

# Procedural Medical Training in VR in a Smart Virtual University Hospital

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**Abstract.** A smart virtual university hospital representing a real-life one, can prepare students for direct patient contact and provide possibilities for clinical practice. Such a virtual hospital will support student learning by providing adaptive and flexible solutions for practicing a variety of clinical situations at the students' own pace. This paper builds on a previous research on the Smart Virtual University concept and explores the possibilities for medical procedural training with Virtual Reality. A scenario focusing on pre-operative neurosurgical procedural training was developed and tested. The procedural training has been enhanced with real world medical data (MRI and ultrasound). The feedbacks from the tests have been generally positive, both in terms of general user experience and expected learning outcomes. The paper presents the implementation procedure, evaluation results and outlines the directions for future work.

**Keywords:** Smart Virtual University Hospital, medical procedural training, Virtual Reality

## 1 Introduction

A smart virtual university hospital mirroring a real life one can prepare students for direct patient contact and provide opportunities for improving clinical practice. We have worked with the long-term idea of establishing an online Virtual University Hospital (VUH) to create a holistic system and a venue for learning, research, and development [1]. The idea is to make a virtual mirror of the St. Olav's University Hospital (St. Olav), which is integrated with the Faculty of Medicine and Health Science at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. St. Olav is a modern university hospital with a state of the art

technological platforms and modern clinical buildings. The first prototype of the Virtual University Hospital has been used for interprofessional communication and collaboration training [1].

Many studies have reported on the potential of 3D virtual worlds for educational activities, especially in medicine and health care [2, 3]. With affordable Virtual Reality (VR) technology, virtual environments can be used in combination with motion tracking and head-mounted displays (HMD, VR goggles) to increase the sense of immersion, making it more believable and transferable to the real life [4-6].

The VR experiences include surgical simulators [7-10], general training facilities for nurses and doctors [2, 3, 6] and anatomy education [4]. The literature reports several benefits in terms of the learning outcomes and student satisfaction [5, 6]. This teaching method can be cost-efficient and user-friendly alternative to real-life role-plays and training programs [2, 3, 10].

In medicine and health care there is a long history of physical simulations with many of the same benefits that VR simulation can offer, such as being safe, available outside the clinical setting, a controlled learning environment and providing opportunity for repeated training. However, traditional simulation tends to be expensive and located at centers with highly specialized equipment, often meaning restricted access [7, 11]. VR simulation has therefore a number of advantages in procedural training that are have been explored in the literature, e.g. for [8-10].

There have been attempts to develop affordable surgical simulators using general purpose input devices. E.g. at Japitur College of Engineering in India, Mathur [12] has developed a surgeon trainer using Oculus Rift with the low-cost input device Razer Hydra [13]. The users of the systems are using the headset to view the virtual world, and the controllers to interact with it from a stationary sitting position.

Accessing medical data such as MR and ultrasound is essential at all phases of medical treatment, from diagnosis to surgery. An example of a simulator supporting virtual interaction with medical data is Dextroscope [14], made to support surgical evaluation and decision making. The system uses preoperative images in combination with segmentation of critical anatomic structures to present an information-fused 3D model on a stereographic display.

Another example of a system that is used at multiple hospitals in the United States, is a NeuroTouch neurosurgical VR simulator [11], consisting of two parts, NeuroTouch Plan and NeuroTouch Sim. In the NeuroTouch Plan images from Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are used to create 3D models of the human head, allowing the neurosurgeons to examine the brain for preparation of neurosurgery by defining the surgical corridor. Once it is defined, the user is moved to the NeuroTouch Sim part, where he/she performs the surgery. However, this system is very complex and expensive, and it is therefore need for more research in this area.

While real world medical data could have immense benefits in a VR learning environment, it has been found to be hard to implement [15]. Also, more knowledge about adding medical data into VR simulators is needed. In order to address this gap in the related work, the main goal of this project has been to develop a low-cost solution for room-scale Virtual Reality (Oculus Rift and HTC Vive) with integrated medical

data for pre-operative procedural training. Detailed description of the scenarios can be found in the master thesis that this article is based on [16]. The work is part of the Smart University Hospital framework earlier described by the authors [1].

