A laparoscopic hybrid simulator for skills assessment and augmented reality surgical applications

Article *in* International Journal of Computer Assisted Radiology and Surgery · January 2011

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Keywords Laparoscopic suturing · Objective assessment · Tool-motion analysis (TMA) · Augmented reality haptic (ARH)

Purpose

Objective assessment of surgical skills is an up-to-date field of research. As being considered one of the most complex procedures [1], most efforts are focused on laparoscopic suturing task [2]. For this reason, different kinds of simulators have been used to train suture skills in the last years [3] and several tracking systems were developed to automate the objective assessment (ICSAD, ADEPT, ARH and other) [2, 4].

The Hand-Motion Analysis (HMA) has been used in minimally invasive surgery studies [5]. However, the use of Tool-Motion Analysis (TMA) which analyses the tooltip movements instead of the hand movements, could improve the results of the objective assessment for laparoscopic procedures. This paper presents an analysis of different parts of the laparoscopic suturing task using TMA in order to decide whether they can improve the current objective assessment tools.

Methods

Twelve people have participated in this study and three groups of four surgeons have been created: novices (minimal hands-on experience in camera guidance), intermediates (between 10 and 50 laparoscopic procedures) and experts (more than 50 cases in laparoscopic surgery). A Simulap-IC05 box-trainer and organic tissue (carcass stomach) were used to perform the experiment while tools movements were recorded with the ARH system. All subjects were right-handed and developed a surgeon's knot. The whole laparoscopic suture was decomposed into four subtasks: *needle puncture*, *first knot* (double looping), *second* and *third knot* (single looping) and different objective metrics were applied during the TMA: *total time* that is the elapsed time before the surgeon can accomplish the subtask, *total path length* performed by the tooltip, *partial path length* defined as the mean path that the user moves the tooltip at the data acquisition rate of the ARH system (approx. 30 Hz), *average speed* of the tooltip and *number of movements* (a new movement of the tooltip is considered when acceleration is zero). A statistical analysis was made and results from three groups were compared with the Kruskal–Wallis test, considering significant differences when $P \leq 0.05$.

Results

At least one of the evaluated metrics of each subtasks presented significant differences between the three groups. Nevertheless, subtasks 1 and 2 present a greater number of significant metrics than subtasks 3 and 4. Figure 1 shows the results of the most relevant subtask (*first knot*). Horizontal bands indicate medians, boxes indicate 25th and 75th percentiles and whisker lines indicate highest and lowest values. Almost all used metrics obtain a better punctuation to the executions accomplished by experts (lower time, total path length and number of movements) than those made by intermediates and novices.

Conclusion

The most important subtasks during suture learning process are *needle puncture* and *first knot*. In the *first knot* subtask, all used metrics obtain significant difference between the three groups (novice, intermediates and experts), with exception of *partial path length* of the right tool. Nevertheless, the first subtask (the *needle puncture*) can distinguish between three levels of surgical experience in five of the nine metrics too.

In conclusion, decomposition of laparoscopic suturing task has contributed to know the most relevant subtasks for training purpose. Furthermore, the TMA could be a useful objective assessment tool to discriminate surgical experience and could be used in the future to certificate surgical proficiency.

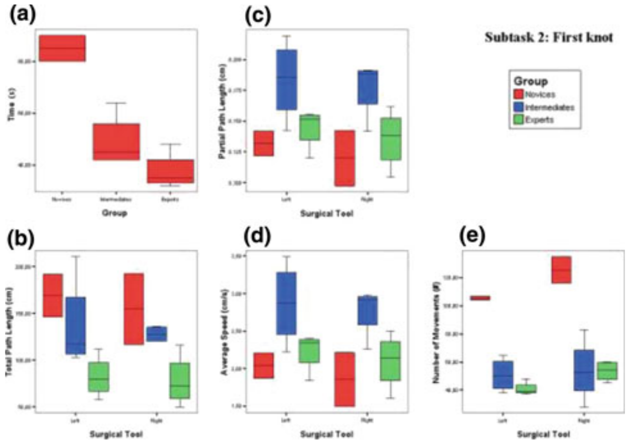

Fig. 1 Comparison of the metrics between novices, intermediates and experts for subtask 2 (*first knot*). Total time (**a**), total path length (**b**), partial path length (**c**), average speed (**d**) and number of movements (**e**)

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A laparoscopic hybrid simulator for skills assessment and augmented reality surgical applications

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Keywords Laparoscopy · Laparoscopic instrument tracking · Training · Video-based tracking

Purpose

In minimally invasive surgery, surgeons traditionally begin their surgical education by observing experienced surgeons in the operating rooms. However, objective assessment of the surgeons' skills is still a challenge, because nowadays there is no an automatic objective assessment method of basic laparoscopic surgical skills that are widely used [1]. During this evaluation process and execution of the training tasks by the surgeon, images displayed on monitors provide the main source of information for the surgeon.

