Demonstrating CleAR Sight: Transparent Interaction Panels for Augmented Reality

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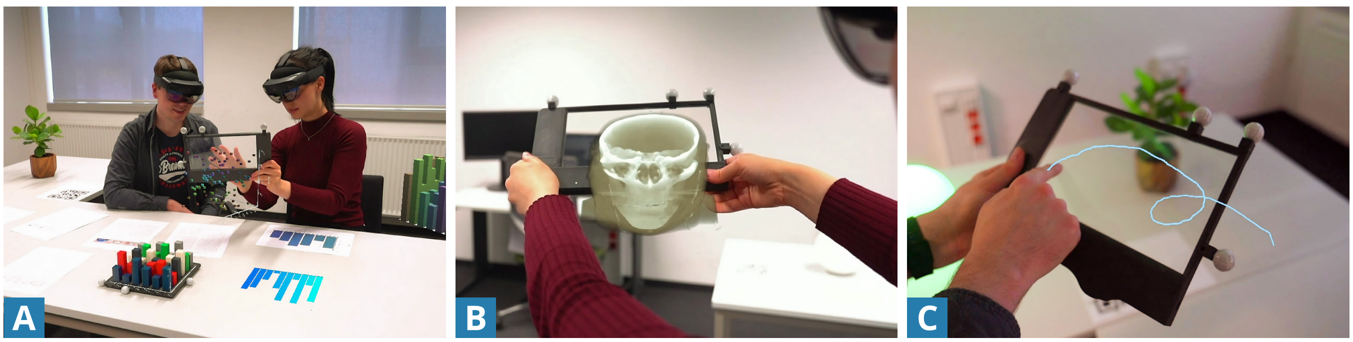

Figure 1: We demonstrate the CleAR Sight research platform. It allows multiple people to use a touch-enabled, transparent interaction panel to perform tasks such as working with abstract data visualizations (A), exploring volumetric data sets (B), and making in-situ annotations (C). All photos in this work were shot with an externally tracked camera and do not fully reproduce the actual prototype.

ABSTRACT

In this work, we demonstrate our concepts for transparent interaction panels in augmented-reality environments. Mobile devices can support interaction with head-mounted displays by providing additional input channels, such as touch & pen input and spatial device input, and also an additional, personal display. However, occlusion of the physical context, other people, or the virtual content can be problematic. To address this, we previously introduced CleAR Sight, a concept and research platform for transparent interaction panels to support interaction in HMD-based mixed reality. Here, we will demonstrate the different interaction and visualization techniques supported in CleAR Sight that facilitate basic manipulation, data exploration, and sketching & annotation for various use cases such as 3D volume visualization, collaborative data analysis, and smart home control.

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CCS CONCEPTS

• **Human-centered computing** → **Mixed / augmented reality**; **Interaction design**.

KEYWORDS

human-computer interaction, visualization, augmented reality, transparent displays

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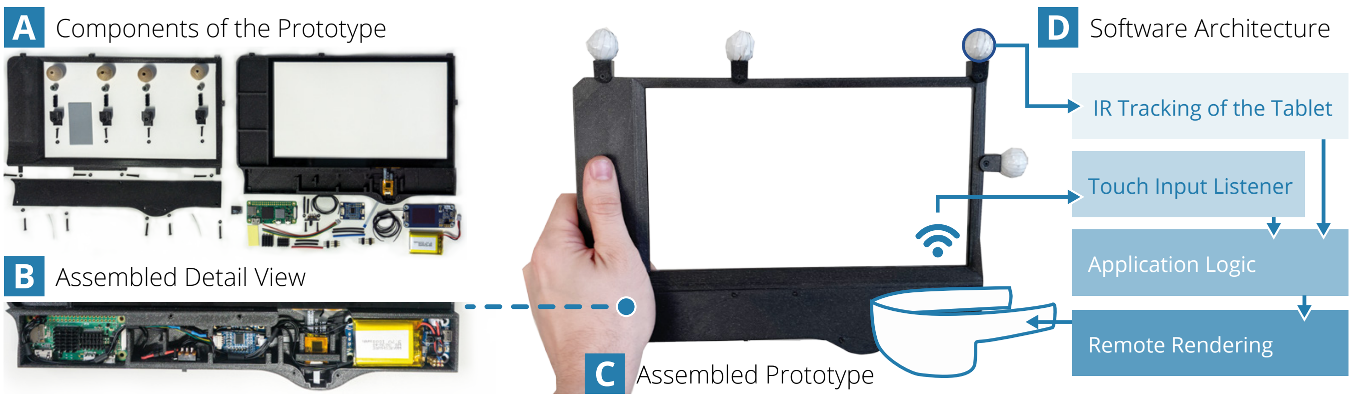

