Head Mounted Display Integration for Orthopedic Surgery

Computer Integrated Surgery II, Spring, 2017

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State of the Art

- Current orthopedic surgery guidance system requires numerous X-ray images for placing wires and screws
- F. Sauer et al. [1] developed an augmented reality imaging guidance system, which enabled the surgeon to see the tumor inside the patient's body while wearing a HMD
- Christoph Bichlmeier et al. [2] introduced a virtual mirror method that navigated the surgeon during spine surgeries.

Introduction & Motivation

- Approximately 5.3 million orthopedic surgeries in 2010, expected to grow to 6.6 million by 2020
- Current guidance system only provides 2D X-ray images, which is harmful and inefficient
- This work uses camera and markers for tool tracking and displays the tracking data in 3D using a head mounted display (HoloLens).
- The presented method is less time-consuming, more efficient and prevents the frequent use of 2D X-rays

Method

This work introduces a solution to track and visualize both the outside and occluded parts of the surgical tool in an optical-see-through head mounted display. The complete approach can be divided into four main sections:

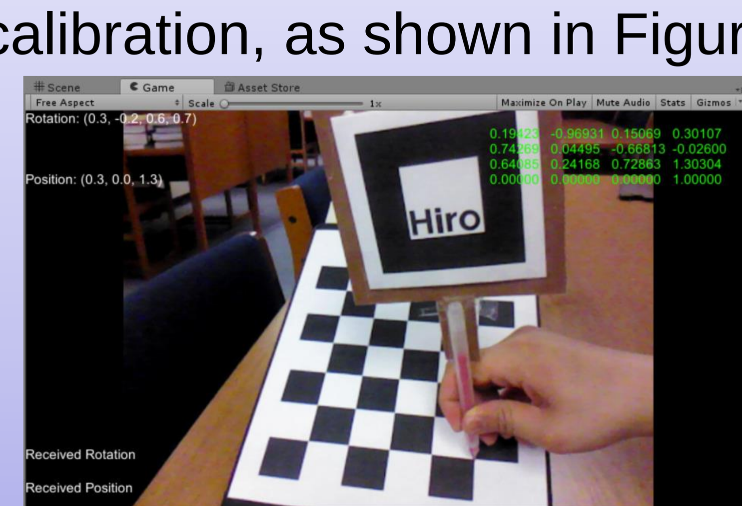
Needle orientation tracking

The surgical tool is tracked by the front-facing 2-megapixel image/video camera (locatable camera) on HoloLens, as shown in Figure 1.

Figure 1: Surgical tool (left) and Locatable camera on HoloLens (right)

Needle tip position estimation

The needle tip position is estimated through the pivot calibration, as shown in Figure 2.

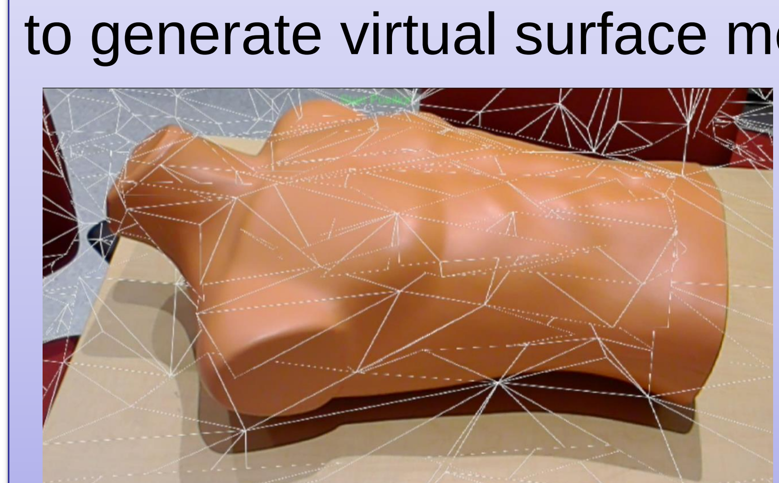


A program was developed in Unity. It runs in real-time to save all the transformation matrices from marker to camera in a text file. As shown in figure 4, the green 4x4 matrix on the upper right corner indicates the current transformation matrix from marker to the camera.

Figure 2: Pivot Calibration using tool tracking

Outside/occluded needle segments classification

HoloLens was used to detect the surrounding environment through its spatial mapping ability, which could be implemented to generate virtual surface mesh on the real-world surfaces



This is achieved by 4 environmental understanding cameras that are on the HoloLens, where each of the camera has a 512x424 time-of-flight image sensor with multi-frequency photo-demodulation.

