ViNet: Interaction with Information Visualizations in VR Applications via Multi-Touch and Tangible User Interfaces

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Abstract: The presentation of 3D data in a Virtual Reality (VR) can be complemented by integrating visualizations of abstract data (like graph visualizations). While the hardware infrastructure of a VR application is also able to support the presentation of information visualizations, means of interaction like fly sticks or head-tracking are tailored to 3D navigation and interaction. Thus, when complementing VR with information visualization, one should also consider supplementing additional interaction devices. In this paper, we present an interaction design for the manipulation of abstract information visualizations being displayed in a VR set-up like a powerwall. For this, we employ a multi-touch and prop enabled tabletop display called Virttable. We realized a prototype and implemented the software ViNet. The powerwall displays the VR as well as the information visualization, while the Virttable runs the ViNet application, showing a different view that allows for manipulating the visualization. This set-up was embraced well in user tests and can easily be applied to VR applications like product design reviews.

Keywords: Multi-Touch, TUI, Information Visualization, VR, and Graph Visualization

1 Introduction

In a typical VR application like a product design review or a planning session in plant engineering, the hardware set-up used is suitable to present 3D data in a realistic and intuitive way. Often, however, the participants in such a VR session also have to deal with abstract data like material flow in a plant or dependencies in a design process. It would be beneficial if this information could be visualized as well. For instance, a graph can illustrate the usage of product parts in a production process [GRDKB09]: if a car is being reviewed it could be beneficial to have the possibility to visualize the door of the car in the 3D visualization and the same door in the flow of material graph. This could provide an intuitive way to create mappings between large graphs and 3D visualizations. The Virtual Reality would form an excellent context for the abstract data. And the VR hardware set-up usually provides a large, high-resolution display space that is also more usable for abstract information visualization than typical desktop displays or simple projections. However, input devices employed for VR like fly sticks, head-tracking or 3D mice are tailored to 3D navigation and selection tasks. The usage of traditional keyboard and mouse interfaces is also not optimal in many VR settings.

To mitigate these shortcomings, we propose to use multi-touch interfaces [LBS85] and tangible user interfaces (TUIs) [IU97] combined in a table set-up as additional input hardware. With this, the interaction with the information visualization part becomes more accessible. And it is possible to conceive dedicated interactions to switch between the 3D part and the abstract part of the visualization. For example, with our proposed set-up, participants gather in front of a powerwall where a table-display, capable of multi-touch and tangible interaction, is placed next to the powerwall. Participants explore the 3D visualization of the 3D data in a traditional way with head-tracking and a fly stick. If their discussion becomes concerned with more abstract questions, the participants are able to switch to an information visualization (like a graph visualization) and they are able to interact with the information visualization (e.g. change of the focus area or change of the semantic level of detail) using the tabletop-display.

This paper elaborates this idea and presents an implementation of the additional interaction device in a specific use case: we use a powerwall as VR set-up, the Virttable (Versatile Illumination Research Touch Table) [LFD09] as additional device and as an example for information visualization graph visualization. We introduce the software ViNet that runs on the Virttable and allows for interaction with the 3D data as well as the abstract data.

The paper is organized as follows. In section 2 a brief review of related work is given, particularly recent multi-touch and TUI developments. While section 3 illustrates our hardware setup, section 4 explains the prototype application ViNet. Section 5 discusses our findings when using this set-up. Finally, section 6 gives a conclusion.

2 State of the Art

Well established VR set-ups like Powerwalls or CAVEs are being used in industrial engineering and development environments. Amongst others they can be employed for design reviews: designers and engineers gather in front of a powerwall in order to review 3D prototype visualizations. The purpose of the review could be to discuss problems that could occur during a manufacturing process. In the literature, successful applications are reported that use these kinds of set-ups also for an immersive interaction with information visualization like immersive graph-based exploration [FGHG05]. Also, combinations of VR and information visualization have been proven to be beneficial, e.g. in the field of VR-based graphical information systems [MQal08]. However, all approaches so far relied on the interaction hardware already present in the VR set-up. Additional benefits can be expected by introducing additional means of interaction like touch-displays or tangible user interfaces that cater specifically to the abstract information visualization.

