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Wildfire Training for Inexperience firefighter Using Virtual Reality

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Abstract：The hazards caused by wildfires have evolved and become more deadly over the years. Due to the rare training opportunities in real wildfire conditions, junior firefighters and volunteer firefighters who have limit wildfire experiences are not trained properly to prepare for ever-changing fireground in real situations. With rapid development, Virtual Reality has become a safe and popular approach to study human behavior in different scenarios. The propose of this study is to provide a VR training system for trainees to understand how the wind speed and directions would affect fire behaviors. This research presents an experimental study that aims to evaluate the effectiveness of a Virtual Environment (VE) to train inexperienced firefighters by using VR-based fire training simulations.

Keywords：Virtual training · Firefighter training · Wildfire simulation

1. Introduction

For the past decade, we have experienced the warmest time on record. Accompanied by the record is the widespread and devastating wildfire from the Amazon to California, the Arctic Circle, and Australia. Even as the area not be known for wildfire, Japan remains at 3, 000 wildfire cases per year with annual loss second in magnitude only to that suffered by the United States. Instances have shown that firefighters today are not properly trained to respond to possible causes of rapid-fire spread due to cost and safety concerns. Virtual Reality (VR) has been tested for disaster exercises and training purposes by many different settings including fire extinguisher operation and rescue training. VR training provides a simulated experience for trainees to explore various emergency scenarios repeated without exposure to the hazard. Although the training system has been successfully used in other fire scenarios, it has not been much explored or tested for effectiveness in the wildfire.

Crucial parameters that would deteriorate the fire and entrap the firefighters in the wildland include topography, flues, vegetation, and weather. Among all the parameters, wind change is the most dynamic causes of the fire behavior. Very slight of wind turbulence and direction change would allow the ‘flanks’ become active head fire. Head fire is the term refers to the side of the fire having the fastest rate of spread, the form of head fire has been considered as one of the most terminal cause of firefighter’s entrapment. Thus, this preliminary study is specifically designed to train junior or volunteer firefighter who has few or none experience to conduct theoretical knowledge of wind change in practical VR training in order to respond fast in the real wildfire.

This study presents an experiment with non-wild firefighting experienced participants where the

effectiveness of a training VE (Virtual Environment) was assessed comparing the participant's response time to the target. The goal of this study is to compare two VR scenarios by using Head Mount Display (HMD) and joysticks to see if participants spend less time to find and put out the head fire in scenario B (harder) after repeat practices in the scenario A (simple). This preliminary study is pertinent by realizing the effective training simulator brings benefits not only to the fire department but also for other fields that need to understand and identify training for the dynamic dangerous.

2. Design

Unity designed non-real-time simulated forest environment allows one trainee to enter the training system each time by using the Vive HMD. Each trainee is represented in the VE by a computer-generated character called an avatar. The trainee can control the avatar's movement by using HMD looking at the direction he/she wants to go and press the PressPad on both joysticks. The simulation applies the first-person point of view to provide a virtual "first-hand" perspective of the setting (Fig.1).

(Fig. 1 Screenshot of first person point view during the training)

The virtual fire ground for this training simulated a terrain with flatlands and hills. Although the topography is not considered as the parameter in this study, it has an important effect on the shape of head fire formation. Fire is already spreading before the trainee enters, as well as the head fire is formed based on the direction of the wind. All the fire is extinguishable by using the fire hose attached to the right joystick controlled by trainees. If the segment of the terrain is burning, fire will be shown in the particular segment. Fire and smoke in this study are already be fully established mature by particle system by the time trainee starts the training. We use the assets Fire Manager provided by Unity to calculate the rare fire locations by input wind speed, direction, and air temperature data. Fire Manager is able to simulate the rare fire by considering the input data and combine with the terrain. The navigation system is not designed in this simulation due to the orientation practice purpose.

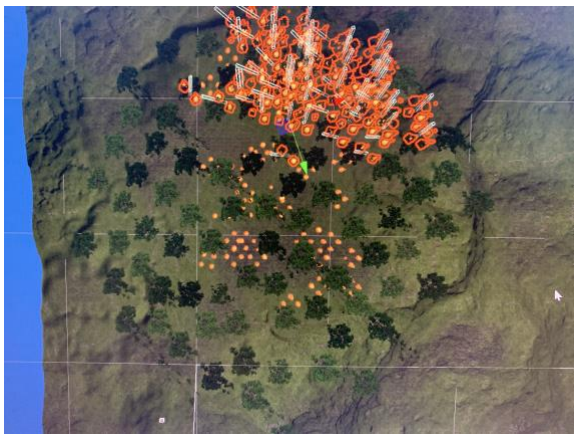
All scenarios design such as terrain, wind direction, and head fire shape in this training system are not particularly referred to any actual wildfire cases, but the fire behavior principle is applied from Japanese fire department certified authority National Fire Prevention Association (NFPA) and academic studies on actual famous wildfire cases.