Figure 2: Our hardware setup consists of a Raspberry Pi Zero 2 W, a 10" transparent capacitive touch panel, and a battery. We installed these components in a custom, 3D-printed case and attached reflective tracking markers. Both the pose data of the tracked interaction panel and touch events are sent to the application. We use remote rendering to stream content to the HMD, which then displays the holograms, e.g., on the panel.

1 INTRODUCTION & BACKGROUND

Augmented Reality (AR) often combines head-mounted displays (HMDs) with additional, mobile devices (e.g., [8, 12]). These phones or tablets are used for both input and output: On the one hand, they serve as additional controllers that provide input modalities such as touch & pen or can be tracked for spatial interaction. On the other hand, they also provide additional output capabilities in the form of handheld personal displays.

Such combinations of HMDs and mobile devices have been shown to be beneficial (e.g., [2]). However, occlusion is a major challenge: Real-world objects are hidden, the environmental context is partially lost, and co-located users may be harder to observe. Even for purely virtual scenes without a strong coupling to the physical environment, unrealistic blending of the mobile device and the virtual content can lead to a loss of immersion and undermine the user's mental model. A natural solution for these issues is the use of transparent devices. These can be based on, e.g., transparent OLED displays or simulated by rendering content at the position of a transparent prop using the HMD. However, designing for such systems is not easy, and in the past, no systematic exploration of this promising device combination has been done.

In our 2022 ISMAR paper [9], we presented *CleAR Sight*, a concept and research platform for the use of transparent interaction panels in HMD-based AR. CleAR Sight features a custom-built touch panel tracked in 3D space and uses the HMD for displaying content, simulating a transparent display. Our work builds on prior research on transparent props and devices. Transparent displays have previously been used in AR, for example, in the form of large, projector-based screens [5] or for exhibitions [7]. Similar to our use case, the *Gravity tablet* prototype by Gravity Sketch Ltd [3] is used for sketching. Schmalstieg et al. [10] used transparent props in their *Virtual Table* environment. In contrast, CleAR Sight supports multiple users in an AR environment. Finally, transparent tangibles have also been examined, e.g., in [1] and for the concept of *Contact AR* in [4].

In our interactivity, we demonstrate this research platform with an interactive showcase drawing from the use cases we originally explored in the paper. In the following, we provide a brief overview of the CleAR Sight concept, the hard- & software design, and the interaction techniques supported by our system.

2 THE CLEAR SIGHT SYSTEM

The basic idea of our concept is to combine a transparent, handheld tablet with a head-mounted display to support interaction in AR. To this end, we designed and built a touch-enabled transparent interaction panel. We use the HMD to render virtual content in the panel's location. In contrast to, e.g., a transparent OLED display, this allows for easy exploration of the role of transparency in AR with a more flexible and affordable setup. Key benefits of such transparency are: 1) Real-world objects and their context are not occluded during interacting with them (e.g., for annotations). 2) Transparent touch displays allow precise touch & pen input in direct visual relation to both virtual & real objects. 3) In multi-user scenarios, users can pick up more social cues (gestures, eye gazes, etc.), potentially benefiting their collaboration. On the other hand, our system also enables us to examine typical challenges of transparent displays, such as the vergence-accommodation conflict [6] and binocular parallax [11].

