BEENG 526 – Final Report
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Mixed Reality Utilization in Anatomical Surgical Practice with HoloLens

Introduction

Microsoft HoloLens 2 is an ergonomic, untethered self-contained holographic device with enterprise-ready applications to increase user accuracy and output. The HoloLens is a mixed-reality (MR) head-mounted display (HMD). MR describes an environment in which real and virtual elements appear to coexist (Al Janabi, Aydin, Palaneer, Macchione, Al-Jabir, Khan, Dasgupta, & Ahmed 2020). The HoloLens has many uses which can be applied to manufacturing, engineering/construction, healthcare, and education.

Microsoft HoloLens 2
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The HoloLens has the ability to enhance the delivery of patient treatment. Microsoft gave the statics that HoloLens reduced training by 30% at an average saving of $63 per hour, reduced average annual PPE cost by 75%, and improved efficiency by 30% to complete ward rounds (*Microsoft HoloLens*). HMDs are becoming increasingly popular in healthcare, particularly in surgical intervention (Al Janabi et al., 2020).

Medicine is a rapidly evolving subject, and innovation is vital to the development of more effective mechanisms in treating and managing disease, delivering optimal healthcare, and assisting medical professionals with executing tasks. For this project, I am utilizing Unity and HoloLens. Unity is a 3D/2D game engine and powerful cross-platform IDE for developers. As a game engine, Unity is able to provide many of the most important built-in features that make a game work. That means things like physics, 3D rendering, and collision detection. Microsoft HoloLens are a pair of mixed reality smart glasses developed and manufactured by Microsoft. HoloLens was the first head-mounted display running the Windows Mixed Reality platform. Mixed reality is an extension of augmented reality that allows real and virtual elements to interact in an environment. This is an already existing project which I have jumped on with Dr, Li from INOVA. So far, I have gathered resources and articles which develop on the idea of simulated surgeries and their effectiveness as practice. I've gone through the process of learning the necessary software's (Unity, MS Visual, MS HoloLens) to go forward with the project. Working on incorporating Space Anchoring to the software which ultimately will allow other users to view the same holograms in the same environment. Was able to receive a collection of CT scans which will then be incorporated to the software for viewing and manipulation as a 3D rendering. Other abilities we are trying to implement are cutting and visual flexibility (viewing things behind holograms). Effectiveness is defined as non-inferior performance-related outcomes, if not superior to the outcomes with a conventional monitor.

A spatial anchor represents an important point in the environment. Each anchor has an adjustable coordinate system based on other anchors of frames of reference. The spatial anchors were used using Azure. Spatial anchors were created and acquired unique resource names and specific key IDs (*Spatial anchors*, *2022*). These were implanted into the Unity project and applied to the holograms. This allows for multiple users to be able to manipulate the holograms and have other users be able to visualize changes made. Specific packages were needed as well in order to incorporate the necessary assets and options.

During surgical procedures, trocars (used to make small, puncture like incisions in outer tissue layers) may be necessary. Most systems that provide visual assistance to trocar placement are complex and expensive. They are usually based either on robotics or magnetic tracking and allow to track a precise positioning of surgical instruments and to provide an augmented visualization on a screen inside the operating room. Few operating rooms own this type of hardware and most surgeons place and insert trocars without visual assistance (Lohou, Miguel, & Azarnoush 2019). A concern of a few papers was the feasibility of introducing HoloLens in a clinical setting, however this is shown to be feasible, and HoloLens has the ability to display radiographic imaging and the endoscopic view simultaneously, and to explore the logistical factors of wearing the HoloLens during surgery (Al Janabi et al., 2020).

Methodology

Currently, there exists a problem within minimally invasive surgery, namely that surgeons often operate on patients with a misalignment between their line of vision and have placement due to monitor positions (Al Janabi et al., 2020). Studies have shown that a disrupted visual-motor axis during surgery can lead to additional problems including declined ergonomics and surgical performance, spatial disorientation, and increased risk of iatrogenic injuries. We have developed a set program which can be used by a HoloLens and visualize certain organs. HoloLens uses several different sensors. The headset is a self-contained computer with Wi-Fi connectivity. The HoloLens has a semi-transparent visor where 3D objects, or holograms are projected. The visible holograms are superimposed on the user's environment through the visor. The user can then interact and manipulate these holograms by recognized gestures. For example: pinching an object to select it and be able to move it or showing an open palm to pull up a menu.

