

Serious game for psychomotor skills training in minimally invasive surgery: Kheiron Training System

L.F. Sánchez Peralta¹, J.B. Pagador¹, N. Skarmearas², G. Tsolkas², E. Fenyöházi³, W. Korb³, J. Sándor⁴, G. Wéber⁴, I. Oropesa^{5,6}, E. J. Gómez^{5,6}, G. A. Negoita⁷, C. Tiu⁷, F. M. Sánchez Margallo⁸

¹ Bioengineering and Health Technologies Unit, Jesús Usón Minimally Invasive Surgery Centre, Cáceres, Spain, {lfsanchez, jbpagador}@ccmijesususon.com

² AVACA Technologies S.A., Athens, Greece, nsarmearas@avaca.gr, tsolkasge@gmail.com

³ Innovative Surgical Training Technologies, Hochschule für Technik, Wirtschaft und Kultur Leipzig, Leipzig, Germany, {Fenyohazi, Korb}@istt.htwk-leipzig.de

⁴ Department of Surgical Research and Techniques, Semmelweis University, Budapest, Hungary, sanjozs@hotmail.com, gyorgyweber@yahoo.com

⁵ Grupo de Bioingeniería y Telemedicina, ETSI Telecomunicación, Universidad Politécnica de Madrid, Madrid, Spain, {ioropesa, egomez}@gtb.tfo.upm.es

⁶ Centro de Investigación Biomédica en Red en Bioingeniería, Biomateriales y Nanomedicina, Zaragoza, España

⁷ MEDIS Foundation, Campina, Romania, {alexandru.negoita, tiucalin}@yahoo.com

⁸ Scientific Direction, Jesús Usón Minimally Invasive Surgery Centre, Cáceres, Spain, msanchez@ccmijesususon.com

Abstract

Minimally Invasive Surgery (MIS) requires particular training of different psychomotor skills. To safely train these skills outside of the operating room, physical simulators, also called box trainers, are usually employed. The application of ICT-based technologies, such as serious gaming and e-learning, to MIS training could provide final users (medical students and surgeons) with a novel tool to acquire basic psychomotor skills. This work presents the Kheiron Training System (KTS), a serious game specifically designed and developed for psychomotor skills training in MIS. The KTS serious game uses a box-trainer and actual surgical instruments as input devices. Movements are detected using an image-based tracking that calculates the 3D position of the instruments within the box-trainer. This information is streamed to the game controller. This together with the game engine controls the gameplay logic. In addition to the main game play, integration with a game server is also provided to allow for social elements. The KTS serious game is carried out in the desk of a young alchemist in his/her quest in finding the Philosopher's Stone. The player is required to complete a set of mini-quests included in the Recipe Book, which serves as guideline along the game.

1. Introduction

Minimally Invasive Surgery (MIS) has become a gold standard in many procedures thanks to its multiple benefits for patients and health systems [1] although it requires the acquisition of specific psychomotor skills due to the differences between open surgery and MIS [2]. The fast and continuous development of MIS requires new systems for initial and lifelong learning training.

Psychomotor training covers the acquisition of the motor skills required to perform a MIS procedure and they need to be acquired in a safe environment, outside the operating room [3]. Therefore, it is initially performed on surgical simulators (physical training boxes or "box-trainers", virtual reality simulators, etc.) and then on an

animal models and cadavers (where available) before performing a procedure on a patient. Psychomotor training is usually acquired in a combined approach with cognitive training by assisting to in-person courses in specialized training centres [4].

Serious gaming is an innovative ICT approach with great success in different fields of education [5] and with an enormous potential to improve medical training by providing non-formal and informal learning or being part of formal training programmes [6]. Initial studies prove the correlation between performance in commercially available games and laparoscopic performance in box trainers; but serious games specifically designed for MIS training and their utility as learning tools have not been fully exploited yet [7]-[9].

Therefore, the objective of this work is to present a new serious game for MIS psychomotor training: Kheiron Training System (KTS). The player plays the role of a young searching for the Philosopher's Stone and is requested to complete a set of mini-tasks which mimic the movements required in MIS procedures.

