# AR Guidance for Trauma Surgery in Austere Environments

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Trauma injuries in austere environments, such as combat zones, developing countries, or rural settings, often require urgent and subspecialty surgical expertise that is not physically present. Surgical telementoring connects local generalist surgeons with remote expert mentors during a procedure to improve patient outcomes. However, traditional telementoring solutions rely on telestrators, which display a mentor's visual instructions onto a nearby monitor. This increases cognitive load for the local mentee surgeon who must shift focus from the operating field and mentally remap the viewed instructions onto the patient's body.
Our project, STAR (System for Telementoring with Augmented Reality), bridges this gap by taking advantage of augmented reality (AR), which enables in-context superimposed visual annotations directly onto the patient's body. Our interdisciplinary team, comprised of computer scientists, industrial engineers, trauma surgeons, and nursing educators, has investigated, prototyped, and validated several AR-based telementoring solutions. Our first approach delivers mentor annotations using a conventional tablet, which offers pixel-level alignment with the operating field, while our second approach instead uses an AR HMD, which offers additional portability, surgeon mobility, and stereo rendering.

**Figure 1.** Left: A mentee views the operating field of a patient simulator through our tablet-based AR system. Right: View of operating field with visual annotations (virtual hand) superimposed.

In our tablet-based AR telementoring system, the mentee surgeon views the operating field through a video see-through tablet suspended over the patient's body (Figure 1, left). Live video imagery from the tablet is transmitted to the mentor, who uses a touch-screen interaction table to author annotations in the form of lines, points, icons of surgical instruments, and prerecorded video footage. Annotations are transmitted back to the mentee site, where they appear directly in the mentee's field of view superimposed onto the operating field elements they describe (Figure 1, right). In a user study in which subjects performed an abdominal incision on a patient simulator under telementored guidance, such tablet-based telementoring led to increased accuracy and fewer focus shifts than conventional telestration.

**Figure 2.** Left: Our AR HMD-based telementoring system being worn by the mentee. Right: First-person view of mentor-authored annotations (virtual instruments) anchored to the operating field.

Our AR HMD-based telementoring system uses a Microsoft HoloLens worn by the mentee surgeon, through which a direct view of the operating field can be seen (Figure 2, left). Video of the operating field, either from a calibrated overhead camera at the mentee site, or from the HMD's on-board camera, is pose-stabilized and streamed to the mentor using WebRTC bandwidth-adaptive protocols. Mentor-generated annotations are rendered as 3D models of surgical instruments that are anchored to the patient’s body (Figure 2, right). In a user study, medical students performed fasciotomies on cadaver legs under remote guidance using our system. Participants using our system, when compared against a control group without telementoring, made fewer errors, scored higher on performance metrics by expert evaluators, and completed the procedure in less time.

Our team is researching additional methods of augmenting both mentor and mentee surgical abilities and communication, such as overlaying data from a hand-held ultrasound device in AR, integrating an autonomous drone to provide the mentor with additional views of the operating field, and offering an immersive VR-based interface for mentors to view and author annotations in full 3D.


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