. Since first concepts as for instance envisioned by Weiser [12], projects like Roomware [9] have investigated interacting and collaborating with large screens in ubiquitous environments. From a technological point of view, we see today powerwalls with sizes as big as 20480×6400 Pixels respectively physical dimensions of 5.5 m×1.8 m and resolutions of up to 100 dpi [7].

In order to interact with these powerwalls, various research projects have been conducted involving different input modalities: Free-hand pointing input for instance has been investigated by Vogel et al. [10]. Malik et al. [6] looked at interacting with large displays (tabletop) using multi-finger and whole-hand gestures from a distance. As an alternative, physical movement has been proposed as a navigational aid [1] as well as physical manipulation [3]. Also, different modalities have been compared to perform certain tasks such as for instance pan and zoom [7].

Similarly, research has been done for collaboration scenarios at powerwalls: Vogt et al. [11] use a large-scale screen to work collaboratively with standard input devices on visual analytics tasks and investigate the collaboration of multiple users. For a touch-enabled powerwall, Jakobsen et al. [4] evaluate the collaborative usage of a powerwall for several tasks of the VAST 2006 Challenge. An example for frameworks that allow interaction with large-screen displays through multiple devices is the Shared Substance

\footnote{http://www.stfc.ac.uk/e-Science/39002.aspx}
framework [2]. The framework uses an abstract data-driven approach. This allows implementing many scenarios although it is more difficult to create specialized solutions. A user-defined approach to find interactions with large-scale displays has been employed by Knudsen et al. [5]. By conducting several workshops, they tried to find out how people use a large-scale display and how they interact with it.

Keeping these previous projects in mind, our goal is to further extend interaction and collaboration possibilities with powerwalls. We also look at extending the (physical) boundaries of powerwalls and at technological advances of these screens (3D output, etc.) and their interaction techniques (e.g., marker-less tracking for gestural input). Experiences about various target domains for such displays will be collected by investigating real-world scenarios, like, e.g., the analysis of eye-tracking experiments.

Besides the interaction aspect of powerwalls, we will also focus on conducting research in the domain of interactive visualizations - both using 3D and 2D output.

**Concept: Interacting at Powerwalls**
As a general concept, we envision an environment consisting of at least a powerwall and potentially additional devices. The powerwall is used to show various contents, especially a variety of visualizations. Different interaction techniques can be implemented and used to allow interaction with the content shown. This may either be done by one or multiple users. Additional devices like tabletops or tablets can be integrated. The visualizations shown can be manipulated in front of the powerwall as well as from connected devices. If additional devices are integrated, these devices may not only show a view of the powerwall (public space) but also offer private spaces that are only visible on the device. These private spaces can for example be used to prepare views for the public or to do personal investigations. The views can be moved between private spaces and the public space. The view of the powerwall on connected devices is intended to be interactive such that a remote interaction with the powerwall can be achieved.

In order to allow the evaluation of various aspects of the use of powerwalls, the effort to visualize and to allow interacting with content should be as low as possible. Therefore, we envision a framework that facilitates the distribution and visualization of different contents and that also allows to manipulate the representation across devices. The framework shall consist of a server component which allows the communication between various clients representing the different interactive devices (powerwall, tablets, tabletops, smart phones), data providers, and clients. Except for data provides, all clients should be able to show visualizations that represent views on the data. The communication part of the framework abstracts the data that is manipulated and visualized. As the visualization data is typically very large, data storage shall be handle by the server instead of storing it on each device. Similarly, also visualizations are abstracted and a plug-in system can be used to easily extend visualizations.

For a real implementation in a powerwall environment, the following components need to be created and connected: a server component to manage the communication across all components, data providers that serve the data to be visualized, and visualization plug-ins to visualize available data sets. For each device (powerwall, additional devices), a local client is required to visualize the desired data. By interpreting the desired input modalities, the views can be manipulated.
Implementation

Low-Fidelity Interactive Prototype

As a first prototypical implementation we use a back-projection powerwall that consists of two full HD projectors providing a resolution of 3840×1080 pixels. If 3D vision is required, another two projectors provide the image for stereoscopic viewing. An off-the-shelf depth camera (Microsoft Kinect²) is mounted to the screen to allow gestural input in front of the powerwall. A Microsoft PixelSense³ tabletop completes the setup that is used for collaboration purposes. The tabletop computer can be manipulated using touch input as well as tangibles objects.

