Exploring the Potential of Virtual Reality in Fire Training Research Using A'WOT Hybrid Method

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Abstract Virtual reality (VR) is a creative methodological approach dedicated to preparing individuals in an intelligent VR condition. Recently, expanding consideration has been attracted to VR for the provision of fire evacuation knowledge and behavioral assessment, as they are profoundly captivating and advance driving psychological learning. The motivation behind this investigation is to characterize and organize the threats, weaknesses, strengths and the opportunities (SWOT) and their sub-factors of the VR as a predictive and effective research tool on human fire behavior. However, SWOT analysis includes no means of analytically estimating the weights defining the intensity of the factors. The proposed framework A'WOT (AHP-SWOT) integrates the analytic hierarchy process (AHP) and SWOT analysis. AHP's connection to SWOT permits precisely and systematically determined priorities for the factors contained in SWOT analysis and makes them measurable.

Keywords Virtual reality · Human behavior in fire · Fire training · SWOT-AHP

1 Introduction

A fire is an emergency in which appropriate individual intervention is essential to limit physical, psychological and material damage. Since an emergency situation in case of fire is also stressful [1] and can therefore hinder performance during emergency response [2], firefighters or ordinary citizens must undergo exercises and training to educate the intervention procedures and apply them under conditions of high psychological and physical stress [3]. The designing of the virtual environments (VEs) is done to provide a few trainings. The present article proposes an integrated framework to evaluate the SWOT of virtual reality-based fire training utilizing the

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AHP in combination with the SWOT. SWOT tool is utilized for the strategic management and strategic planning and has been applied to VR in a variety of contexts such as fire evacuation research [4] and rehabilitation research [5].

The paper is organized as follows. Section 2 presents a literature review on VR in fire training. Section 3 discusses the methodology and how to integrate the AHP model with SWOT analysis (hybrid method). Section 4 contains the results obtained by applying the proposed method and discussion, while Sect. 5 presents our conclusion.

2 Fire Training in a VR

The increasing use of VR devices clearly establishes its high possibilities in different areas, like the human behavior during a fire [4, 6] and the safety measure. Few current researches on VR are presented below. One of the benefits of using VEs for fire training is that they generally attract users, improving their involvement in the process compared to conventional methods. VR has also been used for fire emergency training. Some of these are also very useful in the fire training process [6, 7] and many other emergency situations tackling. For example, VR has been used to teach people to evacuate emergency situations in case of fire [8]. One of the main benefits of using VR technology for fire training is that it provides you to train in dangerous conditions. For example, in a study on the use of VR to teach fire evacuation techniques [9], VR could be most efficient compared to the evacuation drills to motivate people to train in personal fire safety.

The purpose of the comprehensive study is to describe SWOT groups and their sub-factors of VR as an efficient and practical tool for training in fire emergency situation and prioritize them.

3 Research Methodology

3.1 SWOT Analysis

SWOT analysis is considered a powerful used architecture that assesses the threats and opportunities and analyzes the internal factors such as the strength and the weakness of a service or product [10]. In general, the SWOT analysis lists the factors with a description that are associated with the existing and future trend of the internal and external environment. The expressions of the individual factors are imprecise and brief, which describes the subjective opinions. However, SWOT analysis is a powerful and simple tool for assessing the situation and allows a focus group to determine the strengths, opportunities, weaknesses and threats of a given method or product.

- A strength can be considered as capacity that allows VR to achieve its defined goals.
- A weakness can be viewed as a limitation, defect or fault of VR to achieve a specific aim.
- An opportunity comprises external factors that the VR technology can capitalize on or use to its advantage.
- A threat can be any unfavorable external situation that may have a negative impact by presenting a boundary or limit to achieve objectives.

Despite the broad application of SWOT, it has few limitations that are the qualitative measurement of the decision making is impossible and there is no mechanism to rank the one factor versus the other. This would be made possible by combining the SWOT with the AHP.

3.2 The AHP Method

AHP [11] is very appropriate for the weighing problem that is multiobjective as it integrates both the qualitative and the quantitative analyses. It structures alternatives into a hierarchical order through a series of pairwise comparisons. This reference [12] is intended to explain in more detail the general AHP framework.

3.3 A'WOT (SWOT-AHP) Methodology

The point of using AHP strategy inside SWOT examination is to systematically survey factors of the SWOT and compare their powers. Extra esteem from SWOT strategy can be cultivated by doing match insightful examinations between SWOT factors and breaking down them through eigenvalue procedure as applied in AHP approach. This provides a good basis for analyzing the current or anticipated situation, or new strategy alternative deeply and completely [13]. The AHP could convert the intangible criteria into values (numbers) and evaluate the weights of the factors using the pairwise evaluation [11]. The hybrid method A'WOT (AHP-SWOT) proceeds as follows:

Step 1. Evaluation based on the SWOT is done.
Step 2. Pairwise comparisons between SWOT factors are accomplished within every SWOT group.

(1) Structuring the model.
(2) Construct judgment matrix A.

