Validation of Markerless Motion Tracking for Quantification of Surgical Skills

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Background/Clinical Need

Problem: 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.

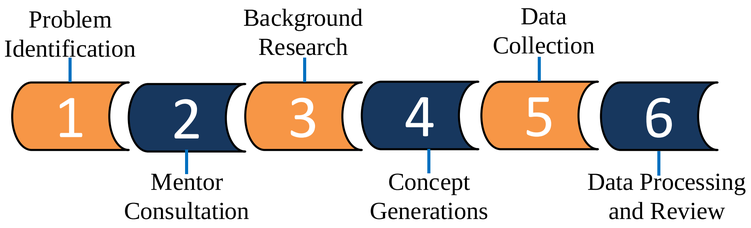
Figure 1: One of ten IR cameras that will be tracking the marker placed on the hand at different angles.

Figure 2: The Intel camera with built-in stereo cameras and IR sensor that will be used to track 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.

Project Planning



Customer Needs/Metrices

Ease of Use and Comfort	Feedback from targeted users
Cost	Target production cost ($2000-$5000)
Reliability	Consistent performance
Accuracy	Benchmarking with marker-based systems; error analysis
Compatibility	Integration with various systems
Real-Time Feedback	Instant data interpretation
Data Privacy	Secure algorithm design
Durability	Stable software and system performance
Training Application	Enhance surgical training and enable hospital use; feedback-driven

Concept Generations

We are developing an algorithm utilizing Google's MediaPipe for tracking markerless hand motion in real time. The finger movements will be tracked by a specific Intel camera with built-in stereo cameras and IR sensor that will record a mock surgery performed by surgeons. After collecting and compiling the data on MediaPipe, we will utilize a program made on Python by one of the Barrow Medical Institute students to analyze the finger movements. The system will be validated against a marker-based tracking system by plotting data of both systems against each other for each finger and calculating the mean error. The tracking error can be used to iteratively refine and train algorithms to improve markerless hand tracking which can be potentially used by surgeons in the operating room

Technical Model

Figure 2: 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.

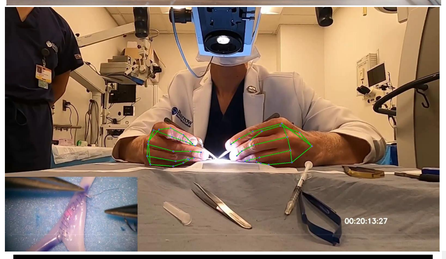


Figure 3: Google's-Media-Pipe tracking surgeon movement and hand joints, reconstructing hand shape and position by comparing orientations to learned datasets.

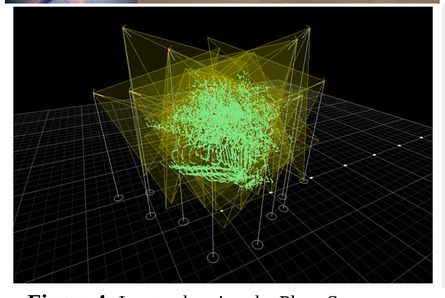


Figure 4: Image showing the PhaseSpace motion tracking system with infrared cameras strategically positioned around the workspace to capture precise movements. Light yellow cones indicate each IR camera's line of sight while the smudged green lines indicate wand movement during calibration phase, confirming that all motions are being accurately tracked in real-time.

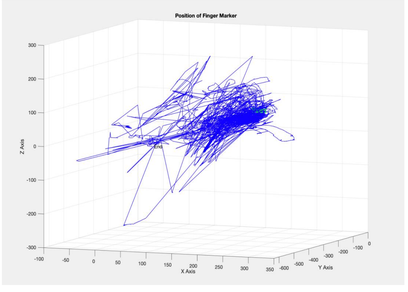


Figure 5: Trajectory motion of middle right hand in 3D coordinates for marker-based system of a neurological suture performed by a BNI medical student.

Pertinent Equations in Models

Root Mean Square Equation for Error Analysis:

$$\sqrt{\left(\frac{1}{N}\right)\sum\left(\left(x^{marker}(t)-x^{markerless}(t)\right)^2+\left(y^{marker}(t)-y^{markerless}(t)\right)^2+\left(z^{marker}(t)-z^{markerless}(t)\right)^2\right)}$$

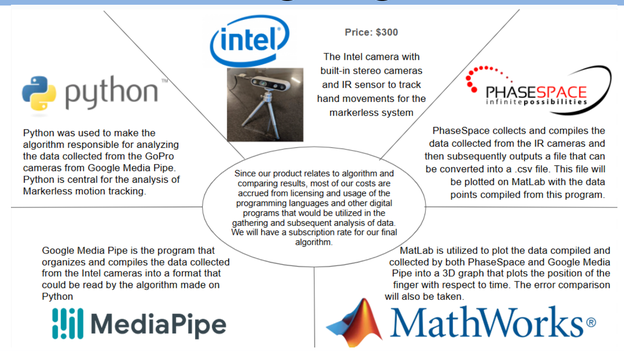
Normalization formula:

$$\frac{x_n - x_{min}}{x_{max} - x_{min}}$$

Camera Position Equation:

$$P_t = K \cdot (R \cdot P_o + T)$$

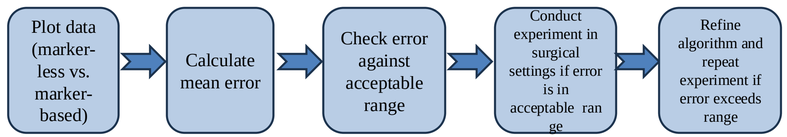
Manufacturing Design and Costs



Final Product Specifications

Markerless system	**Marker based system**
Go Pro Camera	10 IR Cameras
Intel Camera with built-in stereo cameras and IR sensor	10 sensors
Hand Motion Algorithm	Device with Phase-Space Installed
Google's MediaPipe Studio	Markers
	Ethernet Port
	Motion Tracking Program (such as MOKKA)

Future Steps



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