SKIM: Sensor based Surgical Skill Analysis

Thesis subject supported by the LABEX CAMI, http://cami-labex.fr/
Et la Région Bretagne

Thesis location: shared between LTSI (Rennes) and LIRMM (Montpellier)
Application should include CV and letter of motivation and be sent to pierre.jannin@univ-rennes1.fr
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Starting date : ASAP
Keywords : machine learning, surgical training, surgical robotic, skill evaluation, surgical data science.

1. Context and objectives of the research work

Existing computer-based surgical training and assessment systems mainly rely on evaluation metrics based on directly measurable results of the operation (completion time, instrument collisions, workspace overlapping, traveled length, etc.) to estimate performance scores [1]. The trainees have to practice repeatedly by themselves in order to improve their skills and performance if supervision from senior surgeons is not available, which often happens in reality. The relationship between trainee's hand motion and performance (quantitative scores) remains a black box without explanations from experienced surgeons. The objective of this research work is to develop an assessment system which would to be able to interpret the performance scoring numbers in a more "human" way, and to help the trainees with advises of semantic meanings on the arm, wrist, finger motion coordination like human supervisor. In this way, the learning through training will be more intuitive and efficient for the trainee.

The electromyographic (EMG) signal recorded at the surface of the skin contains important information regarding the state of the neuromuscular system [2,3]. Recent developments on this topic show that now, along with the kinematic motion information, the time-variant biomechanical or physiological properties (impedance, stiffness) of the hand wrist and fingers can be estimated from the sEMG signals at the same time as well [4]. Thanks to these latest research findings, it is possible to understand and analyze the surgeon's gestures from a deeper but more natural muscle state level which has direct link with the generated hand/finger kinematic motions. Therefore, the senior surgeon's both hand motion and wrist, fingers muscle state information can be recorded for a given operation paradigm as demonstrating reference. When the junior trainees practice the same operation, their performances are evaluated not only by the kinematic motion and force of operation but also by their muscle states. However, it should be noted that the EMG signal in general reflects the muscle activity for single movement or in a short time. Therefore, the problem to integrate the muscle state information obtained from EMG measurement into the whole training session is that the recorded EMG signal over long duration does not render clear patterns and may only appear as noisy data when examined as a whole. The promising solution is to segment the overall training session and thus the kinematic data according to different gestures, and then label each segment/gesture with the identified muscle state information (stiffness, impedance, etc.) from EMG measurements. In our previous study, an unsupervised machine learning based method has been proposed for automatic and quantitative assessment of surgical gestures which can automatically segment kinematic data from robotic training sessions and detect critical points in the kinematic data which define relevant spatio-temporal segments without relying on any prior information or model.

In this doctoral project, based on our previous study of unsupervised surgical gesture recognition [5,14,15] and research on neuromuscular and skill modeling based on EMG signal [6-13], we aim to develop new surgical training and assessment methods and systems which are more intuitive and efficient. This will be achieved by studying and integrating the muscle state information encoded in EMG data which are segmented according to different surgical gestures with the operation kinematic data of the trainee. This integration will be studied through both data driven and model driven approaches. Machine learning based approaches with deep networks will be studied to correlate both information. In parallel, simple biomechanical models may provide relevant a priori knowledge that may make easier the understanding of the relationships between EMG and kinematic data. Finally, this analysis will be used to suggest online/offline semantic advises on how to correct the gestures and implemented into a surgical simulation system to improve operation performance in more human-like way to facilitate the trainee's understanding and thus reduce the learning curve. This project represents a new topic that has not been addressed in the surgical training literature yet.

2. The CAMI context

Medical Interventions (surgery, interventional radiology, radiotherapy) can benefit from a significant boost for progress in terms of patient-specific optimal planning and performance. To fulfil the patient's demands for quality, senior operators demand to see beyond the immediately visible, to be assisted in their real-time vital decisions and to provide access to enhanced dexterity, while junior operators need to "learn to fly" before being left alone, and public health authorities and companies require demonstrations of the medical benefit of innovations.

The Computer Assisted Medical Interventions LABEX (CAMI LABEX) strategic vision is that an integrated approach of medical interventions will result in breakthroughs in terms of quality of medical interventions, demonstrated in terms of medical benefits and degree of penetration of CAMI technology in routine clinical practice.

3. More information

This PhD will rely on the expertise by both Universities in their respective areas, namely surgical data science and surgical robotics. The PhD student will work both in Rennes and in Montpellier in part-time. He/she will be registered at the University of Rennes 1.

Required skills: The candidate should have a strong background in machine learning, data analysis and computer science. Additional experience in deep learning is a plus.

MediCIS website: http://medicis.univ-rennes1.fr

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