A new virtual reality based environment for surgical training

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Abstract

This research proposes a new virtual reality based environment for surgical training. Minimally Invasive Surgery Simulator Scenario Editor (MIS-SIM) is an innovative environment for surgical content creators and professors empowered to create their own training scenarios. MIS-SIM provides personalised and adaptive learning for surgical professionals in patient-free environments thanks to the new form of content creation. The main goal is to reduce the learning curves and to train more confident professionals. After the implementation process a pilot programme will be carried out in two European sites, The Netherlands (Leiden University Medical Center) and Hungary (Semmelweis University).

1.   Introduction

Education of surgical techniques is a long and challenging process that takes place during graduate and postgraduate years. Traditional training based on tutor-apprenticeship models are now considered, as a general approach, to be subjective, time/resource-consuming and risky for patients, and new structured programmes are being proposed to provide training and objective assessment in patient-free settings.

Several studies have already established the usefulness of VR simulation as a means to train MIS technical skills [1][2][3], and our hypotheses is that flexibility in content definition and adoption of different pedagogical strategies will contribute to further boost this. In this study we present the Minimally Invasive Surgery Simulator (MIS-SIM) scenario editor, designed and developed to fill an existing gap in the market: an editor that can be used to create, edit and train with personalized virtual tasks and scenarios designed for surgical training.

2.   MIS-SIM concept

MIS-SIM is conceived as an environment where users can create, edit and run virtual reality based tasks designed for surgical training. The environment features an editor allowing users to design personalized learning tasks, defining its learning objectives and task goals. A user will later be able to train his/her psychomotor skills through a simulation of the given tasks.

The creation of the tasks is made through the placement of different predefined objects (prefabs) in the scene, applying affine transformations (translation, rotation and scaling) to the given objects in a 3D space. Prefabs such as cubes, planes, spheres, cylinders, capsules, trigger zones, drop zones, rings with and without gravity, etc. will help users to create and edit their own tasks.

In order to evaluate performance and the accomplishment of the tasks' learning outcomes, MIS-SIM is able to measure different metrics defined by the user. These are recorded during the runtime of the simulation, and can be one of two kinds. On one hand, global metrics refer to metrics that affect the entire scenario during the runtime of a task. Some examples of global metrics include "overall elapsed time" and "laparoscopic instrument travel distances". Local metrics, on the other hand, are inherent to each task object prefab, meaning that they will measure things regarding the individual prefab they are attached to. Some examples of individual metrics are a "drop counter" (how many times the object has been dropped), a "floor/wall touch counter" (how many times an object touches a wall), etc. The objects that include metrics measures are called evaluating objects within MIS-SIM.

Once a task is created, it is uploaded to a Cloud Repository, where permissions of access, edition or running are established.

3.   MIS-SIM environment design

Development of the environment has been undertaken using the agile process methodology Scrum [4], involving sprint planning meetings, sprints for developing and sprint reviews.

3.1.   Actors definition

The actors that will interact with MIS-SIM are the following:

- Main Actors:
  - Content Creator: can create or edit different tasks according to pedagogical guidelines described by a teacher. The content creator can also run the created scenario in order to test what has been created.
  - Professor: can create or edit its own tasks and assign who will be able to interact with them.
  - Trainee: can run the scenario and be graded based on proven ability during the simulation.

- Secondary Actors:
  - External controller systems: In order to interact with the simulator, a controller scheme must be implemented. Controller systems need be faithful to real surgical instruments and track their spatial position. In its current build, MIS-SIM will be integrated with the SIMENDO laparoscopy pro3 haptic controllers [5].

3.2. Architecture

The architecture of the MIS-SIM simulator is shown in Figure 1. The base is **Unity Engine** which provides an abstraction over *physics*, *render* and *audio* tasks. However, in terms of readability and scalability of the simulator a series of **Managers** have been designed, responsible for controlling advanced interactions. **Managers** are initialized in the initialization scene, adding a layer over the Unity capabilities that simplify future stages of development.
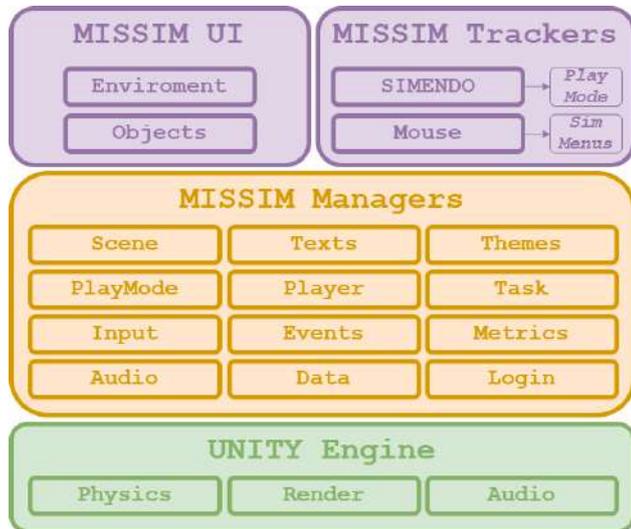

Figure 1. *MIS-SIM environment architecture*

Within the MIS-SIM Managers, the *Text Manager* can be highlighted. It is responsible for translating the entire application through the key-value consultation of a dictionary established for each different language in which the simulator is located. The *Themes Manager* is responsible for changing the entire user interface when the user switches between the different tool "skins". The *Metrics Manager* controls the correct execution of the sub-goals of the task and the measurement of the global metrics associated with the task.