Figure 3: Spatial mapping

Virtual needle augmented visualization

➢ **Virtual Surgical Tool that Aligns the Physical tool**

Figure 4: Virtual line augmentation

➢ **Entry Point Position Estimator & Insertion Effects**

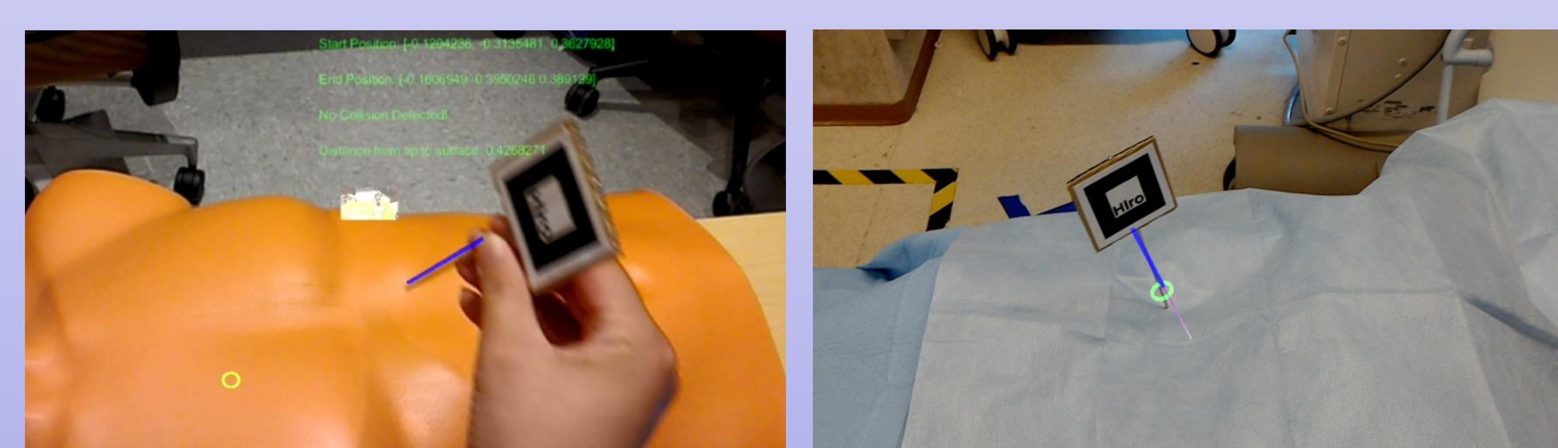


Figure 5: Entry point position estimator & Figure 6: Different effects indicating the insertion part of the surgical tool

Outcomes and Results

- **Accuracy Analysis of Tool Augmentation**
  - X-direction: 5.268 mm
  - Y-direction: 7.843 mm
  - Z-direction: 6.766 mm
  - Error is larger than 2mm, which is required typically for orthopedic surgeries
  - Most of the error comes out from the tracking system

- **User Survey of Visualization Cues**

Rendering Method	Details	Scores			
		Distinguish Entry Point	Distinguish above part	Distinguish occluded part	Depth Perception
Color only	Same Color	5.21	4.73	4.20	4.20
	Two Colors	7.00	7.13	7.13	6.47
Color + Entry Point	Same Color + Entry Point	8.28	7.27	7.13	6.13
	Two Colors + Entry Point	8.57	8.33	8.33	7.93
Above + widths	Thinner occluded part	8.79	8.73	8.73	7.93
Above + gradient colors	Light to Dark	8.92	8.92	8.92	8.23
	Dark to Light	9.08	8.83	8.83	8.83
	Mixed Color Gradient	8.92	8.69	8.84	8.23

Table 1: Average scores of each perception cue

- Scores range from 0 to 10, with 10 indicating great perceptions
- Highest scores are marked as red

Future Work

- Implement HoloLens's spectator view ability. A HoloLens and the DSLR camera could be mounted to the mobile C-arm at the position near the gantry

Credits

- Zhuokai Zhao is responsible for all the work presented in this poster. Special thanks to CAMP members' support and CIS II course staff (Dr. Taylor, Alexis)

Publications

1. F. Sauer , Ali Khamene , B. Bascle , G. J. Rubino, A Head-Mounted Display System for Augmented Reality Image Guidance: Towards Clinical Evaluation for iMRI-guided Neurosurgery, Proceedings of the 4th International Conference on Medical Image Computing and Computer-Assisted Intervention, p.707-716, October 14-17, 2001
2. Joerg Traub, Philipp Stefan, Sandro Michael Heining, Tobias Sielhorst , Christian Riquarts , Ekkehard Euler , Nassir Navab, Hybrid navigation interface for orthopedic and trauma surgery, Proceedings of the 9th international conference on Medical Image Computing and Computer-Assisted Intervention, October 01-06, 2006, Copenhagen, Denmark [doi>10.1007/11866565_46]