Virtual Reality Simulation in Nursing Training: Collaborative Development, Integration, and Advancement

Abstract

This paper presents a comprehensive overview of the collaborative development of a Virtual Reality Simulation in Nursing Training (VRSNT) between the Oxley College of Health Sciences and the Tandy School of Computer Science at the University of Tulsa. The primary objective is to seamlessly integrate the VRSNT into the nursing education curriculum at Oxley College. By delving into relevant literature and incorporating best practices, this study explores the effective utilization of virtual reality simulations in nursing education. Additionally, it sheds light on key features of the VRSNT, including its innovative objective tree system and user-friendly input system. Ultimately, this research contributes to the advancement of virtual reality in nursing education and underscores the distinctive attributes of the VRSNT.

1. Introduction

Game-based learning is an educational approach that employs games, often referred to as "serious games", as a medium for teaching and learning [3] Serious games can and have been used in various fields of study and industries that require training and skill development [2]. Furthermore, the appropriateness and application potential of serious games extends to almost all areas and different learning objectives [2]. Virtual Reality (VR) can provide a unique platform for serious games by offering immersive experiences, realistic simulations, interactive capabilities, and customization options, all of which contribute to enhanced learning and training outcomes [3].

Simulation-based learning (SBL) has been used in nursing education in which nursing students go through high-fidelity live simulations using computerized mannequins, scenarios, and practical static tasks [1]. However, given time and cost constraints students can only attempt them once, increasing student stress.

VR Simulations (VRS) have been used for a variety of purposes however in this context the term VRS is used to describe virtual reality simulations that specifically focus on training and skill development purposes. As such the use of VRS in the curriculum "provide[s] an objective evaluation that may not require the need of human evaluators." [5]. VRS has also been found to be both more time and cost-effective than traditional SBL methods [11]. VRS are "increasingly being used in healthcare education and practice" [9].

Given these factors, the University of Tulsa's Oxley College of Health Sciences reached out to the Tandy School of Computer Science to collaborate with students in the Computer Simulation & Gaming (CSG) program to develop a Virtual Reality Simulation in Nursing Training (VRSNT) to be used as a tool for nursing students to practice the expected order of actions and analyze procedure errors, before the live simulation, reducing stress and providing supplemental training outside the classroom.

The developed VRSNT prototype provides students with the ability to attempt a simulation quickly and receive a report detailing mistakes in missed or out-of-order steps. A non-linear "objective tree" system was designed to allow out-of-order execution of simulation steps while still providing useful feedback and scoring of a student's performance, and easing the creation of simulation scenes.

2. Literature Review

According to Pottle [9] "VR is already transforming medical education. It is helping to free learning from the classroom, allowing learners to apply their knowledge to practice and learn from mistakes."

Dr. Barrow's 2021 dissertation explored the use of VRS in nursing education as having several potential implications for decreasing student anxiety. Barrow [1] concluded that overall, the use of virtual reality simulations in nursing education can help to reduce student anxiety by providing a safe and supportive learning environment that promotes skill development, feedback, and knowledge retention.

A study conducted by Fournel [4] on learning procedural skills with a VRS, accessing the acceptability and usability of a new VRS for procedural skill training among scrub nurses. The study concluded that VRS is acceptable and useful for training purposes. In addition, both expert scrub nurses and non-expert users in the study emphasized the educational value, fun, and realism experienced in the

VRS. However, Fournel [4] note that some participants were affected by simulator sickness. Therefore, simulator sickness should be considered when designing VR training scenarios, and reducing simulator sickness could improve the acceptability and usability of VRS.

VRS were found to be effective in improving knowledge acquisition among nursing students, according to the systematic review and meta-analysis conducted by Woon [12]. The analysis demonstrated a significant improvement in knowledge, with a small-to-medium effect in the VR group compared to the control group. Woon [12] also found that VRS were found to be more effective in increasing knowledge scores among undergraduate nursing students and particularly effective in teaching procedural knowledge when conducted through multiple sessions, ideally, short 30-minute sessions that were self-guided and providing repeated opportunities for learning in a safe environment.