An application focusing on pre-operative neurosurgery was developed, in collaboration with the specialists. The rest of the paper is organized as follows: the following section outlines the implementation details and training scenarios. Section 3 presents the results of a preliminary evaluation with medical specialists using the neuro-scenario, while section 4 discusses the findings. Section 5 concludes the paper, outlining directions for future work.

## **2 Methods**

### **2.1 Implementation of real world medical data**

The models for the environment like hospital hallway, rooms and operating rooms were based on the original design of the VirSam project [1]. They were modelled by taking photographs of the operating room at the Neurological center at St.Olavs, in order to create a familiar environment for neurosurgeons. Unity3D was chosen as the platform for the development of the solutions, to be used with both HTC Vive or Oculus Rift.

Moving on from VirSam [1], it was important to improve the interaction with the virtual world. In the original gynecological VirSam scenario, when performing ultrasound, the physician could only look at a frozen screen and vocally declare the findings. In this new development, two different approaches were taken to implement real world medical data into the application.

The first approach was to map ultrasound images to the position of the ultrasound probe in the virtual world, meaning the image on the virtual ultrasound machine updates when the user moves the probe. The second approach used an advanced software (Volume Viewer Pro) for converting MRI data to a 3D model. This approach was used to create an interactable panel consisting of the axial, coronal and sagittal (ACS) view of MRI data, enabling users to interact with the data like how they do in real life. There are two sliders on each panel, which the user can drag to change the images. It is also possible for the user to interact with the panel by pointing a finger on the screen.

Another implementation of the second approach is the use of the navigation wand. The navigation wand gives the user the ability to navigate the MRI data based on the wand's position relative to the patient's head. The data is displayed on an ACS panel over the surgical bed.

### **2.2 Interaction in the virtual world**

There are several items the user needs to interact with to complete the tasks in the scenario. It was decided to keep the number of interactable buttons to a minimum to enable new users to adapt quickly to the sensation of VR. The first button (tracker button) located under the thumb of the user, is used to teleport/transport the user to the desired destination. The second button (trigger) is used for interacting with objects in the virtual world. This button is located under the index finger of the user. Whenever

the user hovers an object with their virtual hands, the hovering controller will be visible as translucent yellow, indicating which button the user must press to pick up the object. The button on the controller will produce a small vibration. The vibration of the controllers is also used to indicate to the user that they are interacting with the virtual world. For instance, when the user points on the ACS panels or use the ultrasound system, the controller will vibrate.

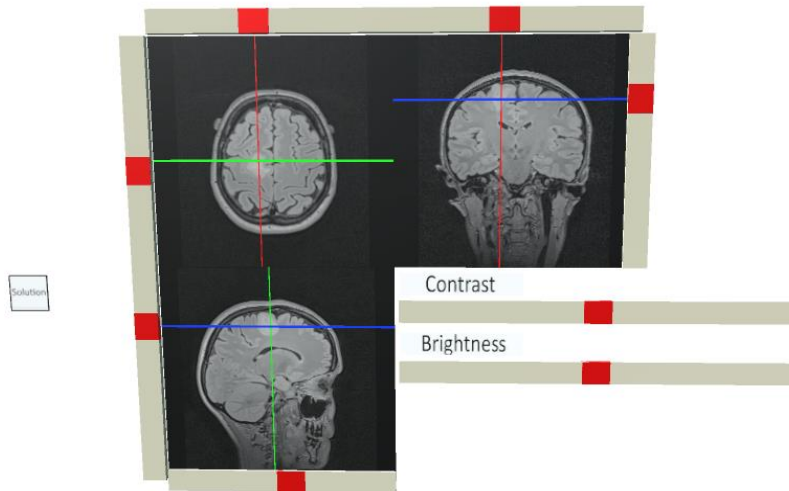
### 3 Evaluation of the neurology scenario

#### 3.1 Tasks performed in the scenario

The neurosurgery scenario consisted of four main tasks:

**1. Select case.** The users can play through three different cases, with different tumor positions. The first task they are given is to select a case they want to play.

**2. Locate tumor based on MRI data.** After selecting the case, the user gets the task of locating the tumor and mark it using the ACS panel. When the user is satisfied with the result, they can press the solution button to toggle between the correct solution and their own result (Fig. 1).



