TECHNISCHE UNIVERSITÄT MÜNCHEN
Human-centered Assistive Robotics
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M A S T E R ' S T H E S I S
for
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Motion Primitive Learning for Robot-Assisted Surgery

Problem description:

Surgical robotics is an important field of research due to various advantages over traditional surgery, especially in minimally invasive cases. With the advances in artificial intelligence, surgical activity recognition in robotic surgery has become an important research area. Surgical activity recognition has the potential to bridge the gap between the surgeon and the patient by providing assistance according to surgical context. Another possibility is to improve the learning curve of surgical robotic systems or surgical procedures by identifying shortcomings of the trainee. However this research area is still not fully explored. Previous research has been done on surgical activity recognition using Hidden Markov Models and Conditional Random Fields with promising results. However, they require frame-level labeling and prior analysis of individual surgical tasks, or *gestures* in terms of *grammar graphs*, which describe the temporal relationship between subtasks. Additionally, they require the whole data before training [1]. While most of the research in the area is based on supervised learning, research has been done recently using unsupervised learning as well. Despinoy et al. use polynomial approximations and support vector machines to segment and classify surgical gestures with promising results [2]. Krishnan et al. present Transition State Clustering for unsupervised segmentation of kinematic data. However these approaches consider only individual gestures and not the relationship between them [3]. Incremental motion primitive learning has been previously shown to perform well on full-body human motion recognition [4]. The approach is unsupervised; it segments and classifies the segments of motion, called *motion primitives*, depending on their similarity. Moreover, the method generates motion primitive graphs automatically from the training data, similar to grammar graphs, mapping the temporal relationship between motion primitives. Additionally, the method is an incremental one, continuously improving the model using new data. The goal of the thesis is to implement a suitable variant of the outlined approach to the MiroSurge System. The implementation will be tested on suitable standardized training tasks [5, 6]. The data will be collected from a user study performing these tasks. The evaluation will be done by comparing the results with other approaches as well as evaluating the implementation on open source benchmark data sets [1].

Tasks:

- Literature research: Surgical activity recognition, motion primitive learning, unsupervised sequence learning
- Decision on training tasks [5, 6]
- Implementation of algorithms: Motion primitive segmentation and learning [4]
- User study for data acquisition
- Feature selection
- Comparison of algorithm performance to other approaches
- Performance on open source benchmark dataset
- Optional: Live demonstration of the algorithm for on-line classification

Bibliography:

[1] Ahmidi et al. A dataset and benchmarks for segmentation and recognition of gestures in robotic surgery. *IEEE Transactions on Biomedical Engineering*, 64(9):2025–2041, Sept 2017.

[2] Despinoy et al. Unsupervised trajectory segmentation for surgical gesture recognition in robotic training. *IEEE Transactions on Biomedical Engineering*, 63(6):1280–1291, June 2016.

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[4] Kulić et al. Incremental learning of full body motion primitives and their sequencing through human motion observation. *The International Journal of Robotics Research*, 31(3):330–345, 2012.

[5] Laparoscopy - uroweb. `http://uroweb.org/education/online-education/surgical-education/laparoscopy/`. Accessed: 22-01-2018.

[6] Lübecker Toolbox - Training. `http://www.luebeck-toolbox.com/training.html`. Accessed: 22-01-2018.

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