VRS provides an immersive, interactive, and flexible learning environment according to Shorey and Ng [11], and is particularly effective in improving cognitive outcomes, such as theoretical knowledge, among nursing students. However, Shorey and Ng [11] also identified that VRS had limitations which included technological issues and the lack of realism in virtual worlds, which could break the immersion.

A study by Kim [6] provided a Virtual Reality Simulation (VRS) template consisting of three main components: educational elements, virtual elements, and scenario outlines. The educational elements focused on the student learning objectives and evaluation. The virtual elements relate to the level of immersion in the virtual environment as well as the technology and tools used for creating the VRS. Lastly, the scenario outlines can be described as the structured narrative that guides the VRS and provides a realistic and immersive experience for the learners.

One method of establishing an immersive experience is through the development of an effective game atmosphere. Riberio [10] determined that game atmosphere, as defined by strong audiovisual thematic cohesion, has a significant impact on players' emotional responses to video games. However, contrary to expectations, the study did not find a significant impact of atmosphere on players' immersion and player experience. Furthermore, the study suggests that the game atmosphere may consist of additional aspects beyond audiovisual cohesion, such as interactivity and sound effects, which should be explored in future research [10].

3. Framework for VRSNT

The VRSNT follows the same basic structure described by the VRS template [6]. The nursing faculty provided the educational elements that included the specific objectives that had to be met for the simulation and how the user was to be evaluated in the simulation; for example, if a certain step could be completed out of order or not.

The VRSNT was designed to be short self-guided lessons as recommended by Woon [12], thereby allowing for repeatable opportunities for learning in a safe and controlled environment to practice and develop their clinical skills, which according to Barrow [1] can help to reduce anxiety and increase confidence.

3.1 Educational Elements and Scenario Outlines

The nursing faculty also provided the scenario outlines consisting of a sample of doctors' orders of different medications for different patients; these scenarios are randomized each time the learner goes through the simulation. Currently, simulation encompasses three separate scenarios, each specifically designed to address the administration of different medication types: oral, liquid, and patch. These scenarios are intended to provide targeted training and skill development for nursing professionals in the safe and effective administration of medications through various methods.

3.2 Virtual Elements

The technology used for the development of the VRSNT consisted primarily of the Unity 3D real-time engine and Blender for 3d modeling.

The environmental assets were closely modeled after the real-world simulated clinical rooms Oxley nursing students currently use for their in-person examination. The aim is to familiarize users with the clinical environment and the equipment used in patient care, which, according to Barrow [1] can help to reduce anxiety and improve performance. In addition to the visuals, ambient hospital noise was used as subtle background sounds, and the high level of interaction within a VRS aims to provide a game atmosphere with aspects that Riberio [8] determined may provide users with greater immersion and player experience.

Figure 1. Reference image of real-world simulated clinical room on the left and 3d modeled room on the right

To help reduce the amount of simulation sickness described by Fournel [2], the VRSNT uses a teleportation feature, in which users use the VR controllers to select and jump to predetermined locations in the virtual environment. Teleportation in VR games has shown to be a preferred option over joystick (free motion) control [5].

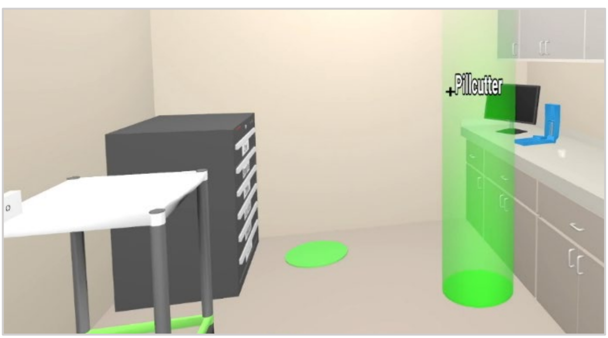

Figure 2. Teleportation locations represented by green circles

The backend development of the VRSNT is comprised of two major systems. The first system is called the Objective Tree System and is used to create the series of steps a training procedure will follow. The second system is an input system, which allows for experiencing the training simulation in both Virtual Reality and PC controls.

