Learning-based Object Tracking for Transfer Tasks in Laparoscopy Training

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Abstract. A real-time, image-based training scenario comprehension method is proposed in this paper. This method is being developed to support a visual and haptic guidance system for laparoscopic surgery skills training. The target task of the proposed method is a simulation model of a peg transfer task, which is one of the hands-on exam topics in the Fundamentals of Laparoscopic Surgery certification. A machine learning-based image understanding is proposed to generate a system object state of the peg transfer task to support the guidance system. An Artificial Neural Network (ANN) is used to discern the object state by using without the aid of any object template or model.

Keywords: Medical simulation; simulation-based surgical training; laparoscopy; image understanding; machine learning.

1 Introduction

Laparoscopic surgery is a popular technique, which benefits patients by minimal invasiveness and fast recovery time. However, to be a well-trained surgeon, one needs extensive practice in a simulated environment before operating on patients. A simulation-based training device, Computer Assisted Surgical Trainer (CAST) [1] [2], has been designed for laparoscopic surgery skills training. CAST is a simulation-based training device with visual and haptic guidance rendered to its users.

The Fundamentals of Laparoscopic Surgery (FLS) [3] program was developed by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES). This program has multiple hands-on exams for trainees to learn the basic laparoscopic skills. The first hands-on exam in FLS program is the peg transfer task. In a simplified scheme, trainees need to manipulate one instrument to grasp a rubber ring like object (triangle) from a peg, carry this triangle in mid-air, and then place the triangle on a different peg on the other side of the board. In this task, CAST provides trainees visual and haptic guidance based on the system object's states [4]: *hold*, *move*, *grasp*, *carry*, *put*, and *drop*.

In the peg transfer task, the intuitive way to detect the state is to use images from a camera. This process is often called object tracking [5]. In this paper, we propose a learning-based object tracking (LBOT) method without using any object template [6] or model to detect the object state of the transfer task.

2 Design concept and architecture

The design concept of LBOT is driven by the need to simulate the system object for our problem. The detected state is the basis of the visual and haptic guidance of the CAST system. LBOT provides real-time implementation of the state detection.
The system is composed of two major processes: a) feature extraction and b) classification. The system inputs are two consecutive frames of the source video image sequence, and the system output is the object state. In the process of feature extraction, the input images are processed by considering several features such as luminance, color, and motion difference. These features are utilized to synthesize the feature image. The second process is classification, which converts the feature images to system object state by using an Artificial Neural Network (ANN) algorithm [7]. The predefined feature image and object state training sets are fed to the ANN whose kernel is generated in an offline manner. Using this ANN kernel, the system object state can be calculated from the input feature image in the online, real time mode.

3 Summary

This paper proposes an LBOT method to detect the system object state of the peg transfer task in the FLS program. This method detects the state based on the image feature extraction and an ANN algorithm without any object templates or models. We will demonstrate its robustness and efficiency to meet requirements of real-time applications (training tasks) in the CAST system. Although the LBOT method is currently implemented in the simplified peg transfer, it has a great potential to be extended to the complete peg transfer task and other tasks of the FLS program.

References

1. Rozenblit, J. W., et al.: The Computer Assisted Surgical Trainer: Design, Models, and Implementation. Proc. of the 2014 Summer Simulation Conference, Modeling and Simulation in Medicine, pp. 211-220. (2014)
2. Nikodem, J., Wytyczak-Partyka, A., and Klempous, R.: Application of Image Processing and Virtual Reality Technologies in Simulation of Laparoscopic Procedures. In International Conference on Computer Aided Systems Theory, pp. 463-470 (2015)
3. Fundamentals of Laparoscopic Surgery, http://www.flsprogram.org
4. Hong, M. and Rozenblit, J.W.: Modeling of a Transfer Task in Computer Assisted Surgical Training. Proc. of the 2016 Spring Simulation Conference, Modeling and Simulation in Medicine, pp. 794-799. (2016)
5. Athanesious, J.J., and Suresh, P.: Systematic Survey on Object Tracking Methods in Video. International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) 1, 8, pp. 242-247. (2012)
6. Hu, W., Tan, T., Wang, L., and Maybank, S.: A survey on visual surveillance of object motion and behaviors. IEEE Transactions on Systems, Man, and Cybernetics, Part C, 34(3), pp. 334-352. (2004)
7. Rogers, S., and Girolami, M.: A first course in machine learning. CRC Press, (2015)