HoloStation: Augmented Visualization and Presentation

Minju Kim[1] Jungjin Lee[1] Wolfgang Stuerzlinger[2] Kwangyun Wohn[1]

[1]GSCT, KAIST [2]SIAT, SFU

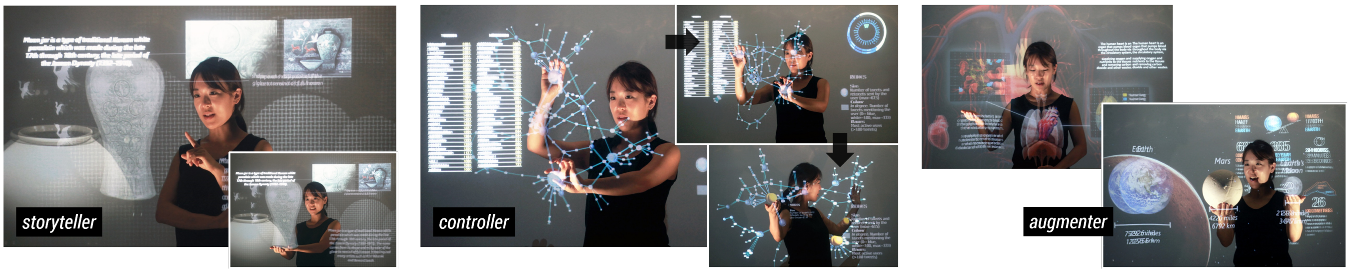


Figure 1: *Application scenarios of augmented presentation. According to the degree of engagement and interaction, the presenters role may vary: from storyteller(left), to controller(mid), to augmenter, who can be considered as a part of digital information(right). The double-images for the virtual content are due to the use of stereo display technology.*

Abstract

As much as stories need to be told, images need to be presented. Although visualizations are meant to be self-explanatory, often enhancing their expressive power by incorporating a certain degree of interactivity, visualized images today often fail to encourage the active engagement of the user/audience. In many cases, interactive interventions by a human presenter have the potential to drastically improve the engagement with visualization. Rather than just showing the content, the presenter then enhances information delivery, e.g., by providing the context of the visualization. In this paper, we propose a novel concept called ***augmented presentation*** in which the human presenter occupies the same physical space as the visualized information, thereby presenting and interacting with the visualized images seamlessly. Depending on the level of engagement the presenter's role may vary: from a simple storyteller to an augmented presenter who may be regarded as a part of the visualized entity. To further the development of the new idea of augmented presentation, we have designed, implemented, and user-tested a visualization system named ***HoloStation***. The presenter is placed between two projection screens: the front one is half-mirrored and the rear one is a conventional wall screen. The 3D stereoscopic images are rendered to appear in-between, thereby creating a coherent 3D visualization space filled with digital information and the human presenter. We have conducted a controlled experiment to investigate the subjective level of immersion and engagement of the audience with ***HoloStation*** compared to the traditional presentation. Our results suggest that our new form of augmented presentation has a potential not only to enhance the quality of information presentation but also to enrich the user experience on visualizations.

Keywords: 3D visualization, augmented presentation, human presenter, information delivery

Concepts: •**Human-centered computing** → **Visualization theory, concepts and paradigms;**

1 Introduction

Visualization alone can deliver messages by itself, but sometimes a certain degree of additional interactivity makes visualization even more powerful. In many cases, interactive intervention of a human presenter is one of the main factors that make information visualization more effective and persuasive. By having the human presenter being involved as a part of the displayed information, he/she increases the realism of the presented information, and thereby enhances the audience' immersion and understanding of the content. The presenter's verbal explanation, gestures, and facial expressions support the process of information delivery and make it possible to have direct interaction with the audience. In addition, the presenter may provide the contextual information to the audience to augment the communicative process between the visualized information and the audience.

Beyond the conventional method of presentation that just simply displays and explains information, there recently have been some attempts to break down the boundaries between digital information and the presenter in order to provide more immersive and engaging presentation to the audience. These attempts mainly focused on two issues: visual integration and direct interaction methods. For the former, half-mirror films are typically used to optically combine the presenter with the visualized information. According to the information visualization theory, this kind of setup enables the viewer to perceive the integrated information in the same field of view. Recently, this kind of presentation form has become popular for performances, live presentations, advertisements and many others where it is important to show the digital information tightly coupled with the physical objects [Geng 2013; Yang et al. 2015]. In regard to the interaction issue, there have been attempts to complement visual communication by raising connectivity between the presenter and the displayed information through the direct input and gesture manipulations [Tapp 1996; Noma et al. 2000; Fourney et al. 2010]. However, previous research has not studied the integration of the visualized information and the presenter into one single integrated visualization framework, and limited to represent them merged spatially and seamlessly. Therefore, it is hard for the presenter to play the roles beyond the traditional ones, and to expand application scenarios sufficiently.

SA '16 Symposium on Visualization, December 05-08, 2016, Macao
ISBN: 978-1-4503-4547-7/16/12
DOI: http://dx.doi.org/10.1145/3002151.3002161

In this paper, we propose a novel concept, called ***augmented presentation***, in which the human presenter occupies the same physical space as the visualized information does, thereby presenting and interacting with the digital information seamlessly. Depending on the level of engagement, the presenter's role may vary from a simplistic storyteller and a controller to an augmenter who may be regarded as a part of visualized entity. Accordingly, the presenter can further enhance the information delivery process in diverse forms by interacting with the three-dimensional information which is surrounding him or her. Therefore, rather than just showing the visual content, the presenter can provide the context of the visualization whilst allowing the audience to experience the immersive visualization and inducing a deeper engagement.

To explore the newly proposed concept of augmented presentation, we have designed and implemented ***HoloStation***. The presenter is located between two screens: a half-mirror film on the front and a wall projection screen on the rear. The 3D stereoscopic images are casted on both screens, which create a continuous 3D visualization space that is filled with the digital information and the human presenter at the same time. We present a spatial visualization technique which allows us to render seamlessly a virtual 3D space between the two screens, and a novel interaction technique which allows the presenter to be aware and control the visual objects. We conducted a feasibility study to investigate the subjective level of immersion and engagement of the audience with HoloStation, as compared to the conventional presentation. Our preliminary study suggests that the newly proposed form of augmented presentation has a potential not only to enhance information presentation but also to better support the delivery of visualizations.

