

Study on Simulation of the Underground Shopping Mall Fire Based on Virtual Reality

Du Xin⁺

Department of Fire Commanding, Chinese People's Armed Police Force Academy

Lang Fang, China

Abstract—Researching on the method of the underground shopping mall under fire from its building structure and fire characteristics, the paper gives out the method of control the movement of fire and smoke in the virtual world by CFD of solid particles through Discrete Model introduced into numerical simulation of underground shopping mall fire risk. Choosing Virtools as the Software platform, fire and smoke Virtual Reality coupling with CFD, the paper achieves the technology realization of the fire smoke to reproduce based on Virtual Reality technology, and it has laid the foundation for a Virtual Reality system of underground shopping mall shopping fire. This system is very important, and provides an extra technology and method to research on the fire fighting and emergency rescue, fire investigation and fire safety training, great significance.

Keywords-Virtual Reality, underground shopping mall fire , CFD, Virtools

1. Introduction

Through the advancement of the society, the control of urban land resource shortage problem has made underground structures as the best way to solve the problem, and the underground shopping mall is very important in the underground space development and utilization. But underground shopping malls are crowded areas, more combustibles, more fire-loads, special structures that no more windows for taking away smoke, temperature increases fast and high risk of fire flashover, no more air for burning, so long time smoldering fire produce toxin gas like CO and H₂S, its fatal risk to the peoples and fire fighters. Otherwise, few emergency exits and long evacuate distance make the evacuation more difficult in the dark environment. It is very dangerous in case of fire which will cause big casualty and property loss, so how to decrease the loss and control the fire in right way, and from design and management to prevent the fire happening is the most important problem that we need to solve, and that is also the important factor to protect the business, life and property. In all of these the abundant results on technology and theory of project safety has been obtained, but most are abstract theories and numerical simulations. Virtual Reality technology brings building fire simulation to a brand new brain storm. Using the immersion and interactivity of Virtual Reality can make fire happen and development visualized in the virtual world, and the result can be laid out better.

The mix of Virtual Reality technology and Computational Fluid Dynamics (CFD) has become the high point of Virtual Reality technology, some other countries have researched in this area, but only display the liquid flow by vector arrow, nothing on the surface of fire and smoke flow. In domestic, research document on mine fire gives the method that using the CFD value of solid particles to control the movement of fire and smoke in the virtual world, builds up mine fire Virtual Reality system and makes Virtual Reality coupled with CFD, because the structure of mine is different from underground shopping mall, so the Discrete Model of

⁺ Corresponding author.

E-mail address: dixon1203@163.com

particles is not fit in the underground shopping mall. Based on the Advantages and Features of Virtual Reality, this paper researches the method of reconstruct Virtual Reality of underground shopping mall fire risk from mall's structure and characteristics of the fire.

2. Simulation of Underground Shopping Mall Fire Scenario in Virtual World

2.1. The structure of virtual reality system of underground shopping mall

The paper researches on the results that mixing the simulations of burning, flame, movement of smoke and CFD. We use "Fluent" as the research software, its abundant physical models, advanced numerical methods and the capability of pre- and post-processing, accurately simulate inviscid flow, laminar, turbulent flows, chemical reactions, multi phase flow and other complex flow phenomena. Using Virtools software package and Microsoft Visual C++ as the development tools, J2ME as final software platform, Visual C++ finish the code.

Both of 3D Modeling and Special Effect are challenging research directions in the field of computers, 3D Modeling is hard because of complex scenario and light emit. It is also hard to simulate the burning scenario of underground shopping mall because fire was taken place instantaneously and shapeless. The paper models the space of underground shopping mall by MutiGen Creator, particles system displays smoke model, by way of particle function Visual C++ performances the result of mixed smoke and CFD numerical simulation, and Virtools finishes the code, then all these can reconstruct the fire scenario of underground shopping mall. The fire simulation system flow chart shows in Fig. 1.