Consumer products such as the iPhone from Apple [App09] or the Microsoft Surface Table [Mic09] have attracted public interest in multi-touch and TUI technology. Multi-touch provides the technical capability to track multiple touches on a user interface. A user can perform gestures like pinching/scaling to enlarge/rotate objects on the multi-touch interface. Multiple users can work simultaneously or collaboratively on the multi-touch enabled device. The navigation becomes more direct (fingers instead of a mouse) and more intuitive (the mouse cursor does not replace a finger on the screen).

A tangible user interface (TUI) allows the user to interact with applications using physical objects (also known as props). TUIs can be combined with multi-touch to enrich interaction capabilities. The props can be used as metaphors from real life. E.g. a real model such as a camera can be used to change the position and orientation of a virtual camera. Many research projects and commercial products exist, that use multi-touch and/or tangible user interfaces in form of a touch-table setup – for instance the reacTable [JKGA06], the DiamondTouch technology from MERL [DL01], Microsoft Surface combined with SurfaceFusion [OW08] or the multi-touch interaction wall by Jeffrey Han [Han06].

(Monoscopic) interaction with stereoscopic projections has been researched in the iMUTS project [SSK+09] in which a powerwall itself was equipped with a multi-touch overlay. However, this setup is not suitable for the control of review situations as interaction takes place directly on the powerwall and cannot be controlled from an external workplace.

3 Hardware Setup

Our hardware set-up is depicted in Fig. 2. The powerwall and the Virttable can but do not need to be connected to the same computer. In the following, the Virttable, the employed powerwall and the computer that has been used are described briefly.

Figure 2: Hardware Setup (left), Live Usage (right)

3.1 The Virttable

The Virttable (Fig. 2 and 3) is a rear-projection touch table that supports both multi-touch and TUI input. The multi-touch tracking is based on frustrated total internal reflection (FTIR) as introduced by Jeff Han for multi-touch purposes [Han05]. Fundamentally, the setup works as follows: a video projector projects an image onto the underside of an acrylic glass, which is equipped with a diffuser foil. Into the sides of the acrylic glass infrared (IR) light is being emitted. According to the FTIR principle, when fingers touch the surface of the table IR light spots will appear underneath the fingertips. These spots are being tracked by a camera, which is connected to a computer (see section 3.3) on which an image processing software calculates the coordinates of the touches out of the camera's image. These coordinates are then being dispatched as touch events to a touch application. Finally, the touch application reacts on the touch events and creates the image that is projected by the projector onto the table.

As FTIR does not support the tracking of markers that are placed on top of the glass plate, the Virttable is also illuminated according to the diffuse illumination (DI) principle, which is for instance used in the Microsoft Surface table. In case of DI, the table is illuminated by infrared light (IR) sources that illuminate the table's surface from underneath the glass plate. Fingers and props placed on the table's surface reflect the light and can be tracked via the camera. However, DI is not as effective as FTIR for the tracking of touches. Thus, in the Virttable both techniques – FTIR and DI – have been combined.

The Virttable's screen has a resolution of 1280 x 720 pixels and a screen diameter of 73 cm.

Figure 3: The Virttable

3.2 The Powerwall

The employed powerwall is a large stereoscopic rear-projection screen that is 2,40 m wide and 1,80 m high. It has a resolution of 1600 x 1200 pixels. An IR-optical tracking system [ART09] allows for head-tracking and wireless 3D interaction devices.

3.3 The Computer

The computer that is used in this setup is a desktop PC with a standard 3 GHz Pentium 4 processor. It uses an NVIDIA Quadro FX 3500 Graphics Card with two DVI outputs. One of those DVI outputs is connected to the powerwall and the other is connected to the Virttable.

For the tracking software that is being employed in this setup, we implemented an application called touchReac. It combines the code of the open source applications Touchlib [Nui09] and reacTIVision [KB07].