The rest of the paper is structured as follows. We start with the related research and study in section 2. Then, in section 3, we describe the concept of augmented presentation including visualization space design and the roles of the presenter. In section 4, the visualization technique and interaction method are described in detail. In section 5, we describe the HoloStation implementation, including the hardware configuration and software, as well as a system evaluation and its results. Finally, we discuss limitations, future plans and conclusions in section 6.

2 Related Work

2.1 Using presenter in visualization

Visualization is presenting complex, abstract, and difficult data by using interactive and visual representations to help people better comprehend and interpret the data [Mazza 2009]. Taking one step further, researchers have shown that it is more effective to add another form of visual information to the existing information than just simply composing the information on the screen, especially in the case of scientific presentation [Ma et al. 2012]. During the presentation when the presenter delivers information to the audience the human presenter has been involved in the visualization in order to inform, teach, motivate and persuade the audience more actively [Noma et al. 2000]. At this time, the presenter utilizes a variety of means, such as speech, body language, equipment and many others to increase audience immersion and their retention capacity [Tapp 1996]. For example, the presenter can use an interactive presentation system to supplement visualization by manipulating it dynamically [Nouri and Shahid 2005; Anderson et al. 2005], use gestures [Baudel and Beaudouin-Lafon 1993; Fourney et al. 2010], and storytelling [Kosara and Mackinlay 2013; Lee et al. 2013] to enhance expressiveness and believability of the presentation. Sometimes, by intervening as a virtual or digital conversational agent, the presenter presents visualization and interacts with the audience in real time [Van Welbergen et al. 2005]. As such, the presenter takes part in the visualization in various forms for richer visualization.

2.2 Integration of presenter and visualization

From the information visualization aspect, it is effective to visually incorporate relevant information, because it is possible for the viewer to quickly compare and contrast different forms of information, to focus on the information, and to productively interact with the information [Liston et al. 2000]. Similarly, there has been a number of studies in presentation contexts that aimed to increase the level of visual integration between visualization and the presenter (Figure 2). With recent advances in display technology, it has become possible to present naturally blended views of digital information and the human presenter [Geng 2013; Yang et al. 2015]. Optically combining visualization and the presenter helps the audience perceive an integrated view and breaks the boundaries in between. Especially, through intervening directly as a part of visualization, the presenter can make the information more realistic, control digital information directly, and help the audience understand the contents better. For instance, Rosling used half-mirror film and floating visualizations in the presentation stage [Rosling 2010]. Then, he, himself, explained it by standing right behind the screen. Stein and Rakkolainen also proposed systems that are able to float visualization in front of the presenter and to manipulate it through gesture interaction [Rakkolainen et al. 2009; Stein 2012]. However, previous research has not studied the integration of both the presenter and the visualized information into one single integrated visualization framework. Most researchers have focused on developing visualization and interaction methods to present and manipulate information in an effective and efficient way. Yet, the spatial presence of the presenter was rarely considered. For those systems that do consider the presence of the presenter, the information and the presenter were typically not merged spatially nor seamlessly. This limits the presenter to traditional forms of presentation, and does not permit an expansion of application scenarios. In this work, we analyze the characteristics and advantages of such an integration. In addition, we not only introduce visualization technique that merges those the visualized information and the presenter seamlessly, but also detail the roles and possibilities of the human presenter involved in the visualization space.

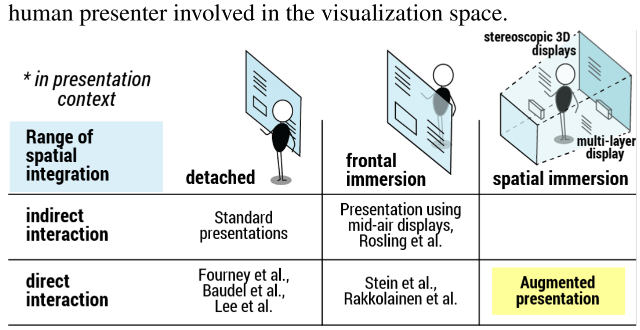


Figure 2: *Presentation systems with human presenter. Augmented presentation fills the void of systems that offer immersed visualization space and direct interaction.*

2.3 Half-mirror display on the real world

Among visual integration techniques, the half-mirror display is the one of the easiest ways to create a seamless image of synthetic imagery and physical objects in the space behind it. Due to such characteristic the technique has been utilized in various fields. Starting with the hologram performance, Peppers Ghost in 1869 [Steinmeyer 1999], such systems has been applied in an increasing number of applications areas, such as telepresence [Ogi et al.

2001], showcases [Bimber et al. 2006], performances [Gingrich et al. 2013], and recently even in desktop workspaces [Hilliges et al. 2012; Hachet et al. 2011], where direct user input is also supported. Going further, Kim et al. and Olwal et al. applied 3D stereoscopic display on a half-mirror to extend the visualization in 3D space and integrate it into the real environment naturally instead of just fixing visual forms on a flat screen [Kim et al. 2014; Olwal et al. 2005]. Also, several researchers have expanded the visualization space by placing additional displays that are physically separated from each other behind the half-mirror display in parallel, typically in form of a Multi-Layered Display (MLD) [Akeley et al. 2004; Prema et al. 2006]. However, the size of existing systems are typically limited to one person's workspace. Also, even if the display system can cover the size of a real person, it requires complicated occlusion handling to integrate the presenter into the three-dimensional information space flawlessly.

Kim et al. discussed the issues associated with presenting physical object and virtual information via a half-mirror display, especially for depth visualization, which aims to support continuous visualization in the space between the two [Kim et al. 2014]. We take this exploration further and present our augmented presentation concept that enhances conventional information visualization by allowing the human presenter to be immersed in the 3D visualization and take an active part in the presentation.

