Holographic Tracking and Visualization in Augmented Reality Guidance for Prostate Fresh Tissue Procurement

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Introduction

Prostate cancer is the most common type of cancer diagnosed in men [1]. Fresh prostate tissue samples obtained from cancerous lesions are imperative for improving diagnosis of the disease and treatment planning. Automatically generated and fabricated patient-specific prostate molds preserve *in-vivo* orientation and shape of the excised organ in correlation with Magnetic Resonance Imaging. However, it is still challenging to procure fresh tissue from the lesion within the excised prostate, while minimizing damage to the adjacent tissue. The goal of this project is to develop an augmented reality (AR) application capable of navigating the biopsy needle into the lesion embedded within the prostate gland by accurately tracking the objects in the real world and visualizing gland and lesion holograms in the virtual world.

Hardware and Setup

We utilized a HoloLens (Microsoft, Redmond, WA, USA), an AR head-mounted display device, for overlaying holograms (virtual objects) over the objects in the real-world environment. The objects were fitted with infrared markers and tracked in the real world with the V120:Trio cameras (OptiTrack, USA).

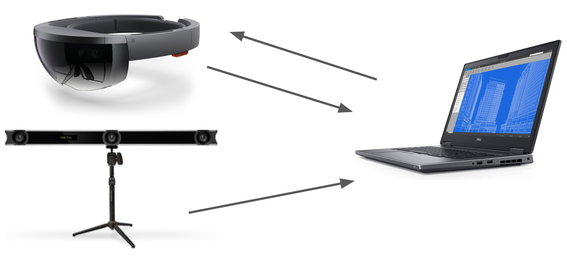

Figure 1. Image of the HoloLens (top left), computer (top right), and V120: Trio (bottom left). The V120:Trio streams tracked markers to the computer through its proprietary software, Motive. The computer processes the data through a custom Python program and sends the data to the HoloLens through UDP. Data from the HoloLens to the computer is sent via TCP.

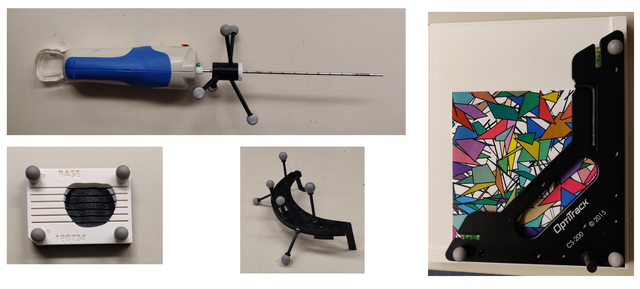

Figure 2. Biopsy needle (top left), prostate mold (bottom left), and HoloLens tracker (bottom middle) with infrared tracking markers, and the calibration square on top of the calibration image (right).

Calibration and Usage

The application pipeline:

1. In the Motive software, generate rigid bodies for the prostate mold and the needle by selecting the corresponding markers attached to each object
2. Start the Python program on the computer that handles communication.
3. Put on the HoloLens and calibrate it using Microsoft's own calibration software accessible in the device. This ensures holograms will look stable to the user.
4. Start the Unity (Unity Technologies, San Francisco, CA, USA) application.
5. Look at the calibration image. Utilizing Vuforia (PTC Inc, Boston, MA, USA), the application samples the position and orientation of the image to anchor the coordinate system and develop the required transforms.
6. Place the calibration bar on the image and set the ground plane for the V120:Trio in Motive.
7. Place the needle in the cylindrical insert on the calibration square and provide the command to start needle calibration.

After calibration, the calibration bar and image are not required to be within the field of view of the HoloLens or the V120:Trio.

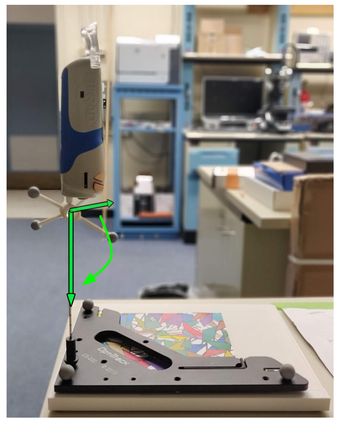

Figure 3. Biopsy needle and markers in the insert with an arbitrary initial orientation and the Y-axis correction.