Table 1 1–9 point scale used for the pairwise comparisons [14]

Strength of significance	Synonyms
1	Equally significant
3	Moderately significant
5	Strongly significant
7	Very strongly significant
9	Extremely significant
2, 4, 6, 8	In-between values in the two adjacent judgments

$$A = (a_{ij}) = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \dots & a_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nn} \end{bmatrix} \tag{1}$$

where

$$\begin{gathered} a_{ij} > 0, \quad i, j = 1, 2, \dots, n \\ a_{ii} = 1, \quad i = 1, 2, \dots, n \\ a_{ij} = 1/a_{ji} (i \neq j), \quad i, j = 1, 2, \dots, n \end{gathered} \tag{2}$$

Saaty's scale is shown in Table 1.

(3) Evaluating the relative weights of decision elements $\lambda_{\max}$
(4) Consistency check:

$$AW = \lambda_{\max} W \tag{3}$$

The consistency check index C.I.:

$$\text{C.I.} = \frac{\lambda_{\max} - n}{n - 1} \tag{4}$$

The consistency ratio C.R.:

$$\text{C.R.} = \frac{\text{C.I.}}{\text{R.I.}} \tag{5}$$

where R.I. is the average random consistency index (Table 2).

The inconsistency level is found to be acceptable if $CR \leq 0.10$. Otherwise, the preferences need to be reviewed and verified.

Table 2 SWOT analysis

Strengths (S)	Weaknesses (W)
• S1: Improved ecological validity • S2: Safe and controlled testing and training environment • S3: Immersive low-cost training environment • S4: Engaging interactive training environment • S5: Great number of trials • S6: Accuracy and error-free training environment • S7: Real-time performance feedback • S8: Multimodal interaction	• W1: Studies in fire training remain infrequent in the literature • W2: Technical challenges • W3: Compatibility with other hardware • W4: Side effects
Opportunities (O)	**Threats (T)**
• O1: The emergence and growth of new technological fields • O2: The commercial availability of VR devices • O3: The adoption of virtual reality (VR) technology in fire drills by professionals • O4: Intuitive navigation platform	• T1: Human sensory limitations • T2: The potential health risks of this technology (nausea, disorientation and so on) • T3: Ethical challenges

Step 3. Comparisons between the four groups in the SWOT are made pairwise.

The detailed framework of the proposed methodology is provided in Fig. 1.

4 Results and Discussion

The first part is comprised of a meeting section to generate factors for each SWOT class that are indispensable to the selection. First, all factors determined by individual members of the focus group were selected. At the end of this session, the focus group participants and interviewees determined the most crucial factors in each SWOT category (see Table 3).

AHP results uncovered that specialists gauge qualities to be the most significant consideration pursued by circumstances, shortcomings and dangers (see Table 3).

Under strengths, improved ecological validity was rated as the most influential factor. This would support the fact that ecological validity takes vital role in the VR fire training research. The central and crucial question is ecological validity of VR when it is used as a predictive tool. It is also the case in VR fire training applications where VR is used to assess human behavior. Actually, in such predictive uses, the closeness of human response within the VE to the equivalent real life is mandatory.

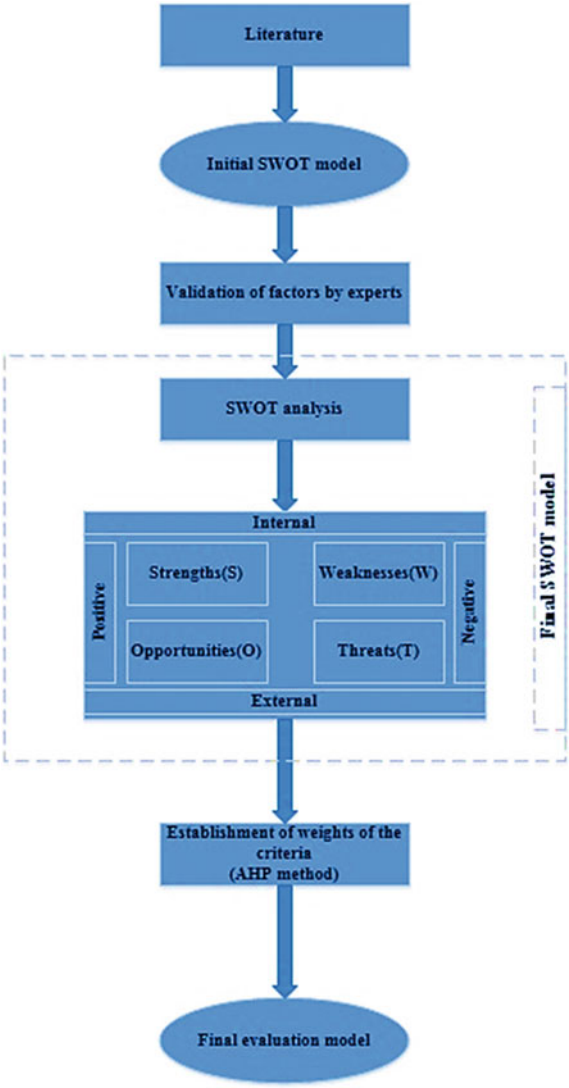

Fig. 1 Process flowchart

Under the weakness category, side effects were the highest rated factor. Based on the expert panel reviews, side effects are more important than the technical challenges. The emerging world of VR is not only providing a new, fully immersive fire simulation, but also creating new ways for people to see the world. The problem, however, is that we do not know its long-term effects on either the body or the mind.