3 Augmented Presentation

Concept: In augmented presentation, the human presenter intervenes as a part of the visualization interactively and enhances the visualization delivery process, rather than just (passively) showing the visualization to the audience. The presenter occupies the same physical space as the visualized information does, thereby presenting and interacting with the digital information in a more realistic manner (Figure 3). To be specific, the presenter can directly encounter and reach into the virtual information that is presented in front of, behind, beside, and above him/her by moving in the presentation space himself. Beyond the typical roles as an explainer and slide navigator, the presenter can further enhance the visualization by explaining, realistically manipulating the visualization that is floating around him/her, or intervening as a part of the information. In accordance with the level of engagement and interaction in visualization, several roles of the presenter might be performed ranging from a storyteller, to a controller, and to an augmenter, who may be considered as a part of digital information. In this way, the audience can observe 3D visualization by integrating the presenter with the digital information, both of which occupy the same physical space perceptually. Moreover, the presenter's dynamic intervention helps the audience be able to watch the visualization in a more immersive and engaging way.

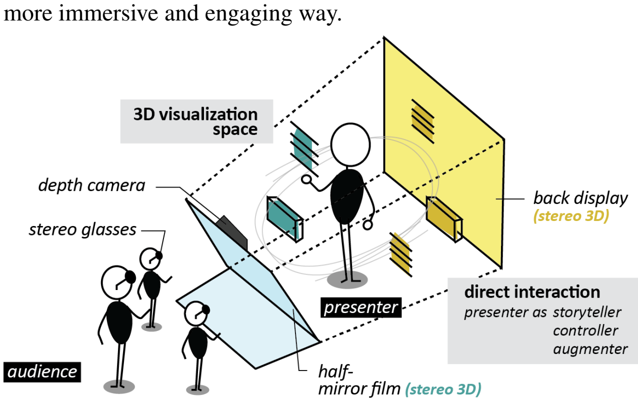


Figure 3: *Augmented presentation concept*

Presentation space: In augmented presentation, the presentation space is the space where the 3D visualization is presented and the human presenter can intervene directly, which are then optically merged. The half-mirror front screen and the wall-projection back screen that are placed in parallel configure a 3D visualization space, and the human presenter is standing between these two screens. The audience stands outside the presentation space and can simultaneously observe the overlapping images of the presenter and 3D visualization on the two screens (Figure 4, left). The half-mirror film enables the display of realistic visualized images in mid-air. At the same time, the rear screen behind the presenter expands the visualization space physically, allowing continuous and spatial 3D visualization connected with the front screen. The rear screen not only increases the amount of visualization space that can show 3D content, but also improves spatial impression through an increased number of displays. Also, after separating the visualization space into front- and back-space according to the depth position of the presenter, and presenting information accordingly on each screen, we can present correct occlusion cues without a complex rendering process. In addition, instead of just overlapping the presenter and two screens, we apply 3D stereoscopic display on both screens which creates a coherent three-dimensional visualization space filled with the digital information and which also completely includes the human presenter in the 3D visualization space. Therefore, we can present digital information at any depth in the visualization space through adapting the stereo disparity of digital information shown at either of the two focus planes (Figure 4, right).

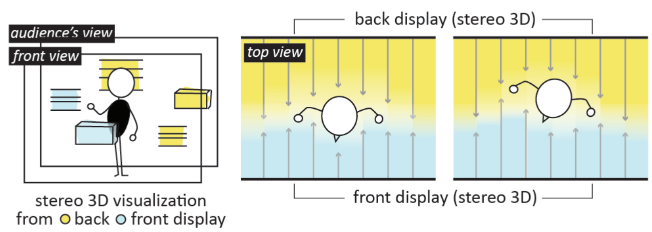


Figure 4: *Front (audience's) view of augmented presentation (left), and application of two stereoscopic 3D displays and human presenter in presentation space (right).*

Opportunities of the presenter: One of the major roles of the presenter is to support and enhance communication between the audience and visualization. In an augmented presentation, the presenter could take the roles of storyteller, controller, or augmenter in accordance with his/her level of engagement and interaction in the visualization (Figure 5). Each has different characteristics and potential as described below.

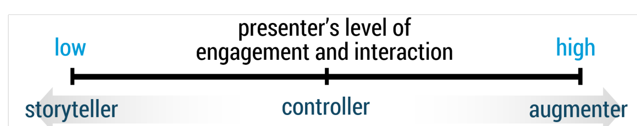


Figure 5: *Presenter's roles in augmented presentation*

Storyteller: As a storyteller, the presenter plays a relatively simple role in the visualization space. Even though the presenter is not directly involved in controlling the visualization, simply looking at the visualization directly that is floating around him/her or approaching it, the presenter explains the visualization to the audience in a more immersive manner. For example, by placing the visualization, which is floating in front of him/her, and the audience at the same line of sight, he/she can explain the information focusing on both the information and the audience's reaction. At the same time, the presenter can create an appropriate context for presentation with the help of supplementary information such as 3D models, background images, which are located in the extended space behind him/her (Figure 1, left). At this time, the audience may participate and be immersed in the visualization more actively by shifting attention along with the presenter's eyes and by looking at the rich visual content simultaneously. Optionally, a remote presenter can be tele-present in the 3D presentation space and share the single presentation space.

Controller: As a controller, the presenter interacts with the visualization more actively than a storyteller does. While a storyteller shares information by speaking out, a controller can use his own gestures or certain physical objects to help him/her control the presentation in a more tangible and realistic way. For example, he/she can (appear to) grasp visual content directly or move it across the space by stretching out his/her hand or taking a simple crossing gesture (Figure 1, mid). Similar to dealing with a physical object in the real world, the presenter can contain the information in his/her hand, and via gestures show the various aspects of the information by changing the properties of the visualization. In addition, he/she can move other supplemental information to the back area to highlight specific target information. The presenter can arrange two different graphs to be overlapped at different depths, or change the form of graphs in real time in order to help the audience perceive the information and relationship of the graphs intuitively. Also, by using physical tool that he/she handles, he/she can manipulate the information that is located where it is hard to reach through gestures only.

