Extensible VR Emergency Preparedness Platform

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Abstract

Emergency preparedness is a cardinal skill required in today's fragile world. Conventionally, individuals acquire knowledge of procedures that they are required to take during an emergency situation through a regimen of training-drills, tabletop exercises, functional exercises and full-scale exercises. These procedures are usually far from reality as these are structured training schedules happening in a utopian environment. To bridge this gap, we developed a generic virtual learning framework. This framework is extensible across multiple scenarios and locations. The proposed platform can complement the conventional emergency training methods to enhance the overall emergency preparedness of private organizations (e.g. workplaces, commercial buildings, etc.) and also indirectly benefit wider communities.

Introduction

Emergency preparedness is very important for the general public (Perry and Lindell 2003). A real-life emergency can be a fire breakout, a natural disaster like an earthquake, or a terrorist attack. Traditional Emergency preparedness training lacks realism, mainly due to the inability to expose the learners to a variety of scenarios multiple times.

Recently, VR-based training has been gaining acceptance as an alternative paradigm for emergency preparedness (Kinateder et al. 2014). VR-based training offers an immersive experience for the learners that not only is more realistic than the table-top exercises but is also cost-effective and can have multiple events with varying complexities.

In order to train personnel to handle various emergency situations, most organizations would perform such training on-site in a real-life environment, in order for personnel to better familiarize themselves with the potential scenarios and provide them with the necessary tools to handle them. However, it may be difficult to do so on a large scale and is often dependent on certain conditions, such as location availability, weather patterns, and time of day to perform such training.

Thus, organizations can turn to the use of Virtual Reality (VR) technology to circumvent these issues (Benvegnù et al. 2021). The researchers in (Benvegnù et al. 2021) simulated a fire emergency where the user would need to decide on what type of fire extinguisher is appropriate to put out specific types of fire. They concluded that VR simulations are the best format for training users as it utilizes both accurate Spatial Representation and a higher degree of interactivity to keep them focused and engaged with the training. Another study (Cha et al. 2012) developed a fire training simulator using a computational fluid dynamics simulation to accurately predict fluid phenomena.

In recent years, there have been multiple immersive implementations addressing various aspects of fire emergency situations like evacuations (Lorusso et al. 2022). (Wang et al. 2022) developed a multi-agent-based passenger evacuation model. Their VR simulation concluded that VR scenario is able to reduce the evacuation time by a significant margin compared to training with teaching videos. Another study (Nilsson et al. 2019) looked into how multisensory feedback would affect on user behavior, utilizing external hardware to simulate heat and smell.

Apart from fire emergencies, there has been active research on other emergency scenarios (Mossel et al. 2017) (Lu et al. 2020). (Lovreglio et al. 2018) incorporated the concept of Serious Games with VR technology to create an earthquake emergency training simulation. They deduced that the most critical element in a VR-based emergency simulation is to capture the depth of realism perceived by users in the environment. Researchers in (Awada et al. 2021) studied the viability of using VR as a tool to analyze human behavior during active shooter incidents, using the user's Sense of Presence as an indicator.

Traditionally, emergency preparedness includes going through the procedures and actions that individuals are required to take during an emergency situation through a regimen of training - drills, and tabletop exercises. This training procedures is quite monotonous and non engaging. Further, it differs from one emergency to another. Thus, there is a need for a generic platform that can be adapted to different scenarios and locations. Other unpredictable hazards that are dangerous may however not be able to be fully recreated. We propose an extensible immersive emergency preparedness platform that can be extended to various emergencies in different environments. We exemplify our framework for fire emergency preparedness and showcase how some parts of the platform can be tweaked to extend to other situations.

