Technical Note

Introduction of the SinaSim: A Low-Cost Laparoscopic Surgery Simulator Using Virtual Reality Environment

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ABSTRACT

Purpose- Virtual reality based minimally invasive surgical trainers have been proved to be highly effective for training of surgical residents before clinical practice. In this article we introduce the SinaSim, a low-cost laparoscopic surgery simulator based on virtual reality environment.

Methods- The most important part in developing a virtual reality system is to making the virtual reality software of a surgical practice and modeling the physical properties and reaction of soft tissues in real time. At SinaSim we used a newly developed graphical engine to minimize the cost and maximize the widespread usage of this system.

Results- Screenshots of the final graphical view of each training task as well as graphical user interface which provides the trainees with necessary information about their learning progress, are included in this report.

Conclusion- The preliminary results of this study shows that the performance of both hardware and software of the SinaSim laparoscopic surgery simulator are comparable with a commercial virtual reality based trainer in spite of its lower final price.

1. Introduction

Technical skills are of paramount importance in surgery. To learn and to develop these essential skills, different methods are available. The traditional method for learning surgery is hands-on experience in an operating room, albeit under supervision of an expert surgeon which is proved to be costly [1].

With the introduction of new surgery techniques, especially Minimally Invasive Surgeries (MIS), a set of required skills for surgery has been altered; hence, new training methods are necessary [2]. To practice those newly developed surgery techniques in which Laparoscopic surgery is involved, a skill acquisition program of surgical residents can start by video box trainers or virtual reality simulators.

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Using any of these two methods before clinical practice can effectively improve learning progress; although, merits and demerits of each methods differs [3, 4].

In spite of the fact that virtual reality systems can never completely simulate reality, their ability to recreate different surgeries and various aspects of surgical situations can be noteworthy [5]. These capabilities of virtual reality simulators have made them one of the most widespread methods for skill acquisition in laparoscopic surgery training. Currently, several commercially available laparoscopic surgery trainers which depend on virtual reality simulation, exist [6, 7] with the base price of more than 50,000 USD. Considering the low education budget in developing countries and the necessity to keep different aspects of medical education process up to date, the development of a low cost laparoscopic surgery trainer in virtual reality environment can not only enhance the skill acquisition procedure for laparoscopic surgery greatly, but also will provide a solid foundation for medical training through virtual reality [8, 9].

Figure 1. The SinaSim laparoscopic surgery simulator [10].

2. Materials and Methods

2.1. Hardware

SinaSim laparoscopic surgery simulator is designed to fully reconstruct surgeon's posture during a laparoscopic surgery. To maximize the similarity of the training process and the surgery, standard laparoscopic instruments have been used. Each of these instruments have the same degrees of freedom of an instrument in real surgery. They are attached to each other with a crescent-shaped link which is fixed on a moving mounting. The mounting is placed on a trolley that carries the computer, monitor, mouse and keyboard. Figure 1 shows the SinaSim laparoscopic surgery trainer.

A microprocessor uses position sensors to measure the state of each degree of freedom to fully define an instrument's position and orientation in its state space. Each instrument has five degrees of freedom including: pitch, yaw, roll, insertion and grasping which each of them connected to a position sensor independently. All of these sensors are connected to the microprocessor installed on the bottom of the moving mounting which communicates with computer through a single USB port.

2.2. Software

To improve and also to assess the essential skills that are important in laparoscopic surgery of those who train with SinaSim, it includes 5 different training tasks, each of which focusing on different aspects of the necessary psychomotor skills.

These essential training tasks strive to better trainee's depth perception, eye-hand coordination, object manipulation, endoscope navigation and the use of laparoscopic instruments.

The software on the computer communicates with SinaSim's microprocessor through the USB port. As it was described in hardware section, the software uses 5 principle joint positions to obtain each laparoscopic tool's position and orientation from the microprocessor. Raw input data from USB is processed by a driver application and then fed into virtual environment software.

The virtual reality software includes a set of objects for each training task. A portion of these objects are rigid bodies; they can be effected by laparoscopic tools, other rigid bodies and static objects. Other objects are static and beside graphical interface, they can only impose physical constraints

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on other rigid bodies and cannot be moved. Both laparoscopic instruments are introduced into virtual environment as dynamic bodies. They will move according to user's hand movement and can collide with other rigid bodies.