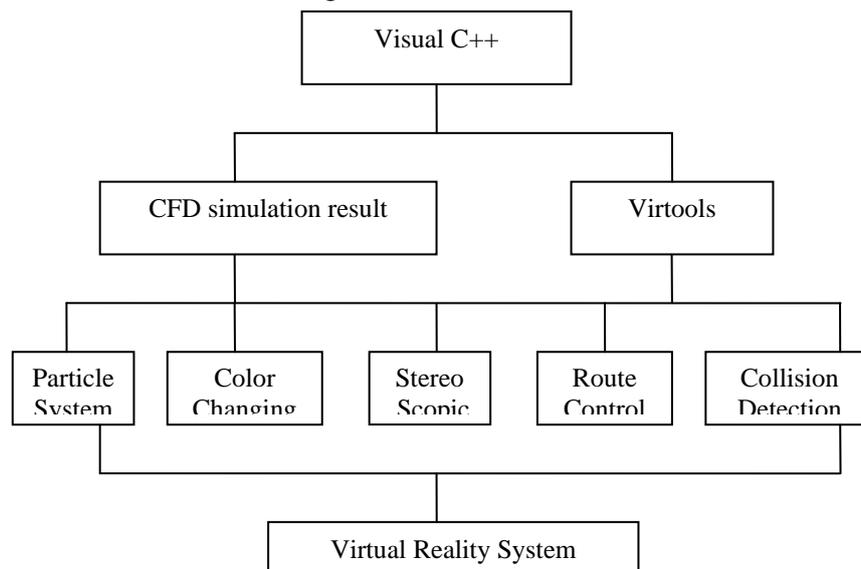


Fig.1. Fire simulation system flow chart

2.2. Smoke CFD stimulation in the fire

The underground shopping mall fire obeys the law of conservation of mass, conservation of energy, conservation of momentum, based on these fundamental laws can we build continuum equation, momentum equation, energy equation, composition equation of fire, and figure out fire flow, temperature, pressure, concentration by turbulence model and computation method. But there are huge number flow fields that simulate by CFD in underground shopping mall space. Fire procedure is an unstable procedure that changed over time, so there are huge data of unstable flow field need calculate. It is difficult to reconstruct Virtual Reality environment by such huge data, and the difficulties include the limit of the computing power of computer and the difficulties of implementation.

In the course of fire, the fuel was usually imperfect combustion, meanwhile the solid particles like soot and ash were given off, and these solid particles flowed and exchanged heat with smoke. The particles movement closely related to the flow, so we can know the variation of the particles and smoke flow and figure out the changes of position, speed and temperature. These changes indirect show out external change features. So considering the difficult and easy to control particles in virtual environment, this paper inputs Discrete

Model into fire flow field. The particles obey conservation of mass, energy and momentum, and simulate the movement relations of particles and flow fields, We can use the following method to simulate the relationship both of particles movement and flow field, to minimize the effects of particles on flow field, considering the effect of gravity and the particles are equally distributed, enter flow field with fixed time and no abrasion and deposition when move with flow field.

Stress Balance Equation of particles in the flow field (direction x):

$$\frac{du_p}{dt} - \frac{g_x(\rho_p - \rho)}{\rho_p} - F_x = F_D(u - u_p) \quad (2.1)$$

where u_p is the viscous hydrodynamic force, its unit is the Pa·s; g_x is the particle quality standard, its unit is the kg; ρ_p is the particle density, its unit is the kg/m³; ρ is the fluid density, its unit is the kg/m³; F_x is the other force, its unit is the N.

Under the assumption that particle's internal temperatures equal everywhere, the relations of particles temperature $T_p(t)$ and surface convection with flow and radiation heat exchange follows(2.2):

$$\frac{dT_p}{dt} = \frac{hA_p(T_\infty - T_p) + \varepsilon_p A_p \sigma(\theta_R^4 - T_p^4)}{m_p c_p} \quad (2.2)$$

where T_p is the particle's temperature, its unit is the K; h is the heat transfer coefficient of convection, its unit is the W/(m²·K); A_p is the surface areas, its unit is the m²; T_∞ is the local temperature of continuous phase, its unit is the K; ε_p is the particle's blackness; σ is the Stephenson-Boltzmann constant, the value is 5.67×10^{-8} W/ m²·K⁴; θ_R is the radiation temperature, its unit is the K.

