CSE 535: Group 46
Augmented Reality & AI for Surgeries

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ABSTRACT

The advanced development in the technology of Augmented Reality (AR) [6] and Artificial Intelligence (AI) is gradually changing the practice of surgery. Combination of AR and AI algorithms can be used to virtually map a procedure for surgery. Here we propose a new structure for the training of the AR device and maintain the patients' sensitive data protected. Federated Learning[5] can be used to protect patients' sensitive data and train the AR model based on past surgeries and procedures. In our approach we are tackling the problems in healthcare informatics and surgical procedures using AI and Federated Learning with Augmented Reality.

KEYWORDS: Augmented Reality, Federated Learning, Surgery.

INTRODUCTION

With the increase in medical complexity, surgeons have to constantly look at the patient's CT scan or MRI on a monitor, which can be distracting. Thus, there is a need for technology that can provide the patient's details and assist the surgeons at the time of surgery. A lot of problems can be solved if we build an AR aide for the surgeon. The development of AR devices allows surgeons to incorporate data visualization into diagnostic and treatment procedures to increase and improve accuracy, work efficiency, safety, and enhance surgical training. This paper reviews the existing solutions and pitfalls of AR devices being used in surgeries and proposes a novel methodology to solve them.

EXISTING SOLUTIONS

AccuVein [9]**:** It's a device similar to a projector and displays a vasculature map on the skin to show the location of veins in the patients' bodies.

Google Glass is a head-mounted display(HMD) [10]. Google Glass [11] has a lightweight wearable superimposed viewing screen with an attached video camera with a high resolution, and similar features to a smartphone-like wireless and cloud accessibility [1]. Since it was an open-source platform, many surgical applications and AR devices for surgical enhancements have been developed [2].

Microsoft HoloLens is another AR-based HMD that includes a CPU, GPU, and holographic processing allowing real-time spatial mapping and processing. It enables users to interact with the environment using holograms while stimulating the senses [3] improving the overall accuracy of the surgery. An MR system for medical use was proposed by Chien et al. [4]. It combined an Intel RealSense sensor and the Microsoft HoloLens HMD system that can superimpose the medical data above the patient's physical-surface. AR will have an indispensable role in image-based augmentation of the surgical environment. It will require powerful microcomputers to drive AR and better power capacity to run the device for long hours, which is currently confined but will improve with time. Another major drawback of AR based applications is health data privacy, which is still a major hurdle due to health compliance policies.

PROPOSED SOLUTION

We have proposed a solution wherein the surgeon wears a Head-Mounted Device (HMD) which works on Augmented Reality for surgeries. The HMD will use Artificial Intelligence (AI) to guide the surgeon throughout the surgical process. It will also be capable enough to answer the questions asked by the surgeon. The proposed methodology will significantly increase efficiency, help reduce errors, and save time as the surgeon does not have to be constantly looking at various parameters, values, the operating area, and know the procedure simultaneously.

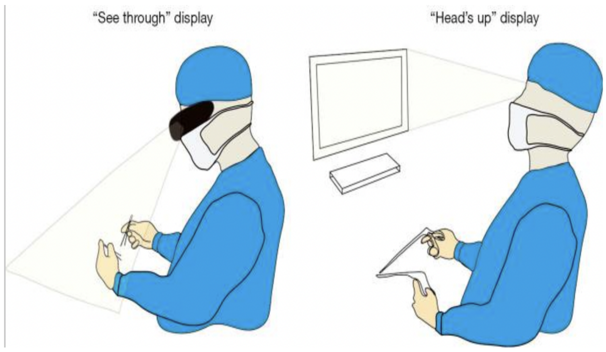

Fig 1: Describes the difference between "see through" display and "Heads up" display

Basic Structure: The input to our system would be the healthcare data of the patient, his medical history, the ground truth methodology of certain surgical procedures, the real time health information monitoring calculators. Although there will be a trained model which will be global and cloud based, the input data required for the operation will be communicated locally using IoT and will not be persisted on cloud or global data centers. The AR will work in the collaborative way and will have the following components:

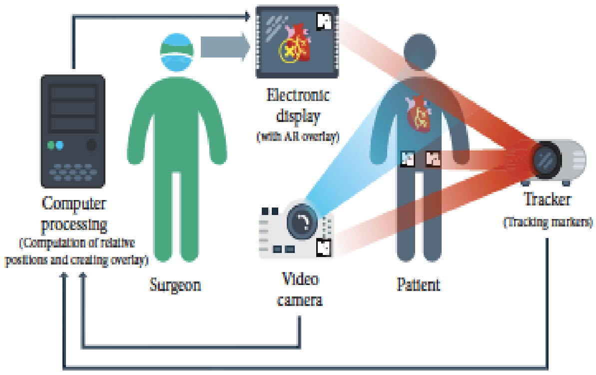

Fig 2: Structure of an AR system

Surrounding data: The surgeon will be able to see the patient's real time heart rate, respiratory rate, ECG graph and more in the same sight as that of the patient's operating area. All the devices will be connected and thus the surgeon will have the liberty to see anything that is needful. For example, his previous CT scans, medical records will be digitally available in his vision at the time of the procedure.

