Augmented Displays: Seamlessly Extending Interactive Surfaces with Head-Mounted Augmented Reality

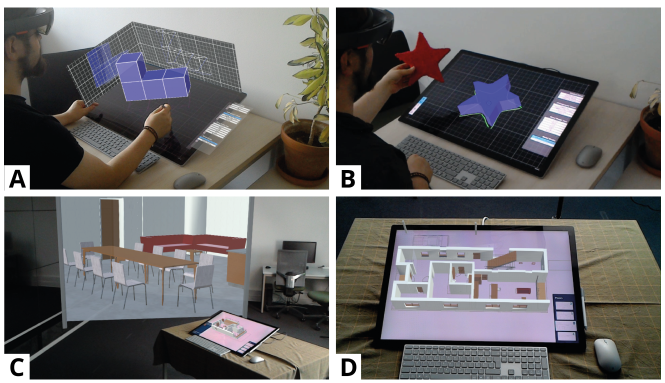

Figure 1: (A) Our immersive 3D modeling tool *DesignAR*, showing the model itself in the center, orthographic cutting views and offloaded menus. (B) 3D model created with pen input in *DesignAR* and based on a real-world object. (C) Our architectural design tool *ARchitecture*, showing the interactive surface, augmented view, and immersive portal view. (D) Close up of *ARchitecture's* interactive surface with the augmented 3D representation.

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Abstract

We present *Augmented Displays*, a new class of display systems directly combining high-resolution interactive surfaces with head-mounted Augmented Reality. This extends the screen real estate beyond the display and enables placing AR content directly at the display's borders or within the real environment. Furthermore, it enables people to interact with AR objects using natural pen and touch input in high precision on the surface. This combination allows for a variety of interesting applications. To illustrate them, we present two use cases: An immersive 3D modeling tool and an architectural design tool. Our goal is to demonstrate the potential of *Augmented Displays* as a foundation for future work in the design space of this exciting new class of systems.

Author Keywords

Augmented Reality; Interactive Surfaces; Augmented Displays; Touch+Pen Interaction; Design; 3D Modeling; Architecture; DesignAR.

CCS Concepts

•**Human-centered computing** → **Mixed / augmented reality; Interactive systems and tools;** *Interaction techniques;* Touch screens; Gestural input;

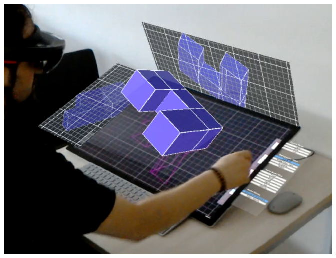

Figure 2: *DesignAR*: Orthographic views showing a 2D projection of the model, one of them is tilted for better visibility to the user.

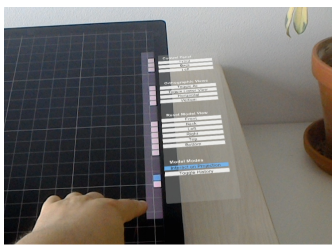

Figure 3: *DesignAR*: Menu offloaded in AR space with the display's borders used for interaction.

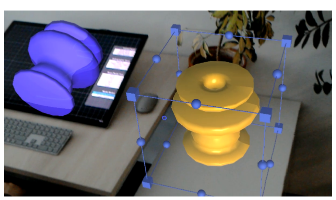

Figure 4: *DesignAR*: A real world reference (yellow) of the modeled object (blue) placed directly in the environment.

Introduction

In today's typical work spaces, the prevalent form of display technology is a non-interactive screen in a desktop environment. However, for design workstations, interactive surfaces become increasingly common and offer natural interaction like touch and pen input. In a a lot of areas, e.g., 3D modeling and architecture, designers work with inherently three-dimensional data (see Fig. 1B, D). Therefore, they would benefit not only from using natural interaction for the design process, but also from using immersive technologies to help experience the content in a stereoscopic, spatial representation. We provide such an immersive work environment by combining touch and pen enabled design workstations with Augmented Reality (AR) head-mounted displays (HMD). This enables users to use natural pen and touch input to interact not only with what is shown on the display but with the AR content around it as well. Consequently, we do not only use the AR space to display stereoscopic 3D objects, but also to extend the screen estate beyond the display's borders.

Related Work

The idea of combining Mixed Reality with conventional displays was first explored by by Feiner and Shamash [4] in their work on *Hybrid User Interfaces*, which can be seen as a part of *Distributed User Interfaces*. Some more recent works utilize this combination to some extend, e.g., by applying an interactive tabletop with video-see-through AR for analyzing visualizations [1], placing AR 3D visualizations next to a conventional display [6], combining a desktop interface with AR for planning factory layouts [5], manipulating AR 3D visualizations utilizing a tablet showing an orthographic view [10], and combining a touch display with a head-tracked video-see-through display for an urban visualization tool [3]. However, all this work concentrates mainly on a specific use case. The connection between Mixed Reality and the display is only loosely described; and rarely can a tight coupling of AR content to 2D screens been observed. Building on the foundation of our previous work *DesignAR* [8], *Augmented Displays* aims to better describe the relationship between head-coupled AR and interactive surfaces, as well as the resulting design dimensions.

