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Research In-Progress

AI-Powered Markerless 3D Motion Analysis for Objective Assessment of Suturing Proficiency

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Introduction: Objective assessment of surgical skill remains a major challenge in medical education. Traditional evaluation methods rely heavily on subjective ratings or intrusive sensor-based systems, limiting reproducibility and applicability. To address this, we developed an artificial intelligence (AI-driven), markerless computer vision framework for analyzing bilateral hand kinematics during suturing. This approach leverages three-dimensional directional decomposition of hand motion to extract spatial and temporal features associated with suturing expertise.

Methods: Hand motion was captured in a controlled laboratory setting using an AI-powered computer vision system, eliminating the need for physical markers or wearable sensors. Participants were stratified into experts (≥50 prior patient suturing experiences) and novices (<50 experiences; medical students). Kinematic features included displacement, velocity, and acceleration profiles across X, Y, and Z axes, as well as temporal efficiency metrics such as total completion time and stagnation periods. Six established machine learning algorithms were implemented to evaluate classification performance.

Preliminary Results: Eleven experts (4 attending and 7 surgical residents) consistently performed significantly different than eleven novices (medical students) across temporal and spatial dimensions. Temporal efficiency emerged as the strongest predictor of expertise, with experts completing suturing tasks significantly faster and exhibiting reduced hesitation. Spatial analysis revealed that experts demonstrated greater displacement amplitudes coupled with smoother, more controlled acceleration and velocity profiles requiring advanced spatial coordination. Machine learning models achieved high accuracy in distinguishing experts from novices. Hand-specific expertise signatures were observed: left-hand performance emphasized in-plane displacement control, while right-hand performance relied more on Z-direction (up and down movements) acceleration and velocity patterns.

Next Steps: Future work will expand participant cohorts and more advanced deep learning algorithms to improve the accuracy and provide more insightful feedback to the trainees. This system aims to provide automated, objective, and scalable skills assessment to support competency-based surgical training.

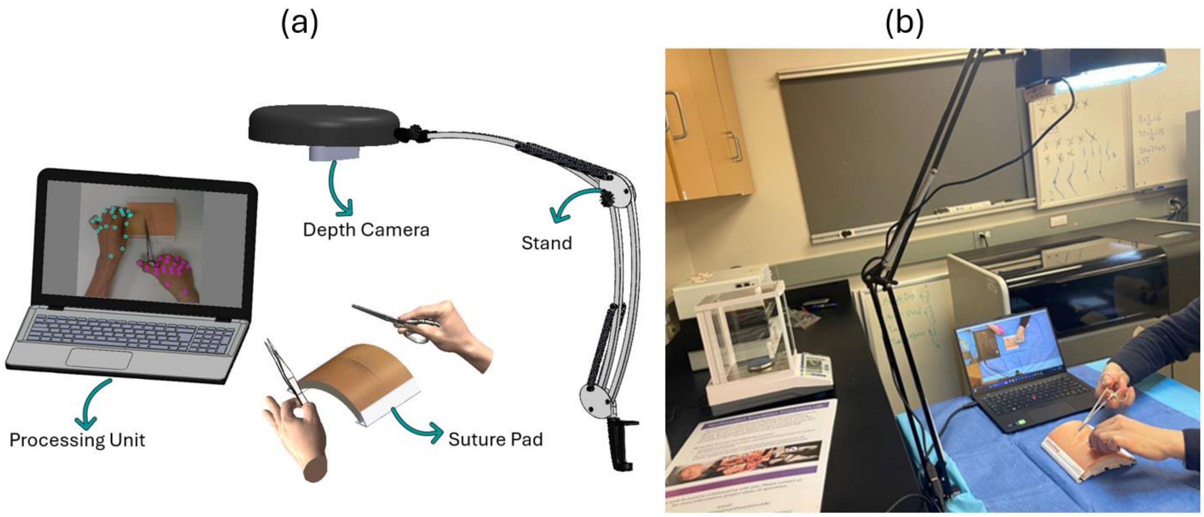

Figure. Schematic(a) and real(b) illustration of the setup.