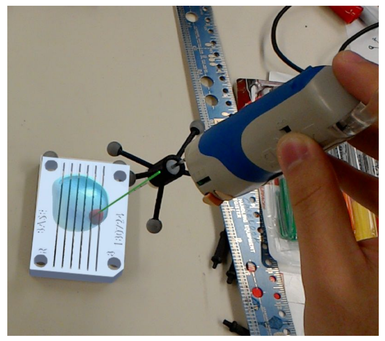

Figure 4. Holograms superimposed over the needle and prostate mold.

Transformations

For any two coordinate systems *X* and *Y*, let ${}^{X}T_{Y}$ denote the rigid body transformation to go from *Y* to *X*. Let I and O denote the coordinate systems of the image and Motive respectively. Assuming that ${}^{I}T_{O}$ is known, the image can be used to coregister the Unity and Optitrack coordinate systems.

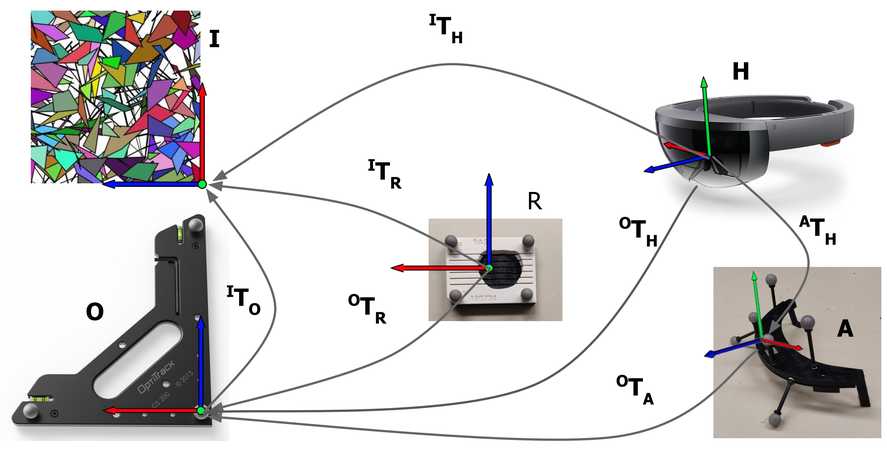

Figure 5. Diagram of all the transforms involved. Let ${}^{O}T_{R}$ denote the transform from any arbitrary Motive rigid body to the V120:Trio origin (prostate mold depicted). Since ${}^{I}T_{O}$ is known, ${}^{I}T_{R} = {}^{I}T_{O} * {}^{O}T_{R}$, which can be used to place holograms relative to the image in Unity. ${}^{A}T_{H}$ is calibrated as a product of ${}^{A}T_{O}$, ${}^{O}T_{I}$, and ${}^{I}T_{H}$ [2,3]. Note that since the markers on the HoloLens are fixed, ${}^{A}T_{H}$ is constant. Then ${}^{I}T_{H} = {}^{I}T_{O} * {}^{O}T_{A} * {}^{A}T_{H}$, which is an estimate of the HoloLens pose in Unity. Comparing this to the actual pose information of the HoloLens provided by the device allows the program to correct the image anchor to improve hologram alignment.

Future Directions

Improving Image Registration - The current system uses Vuforia for image registration. We intend to utilize OpenCV instead, which will provide more control over the algorithms used to analyze the image pose.

Latency Compensation - There is an inherent delay in streaming the data from V120:Trio to the HoloLens. Latency can be compensated for using predictive algorithms to reduce the lag between the movement of the needle and the movement of the hologram [2].

Phantom Testing - Once errors are minimized, the AR implementation can be tested with a phantom to further validate the method.

Other AR Systems - Smartphones can be used as augmented reality displays. Our application can be ported to those devices to develop cheaper and more accessible programs for surgeons.

References

1. R. L. Siegel, *at al.*, Cancer statistics, 2018. CA: A Cancer Journal for Clinicians, 2018, vol. 68, no. 1, pp. 7–30.

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3. M. A. Lin *et al.*, "HoloNeedle: Augmented Reality Guidance System for Needle Placement Investigating the Advantages of Three-Dimensional Needle Shape Reconstruction," in *IEEE Robotics and Automation Letters*, vol. 3, no. 4, pp. 4156-4162, Oct. 2018.