

Simulation of Fire Safety Training Environment using Immersive Virtual Reality

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Abstract: *The Real Time Environments that are very difficult and dangerous to practice can be simulated using Virtual Reality (VR) and can be used as a learning tool. The use of immersive VR supports to demonstrate the three dimensional virtual environment in detail and helps the user to learn about the concepts of fire hazards and practice escape mechanisms in fire surrounded situations. A game like interface techniques is used for VR fire-safety training interaction in order to improve motivation for learning and were encouraged to explore the virtual world. People interact with objects and navigate through environment that are virtually present with full control using a VR controller which gives a feel of an active user. The identification of few fire hazards circumstances at home and office environments are performed based on which a similar virtual environment is designed to practice fire safety and escape techniques. A PASS training for fire extinguishers was included as a core concept of the project. PASS stands for Pull, Aim, Squeeze and Sweep while using a fire extinguisher. Knowing these techniques in times of trouble could be really helpful and mandatory.*

Index Terms: *Fire Safety, Fire extinguishers, Immersive, PASS Training, Virtual Reality (VR), Game interface*

I. INTRODUCTION

Inculcation of fire safety drills in emergency situations is the motivation of this paper. This would be possible only if the user could save himself/herself in the event of a fire accident. So the user would have to pass challenges like saving the individual within a particular time etc. All these activities are inculcated into the program as sort of challenges. Passing these challenges, would earn the user higher points thereby teaching important fire safety drills. The gamification approach is used which teaches people fire safety drills all the while making sure the user understands the concepts of fire safety drills. The system proposed in this paper would be very useful for teaching people about Fire safety drills. One of the most important drills reinforced through this paper is PASS (Pull, Aim, Squeeze, Sweep) training for Fire Extinguishers. Through the Virtual Reality (VR) environment, the user would be able to immerse himself/herself in the virtual world and save people using the fire safety drills learnt. Oculus Rift will be used as the physical hardware for this project. The Oculus Rift would allow the user to physically hold a fire extinguisher in the virtual world and feel it respond to the user's controls.

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In order to understand how a Virtual Reality (VR) environment works, reading articles relating to how the reality could be manipulated in a Virtual environment helped. Challenges in learning about Virtual Reality included aspects of merging sensory controls to a virtual environment and translating the physical motions done by a human being and effectively translate it into a three dimensional lattice. In a highly focused fire environment, it is difficult for the people to reproduce the correct behavior of fire safety practice and hence it is hard to evaluate the level of training being provided in the classroom setting when compared to real time situations. An immersive and enhanced fire safety skill training can be provided using virtual reality like applications under safe environment.

II. BACKGROUND STUDY

Smith, S. and Ericson, E. proposed a framework for virtual reality based fire training system interfaced with fire dynamics data into it. The procedural data processing techniques is included to experience toxic gases and visualize hazard level on three dimensional base. A virtual reality based fire training simulator integrated with fire dynamics data was developed for a simple road tunnel fire scenario for the enhancement of human safety [1].

Cha, M et al., developed a system using CAVE to help children to learn about fire hazards and practice escape mechanisms in fire situation. A game like learning environment was used for simulation where the children found it very fun, engaging and intriguing [2].

U. Ruppel, and K. Schatz designed a BIM-based serious game for fire safety evacuation simulations useful for the Fire-Safety Engineering Group (FSEG) [3]. Quest 3D is an another product from Holland based company which was been used as the virtual reality simulation software to determine how the emergency signs facilitate ways in construction operation [4]. In any place where the fire extinguishers are available for the use by employees in the emergency situation, it is the responsibility of the employer to make arrangements to educate employees on the hazards associated with developing fires and to train them the basic principles and practices of using extinguishers in fighting with fires. It is the specialized form of training that focuses on improving the skills to deal with emergency fire situations. The training involves the usage of fire extinguisher using the Pull-Aim-Squeeze-Sweep technique (P.A.S.S.) when responding to incipient stage fire with in its effective range. In order to teach people about fire safety, real time physical drills were used as a demonstration. This would involve a group of people gathered together and listening to experts



demonstrate the fire safety drills. Each person has to wait for his/her turn and go through the whole process one step at a time. The following issues have been listed in comparison of the proposed system with the existing systems that had been studied and analyzed from the above papers in the literature survey:

- It is very time consuming to do fire safety drills in person.
- There is no effective real time feedback for every individual.
- The success of the fire safety drills depends on the demonstrator which may not always go well.
- It does not provide an immersive experience.
- It doesn't create a similar real life fire accident scenario.

