System Design of a Simulation System for Hazardous Chemicals Leakage

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1. Introduction

Over recent decades, the number of chemical industry parks increases greatly, and the park format has become one of chemical industry development trend in China (Haiquan 2009). A chemical park has large number and high density of major hazards, which leads to extraordinary big accident risks. Therefore, establishing a safety monitoring and emergency response system for a chemical industry park is of great importance.

Up to now, a number of such systems have been established, some of which were based on WebGIS (Binyu 2011) and some are just based on the video monitoring system. The current safety systems can monitor the chemical park and give an alarm when emergency occurs, such as hazardous gas leak, however, they could not show how the emergency evolve. In order to provide a more intelligent and useful system to help emergency response, we design a Simulation System for chemical industry parks.

2. Overall System Design

2.1 System Components

The system is made up of three main parts: the sensor network, the spread model library, and the simulation software package.

The role of sensor network is providing real time monitoring data. It contains several types of sensors, such as thermometer, hygrometer, anemometer, camera and some special sensors that can detect specific dangerous chemical gas like Nitric oxide, Sulfur dioxide. The spread model library can predict how the gas spread after it leaks. The mode of the source of the leak has an important impact on leakage and diffusion mode. In the actual accident, the main factors affecting the source of the leak mode including storage state, storage conditions, leak location, leak area, restrictions on movement and leakage form. Since different models are applicable to different types of gas, we integrate several models to the spread model library, including Gauss Model, Box Model (Eidsvik 1980, Qiping 1998, Xuhai 2003), BM Model (Blackmore 1982) and so on. The simulation software package mainly focuses on how to visualize the scene. It is based on GIS platform, OpenSceneGraph (OSG) Rendering Engine, and CUDA. The GIS platform supply the fundamental function such as display vector data, raster data, building data, and pipeline data of chemical industry park. The OSG Rendering Engine is used for visualizing the result that calculated by the spread model library. CUDA™ is a parallel computing platform and programming model invented by NVIDIA. It enables dramatic increases in computing performance by harnessing the power of the graphics processing unit (GPU). We will use CUDA for accelerating the reader process, so the system has the ability to show the real time simulation result.

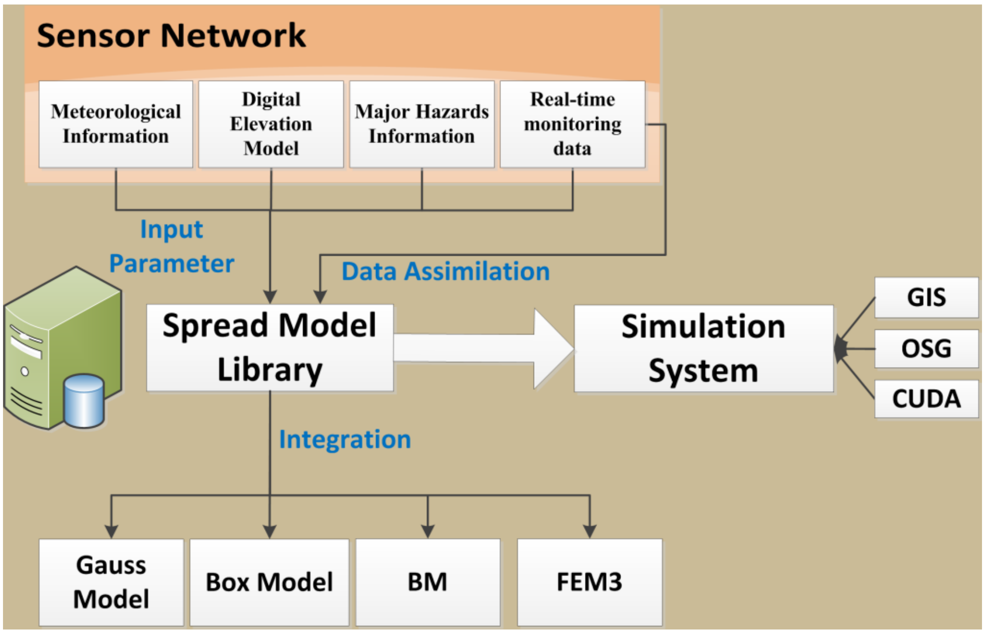

Figure1. Main Components of the System

Figure1 shows the main components of the system and how they connect as a whole system. When there is hazardous gas leakage, the corresponding sensor can detect it and send the data to our model server, and simultaneously an altering signal will send to the Emergency response center. The model server use the sensor data as the input parameter to compute, and it can choose the most suitable model to use according to the type of the leaking hazardous gas. The model can simulate the spread status at a series of points in time, and we can obtain the real time from the sensor network when the time reach that points, obviously, they are not equal, and that means the model need be amended. So we can make use of the difference between the model result and the real monitoring data to improve the model. In order to achieve this purpose, the theory and methods of data assimilation should be used, and we will design a class to implement it.

2.2 Detail Design

The system architecture is divided into three levels: database, model server, and three-dimensional simulation software package, the structure of the program is the Client/Server mode. The J2EE architecture standards as well as Struts, Spring, Hibernate will be used on the server-side to build a model server. The model server is responsible for the model packaging and model calculating, the simulation software package is responsible for rendering of basic geographic data, loading and rending the result data of model calculating.

PostGIS which is based on PostgreSQL will be used as the database management system to store and manage both spatial data and non-spatial data. Sensor data and non-spatial data will be directly retrieved from the database while the spatial data will be retrieved from the database via Geoserver.

