Mixed Reality Surgical Team Training:
Background Reading

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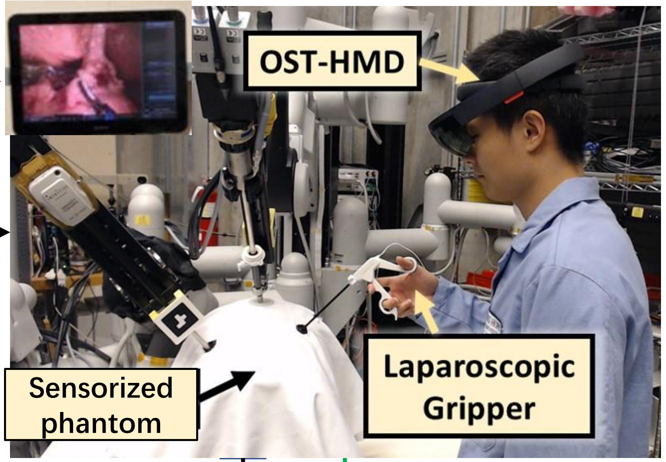
Project Review:

2D video



HMD optional (could deliver training info)

Sensorized phantom provides 3D point clouds of inserted instruments

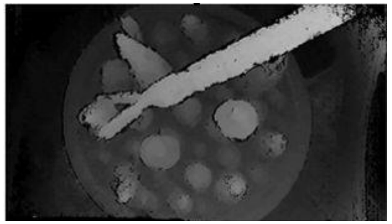
Endoscope video (of instruments)

Point clouds of hand-held (and robotic) instruments from sensorized phantom

3D endoscope video (simulated patient, real instruments)

Simulator

Anatomy is simulated, instruments are real.
Realistic physical interaction with system (except for direct interaction with anatomy)



Unmodified da Vinci data

Simulator video output

Sensorized phantom output

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

Information:

Author: Long Qian, Xiran Zhang, Anton Deguet, and Peter Kazanzides
Present on MICCAI 2019

Summary:

Researchers 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.

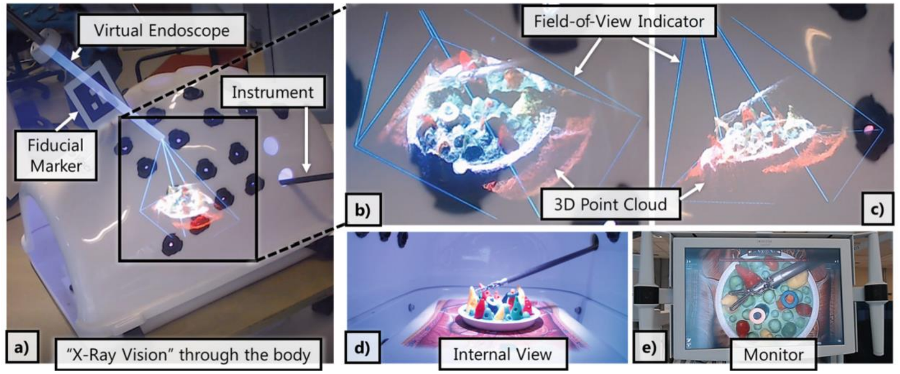


Fig. 1. (a) The "x-ray vision" provided by *ARAMIS*, captured using a camera behind HoloLens. (b, c) Closer views of the 3D point cloud overlay. (d) An alternative view inside the body phantom. (e) Traditional monitor for laparoscopy.

Connection to the project:

Provided initial ideas for the current project.
The paper inspired me on how to do the point matching task.
What I am doing is some of the "future work" mentioned in this paper.

Technical Approach

1. Rendering the point cloud

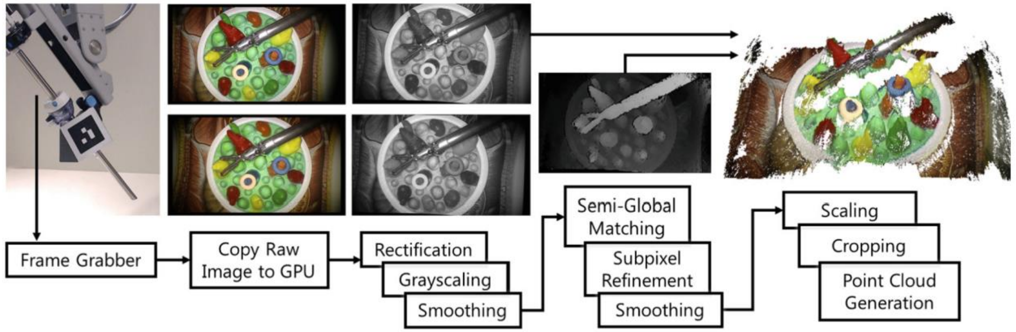


Fig. 2. Image processing pipeline in *ARAMIS* to generate real-time point cloud

2. Located the position of hololens

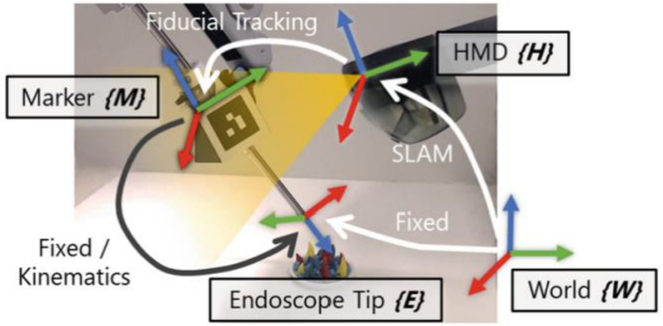


Fig. 4. The transformation between each component in *ARAMIS*, ${}^{H}T_{E}$ is necessary for real-time point cloud rendering