On top of the managers there is the user interface, which is an overlayered 2D layer above the 3D environment (which receives the mouse interactions) and the 3D environment itself whose scene objects receive the interactions from the mouse in edit mode and from the SIMENDO controller in run mode.

3.3. Screens' flow diagram

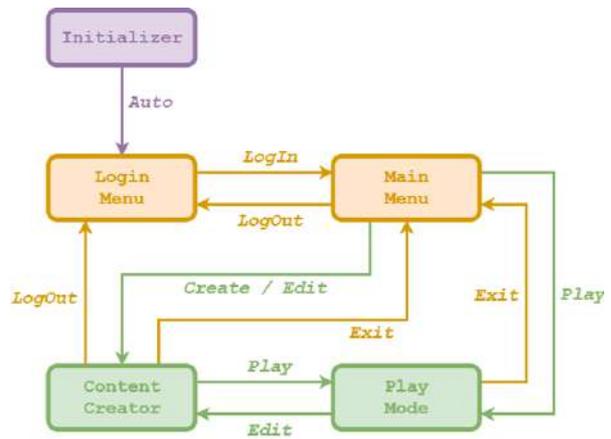The screens' flow diagram of the environment is shown in Figure 2.

Figure 2. *MIS-SIM screens flow diagram*

The *Login Menu*, as its own name suggests, shows the user the screen where he or she can enter his or her access data, also allowing to configure the interface language using an intuitive drop-down menu.

In the *Main Menu*, the **professor** or the **content creator** user will be able to select between *Content Creator Mode* to design a new task; *Play Mode* to run a task, or *Manage tasks* to access and edit tasks from the Cloud Repository. On the other hand, the **trainee** user can only load tasks and play them.

In *Content Creator Mode,* **professors** and **content creators** will be able to create a task with whatever elements that are deemed necessary. The scene presents a 3D environment (the workspace and the task) overlaid with the user interface. In the user interface it is possible to configure properties of the objects introduced in the scene, their behaviour according to the task's goals and the local metrics of the object. Finally, global metrics can be configured, as well as whether the goals of the task must be accomplished in order.

In *Play Mode*, **students** will be able to load and run tasks. For each new task execution, a metric file (according to the task design) is generated and at the end of the session uploaded to the Cloud Repository.

3.4. User interface design

Usability implies that users should be able to use MIS-SIM (for creating or running surgical tasks) without finding the process frustrating or annoying. A user interface design process has been followed to deliver a smooth user experience in a simple and accessible way, taking into account the target users of the environment.

Figures 3-5 show three different mock-up views of the editor. Figure 3 shows the main view of the environment where information about the objects can be found. The user can place a new object (for example, from the prefab tab) in the scene, or edit an existing one modifying its different properties (location, scale, rotation, colour…). Within this main window users can also set object metrics such as distance, object drops, or collisions with other objects.
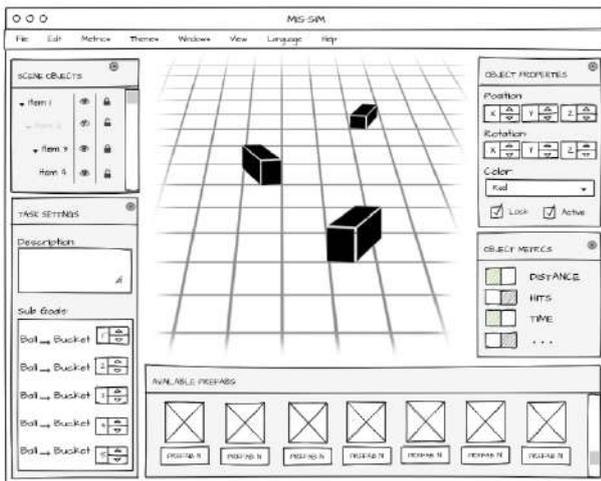
Figure 3. Main view of MIS-SIM

Figure 4 shows a mock-up for the definition of global metrics. Current global metrics available are: total simulation time and total distance travelled by the right and left gripper of the laparoscopic instruments
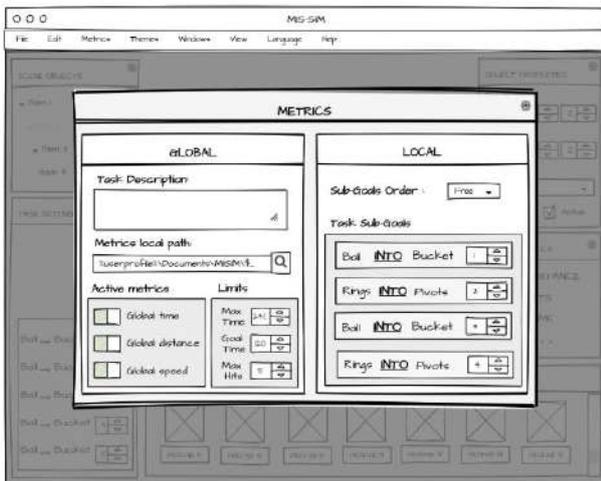