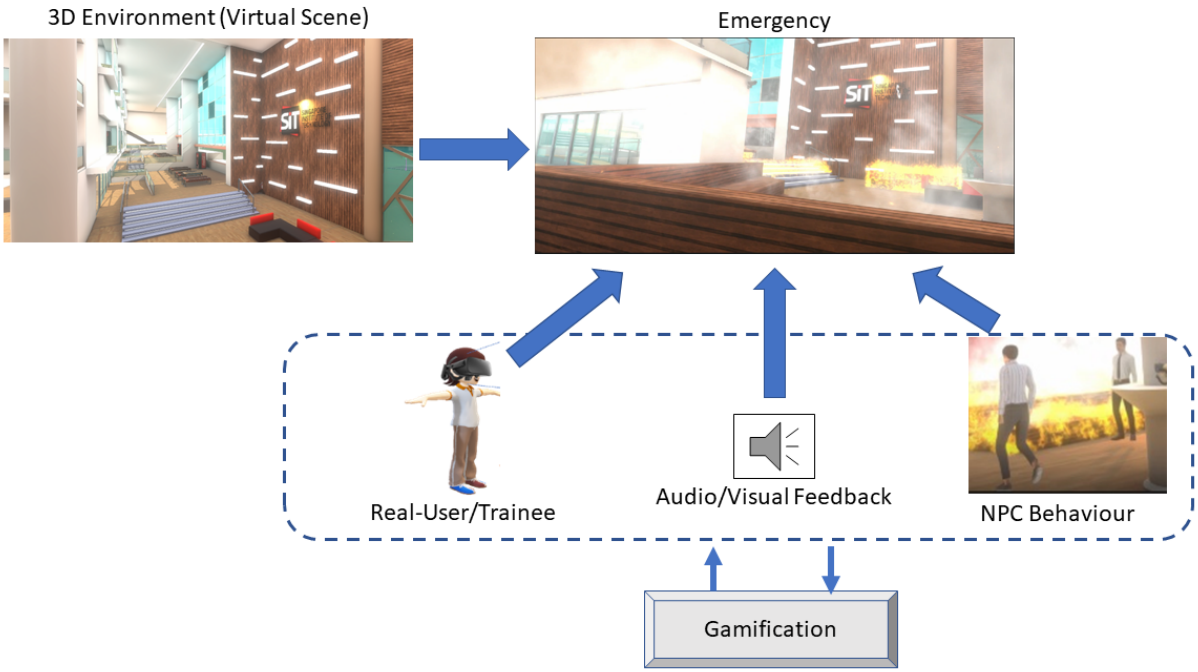

Figure 1: Proposed framework which includes different components of our Virtual Emergency Preparedness Platform

Emergency Preparedness Framework

The framework shown in Fig. 1 showcases the different components of our Virtual Emergency Preparedness Platform(VEPP). It has been employed to simulate a realistic emergency scenario to prepare trainees for the steps they need to take if they encounter the same in real life. The framework for our proposed system is made up of modular components in order to accommodate the different types of emergencies that the training may cover.

The first component of this VEPP multi-user (Fig. 1), is the 3D Environment module which is comprised of the virtual scene/environment in which the users navigates in. The simulated environment's primary requirement had been to closely resemble a real-world facility which further needed the 3D scene to be quite realistic in terms of scale and aesthetic detail. The VR environment was created using the best available physical models which corresponded to any real-life scenario. It also represented an environment with physical space in the virtual world which allowed users to feel the actual physical environment in the virtual world. As shown above, in the simulated VEPP, using Unity a miniature version of the SIT at Nanyang Polytechnic had been created. The snapshot shown above is from the actual simulation of the 3D environment. This can be employed for any emergency scenario.

The 3D environment creation is independent of the emergency scenario being simulated. The components specific to the emergency scenario formed the second component of the VEPP. This component could be customized dependent on the emergency being simulated. Here we exemplify using a fire emergency, as shown in the snapshot showcases a fire-related simulated scenario. This included a fire extinguisher, fire alarm, and fire simulation. Extending the framework for another emergency would require calibrating this component with the features specific to it.

The immersive experience formed the third component of the VEPP. An important aspect of this module has been the real player avatar and the Non-Playing Characters (NPC)/computer players. The real player could join the platform using a head-mounted device (Oculus Quest 2 in our case) and could walk around in the simulated environment using hand-held sensors. The realistic scenario also included some computer players. These NPCs have been equipped with some pre-defined animations that defined their movement in the VR environment. For the creation of a realistic emergency scenario specific to the situation, smarter NPCs have been developed. The enhanced NPCs are embedded with rule-based knowledge which defined sequential measures that had to be undertaken during that particular emergency. For example, in case of fire, the NPC will find the nearest exit and rush in that direction or how to use a fire extinguisher etc. Further, for efficacy, the activity of the NPC can be triggered by the actions of the trainee (real player).

The Feedback module controls the various sensory outputs that the users perceived during the simulation, from Audio sound effects to simulated background noise to Visual effects such as smoke or flashing lights. Gamification of VEPP has a two-fold advantage. One, it allowed asyn-

chronous learning for trainees as they could play at their own pace. Second, it enhanced the trainee experience and exposed them to realistic scenarios. Scores given during the simulation helped the users in understanding how they could optimize their actions.

