

Minimally Invasive Surgical Video Analysis: a powerful tool for Surgical Training and Navigation

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Abstract. Analysis of minimally invasive surgical videos is a powerful tool to drive new solutions for achieving reproducible training programs, objective and transparent assessment systems and navigation tools to assist surgeons and improve patient safety. This paper presents how video analysis contributes to the development of new cognitive and motor training and assessment programs as well as new paradigms for image-guided surgery.

Keywords. Minimally invasive surgery, video analysis, training, navigation

Introduction

Automatic analysis of minimally invasive surgery (MIS) videos captured by the endoscope has the potential to drive new solutions for safer surgeries. Reproducible training programs, objective and transparent assessment systems and navigation tools to assist surgeons and improve patient safety can be developed by means of the analysis of video sequences [1]. Surgical video sequences provide useful information about the position of instruments and organs, surgical maneuvers, measurements of distances or even an approximate 3D reconstruction of the surgical scene. Endoscopic video images are an always available source of information and can be used without adding extra technological components in the operating room (OR).

Cognitive and motor training can benefit from the use of video images captured by the endoscope since they can be useful multimedia didactic resources [2]. Early familiarization with the view present in the operating rooms can shorten learning curves of trainees. Existing video repositories appear bound to web technologies for cognitive on-line training, enabling anytime-anywhere education.

Endoscopic video analysis can also be useful for assessment of surgeon's skills. Motion analysis of the laparoscopic instruments' movements has been proven to be a relevant source of information on psychomotor performance [3]. Video-based tracking can offer an alternative to sensor-based systems to this end, which are usually bulky and may modify the instruments' ergonomics.

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Finally, video information can help surgeons during procedures providing surgical guidance, strongly relying in the information conveyed by the endoscope to track all elements (instruments, laparoscope, trocars and anatomic structures) in the surgical scene. In this research we compile our advances using video analysis for training and navigation fields.

1. Surgical training

The paradigm change from traditional surgery to minimally invasive procedures has brought forth a necessary change in education programs for new surgeons: because of the reduced time available for education, training based on mentor-apprentice relationship is no longer sufficiently efficient.

In order to deal with cognitive training, a learning platform based on Technology Enhanced Learning for achieving a personalized learning experience while using pedagogically inspired solutions was implemented [4]. This platform is envisaged as a new cognitive learning concept to create, share and reuse scalable didactic content and to adapt content to learners' individual needs according to pedagogical models. The proposed environment has a four-pillared architecture: (1) an authoring tool that allows the creation of video-based, structured, enhanced, didactic contents; (2) a learning content and knowledge management system that provides adaptive learning to users based on their progress and behaviors in the training platform as well as a modular and scalable system to capture, catalogue, search and retrieve multimedia content; (3) an evaluation module that provides both formative and summative feedback to the trainee; and (4) a professional network for collaborative learning.

In this environment creation is not simply understood as a matter of digitalizing traditional materials; it also involves new approaches to constitute a well-designed surgical educational process. The environment incorporates a multimedia didactic authoring tool that offers the creation of formal learning content, the efficient use of surgical videos with enriched didactic value and the addition of multimedia objects to enhance surgical explanations.

Moreover, a video-based method for tracking laparoscopic instruments, named EVA Tracking System, was implemented in order to deal with motor training [5]. The system exploits 2D information of the instruments on the screen and detects the instruments' borders and tips. Analysis of geometrical properties of the instrument allows obtaining the 3D depth component.

The first prototype was validated with offline recordings of a MIS assessment task in a box trainer environment. Several motion-related measurements were obtained for each participant, and statistical analysis on performance was carried out. The study reflected construct validation when comparing performance of students, residents and experts; and concurrent validation when comparing measurements with an optical-based sensor system.

2. Surgical navigation system

Planning and navigation systems arise to aid surgeons during procedures. Navigation systems allow to transfer preoperative data, images and decisions from the planner directly into the OR, giving surgeons guidance during the procedure. Difficulties arise

in soft-tissue surgeries where the lack of rigid landmarks makes harder to correlate intraoperative and preoperative data, due to anatomical alterations caused by organ-shifting, tissue deformations, patient movement and surgeon's manipulation.

Analysis of minimally invasive surgical videos allows the creation of a new image and video guided surgery paradigm for soft-tissue navigation based on the intelligent exploitation of the information provided by the endoscopic video [6]. Three main motivations lie behind it: (1) enabling surgical guidance without modifications of the surgical workflow; (2) tracking surgical objects (instruments, anatomic structures and endoscope) without alterations of their ergonomic properties and (3) avoiding cluttering of equipment in the already overloaded space in the OR. A surgical navigation prototype for liver surgical treatment was implemented following the paradigm, with a flexible design to ease integration into the surgical work flow, using non-intrusive technologies to minimize disturbances to surgeons during procedures.

As tracking presents even greater challenges due to pneumoperitoneum phenomena, and the use of markers and optical or electromagnetic systems to track deformations is not a feasible solution in many cases, automatic video processing provides information regarding position of instruments, organs, trocars and endoscope, surgical maneuvers, distances and 3D reconstructions of the surgical scene offering new information to surgeons when performing interventions.

3. Conclusions

Laparoscopic video, an ever-present resource in minimally invasive surgical techniques, may be further exploited to overcome some of the limitations of this type of surgery. Its analysis can be a powerful tool for surgeons. The use of endoscopic video images has several benefits: it is an always available information source that can be used without increasing surgeons' workload does not add extra technology components in the OR. Several examples have been shown both for developing new training environments and for creating new navigation systems with intraoperative aids to the surgeons.

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