Figure 4. Metrics definition view of MIS-SIM

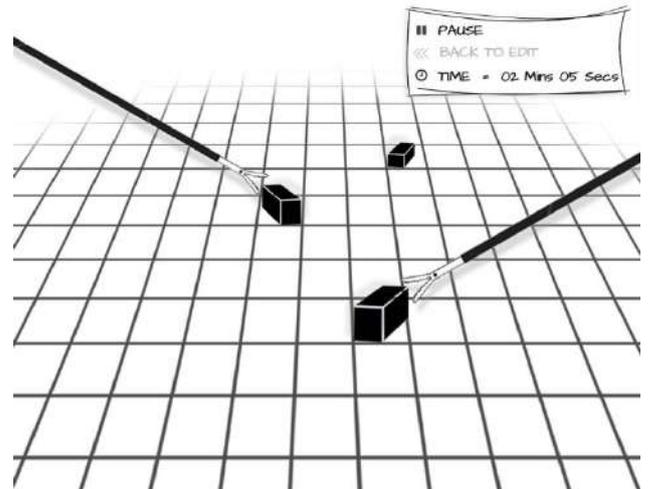Once a task has been created, and is assigned to a student, he/she can run it in a window similar to Figure 5.

Figure 5. Runtime mock-up of MIS-SIM

4. MIS-SIM implementation

MIS-SIM has been developed using the game engine Unity 3D. Unity allows the use of C#, UnityScript and Boo scripts for its attachable components onto GameObjets in the scene.

The current prototype can be seen in **¡Error! No se encuentra el origen de la referencia.**. It is an early approach to Figure 3, with the availability of editing behaviours associated to an evaluating object, the ability to manage the scene intuitively with the mouse, keyboard shortcuts and menu bar that should be expected in any editor.

Figure 7 shows how the user interface during the game is as non-intrusive as possible so as not to distract the trainee while carrying out a task.
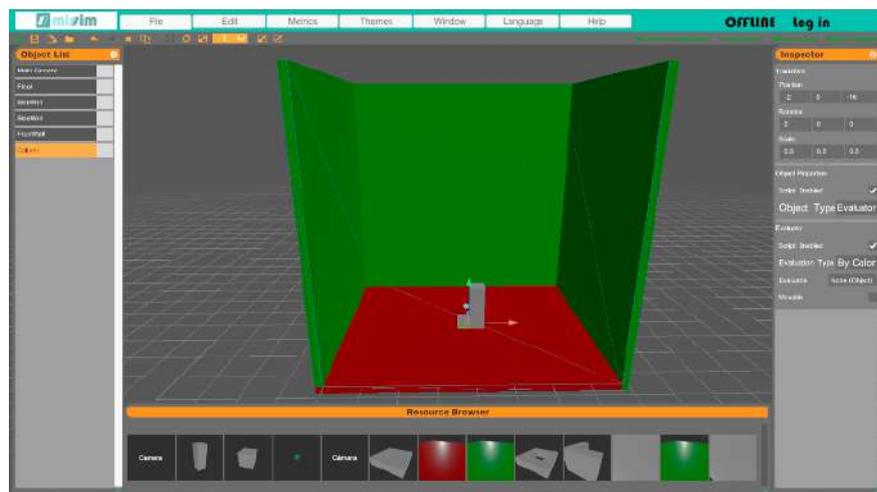

Figure 6. Main view

Figure 7. *Runtime view*

5. Discussion

In this study we have presented a novel VR simulator for MIS training allowing course creators the means to define their own training tasks. The need for new personalized training contents is clear in the surgical community. MIS-SIM fills an existing gap in the state of the art: an editor that can be used to create, edit and run personalized virtual tasks and scenarios designed for surgical training.

With this new environment content creators and professors will be able to define personalized MIS training activities tailored to the pedagogical needs of their students, reinforced by all the advantages of VR systems such as repeatability or objectivity. Learners will thus benefit from having VR tasks built to cater for their specific needs.

Once the editor is developed a pilot programme will be carried out in two European sites, The Netherlands (Leiden University Medical Center) and Hungary (Semmelweis University). The pilot will integrate the use of MIS-SIM in these medical institutions regular training courses. Additionally, short courses will be programmed during the academic year. Validation will be carried out within the framework of an EIT Health Campus project.

With these courses we expect to generate evidence on the learning curves of trainees as well as on the predictive validity (i.e.: transfer of skills to the OR) based on MIS-SIM performance data gathered at the different validation sites.

6. Conclusions

Introducing a new VR-based learning paradigm will contribute to improve the efficiency and effectiveness of training technical skills between surgeons. MIS-SIM provides personalised and adaptive learning for medical professionals in patient-free environments thanks to its innovative methods for content creation. Its use will help reduce the learning curves and to train more confident professionals.

Acknowledgements

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