

Mixed Reality Surgical Team Training: Background Reading

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Selected Papers information:

Paper 1:

Title: An Interactive Mixed Reality Platform for Bedside Surgical Procedures

Author: Ehsan Azimi, Zhiyuan Niu, Maia Stiber, Nicholas Greene, Ruby Liu, Camilo Molina, Judy Huang, Chien-Ming Huang, and Peter Kazanzides

Conference and year: MICCAI 2020

Reason for selecting and connection to project:

This paper is a great example of how mixed reality can improve the result of surgical procedures. The paper was written by SMART lab which happens to be the lab where the mentor of this project runs. The successful result of this paper has a great impact on the idea of a mixed reality training simulator. Not only that, the technical detail including registration and computer vision-based tools localization provided some ideas of my current project which also includes the registration between the different objects.

Paper 2:

Title: ARAMIS: Augmented Reality Assistance for Minimally Invasive Surgery Using a Head-Mounted Display

Author: Long Qian, Xiran Zhang, Anton Deguet, and Peter Kazanzides

Conference and year: MICCAI 2019

Connection to current project:

This paper also provided some initial ideas for my current project. The paper was written by SMART lab as well. This paper mainly influences me on how to do the point matching task and localizing the endoscopic tips is also necessary for my project as well. What I am doing is some of the "future work" mentioned in this paper.

Technical summary of papers:

Paper 1:

This paper focused on using mixed reality technic to guide the surgical team to let the surgical tool reach the internal anatomy targets. Paper used ventriculostomy as the experiment procedure and perform a controlled experiment over a simulator to prove the effectiveness of mixed reality technic used in the procedure.

System mentioned in the paper contains following necessary components: tracking, image segmentation, registration, guidance, and visualization.

Tracking refers to tracking the position and pose of the patient and the position and pose of the hand-held tool. The researcher used tags screwed into the skull to track the position of the patient and another tag mounted on the tool to track the position of the tools. Researchers used Vuforia Engine to track the tags.

Image segmentation refers to scanning, segmenting, and reconstructing the 3d model of the subject of interest. Researchers segmented the CT scanned the patient using the connected threshold filter from SimpleITK (www.simpleitk.org) for the ventricles and segmented the skull using 3D Slicer (www.slicer.org).

Registration refers to registration between the medical image data and the actual patient's anatomy. Fiducials were affixed on the skull prior to the CT scan and their position was identified by using a 3d slicer. The surgeon then selects the corresponding points on the patient's skull by touching the fiducials using the tracked tool. The paired point registration method that was mentioned in the paper which was used to register the CT scan and anatomy was not covered in detail.

User interface was designed in unity engine to support the whole procedure of the experiment.

Surgeon can verify the accuracy of mixed reality positions by visually seeing the distance between the tip marker rendered in the HoloLens and the actual tips of the tools. Similarly, the surgeon can register and verified the accuracy of mixed reality position by showing the skull and visually verifying the result between skull and the model in HoloLens.

Next, surgeon can overlay a virtual circle at the nominal position of the burr hole, then a guideline between the hole and the target area will display.

The experiment mentioned in the papers contains a skull phantom filling with gel that mimics the feeling of brain tissue during inserting tools and additional three spheres as targets. One of them representing the normal position of Foramen of Monro, and the other two represent the abnormal position of anatomy structure. Researchers performed a CT scan for the phantom and used the previously mentioned method to register the model.

A computer vision-based measurement system was built inside the phantom as well to measure the performance of participants in the experiment.

Totally 10 volunteers participated in the experiment. After basic training, every volunteer was asked to perform inserting tools into each of the three targets with and without an MR environment. Researchers then analysis the difference of performance between with and without MR environment. Result shown that MR environment will increase almost 40% of accuracy during the tool inserting procedure.

Paper 2:

The paper proposes ARAMIS, a solution to provide a real-time rendering of a patient's internal structure to the surgeon, via an optical see-through head-mounted display (OST-HMD), in minimally invasive laparoscopic surgery.

System mentioned in the paper contains a stereo camera, in this case, it is the stereo camera equipped on Da Vinci robot. The stereo image was output into a workstation with an NVIDIA Titan GPU to do a GPU-accelerate semi-global point matching and point cloud location calculation.

The first stage of the system operation is to obtain the stereo image captured from the binocular endoscope mount on the Da Vinci robot.