Augmented Displays

In this work we want to demonstrate the concept of *Augmented Displays*, which we define as the seamless combination of high resolution touch and pen enabled displays with head-coupled Augmented Reality (AR). We propose to use the display as a frame of reference for AR content and place particular emphasis on the spatial alignment between the display and its associated augmentations (see [8]).
AR objects can generally be divided into three levels of spatial proximity: (L1) Placed directly on and aligned with the display (Fig. 2), (L2) placed at or close to the edges of the display (Fig. 3), and (L3) spatially independent of the display (Fig. 4). L1 and L2 provide a tight coupling and invoke the perception of the seamless integration of display and AR content (see Fig. 1A, D). This way, we are addressing the lack of immersion of traditional displays and expand the available space for content above and beyond the display's screen. Furthermore, this strong spatial relationship enables utilizing natural pen and touch input to interact with AR objects. This direct manipulation of AR objects provides faster and more precise input than the otherwise common mid-air interaction. L3 lacks the strong spatial link of the previous two, but still shares a semantic connection to the display, so that changes to either one reflect on the other. They can for example provide a real world reference to objects on the display to gain a better understanding how those objects integrate into the environment (see Fig. 1C, 4). To enable the transformation of objects within the third level independently from the display, we propose to use

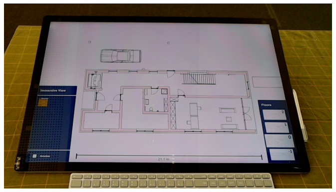

Figure 5: *ARchitecture*: Technical drawing in high resolution on the interactive surface.

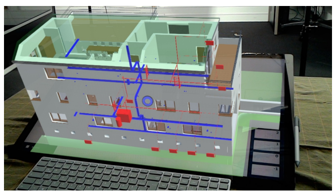

Figure 6: *ARchitecture*: 3D model of the building directly augmented and aligned with the technical drawing (with visible pipes for heating and electric cabling).

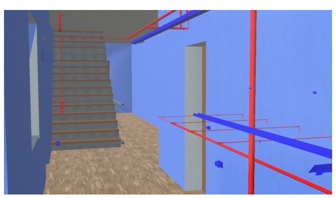

Figure 7: *ARchitecture*: Immersive first-person view through the portal next to the display (again with visible pipes for heating and electric cabling).

mid-air interaction in this case.

Objects or data which are inherently 3D can be positioned directly on the display using the AR HMD. Thus they can be perceived in an immersive, stereoscopic fashion and explored using physical navigation. The AR space around the display can be used in various ways to assist or extend the display. It can expand the view on the display beyond its border, e.g., for maps or visualizations. This can provide users with a useful overview, while the display's high resolution and touch input can be used for detailed exploration and manipulation of the data. The space around the display can also be used to show supplemental views to provide helpful information without using any additional screen estate (see Fig.1A). This also defines the role of an augmentation: AR objects can either take the primary role within an application with the display providing menus and interaction capabilities to manipulate the AR objects, or AR objects can take an auxiliary role to the content on the display itself. Consequently, primary objects are more likely to be placed on the display's screen itself, while auxiliary objects often occupy the borders of the display.

By tightly integrating AR and the display, we create a close relation and break up the distinction between the two modalities. This has the potential to provide the seamless transition among content on the display and in AR and thus, between different categories on the Mixed Reality Continuum. Furthermore, it is also suitable to bridge the gap between ubiquitous and terminal computing [7], offering a dedicated workstation while also utilizing the environment around the users to provide additional content.

Use Cases

We want to demonstrate the concept of *Augmented Displays* with two use cases: First our previous work *DesignAR* [8], an immersive 3D modeling application, and second an architectural design tool called *ARchitecture*.

One of the main aspects we explored in *DesignAR* was how the borders of the display can be used to maximize the screen estate available for modeling. We suggest to place orthographic projections, typical in modeling tools, in AR space at the corresponding borders of the display (see Fig.2). It does not sacrifice any screen space and the correspondence between each orthographic projection and the associated view becomes immediately obvious. Furthermore, we propose to use the respective display border for interaction, e.g., to show or hide views, change their rendering mode, and tilt them horizontally for better visibility. Besides specialized views, general UI elements can also be offloaded into AR space, e.g., by simply swiping them towards the border of the display (see Fig.3). They may still be interacted with using touch input on the display's border. Furthermore, *DesignAR* also enables placing instances of the modeled object directly in the environment using mid-air interaction (see Fig.4). Those instances immediately reflect any changes of the model.

Our second prototype, *ARchitecture*, explores how *Augmented Displays* can be used to bridge the gap between abstract and immersive 3D representations in an architectural context. On the display's screen, it provides 2D high-resolution technical drawings of a building commonly used by architects (see Fig.5). A 3D AR view of the building is situated directly on and aligned with the floorplan to enable the natural perception of the building (see Fig.6). In contrast to traditional tools, the 3D view is not separated from but directly extends the drawing. Additionally, a real-sized representation of the building is placed in AR next to the display and can be viewed through a portal (see Fig.7). This enables a fully immersive exploration of the design, giving a strong impression of how the building would look in the real world. Thus, *ARchitecture* creates a continuous display environment that seamlessly integrates several views of varying degree of immersion into a single system.

Implementation Details

Both use cases combine the Microsoft HoloLens AR HMD with the MS Surface Studio interactive surface. We use the Unity 3D engine for both applications (display and HMD) and a custom client-server architecture to synchronize them. The coordinate systems are calibrated by placing a common anchor for AR objects at the bottom left corner of the screen using a dedicated transformation widget. By using off-the-shelf hardware to build our prototypes instead of specialized systems, a reasonably priced system can be achieved, that closely resembles existing design workstations and work environments.

Conclusion

We presented *Augmented Displays*, combining an interactive surface with head-mounted AR and demonstrated how to utilize the space above and beyond the display. Furthermore, we provided two use cases to illustrate our concepts. Besides our own examples, existing work like the ones from De Araùjo et al. [2], Butscher et al. [1], and Riemann et al. [9] can also be considered as Augmented Displays given the previous definition. Thus, we contribute another stepping stone towards this existing new class of display systems, which we plan to further explore in the future.

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