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2023-2024 Recipient of the Alfred Bader Fellowship in Memory of Jean Royce

A Summary Statement of the Studies and/or Research:

Title: Video-based surgical tool tracking for computer-assisted medical training
Background: Medical training today relies on the active presence of expert physicians to instruct and evaluate trainees, placing a huge burden on institutions as physicians struggle to find time to give their trainees adequate feedback which is critical to learning. These needs are acutely pressing in teaching needle-based minimally invasive surgical interventions, the focus of my research. In a medium-size medical school, the number of practice needle insertions exceed 20,000 a year, for trainees to acquire and retain the requisite skills in procedures like lumbar puncture and catheter port placement.

Computer-assisted skill assessment can alleviate the need for expert physicians and, at the same time, can improve the learning process. Unfortunately, current solutions rely on expensive position tracking systems to obtain surgical tool and hand motion data that are necessary for analyzing trainee performance. Video imaging offers an inexpensive alternative for position tracking. Researchers in computer vision have long been studying object tracking in video and recent advances in machine learning involving neural networks have made it possible to try out some of these techniques in surgical tool tracking. Nearly all existing research focused on laparoscopic surgery and microsurgery that cover only a tiny fraction of demands for training. Moreover, these techniques do not translate to needle-based procedures, where the workspace is larger, tools come in a greater variety of shape and size, and there are seemingly infinite variations in the manner competent physicians handle the tools.

Objective: I propose to develop an artificial intelligence (AI) system utilizing consumer webcam video technology fortified by novel deep learning methods to achieve accurate surgical tool tracking for quantitative skill evaluation. I will evaluate my system on a variety of medical procedures including: Central venous catheterization, percutaneous nephrostomy, cataract surgery and open inguinal hernia repair.

Methodology: I choose webcam video because it is affordable, easily accessible, requires minimal setup and calibration, and the technology can be translated to many other medical procedures. I will integrate a pair of inexpensive consumer webcams that will function as a cost-efficient alternative to a stereo camera. The webcams will be angulated to share a common focus, to allow tracking objects in three dimensions. To eliminate the dependence on bulky external markers that most optical tracking systems use, I will adapt neural networks that were originally designed for object detection, albeit with different input data. I will investigate if and how recent object detection neural networks can be repurposed for tracking surgical tools used in needle-based interventions.

Contribution to Open Science: Along with my previous work in video-based workflow recognition, I will implement the proposed methods and system on the 3D Slicer (www.slicer.org) free-open-source research platform. 3D Slicer is primarily used in medical image analysis, visualization, and offers facilities for computer-assisted intervention research, developed by my Queen's home lab. By making my well-curated imaging databank public, I intend to promote cooperation and communication in my field.

Contribution to Global Health: Queen's is co-leading in Train the Trainers, an international program to assist medical schools in Western Africa with free open-source software-based systems for learning digital anatomy, medical imaging, and minimally invasive interventions. By incorporating my work in the

3D Slicer platform, it will be distributed through the Train the Trainers program. My training system for percutaneous nephrostomy is currently deployed on loan for a pilot trial at Universite Cheikh Anta Diop and Ouakam Military Hospital in Dakar, Senegal.

Contribution to the Field: I aspire to provide clinical educators with a turn-key solution for objective medical skill evaluation, enabling them to develop novel training curricula for a wide variety of medical procedures. By integrating my research in the widely used 3D Slicer open-source platform, I wish to encourage free translation of my work to use by the medical imaging research community worldwide.