The second stage of the system would rectify, grayscale, and smooth the image.

The third stage of the system would be performed semi-global point matching in the 1d direction. Because stereo camera mounted on the Da Vinci robot was aligned horizontally, using the constrain from Epipolar Geometry. The system can make sure pixel only can be matched with another pixel on the other image with same pixel height. Researcher used traditional semi-global matching technic including maximum disparity limitation with a pre-computing bias for limiting the searching, census transform to calculate the similarity of two pixel, and finally a global aggregation to punish the multi to one matching pixel result. Finally, a sub-pixel refinement was applied. The point cloud on the edge was dropped due to unstable and noisy.

The fourth stage of the system would be calculating the point cloud data using the triangulation method. The researcher used disparity of a reference depth plane instead of directly storing the depth data to decrease the usage of ram.

The fifth stage of the system would be located the location of the binocular endoscope relatively to the OST-HMD Microsoft HoloLens. The researcher used two ways to achieve that. One is mounting an AR tag on the endoscope. By calculating the SE(3) between AR tag and endoscopic tip and SE(3) between AR tag and HoloLens, then the relative position is given. The second way to do this is to find the relative position between

the HoloLens and world frame, then find the relative position between the world frame and endoscopic tools by forwarding kinematic given by the robot.

Apart from the localization of the endoscope tip, a display calibration procedure is also required for correctly display the point cloud.

Researchers test the accuracy of the system; the result is an angular error of 0.53 degrees with a standard deviation of 0.15 degrees. When the distance between endoscopic tips and tools of 0.5m, the distance error between the displayed image and the actual object is 4.6mm. Those errors correspond to the error between the actual object and the displayed image, which is an end-to-end error.

Researchers test the latency of the system; the result is average latency is 256.7+-30.8ms for relatively high fidelity 1080×680 images. With 223.0 ± 24.7 ms latency and 26.16 Hz update rate when the point count is 648×408 . With 178.3 ± 21.0 ms latency and 36.98 Hz when 540×340 points. With 158.7 ± 19.0 ms latency and 41.27 Hz when 432×272 points.

The researcher also performed a Preliminary User Study. With 25 volunteers participating in the experiment and 150 trails, there was no significant difference between the finish time of the traditional endoscopic setup and ARAMIS. However, volunteer reported the Subjective ratings of ARAMIS is better than traditional setup.

Analysis of the selected papers:

Paper 1:

Overview:

This paper used ventriculostomy as an example to show the effectiveness of mixed reality. The team focused on using mixed reality technic to guide the surgical team to let the surgical tool reach the internal anatomy targets and perform a controlled experiment.

Pros:

The experiment setup is very detailed, and the way system design is clearly aimed at clinical usage, so it is a practical experiment. Provided a great foundation for future development such as animal model trail and so on. The accuracy of the system is also very great for most clinical usage.

Cons:

The technical details of the registration of the skull are missing. Only 10 volunteers (one real surgeon) were participated in the experiments, if more volunteers, maybe more real surgeons, can participate in the experiment, then the result will be more convincing. Ventriculostomy is proven that MR can vastly improve the result, but if the research team

wants to push the boundary of application, maybe the team need to design more experiments related to other procedures.

Paper 2:

Overview:

In this paper, the researcher proposes and implements an AR guide surgical method to achieve “x-ray vision” in laparoscopic surgery. Result shown that AR technology will subjectively improve the user experience and provided better depth viewing.

Pros:

The way researcher does point cloud matching is very clever and obtained very great results. And the way researchers thinking not limited the position of surgeon is very thoughtful. Accuracy data and latency data is very detailed and provided great reference for future study.

Cons:

The result was not very significant compared to the traditional setup. One of the methods of obtaining endoscopic tips location is limited to the Da Vinci robot which limited the application of this new technology to some specific hospitals.

Reference

Azimi, E. *et al.* (2020). An Interactive Mixed Reality Platform for Bedside Surgical Procedures. In: *, et al.* Medical Image Computing and Computer Assisted Intervention – MICCAI 2020. MICCAI 2020. Lecture Notes in Computer Science(), vol 12263. Springer, Cham.

Qian, Long *et al.* “ARAMIS: Augmented Reality Assistance for Minimally Invasive Surgery Using a Head-Mounted Display.” MICCAI (2019).