3.3 Objective Tree System

The Objective Tree System (OTS) controls how the simulation assesses which training steps have been correctly completed by the user. It is based on the idea of representing the training procedures as flow charts so that they can be easily understood and edited by anyone. The objective tree is created by connecting many "Logic Nodes" of different types. These nodes can in turn be filled by various events or conditionals to specify what is necessary for the user to move forward in the simulation

3.3.1. Logic Nodes

Logic nodes can be considered the "building blocks" of the OTS. Each type of logic node has a set of slots that can be filled either with an event, a logical comparison, or another logic node. Figure 3 depicts a list of all the currently considered logic nodes.

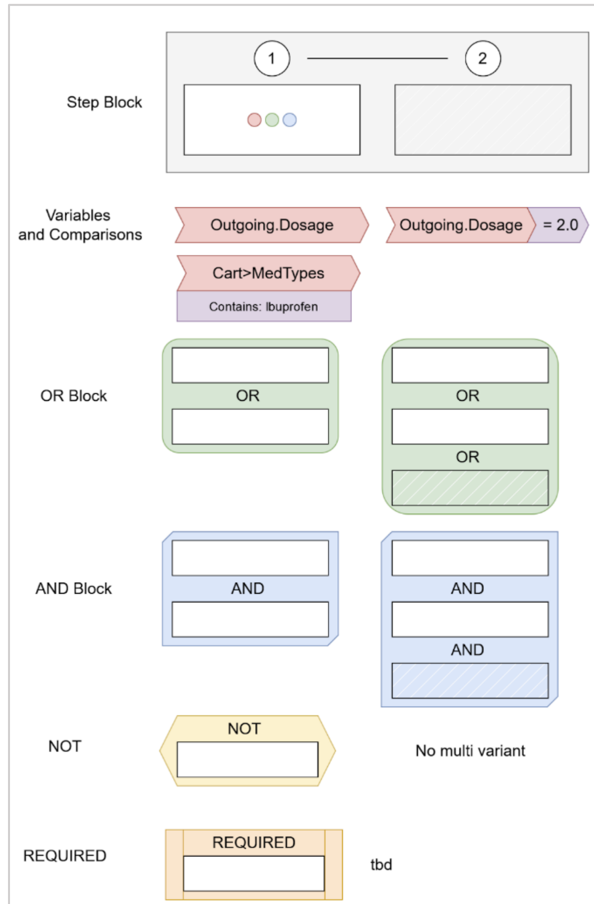

Figure 3. List of Logic Nodes.

One should take note of the "Step Block" as this is the logic node that allows for the ordering of steps in the VRSNT. In essence, the slots of the step block are evaluated one after the next. Once whatever is in slot 1 of the block gets evaluated as true, the VRSNT will then start evaluating what is in slot 2. Once all slots in the step block have been evaluated as true, the step block as a whole can be evaluated as true or completed.

Other logic nodes include basic logical operators: AND, OR, NOT. The AND and OR blocks can both expand to have as many slots as are desired, with the OR block evaluating true if one or more of its slots are true, and the AND block evaluating true if all of its slots are true. The NOT block has only one slot and will return the opposite of whatever the boolean value of that slot is. Figure 4 shows an AND block filled with 3 conditional statements.

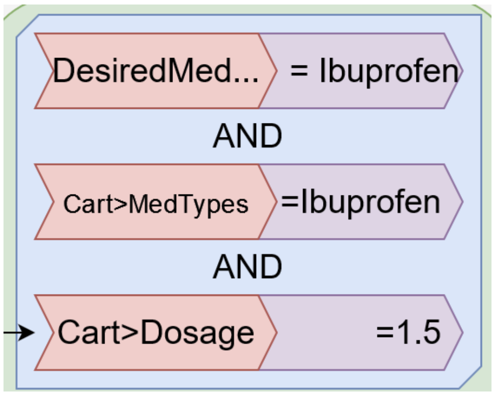

Figure 5. Example of a filled AND Logic Node

3.3.2 Objects and Variables

To create conditional statements inside the logic blocks, the OTS must have access to important objects and variables that are used in the simulation. There are two types of variables in the OTS: Discrete and Object variables.