4 Interaction Design and Realization

In this section, we take a closer look on the application that runs on the Virttable: ViNet. ViNet is an application that facilitates interaction with abstract information by using the multi-touch and tangible tabletop Virttable. To illustrate ViNet we used the Last.fm [Las09] database as test data. Last.fm is a social online network in which users can browse music artists, concerts etc. This information can be programmatically accessed via web-services.

4.1 Overview

ViNet allows users to interact with large abstract graphs and manipulate their layout and other parameters. For example, users have the ability to prepare graph views in advance on the Virttable and transfer these views to the powerwall after the preparations had been finished. Typical tasks involved would be searching connections between different nodes or choosing different level of details for single nodes and sorting them.

The Virttable can not only be used complementary to standard input methods in order to provide alternative means for interaction. The Virttable can also be suitable as an additional input device in a standard VR for the interaction to control various aspects of a 3D scene and to control the switching between VR and information visualization.

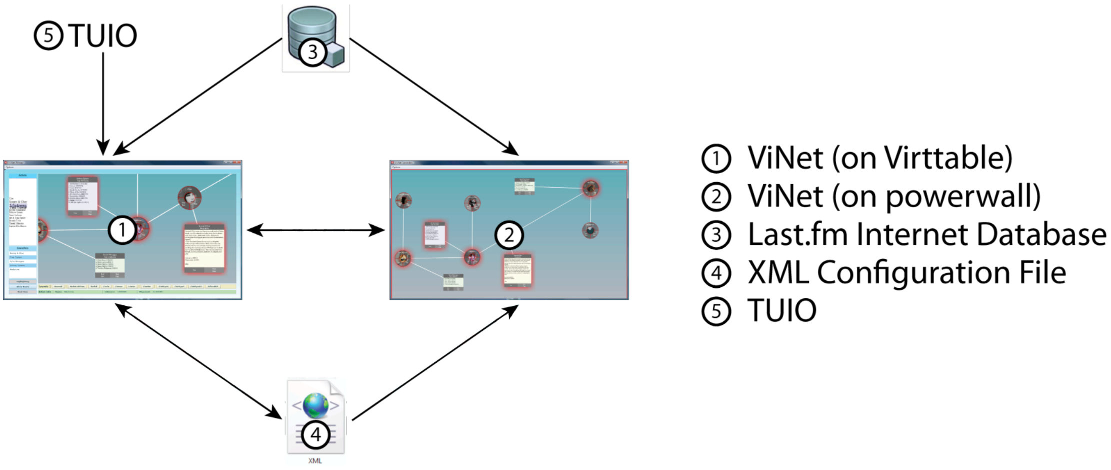

Figure 4: ViNet Architecture

ViNet consists of two applications, one of them (also known as ViNet Primary) is running on the Virttable and the other (also known as ViNet Secondary) is running on the powerwall (see Figure 4) concurrently with a VR system. Both applications retrieve the data needed for the building of their graph from a common database and are able to load saved graphs from XML files as well.

4.2 User Interfaces

The application running on the powerwall (ViNet Secondary) shows the full graph (see Figure 5 on the right). ViNet Primary processes the user's multi-touch and TUI input and allows the manipulation of the graph. The user interface contains widgets (see Figure 5 on the left).

Britney Spears
Top 10 Tracks
1. Womanizer (1383238)
2. Circus (1497476)
3. Toxic (315113)
4. Break the Ice (322260)
5. Piece of Me (360905)
6. If U Seek Amy (888175)
7. Everytime (188937)
8. Gimme More (302173)
9. Radar (333739)
10. Kill the Lights (437821)

Sonny & Cher
Biography
Sonny & Cher were an American rock and roll duo, made up of husband and wife team Sonny Bono and Cher in the 1960s and 1970s. They were among the first hippie personas with mainstream appeal.
Cher first met Sonny Bono in a Los Angeles coffee shop in November 1962, when she was sixteen. Sonny was already twenty-seven and working for record producer Phil Spector at Gold Star Studios in Hollywood. The two became fast friends, eventual lovers, and later, husband and wife.