The emergency scenario showcased is a Fire Emergency. The simulation includes a fire breaking out in a part of the environment and spreading across the facility. The objective of the user is to participate in the simulation by means of completing certain tasks given to them based on the roles provided (Civilians, Fire Warden, etc). The real user needs to apply his/her knowledge and reach the assembly point, where the simulation ends. The whole platform is created and executed in the Unity Platform. First we create the 3D environment, then we add various emergency-specific assets, such as fire extinguisher, smoke etc. Ignis - Interactive Fire System by Arctibyte has been employed for generating Fire visual effects. Next we add the NPCs along with their behaviors into the simulated environment. The NPC behaviors comprises of some generic actions like wandering, running etc. which are common to any scenario. The other set of behaviors are specific to the emergency like operating the fire extinguisher, navigating to the assembly location etc. Lastly, we add in the gamification module for capturing and assessing real users' interaction in the platform. Currently, the real user can join the platform using Oculus Quest 2 (nottested with any other head mounted device) and hand held sensors.

Discussion

Conventionally, emergency preparedness is carried out through a regimen of training - drills, and tabletop exercises. Emergency preparedness through the use of VR-based training has been a key application of immersive simulation. This platform differs from others in that it proposes a generic and extensible framework that leverages VR environment for emergency preparedness training. In other words, it is not bound to a particular domain area but it is architecturally extensible to promote re-usability through separation-of-concerns. To create high levels of realism for the exercises, some of the threats and hazards would have to be recreated and this usually may come with high investment in terms of time, cost, and coordination efforts. Other unpredictable hazards that are dangerous may however not be able to be fully recreated. With the proposed software, it can complement the conventional emergency training methods to enhance overall emergency preparedness.

Future Work

In the future, we plan to extend the platform to other emergency scenarios like chemical leaks, and terrorist attacks. Many simulations utilize a combination of audio/visual or social elements in order to create the intended user experience. Another avenue of research would be to analyze the types of design elements such as audio-visual or social cues used in different VR simulations.

References

Awada, M.; Zhu, R.; Becerik-Gerber, B.; Lucas, G.; and Southers, E. 2021. An integrated emotional and physiological assessment for VR-based active shooter incident experiments. *Advanced Engineering Informatics*, 47: 101227.

Benvegnù, G.; Furlan, M.; Orso, V.; and Gamberini, L. 2021. The Role of Virtual Spaces and Interactivity in Emergency Training. In *Proceedings of the 32nd European Conference on Cognitive Ergonomics*, 1–5.

Cha, M.; Han, S.; Lee, J.; and Choi, B. 2012. A virtual reality based fire training simulator integrated with fire dynamics data. *Fire safety journal*, 50: 12–24.

Kinateder, M.; Ronchi, E.; Nilsson, D.; Kobes, M.; Müller, M.; Pauli, P.; and Mühlberger, A. 2014. Virtual reality for fire evacuation research. In *2014 federated conference on computer science and information systems*, 313–321. IEEE.

Lorusso, P.; De Iuliis, M.; Marasco, S.; Domaneschi, M.; Cimellaro, G. P.; and Villa, V. 2022. Fire emergency evacuation from a school building using an evolutionary virtual reality platform. *Buildings*, 12(2): 223.

Lovreglio, R.; Gonzalez, V.; Feng, Z.; Amor, R.; Spearpoint, M.; Thomas, J.; Trotter, M.; and Sacks, R. 2018. Prototyping virtual reality serious games for building earthquake preparedness: The Auckland City Hospital case study. *Advanced Engineering Informatics*, 38: 670–682.

Lu, X.; Yang, Z.; Xu, Z.; and Xiong, C. 2020. Scenario simulation of indoor post-earthquake fire rescue based on building information model and virtual reality. *Advances in Engineering Software*, 143: 102792.

Mossel, A.; Froeschl, M.; Schoenauer, C.; Peer, A.; Goellner, J.; and Kaufmann, H. 2017. VROnSite: Towards immersive training of first responder squad leaders in untethered virtual reality. In *2017 IEEE Virtual Reality (VR)*, 357–358. IEEE.

Nilsson, T.; Roper, T.; Shaw, E.; Lawson, G.; Cobb, S. V.; Meng-Ko, H.; Miller, D.; and Khan, J. 2019. Multisensory virtual environment for fire evacuation training. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–4.

Perry, R. W.; and Lindell, M. K. 2003. Preparedness for emergency response: guidelines for the emergency planning process. *Disasters*, 27(4): 336–350.

Wang, Z.; Mao, Z.; Li, Y.; Yu, L.; and Zou, L. 2022. VR-based fire evacuation in underground rail station considering staff's behaviors: model, system development and experiment. *Virtual Reality*, 1–11.