The smart headset can scan the user's environment and holograms can interact with it. Available software libraries like MixedRealityToolkit-Unity (MRTK) allows developers to design interactive 3D graphic applications that can be deployed in this type of hardware.
3D objects must be modeled with a 3D modeler software then it must be imported into Unity and arranged in the 3D scene. Interactions can then be encoded through C# scripts in Visual Studio (Lohou, Miguel, & Azarnoush 2019). The general steps a surgeon must perform to design specified digital content include (1) to segment part of body or organ, (2) to import the torso mesh into a Blender software and to decimate the torso mesh which allows for reduced data volume to be projected on the visor's headset, (3) import object of interest in Unity application, and (4) deploy the application to the HoloLens headset.

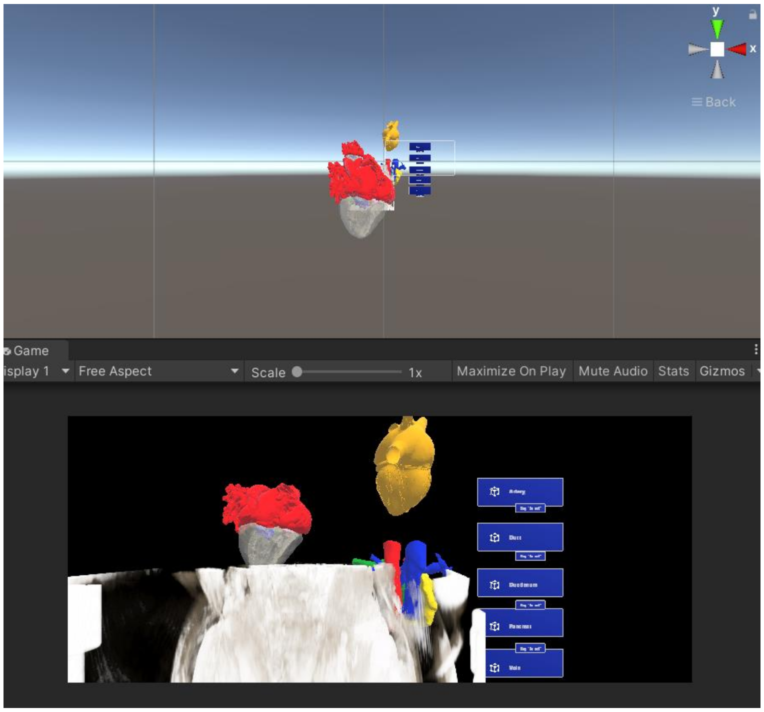

Figure 1. Unity interface of Holograms which can be better view with HoloLens.

A view of the holograms through the visor of the HoloLens proved a challenge its self. Figure 1 shows multiple holograms of organs in the UI on Unity 3D. The menu blocks can be seen which are hidden when visualizing organs. Voice recognition is also apart of the software. Using key words, specific organs can appear and disappear. Three heart models are included and a vascular portion as well.