Augmenter: An augmenter has the highest spatial integration level with the visualization. This role helps the augmenter to express the information more realistically as he/she can fully interact the visualization by becoming a part of it. The shape, size, and characteristics of the human presenter become another set of physical information and are used to makes existing visual content more realistic and practically useful. Sometimes, the presenter can augment the visualization through the physical object (information) that he/she accompanies and handles. For instance, the presenter's body can be used as an interface, while the physical cue through the part of his body may present the information more intuitively and at spatially appropriate locations (Figure 1, right). The presenter's height and the distance between his/her arms can offer a sense of the physical size of the digital information allowing the audience to intuitively estimate the size of the abstract visualization. Furthermore, after inputting certain digital information into the physical object (information) that the presenter handles, the presenter can integrate that object with the digital information that is shown in the presentation space. Intervention of the related physical information in the digital information could facilitate the visualization more abundant and dynamic (Figure 1, right).

Even though we divided the presenter's roles into three forms depending on the level of the presenter's engagement and interaction in visualization for this discussion, in practice the roles of the presenter can be seamlessly combined with each other, and also the roles can take another different dimension to define themselves.

4 HoloStation Design

In order to realize our augmented presentation concept, we created a prototype presentation system: HoloStation. There are two main issues to deal with, one each for the audience and the presenter: 1) for the audience we need to provide a visualization technique that seamlessly integrates the presenter and two parallel displays, allowing the audience to experience a continuous and immersive presentation space. 2) for the presenter we need to provide an interaction environment that is able to sufficiently support various roles of the presenter, while being fully immersed in the 3D presentation space. In this paper, we state the problems and importance of two issues above, and especially focus on the visualization technique for the integration of the presenter and digital information.

4.1 Spatial integration

For the audience and in terms of spatial integration of the presenter and the two displays, we first need to verify if two stereoscopic displays and the physical object in between can integrate seamlessly and thus create a 3D presentation space. For this, we present a method to organize the depth space using two displays to provide an effective and stable visualization experience to the audience and evaluate it through a quantitative user study. Secondly, we need to come up with visualization technique to present digital information effectively even at the depth boundary between the 3D displays generated by the two screens, as it inevitably occurs when two parallel displays are optically overlapped.

Exploration of the depth: In a previous study, Kim et al. already did explored if it is possible to enable the user to perceive an integrated 3D presentation space through two layered stereo displays [Kim et al. 2014]. In their exploration, they identified that the most participants perceived the depth correctly (87.5%), but large disparities can disturb the participants' accurate depth recognition. The presence of a human presenter or objects inside HoloStation can only exacerbate this issue, thus we realized that we need to optically compose the two 3D displays in a better way to enable viewers to integrate the images more accurately.

There are several approaches to optically overlap two stereoscopic displays with the presenter at the same time. One intuitive approach is to divide the depth space according to the depth position of the presenter and assign the front and back display to the relative area respectively. Nevertheless, we need to identify how we can handle the display area that the presenter does not occlude (which is typically the majority of the displayed content). Although we can designate the depth area that front and back screens cover according to the stereoscopic comfort zone theory, we need to examine this more closely, as our system uses two overlapped screens simultaneously and the properties of screens, especially their transparency level, are different. Therefore, we conducted a user study to explore the depth visualization capabilities of each screen in the presence of an object between the screens more precisely.

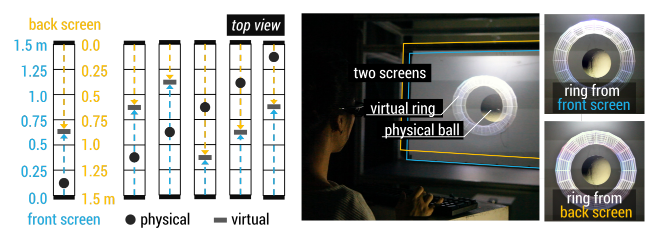


Figure 6: *In this study the user adjusts the depth position of the virtual ring that is presented from the back or front stereoscopic 3D display to be spatially aligned with the physical ball. The six test sets are shown on the left (12 tasks in total).*

Task and procedure: We placed a physical ball inside the system and presented a virtual ring 0.5 meters away from the physical ball. Users were asked to use the keyboard to adjust the virtual ring and arrange it spatially aligned with the physical ball (Figure 6). We divided the presentation space evenly into 6 areas and moved the physical balls position in each test set to explore the whole depth range that a physical object can occupy. For each position of the physical ball, a random sized virtual ring appears alternatively on the front and back focus plane centered at the same spot. This enables us to measure and compare the depth effect of both screens against each other. After the participants conducted the task for all areas, we measured the error value (the difference of the position between the two physical and virtual objects in 3D space) and the task completion time. To guarantee high accuracy, we fixed the user's eye position. 8 users (3 female, average age: 27.8) participated in the study and each participant performed 12 test sets (6 depths x 2 focus planes).

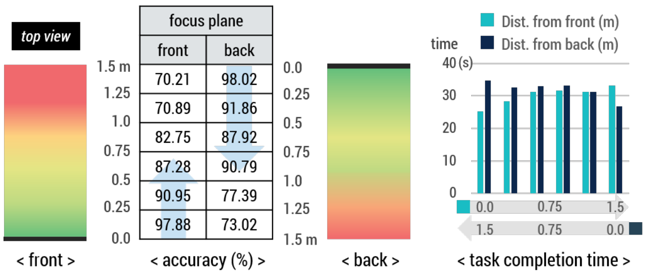


Figure 7: *Results regarding the immersive and stable depth zone for the front and back displays. The greener the zone is, the better it is suited to present 3D digital information.*

Results: The results show that when presenting digital information at about 50% of the front area on the front screen and at about 66.7% of the back area on the back screen, the participants perceived the most stable and correct three-dimensional information volume. Also the task completion time is shorter in the greener zones in Figure 7. Based on the comfort zone of stereoscopic theory [Sun and Holliman 2009] argues, we at first anticipated that the front display that renders positive parallax would be beneficial for a larger depth range compared to the back display, but the result suggested that it is more effective to let the back display cover more of the depth range. We need to verify this more profoundly through experiments, but at the current time, we believe that both the presence of a physical object as well as the transparent nature of the half-mirror display affect the test results. In this regards, in the case where the presenter occludes the screen, we can divide the space in accordance with the presenter's depth map, while the depth space of the remaining range can be divided according to our results (Figure 8, left).

