I Want to Be a Surgeon! Role Playing for Remote Surgery in Mixed Reality

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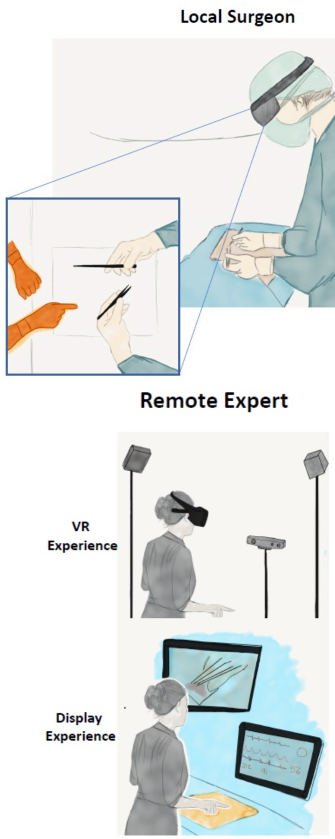

Figure 1: Envisioned Remote surgery Aids: Top Local Surgeon using Augmented Reality (AR); Bottom: Remote expert using either Virtual Reality (VR) or an immersive large display experience.

ABSTRACT

Designing interactive Mixed Reality (MR) applications with hard to reach domain experts is challenging, especially in the healthcare domain. In previous research we introduced new ways of using head mounted Augmented Reality prototyping tools to develop and iterate over rich spatially distributed experiences. In this paper we report on using prototyping and role-playing with a group of surgeons to develop novel MR applications to support visual aids for remote procedures. Our work shows how immersive prototyping in MR uniquely supports the uncovering of key aspects of spatial interactive systems, and accelerates the development of novel design ideas in the surgery space.

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KEYWORDS
Augmented Reality, Mixed Reality, Virtual Reality, Sketching, Prototyping, Remote Surgery, Telesurgery, In-Situ, Role-Playing

Figure 2: Mock operating room used for Role Playing in MR. Top: Local Operating Room; Bottom: Remote expert site

INTRODUCTION

Creating interactive systems for highly specialized environments is complex and requires continuous feedback from domain experts [2]. When the specific application requires the use of emerging interactive technology such as Augmented Reality (AR) and Virtual Reality (VR)—often not fully understood by the domain experts—design and development activities become even more difficult and bare the risk of not yielding the desired results in a reasonable amount of time.

In this paper we present a use case that documents our approach to solve this complex design problem using a new technique for prototyping Mixed Reality (MR) applications with domain experts in surgery. Specifically, our work focuses on developing a MR system that spans AR, VR, and immersive environments to enable "Augmented Reality Technology Enabled reMote Integrated Surgery" (ARTEMIS) (Fig. 1).

PROTOTYPING FOR ARTEMIS

Our work is in collaboration with a group of surgeons from the Naval Medical Center in San Diego (California) who act as the domain experts and are guiding the requirements for our interactive MR remote surgery application.

In order to elicit requirements from the surgical team we organized a design workshop with seven domain experts (4 surgeons, and 3 operating room technology specialists) and 4 human-centered design researchers, experienced with health technology. The workshop was organized around a design thinking exercise that helped the team identify requirements for the envisioned system. We identified a high-level remote surgery process map to guide our approach that distinguished six different phases: (1) Start Experience, (2) Establish Context, (3) Pre-operative, (4) Procedure, (5) Post-operative, and (6) End Experience. For each of these phases, we identified specific needs that we intended to then translate into prototypes.

In light of the needs identified across the six phases, we used a standard human-centered design approach and used speculation, drawings, and paper prototypes to convey our ideas. We prototyped our system in a mock operating room, (Fig. 2) which provided context to the envisioned application. However, very quickly, the limitations of paper prototyping in the environment became clear as it only afforded us a weak understanding of the user's perspective and of the environment. This led us to think about in-situ prototyping for AR and using AR [3, 5]. We used PintAR, a low-fidelity AR prototyping application running on Microsoft's Mixed Reality Headset (HoloLens) and used in conjunction with a tablet to sketch interactive experiences [1]. With PintAR we were able to quickly draw sketches on a tablet and place those sketches in the HoloLens's augmented world. It also provided animations for our sketches, and tools for mocking (or wizarding) behaviors that did not yet exist. Using a prototyping tool in AR allowed us to think *through* the space (rather than about it), creating new interactions

Figure 3: Novice's view with the 'Call Surgeon' button

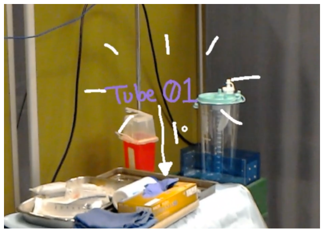

Figure 4: Guiding novice to tracheal tube

Figure 5: As the expert's holographic hands trace along the patient, annotations are created and anchored to the body

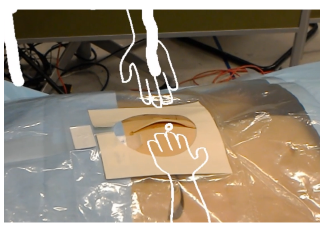

Figure 6: Holographic representation of the expert's hands instructing the novice how to open the incision

where we *saw* design gaps (rather than predicted them), and to understand how a user would navigate and interact with the interface we were creating for them.

