Real-Time Workflow Segmentation for Needle-Based Interventions

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PURPOSE: Traditionally, medical trainees have learned and practiced surgical skills under supervision of an expert; however, in contemporary medical education there are more trainees, more procedures and limited expert time for teaching. A system which can automatically identify a trainee's surgical motions and provide feedback accordingly could allow for independent practice and complement expert supervision in specific stages of the training protocol. We propose a real-time system for feedback based on a previously validated workflow segmentation algorithm, which automatically identifies the task a user is performing based on needle-tracking data, and software from the PLUS library and the Slicer 4 platform (Figure 1).

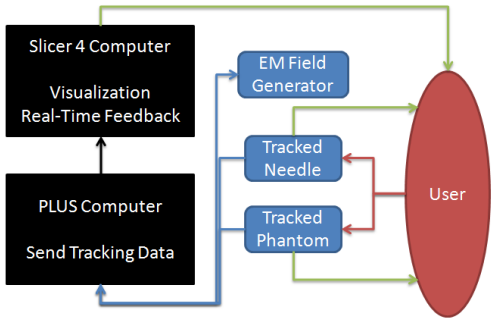

Fig 1. Proposed real-time feedback system setup using workflow segmentation algorithm. User interaction is indicated in red, feedback to the user is indicated in green.

METHODS: Previous results have demonstrated the feasibility of an algorithm following a pipeline: (1) Gaussian filtering – to smooth the trajectory, (2) orthogonal transformation – to extract motion features, (3) principal component analysis – to reduce dimensionality, (4) *k*-means clustering – to discretize data, (5) Markov modeling – to characterize sequences of data [1]. The algorithm has been further verified in simulated real-time scenarios for both the lumbar puncture and the ultrasound-guided epidural procedures. In the proposed system, the algorithm is implemented as a Slicer 4 module, as part of the SlicerIGT extension [2]. The PLUS [3] software library sends real-time needle tracking data which the module uses to perform online workflow segmentation.

RESULTS: The proposed system offers real-time feedback to medical trainees, which improves the learning experience for unsupervised practice of needle-based interventions. The algorithm provided 82% and 81% accuracy for the lumbar puncture and ultrasound-guided epidural studies respectively. For a random subsample, 84% consistency was found between manual segmentations, which were used as the ground-truth, and the algorithm demonstrated 93% accurate relative to this benchmark.

CONCLUSION: This algorithm performs workflow segmentation with sufficient accuracy for implementation in a medical training system. Current work focuses on adapting the algorithm to suit a medical training system and optimizing the algorithm for this real-time application.

[1] Holden, M. S., T. Ungi, D. Sargent, R. C. McGraw, and G. Fichtinger, "Surgical Motion Characterization in Simulated Needle-Insertion Procedures", *SPIE Medical Imaging 2012*, San Diego, California, USA, pp. 8316-31, 02/2012.
[2] SlicerIGT: Open Source Software Platform for Image Guided Therapy: https://www.assembla.com/spaces/SlicerIGT
[3] PLUS: Public Library for Ultrasound Imaging Research, https://www.assembla.com/spaces/PLUS