Motion Tracking Optimization for Augmented Reality Guidance to Assist Prostate Fresh Tissue Procurement

Matthew J. Rosenblatt[1,2], Wally L. Niu[1], Cody Bastian[2], Marcial A. Garmendia[2], Sinisa Pajevic[2], Javier I. Mendez[2], John W. Kakareka[2] , Peter A. Pinto[3], Sherif Mehralivand[3], Peter L. Choyke[3], Baris Turkbey[3] , Raisa Z. Freidlin[2], and Thomas J. Pohida[2]

[1]National Institute of Biomedical Imaging and Bioengineering, [2]Center for Information Technology, [3]National Cancer Institute

National Institutes of Health, Bethesda, MD

Introduction

Prostate cancer is one of the most common cancer types and one of the leading causes of cancer death among men in the United States [1]. Prostate fresh tissue procurement is a procedure that can provide invaluable information used in the prostate cancer research areas of diagnosis and treatment. Current procurement techniques rely on patient-specific prostate molds that guide the needle using channels; however, this task can be difficult and time-consuming. We believe that an augmented reality approach, which integrates a virtual biopsy needle and virtual prostate mold, will allow for more rapid, flexible, and effective tissue procurement. In this poster, we describe how motion tracking and calibration methods improve the accuracy of the overlaid virtual projections, as seen through a HoloLens (Microsoft, USA).

Motion Tracking

We used the V120:Trio (OptiTrack, USA) to track the biopsy needle (Figure 1) and prostate with embedded lesion placed in the prostate mold. Each object was tracked as a rigid body with passive infrared markers. To guide the biopsy needle, the infrared markers must be configured so that the center of mass of the markers is aligned with the center of the needle, as this allows the HoloLens to properly align translational and rotational movements of the virtual object (hologram) with the respective real object.

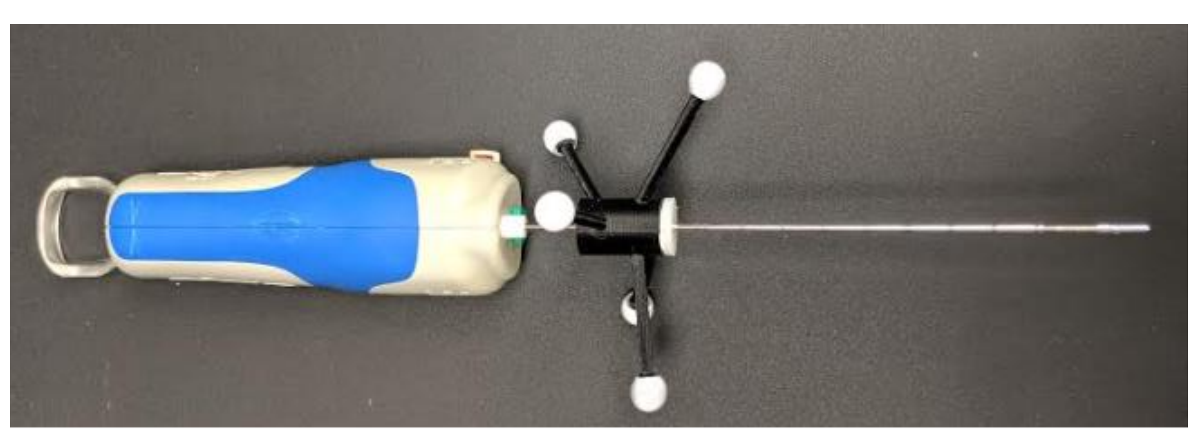

Figure 1. Biopsy needle with 3D-printed holder for infrared markers.

Several important factors contributed to the design of the needle marker configurations (Figure 2), such as ensuring maximum marker visibility at various angles and avoiding interference with the surgeon's hand. Multiple designs are shown below.

