Computer Aided Medical Procedures

Head Mounted Display Integration for Orthopedic Surgery

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Background

- **Motivation: Orthopedic Surgery**
  - Placements of screws and wires into bones for fracture reduction
  - Image-guided systems provide 2D view
  - Complex task to do 3D alignment with 2D images ➔ Requires frequent re-positioning of X-ray machine
  - **Can augmented reality help?**

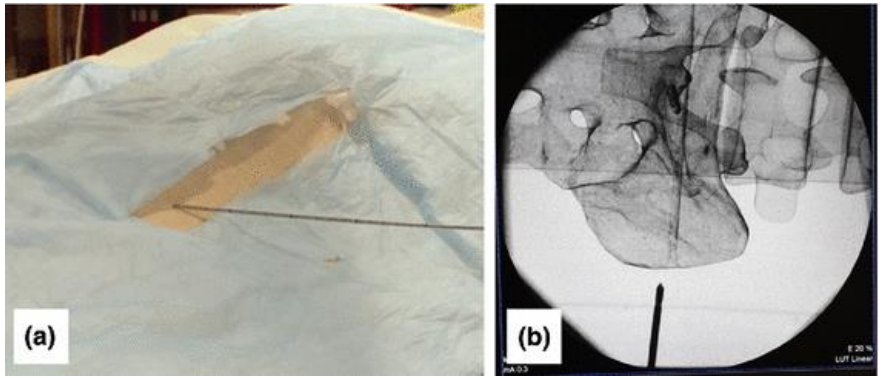
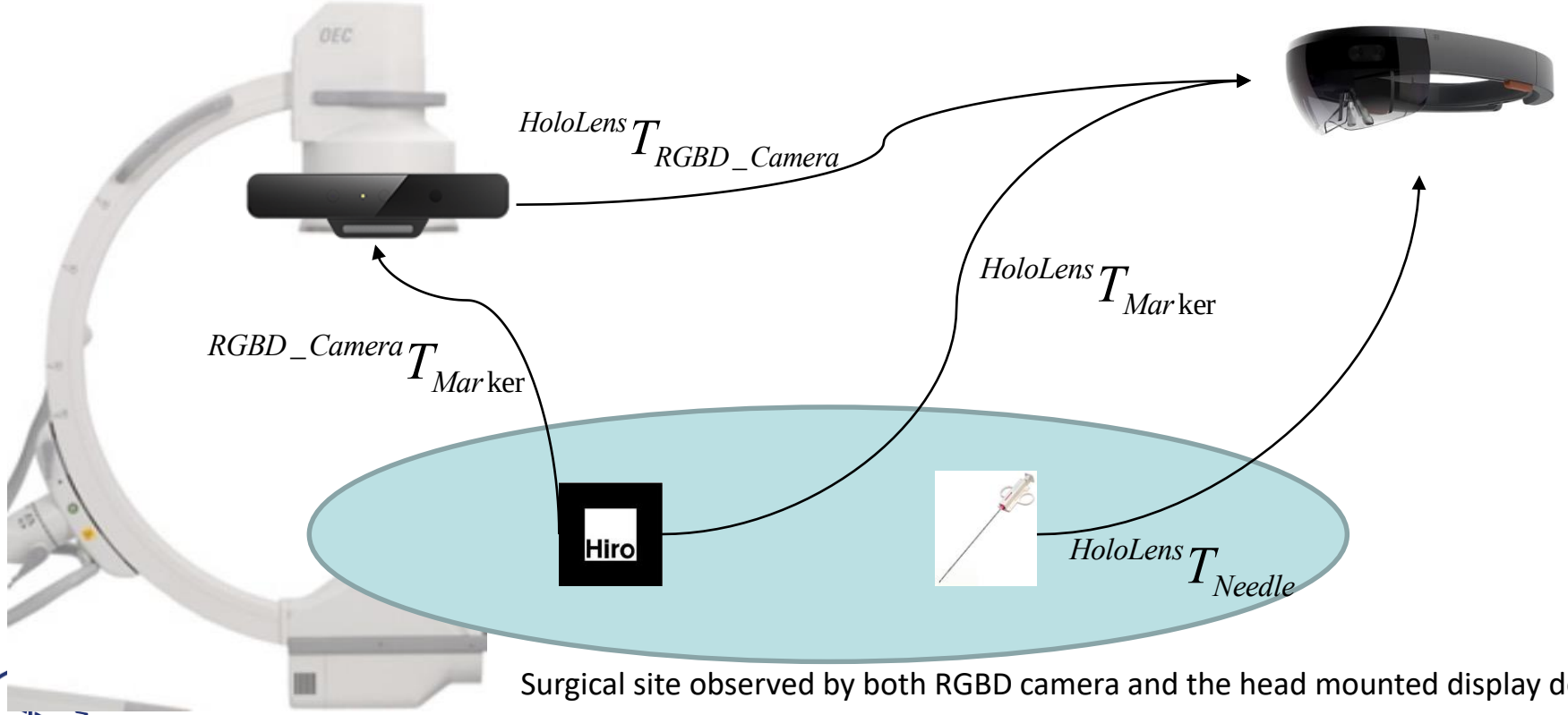


Image Source: Lee, S. C., Fuerst, B., Fotouhi, J., Fischer, M., Osgood, G., & Navab, N. (2016).
Calibration of RGBD camera and cone-beam CT for 3D intra-operative mixed reality visualization.
International Journal of Computer Assisted Radiology and Surgery, 11(6), 967-975. doi:10.1007/s11548-016-1396-1

Goal

- Deploying HMDs with simple 2D X-ray views to orthopedic surgery
- Use augmented reality to visualize the occluded part of the needle
  - Build a needle model in Unity which could be later deployed to HoloLens
  - Display (Optical See-through) the part of the needle that is inside the patient's body with HoloLens
- Comparison of user's perception of AR visualizations
  - Use ARToolKit to track the wire for evaluation purposes
  - The virtual needle should align with the physical needle
  - The virtual needle should move with the physical needle
  - Which AR visualization is the best?