2. Material and methods

2.1. Setup

In order to play the KTS serious game, the following elements are necessary (Figure 1):

- Physical box-trainer.
- Box and camera. The box is placed within the physical box-trainer and allows for a standard, white, empty recipient with fixed dimensions, peripheral illumination and a camera to track the instruments. The tracking camera is in a fixed position and is independent of the game camera.

Its main purpose is to provide the position of the instruments within the training box.

- Surgical instruments. They will act as input devices for the KTS serious game. They will be tagged with a colour mark that will allow for the image-based tracking.
- Computer. It will run the serious game as well as the image-based tracking of the surgical instruments.
- Monitor



Figure 1. Setup to play the KTS serious game

This setup mimics a typical setting for surgical training in a physical simulator, used in the early stages of surgical training.

2.2. Technical Requirements

End users were involved in the design process through the organization of different co-creation workshops where they joined representatives of the serious game development team in order to jointly work on the detection of user needs. Table 1 shows the categories into which the identified user needs were classified.

Classification of user needs	Number of identified needs
User friendly interface	8
Designed as a video game	21
Improving professional skills	18
Accessibility and availability	6
Evaluation	5
TOTAL	58

Table 1. User needs

Based on these user needs, a set of technical requirements were defined and classified as indicated in Table 2.

The relationship between the user needs and technical requirements are established through a quality function deployment matrix. Importance of user needs is rated as well as the degree of relation of each user need with each technical requirement. This allows for a final rating of the importance of the technical requirement, based on which the implementation of each requirement can be prioritized.

Classification of technical requirements	Number of identified technical requirements
Hardware functional requirements	4
Software functional requirements	4
Scoring and leader boards	3
Awards and achievements	2
Feedback provision	4
Difficulty levels	4
Unlockables/items/power-ups	4
Online and multiplayer	3
Help	2
TOTAL	30

Table 2. Technical requirements

Top rated technical requirements are:

1. The game will allow unlocking new items in exchange of XP points.
2. Users will be able to share their best runs at different levels by uploading their performance data to the server.
3. The game will require using common laparoscopic instrument movements.
4. The gaming platform will allow the use of actual laparoscopic instruments to control movements in the serious game.

2.3. System architecture

The system architecture is shown in Figure 2. The box controller tracks the movements of the surgical instruments within the box and communicates a stream of data to the game controller. This together with the game engine controls the gameplay logic.

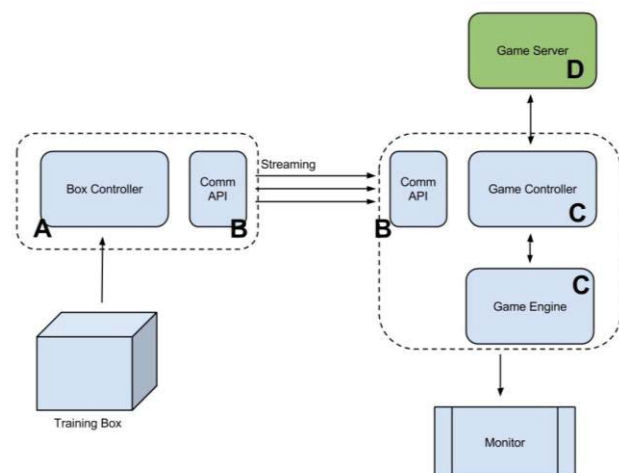


Figure 2. System architecture

Movements in the box (A) are detected via image recognition algorithms and they are translated to

coordinates which are streamed in real time mode to the game. The interface between the two systems is via USB port. Some open source libraries for allowing the interoperation of the two different platforms have been used, namely Apache Thrift and ZeroC. The messages streamed are passed to the game and they translated into movements of the game elements (i.e. the magic sticks of the alchemist). The game engine is written in Unity and all the rendering, collision detection, animations, etc. are implemented in this engine (C). The streaming is translated as moves of the game devices.