Listeners: 80814
Playcount: 324901

URL:

Dannii Minogue
Top 5 Albums
1. Club Disco (196560)
2. Neon Lights (20451)
3. Neon Nights (12606)
4. Neon Nights (10340)
5. The Hits & Beyond (18304)

Artist Info | Name: Select a node | Listeners: Select a node | Playcount: Select a node

Figure 5: ViNet Primary (on Virttable) (left), ViNet Secondary (on powerwall) (right)

There are two widgets positioned on the left: one for the nodes representing datasets loaded from the database (loaded nodes widget) and one for managing favorite nodes (favorites widget). The loaded nodes widget is a fisheye menu [Bed00] that lists all loaded nodes. Selected nodes in the widget will be highlighted in the ViNet Primary user interface but not in ViNet Secondary. There is other functionality offered in the widgets, e.g. two nodes can be selected and the system checks whether there exists a path in the graph that connects these two nodes. The buttons on the bottom allow to apply different automated layouts or views to the nodes (see Figure 6) and to view properties of a single selected node. The implemented layouts and views in ViNet include amongst others a node link tree layout, a radial layout, a circle layout, fisheye views and bifocal views.

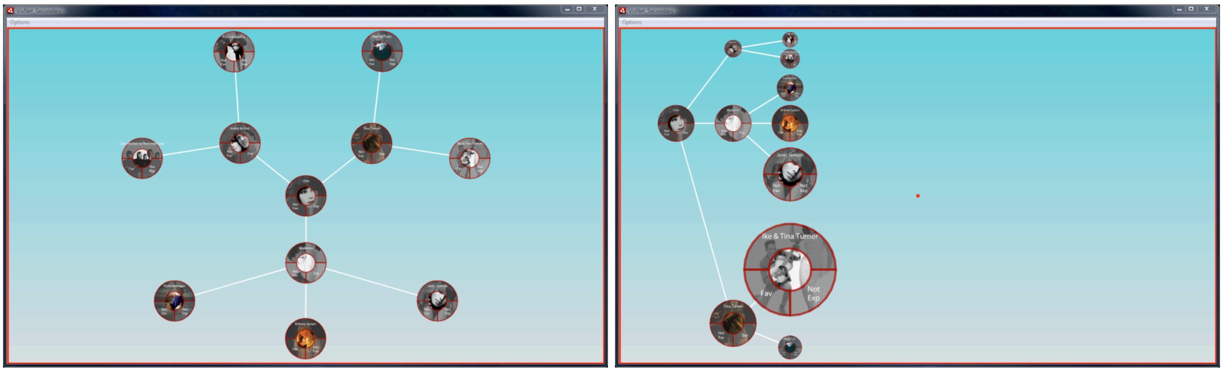

Figure 6: Radial Layout (left) vs. Fisheye Y View (right)

In contrast to ViNet Secondary, which can use up to the whole of the available screen space for presenting the graph visualization, ViNet primary needs additional screen space for these widgets. It has fewer screen space available to begin with, because the size and resolution of the Virttable's display is smaller than that of the powerwall. Therefore, the Virttable employs a preview window of the graph visualization where a user can look at a part of the graph in more detail or a scaled down version of the whole graph visualization or a preview of the VR scene.

4.3 Multi-touch Interaction

Multi-touch interaction (see figure 8) allows working with ViNet without the need for a mouse or a keyboard. A pinching gesture can be used to zoom in and out within the preview window of the graph, while dragging is used to move the preview window to a different area of the complete graph. A user can browse the graph via multi-touch interaction on the Virttable.