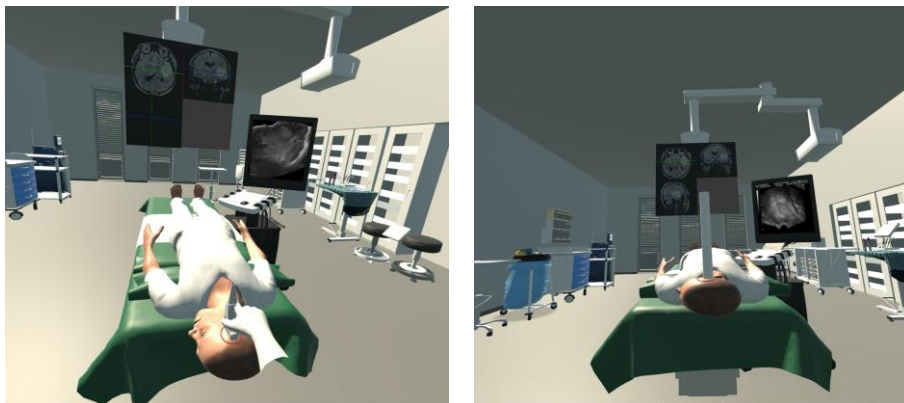
**Figure 1:** Locating tumor on the ACS panel

**3. Patient positioning, shaving and marking the entry point of the craniotomy.**

Based on the result obtained in the previous task, the user is tasked with positioning the patient correctly on the surgical bed. The head of the patient needs to be correctly rotated to ensure proper access to the tumor and optimal conditions for ultrasound acquisition. When the patient is laid correctly, the patient needs to be shaved to get access to the point of operation. When the patient is shaved, the user marks the point of surgical entry. After marking the point of entry, the user clicks on the solution button to toggle between the correct setup and their own.

**3. Navigation and ultrasound acquisition.** When the patient is positioned correctly, the next task is to verify the position of the tumor. This is done in two steps. Both steps are illustrated in Figure 2. The first step is verification by use of the navigation system (MRI data on the ACS panel above the bed).

The second step is verification by ultrasound. In neurosurgery, it is not sufficient to rely solely on the MRI when performing an operation. Firstly, the registration of the patient's MRI data is not completely accurate. The inaccuracy of the registration process can be close to a centimeter. In addition, once the operation has started, the brain might move around, making the tumor move as well. To remedy these issues, ultrasound is used complementary to the MRI during the operation as this modality is not affected by registration issues. Being an intraoperative modality, the ultrasound images will give an updated view of the current patient anatomy. New ultrasound scans are performed when needed to determine the current position of the tumor and critical brain tissue. These scans are compared with each other throughout the surgery. In the last task, the user has to perform the first ultrasound scan. To perform the scan, the user picks up the ultrasound probe and move it to the point of entry on the head. If the tumor is observed at the assumed location the user has completed the scenario (Fig. 2).



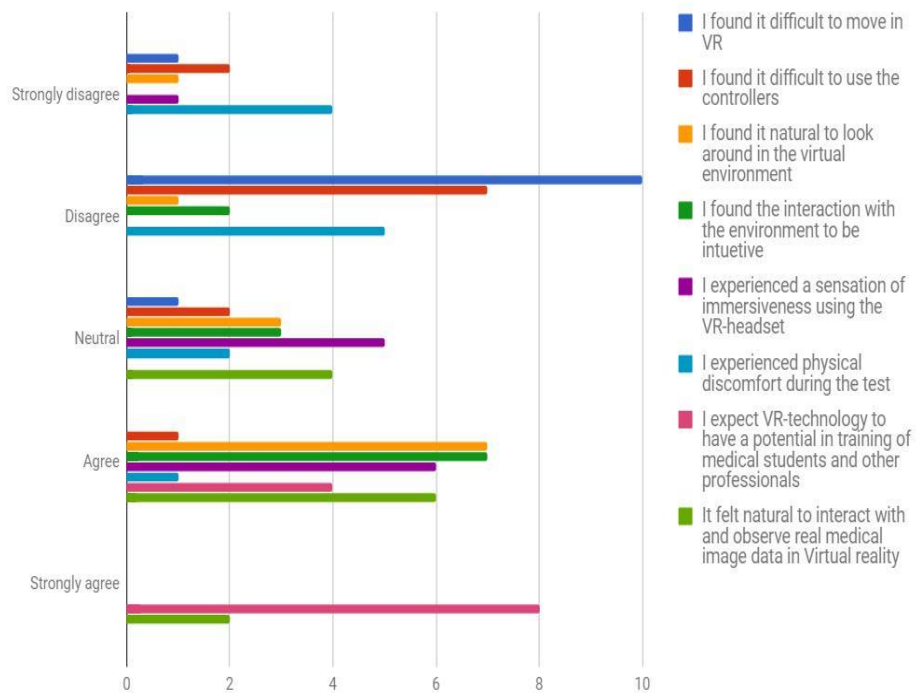
**Figure 2:** Use of navigation system and ultrasound