Depth boundary processing: As two layered displays work simultaneously in HoloStation, the occurrence of a boundary between two depth planes is hard to avoid whenever an object crosses this boundary. Even if the alignment of the two screens is perfect, any optical difference between them causes a discontinuity. Therefore, when 3D digital information is presented in the boundary area, the discontinuity makes the information presented unnatural. Moreover, when digital information transits between the two displays, e.g., when moving back to front, a 'pop-out'phenomenon can be observed. In multi-plane displays system, previous researches have investigated representing digital information continuously at the depth boundary without disturbing the entire context [Akeley et al. 2004; MacKenzie et al. 2012]. To overcome the problem, they set the space between the layers to be very narrow or used a spaced stack of more than two displays to produce smooth 3D volumetric images. However, unlike the configurations in these systems, HoloStation has two focus planes placed in parallel with a distance of 1.5 meters. This requires a new visualization technique to simulate a natural continuity around the depth boundary between the two displays. Thus, we apply depth filtering approach for two-layer displays [Lee et al. 2009; Akeley et al. 2004]. When representing information in a volumetric display that is composed of a number of widely spaced image planes, depth filtering distributes the image intensity at each display plane according to the spatial and depth dimension. This makes spatial antialiasing within digital information plane possible, ensuring a continuous volume representation. When digital information is moving into the depth boundary region, the content of the digital information is replaced with gradual intensity gradients according to the depth position and distributed between front and back layer of the digital information in a linear proportion. Then, when the depth filtered voxels of digital information are optically summed and convolved (through the human eye), there is no discontinuity, but just a gradual intensity changes in the voxel images themselves allowing the audience observe continuous visualized information (Figure 8, right).

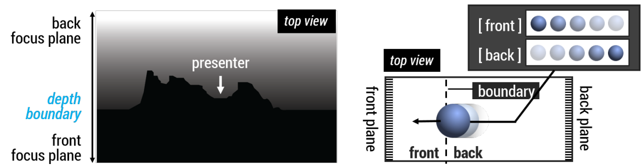


Figure 8: *Divide the space according to the presenter's depth map and test results (left), transit between two screens (right).*

4.2 Spatial interaction

In terms of spatial interaction, there are several issues to consider to let the presenter, who is fully involved in the presentation space, actively interact with the visualization.

Visual feedback: It is important to provide appropriate spatial visual feedback to the presenter who is presented in the information space and who augments and is merged with the digital information allowing him/her to recognize the digital information. Since a half-mirror based system reflects the virtual images to the direction of the audience's point of view, in traditional solutions digital information is invisible to the presenter who is standing in the system. Therefore, only the audience can see the digital information. Thus, up until now, presenters or actors need to fully acquaint the digital information in advance in live presentations, performances and many other systems that have used a similar half-mirror system. As they cannot see that information, they need to get feedback by attaching additional sensors, such as auditory or tactile ones, to their body or get visual feedback by installing supplementary guide screen [Gingrich et al. 2013]. However, there are limits to the abilities of the presenters to fully understand the forms and the positions of all the digital information beforehand. Also, additional devices such as screens, cameras, and sensors could be distractions to the audience, as they are transmitted through a half-mirror film. Above all, it is difficult for the presenter to make eye contact with the audience making the presentation less attractive. In this paper, we display the same digital information shown to the audience also on the backside of the film mirror to provide visual feedback to the presenter, without disturbing the audience's viewing experience. We discuss how we realize this in the implementation section.

Spatial interaction: It is important that the presenter has an interactive and immersive environment available that lets him/her interact with the 3D visualizations directly and naturally in the presentation space. Then, the presenter is able to access the presented information easily and the system can facilitate interaction with the information. In HoloStation, parts of the presentation space might be hard to reach by the presenter, due to the large presentation space that fully covers the upper body of the human presenter. To solve this problem, previous studies have provided pointing metaphors, shadow reaching, or eye gaze interaction method [Yoo et al. 2010]. Likewise, in HoloStation, we need a presenter-centered interaction design that enables him/her to easily access the information and provide opportunities for richer augmented presentation to the audience. Also, it is important to provide advanced feedback to the presenter. In particular, the presenter in HoloStation interacts with the floating information by touching it without any obstacles in-between, such as a monitor display. In this regard, we need to offer adequate spatial feedback that enables the presenter to perceive realistic depth cues for interaction and manipulation through touch. In this paper, we provide for interaction within the HoloStation prototype by tracking the spatial position and gesture interaction of the presenter, then making it fully connected with the visualization interactively (Section 5). We will study the above issues more deeply in the future.

5 HoloStation Implementation

Hardware: HoloStation uses two large displays that are big enough to cover the presenter's upper body. The size of the front screen is 1200x800mm, and the back screen is 1920x1200mm. On top of the system, we installed two 120Hz projectors to project stereoscopic digital information onto a bottom respectively rear screen. Each DLP projector displays 1280x800 pixels images at 3000 ANSI LUMEN. We used an active shutter 3D system, as polarization-based 3D display cannot be used with our diffusion screens and active shutter 3D systems generally have higher contrast. The front display of HoloStation uses the image projected onto the bottom screen and shows it to the audience via a half-mirror film with about 50% light transmission. The half-mirror film is installed at a 45-degree to the direction of the audience and reflects digital information, manifesting it as if it was displayed in the mid-air. In addition, to provide the same digital information to the presenter in real time, we installed a total reflection mirror that has high reflectivity on the ceiling. A standard wall projection screen is used for the back display. The two displays are placed in parallel and 1.5 meters physically apart from each other. In addition, a Kinect depth camera is installed at the top frame of the system, facing the presenter to track user movements in real time. We installed controllable lights through an ARDUINO inside the system to improve the visibility of the human presenter. Our physical configuration for HoloStation is illustrated in (Figure 9).

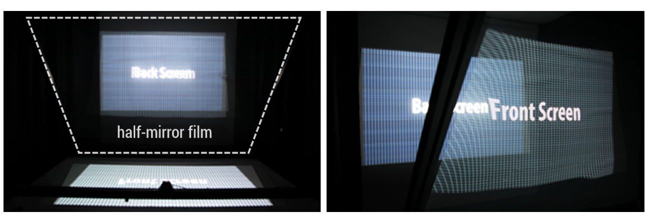


Figure 9: *HoloStation configuration: front and side view of two-layer stereoscopic 3D displays.*

To implement good visual feedback for the presenter without installing an additional projector, we use a total reflection mirror and place it on the ceiling parallel to the bottom screen (Figure 10, left). The mirror reflects the digital images from the bottom projection screen and then reflects it back via the (other side of the) half-mirror film to the presenter. Thus, both digital information projected on the back screen and the presenter itself can be reflected on the mirror and the film at the same time and provided to the presenter as visual feedback. Accordingly, the presenter can properly perceive and interact with the digital presentation space including his/her image (Figure 10, right).

