Visualization of 3D patient-specific bone models using mixed reality.

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Rational

During image-guided surgeries (IGS), surgeons are required to integrate multi-modal imaging data from several sources while performing the intervention on the patient; this places a heavy cognitive load on the surgeon (Sielhorst et al., 2008). Figure 1 shows an observed operating room at the Groote Schuur hospital, South Africa, the surgical setup epitomizes the need for reducing the cognitive load surgeons experience during IGS.

The aim of this project is to develop a proof of concept mixed reality (MR) system to explore the reconstruction, tracking and visualization of 3D patient-specific image scans using extended reality (XR) technology specifically for surgery and broader clinical applications. For this project, a virtual view of a patient's CT scan will be used to visualise the patient's specific bone model via the MR system prototype. The technological modules required to reach this aim are as follows:

Figure 1: Image-guided surgery at Groote Schuur OR with IGS and with C-arm (2018). As shown by the arrows which point to electronic screens that display the image information used during surgery, surgeons are required to integrate multi-modal imaging data from several sources while performing the intervention on the patient.

Augmented reality (AR)

With augmented reality (AR) the user is not transported out of his/her real environment, but rather, through the use of a display or projection information is added to his/her view as a hologram. For medical visualizations using AR, the data source is a medical image in the digital imaging and communication in medicine (DICOM) standard, which can be obtained from MRI, CT or PET. Using an AR head mounted display (HMD) to display an in vivo 3D AR view of a patient's captured image modality during surgeries has been proven to reduce the cognitive load of the attending surgeons. The process of creating an AR view via the HMD is shown in Figure 2.

Figure 2: Hologram for AR view acquisition in FOV

Limb tracking

During IGS of the hand, the limb is often moved and manipulated requiring re-registration which increases surgical time (Sheehan et al., 2016). Developing limb tracking functionality to trail the hand with an infrared sensor can be used to automate this procedure and reducing surgical time. Tracking of larger limbs and joints can be extrapolated from developing this system. Tracking of the hand as shown in Figure 3 will also be relayed in real time to visualize the actual movement occurring in the patient's hand, this can be used to analyze post-operative review.

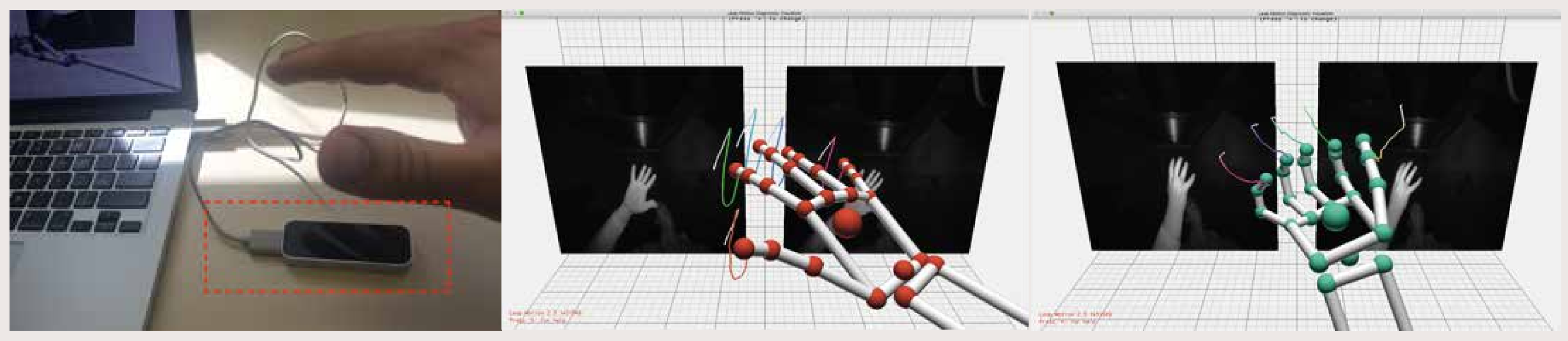


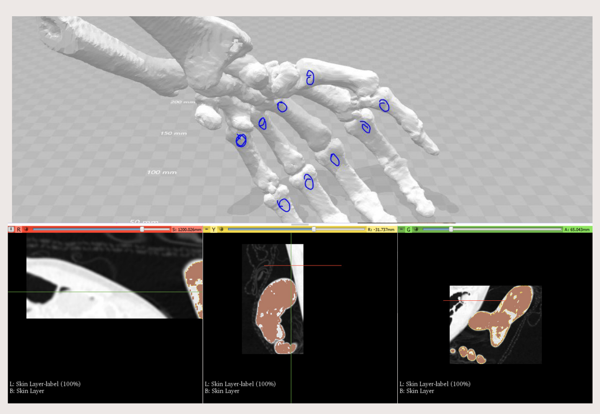
Figure 3: The Leap Motion is a tracking module specifically developed for tracking hand gestures

Mixed reality medical head mounted display system

Currently, AR medical systems only display static images limiting the functional understanding of anatomy such as joints. For a XR system to be classified as a MR system, both AR and augmented virtuality (AV) needs to be present. Augmented virtuality refers to when an object from the real space is digitized and represented as a virtual object via a display. Combining the view of hologram in the clinicians FOV via the AR HMD with the location data of the patient's hand from the limb tracking sensor to update the hologram creates a mixed reality experience. This creates in situ surgical guidance to further reduce cognitive load. Possible physiological understanding of the surgical site for pre-surgical planning and post-operative review can also be established.