### 3.2 Testing scenario

**Test of first prototype.** The first round of testing was performed during the 2017 Network Conference for medical simulation in Norway, held at the Medical Simulation (MedSim) Centre at St. Olavs hospital spring 2017. The version tested was a prototype, meaning that it was not yet robust enough to leave the testers on their own. In order to make new users familiar with the unusual interface, 'virtual hands' were implemented and programmed to animate in a manner that simulated the physical movement of the fingers.

This test was conducted using one VR headset Oculus Rift, i.e. one person at the time did the testing. The individuals participating in these tests were 12 technical and

medical experts from different parts of Norway, interested in simulation in medical practice. They were only asked to try out the functionality and fill out a short survey. All questions were posed in a manner that should be answered on a Likert scale from 1, strongly disagree, to 5 strongly agree (Fig. 3).



**Figure 3:** Chart created based on feedback from MedSim

**Test of final version.** In June 2017, the application presented in this paper was demonstrated at the 9th international Ultrasound in Neurosurgery course in Trondheim, Norway. The application was used as one of four stations where the participants should explore the simulation methods and get a first-hand experience with different equipment and concepts regarding ultrasound in neurosurgery. The focus in this test was shifted somewhat from what was already established in earlier user tests. Instead of focusing on whether the users were able to interact with the VR gear and the virtual environment, observations were made on how the users interacted with the medical equipment and the medical data.

*Setup and execution.* The execution was a three-step process for each test subject. Firstly, to give the testers an overview of the application and make them ready for the tasks they were given a quick walk-through by team members. Secondly, they were given a quick introduction to the controller and the different buttons they needed to use

to interact with virtual world. Lastly, they were given the headset and guided through the scenario.

*Test subjects.* The test subjects in this execution were mainly surgeons in training or surgeons who wanted to expand their knowledge on ultrasound guided neurosurgery. The age of the participant ranged from late twenties to sixties. None of the testers had any previous experience in the use of VR.

*Findings.* The data gathered in this test was made by observation and posttest talks with focus on the following aspects:

- 1) How quickly the testers became familiar with the environment (number of seconds from start of the test until first teleport and until the case was chosen)
- 2) How quickly the testers were able to locate the tumor in the ACS-panel; (number of seconds between the first attempt to interact with the panel and until the tumor was marked correctly)
- 3) How well the testers were able to position the patient and mark him correctly (related to the pre-defined correct solution)
- 4) How well the testers were able to interact with the medical data using the MR-Wand and ultrasound probe and to locate the tumor.

The average time users spent before choosing the case was 1:24 minute, while the average time required to locate the tumor was just under a minute. The time spent was mostly used as an indicator on the user-friendliness of the system, without comparing to how much time is required for such procedures in real life. Placing the patients correctly proved mostly to be successful. Only two out of the nine participants had crucial errors in their placements or markings. The rest of the participants had the patient mostly correctly placed. All those who got the time to test the navigation wand and ultrasound were able to use those tools and locate the tumor. Some needed assistance on how to use one, or both, but most understood that they were supposed to use the VR gear as they would do in real life. The main issue with the ultrasound probe was the inability to rotate the probe and get a proper rotated view, but most testers did not notice this flaw. One of the testers claimed that the navigation system and the ultrasound implementations made it feel like he was working on a real patient. The user did not look at the patient when performing the navigation, instead he was only looking at the screen.

## 4 Discussion

The application was tested on two occasions, both during and after the development was finished. The feedback gathered presents interesting findings related to the usefulness of the application, especially in an educational context.