Under opportunities, the adoption of VR technology in fire drills by professionals is the highest rated factor. According to expert group reviews and analysis, it looks that the growth will really be seen in the professional space. Based on various VR

Table 3 Factor priority scores and global priority scores of SWOT factors

SWOT groups	Weight	SWOT factors	Local priority	Global priority
Strengths (S)	0.478	S1: Improved ecological validity	0.413	0.197
		S2: Safe and controlled testing and training environment	0.171	0.082
		S3: Immersive low-cost training environment	0.078	0.037
		S4: Engaging interactive training environment	0.121	0.058
		S5: Great number of trials	0.039	0.019
		S6: Accuracy and error-free training environment	0.079	0.038
		S7: Real-time performance feedback	0.048	0.023
		S8: Multimodal interaction	0.050	0.024
Weaknesses (W)	0.138	W1: Studies in fire training remain infrequent in the literature	0.135	0.019
		W2: Technical challenges	0.271	0.037
		W3: Compatibility with other hardware	0.070	0.010
		W4: Side effects	0.524	0.072
Opportunities (O)	0.256	O1: The emergence and growth of new technological fields	0.142	0.036
		O2: The commercial availability of VR devices	0.214	0.055
		O3: The adoption of virtual reality (VR) technology in fire drills by professionals	0.550	0.141
		O4: Intuitive navigation platform	0.094	0.024
Threats (T)	0.128	T1: Human sensory limitations	0.286	0.037
		T2: The potential health risks of this technology (nausea, disorientation and so on)	0.571	0.073
		T3: Ethical challenges	0.143	0.018

statistics, the VR technology is going to be a huge industry in a few years, in both software and hardware.

Lastly, in threat category, the potential health risks of the VR technology are the highest rated factor. Due to the rapid growth of VR technology, such profound advances come with equally serious risks to our physical and emotional well-being. Consider that a high percentage of participants experience stress or anxiety after wearing a VR headset for more than a few minutes. Other unfavorable physical side effects can include severe eyestrain, motion sickness and nausea. This can be viewed as a dubious point for VR fire training research. Other external factors that affect VR in fire training are human sensory limitations and ethical challenges.

Table 4 shows the values of the global and local priority of the SWOT analysis factors.

5 Conclusion

This article presents a SWOT-AHP hybrid method for the field of VR fire training. Numerous VR strengths are depicted that will keep giving a justification for developing existing VR fire applications and making new ones. Weaknesses exist in the VR, especially with certain limitations in areas of human sensory technology and health risks, but do not compromise the reliability of the VR field. With thoughtful system design that targets fire research applications, it is anticipated that VR in fire research will keep on exponentially developing and gain acknowledgment as a standard tool. Threats to the field do exist; however, none are unsafe and all are likely addressable with the high inspiration that seems to be with the many scholars of this area. The current study was realized by combining SWOT with the AHP to generate the internal and the external factors qualitative values. The results of the hybrid method were promising. Making pairwise examinations powers the specialists to consider the heaviness of the elements and to analyze the circumstance in more profundity and detail. This methodology does not consider interdependencies between levels because AHP lacks this functionality. In our future work, this can be avoided by replacing AHP with the analytic network process (ANP) [14]. Likewise, the positioning of SWOT factors with pairwise examinations can account for the inconsistency of subjective opinions.

Appendix

SWOT factors—pairwise comparison of matrices.

Strengths	S1	S2	S3	S4	S5	S6	S7	S8	Local weight
S1	1	3	5	4	9	6	7	8	0.413
S2	1/3	1	3	2	4	2	3	3	0.171
S3	1/5	1/3	1	1/2	2	1	2	2	0.078
S4	1/4	1/2	2	1	3	2	2	3	0.121
S5	1/9	1/4	1/2	1/3	1	1/2	1	1/2	0.039
S6	1/6	1/2	1	1/2	2	1	2	2	0.079
S7	1/7	1/3	1/2	1/2	1	1/2	1	1	0.048
S8	1/8	1/3	1/2	1/3	2	1/2	1	1	0.050

Weaknesses	W1	W2	W3	W4	Local weight
W1	1	1/2	2	1/4	0.135
W2	2	1	4	1/2	0.271
W3	1/2	1/4	1	1/7	0.070
W4	4	2	7	1	0.524

Opportunities	O1	O2	O3	O4	Local weight
O1	1	1/2	1/4	2	0.142
O2	2	1	1/3	2	0.214
O3	4	3	1	5	0.550
O4	1/2	1/2	1/5	1	0.094

Threats	T1	T2	T3	Local weight
T1	1	1/2	2	0.286
T2	2	1	4	0.571
T3	1/2	1/4	1	0.143

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