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Lumbar Puncture Trainer

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Abstract

This Technical Report presents a virtual environment for training the Lumbar Puncture Procedure, an operation necessary for the diagnosis of Meningitis and other conditions. A haptic simulator called Lumbar Puncture Trainer has been developed that allow trainees to practice the procedure without using an actual patient or expensive test dummy. This application of virtual environments and haptics, using a 3D Games engine, is beneficial because it improves patient safety and reduces spent capital. There are ethics surround these issues but are not discussed in this Technical Report.

1 Introduction

The purpose of the project was to create a training simulation using a virtual environment that utilises Haptic technologies for the lumbar puncture procedure. This was achieved using a 3D games engine and visualisation to create the virtual environment necessary for the simulation, force profiles, scripting and a 3DoF (Three Degrees of Freedom) Haptic device to generate the force feedback and realistic simulation of the procedure and triggers to detect the needle insertion and object collisions. The use of Haptics and virtual environments for training simulators for medical procedures, like the lumbar puncture, are beneficial to medical training because it cuts the risk of injuring patients and it less capital is needed and the equipment will last longer. There are ethics around virtual environments and patient care but they are not discussed in this technical report.

2 Background

The lumbar puncture is a procedure that inserts a needle into the patient's lumbar region, between the L1 and L2 vertebrae, and extracts Cerebral-Spinal Fluid (CSF). This procedure is used to test for different medical conditions like meningitis and subarachnoid haemorrhage. Practitioners' poor technique can lead to patient discomfort, paralysis and, in the worst cases, death.
Currently, the only way for practitioners to hone their technique is by utilising cadavers, physical simulators or living patients for this procedure. Patient safety is a critical concern when using live patients, and cost is the next significant issue to arise using the other methods. Using a haptic device to simulate the procedure, practitioners can practise the procedure repeatedly without the risk of injury to others and to improve their performance.
Haptics is a form of non-verbal communication involving touch, this concept is used in force or tactile feedback technology to recreate the sense of touch by applying forces, vibrations and/or motion to the user. Haptic devices are devices that provide force or torque feedback to create a sense of touch and realism for the user by tracking the position of end effectors and applying forces to them when necessary, these devices generally tend to have either 3DoF or 6DoF (Six Degrees of Freedom) allowing them to provide a full range of motion around the virtual environment and to increase the realism for the user.
Visualisation is the technique of creating images, diagrams, animations and other media or objects to communicate a message or concept. Visualisation can be use to visualise basic objects like cubes, sphere or more advanced systems like the nervous system, respiratory system or human muscle structures. These visualisation can then be used in presentations or as teaching/training aids such as a simulator for an aircraft or a medical procedure, or an exploratory tool for exploring the human anatomy.
The use of Haptics in medical practice [1], Use of Haptics for Needle Insertions [2][3] all support the use and development of Medical Training Simulators using Haptic devices.

3 Development

3.1 Haptics - Force Feedback

To get realism in the needle insertion, the force feedback of the haptic device was utilised because it can give enough force to provide the feedback felt in the real operation. To get the force feedback to create this realism, the forces given to the device were based on a force profile (see Figure 1) obtained by using a device to measure the force exerted by the surgeon as he inserted the needle into the Patient.

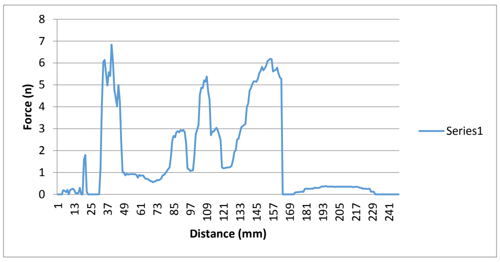

Figure 1: Force Profile - Courtesy of Marc Edwards (Bangor University)

The force given to the device is then based on the distance from the needle insertion to the tip of the needle, this distance is compared to the x value of the force profile and the y value (the force) is then passed to the device to give the force feedback. The Novint Falcon is a 3DOF device that can move in the X, Y and Z directions, allowing it to move around the virtual space but doesn't allow for rotation of the object it is controlling. This device can then be sent information from the environment and apply forces based on this information to create the force feedback required.

3.2 Visualisation - Unity3D

A Games Engine is a framework designed for the creation and development of graphical applications, usually video games, that use collision detection and physics based operations.
Game engines, like Unity3D, can be used for applications that require a virtual environment because they give a blank environment or scene and it allows for the import of models and scripts as assets that can then be added directly into the scene and manipulated to create the environment required by the application. All the assets, lighting and camera are positioned to make the environment look as close to reality as possible.
The models of the spine, pelvis and torso were segmented from medical image data obtained from a volunteer who had a CT scan in the position that a patient would be in when undergoing lumbar puncture. The models were originally generated for the WebSET project [4](see Figure 2).

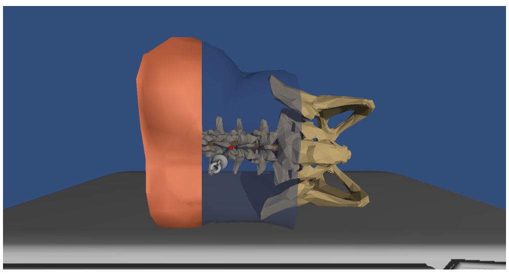

Figure 2: 3D Visualisation

3.3 Scripting - C#

The Falcon has native support for use in C++ and is normally developed with the OpenGL graphics library as a visualisation for the environment. Unity3D uses C# as one of its native language for scripting and uses either DirectX or OpenGL for it's visualisations. Because of the difference in native support, a wrapper class was obtained to allow for the interaction between Unity3D and the Falcon.
The use of triggers in the scripts and environment allowed for the detection of the needle insertion, allowing the script to lock the movement of the needle so it will only move in and out of the body, detecting whether the needle has hit the correct part of the spinal column or whether they have caused injury to the patient.

4 Conclusion

In Conclusion, the technology components have been successfully integrated into a working training simulation. Validation studies are now needed to demonstrate that this tool is useful in training medical students and neurosurgeons. Using training simulators and Haptic devices for the training and practice of surgeons cuts the risk of causing injury, paralysis or potential of a patient and reduces the capital spent on equipment.

5 Acknowledgements

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