3D Surgical data: We will have the AR model trained on surgeries which will help surgeons with the computation and visualization of organs, the exact measures of various procedures, 3D view of organs etc. For instance, for a surgery which involves fitting screws in a bone, the exact length/width of the screw as well as bone measurements can be seen which will help the surgeon operate seamlessly. A lot of progress has been made in the field of image registration and video tracking that allows real time video feed to track objects in the area that suit the orientation and scale of the device to give accurate superimposition. It can be used as an application in surgical AR systems and will revolutionize the way surgeries are carried out by significantly reducing the operation time and consequently errors.

Fig 3: Example of 3D surgical Data

Surgical AI: We propose to have an AI system inside the AR goggles that will be trained on the surgical procedures that will help the surgeon wearing it, in the surgeries. It can suggest different approaches, help the surgeon with a complex task and even predict the probability of a certain task going wrong. The reason why this AI can be very powerful is because it will have access to the live procedure, previous procedures, all medical records and history, patient's live health data along with continuous training based on the success or failure of a surgical procedure. A machine learning model can be trained with a lot of feature inputs which a human can not analyse at the same time. Thus we want to leverage this to provide help to the surgeon with the surgeries taking place everywhere. This AI will be a centralized system which can help corroborate different surgical methods to the surgeons as the model would be trained on prior surgeries carried out by other surgeons too. We cannot fully depend on an AI, thus we would not let the AI take the decision but it will help the surgeon make certain decisions based on the trained model. This will not only revolutionize surgeries, improve the efficiency but also give time for more innovation in the domain of surgeries.

Fig 4: Example of Surgical AI

Data Privacy: Reviewing, Storing or transferring patient data still continues to be an issue with Ethical and legal obligations. Data Encryption techniques improve data privacy, and do not guarantee protection from data hijacking attacks [12,13]. The system that is developed needs to abide by the rules of healthcare information governance[14]. To tackle this issue, we propose the use of Federated Learning. It is a machine learning technique which trains an algorithm across multiple decentralized edge devices or servers holding local data samples, without exchanging them. It allows mobile infrastructure to collaboratively learn a shared prediction model and keeps all the training data on device, decoupling the ability to do machine learning from the need to store the data in the cloud. This is very useful for the sensitive healthcare and surgical data which we want to use to train our model for making the Surgical AI aware of the patient's history, his condition and how a surgical operation suits him. This sensitive data would not be shared and at the same time one global Surgical AI would get trained on all the operations giving it full knowledge and mapping of which surgical nuances are better for patients with certain conditions. This way the patient's data is not mapped with the patient but it is mapped with the kind of surgical strategy that best works for the inputs similar to the patients conditions. The Feature inputs for this model are enormous and thus a CNN with a systematic way of training would be required.

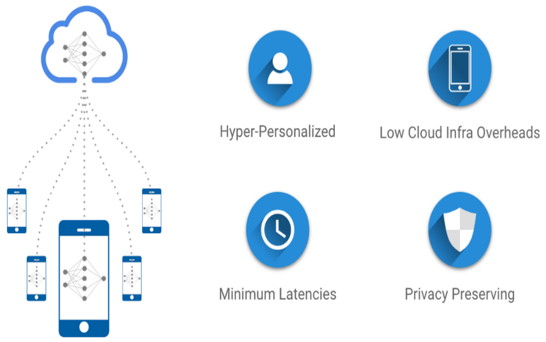

Fig 5: Federated Learning Model

HOW IS AR RELATED TO MOBILE COMPUTING: The AR device (Head-Mounted Device) and different machinery required for real time monitoring of the patient's condition, patient's medical history etc required for surgeries are all connected and there is information synchronization such that all the information can be seen in the HMD. This will enable IoT which will connect all the devices locally and will involve Edge computing. This is a classic example of mobile computing where most of the data is present locally on devices and local data centers. The global AI model being used in the system will have to be stored on cloud so that it can be used by everyone. This will enable surgeons from all over the world to operate on patients with health conditions already seen by the AR model.

CONCLUSION

In conclusion, we proposed a method which uses AR during surgery which would allow surgeons to make better decisions during the surgical procedures, thus increasing surgery efficiency and patient safety. Overall, HMD with AR will have great potential in the field of surgery as it has features that offers surgeons visually vivid and easily comprehensible images in the operating field that can assist with the surgery

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