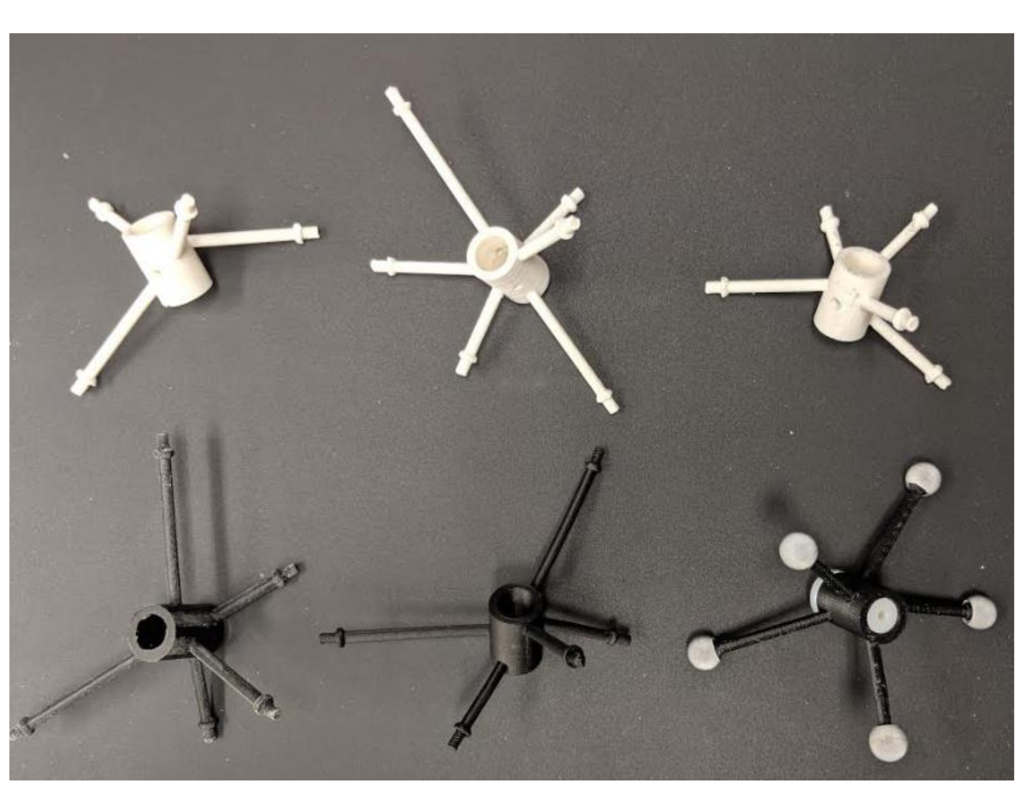

Figure 2. Marker configuration designs for the biopsy needle. Important parameters include marker size, separation, and orientation.

System Setup

As shown in Figure 3, The V120:Trio camera system streams rigid body (the needle and prostate mold) data to a Python server, which acts as an intermediary between the tracking system and the HoloLens. The HoloLens then overlays holograms onto the objects based on the position and rotation data received from the V120:Trio.

