Chapter 3
A Systematic Literature Review on Virtual Reality-Based Fire-Safety Training in India

Anmol Srivastava

1 Introduction

Fire is hazardous and can cause severe damage to lives and properties. During fire emergencies, there is often no time to think and respond quickly, thus causing panic and severe loss to lives or properties. In the year 2015 alone, more than 18,000 fire accidents were reported [1, 2] in India. However, a study by [3] indicates that the issue of fire accidents is more severe than reported. The officials are only able to report a few cases that have been registered by the police. A lot of cases go unregistered in reality. While there can be many reasons behind fire accidents, sensitizing people regarding complications of fire and training them to handle various related situations can help facilitate preparedness during fire accidents. Typically, fire trainings are conducted in workplaces to raise fire-safety awareness and teach people regarding fire hazards. However, a quick survey and field observations reveal that such training is not conducted at regular intervals. Further, Indians who are mostly homebound, such as housewives, young children, and elders, there are no fire-safety training available them. This raises questions like how can fire-safety training be provided to the masses? Other settings where fire-safety training is conducted are in fire-fighting trainings, mining, petroleum industry, military, etc. to name a few. Even in settings that have proper setups for providing technical fire-fighting training, difficulties arise in terms of resources. As many of the training modules are built to be stationary (for example smoke chamber), it is not possible to provide training in remote areas and in locations other than the training centres. Hence, going with e-learning modules based on two-dimensional (2D) computer screens are often the best choice. However, these 2D platforms lack the immersion and experience of real-world scenarios, thus raising questions as to how can such fire-fighting and safety training be made more

A. Srivastava (✉)
XR & IxD Lab, School of Design at University of Petroleum and Energy Studies, Dehradun, India
e-mail: asrivastava@ddn.upes.ac.in

L. P. Singh et al. (eds.), *Productivity with Health, Safety, and Environment*, Design Science and Innovation, https://doi.org/10.1007/978-981-16-7361-0_3

realistic? VR provides the ability to immerse in a three dimensional (3D) virtual environment thus enabling users to experience various scenarios. This capability of VR can, therefore, provide a powerful platform for fire-safety training. However, how can VR be utilized for fire-safety training in India? This paper aims to advance knowledge in the area of utilizing VR for fire-safety training in India. The intention is to provide an initial direction for research in this domain.

2 Methodology

A. *Systematic Literature Review*

A systematic literature review (SLR) was conducted based on the method discussed in the literature [4]. SLR provided an in-depth understanding of the research area in concerns and its future direction. It utilizes a systematic approach to identify literatures through a structured set of research questions. Based on the guidelines provided by literatures [4, 5], a protocol (see Fig. 1) was developed for conducting SLR.

Initially, research questions were formulated based on which search strings and literature sources were identified. After carefully reviewing the papers gathered from sources, relevant literatures that answered the formulated research questions or a part of research questions were considered for the final analysis. Title, Abstract, and Keywords (TAK) of the literatures, as described in [4], were adopted for conducting the reviews. This helped in quickly identifying relevant insights and future direction for research.

B. *Research Questions*

Published literatures on fire-safety training in VR were surveyed and reviewed. The following research questions (RQ) were formulated to conduct SLR:

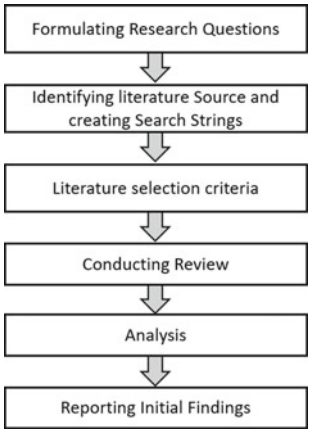


Fig. 1 Protocol for supporting systematic literature review

- RQ1: How does VR assist in fire-safety training?
- RQ2: What are the relevant areas for VR fire-safety training?
- RQ3: What type of VR hardware is utilized for VR safety training?
- RQ4: Are there any VR-related fire-safety training published research in India?

III. *Search strings, literature sources and screening process*

For the selection of literature sources, ACM, Springer Link, Science Direct and IEEE were considered. The search string was chosen based on synonyms for 'virtual reality fire training', 'fire-safety training', 'fire-hazard' and 'Virtual Reality'. As the goal of the study was to identify the current state of the art in VR fire-safety training in India, keyword 'India' was applied with the search strings, i.e. 'fire-safety training in India' AND 'virtual reality'. The instances of the search strings were also modified to 'fire-hazard training in VR in India', 'fire safety' AND 'VR' AND 'India'. It was found that there were very no search results for VR-related fire training in India to the best of author's knowledge. Hence, the scope of the literature review was broadened to consider VR-related studies outside of Indian context. In certain cases, literatures from other sources were also considered if they were addressing the research questions. Different instances of the search string were also designed in order to suit the source databases. However, the logical value was kept the same. Table 1 shows the number of search results for the search instance 'fire-safety training VR'. It was observed that the search results also displayed literatures not pertaining to fire-safety training. Hence, a critical reading approach [6] was utilized to identify relevant literatures that can address the RQs. Out of a number of literatures available from the search results, 30 (N = 30) were shortlisted for review. In the case of a few literatures, screening was done based on the in-depth reading. Table 2 depicts the total number of literatures finally selected for SLR from the selected database.