Calibration and Sensing: Even if the presenter is presented in the presentation space, it is important to represent merged digital information naturally and accurately without disturbing the presentation of the existing information. To support this, our prototype uses the Kinect to track the position of the presenter and his/her hand gestures in the presentation space. To guarantee the tight spatial coupling between the Kinect and the virtual space, we spatially calibrated the system. We used a standard checkerboard-based method to retrieve the calibration of intrinsic and extrinsic parameters of the Kinect [Zhang 2000; Hilliges et al. 2012]. Then, we can track the position of the presenter's body and hand joints in real time without any body-worn hardware. We recognize and track the 3D pose of the body and both hands of the moving presenter by using skeletal tracking of the Kinect SDK. Then, we identify the presenter's hand gesture based through a gesture recognition algorithm. In our current prototype, we borrow well-established interaction techniques from the 3D user interface community and implement basic interactions such as selecting, moving, scaling, and rotating 3D digital information. As a result, the digital information can be aligned according to the acquired presenter's position, and the visualization can be accurately manipulated by the presenter's gestures.

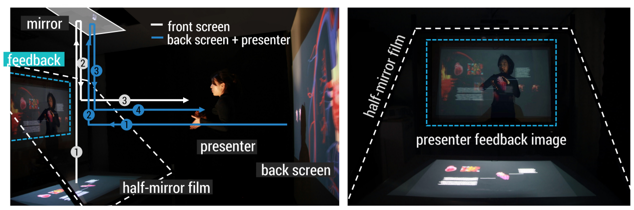


Figure 10: *Light path for the visual feedback (left) and visual feedback image from the presenter's point of view (right). To show the visual feedback for the presenter more clearly, we manipulated the image in terms of contrast.*

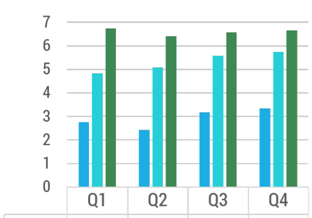
Optical Calibration: Our system consists of stacked displays using a half-mirror film and a wall. For this setup, it is important to calibrate the brightness and color levels on the two screens, since the perceived brightness and color of projection onto a wall are higher than projection onto a half-mirror film [Lee et al. 2009]. To solve this problem, we calibrated the projectors to achieve intensity consistency between the two final images. Also, in our software, we adjusted the color level of the final images rendered, so the audience can perceive equivalent images. Moreover, we leverage the real-time depth data of the presenter from Kinect to handle the boundary between the depth ranges covered by the two displays. After mapping the presenter's depth values to the virtual space, we adjust the depth range that each display covers adaptively in accordance with the tracked presenter's position. We implemented the system in Unity3D. In the Unity3D virtual environment, we set two virtual cameras that account for the front and rear screen, respectively. We wrote a custom shader that discards the pixels by comparing their z values with the corresponding value from the presenter's depth map. Also, in the case where the presenter does not occlude the screen, we applied our results for the suitability of depth ranges from Section 4.1. This enables us not only to compose the presentation space effectively by using two screens simultaneously, but also to present correct occlusion without a complex rendering process (Figure 8, left). Furthermore, to handle objects crossing the depth boundary, we created front and back material layers for each item of digital information. Then, whenever digital information passes through the depth boundary, we activate both layers applying appropriate intensity gradients (Figure 8, right). Accordingly, the audience can observe continuous and consistent 3D visualization through the two (optically) blended material layers.

Feasibility study: We conducted a controlled experiment to investigate the subjective level of immersion and engagement of the audience to investigate the different types of presentation: HoloStation *(Holo.)* compared them to traditional presentation *(Trad.)* as well as frontal immersed presentation *(Front)*, as mentioned earlier in Figure 2. We created a test presentation about 3D network visualization, which uses all three different roles of the presenter. Additionally, we added 3D models, images, and texts in order to make the presentation material more complex.

Participants and study design: We recruited 12 participants (5 females, average age 26.6) to evaluate the audience experience. All participants passed through a stereopsis test beforehand. We conducted the feasibility study as a within-subjects design. After the presenter was fully familiar with the system and the contents, he presented all three types of presentations to each audience member. To measure the level of immersion, which we consider as an essential element for viewing spatial overlaid information, and engagement with the overall information viewing experience, we surveyed participants' subjective ratings for each type. Questions were as follows: Q1) how immersive was the presentation with the presenter?, Q2) how immersive was the system?, Q3) how much were you engaged with the presentation?, Q4) how much did you enjoy the presentation?.

Procedure: We first explained the goal of the feasibility study and characteristics of each type of the presentation. Then, the presenter gave the presentation with each type of presentation for about 3 minutes. Each subject participated in each test set and, we counterbalanced the order of the three types to avoid ordering effects. After that, the subjects were asked to fill in a questionnaire on the three types of presentation they watched. In the case of Front. and Holo., participants had to wear the stereo glasses, but we asked them to ignore any inconvenience due to wearing the glasses in their evaluation responses. The experiment took about 30 minutes for each participant.

Results and discussion: The responses to the four questions measured the subjective level of immersion and engagement using a 7-point Likert scale, with 1= Strongly disagree and 7=Strongly agree for Q1 (immersive presentation with presenter), Q2 (immersive system), and Q4 (enjoyment). Q3 (engaged with the presentation) was designed with 1= Not engaged and 7=Highly engaged. Figure 11 shows the average subject responses from the participants for the three types of the presentation. We analyzed theses subjective responses using a one-way ANOVA Test, and Bonferroni correction for Posthoc pair-wise comparisons.



