ACS 2024 Surgeons and Engineers: A Dialogue on Surgical Simulation Meeting

P-C-08

Research Abstracts

Segmentation of Surgical Motion Using Instantaneous Screw Axes

Heath James Boyea; and Ann Majewicz Fey, PhD

University of Texas at Austin, Austin, TX

Introduction: Supervised segmentation and classification of surgical skills is time consuming and expensive, while self-supervised algorithms can find mathematical meaning but don't necessarily reflect the qualitative judgement of a human observer. In this work we propose a novel approach to surgical task segmentation and skill analysis through instantaneous screw axes (ISA) and k-means clustering. Pettinger et al. demonstrated that simple tasks can be optimally represented as displacements about a screw axis [1]. We propose extending this method to more complex tasks with numerous ISAs in the surgical environment.

Methods: We analyzed needle driving movements from the JIGSAWS dataset [2]. An ISA algorithm was developed by calculating transformation matrices between manipulator poses at each time step. Rodrigues' rotation formula was then applied, producing an axis of rotation (ω) and angle of rotation (θ). With this, the linear velocity and screw pitch was calculated. A linear least squares solver was then implemented to determine the center of rotation between these poses (q). Radial movements, such as needle driving, should produce similar ISAs throughout the entirety of the movement so we implemented K-means clustering to segment these movements into subtasks. Since these clusters represent continuous translations and rotations, decreasing the number of required clusters implies more ideal movements.

Results: Our ISA algorithm was applied to 164 suture recordings. Figure 1 (attached) displays the median, upper/ lower quartile, and maximum/ minimum number of ISA clusters for experts, intermediates, and novices. We performed Kruskal-Wallis analysis on this data and calculated a p-value of 8.9×10^{-8}. We then performed a Dunn-Sidak correction and determined that novices have a significantly higher number of gestures than intermediates and experts.

Conclusions: Our minimal ISA approach can determine how optimally needle driving is performed between skill groups. In future work we look to utilize pattern detection to analyze more complex, compound tasks.

Figure 1: Number of Segmented Subgestures Across Skill levels