An Immersive Fire Training System Using Kinect

Qiuhai He
Beijing Forestry University
Beijing, China
University of Oulu
Oulu, Finland
qhe@ee.oulu.fi

Xiaopeng Hong
University of Oulu
Oulu, Finland
xhong@ee.oulu.fi

Guoying Zhao
University of Oulu
Oulu, Finland
gyzhao@ee.oulu.fi

Xinyuan Huang
Communication University of China
Beijing Forestry University
Beijing, China
hxy@263.net

UbiComp'14 Adjunct, September 13-17, 2014, Seattle, WA, USA
ACM 978-1-4503-3047-3/14/09.
http://dx.doi.org/10.1145/2638728.2638764.

Abstract
Lack of awareness of potential fire hazards is a leading factor of fire, especially when the child is alone. This paper presents a simulation training system to help children learn fire hazards knowledge and escape skills. The first part of this system is an application designed for theoretical study, which is featured by gesture interaction using Microsoft Kinect and large screen display environment. It includes three modules, namely animation, quizzes, and a 3D serious game. The second part is a simulated environment of fire escape route, which aims to test learning outcomes. Experimental results show the fire escape skills of 100 children are greatly improved.

Author Keywords
Fire training; gesture interaction; Kinect; large screen; virtual reality

ACM Classification Keywords
H.5.1 Multimedia Information Systems

Introduction and Related Work
Fire safety education is extremely important for teenagers. According to the U.S. Fire Administration and National Fire Data Center, accounting for 121,000 children by age 14 were injured or killed in fires in 2002

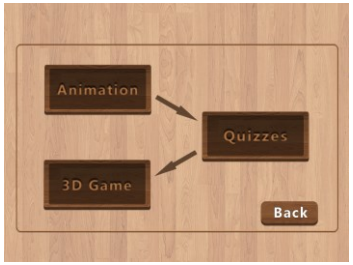

Figure 1. The three modules in training system.

Figure 2. Example of animation.

Figure 3. Quizzes UI.

[9]. Obviously fire brings a large threat to the safety of children. The best way to avoid fire injuries is to realize the potential hazards in advance and master the basic skills to escape.

Related Work and Problems

Virtual reality (VR) has been used to simulate situations that are too dangerous to practice in real life. A number of past efforts focus on serious games for fire safety education (FSE) [1, 2, 5, 6, 7, 8]. However, these FSE games still stay on traditional computer display, which can only be played individually and not bring immersive feeling. Moreover, as these FSE games are not specifically designed for children, they are usually too serious such that they cannot attract children's attention continuously. In addition, they do not provide practical exercises to examine learning outcomes.

Solution

In this paper, we design an immersive fire training system, which consists of a large-screen Kinect application for learning theoretical knowledge and a simulated environment of fire escape route for evaluating learning outcomes.

As suggested by the widely recognized research [3], organizational learning builds spatial memory structure and help children share knowledge with each other. Hence we transfer the training system from a traditional display to a large screen, with which trainees can work together to complete their missions. Therefore both individual and organizational learning become possible.

In order to make the interaction more natural and interesting, and to enhance the control of a large screen, we propose to use the Kinect sensor in our system. The depth data offered by Kinect enable to define various gestures and functions, such as a 'Push-up' gesture to activate the cursor, and a moving-hand gesture for 3D scenes navigation.

To bring the immersive feeling, the game module is rendered in the first-person perspective (FPP). Usually in a Kinect based environment it is difficult to realize free moving and rotating. However, they are crucial for a FPP game. To overcome this difficulty, we develop a set of auto-hidden buttons, which are located near each side of the screen, for moving forward or backward and rotating left or right freely.

The remaining parts of this paper mainly discuss the design, implementation, and the learning outcomes of the fire training system.

Design of the Learning Application

Animation and games provide an efficient way of catching children's attention continuously. Moreover, it is well known that transferring of practice to the game can enhance memory. As a result, we incorporate these elements into our learning application, which contains animation, quizzes and 3D serious game (Figure 1).

In order to make teaching easy to understand and vivid, we make a series of animated short films (Figure 2). Each of them tells a story about the correct response to fire. The story scripts are designed according to [9]. The second module (Figure 3) is multiple-choice quizzes from a database of two hundred questions which are designed according to the knowledge provided by National Fire Protection Association [4]. In the third module, three 3D scenes of

Figure 4. Serious game.

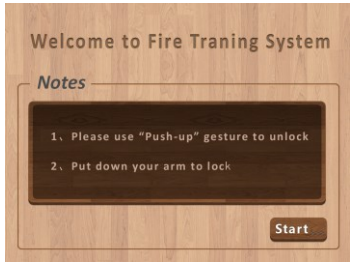

Figure 5. Start menu.

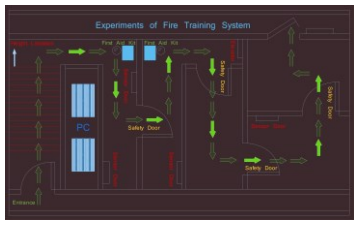

Figure 6. The simulated environment of fire escape route.

fire-prone places (home, school and mall) are designed for the serious game (Figure 4). The trainees' mission is to find out the hazards in these places.

The user interaction is realized based on the gesture recognized by a Microsoft Kinect sensor, which is placed in the middle and right below the bottom of the screen. With the help of depth data offered by Kinect, we are able to achieve the following functions:

Activate and Freeze Cursor
As the screen is large and user stands 1.2m-3.5m away from the screen, the normal cursor is too small, which is not convenient for users. In this case, a hand-shaped image is used to substitute the normal cursor. No matter on main menu or submenus, user can freely move the active hand to control the new cursor.