	Q1	Q2	Q3	Q4
Trad.	2.75	2.417	3.167	3.333
Front	4.833	5.083	5.583	5.75
Holo.	6.75	6.417	6.583	6.667

Figure 11: *Average subjective responses from the participants on 7-point Likert scale. 1=Not engaged or Strongly disagree and 7 = Highly engaged or Strongly agree.*

The responses on Q4 showed that the participants enjoyed *Holo* the most ($F_{2,33}$=26.939, p<0.05). They reported that rather than a mouse or pointer, the presenter's active gestures brought the presentation more to life when he pointed at the presentation material. In Q1 and Q2 responses, there was the highest preference for *Holo.* presentation. (Q1: $F_{2,33}$=29.841, p<0.05, Q2: $F_{2,33}$=9.662, p<0.05). Especially for Q1, *Trad.* and *Holo.* showed the strongest difference. Several participants commented that when the virtual 3D model was right above the presenter's hand or the presenter accurately pointed at the information in the stereoscopically presented 3D presentation space, instead of just being overlaid superficially, they were able to stay more focused and immersed in the presentation. They also stated that the 3D information placed behind the presenter at the rear screen made the presentation richer. Also, in Q3, there was a significant difference among all types of presentation ($F_{2,33}$=33.406, p<0.05). Especially, P3 mentioned that he was better engaged in *Holo.* when visualization nodes were presented around the presenter's body and moved interactively according to the presenter's movement. However, P6 commented that when the presenter explained the information by looking at it floating around him, there seemed to be no substantial difference between *Trad.* and *Holo.* In addition, several participants mentioned that it was hard to read the textual information when they were overlaid on one another at different depths, or, especially when overlaid on the presenter. Also, P4 and P5 stated that in *Holo.* when there is mismatch between the presenter's hand and his target visual aids, they got distracted from the presentation. These issues will be discussed in the next section.

6 Limitations, Future Plan, and Conclusion

6.1 Limitations and future plan

As a first step toward augmented visualization and presentation, we proposed a new immersive and engaging information delivery method. However, the current concept and prototype system still have limitations that could be improved upon in the future. The limitations are as follows:

First, at this stage, we defined the presenter's roles as storyteller, controller, and augmenter by investigating a conventional presenter's roles, and considering the potential capacity of his/her in augmented presentation. To take this further, we need to examine the presenter's roles more carefully. For this, we are planning to build a well-established interactive visualization taxonomies from the visualization community [Yi et al. 2007; Ward et al. 2010]. Based on such work, we can then explore more thoroughly how each interaction properly functions in augmented visualizations and other forms of presentation. After that, we can identify suitable interactions, and then build a model of the presenter's role. Through this, we can explore the feasibility and scalability of various roles for the presenter, and/or even identify different dimensions of roles.

Second, we conducted the experiment in a laboratory-sized environment, and did not deeply consider the gap between displays. Further investigation concerning the gap between displays is required in order to present stable multiple stereo images for a given audience distance. Ideally this should be based on human perceptual characteristics. Then, we can potentially expand the gap between displays or install additional layers of displays according to the optimal gap value when the HoloStation is used in a larger space, such as performance stages. Furthermore, in our current HoloStation prototype, the ability to offer an appropriate sense of visual depth to the presenter is limited. Yet, we need to offer sense of depth to the presenter to enable him/her to more accurately perceive the position of the information in presentation space and to control it more naturally. For example, it would be useful to offer stereoscopy to the presenter to help their depth perception.

Third, additional work is required on identifying suitable types of visualization for presentations that use the full presentation space. In our feasibility study, we observed that some participants found it hard to read text when several layers of texts were presented in space simultaneously and/or overlapped with the presenter. We also plan to do empirical evaluations to explore suitable types of visualization for HoloStation by considering various factors, such as visualization categories, dimensions, and textual information, with the goal to identify those factors that make to lead to more effective visualizations and a stable viewing experience for the audience.

Last, even though we conducted a feasibility study to confirm the audience's level of immersion and engagement for the HoloStation at the early stage, a full-scale user study is needed to verify the proposed concept and system. For instance, we can evaluate the effectiveness and efficiency of the augmented presentation for visualization delivery, the validity of the proposed presenter's roles, and the degree of understanding and interest in the audience for the content of the presentation. Also, we need to evaluate the system from the presenter's point of view. A deeper user study of the role of the presenter in an augmented presentation space, in terms of semantics, efficiency, attractiveness, and stress, would be useful to understand more about the possibilities of augmented presentations.

6.2 Conclusion

Rather than just showing the contents of a presentation, we presented a new concept, augmented presentation, which enables a presenter to enhance the process of visualization delivery by providing context and other forms of enhancements, such as direct manipulation in a 3D space. In augmented presentation, as seen from the audience, the presenter enhances the presentation by being fully immersed in the 3D visualization space and by directly pointing at and interacting with the digital information. We summarize our contributions as follows: 1) we presented the novel concept of augmented presentation for visualization delivery, designed a 3D presentation space, and proposed presenter roles ranging from storyteller, over controller, to augmenter. 2) We presented a prototype system, HoloStation, which uses two stereoscopic 3D screens of human size and which integrates the presenter and 3D visualization. Furthermore, we proposed interaction methods where the presenter can offer interaction with the augmented presentation to support the different roles of the presenter. 3) We conducted a feasibility study to investigate the subjective level of audience members in terms of immersion and engagement for the HoloStation. Results showed that the audience is more immersed and engaged with a presentation in the HoloStation than with conventional types of presentation. We believe this illuminates the potential of augmented presentations as a novel presentation concept to support new forms of visualization and information delivery.

Acknowledgements

This research was partially supported by NRF and the BK21 Plus Framework.

References

AKELEY, K., WATT, S. J., GIRSHICK, A. R., AND BANKS, M. S. 2004. A stereo display prototype with multiple focal distances. In *ACM transactions on graphics (TOG)*, vol. 23, ACM, 804–813.

ANDERSON, R., MCDOWELL, L., AND SIMON, B. 2005. Use of classroom presenter in engineering courses. In *Proceedings Frontiers in Education 35th Annual Conference*, IEEE, T2G–13.

BAUDEL, T., AND BEAUDOUIN-LAFON, M. 1993. Charade: remote control of objects using free-hand gestures. *Communications of the ACM 36*, 7, 28–35.