For each frame, the position and orientation of each object is calculated by physics engine and simultaneously, the graphics engine renders the final image to be displayed, accordingly. Since there is no force feedback in hardware, the position of dynamic objects (laparoscopic instruments) are restricted by the software.

The software displays the elapsed time on the upper right corner of the monitor. As the trainee proceeds to complete a task, the number and duration of errors are tracked by the software. To quantify the skills of each trainee, his or her score decreases by a constant rate as time passes. In case of minor error, the score will be reduced by a higher rate. In this scoring system, major errors are reflected by a sudden decline in score.

Each user can sign into the program with an ID and corresponding password. After each training task, the completion time and the total score is stored on a database for each user. The software uses this data to draw user's learning curves for each training task, which will allow the trainee to track the development of his or her skills. Also, these performance data can be used to measure and assess the trainee's current skill level.

3. Results

Figure 2 shows a scene from each different skills training tasks designed for the SinaSim laparoscopic surgery simulator. The real-time graphics and physics simulated by the virtual environment software are lifelike and are rendered at 60 frames per seconds (on average) by the computer included in the trainer.

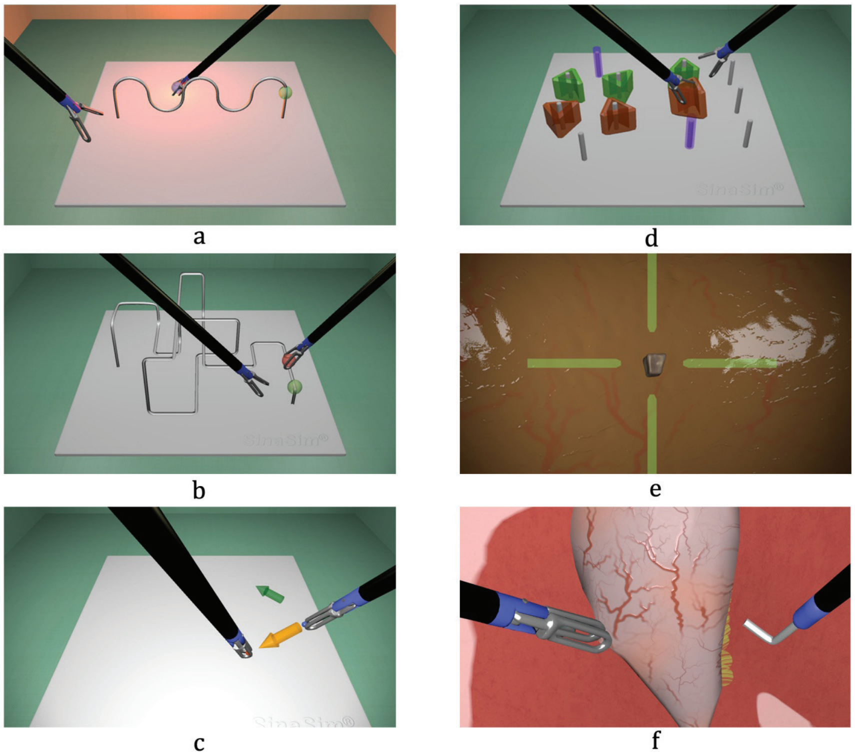

Figure 2. The SinaSim training tasks simulation: (a) Simple Path Navigation, (b) Advance Path Navigation, (c) Object Manipulation, (d) Peg and Hole, (e) Camera Navigation, (f) Laparoscopic Cholecystectomy.

Figure 3 represents the graphical user interface which shows the progress of trainee's skills. Note that this feature is only available to registered users and the performance of those who log in with a guest account cannot be tracked. New users can sign up and create their own account to ensure that their learning progress will be recorded.