3. Methodology

One trainee with no wildfire experience tested this VR simulation program. There is no collection for trainee's reaction speed but the trainee is around 20-25 years old which is similar to the age of junior firefighters. Detail instructions including the initial direction trainee are facing when he enters the training, the direction of the wind and speed of the wind are provided to the trainee before the training starts. The trainee needs to locate the head fire and extinguish it by calculating the information. Based on different scenes trainee is placed, there will be rare fire trainee need to extinguish before arrived the head fire location.

Three scenes are designed in this training system: a pre-scene for the trainee to understand the use of HMD, Joystick and the rules; a simple scene (scenario A) for the trainee to practice how to locate the head fire; and a hard scene (Scenario B) using for comparing the time to evaluate the effectiveness of the training system. In all three scenes, the trainee is facing North as the initial start point. Scenario A consists of a west wind with a speed of 5mph. The close distance between head fire and trainee forced trainee's quick response of information process and orientating (Fig. 2). The complexity of scenario B made it more likely for the trainees to become lost. The 20mph Northwest wind spreads more rare fire in the fire ground between the head fire and trainee (Fig. 3).

(Fig. 2 Over view of simple scene scenario A with West wind, the highlighted fire is the head fire area)



(Fig. 3 Over view of complex scene scenario B with Northwest wind, The highlighted fire is the head fire area)

The trainee participates in scenario B first after experienced in pre-scene. The time trainee reaches the head fire area and the total time he spends from start to extinguish the head fire will be recorded. This simulates the authentic time length junior firefighter would use to locate the head fire in the real wildfire ground without practical practice. After the first implementation in scenario B, the trainee is asked to practice in scenario A four times with the same equipment for a better understanding of the relationship between wind direction and fire behavior. Trainee conducted again with the same environment and time record criteria as the first time in scenario B after the practices in scenario A. The time trainee used in Scenario B first time and the second time is used to evaluate the effectiveness of this training system. If the time trainee speed for locating and extinguish the head fire in the second time is shorter than the first time then the training system is potent.

4. Result

Due to the lack of sample for statistical analysis, this study chose to make a descriptive analysis with an inferential character. The result is shown below in Table 1. The trainee after practices in scenario A were found to complete scenario B second time faster than the first time without practices. Trainee reported that with the faster wind speed, he is able to oriented the head fire location instantly by observe the tree movement. That has caused the time reaches head fire area is not improved significantly in scenario B test 2. However, the time trainee spend in total was about 49 seconds faster in test 2 than in test 1 meaning that in the second test after practices, trainee was located and extinguish head fire precise by information process and experiences instead of instinct.

Table 1. Result of trainee's time speed in the test

	Time reaches head fire area	Total time spend until extinguish the head fire
Scenario B test 1	01:15.26	02:58.44
Scenario A practice 1	00:40.79	02:21.58
Scenario A practice 2	00:12.93	02:13.17
Scenario A practice 3	00:14.08	02:09.84
Scenario A practice 4	01:16.34	02:49.02
Scenario B test 2	01:14.04	02:09.19

We received feedback from the trainee who reported that he is not able to remember the location of the head fire once he entered the fire zone because the first person point of view doesn't allow panorama map. This has indicated that improved performance was a result of the VR practices and not from increased familiarity with the environment.

The trainee was successfully completed all scenarios and during the after training discussion, the trainee confirmed the training helps him to understand the impact of wind direction changes on fire more directly and process wind information faster to locate the head fire. Besides, the comments at the end of the virtual training were very positive and proved the preliminary wildfire VR training is efficient.

5. Limitation and future work

Some limitations exist in the preliminary testing of the wildfire VR training for junior firefighters and more rigorous testing and refinement are required. First, the

immersions of trainee effects the decision making in the actual fire ground. This VR training is not able to reproduce the sense of crisis enough to train firefighter's processing information reaction skills. Second, all parameters such as topography, plant, fuels in the real fire ground have high potential threaten to firefighter's life and they are interdependent. Future researches are needed to consider and combine those parameters into the environment for a more comprehensive training system. Third, due to the current situation, this study only conducts one sample for the test, the result is not sufficiently contrastive and representative. Future studies are needed to evaluate the effectiveness of the VR wildfire training with different sample populations.

For future work, it is intended to implement a control group to compare the more different scenarios. This will allow us to have more statistics and rigorous data to evaluate the effectiveness of the training system. Also, improvements in scenario design will increase the trainee's sense of presence and having a more accurate orientation process time.

6. Conclusion

The main goal of this study was to evaluate the effectiveness of a virtual environment to train inexperienced firefighters' in wildfire situations. As the preliminary study, this work is specifically designed to train participant's orienting head fire skill under the change of wind direction and speed. To achieve this, the study provides the practice scenarios and simulated real wildfire scenario for comparison. The result indicates that our virtual wildfire training improved trainee's head fire orienting skill by processing the information of wind direction.

Although the response time from the virtual training environment was far different from the ones achieved in the real environment, these are important because they will serve as a reference for future wildfire VR training development for both understanding of wind change as well as for other factors. In the future, we hope to use the result from this experience to create a virtual environment that can train and certify firefighters and other first responders effectively.

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