Input 1: Medical image source

Captured 3D surface data segmented from medical modality converted into a hologram for AR view



Input 2: FOV of the clinician

The Microsoft HoloLens will be used to capture video footage of user's FOV for image processing.

Input 3: Patient's hand position in relation to FOV of the clinician

The HMD's coordinate position and orientation needs to be tracked in relation to the orientation of patients hand position and coordinate location to render the MR visualisation.

Mixed reality processing framework

The Leap Motion will be connected to a processing device, with the tracking data transfer being wireless to the Microsoft HoloLens to update the hologram. The MR processing framework needs to combine the coordinate information with the CT hologram at runtime via the rendering engine to create the juxtaposed view to render the MR visualisation.

Output: Juxtaposed CT scan

An in situ visualization of the patient-specific CT scan as a hologram in real time.

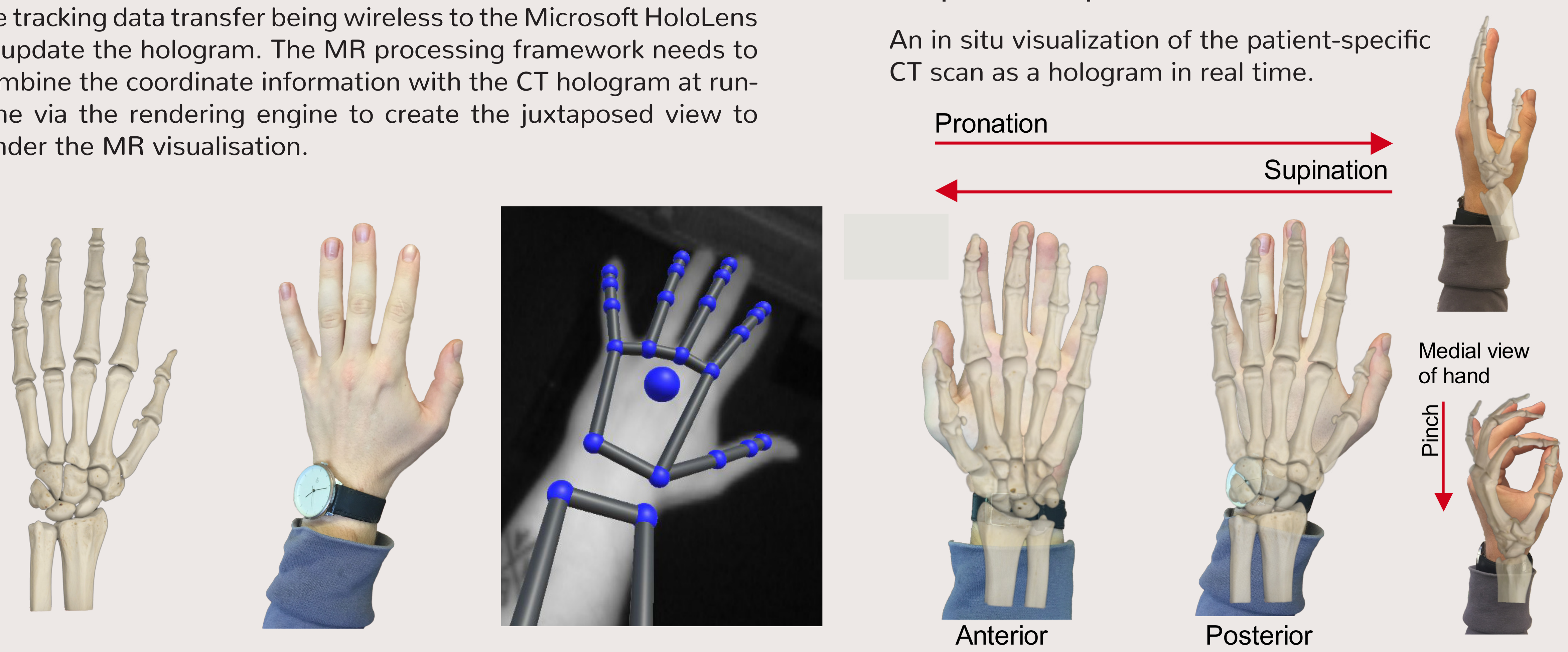


Figure 4: The process flow of the MR medical system to juxtapose the AR CT view of the patient's hand in situ in real time via the HMD.

References:
Sheehan, S. E., Wortman, J. R., & Dyer, G. S. M. (2016). Traumatic Finger Injuries : What the Orthopedic Surgeon Wants to. RadioGraphics, 36(4), 1106–1128. https://doi.org/10.1148/rg.2016150216
Sielhorst, T., Feuerstein, M., & Navab, N. (2008). Advanced medical displays: A literature review of augmented reality. IEEE/OSA Journal of Display Technology, 4(4), 451–467. https://doi.org/10.1109/JDT.2008.2001575