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Research-In-Progress

Vision-Based Tooltip Tracking for Automated Surgical Skill Assessment in Robotic Surgery

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Introduction: The rapid growth of robotic surgery emphasizes the need for effective and objective performance assessment. Current methods rely on expert analysis (Goh et al. 2012), which tend to be subjective, costly, and time-intensive. Our research aims to address this challenge by developing and validating standardized performance assessments through the measurement of surgical tool-tip smoothness metrics extracted from surgical videos by employing computer vision and artificial intelligence techniques.

Methods: To achieve automated, objective skill assessment, tracking of instrument movement becomes critical. For this purpose, we manually annotated tool-tips and poses in video frames sourced from the MICCAI Robotic Instrument Segmentation Sub-Challenge (2017), creating a labeled dataset. Pretrained deep-learning models were then employed and fine-tuned to detect instrument tips across frames.

Preliminary Results: We explored two types of deep learning models for tool-tip tracking - (1) Pose estimation models (Kurmann et al. 2017, POET) from which tool pose is estimated. These models did not train well, possibly due to few training samples. (2) Segmentation models (UNet, TernausNet, DeepLab-v3, FCN-resnet101) that are trained to segment out tool-tip regions. Current evaluations show that the FCN-resnet101 model predicts tool-tip locations best with a mean squared error of 14 pixels (1024x1280 image-size), with 89% of frames having successful detections on the MICCAI dataset.

Next Steps: We aim to improve tracking performance by using temporal consistency priors, more labeled data, and semi-supervised learning methods. These will be assessed on 25 robotic surgery videos capturing diverse expertise levels. Prior research has established correlations between surgical skills and the smoothness metrics obtained from tool-tip kinematics in endovascular surgery (Murali et al. 2021). Future work involves calculating similar metrics for tool-tips in the recorded videos. These metrics will determine if similar correlations exist with expert evaluations made using the GEARS rubric in the context of robotic surgery.