Object variables are variables that exist inside a specific objective object. Each instance of an object will have its own set of these variables which allows the OTS to evaluate the state of different objects independently. Discrete variables are not tied to any objects. They can be considered as global static variables for the simulation to hold data.

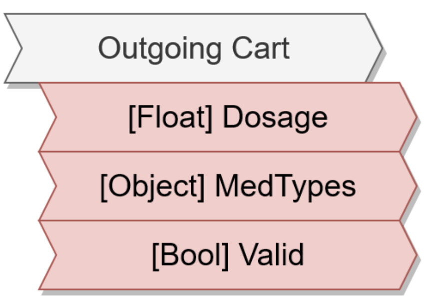

Figure 6. Example of an Objective Object with 3 variables

Currently, objective objects and variables are manually coded into the scripts of the simulation and then the OTS makes references to the scripts to access their states. Future development of the VRSNT will include developing code generation for the OTS, which should help automate connecting the Objective objects and variables to those in the simulation.

3.3.3. Usage

A conceptual graphics interface for the OTS is illustrated in Figure 6, along with several notes clarifying certain areas of the Graphical User Interface (GUI). To build an objective tree, the user would start with the area in gray and on the right, being empty, with only the selection of logic nodes on the left available. The user would then drag logic nodes into the gray area to begin building the OTS. Objects and variables could be created in the area underneath the logic nodes, which could then be dragged into the slots of the logic blocks. Figure 7 shows an example of how this “Drag-n-Drop” system would look.

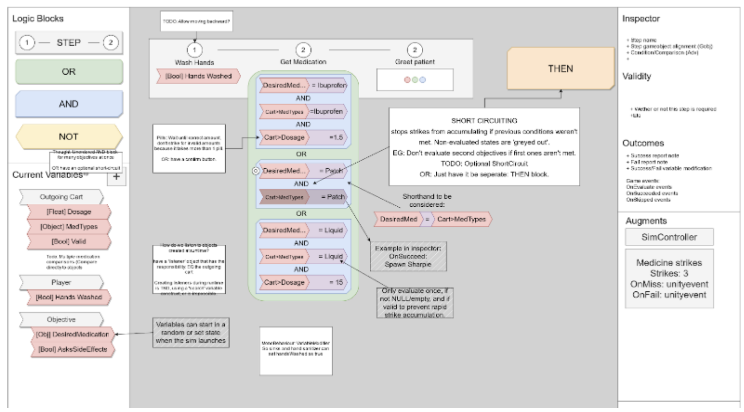

Figure 4. Objective Tree Conceptual GUI.

On the right side of the GUI is an Inspector window, which displays information on whatever element in the objective tree is currently selected. Such as a logic node’s name, if it is a required step, what conditionals are connected to this node, etc.

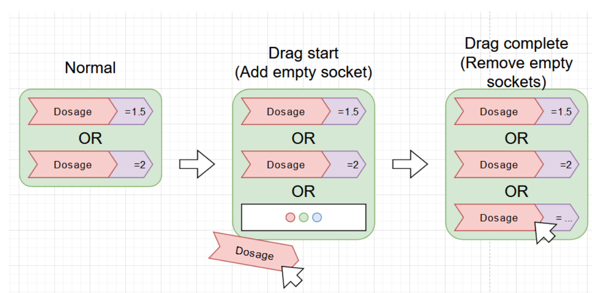

Figure 7. Depiction of Drag-n-Drop system

Figure 8 shows the class diagram for the current implementation of the OTS. However, this is subject to change as development is ongoing.