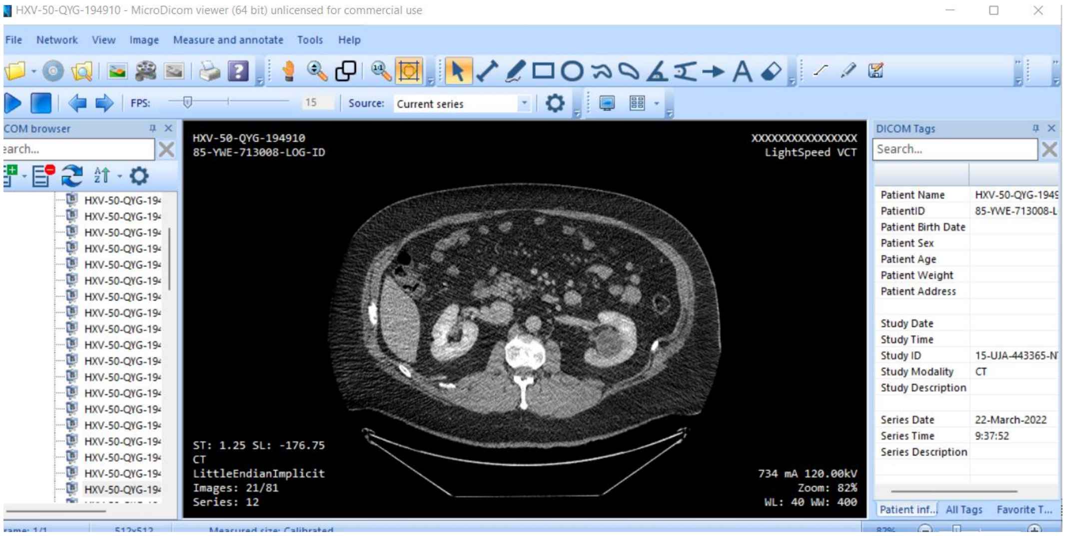

Figure 2. Viewing of CT slice

Figure 2 is demonstrating a slice of a CT scan which can be used in making 3D models for the software. When booting up the HoloLens, a menu appears which several options can be taken. To initiate the program, the file needs to be uploaded into it. When selecting the proper program, the organ holograms can be seen and manipulated off the get go. A separate side menu is included as well to add more accessibility to showing certain holograms or not. Implementation of Space Anchoring into software was conducted to allow multi-user accessibility to the software.

Discussion

A study with a 80-year-old patient with advanced arthritis of the shoulder combined with rupture of the tendons covering the joint, motivating the implantation of a shoulder prosthesis underwent a procedure with a HoloLens (Gregory, Gregory, Sledge, Allard, & Mir, 2018). A standard reverse shoulder arthroplasty was performed. This is where damaged aeras of bone are removed and replaced with parts of metal and plastic. The challenge in this surgery was the limited bone stock. There was no calibration between HoloLens and the navigation system, as the HoloLens has the capacity to drag the holograms manually. A holographic 3D reconstruction of the scapula was positions in a way that the visible part of the bone matched the corresponding part of the hologram. The surgeon was able to access the patient’s medical data combined with the data of the operative technique, which were sent to the headset in real time during the procedure. This allowed the surgeon to compare what was being done and what needed to be done. In this situation, the total duration of surgery was similar to the average duration of this kind of procedure. A better understanding of the patient’s anatomy was allowed by the use of the headset contributed to saved time (Gregory et al., 2018). CT imaging showed adequate position of the prosthesis and the patient experienced no complication. Compared to a traditional surgical procedure, the use of HoloLens could provide an improvement in results for both surgeon and patient, without reducing the safety factors. The 3D holograms showed critical organs and provided an increase in accuracy and safety in the procedure.

In Al Janabi et al. study, 72 participants were recruited, of which included novice medical students, urological trainees, and specialists. All participants were then organized into different expertise levels based on the number of procedures previously performed. All participants were eligible for inclusion if they were a medical student, urological trainee, or a specialist. All participants were taught how to use the HoloLens with its main gestures and allowed a practice session. In training and assessment sessions, real operative equipment was used in order to simulate the realism and applicability of the training. The HoloLens were calibrated to each participant in the beginning of sessions to provide optimal view and ensuring standardization between all participants. Categories which were scored include respect for tissue, time and motion, instrument handling, handling of the endoscope, flow of the procedure, use of assistants, and knowledge of the procedure (Al Janabi, et al 2020). The participants were asked to describe any symptoms they experimented during usage of the HoloLens and rated the severity from 0 to 3, representing “no symptoms” to “severe symptoms”, respectively. The procedural times were compared between the HoloLens and conventional monitor. Procedural times were shorter on average with the HoloLens compared to a conventional monitor. Objective Structured Assessment of Technical Skills (OSATS) scores were taken and similarly, participants scored higher on average using the HoloLens compared to a conventional monitor. From surveys give to the participants, 95% agreed or strongly agreed that the HoloLens will have a surgical practice and is feasible to be introduced into the clinical settings. 97% of participants agreed of strongly agreed that the HoloLens will have a role in surgical education. When the participants were asked about the usefulness of the CT images provided in the HoloLens during the procedure, 77% of participants agreed or strongly agreed that it was a useful feature. Feedback they received regarded image quality, image lag, multitasking ability, comfort, sterility, practicality, and spatial awareness. 90% of participants did not experience any symptoms, however those who did described it to be a mild severity. Frequent complaints reported were eye fatigue, neck stain, headaches and nausea (16%, 15%, 5%, 3% respectively). No moderate or severe symptoms were experienced while using the HoloLens (Al Janabi, et al 2020).

Effective OR setup remains a challenge in minimally invasive surgery. Evidence from ergonomic studies suggest placement of endoscopic monitor in alignment with surgeon’s forearm is more effective in terms of performance, comfort, and safety. The guidelines for the optimal ergonomics state that the monitor be placed directly in front of the surgeon at a 15 degree angle in horizontal plane and approximately 15 degrees downward in the sagittal plane (Al Janabi, et al 2020). According to an international questionnaire survey conducted to 282 surgeons found that 74% of surgeons reported neck discomfort due to a bad monitor position. 88% agreed that they experience muscle fatigue due to the static posture.