In addition to the literatures selected from databases, additional survey of VR based hardware utilized in fire training was conducted. This was conducted mainly to address RQ4.

IV. *Literature selection criteria*

Selected papers were collated in a spreadsheet format in TAK format. Further reading on TAK reading was conducted based on which duplicate studies were removed.

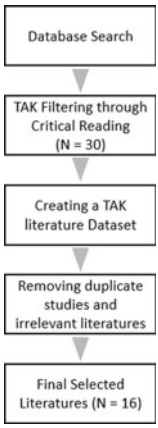
Table 1 Search results in literature source

Database	Search string	Number of search results
ACM	Fire-safety training VR	31,528
Science direct	Fire-safety training VR	689
Springer link	Fire-safety training VR	74
IEEE	Fire-safety training VR	3

Table 2 Search results in literature source

Database	Selected for Review
ACM	5
Science direct	9
Springer link	1
IEEE	1
Total	**16**

Fig. 2 Literature selection criteria



Finally, a review of N = 16 selected literatures were conducted. Figure 2 depicts the literature selection process. Section III presents a review of selected literatures.

3 Literature Review and Mapping

A. *Literature review*

Bernardes et al. [7] describe a theoretical methodological framework for providing fire-safety training to company workers in office settings. The authors [7] suggest that VR can be utilized effectively to train workers to handle real-life stress situations. Zuo-fu et al. [8] present a discussion on utilizing VR to train fire-safety professionals in hazardous conditions such as chemical leakage and fire explosions. An experience emergency training system is discussed with a posit that it will improve the emergency response among professional fire-fighting rescue team. Chun et al. [9] utilize web VR to provide collaborative immersive emergency drill training to petrochemical workers. Moreno et al. [10] studied how VR based fire-spread simulations. Various simulations dealing with fire-extinguishment actions, natural and artificial firebreaks and variable wind conditions have been discussed. Fanfarová et al. [11] propose a new

Table 3 Mapping research questions and literatures

Research questions	Literature
RQ1	[18–21]
RQ2	[8, 9, 14–16, 20] [10–12]
RQ3	[21, 22]
RQ4	–

simulation model design for fire and rescue service. The study [12] also presents VR-based simulation training of roof fall after blasting in mines. Literature [13] discusses various modalities such as screen-based, projector-based and head-mounted (HMD) type VR for training purposes. Requirements such as consideration for user task, input–output modalities and software databased requirements have been outlined. Zang et al. [14, 15] discuss a study on fire safety education. Yang et al. [16] utilize VR for gas explosion training. Kobes et al. [17] utilize VR for behavioural assessment of participants to study pre-evacuation behaviours and exit movements during fire incidents. A team-based fire-fighting training platform has been discussed by Ref. [18]. Various VR, augmented reality and haptics were utilized. A storytelling-based approach to VR fire-training has been adopted by Querrec et al. [19]. Vega et al. [20] utilize a gamified view for VR fire training for the campfire. A multi-sensorial aspect to VR fire training has been discussed in the literature [21].

B. *Mapping literatures to research questions*

Table 3 Presents the relevant literatures that addressed formulated research questions.

4 Analysis

The literature review reveals that there is a dearth of published VR-based research studies in India. The search strings, to the best of author's knowledge, did not yield any results pertaining to the use of VR-based fire-safety training in India in the searched databases. It was also identified from web searches that VR-based training modules are being developed by corporate startups in India. However, no published research evidence was found.

The review also highlights potential areas of research in this direction. These areas can be extended in the context of India for further research considerations. Figure 3 highlights potential direction for research in this area based on SLR.

Table 4 depicts the relevant literature based on which potential technologies utilized for VR fire-safety training were identified. Relevant research area for which various technological implementations have been done is highlighted. Simulation modelling has also been considered under technology emphasis as various algorithms/numerical methods have been utilized to model real-world situation and

Fig. 3 Potential research areas for VR fire-safety training identified from SLR

Table 4 VR technologies reported in literatures

Technology emphasis	Relevant topic, literature
Head-mounted HTC	Education [14, 15]
Web VR	Petro-chemical industry [7]
Multi-sensorial	Heat simulation [21]
Haptics, gestures	Using Leapmotion [13], Using Haptics [17]
Simulation modelling	Fire conditions [10], Fire simulation [11], Roof-fall [12], Numerical analysis for modelling fire [17]
Tele-presence/collaborative	[22]

behaviours in several literatures. This aspect highlights another aspect of important research area for VR safety training.

