Research of Virtual Ship Fire-fighting Training System Based on Virtual Reality Technique

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Abstract. For ocean-going ships, safety is very important. And fire would be the brunt of ship disasters and accidents. So fire emergency training is a priority. The virtual ship fire-fighting training system based on virtual reality technique plays an important role on training.

1. Introduction
Ship fire accidents account for a large proportion of ship disasters and are vital to ship survivability. When a ship has a fire accident, the crew's safety skill level is the determining factor. The emergency elimination and repair measures taken after the disaster, the mastery of the escape skills and the use of fire-fighting equipment are directly related to the safety of each crew member. The success of disaster management depends on proper command, skilled technology and tight organization. However, due to many problems in the actual training, computer simulation and simulation of ship fire and fire has become a hot spot in ship fire training research. Virtual reality technology has built an effective platform for ship fire and fire protection visualization.

2. Demand analysis
At present, there are many restrictions on the crew's fire safety skills training. First, the fire safety skills training content is too large and complex, including a series of subjects such as fire command, equipment use, tactical coordination, etc. It requires multiple systems to cooperate with training, involving a wide range of positions and many personnel. In actual training, it is often limited by time and funds. It is difficult to ensure that the training is in place. Second, the firefighting skills training has higher requirements on the site, while the space inside the ship is limited. Some areas such as the engine room and small cabin are difficult to carry out real fire drills. Third, the ship firefighting equipment has many restrictions. Long-term in a state of waiting, under normal circumstances, personnel are not allowed to operate at will; fourth, fire training involves many risk factors, and the safety risks are high. In actual training, it is easy to cause casualties. Many of the above restrictions urgently require a realistic and easy-to-use simulation training system to replace actual training.

3. Application of Virtual Reality Technology in Ship Fire Fighting Training
The ship fire-fighting training system developed by virtual reality technology can realize a variety of training purposes. In summary, it mainly includes training of fire-fighting skills, familiarity of all fire-fighting equipment functions, handling of fire accidents in different locations of ships, and decision-making command, including:
a). Crew fire education and escape training. The system introduces the provisions of international ship safety regulations in various forms such as text, images, video, and animation. The 3D technology is used to simulate the whole ship. Through three-dimensional display, personnel can realize the whole ship roaming, have a more intuitive understanding of the ship safety facilities setting structure, escape route, etc., and improve the crew's fire awareness and self-rescue ability.

b). Fire equipment operation skills training. The trainees train the firefighters on the operation, maintenance and repair skills of the equipment by operating the virtual fire equipment and equipment, familiar with the installation principle, function and operating procedures.

c). Emergency fire rescue and adaptive training. Construct various fire accident scenes such as cabins, decks, cabins, etc. Firefighters can experience virtual disaster equipment through visual and auditory operations, operate virtual fire equipment, interact with virtual scenes, and play any role such as firefighters and firefighters. Fire, isolation, firefighting and other skills training.

d). Fire control decision, command, and coordination ability training. Multiplayer online role-playing cooperates with all the processes of ship disaster management, and mainly exercises the organizer's on-site command, fire-fighting decision-making and emergency response capabilities, as well as the operator's awareness of cooperation.

4. Overall design of ship virtual fire training system

4.1. System composition and working principle
The virtual fire training system consists of two parts: software and hardware. Hardware devices include servers, switches, display devices, general microcomputers, etc. The software is an executable file developed with software such as 3Dmax, Unity, and Photoshop. The system adopts distributed network technology to establish a local area virtual ship disaster environment where multiple members can participate at the same time. Multiple participating members can cooperate with each other and communicate in real time through voice or text, such as coordinated command and interaction during fire. Dialogue, etc. Such a system is an immersive system for multiple members, which can respond to local individual member actions, and also reflect the interaction between different members, and show the interaction effect of the overall environmental entity and all members, and the main server undertakes maintenance. And processing data with global effects, the extension obtains global data from the main server, is responsible for interaction with independent members, and generates a partial view.