The game is designed to be controlled by real laparoscopic instruments, in order to enhance the realism of the environment. Instruments can be tracked by means of any sensing technology available, such as optical or magnetic sensors. The game implements a common API that receives the signal from the selected tracking system and updates the in-game position of the instruments accordingly. Currently, the EVA Tracking System is being used for tracking. The EVA incorporates and artificial vision-based algorithm that allows tracking the laparoscopic instruments' position. Since there is no need for external sensors, this reduces the overall cost of the game, making it more affordable for hospitals and residents.

In addition to the main game play, integration with a game server (D) is also provided to allow for social elements like profiles, leader boards etc.

2.4. Scoring

Different metrics are automatically calculated while the user plays each recipe of the serious game: time, path length (left and right instrument). Based on these metrics, an overall score is computed using the time the instruments are crossing each other, the time they are not and path length sum for both instruments. The overall score of the recipe will be larger for a better performance.

3. Results

3.1. Background story

The game follows the story of a young alchemist and his/her quest in finding the "Philosopher's Stone". To accomplish the main objective, the player has to complete a set of mini-quests. The Recipe Book, which serves as guideline along the game, includes the different recipes with the specific objectives.

The game takes place on a fully interactive alchemist's desk where various ingredients and objects exist at the disposal of the player. On each level the player has to accomplish a certain tasks accordingly to the instructions provided and, when specified, within a certain time limit. As the player evolves on the game, new recipes are unlocked.

3.2. Tasks

Some screen captures of the KTS serious game are shown in Figure 3. It is composed of 13 recipes that request movements similar to those included in a traditional training program in order to complete the recipe, for example triangulation tasks represented by lighting candles. After the fulfilment of each recipe, metrics and the score, in the form of knowledge points, are presented to the user in the corresponding page of the Recipe Book.

3.3. Gamification

In order to increase the user motivation, some gamification aspects from commercial videogames have been implemented in the KTS serious game:

- Knowledge points based on the player performance.
- Leaderboard accessible to all players to increase competitiveness.
- Achievements to be unlocked along the game progress and included in the Recipe Book, awarding the player with greater score.
- Time bonus. It appears during the execution of the recipe and challenges the player to catch it before it fades to improve the score as it reduces the time devoted to complete the task.
- Blocked tasks. When a recipe is successfully completed, new tasks might be unlocked (accordingly to the game logic).

4. Conclusions

Psychomotor skills are highly involved in any MIS procedure; therefore their acquisition is essential in any training program. Mostly in the early stages, box-trainers are widely use because they provide a safe environment where novices can make mistakes without consequences. On the other hand, serious games are arising with great success in different fields of education and they also have an unexploited potential to improve medical training [7]-[9]. To our knowledge, there is still no commercially available serious game which is specifically designed for MIS training and which only make use of actual training elements, such a box-trainer or actual surgical instruments.

Therefore, this work presents the development of the KTS serious game, which is specifically designed for psychomotor skills training in MIS. It is based on actual surgical simulators instead of commercially available video consoles and makes use of actual surgical instruments as input devices instead of mouse for PC or controllers for commercial video consoles. This way, the conventional training setup is mimic as much as possible, in terms of materials and requested movements, although the background story is radically unrelated.



Figure 3. KTS serious game screen captures. a) Recipe book; b) Recipe 3: light candles with both hands at the same time; c) Recipe 5: pull the string and cut it in the marked area; d) Recipe 10: mixing potions.

With the development of a serious game with these characteristics combined with e-learning, medical students and surgeons will be provided with an ICT-enhanced training system that will cut across traditional in-site training systems including open and distance learning and open educational resources.

5. Future work

The next step is the validation of the KTS serious game. For this purpose, expert surgeons and end users (medical students and surgical residents) will be recruited. Expert surgeons will participate in the content and face validity of the serious game, while medical students and surgical residents will determine the usability and interest of the KTS serious game to train psychomotor skills in MIS. Final validation of the serious game will have to prove the acquisition of skills and its transfer to the operating room. Besides, the framework proposed by Graafland et al.[10] will also be taken into consideration.

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