III. PROPOSED SYSTEM

The system proposed in this paper would be very useful for teaching people about Fire safety drills. One of the most important drills have been reinforced through this program is PASS (Pull, Aim, Squeeze, Sweep) training for Fire Extinguishers. Through the Virtual Reality (VR) environment, the user would be able to immerse himself/herself in the virtual world and save people using the fire safety drills learnt. Oculus Rift has been used as the physical hardware for the implementation of this system. The Oculus Rift would allow the user to physically hold a fire extinguisher in the virtual world and feel it respond to the user's controls. The software used are Autodesk Maya, Substance Painter, Quixel suite and Unreal Engine. Table 1. Shows the software and its description. The hardware requirements include the following components:

- High End VR Device - Oculus Rift/ HTC Vive
- CPU : Any latest gen processor
- 8GB DDR3/4 RAM
- GPU : Recommended GTX 970 4 GB GDDR5
- 2 GB Storage Space

TABLE I
SOFTWARE AND ITS DESCRIPTION

Software	Description
Autodesk Maya	Used to create interactive 3D applications
Substance Painter	3D Painting Software used to texture, render and Share.
Quixel suite	Texturing suite used to texture beautiful ideas and objects.
Unreal Engine	Integrated development Environment(IDE) for game developers to design, build games, simulations, and visualizations
Oculus SDK	Used to develop any VR based games, social experience, entertainment or education application

Nvidia Game Works

It is Nvidia's middleware software suite that offers Visual FX, PhysX and Optix SDKs which is used to provide a wide range of enhancements pre-optimised for Nvidia GPUs.

Spatialized audio

It is a sound processor to provide impression of sound in 3D environment to the listener

IV. FIRE SAFETY TRAINING ENVIRONMENT DESIGN

Designing the simulation of virtual environment for fire safety training involves various steps like 3D Modelling of objects to be used, Photography and texture creation, object and surface texturing, environment design, sound design, and game interface programming.

A. 3D Modelling

Autodesk Maya software is used for Modelling and it involves basic knowledge of 3D Modeling. A model is categorized into low poly mesh and high poly mesh. A low poly mesh can be created using set of modeling tools like Bevel, Extrude, Insert Edge loops etc. available in maya. A high poly mesh is an extended version of low poly. High poly cannot be used in the final software as it juices out more performance from the system. Low poly is tricked to look like high poly using texturing software and the process is called baking. Figure 1 shows the 3D modelling of a fire extinguisher using Maya

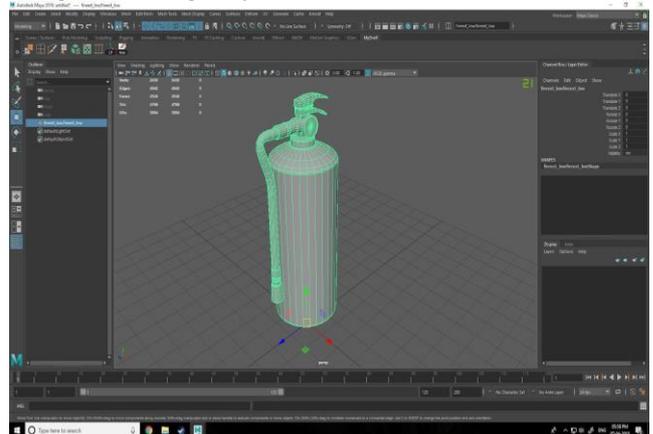


Fig. 1 3D Modelling of Fire Extinguisher

B. Photography and Texture Creation

High End DSLR is used to capture the real life tiling textures. The textures captured with camera is exported as PNG or TGA file. Quixel suite is used to generate texture maps from the texture like normal map, occlusion map, height map, reflection map. These texture maps are then combined to create a material in substance painter. The texturing of 3d mesh is explained in the texturing process.





Fig. 2. Texturing Sample

C. Texturing

Substance Painter 2 is used for texturing. First process involves importing the low poly and high poly mesh into the software. Then texture maps (normal, ambient occlusion, height, curvature) are generated by baking high poly mesh over low poly. These texture maps act differently in different lighting scenarios adding reflection details to create life like materials. Creating ID map for the mesh to separate each part of the mesh and apply materials presets create from the above process or doing a custom paint job. Finally, export the textures to the environment. Refer Fig. 2. for a texturing sample for a fire extinguisher.