**Interactivity.** Developers of VR solutions need to account for typical problems experienced by complete novices, such as understanding how to aim the teleport beam and what button to click are problems. The fact that users need some time to become familiar with the VR gear is to be expected. As shown in the test performed at MedSim, there was largely a consensus that the interaction with the controllers was not difficult. During earlier tests, some users had trouble finding out which items were possible to

interact with and which button to press to interact with it. Therefore, the interactable items have been differentiated from non-interactable ones by shape and color.

**VR-sickness.** A recurring concern with VR applications have been VR-sickness, which may leave users unable to use applications for a prolonged period of time. In this project, numerous design decisions have been adopted to minimize the sensation of nausea and strain on the users, such as optimizing performance and implementation of teleport functionality, which removes the discrepancy between the user's physical and virtual movement. As a result, only one participant reported discomfort during the test (Fig. 3).

**Using real medical data.** From the literature, the use of real world medical data is perceived as having a significant potential in educational applications, but difficult to implement [15]. The evaluation of the prototype shows that it is indeed possible to utilize real world medical data to support a relatively low-cost learning application. Proper use and interpretation of MR and ultrasound images is a field of study in itself. Therefore, it is paramount that the interaction with the medical data is as similar to the real world interaction as possible, or manipulated in a way as intuitive as possible. From the user tests, we can see that the average tester spent an average of just under a minute to properly locate the tumor in the ACS-Panels. Having the ability to use the sliders and finger pointing, the ACS-Panels were made to simulate desktop computers and touch screens in the operating room, enabling the testers to interact with the equipment in a way that was familiar to them.

At the same time, being able to interact with the models and imagery of the human body in a fully immersive virtual environment enables exploration of the data in a new way. Utilizing medical imagery to recreate apparatus and scenes that are known and familiar to the users will help them to perform training on well-known procedures, as well as developing new training scenarios focusing on advanced interaction, interpretation and 3D visualization of medical data.

## 5 Conclusions and future work

In this paper, we have discussed developing a virtual university hospital environment designed for procedural training in VR. The initial setup and introduction to VR might be time consuming. However, with a well-designed user interface, and with careful guidance, it is achievable to have novice users interacting with the virtual world with some degree of proficiency after minutes. The design of educational applications is a complex process, and one way to solve this is to design such an application based on a set of tasks where each one brings educational value, preferably in collaboration with an expert. This is why the application in this project have been centered around scenarios with a clear structure and learning goals.

Integrating real world medical data further increased the sense of immersion the users could feel when playing the scenario and gave them an exciting new way to interact with MR and ultrasound images. The users were forced to use their knowledge of MRI and ultrasound in order to complete the given tasks properly through experimentation and analysis of the medical data in the virtual environment.



Construction of these types of scenarios needs to be done in close collaboration with experts in the given field.

Based on experimentation and exploration in this project, multiple directions for future work have been identified:

**Medical data.** The testers suggested that further integration of medical data in the application is desirable, with two possible improvements. The first one is the ability to slice the data at a random angle and offset, simulating the use of an ultrasound probe in the real world. Another way of interacting with the data that was suggested in the tests with surgeons, is the ability to view the navigation markers position on the ACS-Panel that is positioned above the bed. Such functionality will immerse the user even further as well as open for more complex scenarios.

**Improved feedback system.** Today, the application provides an expert-set solution for the scenarios, and the user may assess his or her success in the scenario based on the solution. During the development, the team came up with different ideas for more a complex feedback systems, some sort of numerical feedback that in a meaningful way grades the performance of the user. A score system could be visible after the user is done setting up the patient, and could be showed in VR or outside, with pass or fail values, giving the users further feedback on what is expected from them.

An example of possible feedback to the user could be to inform about potential dangers to the patient if the entry point and target were marked in such a way that critical structures would be on the surgical path down to the tumor. Personalized and adaptive feedback based on different metrics like the placement of the head or the angle of the neck of the patient would be useful for the learner as well.

**Further development of the Smart Virtual University Hospital.** The goal of this project was to develop a medical learning application for procedural training within the Smart Virtual University Hospital framework. Compared to the previous implementations of Virsam/VUH [1], the user was able to move freely in the virtual environment, interact with equipment using physical movements and access medical data. This contributed to increased immersion, made it more user-friendly and resulted in reduced time needed to be proficient in the application. The new features introduced such as smart medical equipment with medical images dynamically changing according to the user's hand movement constitute additional smartness levels, e.g. adaptation [17]).

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