To connect all the devices we employ a .NET-based first implementation of our envisioned communication framework. The communication framework uses an extensible and server-based message system to abstract the communication. Within the framework, data containers are used that can contain any type of visualization data. To be platform-independent, the framework uses webservices based on the SOAP protocol.

To access visualization data, the framework contains an interface for data providers that is used by the server. Each data provider provides data for a number of disjunct datatypes. Each device shows all public visualizations. The status and position of the visualizations are synchronized using the communication framework. The PixelSense has additionally a private space for visualizations that are not shown on the powerwall.

High-Fidelity Prototype: 3D Powerwall

For more complex scenarios as well as for research on interactive computer graphics and visualizations, we use a second powerwall setup: A seamless powerwall uses ten VC DLA SH4K projectors to provide a screen resolution of 10800×4096 pixels (about 44 million pixels per eye) respectively a physical dimension of 5.97 m×2.26 m. That means that each pixel has a size of about .55 mm. Using the INFITEC technology⁴, a channel separation is achieved to enable 3D vision on the powerwall with 44 million pixels per eye (Figure 5). The projectors are installed in portrait mode and arranged in groups of two forming stereo pairs that project on the same area. The image therefore consists of five columns and four blending areas (Figure 4).

Figure 3: Technical overview of our 10800×4096 pixels and 3D enabled, seamless powerwall.

As the intended use cases of the powerwall system are interactive computer graphics and visualization with at least 30 frames per second, a rendering cluster provides the necessary input. A set of ten dedicated display nodes consisting of ten machines with two graphics processors each is used to provide the input to the powerwall (4 graphics cards per projector). If complex scenes need to be rendered, more computing power is required. An additional

³www.microsoft.com/en-us/pixelsense/
⁴http://www.infitec.net/index.php/en/leistungen/equipment
set of 64 rendering nodes therefore prepares a small part of the image which is then delivered via a high speed interconnect to the display nodes.

**Exemplary Scenario**

There are several possible scenarios for users to interact with large datasets collaboratively. This includes a single view on the data or several views.

As a first specific scenario, we chose the analysis of eye-tracking data where users have several views on the data with several visualizations. The visualizations show either the whole dataset or only a part of it. The general workflow is based on the Visual Information-Seeking Mantra (“overview first, zoom and filter, details on demand”) by Shneiderman[8]. The overview is ideally gained by using the powerwall: A large screen and potentially a high resolution allow the users viewing as much data and as much detail as possible. In case of incompatible datasets, for example two different stimuli of an eye-tracking study, they can be shown in two separate views. The overview can thereafter be discussed by all present users. When the group gained an overview of data, it can be explored by filtering and zooming. Therefore, new views on the data can be created that show the data in a filtered and zoomed state. This allows keeping the overview of data and also having several detailed views with different visualizations. The visualizations can be explored using the Kinect sensor to directly manipulate the view on the powerwall or by controlling the powerwall remotely using the tabletop computer.

Another approach would be to divide the data after the overview step. The users also split into smaller groups and explore the data in a “divide and conquer”-style. Likewise, the groups can analyze different aspects of the data using different visualizations. Therefore, new views with visualizations can be created at the private space of the tabletop/personal device, or on one part of the powerwall. Multiple Users can explore the data collaboratively by coupling the views on the data layer or the visualization layer. Then, each researcher can use one view with the same data or even with the same visualization and same viewport. Therefore they can move their views from the private space to the public space so that they are shown on the powerwall.

**Current Status and Future Work**

As mentioned in the previous chapters, we built a first implementation of a framework that facilitates interacting in a powerwall setup as well as visualizing data on various devices including the powerwall itself. In order to allow carry out various user studies and investigate interactive visualizations, two different powerwalls have been built and are now ready to be used.

With regard to the investigation of different usage scenarios, the analysis of eye-gaze data generated during eye-tracking experiments has been chosen as a first example. The idea of a potential analysis environment has been developed. A first prototype of the corresponding visualizations has been implemented and is ready to be shown on the powerwall as well as on the tabletop. As we want to explore how an analysis of such data can be done as efficient and natural as possible, we aim at conducting several experiments to find user-defined interaction styles [13] that suit this scenario best. As a first step, we therefore want to look at gestural interaction that can be extracted using off-the-shelf hardware (e.g., Microsoft Kinect) as well as interaction and collaboration using multitouch and tangible objects on the tabletop (Microsoft PixelSense).
References