Cher

Cher
Top 5 Albums
1. The Very Best of Cher (176080)
2. Believe (126895)
3. The Greatest Hits (21869)
4. The Best of Cher (13765)
5. Take Me Home & Prisoner (10971)

Cher
Top 10 Tracks
1. Believe (100242)
2. If I Could Turn Back Time (76470)
3. Strong Enough (52094)
4. The Shoop Shoop Song (It's in His Kiss) (34656)
5. Just Like Jesse James (31030)
6. I Found Someone (22858)
7. Gypsies, Tramps and Thieves (20721)
8. Heart of Stone (15753)
9. Take Me Home (13426)
10. Dark Lady (15496)

Cher
Biography

Cher (born Cherilyn Sarkisian on May 20, 1946, later adopted by Gilbert LaPierre.) is an American singer, actress, songwriter, author and entertainer. Among her many career accomplishments in music, television and film, she has won an Academy Award, a Grammy Award, an Emmy Award and three Golden Globe Awards among others. Cher first rose to prominence in 1965 as one half of the pop/rock duo Sonny & Cher.

Listeners: 408061
Playcount: 3357273

URL: http://www.last.fm/music/Cher

① picture ② top albums ③ top tracks ④ biography

Figure 7: Level of Details of a Node

Multi-touch is also used to switch between different semantic levels of details (LODs) of each node. ViNet offers support of up to 4 different LODs, each of them containing different information and having a different size (see Figure 7). In our example data, for instance, the first level is the smallest in size and shows just an image of the node's music artist. The second LOD shows the top albums, while the third LOD shows the top tracks of the artist. The last and biggest in size LOD offers a short biography of the artist. In order to switch to LOD *n* directly the user taps with *n* fingers on the visual representation of the node. These gestures allow a quick access to contextual information. Multi-touch interaction is used in the loaded nodes widget, where a user can navigate by dragging one finger through the list. While holding the name of a node with one finger, a tap with a second finger on it causes the preview window to center on the desired node.

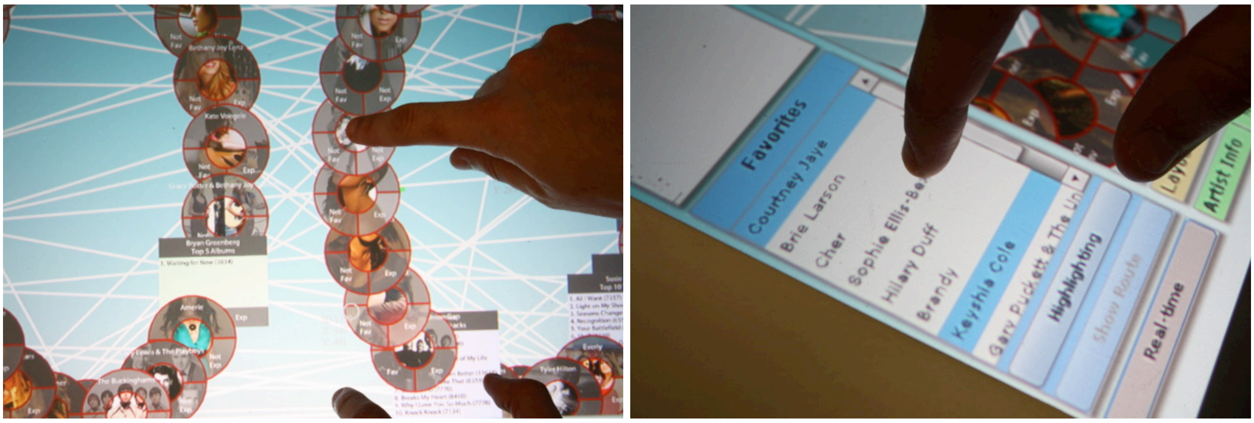

Figure 8: Touch Interaction with the Virttable

4.4 TUI Interaction

TUI interaction is provided via props (see Figure 9). The props can be used for zooming and panning of the preview view on the Virttable. The same procedure can also be applied to the powerwall view. Here the border of the Virttable display serve as the frame of reference, i.e. there are specific props that are used for manipulating the powerwall visualization directly (and not the preview window on the Virttable). When using these specific props it does not matter what is currently shown on the Virttable – only the position of the props relative to the border of the Virttable display are important. This makes manipulating the powerwall visualization easier as the user does not need to look on both displays simultaneously. Other props are used to save the state of the graph and to load a new one.

