LAPAROSCOPIC SKILLS SIMULATOR: A GRADUAL STRUCTURED TRAINING PROGRAM FOR ACQUIRING LAPAROSCOPIC ABILITIES

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ABSTRACT

Aim of this study is to investigate the importance of acquiring basic and avdanced laparoscopic skills with a virtual reality low cost simulator in laparoscopic general surgery.
We considered six basic skills and five advanced skills.
The first exercises are related to the acquisition of tasks which allow students to reach basic gestures competences.
In the second phase students will perform complex drills acquiring a correct gesture in the use of specific instruments.
We developed a standardized, graduated and evidence-based curriculum.
The team designed a new software able to handle the training task, creating a virtual interface based on the concept "student - exercise – evaluation".
The results are “attended results” because the data analysis will be possible only after a period of testing of the simulator on different samples of students. Referring to experience from other scientific groups, we expect significant results in terms of: reduction of learning time, better dexterity and ability to intervention in case of procedural errors.

Keywords: laparoscopic surgery, training, simulator, skills

1. BACKGROUND

The use of simulation in laparoscopic surgery training appears to be qualitatively effective if supported by a suitable evaluation system.
The continually increasing demand of more complex laparoscopic simulators has inspired the creation of a 4d simulator which is a physical low-cost laparoscopic training platform that reproduces the tactile feedback: eLaparo4d) integrated with a software for virtual anatomical realistic scenarios (Unity3D V 4.1).
The School of Medicine of Genoa and the Biomedical Engineering and robotic department (DIBRIS) have cooperated to create a low-cost model based on existing and brand new software.
Aim of this work is to describe the educational-training course and tools that students can use to achieve a complete mastery of surgical gestures till to the correct execution of a laparoscopic cholecystectomy task.

2. MATERIALS AND METHODS

For a correct evaluation of the training assessment, the team designed a new software able to handle the training task, creating a virtual interface based on the concept "student – exercise – evaluation".

2.1 The simulator system

The system is based on a nodejs application server that manages the visualisation system, the communication with hardware interfaces and the database where users' data are stored. The server technology is indeed a sort of data gateway between the several different elements, regardless they are hardware or software. The following figure (figure 1) shows how communication data are exchanged from the very low part of the system (Hardware Interfaces, bottom) to the user interface (HTML Client,top).

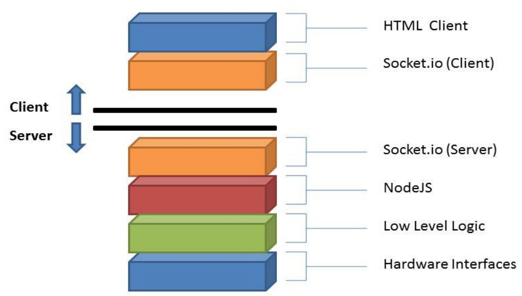

Figure 1: part of the system simulation

The user interface is a simple HTML5 web page running a Unity3D engine (12) plugin. We run several performance tests to compare Unity3D and native WebGL, getting same results. We finally decided to adopt
Unity3D engine due to its rapid development time. WebGL is a great technology but still too young to allow us working on a powerful and robust framework. The use of web pages as the main user interface allows us to be more versatile and in the future will give us the possibility, thanks to HTML5 powerful characteristics, to easily share contents in a live way with other systems. An interesting feature is, for example, having the possibility to be guided by an external supervisor, who is monitoring the training phase, while data are quickly exchanged via internet.

2.1.1 Visual and fisical modelling

As previously introduced, visual modelling is a very important aspect of the entire project. A videolaparoscopic surgery simulator needs a detailed representation of the organs and the tissues inside of the human abdomen. The meshes included in eLaparo4D are developed in Blender 3D Modelling software, and then imported in Unity3D, including textures and UV maps. Eventually, in Unity3D render shader materials are added to the raw meshes, to simulate the specific surface of each of the modelled tissues. In Figure 2, a screenshot of the current virtual environment is shown.

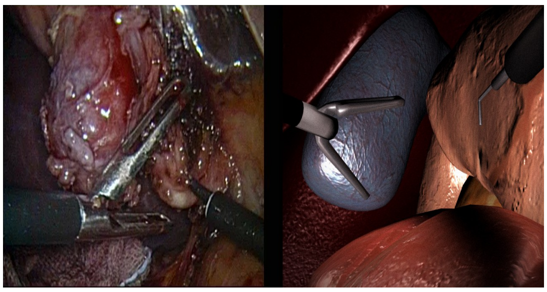

Figure 2: a screenshot from the current aspect of the virtual environment compared to a screenshot of the camera view of a real surgical operation.