The initial prototypes were created by two designers. The experience was created through a combination of animations, triggers, and mocking, controlled by whichever designer was not posing as a user at that time. The overall goal was to simulate a remote surgery application where a "novice" with limited medical training and little equipment at their disposal could call a remote medical "expert" to help the novice carry out the procedure. We used the results of our design thinking exercise to decide what to sketch in our first prototypes, and prototyping all of the interactions across novice and expert experiences took a total of 3 hours. In addition to designing the experience, the two designers used role-playing to better contextualize, as well as to test the application [4]. During role-playing both novice and expert were wearing headsets.

In the remainder of this section we describe our prototyping results. We outline how AR prototyping allowed us to engage in the novice's and the expert's perspectives through role-playing, and how this supported iterative design of low-fidelity, but ecologically valid AR prototypes critical to the conception of ARTEMIS.

Novice – After the novice put on the headset, a button was immediately visible hovering over the patient with the words 'Call Surgeon' (Fig. 3). When pressed, an avatar appeared representing the expert standing across the patient bed from the novice as if the surgeon was in the room. The novice was verbally instructed to get a tracheal tube, which immediately resulted in an indicator lighting up — showing the novice where the tube was in their operating room (Fig. 4). The expert then began to guide the novice by demonstrating the manoeuvre using a tracheal tube that was represented as a hologram to the novice. The novice was then able to complete the procedure by mimicking the expert's actions, while the expert was able to make corrections when needed.

A second prototype was meant to guide the novice towards making an incision in the patient's thorax (Fig. 5). The scalpel lit up in the same way as the tracheal tube did, and the surgeon pointed to where the cut would be made. The surgeon's hands appeared as a hologram, and when they traced along the patient to indicate the path to cut, a line automatically appeared on the patient's body (Fig. 5). The novice used this line as a guide while making the incision. Once done, the expert was able to lead the novice through the opening of the incision to allow for inspection of the tissue underneath. This happened through verbal and gestural explanations, via the holographic hands (Fig. 6).

Expert – From the experts point of view, everything started when receiving a call. The expert was able to see information about the novice's operating environment (like the tools available to the novice), patient data, and the room layout as an aerial map (Figs. 7 and 8). With the headset on, the expert was then guided to a particular point in space (away from walls and obstacles) where

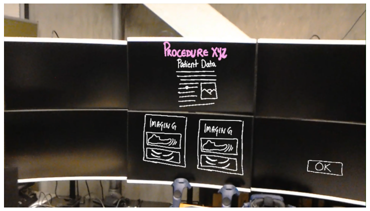

Figure 7: Information on the patient and the operation than needs to be performed, from the expert's view

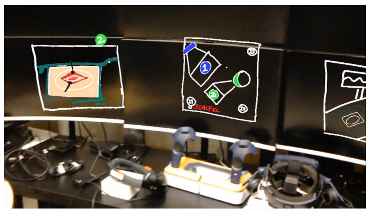

Figure 8: Visualizations of the novice's environment and tools as seen by the expert

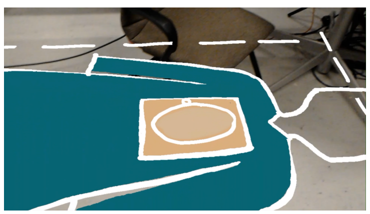

Figure 9: Expert's view of the patient as a hologram

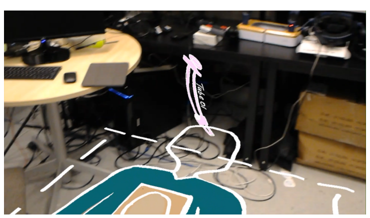

Figure 10: The tracheal tube hologram as seen from the expert's view. As the novice moves the physical tube, the hologram seen by the expert moves

a hologram of the patient was lying on an operating table (Fig. 9). Just as the novice could see the expert across the bed, so could the expert see the novice. The expert realized a need to intubate the patient, and picked up a tracheal tube. In doing so, the novice was informed to get the tube as well. The expert demonstrated the procedure, explaining common pit falls and other relevant information. As the novice then performed the procedure, the expert was able to see holograms of the novice's hands and the tube being inserted into the patient's trachea (Fig. 10). The second prototype created a similar experience for the remote expert, but focused on the incision described above.

DISCUSSION & FUTURE WORK

Through our process of role-playing in AR, we showed how technical requirements became explicit: as designers we now had a more detailed understanding of which visual aids would and would not be helpful for both the expert and novice.

For instance, the ability for the expert to make annotations on the patient's body was an anticipated feature, but *how* it might be implemented was unclear. Once in the MR environment, the inclinations of users became clearer, and we decided to implement a natural point-to-draw interface in our upcoming ARTEMIS system.

The need for a tracking system was also discovered in a similar way. While it was clear that the expert needed to know exactly where the novice's tracheal tube was positioned relative to the patient, our process helped uncover the value in the surgeon's ability to demonstrate procedures with their own tools. This led to the decision to implement accurate tracking of both novice's and expert's tools.

We intend to continue using AR prototyping tools in an iterative participatory design process with our domain experts (surgeons). Through weekly collaborative prototyping sessions in AR, we expect to collect contextual feedback on the interface elements, interactions, and content required to drive development and achieve the vision of ARTEMIS.

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