D. Environment design

Unreal Engine 4 is a Game Engine where game objects are organized and given life to the objects using programming. The environment design involves importing the low poly meshes and textures into the engine. The suitable material is created from above textures using Unreal Engine’s material creator. Then the material is applied to the mesh. Now organize the assets to create an environment and setup lighting like Direction light (sunlight), skylight, Spotlight for interior lighting. There are two kinds of lighting methods static and dynamic. We used static lighting as dynamic is resource heavy and cannot produce realism as static lighting. The static lighting consumes lot of time for baking and the environment took around 3 hours to bake it into a final scene with accurately calculated lighting and reflections using the engine’s algorithm. Fig. 3, shows a sample of simulated virtual environment design used for fire safety training.



Fig. 3. Simulated virtual environment design used for fire safety training.

E. Sound design

Captured sounds like fire, office ambience, sparks, fire alarm etc. A special mic is used to record and edited using audio software iTunes Garageband to achieve spatialization.

F. Game Programming

Unreal Engine 4 uses object oriented programming. It’s native scripting language called Blueprints which is a virtual scripting language built on top of C++ libraries. Every interactive object is called as actor in UE4. There different types of Blueprint classes available are shown in Table 2. Every class has member variables, functions, Events and Construction script. It supports polymorphism and inheritance as in OOPS. Dragging and dropping the class into the scene instantiates it as an object and an object can be duplicated. Fig. 4. Shows the sample VR Pawn class.

TABLE 2

GAME PROGRAMMING – BLUEPRINT CLASSES	
Class	Description
Actor	An Actor is an object that can be placed or spawned in the world.
Pawn	A Pawn is an Actor that can be "possessed" and receive input from a Controller.
Character	A Character is a Pawn that includes the ability to walk, run, jump, and more.
PlayerController	A Player Controller is an Actor responsible for controlling a Pawn used by the player.
Game Mode	A Game Mode defines the game being played, its rules, scoring, and other faces of the game type.



Fig. 4. Sample VR Pawn Class

V. IMPLEMENTATION METHODOLOGY

The implementation methodology of the system has undergone several steps of pre-production and post-production. “Agile software development” life cycle has been used for the implementation trails because it would best suit the evolving needs of the problem statement. The project has to undergo a multitude of steps using various software listed above. The following steps are done in order as follows – 3D Modelling, Texturing and Environment design.



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The 3D modelling phase involves the actual sculpting of the real world objects. It is in ways, similar to clay modelling. This process is done through a software called Autodesk Maya. After this phase, the 3D model undergoes a process known as Texturing, where the skin or colour of the model is added. The Texturing is done through Substance painter. After the texturing phase, comes a phase known as Environment design, where the objects would be placed in the environment. This can be done through Unreal Engine.

After these three phases, the objects are integrated into the environment to create a scene. This would be the workspace/ visual area exposed to the user. After this, Unreal engine is used & the controls are coded and integrated. The file is exported in a Virtual Reality compatible format. This executable file could be opened using a high performance PC connected to a Virtual Reality device - the Oculus Rift. The user has to wear the goggles to immerse himself into the Fire & Safety VR where he/she would be able to pick up fire extinguishers using the handheld VR controllers and save people from fire.

VI. WORKING PRINCIPLE

The working principle of the system is described as follows:

- After launching the Fire safety immersive VR application, the user will be prompted by a tutorial which teaches the PASS training for the fire extinguisher.
- The training will teach how to use the extinguisher using the handheld controller.
- After the successful completion of the tutorial, the user can select either “Replay tutorial” or “Take me to simulation” options using the handheld controller.
- If the user selects the latter option, the user will be put into an office room where the fire will breakout and the user has to save the person inside the room by taking him to the door near the corridor before the fire kills him.
- The user has a timer running, having a time limit of 7 minutes and it is customizable. If the user fails to save the person within 7 minutes, the application will restart the simulation environment.

VII. CONCLUSION AND FUTURE WORK

Thus the system proposed will help people get trained in Fire safety drills using Virtual Reality(VR). This will immensely save time and resources and also teach the users the basics of Fire safety drills. Since a timer and fire safety program is included in the software, it will help the user in knowing how long does he/she have before saving some stuck in a fire. It also encompasses PASS training methodology for the fire extinguisher. The future work will include inculcating this technology into other streams like Augmented Reality and also on making this system more user friendly and accessible to many users.

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