As remarked by our colleagues of the Videolaparoscopy Unit of the Department of Clinical Surgery, highly specific training sessions are required to help the operator achieving a proper skill set. In an ideal scenario, medical students should have access to a complete simulator composed of several training scenes, as part of a modular and step-based training process. While the main components and controls of the simulator should be in common, each scene should focus on a very specific surgery operation, differentiating in: the zone and the organs physically manipulated (the target), the particular surgical maneuvers performed (the task), and the type of manipuli used (the means).Considering these remarks, we developed a dynamic parametric physical simulation approach, arbitrary applicable to the rendered meshes in every scene and able to avoid system overloads. Such an approach permits the creation of different scenes starting from the same set of models and interaction algorithms, easily supporting a step-based training. In detail, each 3D object in the scene carries a selectable 3 layer collider component, driving a vertex deformation script. The first layer is a simple box collider; the second one is a combination of simple shape colliders which cover, with good approximation, nearly all the volume of the object; the third is a precise mesh collider which exactly coincides with the vertex disposition of the object's mesh. In the foollowing figure (figure 3) is possible to see the 3 different collider layer for a gallbladder model.

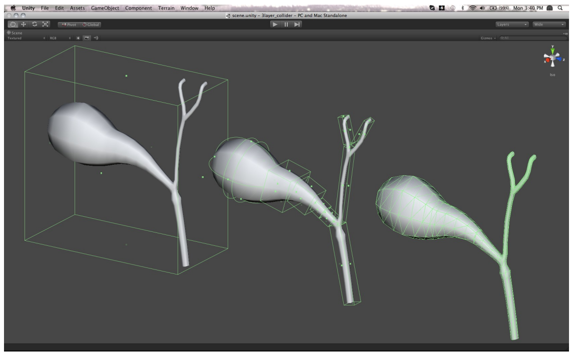

Figure 3: I.e of a collider layer for a gallbladder model

2.1.2 Feedback system

Haptic feedback is implemented thanks to the use of three Phantom Omni devices from Sensable. The first two are used as manipuli (grasper, hook or scissors) and the third one is used to move the camera within the virtual abdomen, as it happens in a real scenario. The system generates a resultant force when the user puts a manipulus in contact with a mesh, according to the executed task. Phantom devices have been chosen because reasonably low cost although precise enough for the needed level of realism. Furthermore, their stylus-like shape will permit a complete merging of the devices with the physical environment reconstruction; in particular, each stylus will be easily connected to real manipuli. Thanks to an Arduino board connected to a vibrating motor we have also included a vibration feedback. Vibration is used to enhance the realism of operations like tissue shearing (hook) and cutting (scissors).

2.2 The training model

The training course is divided into three main phases according to the literature review:

Acquisition of basic skills: exercises related to the acquisition of tasks which allow students to reach basic gestures competences. They could practice using probes that simulate the haptic feedback according to the kind of action.

We considered six different tasks:

1. Grasp: this task aims to evaluate the abiltity to grasp a object in a lot of position.
2. Transport: this task required the participant to grasp an object and to transport it to a target.
3. laparoscopic - focusing - navigation: This task aims to evaluate the ability to navigate a laparoscopic camera with a 30º optic. This is done by measuring the ability to identify 14 different targets placed at different sites. Each target includes a large symbol only identifiable from a panoramic viewpoint and a small symbol only identifiable from a close up viewpoint. The task starts by identifying the large symbol on the first target (i.e. 1) and then the small symbol situated next to it, which must be shown on the centre of the screen. This small symbol indicates the next large symbol to be identified. Following this order, the participant continues until the identification of the small symbol on the last target (i.e. end).
4. hand – eye – coordination (HEC): This task aims to evaluate the ability to navigate a laparoscopic camera with a 0º optic with the non-dominant hand (NDH) and to handle laparoscopic forceps with the dominant hand (DH). This is done by measuring the ability to grasp and transport six pre-defined objects to six pre-defined targets in the LASTT model, which is fitted with coloured objects (5 x 4 mm open cylinders) and coloured targets (10 x 1 mm nails). The matched targets and objects are identifiable by colour. The exercise starts by identifying a target and an object of the same colour. The object is then grasped, transported and introduced onto the relevant nail. Only when the participant has succeeded in introducing the cylinder into the matching nail is he/she allowed to continue with the next object.
5. pick – up: consists in moving a lot of object to different targets with different form.
6. ring and rail: consists in moving a ring along a twisted metal rod without applying excessive force to either the ring or the rail.

Acquisition of advanced skills: in this phase students will perform complex drills acquiring a correct gesture in the 'use of more specific instruments such as scissors, needle holder and retractors.