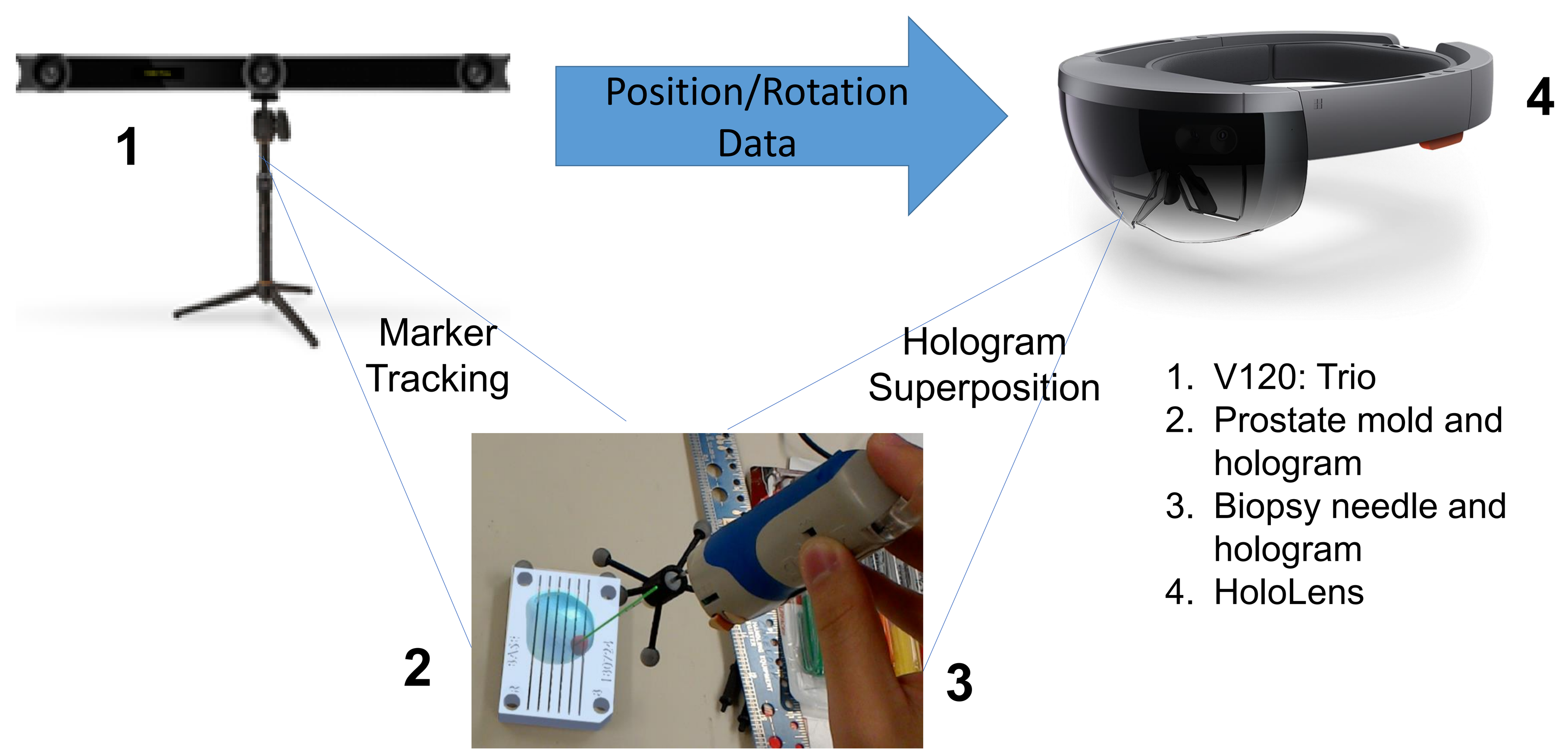

Figure 3. Schematic overview of the system setup

Calibration Optimization

In order to align coordinate systems of the V120:Trio and the HoloLens, system calibration must be performed. We developed a voice-controlled user interface to allow the surgeon to perform the calibration process hands-free. The major step in this process involves aligning a hologram of an image to a physical image via the HoloLens' live video feed. This alignment process estimates the location of the HoloLens anchor point that corresponds to the origin of the V120:Trio coordinate system. We implemented a density-based clustering algorithm [2] that uses seven parameters, i.e., three positional (Figure 4 shows clustering results for z coordinate) and four rotational, to find the points that represent when the hologram is most closely aligned to the physical image target.