4.2. Construction of the test scenario
Develop virtual experiments using 3Dmax and Unity technologies. First use 3Dmax to build a 3D test scenario, then use Unity for data processing. 3Dmax provides powerful modeling capabilities, providing tools for polygon modeling, lofting, surface modeling tools, and more. Unity's model input is simple and close to perfect, flexible and easy to operate, and the design process is more efficient and more traceable. Unity does not have a modeling function. After 3D model or animation is created with 3Dmax, the file is saved in FBX format, and then the generated FBX file is imported in Unity. The process of 3Dmax building a ship model is mainly:

a). Collect ship-related information and organize data. The information is as complete, unified and planned as possible.

b). Plan the plan, plan the time allocation of the ship model and map, and layout the model.

c). The ship model is produced, accurately modeled according to the collected data, and streamlined and optimized locally.

d). Map texture. Process textures as needed and perform texture mapping.

e). synthesis. Combine the local models as required and adjust the lights and materials.

f). Adjustment and optimization. View actual rendering effects, adjust for individual situations, and optimize.

g). Get the results of the model.
4.3. Create basic behaviors for roles within the scene
In the system, the participants must pass the virtual roles in the command training system, as shown in Figure 2, to complete various firefighting, message delivery, and equipment shutdown to deal with disasters, so as to accumulate experience in disposing of various dangers. Improve the level of training.

4.4. Fire model setting
There are generally three simulation methods for flames: texture technology methods, particle system methods, and physical model methods. The texture technology is used to simulate the flame, which is
fast and consumes less computer resources, but the artificial traces are more obvious, and it is difficult to express the dynamic scene. The particle system method can express certain combustion scenes and combustion details, and is easy to implement, and is suitable for situations where the simulation effect is not too high. The physical model method is based on physical properties, and makes a reasonable calculation of the motion change of the flame, which can realistically simulate the process of flame combustion. However, the calculation of this method is too complicated, and its continuity is beyond the capabilities of existing computers.

The system uses particle system to realize the simulation of fire, and simplifies the physical characteristics of fire in reality, and controls the fire by controlling the size, shape and number of fire particles.

The Emission parameter of the Unity particle system determines the number of particles emitted per frame. The Emission Variance parameter determines the maximum range of the number of particles per frame. Therefore, the number of particles emitted by each frame of the fire particle system is as shown in equation (1).

\[ N() = \text{Emission} + R() \times \text{Emission Variance} \]  

The size of the fire is determined by the size of the fire particles. Unity's particle system characterizes the initial size of the particle by adding the Start Size parameter, characterizing the maximum variation range of the initial particle size by Start Size Variance, characterizing the average size of the particle death by Ending size, and characterizing the maximum particle size at death by Ending size Variance. Variation range. Therefore, according to the method of generating random particles, the size of the new particles is as shown in the formula (2).

\[ I() = \text{Start Size} + R() \times \text{Start Size Variance} \]  

**Table 1. Dynamic fire influence parameters**

| Initial state I | Describe the initial size of the fire to determine the training difficulty of this training |
|-----------------|------------------------------------------------------------------------------------------------|
| Development speed V | This system assumes that the speed of fire development is constant. |
| Time T | Length of time from the start of the fire to the time the fire is extinguished |
| Number of fire extinguishers N() | Number of troops assigned by the trainer |
| Loss factor a() | Firefighting capacity of each force |
| Extinguishing time t() | The length of time that the force begins to extinguish until the fire is extinguished. |
| Equipment factor b() | Firefighting capacity of different equipment |
| Fire devaluation W | Threshold that the fire cannot control |

The positive development value of fire is I + VT, and the reverse development value of fire is from \( N(i) \times a(i) \times t(i) \times b() \). The growth rate of the two trends of fire determines the effect of fire extinguishing. When a fire occurs, the participants will judge the fire according to their experience. A firefighter will be sent to extinguish the fire first. If the fire is not controlled, the firefighters will be remedied in time to send firefighters to the fire. Therefore, the number of firefighters and the physical strength coefficient. The fire extinguishing time is a function of the function with the force number i as a variable, and the equipment coefficient is the set value, and the setting value of each firefighting equipment is different. When the fire exceeds the threshold, the system directly announces that the training failed. Figure 4 shows the firefighting scenarios for different equipment in different locations.
Figure 4. Simulation of different firefighting scenarios

5. Conclusion
The application of virtual reality technology in the field of ship fire protection has the advantages of large amount of training, close to reality, flexibility and convenience, strong interaction and low cost, which is of great practical significance for guiding crew fire training. With the continuous development of computer hardware and software technology, fire training based on virtual reality technology will become the dominant direction.

References
[1] Chang Zhuang, Qiu Jinshui, Zhang Xiushan. Research on Architecture of Ship Virtual Fire Training System Based on Virtual Reality Technology [J]. Chinese Ship Research. 2009 (3): [33 - 39].
[2] Ge Beibei, Liang Jingguo, Li Yizhen. Ship fire emergency management simulation system [J]. Heilongjiang Science and Technology Information. 2011 (6): [20 - 21].
[3] Song Qiaoqiao. Research and implementation of ship intelligent damage management system based on Virtools [D]. Central South University. 2011 (1): [46 - 49].