2.1 Hardware Setup

Our technical setup comprises a custom-built transparent handheld tablet, a Microsoft HoloLens 2, an OptiTrack 3D tracking system, and a dedicated workstation for remote rendering. The handheld prototype consists of a Raspberry Pi Zero 2 W, a 10" transparent capacitive multi-touch surface, and a battery shield (see Figure 2, A). To save space, we cut all connection wires to an appropriate length, equipped them with small electrical connectors, and soldered them onto the circuit boards. The touch controller is directly connected to the internal USB port of the Raspberry Pi and is natively supported as an HID-compatible touch device. In addition, the battery shield is attached to the power pins and incorporates a Li-Po battery

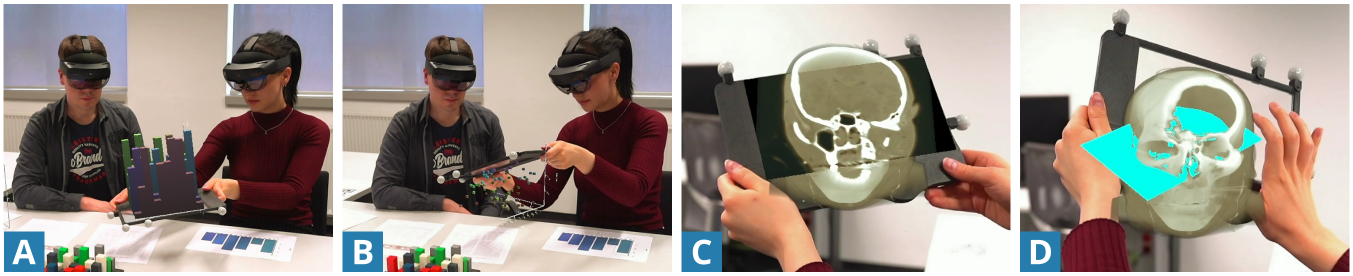

Figure 3: Besides the clipping of volumes (see Figure 1, B), a user can also pick up visualizations for closer inspection (A). Clipping can also be used to filter 3D visualizations (B). Furthermore, using the tablet as a tangible, an arbitrary slice through volumetric data sets can be defined and viewed, e.g., showing a different projection (C). The volume can be frozen, allowing users to annotate directly on the clipped visualization, and bookmarks can be created to indicate interesting slices (D).

switching charger, 5 V voltage boost chip, and supports battery status monitoring via I^2C. Typically, the 1000 mAh battery lasts about two hours and can be easily charged via micro-USB. Finally, all components are housed in a 3D-printed case which measures 29×19×1 cm (see Figure 2, B). The total weight of the interaction panel is 330 g. To ensure that the tracking system can precisely capture the tablet in space, we attached IR reflective markers (20 mm diameter) to the tablet. They also serve as locking clips for the cover (see Figure 2, C).

2.2 Software

Our software is built on Unity, and we use remote rendering to stream the content to the HMD. We broadcast touch data over the network via UDP and inject the touches into the Unity event pipeline in our application (see Figure 2, D). We use an external IR tracking system to track the tablet's pose. We receive the streamed pose data using a modified version of the MotiveDirect[1] library. The transformation between the tracking system and the Unity coordinate system is computed based on a set of reference points which consist of a printed QR code and adjacently attached IR markers. We have released the source code and provide detailed step-by-step instructions and resources on our project website[2].

3 INTERACTION TECHNIQUES & APPLICATION CASES

Our prototype, described above, serves as a research platform that allows us to examine different use cases for transparent tablets in AR easily. We implemented three applications to investigate the advantages and challenges of this novel device combination: The exploration of 3D volume data, collaborative InfoVis, and the control of smart home devices. In our interactivity, we present a showcase demo that integrates important aspects of these three applications. In the following, we will describe the interaction techniques that we support in CleAR Sight in three categories: data manipulation & exploration, sketching & annotation, and menus & UI tools.