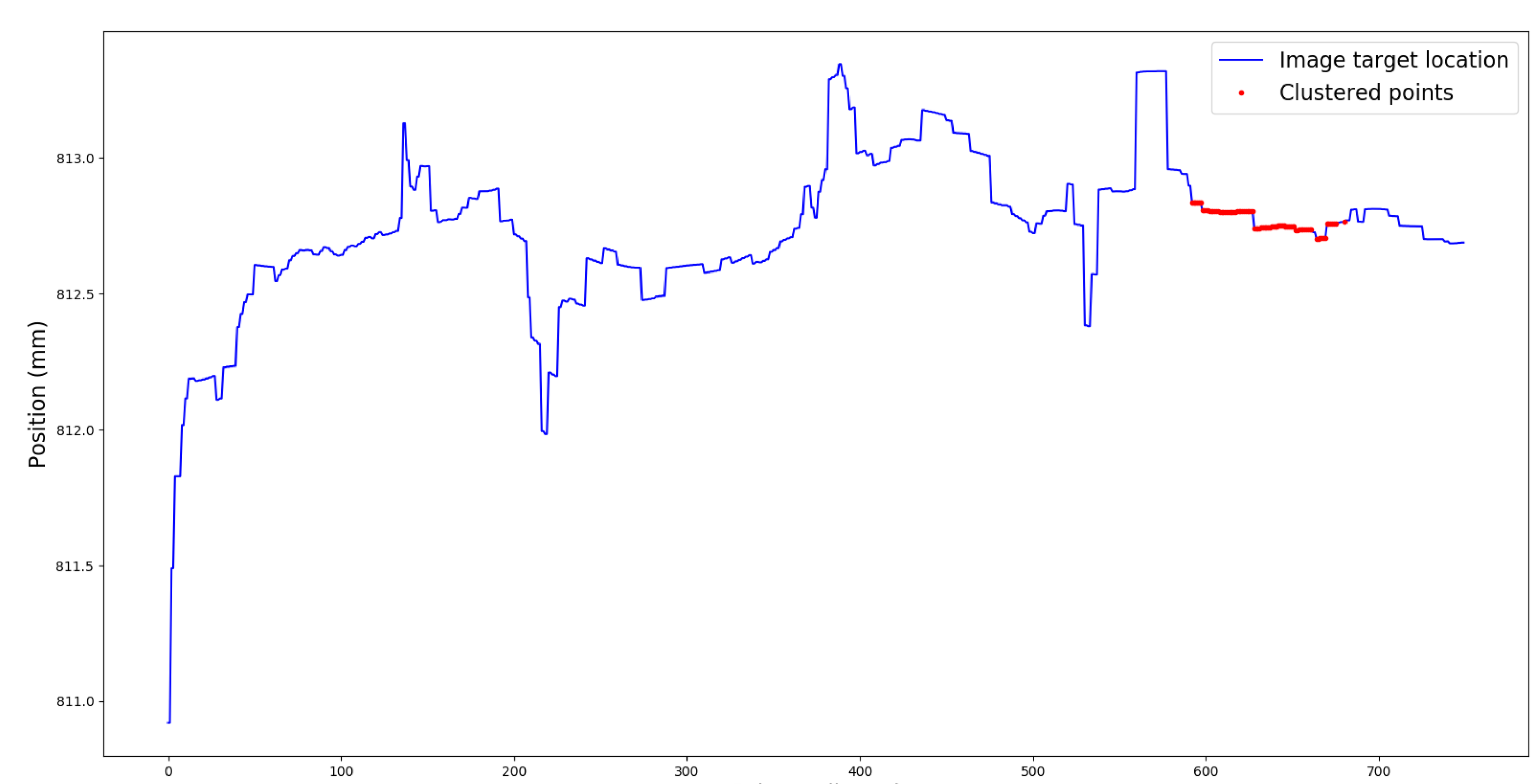

Figure 4. Example density-based clustering results for z position. Our implementation uses both positional and rotational data to find the most dense cluster of points, which represents alignment of the hologram and image target. This data is used to synchronize the V120:Trio and HoloLens coordinate systems.

Prediction and Smoothing

We implemented a double exponential smoothing and prediction algorithm based on the work of Joseph LaViola Jr. [3] for both position and rotation data (Figure 5). The algorithm predicts needle location and rotation, which reduces latency.

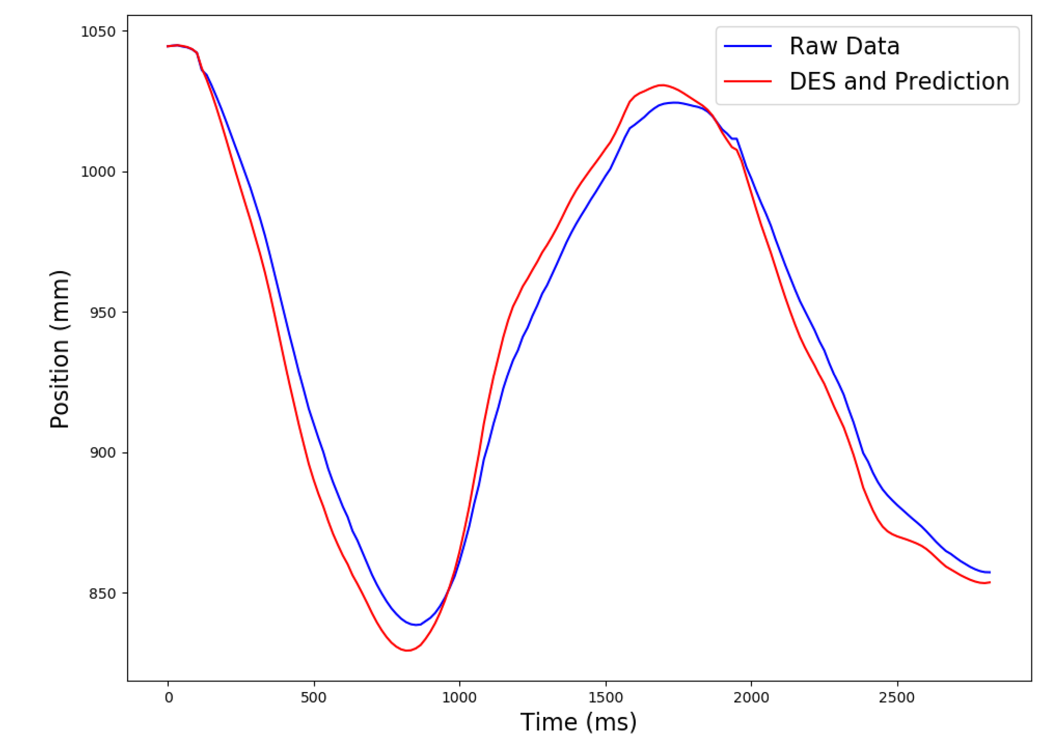

Figure 5. Example of double exponential smoothing and prediction for z position. Smoothing and prediction are applied to x, y, and z position, as well as to the quaternion. This example shows a 50 ms future prediction, used to reduce visual hologram latency.

Conclusions and Future Directions

We have demonstrated the application of augmented reality guidance with prostate fresh tissue procurements. Future directions may include:

- Developing with the HoloLens 2, which includes improved camera with autofocus, eye tracking, and increased field of view.
- Refining marker configurations on biopsy needle for improved tracking accuracy
- Implementing an Extended Kalman Filter for smoothing and latency reduction

References

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For more information about our project, please see poster AM-7.