We can connect particles with fluid state parameters in the flow field by (2.1) and (2.2). By way of calculating the integral of (2.1), we can know the speed and position of particles in a defined time by Locus Equation. And the temperatures in different moments result from calculating the integral of time in (2.2). The absorbed (or released) energy that particles penetrated fluid units will act as the source phase effect in energy equation of continuous phase. The paper takes the momentum that particles collide on the wall boundary as reflection, or keeps both normal and tangential momentum same after collide, and the particles died (or stop calculate the orbit) when they reach the boundary of entrance and exit. Based above we can know the particle's position, speed and temperature with time, and provided data support for the Virtual Reality.

2.3. Virtual Reality of flame and smoke

Flame and smoke are both of gas flow phenomena, consisting of numerous small particles in random movement, irregularly shape, no smooth surface, complex and random, and changing with time. We are familiar with these kind phenomena, but it is hard to shape it. The flowing movement of flame and smoke connects with CFD, we use particle system to build smoke flow of fire in underground shopping mall, and the movement of smoke flow controlled by CFD in real time. We can simulate the flame by particles, but using CFD to simulate the flame is still very hard, so we use mapping method to simulate the flame.

We can get the data of particle's spatial position, temperature and speed in fixed intervals by Numerical Simulation, and position, speed and temperature parameters are extracted.

3. Conclusion

Computer calculates and makes decision very fast, simulating the process of fire and rescue by computer Virtual Reality makes the fire fighter clear the source of fire, fire spread tendency and rescue effect, provide a new technical way for fire investigation and staff safety training. This paper builds a fire simulating Virtual Reality system of underground shopping mall by the advantage of Virtual Reality and CFD, coupled Virtual Reality and CFD simulating technology, it has certain practical significance and applicative value.

With the development of Virtual Reality theory and technology, the research of Virtual Reality system of underground fire should be closely followed the time. Strengthened the research of flame and smoke visualization, particle fuzziness and coupled with CFD simulation, make Virtual Reality system can shape the fire in the complex structures.

4. References

- [1] Timothy Walsh. Virtual Reality for explosion/fire prevention and management[D].U. K.(Nottingham):University of Nottingham,1999.
- [2] WANG Haiyan,ZHOU Xinquan. Study on Virtual Reality in Mine Fire [J]. Proceedings of 2006(Shenyang) International Colloquium on Safety Science and Technology,2006.
- [3] SUN Zhiyi ,WU Xiaorong. Discussion and Application of CFD Numerical Simulation Technology[J]. Water Conservancy Science and Technology and Economy,2008.
- [4] FLUENT. Inc. The FLUENT user guide[M]. Centerra Resource Park 10 Cavendish Court Lebanon,2001.
- [5] LIU Yaolin, KONG Jianyi,JIANG Guozhang, SUN Liangbo. Development of Virtual Reality Technology [J]. Journal of Hubei University of Technology,2005.
- [6] GUO Dong, LIN Guoshun. To Study on Applying Simulation System of Virtual Reality Technology in Aircraft Accident above the Ocean[J]. Value Engineering, 2008.
- [7] ZHANG Xiaoming, LI Feng, XIE Yuanyi, WANG Peng. Ventilation simulation under fire condition in extra-long highway tunnel in Zhongnanshan Section[J]. Fire Science and Technology,2007.
- [8] ZHUANG Lei, YANG Qingyun, SUN Zhiyou, LU Shouxiang. Design and Evaluation of Fire-resistant Partition in Big Underground Business Buildings. Fire Science and Technology,2007.
- [9] CAI Huanhuan, ZHONG Ke, KANG Yanming. Numerical Simulation of Spatial Distributions of Particle Concentrations in a Courtyard[J]. JOURNAL OF DONGHUA UNIVERSITY (NATURAL SCIENCE),2007.
- [10] LIU Songtao, ZHOU Xinquan, YAN Ning, WANG Haiyan. Optimization of ventilation mode for subway platform fire based on CFD[J]. Journal of Liaoning Technical University(Natural Science),2008.