Result

System Accuracy:
Angular error: 0.53° (SD: 0.15°)
Distance error: 4.6mm when 0.5m between endoscopic tips and tools.

System Latency:
256.7 ± 30.8 ms /10.91 FPS @1080×680p.
223.0 ± 24.7 ms /26.16 FPS @648 × 408p.
178.3 ± 21.0 ms /36.98 FPS @540 × 340p.
158.7 ± 19.0 ms /41.27 FPS @432 × 272p.

User Study:
Peg transfer with traditional laparoscopic setup (LAP) and ARAMIS.
25 subjects × 3 ports × 2 setups=150trails. 3 failed trails.
Avg Finish time: No statistical significance difference
22.02 ± 18.06 s @ LAP.
20.08 ± 15.02 s @ ARAMIS.
Subjective ratings: significantly prefer ARAMIS
2.0 @ LAP
4.2 @ ARAMIS

Assessment

Pro:
Point cloud matching is very clever and obtained very great results. (Take away)

The real-time performance of the system is good.

Accuracy data and latency data is very detailed and provided a 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.

An Interactive Mixed Reality Platform for Bedside Surgical Procedures

Information:
Author: Ehsan Azimi, Zhiyuan Niu, Maia Stiber, Nicholas Greene, Ruby Liu, Camilo Molina, Judy Huang, Chien-Ming Huang, and Peter Kazanzides
Present on MICCAI 2020

Summary:

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.

Connection to the project:
This paper is an example of mixed reality improving the result of surgery. The registration and computer vision-based tools localization technical details provided some ideas for current project.

Fig. 1. Left: User wearing HMD and holding tracked pointer to perform registration. Right: Updated skull phantom (new fiducials, reference frame attachment and borescope cameras for measurement).

Technical Approach

1. **Tracking**: Using tags screwed into the skull and attached on the tools.

2. **Image segmentation**: Segmentate the CT scan to obtain 3d model of patient's ventricle and skull.

3. **Registration**: Fix fiducials before scanning and using the fiducials point as reference point.

4. **User Interface**: Using unity engine to design and support the figure 2 workflow.