Limitations that surfaced were focused on heterogeneity in settings and training. The variability in the equipment utilized may also be a factor with the more advanced systems and monitors providing a better resolution. Limitation in regard to operating the HoloLens are as followed. The HoloLens has a restricted projection size and field of view. This impacts the immersive experience. When turning your head a direction, the borders of the screen may cut off and limits the number of screens that be can be supported simultaneously. Some participants in

Al Janabi et al's study had difficulty utilizing the head strap and visor adjustments effectively (Al Janabi, et al 2020). This is what may have contributed to the reported rates of neck strain.

Future Works

A large number of surgical techniques have developed to become minimally invasive surgical techniques (MIS). These techniques lead to faster recovery and shorter hospitalizations. In cases where the surgeon has no direct vision of the organs they have to handle, visual assistance is available with HoloLens (Lohou, Miguel, & Azarnoush 2019). Lohou and Azarnoush have studied a way which is feasible to assist cardiac surgeons to position trocar and it is difficult to evaluate any positions or orientation accuracy. It remains difficult to perform a precise interactive placement of the trocar (Lohou, Miguel, & Azarnoush 2019). The HoloLens offers a far more immersive technology compared to previous head-mounted display and it may address the issues of hindered non-technical skills, registration difficulties, portability sterility, and several other factors. The HoloLens enables users to visualize multiple holograms at once which allow integration of other important medical information. Studies using other smart headsets have been described suffering significant limitations due to the restricted technology of those devices utilized, including loss of spatial awareness, frequency spatial disorientation, extensive cabling, poor battery life and device discomfort (Al Janabi et al., 2020).

In continuing this project, another goal is to increase the number of possible users in one session. This would allow for a more collaborative procedure and would allow other members visualize holograms and the movements the surgeon is making. The HoloLens may propose further symptomatic problems in longer procedures. Methods need to be put into place to reduce this limiting factor. This could be impacted by having future editions be made lighter and good battery life to facilitate lengthier and more complex procedures. The promise of AR usage in medical procedures is very impactful. It allows the surgeon to gain access to computer-based solutions in real time during procedures while remaining totally sterile, to gain access to 3D holograms related to the patient imaging or the surgical technique, and to remotely interact with colleagues located elsewhere.

Works Cited

Al Janabi, H. F., Aydin, A., Palaneer, S., Macchione, N., Al-Jabir, A., Khan, M. S., Dasgupta, P., & Ahmed, K. (2020). Effectiveness of the HoloLens mixed-reality headset in minimally invasive surgery: A simulation-based feasibility study. *Surgical Endoscopy*, *34*(3), 1143–1149. https://doi.org/10.1007/s00464-019-06862-3

Gregory, T. M., Gregory, J., Sledge, J., Allard, R., & Mir, O. (2018). Surgery guided by mixed reality: Presentation of a proof of concept. *Acta Orthopaedica*, *89*(5), 480–483. https://doi.org/10.1080/17453674.2018.1506974

Lohou, C., Miguel, B., & Azarnoush, K. (2019). Preliminary Experiment of the Interactive Registration of a Trocar for Thoracoscopy with HoloLens Headset. In E. Ricci, S. Rota Bulò, C. Snoek, O. Lanz, S. Messelodi, & N. Sebe (Eds.), *Image Analysis and Processing – ICIAP 2019* (pp. 694–703). Springer International Publishing. https://doi.org/10.1007/978-3-030-30645-8_63

Microsoft HoloLens | Mixed Reality Technology for Business. (n.d.). Retrieved April 20, 2022, from https://www.microsoft.com/en-us/hololens

Sun, Q., Mai, Y., Yang, R., Ji, T., Jiang, X., & Chen, X. (2020). Fast and accurate online calibration of optical see-through head-mounted display for AR-based surgical navigation using Microsoft HoloLens. *International Journal of Computer Assisted Radiology and Surgery*, *15*(11), 1907–1919. https://doi.org/10.1007/s11548-020-02246-4

thetuvix. (2022). *Spatial anchors—Mixed Reality*. Retrieved May 3, 2022, from https://docs.microsoft.com/en-us/windows/mixed-reality/design/spatial-anchors

Zuo, Y., Jiang, T., Dou, J., Yu, D., Ndaro, Z. N., Du, Y., Li, Q., Wang, S., & Huang, G. (2020). A Novel Evaluation Model for a Mixed-Reality Surgical Navigation System: Where Microsoft HoloLens Meets the Operating Room. *Surgical Innovation*, *27*(2), 193–202. https://doi.org/10.1177/1553350619893236