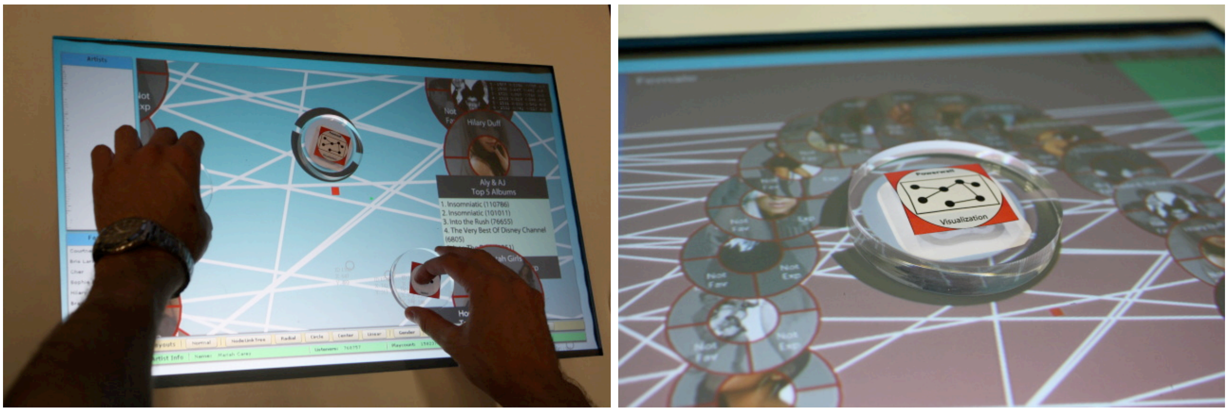

Figure 9: Prop Interaction on the Virttable

To change the layouts, different props can be used. A layout prop can be placed on the table to switch to the according layout. In a view like a fisheye view, the prop is the focal/anchor point of the visualization. Moving the according view prop on the table moves the focal point.

4.5 Implementation

ViNet is written in Adobe Flex [Ado09]. Multi-touch and TUI interaction is based on the reception of TUIO packets in ViNet Primary (see Figure 4). TUIO (tangible user interface over OSC) [KBBC05] is an open framework that defines a UDP-based network protocol for the transmission of touches and objects in a multi-touch/TUI setup. For this purpose a TUIO enabled tracker application and a TUIO client application are necessary in such a setup. The TUIO enabled tracker application sends TUIO packets over the network to the TUIO client. In our case ViNet is the TUIO client and touchReac (see section 3.3) is the TUIO enabled tracker.

The graph is built independently in both applications using the Flash visualization framework Flare [Fla09] that is based on the visualization framework prefuse [HCL05]. The synchronization of the graph between the two ViNet applications is achieved via Flex's LocalConnection class, which is based on network communication. This implementation gives flexibility by allowing the two applications to run on different machines. Since the CPU renders the application, the approach with both applications running on different machines leads to better performance especially when large graphs are being used. However, both applications can also run on the same system using different monitor outputs as in our setup.

It is noteworthy that the costs of the multi-touch and TUI hardware are relatively low (material costs are below 1000 Euro).

5 Discussion

The Virttable has been evaluated in user tests with 16 participants. When asked whether they consider usage to be difficult or easy, a significant part of the participants answered that the Virttable can be handled easily (Wilcoxon test, probability of error $p < 0.01$). When touched, the Virttable has a delay of 145.7 ms (standard deviation $sd < 20$ ms). Although this time lies within a recognizable interval it has not disturbed the participants ($p < 0.01$). Some users remarked that they liked working directly with their fingers on the screen.

The reaction time for tangible interaction is worse: the mean value is 598 ms ($sd < 125$ ms). However, users found this delay not disturbing ($p < 0.04$). Additionally, participants did not find the concept of the used props complicated ($p < 0.01$). A fundamental problem pertains quick movements of the marker-tracked props: the camera does only sample the Virttable's surface with 15 frames per seconds which leads to a motion blurring if props are being moved quickly.