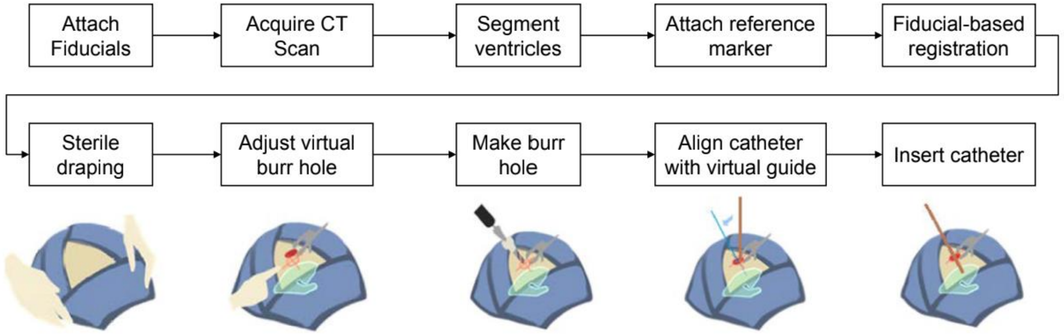


Fig. 2. Procedure workflow for ventriculostomy

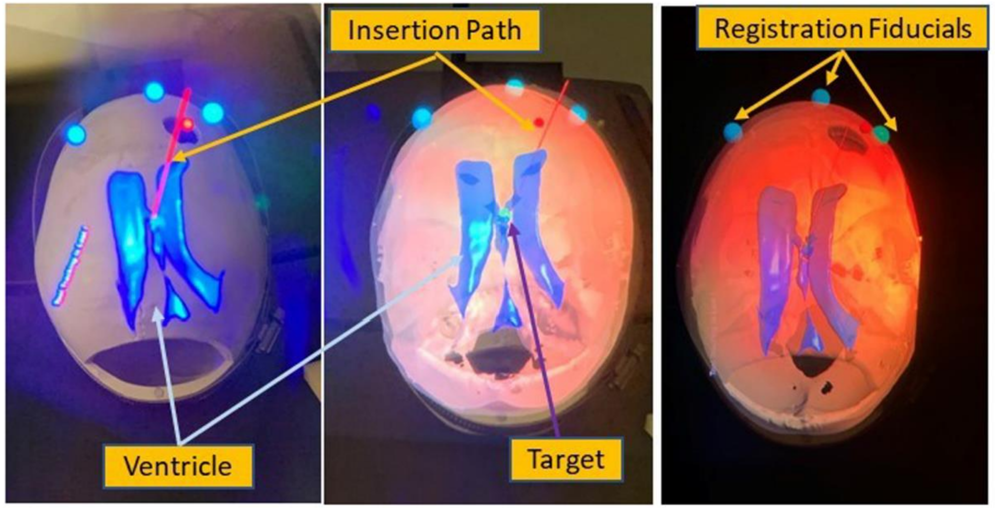


Fig. 3. Guidance and visualization in mixed reality captured from the user's view. The virtual skull is overlaid on the real skull and 3 registration points are shown. The red line is the virtual guidance path for the catheter.

Experiment design

1. Create a skull phantom

2. Generate CT scan

3. Using optical measurement (stereo camera):
   Distance error comparing to CT scan:
   0.48 mm, −0.36 mm, and 0.10 mm.

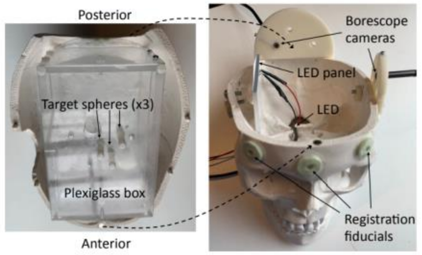


Fig. 4. Left: top of skull showing plexiglass box and targets. Right: bottom of skull showing borescope cameras and LEDs.

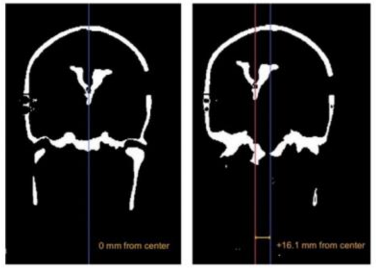


Fig. 5. Coronal views of two synthetic CT scans (left: nominal; right: abnormal).

4. 10 participants. Age between 21 to 35 (M = 25.44,SD = 5.11). With engineering or medical background. With moderate familiar with mixed reality devices. (M = 2.7 out of 5, SD = 0.82)

5. 5 Participants are very familiar with MR and one participant is neurosurgeon.

6. Each participants were asked to performed two questionnaires, a pre-task survey and demographics. Then perform the ventriculostomy with and without helping of MR. (10 subjects × 3 points × 2 setups=60 trails)

7. Measure the distance as between tips and target as objective indicator. Finish a questionnaire after the test in term of usability and perceived workload as subjective indicator.

Experiment Result

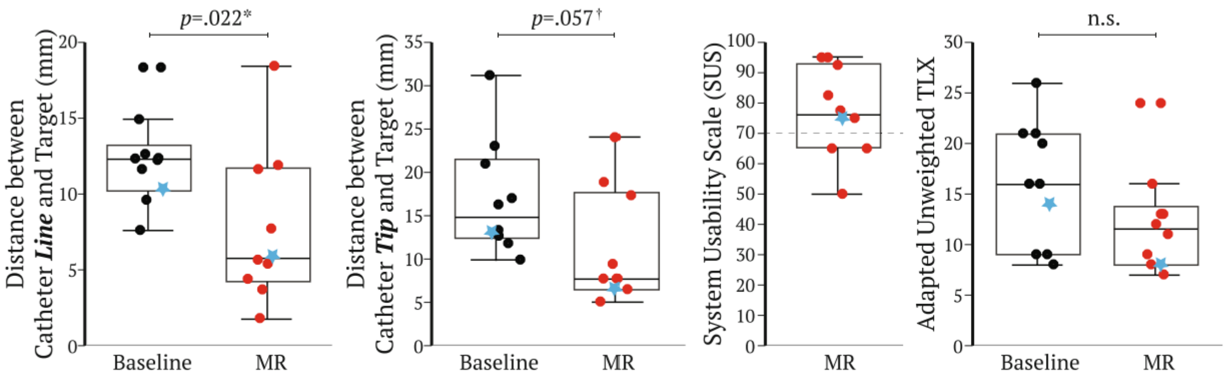


Fig. 7. Experimental results (blue star represents surgeon's data). We note that for the distance and TLX metrics lower values indicate better performance. For the SUS index, higher is better. (Color figure online)

ANOVA test suggests a significant difference in measuring the line distance:
MR condition: M = 7.63,SD = 5.00;   Baseline condition: M = 12.21,SD = 2.93.

Marginal difference in measured tip distance:
MR condition: M = 10.96,SD = 6.61; Baseline condition: M = 16.93,SD = 6.52.

MR also provided lower perceived workload and high usibility.

Assessment

Pros:
Successfully shows the advantage of using Mixed reality.

The result is very uplifting.

The way doing registration inspired the current project's registration process.

Cons:
The technical details of the registration of the skull are missing.

Only 10 volunteers (one real surgeon) were participated in the experiments. Perhaps need more trails.

Thank you