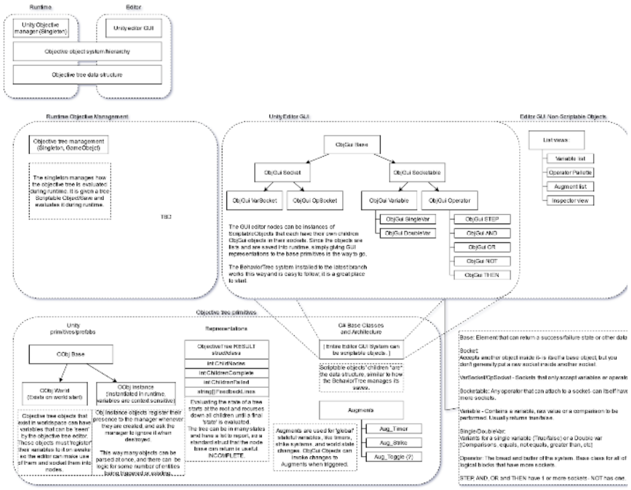

Figure 8. Class Diagram.

3.4 Input System

The input system for the VRSNT was designed to accommodate both VR controls and traditional PC controls using a mouse and keyboard, to ensure accessibility for more users. However, developing an input system that effectively caters to both VR and PC controls proved to be a significant challenge during the development process. This section discusses the design challenges encountered and outlines the evolution of the input system, as well as the future goals for further improvements.

3.4.1. Design Challenges for Developing a Contiguous VR and 3D Input System

The following challenges needed to be addressed to properly design an input system capable of seamlessly supporting VR and PC controls:

1. Dual Rigs: Determining whether to create separate rigs for 3D and VR or to integrate XR controls into custom scripts for 3D.
2. Object Manipulation: Establishing methods for handling dropping and picking up objects.
3. UI and Buttons: Implementing user interface elements and interactive buttons compatible with both VR and 3D controls.
4. Device Detection: Developing a mechanism to detect and differentiate between the input device being used (VR vs 3D).
5. Mode Switching: Enabling a smooth transition between VR and 3D modes within the input system.
6. Collision Detection: Combining collider triggers and mouse click detection for comprehensive interactivity.

3.4.2. Initial Attempts

During the early stages of development, many design mistakes were made, such as creating two isolated input systems, one using Unity's prebuilt XR Toolkit package designed for VR interaction and the other being a custom input system for handling 3D for PC controls. Additionally, these early attempts used a device-based XR rig, causing compatibility issues when testing with different VR headsets such as the Oculus and HTC Vive.

3.4.3. Current System

Currently, the VRSNT employs a singleton to determine which input system to activate depending on if the XR components in the application was able to detect a VR device. Custom triggers were also implemented to detect interactions from both VR hand tracking and mouse clicks. However, this system is not without its limitations. The separated nature of the input system requires extensive testing and consideration of edge cases that may arise on one input style but not the other.

3.4.4. Future Goal

As development on the VRSNT continues, the goal for the input system is to merge VR and PC controls into a unified system, aiming to streamline the development process and facilitate more efficient testing of iterations. By consolidating the input systems, a reduction in duplicated testing and a more cohesive experience for the user is anticipated.

4. Future Development

While much progress has been made on the VRSNT, before it can be implemented into the nursing curriculum there are still many elements that need refinement and development; such as:

1. Completion of work on the GUI for the OTS
2. Development of a custom GUI window inside the Unity editor allowing for better utilization of the system
3. Development of a dialogue system that incorporates Large Language Models allowing for an immersive experience of talking to a patient.
4. Development of a reporting system that outputs user results to a server, which can be accessed by both users and instructors for assessment purposes.

While further development of the VRSNT is necessary, the research conducted thus far has explicitly demonstrated the effectiveness of VRS as a valuable tool in nursing education. By following best practices for creating immersive and interactive virtual learning environments, the VRSNT holds immense potential as a viable and impactful addition to the nursing education curriculum. The findings highlight the significance of continued efforts in improving and expanding the VRSNT, aiming to enhance nursing students' learning experiences and better prepare them for real-world clinical practice. Future research and collaborative endeavors will play a pivotal role in further advancing this innovative tool and unlocking its full potential within the field of both VRS development and nursing education.

4. References

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