[1]MotiveDirect: https://github.com/XmanLCH/MotiveDirect
[2]Project website: https://imld.de/clear-sight/

3.1 Data Manipulation & Exploration

We make use of transparency to support techniques for the *object selection & manipulation* of objects. Using a combination of through-the-window touch interaction and spatial interaction akin to a magic lens metaphor, users can directly manipulate both virtual objects and physical (smart) devices. For example, visualizations can be scaled or rotated (see Figure 1, A) or scooped up with the tablet to inspect them closely (see Figure 3, A). Furthermore, the interaction panel can be used as a physical prop to define *clipping planes*. This can be used, e.g., to define slices in a volume visualization (see Figure 1, B and Figure 3, C) or to filter cluttered 3D visualizations (see Figure 3, B). We also allow to *freeze* the current cutting plane and to place and remove *visual bookmarks* that may help to highlight interesting views into the data (see Figure 3, D).

3.2 Sketching & Annotation

In CleAR Sight, we support different techniques for annotations. All of them allow the user to write on a real surface while keeping the environment's visual context. *On-tablet annotations* can be written directly on the panel, making use of its haptic qualities, and then released at the desired location in space. These also allow the direct annotation of, e.g., paper documents, similar to [4] (see Figure 4, A). *In-situ annotations*, on the other hand, allow users to directly sketch in 3D but with the added benefit of the physical screen of the device as a frame of reference (see Figure 1, C). Finally, *projected annotations* use the HMDs scene reconstruction capabilities to project their annotations onto surfaces in the environment, allowing users to directly sketch on objects in the scene (see Figure 4, B & C).

3.3 UI Tools & 2D Visualizations

For more complex use cases, *menus* and other *UI tools & widgets* are necessary. Thus, our prototype supports 2D UI elements that can be displayed on the transparent tablet but may overlay real or virtual objects in the environment. The transparency in CleAR Sight makes it possible to get unoccluded live feedback for the interactions with such UIs. For example, a user may change the light color of a smart lamp and immediately see the effect of their interactions in the environment (see Figure 5, A & B). Similarly, we can also show other content on the interaction panel, e.g., *2D visualizations*. These can be used on their own, are semantically

Figure 4: In addition to in-situ annotations (see Figure 1, C), we support on-tablet annotations that can be placed in space or allow users to annotate documents by placing the tablet on top of them (A). In addition, projected annotations allow users to annotate surfaces from a distance (B, C).

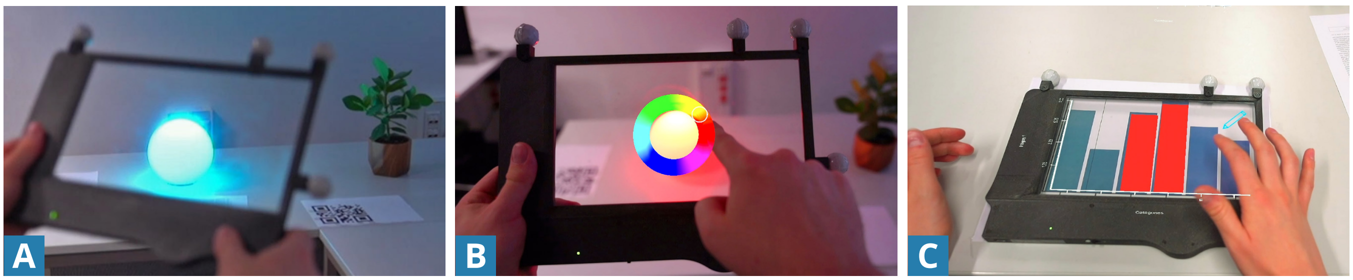

Figure 5: CleAR Sight allows configuring smart devices such as smart bulbs (A) and directly seeing the effects, e.g., color changes (B). We can show interactive 2D content on the panel. For example, when used as an overlay, the tablet allows selection in printed charts; selected data points are highlighted (C).

connected to other objects, e.g., for situated analytics use cases, or serve as direct overlays for existing content. For example, they allow interaction with charts printed on paper (see Figure 5, C).

4 CONCLUSION

In this work, we presented CleAR Sight, a concept and research platform that uses a transparent interaction panel to support interaction & visualization in HMD-based AR environments. We described the hardware and software of our system, as well as the different interaction and visualization techniques with which we support basic manipulation, data exploration, and sketching & annotation for various use cases, such as 3D volume visualization, collaborative data analysis, and smart home control. In our interactivity, we demonstrate CleAR Sight with an interactive showcase that combines important aspects of these use cases.

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