A real-time system for training assistance in laparoscopic surgery is presented. This system provides support visual content during the execution of the laparoscopic training procedures, tools to carry out an automatic three-dimensional video-based tracking of the laparoscopic instruments, and a more reliable image of the surgical scenario.

Methods

To assist the laparoscopic training process, we insert support content into a stable position of the workspace using a visual tracking method of a point marked by the surgeon in the field of vision. A stereoscopic system inside the physical laparoscopic simulator SIMULAP-ICO5® (CCMIJU, Cáceres, Spain) has been installed to track the position of the laparoscopic instrument during the training tasks (Fig. 1). To evaluate the system's precision in calculating the depth position of laparoscopic instruments, we computed the accumulated distance error [2].

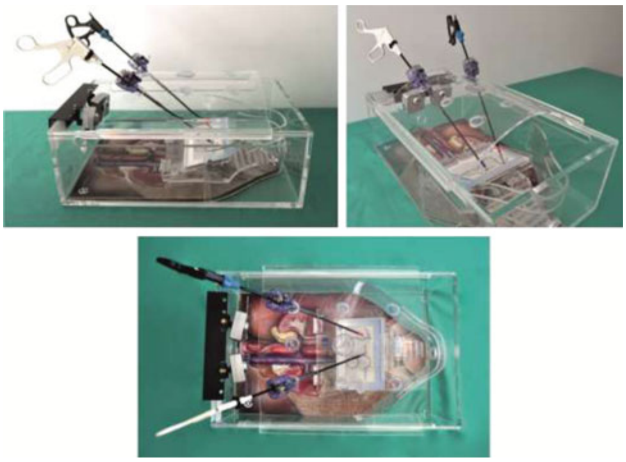

Fig. 1 Physical laparoscopic simulator with the stereoscopic system. This stereo system allows tracking the 3D position of the laparoscopic instrument in real time

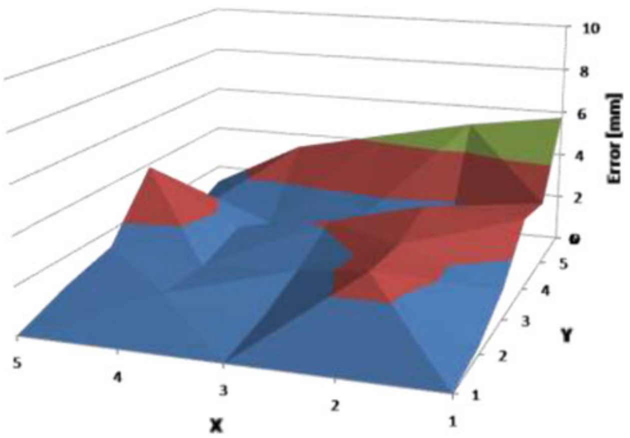

Fig. 2 Graph of the accumulated distance error. The distances are computed between the depth value (*Z*) of the first row $P(i, 1), \quad i = 1, \ldots, 5$ and the remaining rows in the measurement grid $P(i,j), \quad j = 1, \ldots, 6$

Results

We implemented a dynamic artificial environment which represents the working area of the training procedure to show the three-dimensional location of the laparoscopic instrument and the visual support content. The maximum depth error obtained by the tracking system is 5.750 mm at 415 mm from the stereo system (Fig. 2).

Conclusion

The proposed system provides surgical assistance during the laparoscopic training process and performs a three-dimensional video-based tracking of the laparoscopic instrument's tip which is a useful tool to carry out an objective assessment of surgical skills. Similarly, this device is an important step in the development of surgical support scenarios based on Augmented Reality.

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Medical hybrid model generation with Polyjet Matrix rapid prototyping technology based on CT data

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Keywords Reverse engineering · Hybrid model · Rapid prototyping · CT · Polyjet matrix

Purpose

Rapid Prototyping (RP) techniques allow for creating physical models of real anatomical structures. Polyjet Matrix allows additionally for fabrication multipart, multimaterial structures within the same object. It could be extremely useful for manufacturing hybrid models of both: bones and soft tissue in one technological process. For medical object, data can be obtained from CT, MR or rotational angiography. The application of this technology can be widespread along with the modern data acquisition systems, especially Computer Tomography (CT). Commonly used spiral computer tomography can be utilized for data preparation for hybrid modeling. The aim of this work is:

- To present the application of Reverse Engineering and Polyjet Matrix RP technology to multistructure medical model manufacturing,
- To work out,
- To present the areas of possible applications, the virtues and limitations of proposed method,
- To manufacture real hybrid models using rapid proto-typing technology based on CT data.

Methods

CT examination of 38 years male's jaw and mandible regions with easily visible teeth deficient was performed using Siemens Somatom Sensation 16 CT scanner for method evaluation. The dedicated scanning protocol was applied (collimation 0.6 mm, slice thickness 0.6 mm, reconstruction increment 0.5 mm, sharp kernel U80u, matrix 512 × 512 pixels, reconstruction FoV (Field of View) adjusted to jaw and mandible region) to get the highest possible spatial resolution with acceptable imaging noise level for soft tissue