Validation of Markerless Hand Motion Tracking for Quantification of Surgical Skills

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Background/Clinical Need

Quantification of surgical skills is essential for evaluating training effectiveness and optimizing surgeon performance to ensure the best outcomes. In terms of skill assessment and optimizing surgical skills, marker-less motion tracking of hand movements in simulated surgeries offers a promising alternative to traditional marker-based systems.

Figure 1: One of ten IR cameras that will be used for tracking the 3D hand trajectories through the markers placed on the fingertips

Figure 2: The Intel RealSense D435 depth camera with built-in stereo cameras and IR sensor that will be used to track 3D hand movements for markerless system through Google's MediaPipe.

Mission Statement

We strive to revolutionize surgical training and performance through marker-less motion tracking. Our goal is to empower surgeons with data-driven insights to enhance their skills and improve patient outcomes.

Final Technical Model Equation

Euclidean Distance Equation for Error Analysis:

$$\sqrt{(x^{marker}(t)-x^{markerless}(t))^2+(y^{marker}(t)-y^{markerless}(t))^2+(z^{marker}(t)-z^{markerless}(t))^2}$$

Final Product Specifications

Markerless System	Markerbased System
Intel RealSense D435 Depth Camera	10 IR cameras
Hand motion algorithm	Master Software with PhaseSpace installed
Google's MediaPipe Studio	Markers
	Ethernet cable
	Motion Tracking Program (such as MOKKA)

Prototype

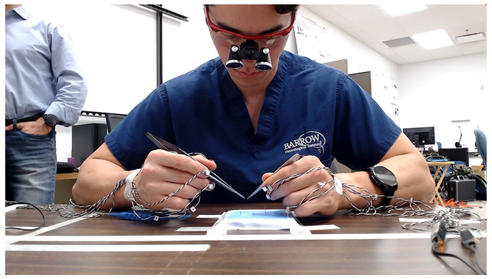


Figure 3: Thomas, a medical student is performing neurosurgical suturing with 1 marker on each finger (10 markers total), tracked by 10 PhaseSpace IR cameras for movement analysis.

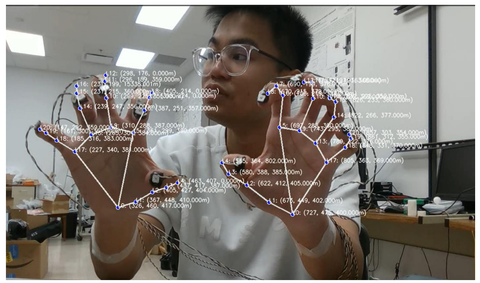


Figure 4: Ashton, a group member is performing calibration poses to calibrate both systems before the experiment. The hand trajectory points in 3D are shown which are tracked through the MediaPipe.

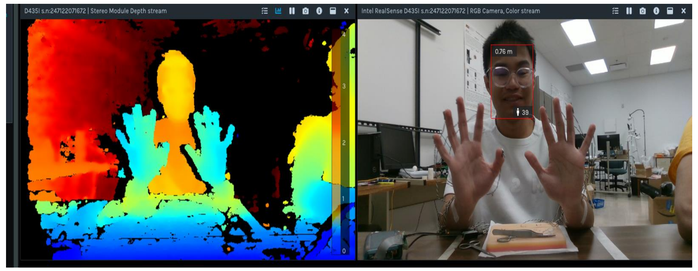


Figure 5: Visual representation of RGB camera and depth sensor of the Intel Depth Camera for the markerless tracking.

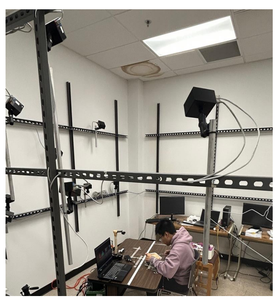


Figure 6: Infrared Camera Setup for Markerbased Tracking

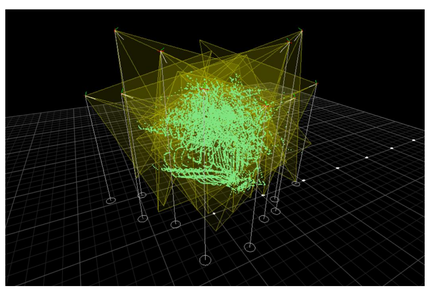


Figure 7: The PhaseSpace software's visual representation in a 3D space. The IR camera's Line of Sights are represented by the yellow cones and the smudged green lines indicate the movements undertaken to calibrate the system prior to recording.

Verification Results

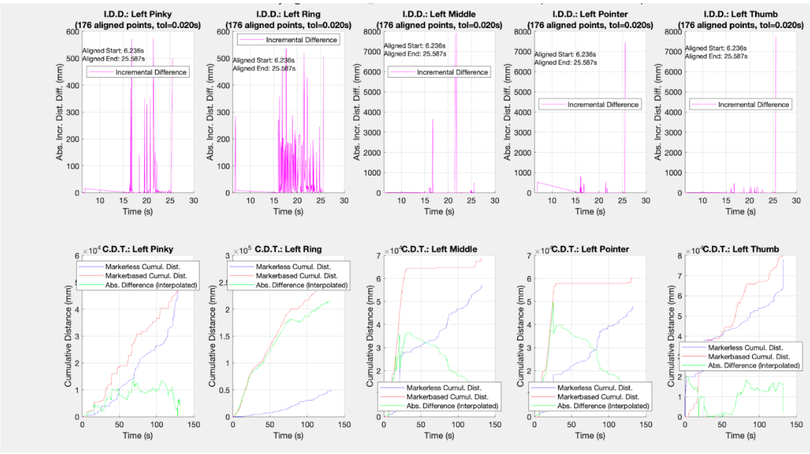
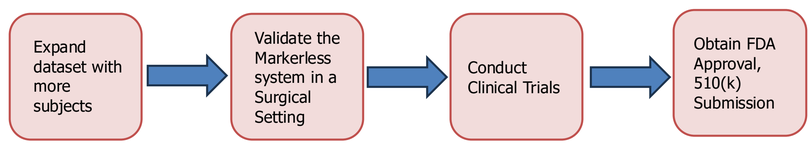


Figure 8: The top five plots show the incremental distance differences for each finger of the left hand and the bottom five plots show the cumulative distances of the two systems and the cumulative distance differences between the systems for each finger of the left hand.

Discussion

- Both cumulative and incremental differences were measured by the Euclidean distance equation.
- Thumb and pinky had lower values of CDT and IDD than the other fingers, meaning that the markerless system tracked the best for these two fingers.
- The markerless system tracked the worst for the ring finger.
- The main drawback was the inconsistent FPS value of markerless for each time period.

Future Steps



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