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EndovascuIAR: Utility of Mixed Reality to Segment Large Displays in Surgical Settings

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Abstract

Mixed reality (MR) holds potential for transforming endovascular surgery by enhancing information delivery. This advancement could significantly alter surgical interfaces, leading to improved patient outcomes. Our research utilizes MR technology to transform physical monitor displays inside the operating room (OR) into holographic windows. We aim to reduce cognitive load on surgeons by counteracting the split attention effect and enabling ergonomic display layouts. Our research is tackling key design challenges, including hands-free interaction, and occlusion management in densely crowded ORs. We are conducting studies to understand user behavior changes when people consult information on holographic windows compared to conventional displays.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed / augmented reality; Applied computing—Life and medical sciences—Health care information systems

1 Introduction

Endovascular surgeries such as cerebral angiographies and stroke rescue therapies are commonly performed medical procedures. In these procedures, a catheter is inserted into an artery and navigated through a patient's vasculature for diagnostic or interventional purposes. The small size and deformable nature of the target arteries can create constantly changing conditions. These dynamic conditions require the surgeon to consult many different information streams simultaneously, e.g. preoperative scans, intraoperative X-ray feeds, and textual patient information. Given the limited space available for physical displays in the operating room (OR), many angiography suites provide this information to the surgeon on a single large monitor, sometimes with resolutions up to 8K.

While this solution succeeds in providing the required information to the surgical team, it comes with significant drawbacks from a usability standpoint. During the procedure, surgeons must maintain a sterile surgical field to avoid infection. This sterility constraint prevents surgeons from physically interacting with the monitor. If the monitor requires adjustment intraoperatively, the surgeon must request assistance from another medical staff member. However, the staff may not always adjust it exactly as the surgeon prefers, leading to additional communication overhead and longer procedure times.

Another key issue that surrounds the physical display modality is the introduction of the split attention effect. This phenomenon is well documented in learning research and indicates that referencing

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Figure 1: An example of an endovascular monitor with multiple windows showing scans, patient vital signs, surgical feeds, and 3D reconstructions.[1]

information from multiple sources can increase cognitive load. This increase in cognitive load can negatively affect task performance [1]. The endovascular display in the OR is often not positioned in the same field of view as the patient and the surgical field. This forces the surgeon to split their attention between the surgical task and the information on the monitor.

Mixed reality (MR) provides natural solutions to these challenges. MR can enable the surgeon to segment the various surgical feeds displayed on the large monitor into several holographic monitors. These holographic monitors are not affected by sterility and can be spatially positioned inside the OR ergonomically.

2 Design Challenges

Prior studies conducted with medical experts [3, 4] have shown utility of surgical holographic monitors for various surgical tasks. Yet, applying this approach in endovascular surgery specifically presents a multitude of user-centered interaction design challenges that remain to be explored.

2.1 Hands-Free Interaction

In the context of surgical settings, where the physician's hands are generally occupied and must remain sterile, conventional methods of interacting with holographic displays, such as using controllers or hand gestures are impractical. For this reason, novel interaction techniques that permit the surgeon to interact with holograms without using their hands will be required.

2.2 Virtual Monitor Occlusion

The operating room is often heavily occupied with surgeons, nurses, and other essential personnel. Given the high number of people condensed in a relatively small area, occlusion of holographic monitors with physical objects (e.g, body parts) may be common. Because

[1]Image source: https://www.siemens-healthineers.com/en-us/angio

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Figure 2: The Lego study's three display modalities (left to right): large monitor, tablet, and mixed reality.

physical monitors are visible to all people in the OR, individuals can consciously avoid occluding them. However, holographic monitors are only visible to select people and can unintentionally be occluded during critical surgical moments. This necessitates the development of new techniques to mitigate occlusion of virtual displays.

3 Work in Progress

Lego Study. To address interface design challenges in MR, it is crucial to first examine how user behavior varies when referencing information on different display modalities. Our ongoing study aims to identify differences in user performance and perceptions across three distinct display modalities (see Fig. 2). In the first modality, participants engage with two Lego sets, switching between them as prompted, while referring to instructions and images on a large screen placed at a distance. This screen also displays irrelevant information, increasing cognitive load. The second modality involves using the Microsoft HoloLens 2 to create holographic monitors, allowing participants to spatially position their displays while building the Lego sets. The third modality is a personal tablet that allows users to separately position segments of the large monitor's content. This serves as an analogue for commonly used technology to manage information on a per-user basis. We are assessing cognitive load and situational awareness through the NASA-TLX [2] and SART [5] questionnaires, and conducting interviews for preferences. We hypothesize that leveraging the affordances of MR to move information into and out of context spatially will improve task performance. If successful, this could suggest that MR improves user experience in complex information gathering scenarios. Future work may explore hands-free interaction methods like voice commands and eye tracking.

Surgical Ergonomics Study. Concurrently, we are applying a similar MR system to tasks in the operating room to investigate its benefits for surgical ergonomics. The study will happen in two stages. First, surgeons will perform a cerebral angiogram while using the standard display technology in the operating room. During this step, the contents of the large monitor will be recorded using a specialized capture device (see Fig. 3). In the second stage of the study, surgeons will watch the previously captured video from the monitor in the angiography suite using MR in a simulated surgical field. Participants will have the flexibility to select specific windows from the larger external monitor display and strategically position them in the air around them. As they view the recorded surgery, they will interact with these monitors as though they are performing the recorded surgery in real-time. This immersive approach simulates a live surgical experience, allowing us to closely observe and analyze how MR technology can enhance surgical performance and decision-making in a dynamic, virtual setting. Following the complete playback of the surgical video, surgeons will be asked a series of semi-structured interview questions to gauge their experience with the MR display and its impact on the surgical workflow.

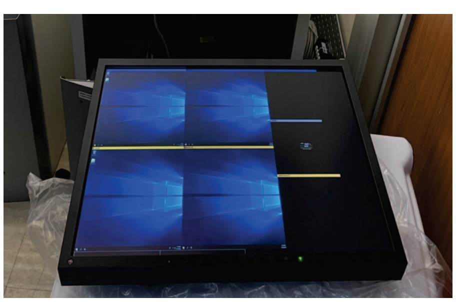

Figure 3: The angiography display capture device being used to view the contents of the large monitor during startup.

Holographic Occlusion. Moreover, we also need to understand how virtual display occlusion impacts the surgical workflow before attempting to implement a design solution. We plan to run a study presenting various different occlusion resolution strategies, including altering opacity and automated hologram displacement, and measure user sentiment for each proposed solution.

4 Conclusion

MR presents new opportunities for users to interact with information often without limitations of the physical world. The specific needs for presenting information in endovascular procedures highlight an important use case for these techniques. By developing a better understanding of user behavior when presented with holographic monitors and the impact of holographic display occlusion in the operating room, we can move towards crafting more efficient, better surgical interfaces in MR to decrease task load and improve patient outcomes.

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