System Setup



Surgical site observed by both RGBD camera and the head mounted display device

Technical Summary

- Calibrate RGBD camera (Intel SR300) and HMD device (HoloLens)
  - A marker is placed in surgical site observed by both RGBD camera and the head mounted display device
  - Use ARToolKit to track and get the transformation of marker between RGBD Camera and head mounted display device

- Patient's body model detection and recognition
  - Approach by developing basic algorithms with thresholding on point clouds

- Display the under-skin virtual needle in HoloLens
  - Optical See-through problem, virtual needle needs to align with the physical needle
  - Unity needle model in 3D, build and deploy in Visual Studio
  - Locations depend on result from above

Deliverables

- Minimum
  - Roll out HMDs to the hospital operating room
  - Camera calibration algorithm for RGBD camera and the head mounted display device
  - Marker tracking algorithm used to track needle movements
  - Skin model detection algorithm with basic thresholding on point clouds
- Expected
  - Needle location and orientation estimation in 3D space
  - Algorithms that determine which part of the needle is within the patient's body
  - Display the part of the needle that is within the patient's body via HoloLens
- Maximum
  - Implementation of different perceptual cues
  - Evaluation and comparison of different visualizations

Dependencies

Hardware

- Microsoft HoloLens ✓
  - Mentor Supplies
- Intel RealSense SR300 ✓
  - Mentor Supplies
- Windows Laptop/Desktop ✓

Software & Others

- ARToolKit ✓
- Visual Studio 2015 Update 3 ✓
- HoloLens Emulator ✓
- Intel RealSense SDK ✓
- Checkerboard used for calibration ✓

Management

- Weekly CAMP Meetings
  - Wednesday 9 – 10 am
  - Discuss the progress with Dr. Fuerst and Dr. Navab

- Weekly Meeting with Mentors
  - Tuesday 3pm
  - C-arm related resources/questions: Javad and Sing Chun
  - Head Mounted Display related resources/questions: Alex and Long

Time Table

	Week:	2/12	2/19	2/26	3/5	3/12	3/19	3/26	4/2	4/9	4/16	4/23	4/30
Minimum	Roll out HMDs to the hospital operating room												
	Get familiar with ARToolKit, Unity and HoloLens												
	Perform single-camera calibration for SR300 and HoloLens												
	Camera calibration algorithm for both SR300 and HoloLens												
	Marker tracking algorithm used to track needle movements												
	Skin model detection algorithm to classify the patient's body												
Expected	Needle location and orientation estimation in 3D space												
	Algorithms that classifies the needle part that is in the body												
	Display the needle part that is in the patient's body in HoloLens												
Maximum	Implementation of different perceptual cues												
	Evaluation and comparison of different visualizations												
	Final report, poster design, and presentation preparation												

Milestone Dates

Date	Milestone Description
Feb. 24th	Get familiar with implementing ARToolKit with Unity, and implementing customized HoloLens ARToolKit with HoloLens
Feb. 26th	Start rolling out HMDs to the hospital operating room for advice
Mar. 3rd	Finish camera calibration for Intel RealSense SR300 and HoloLens independently. Save the intrinsic parameters. Start calibration algorithm between SR300 and HoloLens. Start using ARToolKit to track the needle movements. Test using both RGBD camera and HoloLens.
Mar. 10th	Finish calibration process and marker tracking. Start working on detecting and recognizing patient model's body. Start working on solving the estimation of needle tip location and orientation.
Mar. 24th	Finish skin model detection and needle tip location estimation. Start working on classifying which part of the needle is inside the patient's body.
April. 2nd	Finish classifying the needle part that is inside the patient's body. Start to work on visualize the part of needle in HoloLens. Make the virtual needle align with the real needle
April. 16th	Start HMD implementation of different perceptual cues
April. 28th	Finish all the code and algorithm work. Start writing report, poster and evaluating different visualizations

Supplemental Readings

- Brand, J., & Mason, J. (n.d.). A comparative assessment of three approaches to pixel-level human skin-detection. Proceedings 15th International Conference on Pattern Recognition. ICPR-2000. doi:10.1109/icpr.2000.905653
- Tan, W. R., Chan, C. S., Yogarajah, P., & Condell, J. (2012). A fusion approach for efficient human skin detection. IEEE Transactions on Industrial Informatics, 8(1), 138–147. doi:10.1109/tii.2011.2172451
- Pauly, O., Diotte, B., Fallavollita, P., Weidert, S., Euler, E., & Navab, N. (2015). Machine learning-based augmented reality for improved surgical scene understanding. Computerized Medical Imaging and Graphics, 41, 55–60. doi:10.1016/j.compmedimag.2014.06.007
- Zhang, Z. (2000). A flexible new technique for camera calibration. IEEE Transactions on Pattern Analysis and Machine Intelligence, 22(11), 1330–1334. doi:10.1109/34.888718

Supplemental Readings Continue

- Yogarajah, P., Condell, J., Curran, K., McKevitt, P., & Cheddad, A. (2012). A dynamic threshold approach for skin tone detection in colour images. International Journal of Biometrics, 4(1), 38. doi:10.1504/ijbm.2012.044291
- Robert Discover (2016, April 20). *Augmented reality (ARToolkit + unity3D)* Retrieved from https://youtu.be/T8O-XKQ2Avo