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SIDF: A Novel Framework for Accurate Surgical Instrument Detection in Laparoscopic Video Frames

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Abstract

Background and Objectives: Identification of surgical instruments in laparoscopic video images has several biomedical applications. While several methods have been proposed for accurate detection of surgical instruments, the accuracy of these methods is still challenged high complexity of the laparoscopic video images. This paper introduces a Surgical Instrument Detection Framework (SIDF) for accurate identification of surgical instruments in complex laparoscopic video frames.

Methods: Based on the Generalized Near-Set Theory, a novel image segmentation algorithm, termed Generalized Near-Set Theory-based Image Segmentation Algorithm (GNSTISA) was developed. According to SIDF, first GNSTISA is executed to segment the laparoscopic images. Next, the segments generated by GNSTISA are filtered based on their color and texture. The remaining segments would then indicate surgical instruments.

Findings: Using the laparoscopic videos of varicocele surgeries obtained from Hasheminezhad Kidney Center, the performance of GNSTISA was compared with previous image segmentation methods. The results showed that GNSTISA outperforms the earlier algorithms in term of accurate segmentation of laparoscopic images. Moreover, the accuracy of SIDF in identifying the surgical instruments was found superior to that of other methods.

Conclusions: SIDF eliminates the limitations of previous image segmentation methods, and can be used for precise identification of surgical instrument detection.

Keywords: Laparoscopy, Surgical instrument detection, Image segmentation, Generalized Near-set Theory

Background and Objectives

Laparoscopy is a relatively new minimally-invasive surgery method, in which, the surgeon rather than looking directly into the inside of the patient's body, uses a camera inserted into the patient's body called “laparoscope” to perform the surgical operation. The laparoscopic video frames can be recorded and processed to yield valuable information. The extracted information can be used in improving the operation room performance, surgical simulations, and robotic surgeries. Simulating a laparoscopic surgery can be used in training surgeons and enhancing their surgical skills [1].

Segmentation of laparoscopic video frames and identifying surgical instruments in each frame allow for extraction of more useful information. For example, time-waste in each laparoscopic surgery can be identified and analyzed using surgical instruments' pattern of usage and motion track. Analysis of laparoscopic time-waste in turn can lead to identification of its causes, thereby helping reduce the potential time-waste, and hence improve the efficiency of resources utilization and shorten the time required for each surgery.

In image segmentation, the pixels are grouped into different homogeneous regions using mathematical algorithms [5]. Several image segmentation algorithms have been introduced [5, 11-15]. While in some methods, images are segmented based on their texture features [11-13, 16], others employ color features for segmentation [17-20]. There are also a number of methods, which combine color and texture features for image analysis [5, 15].

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