The main actions are classified in five classes:

1. cutting: This task required the participant to cut a circle from a rubber glove stretched over 16 nails in a wooden board. Penalty points were calculated when the individual deviated from cutting on the line. Score=time in seconds + surface of glove in milligrammes deviated from the circle.
2. knot tying: This task involved the tying of an intra-corporeal knot (two turn, square knots) in a foam uterus. A penalty was calculated to reflect the security (slipping or too loose) of the knot. Score= time in seconds + 10 when knot was slipping or loose.
3. work simultaneously: the purpose of this task is to evaluate the students' skills in handling the camera in one hand while working with an instrument in the other hand. The task involved moving three pieces of linen , one at a time, from one structure to another, which was so far from the first structure that both could not be seen in the camera at the same time.
4. touching clips: the purpose of this task consists in touching endoclips on a structure.
5. pipe cleaner: this task involved the placement of a pipe cleaner trough four small rings. A penality was calculated when a ring was missed . Score= time + the number of missed rings x 10

A progressive performance "step-by-step" of laparoscopic basic and intermediate abilities: this phase requires the simulation of surgery. The student works in a virtual surgical environment.
I.e.: five steps: cystic elements isolation, clipping, dissection, recovery, haemostasis procedures, that could the students complete a laparoscopic cholecystectomy.

For each phase common simple activities are defined to be evaluated,:

Vision/ navigation

Tools selection: the software allows the student to use several different operational devices: dissector, grasper, scissors, clip appliers).Through a graphical interface students will be able to choose the appropriate device.

Correct use of tool

Change of medical parameters: i.e. our software allows to manage the coagulation values and other conditions such as the level of pneumoperitoneum.

The educational assessment provides the application of gestural acquisition "step by step".
Students own their ID and password which allow the access to their virtual academic book and consequently to the exercises planned, updating their training through a personal academic profile.
The program manages the educational value of defining a standardized scale (Guilbert Scale) in relation to the

level of competence - mastery of a single surgical act: the scale consists of 5 points (0: no mastery ... 5: complete mastery).
The variables which can influence the evaluation are:

Score cut off: standard score benchmark below which the student will not have access to the next stage. This method was adopted both in the basic activities and advanced.
(Phase I: 30 pt; Phase II: 25 pt; Phase III: 25 pts)

Running time: each exercise is time-dependent; student will have a set time to complete the simulation. (Single Exercise Phase I: t = 180 sec, t = 240 sec phase II, phase III t = 800 sec)

Errors: quantified according to their severity (mild, moderate, severe) (slight error: - 1 pt; moderate error: -1.5 pt; serious error - 2 pt) and the difficulty related to the intervention's context (basic, intermediate, advanced) defining for each context a compensatory positive bonus value (base + 0 pt; intermediate + 0.2 pt; advanced + 0.5 pt).

3. ATTENDED RESULTS AND DISCUSSION

In the recent years the demand for laparoscopic simulators is growing up. Consequently, it becomes mandatory to make use of assessment instruments suitable to the complexity of new simulators in order to validate the training experiences even at advanced level.
In this sense, was carried out a review of the relevant scientific literature through PubMed and Medline database using the following keywords: simulation, skill, task, laparoscopic.
We provide a "scan" of the medical literature over the past 10 years in terms of simulation outcomes in laparoscopic surgery, learning efficacy years 2003-2013 (94 articles).
Ten studies were included in the review of the literature. The literature was categorized into three themes:

- internal outcomes
- external outcomes
- clinical evaluation

These works describe, in our opinion, the more specialized and main interesting learning experiences .
The aim of this study is to demonstrate the effectiveness of the suggested educational program. The model is based on the acquisition of clinical and gestural skills in laparoscopic surgery through the use of two integrated devices: the laparoscopic simulator "eLaparo4d" and the software for the virtual reality (Unity3D V 4.1).
We provides an experimental teaching to a sample of students, evaluating different variables such as the time of learning, the user satisfaction and the level of competence at the end of the clinical didactic trail. Preliminary results will be presented.
Our proposed curriculum represents an individual training program tailored to each trainee's needs and performance levels.
In this sense we established a set of benchmark criteria based on experienced surgeons' performance.
The concept of virtual training has been acknowledged for some years and a number of studies have been published on the importance of this new potentially rewarding technology.
The tasks were based on the studies of Derossis et al. The results of our study provide a firm basis for the simulation model to be implemented as mandatory in the residency training curriculum, with the laparoscopic experts' performance level as the training goal.
Simulator has just been introduced in the university curriculum.
The results are "attended results" because the data analysis will be possible only after a period of testing of the simulator on different samples of students. Referring to experience from other scientific groups, we expect significant results in terms of: reduction of learning time, better dexterity and ability to intervention in case of procedural errors.

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