BIMBER, O., FRÖHLICH, B., SCHMALSTIEG, D., AND ENCARNAÇÃO, L. M. 2006. The virtual showcase. In *ACM SIGGRAPH 2006 Courses*, ACM, 9.

FOURNEY, A., TERRY, M., AND MANN, R. 2010. Gesturing in the wild: understanding the effects and implications of gesture-based interaction for dynamic presentations. In *Proceedings of the 24th BCS Interaction Specialist Group Conference*, British Computer Society, 230–240.

GENG, J. 2013. Three-dimensional display technologies. *Advances in optics and photonics 5*, 4, 456–535.

GINGRICH, O., RENAUD, A., AND EMETS, E. 2013. Kima-a holographic telepresence environment based on cymatic principles. *Leonardo 46*, 4, 332–343.

HACHET, M., BOSSAVIT, B., COHÉ, A., AND DE LA RIVIÈRE, J.-B. 2011. Toucheo: multitouch and stereo combined in a seamless workspace. In *Proceedings of the 24th annual ACM symposium on User interface software and technology*, ACM, 587–592.

HILLIGES, O., KIM, D., IZADI, S., WEISS, M., AND WILSON, A. 2012. Holodesk: direct 3d interactions with a situated see-through display. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 2421–2430.

KIM, M., LEE, J., AND WHON, K. 2014. Sparogram: The spatial augmented reality holographic display for 3d visualization and exhibition. In *3DVis (3DVis), 2014 IEEE VIS International Workshop on*, IEEE, 81–86.

KOSARA, R., AND MACKINLAY, J. 2013. Storytelling: The next step for visualization. *Computer*, 5, 44–50.

LEE, C., DIVERDI, S., AND HOLLERER, T. 2009. Depth-fused 3d imagery on an immaterial display. *IEEE transactions on visualization and computer graphics 15*, 1, 20–33.

LEE, B., KAZI, R. H., AND SMITH, G. 2013. Sketchstory: Telling more engaging stories with data through freeform sketching. *IEEE Transactions on Visualization and Computer Graphics 19*, 12, 2416–2425.

LISTON, K., FISCHER, M., AND KUNZ, J. 2000. Designing and evaluating visualization techniques for construction planning. *Computing in Civil and Building Engineering 2*, 1293–1300.

MA, K.-L., LIAO, I., FRAZIER, J., HAUSER, H., AND KOSTIS, H.-N. 2012. Scientific storytelling using visualization. *IEEE Computer Graphics and Applications 32*, 1, 12–19.

MACKENZIE, K. J., DICKSON, R. A., AND WATT, S. J. 2012. Vergence and accommodation to multiple-image-plane stereoscopic displays:real world responses with practical image-plane separations? *Journal of Electronic Imaging 21*, 1, 011002–1.

MAZZA, R. 2009. *Introduction to information visualization*. Springer Science & Business Media.

NOMA, T., BADLER, N. I., AND ZHAO, L. 2000. Design of a virtual human presenter. *IEEE Computer Graphics and Applications 20*, 4, 237–246.

NOURI, H., AND SHAHID, A. 2005. The effect of powerpoint presentations on student learning and attitudes. *Global Perspectives on Accounting Education 2*, 79–85.

OGI, T., YAMADA, T., YAMAMOTO, K., AND HIROSE, M. 2001. Invisible interface for the immersive virtual world. In *Immersive Projection Technology and Virtual Environments 2001*. Springer, 237–246.

OLWAL, A., LINDFORS, C., GUSTAFSSON, J., KJELLBERG, T., AND MATTSSON, L. 2005. Astor: An autostereoscopic optical see-through augmented reality system. In *Fourth IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR'05)*, IEEE, 24–27.

PREMA, V., ROBERTS, G., AND WUENSCHE, B. 2006. 3d visualisation techniques for multi-layer display technology. In *IVCNZ*, vol. 6, 27–29.

RAKKOLAINEN, I., HÖLLERER, T., DIVERDI, S., AND OLWAL, A. 2009. Mid-air display experiments to create novel user interfaces. *Multimedia tools and applications 44*, 3, 389–405.

ROSLING, H. 2010. The joy of stats. *London: BBC4 9*.

STEIN, M. 2012. Arcade: a system for augmenting gesture-based computer graphic presentations. In *ACM SIGGRAPH 2012 Computer Animation Festival*, ACM, 77–77.

STEINMEYER, J., 1999. The science behind the ghost: A brief history of pepper's ghost.

SUN, G., AND HOLLIMAN, N. 2009. Evaluating methods for controlling depth perception in stereoscopic cinematography. In *IS&T/SPIE Electronic Imaging*, International Society for Optics and Photonics, 72370I–72370I.

TAPP, S. R. 1996. Secrets of power presentations. *The Journal of Personal Selling & Sales Management 16*, 4, 67.

VAN WELBERGEN, H., NIJHOLT, A., REIDSMA, D., AND ZWIERS, J. 2005. Presenting in virtual worlds: Towards an architecture for a 3d presenter explaining 2d-presented information. In *International Conference on Intelligent Technologies for Interactive Entertainment*, Springer, 203–212.

WARD, M. O., GRINSTEIN, G., AND KEIM, D. 2010. *Interactive data visualization: foundations, techniques, and applications*. CRC Press.

YANG, L., DONG, H., ALELAIWI, A., AND EL SADDIK, A. 2015. See in 3d: state of the art of 3d display technologies. *Multimedia Tools and Applications*, 1–35.

YI, J. S., AH KANG, Y., STASKO, J., AND JACKO, J. 2007. Toward a deeper understanding of the role of interaction in information visualization. *IEEE transactions on visualization and computer graphics 13*, 6, 1224–1231.

YOO, B., HAN, J.-J., CHOI, C., YI, K., SUH, S., PARK, D., AND KIM, C. 2010. 3d user interface combining gaze and hand gestures for large-scale display. In *CHI'10 Extended Abstracts on Human Factors in Computing Systems*, ACM, 3709–3714.

ZHANG, Z. 2000. A flexible new technique for camera calibration. *IEEE Transactions on pattern analysis and machine intelligence 22*, 11, 1330–1334.