There were no problems with system performance, for example the transition animations applied when the graph is transformed ran with at least 15 fps in the system configuration described in section 3. Asked about the set-up as a whole, test users commented that they find it appealing. Our set-up could also alleviate the task of operating the VR application in a way that an explicit operator, who has specific knowledge about the VR system, is not needed anymore. The role could be taken over by a regular participant in a VR review session or at least the task of the operator becomes easier.

Feedback from using the prototype encourages additional uses of the tangible user interface. For instance, if a car is being reviewed, it could be beneficial to have the possibility to visualize the door of the car in the 3D visualization and the same door in the flow of material graph. There should be a prop to change from the actual viewpoint in a 3D visualization to the according point in the graph visualization. The switching itself is accomplished by simply laying this specific prop on the Virttable. However, if the users navigated in the graph there are different options when they switch back to the VR scene making it necessary to provide more than one prop for switching between 3D and abstract representations. One prop could lead back to a default viewpoint. A second prop could select the viewpoint from which the users switched to the abstract graph. And a third prop could switch to the 3D representation of the current focus point in the abstract graph. For instance, if the users navigated from the door to a back wheel of the car in the graph, the second prop would take them back to the door in the VR while the third prop would show the according back wheel.

Additionally to the interaction with abstract information, there could be additional use cases for the Virttable in a VR. The Virttable could be a replacement to a worlds-in-miniature metaphor: If a large plant is being reviewed in a 3D visualization it is difficult to navigate quickly from one end of the plant to the other with a fly stick. The user would have to make the zoom out and zoom in gesture with the fly stick very often. However, the floor plan of the plant could be displayed on the Virttable. A dedicated camera prop would provide the possibility to quickly navigate to certain points in the plant in the 3D visualization by simply putting the camera prop on the desired point on the floor plan. The precise navigation in the 3D scene would still be carried out with a device like a fly stick.

The Virttable could also provide quick access to predefined scenes via props. In a VR product review process there usually is one person that is the operator for the scenes. This person typically uses a workstation with monitor, keyboard and mouse to prepare the VR, e.g. by setting aspects like camera positions and lighting. Additionally, reviewers can ask the operator during the review to make custom changes for instance to set the camera to a certain viewpoint. It is possible to conceive that instead of controlling it from the workstation the review could be controlled from the Virttable. For instance prepared scenes could be mapped to certain props and could be put onto the surface of the Virttable during the review to apply their transformations. Additionally, scenes could be adjusted manually: 3D scenes could be prepared on the Virttable by putting props on it that control camera and light positions etc. However, like in ViNet, these changes need not necessarily be reflected directly on the powerwall. After finishing the preparation of the scene on the screen of the Virttable, the changes could be applied to the visualization on the powerwall by adding the appropriate prop. Hence, all reviewers could take part in the control process of the review by simply adding or removing the appropriate props to the surface of the Virttable to go to scenes in the visualization or to fine-tune aspects like lighting or camera position. One of the major strength of the Virttable is that more than one user can interact with it simultaneously: while one reviewer changes the level of detail of a node, at the same time another reviewer can check the graph for specific nodes, while still other reviewers can manipulate props, remove them or put them on the tabletop display. In contrast, with a workstation and one operator everything needs to be serialized. These concurrent interaction possibilities with a tabletop in a VR might lead to a more communicative review process.

6 Conclusion

We suggested means for the interaction with abstract information via multi-touch and TUI in VR applications, presented some dedicated interaction metaphors and implemented a prototype application. Using the above techniques makes the interaction with abstract information easier than with common VR interaction devices. Our approach has also the potential to improve the experience of a VR application as a whole. After confirming that our set-up is usable in principle, as future work we see the usage of the application in real design reviews in order to assess the added value from an application's perspective. Additionally, it is conceivable to investigate manipulation possibilities of a stereo-projection 3D view on a powerwall via a monoscopic visualization on the Virttable in terms to evaluate perception, decrease of immersion and increase of information retrieval efficiency.

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