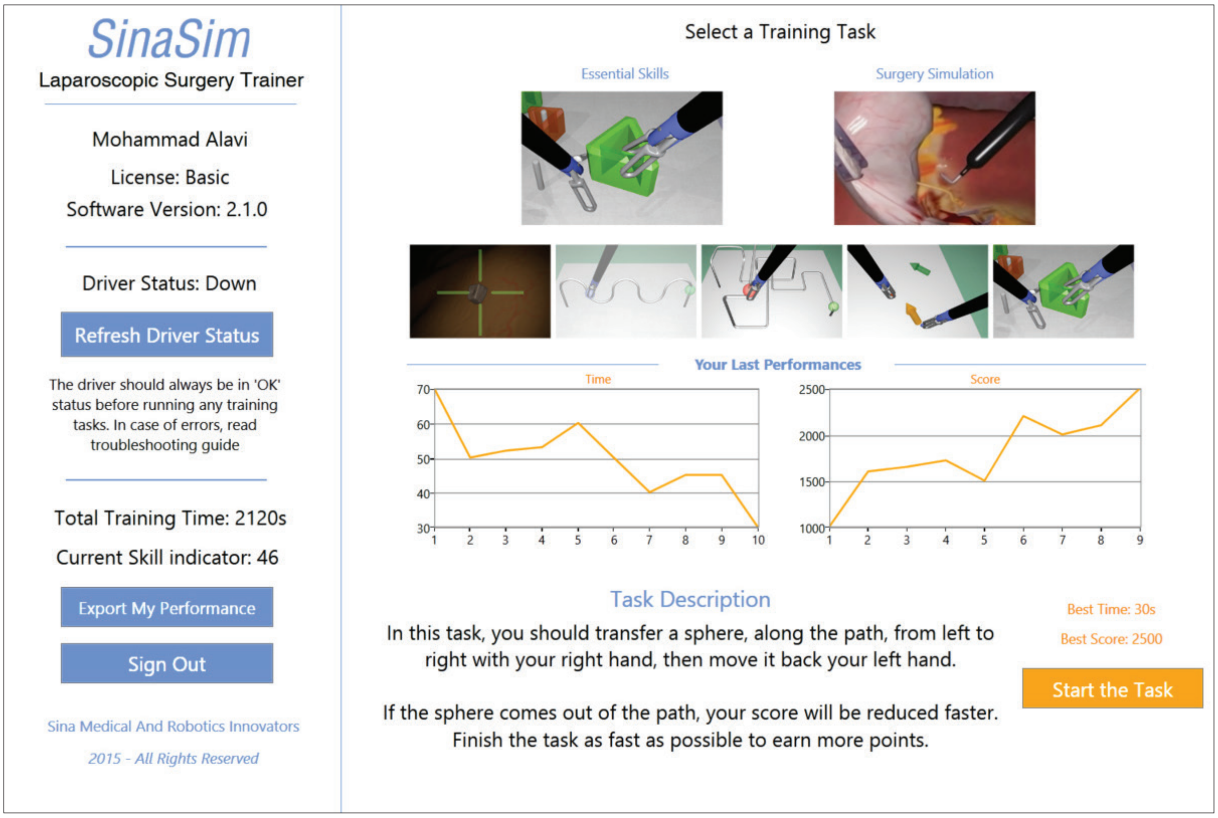

Figure 3. Graphical User Interface of the SinaSim.

The final configuration of the SinaSim laparoscopic surgery simulator is shown in Figure 1. The electronic parts including the microprocessor are hidden on the bottom of the mounting, while the computer is installed horizontally on the lower part of the trolley.

4. Discussion

We investigated the basic feature of the SinaSim laparoscopic surgery simulator in this report as well as the rationale of our focus on this field of medical education. The physics and graphics of the final version of the SinaSim have great credibility and are comparable with other competitors in this regard.

As the concept of virtual reality is experiencing an exponential increase in its popularity because of the emergence of high performance computers and physics and graphics engines, the development of a laparoscopic surgery trainer based on virtual reality can be a step toward a more effective preclinical curriculum based on virtual reality for medical educators.

The preliminary investigation of the SinaSim laparoscopic surgery simulator showed that its graphical quality, motion tracking accuracy and software capabilities are up to the standards of the current commercialized virtual reality surgery trainers. Further performance assessments and the evaluation of the effects of skill acquisition through virtual reality for laparoscopic surgery training are necessary and are currently under study.

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