5 Conclusion

The paper presents an early work towards understanding how VR can be utilized for fire-safety training. Potential areas and research directions have been identified. However, the present search does not reveal any published research work in India. More literatures have to be surveyed in the future for gaining critical insights.

Acknowledgements The author is thankful to Anand Gurnani from VAMRR Pvt. Ltd., Bangalore for providing insights into VR technology. The author would like to acknowledge the 'Abhigyat' support provided by UPES for industrial exposure and research purpose.

References

1. NCRB, National Crime Records Bureau, pp. 192–206 (2013)
2. OGD, All India level Place of Occurrence-wise Number of Fire Accidents, Persons Injured and Died during 2015 | data.gov.in. https://data.gov.in/resources/all-india-level-place-occurrence-wise-number-fire-accidents-persons-injured-and-died. Accessed 17 Sep 2019
3. P. Sanghavi, K. Bhalla, V. Das, Fire-related deaths in India in 2001: a retrospective analysis of data. Lancet **373**(9671), 1282–1288 (2009)
4. A.M. Nascimento et al., *A Systematic Literature Review about the impact of Artificial Intelligence on Autonomous Vehicle Safety*, Apr. 2019
5. A. Siddaway, *What is Systematic Literature Review*?
6. Reading Critically What Needs To Be Done To Prepare For Critical Reading? What Is The Process For Reading Critically?
7. S.M.F. Bernardes, F. Rebelo, E. Vilar, P. Noriega, T. Borges, Methodological approaches for use virtual reality to develop emergency evacuation simulations for training, in emergency situations. Procedia Manuf. **3**, 6313–6320 (2015)
8. B. Zuo-fu Yua, J.-l. Guana, *Fire and Rescue Combat Technical Training System Construction for Dangerous Chemicals* (2016)
9. W. Chun, L. Lei, Y. Jiwu, Z. Liangyun, L. Gang, Development of emergency drills system for petrochemical plants based on WebVR. Procedia Environ. Sci. **10**, 313–318, Jan. 2011
10. A. Moreno, J. Posada, Á. Segura, A. Arbelaiz, A. García-Alonso, Interactive fire spread simulations with extinguishment support for Virtual Reality training tools. Fire Saf. J. **64**, 48–60, Feb. 2014
11. A. Fanfarová, L. Mariš, Simulation tool for fire and rescue services. Procedia Eng. **192**, 160–165 (2017)
12. E. Isleyen, H.S. Duzgun, Use of virtual reality in underground roof fall hazard assessment and risk mitigation. Int. J. Min. Sci. Technol. **29**(4), 603–607 (2019)
13. H. Zhang, Head-mounted display-based intuitive virtual reality training system for the mining industry. Int. J. Min. Sci. Technol. **27**(4), 717–722 (2017)
14. K. Zhang, J. Suo, J. Chen, X. Liu, L. Gao, Design and implementation of fire safety education system on campus based on virtual reality technology, in *Proceedings of the 2017 Federated Conference on Computer Science and Information Systems, FedCSIS 2017*, pp. 1297–1300, 2017
15. S. Ooi, T. Tanimoto, M. Sano, Virtual reality fire disaster training system for improving disaster awareness, in *ACM International Conference Proceeding Series*, vol. Part F1481, pp. 01–307 (2019)
16. W. Yang, G. Fu, J. Zhang, S. Qing, N. Shao, Z. Chang, Analysis and methods of the blasters' unsafe behavior taking gas explosion accident as an example. Procedia Eng. **45**, 220–224 (2012)
17. M. Kobes, I. Helsloot, B. De Vries, J. Post, Exit choice, (pre-)movement time and (pre-) evacuation behaviour in hotel fire evacuation—Behavioural analysis and validation of the use of serious gaming in experimental research. Procedia Eng. **3**, 37–51 (2010)
18. J. Lee, M. Cha, B. Choi, T. Kim, A team-based firefighter training platform using the virtual environment, in *Proceedings of the 9th ACM SIGGRAPH Conference on Virtual-Reality Continuum and its Applications in Industry—VRCAI '10*, p. 299 (2010)
19. R. Querrec, P. Chevaillier, Virtual storytelling for training: an application to fire fighting in industrial environment. Lect. Notes Comput. Sci. (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) **2197**, 201–204 (2001)
20. J. Vega, S. Rose, C. Eckhardt, L. Tahai, I. Humer, K. Pietroszek, VR wildfire prevention: teaching campfire safety in a gamified immersive environment, in *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST*, vol. Part F131944 (2017)

21. E. Shaw, T. Roper, T. Nilsson, G. Lawson, S.V.G. Cobb, D. Miller, The heat is on: exploring user behaviour in a multisensory virtual environment for fire evacuation, in *Conference on Human Factors in Computing Systems—Proceedings*, pp. 1–13 (2019)
22. G. Ha, H. Lee, S. Lee, J. Cha, S. Kim, A VR serious game for fire evacuation drill with synchronized tele-collaboration among users, in *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST*, vol. 02–04, pp. 301–302, Nov. 2016