2019 Military Heath System-Research Symposium (MHS-RS) Abstract

Augmented **R**eality **T**echnology to **E**nable re**M**ote **I**ntegrate **S**urgery (**ARTEMIS**): a review of technical considerations and study design.

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The "golden hour" immediately following a traumatic injury holds the highest likelihood where medical and surgical treatment may prevent mortality and morbidity to patients. In life-threatening non-traumatic injuries, timeliness of treatment has also been correlated with mortality for a wide range of conditions. The Military Health System (MHS) delivers care around the globe, often deploying its service members to remote environments with limited organic or host-nation medical support. Over the last 20 years of conflict in the Middle East, survivability has been maintained, in part, through the rapid transport of critically ill and injured patients to "Role 3" referral medical facilities within Iraq and Afghanistan. As the US military begins to plan for future conflict with peer/near-peer adversaries, we are confronted with dispersed engagements that will necessitate the prolonged field care of casualties. Instead of medical evacuation occurring within 60 minutes, patients may require field care for 48-72 hours before reaching a referral facility. This reality, where the needs of a patient outstrip the local and immediate resources can be referred to as an austere operating environment. Although austerity is commonly encountered by the MHS, it is not unique to military physicians and caregivers. Many patients in rural America may find themselves injured or ill far greater than 60 minutes from the closest tertiary-level medical facility. The increasing occurrence of both large-scale natural and man-made disasters may further overwhelm a local medical system such that patients find themselves without timely access to the necessary medical expertise. In order to address this capability gap, leaders in both the military and civilian medical care environments are exploring the application of telemedicine.

Most forms of telemedicine, also referred to as telehealth, attempt to connect patients to their care providers using synchronous audiovisual communication. Unfortunately, video-teleconference (VTC) or web-based real-time conferencing (WebRTC) have limited ability to enhance the procedural and surgical skills that are often required to care for trauma and critically ill patients. Augmented Reality (AR) technology allows the user to see through a display, while simultaneously inserting digital information into their field of view. Long-used within the aviation industry, this technology has only recently been introduced within the medical field. Explorations of medical AR to date, have largely taken the form of "show & tell" demonstrations. A foundation of modern medical practice, is the application of rigorous scientific method to inform clinical decision making and action. Unfortunately, a demonstration of medical AR is insufficient to evaluate whether the capability can augment human performance, and enhance patient care. For this reason, the **A**ugmented **R**eality **T**echnology to **E**nable re**M**ote **I**ntegrated **S**urgery (**ARTEMIS**) study was established.

ARTEMIS is a JPC 6.7-funded study that will evaluate the performance of novice medical personnel using a prospective randomized study design. Participants will be graded on performance of a series of standardized life-saving interventions involving reperfused cadavers.

In this presentation, we describe the technological components and design requirements to establishing a telementorship environment that is conducive towards high-quality mentorship and rapid translatable skills to enable novices to perform life-saving procedures such as tracheostomies, lung decompressions, or REBOA catheter deployment. The system involves a bidirectional communication link for streaming 3D-positioned video and audio from both remote (novice) and local (expert) users, 3D localization and tracking of users hands, head, and eyes, and 3D dynamic reconstruction of the environment to create a virtual scene for the expert to interact and demonstrate complex procedures. Finally, the total collection of technologies that include Augmented Reality (AR) headsets, hand and body trackers, 3D vision systems, etc. are achievable at reasonably low costs with off-the-shelf hardware. We have established this network via collaboration between the Navy Medical Center in San Diego and UC San Diego with the goal of developing an Augmented Reality Telementorship platform.

3D reconstruction is performed using remote 3D depth cameras that provide color and depth information to the user. Because of the typical narrow field of view of these cameras (in this case, Intel's RealSense), it is important to perform 3D fusion of the scene since a narrow viewpoint will not capture all the pertinent information in the scene. KinectFusion is used to fuse together multiple viewpoints from the streaming 3D depth data; the fused (and colored) point clouds are then presented to the expert on the VR headset so that they may annotate or interact with the dynamically reconstructed scene. Dynamic objects such as the patient or remote user's body or moving around of surgical instrumentation is captured intrinsically within the Kinect Fusion algorithm when previously captured point clouds are no longer present in their original location, resulting in a gradual decay and removal of those features from the scene. The Kinect Fusion algorithm runs at up to 60 frames-per-second with negligible latency. For larger scenes, a significant amount of data transfer would be required if point-cloud information was transferred bidirectionally for analysis and display. Thus, for future efforts, local point cloud rendering may be required such that only stereoscopic images pertinent to the local or remote users are transferred, thus limiting the amount of data transfer needed.

Dedicated visual aids support both the remote (novice) and local (expert) during the execution of complex remote interventions. We use spatial augmentation through AR visualizations using Microsoft HoloLens for the novice, and mixed AR/VR visualizations using HTC-Vive in video-see-through modality for the expert. We employed a human-centered design approach based on rapid and low-fidelity AR prototyping to first uncover and then implement the needed visual aids. By combining Leap-Motion hand/finger trackers with the VR headsets we enabled hand manipulations by the experts to be communicated to the novice and be represented in real-time within the field of view of the novice. The same Leap-Motion hand/finger tracker device on the novice side enables capturing how the novice approaches the procedure, and project hand and finger movements in real-time on top of the depth-camera-reconstructed patient body into the visual field of the expert. By using dedicated gestures, the expert can initiate a number of interactions with the remote novice, including 3D annotations through remote telestration, visualization of specific videos or photos to help with the current procedure, as well as projection of hands and body gestures to demonstrate particular maneuvers that the novices can mimic by just overlaying their hands on the remotely projected ones.

The developed ARTEMIS system will be validated using a randomized controlled trial involving complex combat casualty care. Our validation will allow us to test the wearable and ubiquitous computing technology we integrated to achieve this advanced form of telepresence, and evaluate critical decision making, timeliness and accuracy of surgical intervention. We expect the hyper-realistic ARTEMIS platform could be used in future training, and also to evaluate other virtual health tools in the provision of combat casualty care. We believe that the wearable AR-enabled platform that we developed as part of this research paves the way for next generation procedural tele-mentorship within our operational forces, thereby supporting the delivery of prolonged field care of casualties.