We define the 'Push-up' gesture to active cursor. Conversely, if we need change the operator or lock cursor, just put down the arm to deactivate tracking. Moreover, once the active hand going out of the recognizable area over 5 seconds, the cursor will freeze automatically. These using notifications are placed at the start menu of the system (Figure 5).

Menu Selection
To choose an icon or option, the cursor needs to stay on the icon over 1 second. When the cursor moves over icons, a timer presented by an aureole animation around the chosen icon will be activated. If the cursor stays on the icon less than 1 second and then moves away, the aureole will disappear and the timer will reset.

Quizzes
In the quizzes module (Figure 3), a tick or cross symbol, represented by animation, shows the answer correct or wrong respectively. If the answer is right, it will jump to the next question; if not, it will show the right answer last for 5 seconds and then jump to the next question. The application extract 10 questions randomly from the question database in each training loop.

3D Serious Game
Different with the control method in traditional FPP 3D games, users can't use keyboard and mouse to move and rotate. We design a solution by using gestures. There are 4 touch-sensitive auto-hidden buttons near the each side of the screen. Once the cursor moves near any side of the screen, the corresponding buttons would appear (Figure 4). The up and down buttons control the camera moving forward or backward at a speed of 1.5 meters per second. The left and right buttons control the camera rotating left or right at a speed of 5 degree per second. When the cursor is activated, user can freely navigate in the virtual space. In the current design of the game prototype, user's game mission is to find out the fire hazards. In the position below the center, there is a stationary square box for picking up objects. Users can put the potential fire hazard objects into the square. Then the game system will judge if it is correct.

Implementation
A desktop computer (Intel® Core™ i7 Extreme Processor; 16GB Memory; NVIDIA® GeForce® GTX 770) is used as the master control of the entire training system. The learning application is played on a large screen, whose size is 355 x 203cm. In addition, we use

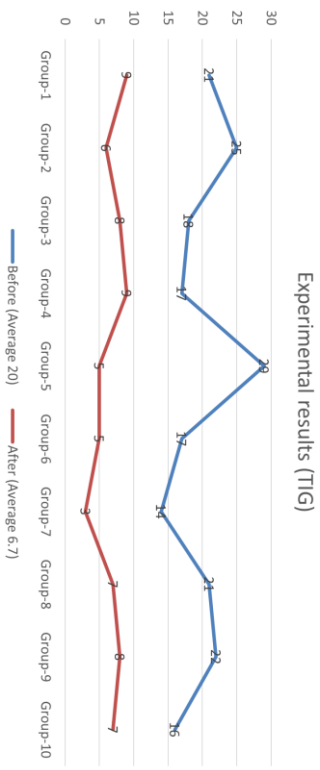

Figure 7. Experimental results.

the Unity3D Game Engine as the basic graphical solution to integrate the three modules, and OpenNI (Open Natural Interaction) to track and determine the location of 20 joints.

Simulated evaluation environment

We use a simulated environment of fire escape route (FER) to evaluate the training system (Figure 6). The skills for using fire safety devices and the special regulation applied on fire are covered in the FER, such as first aid kit (towel and water), elevator door and normal door with sensors, and height limit area.

Experiments

One hundred Chinese children are invited as the trainees to participate the test of our training system. We equally divide them into 10 groups. If any group member does the wrong actions when passing the FER, an alarm will be activated. The total times of incorrect actions of a group (TIG) are counted as the testing criterion.

The trainees do this test twice to evaluate their learning outcomes. The results in Figure 7 show the average TIG is improved from 20 (before training) to 6.7 (after training). Obviously, our training system significantly increased the escaping fire skills of children.

Conclusion and Future Work

We present an immersive fire training system to help teens realize the potential fire hazards and master the basic skills to escape. It realizes organizational learning through natural interactions in the first-person perspective. It also provides a simulated evaluation environment to examine the training outcomes. In the future, we will enrich the system by more interesting interaction techniques.

Acknowledgements

This work was partially supported by the Academy of Finland and Infotech Oulu. We also appreciate Mr. Pengkun Shao for the artists' work and Mr. Kai Tang's team for building the simulated environment.

References

[1] C. Luca, and R. Ranon. "Serious games for training occupants of a building in personal fire safety skills." *Proc.* VS-GAMES, 2009.

[2] Coles, Claire D., et al. "Games that "work": Using computer games to teach alcohol-affected children about fire and street safety." *Research in developmental disabilities*.28.5 (2007): 518-530.

[3] March, James G. "Exploration and exploitation in organizational learning." *Organization science* 2.1 (1991): 71-87.

[4] National Fire Protection Association. http://www.nfpa.org/training.

[5] Padgett, Lynne S., et al. "Case study: using a virtual reality computer game to teach fire safety skills to children diagnosed with fetal alcohol syndrome." *Journal of pediatric psychology*.31.1 (2006): 65-70.

[6] Ren, Aizhu, et al. "Application Of Virtual Reality Technology To Evacuation Simulation In Fire Disaster." *Proc. CGVR*. 2006.

[7] R. Uwe, and K. Schatz. "Designing a BIM-based serious game for fire safety evacuation simulations." *Advanced Engineering Informatics*.25.4 (2011): 600-611.

[8] S. Shana, and E. Ericson. "Using immersive game-based virtual reality to teach fire-safety skills to children." *Virtual reality*.13.2 (2009): 87-99.

[9] U.S. Fire Administration. Residential Fires and Child Casualties. Topical Fire Research Series, Vol. 5, No. 2, 2005.