3. The Simulation Software Package

There are two key problems that we should deal with seriously about the simulation software package.

Firstly, we should consider how to convert the data calculated by the model library server to the data that can be visualized by our rendering engine. In order to solve this problem, we design a data transformation engine. When there is hazardous gas leakage, the model library can be driven to make calculations, and the results can indicate the scope that the gas diffuses at some moment in the future. However, the results that calculated by the model server are just some simple parameter that indicates the scope and a function that indicates the intensity at assign position, so it cannot be directly used by the rendering engine, and this work will be done by the data transformation engine. It can transform the simple parameter to another data structure that can be rendering. The data structure divided the scope into many small cubic, and contains the information such as intensity in every cubic, so the rendering engine can easily understand the data structure and visualize it.

Secondly, the simulation of hazardous gas leakage is a little difficult when it is three dimensional, because three-dimensional simulation will use a lot of system resources. Still more, it will be more difficult if the simulation system is based the real time data and it should visualize the status in the future that are calculated by the model server according to the time specified by customer, because we must render the scene quite fast to ensure the system running normally and fluency. Therefore, we must design an efficient simulation system. In order to realize this, we choose the OpenSceneGraph as our rendering engine, which is an open source high performance 3D graphics toolkit. It is based around the concept of a Scene Graph, providing an object-oriented framework on top of OpenGL, so it is high efficient in managing and rendering the three-dimensional scene. In addition, OSG support the particle system which can be used for realistic smoke and fire simulation, and developers can define their own particle system that inherited from the base class that OSG supply, in order to realize some special effects. Figure 2 shows the effect of our simulation software package, such as building rendering, smoke simulation, fire simulation and particle emitter, the data we used now was some test data and we will test the real data since our sensor network is built up and working. Figure 3 shows how we can design the particle system for simulation of hazardous gas leakage, and we will use it to simulation an approximate real scene of gas leakage according the spread models.

4. Conclusion

In this paper, a system based on sensor network, spread model library, and the OpenSceneGraph Rendering Engine has been designed for monitoring and simulating the hazardous gas leakage in chemical industry parks. The spread model library server can automatic determine which model should be used according to the practical situation, so it can ensure the accuracy of the result to some extent. The custom particle system can visualize the status of gas leakage according to our set and it can achieve realistic effects. The system we design will be demonstrated in the chemical industry parks next year, and some improvement will be made by the time.

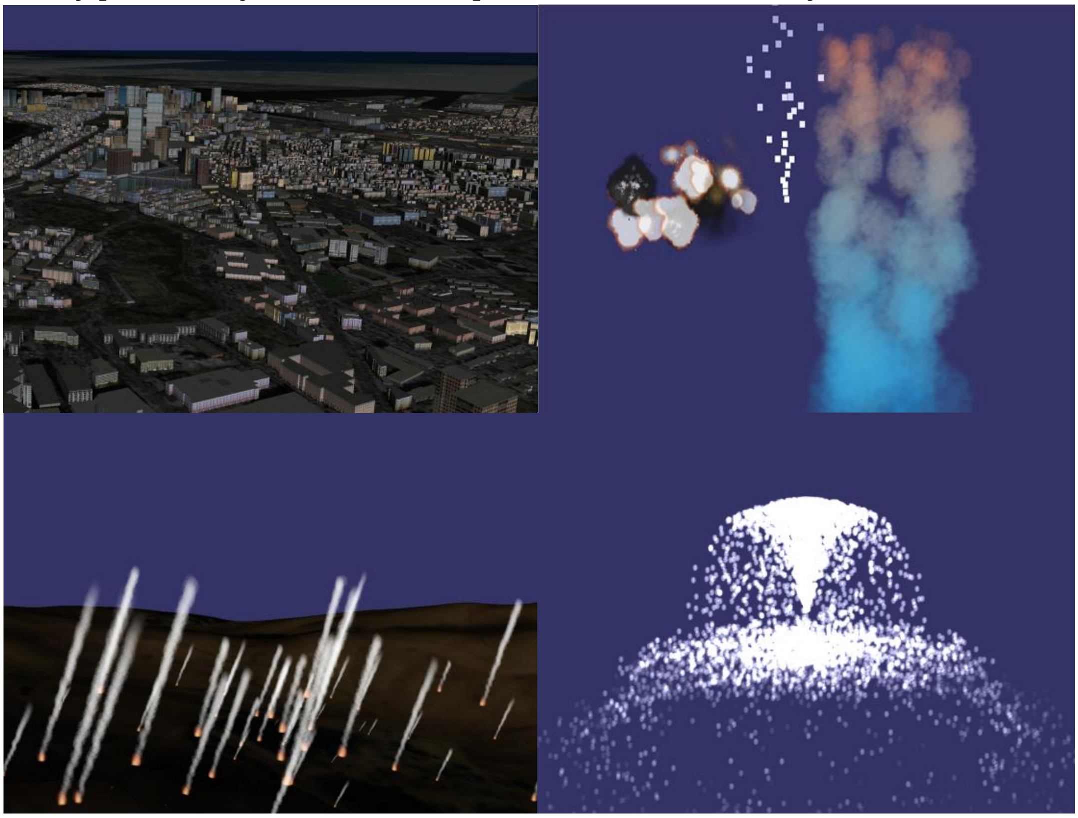

Figure2. Effect Picture of the Rending System

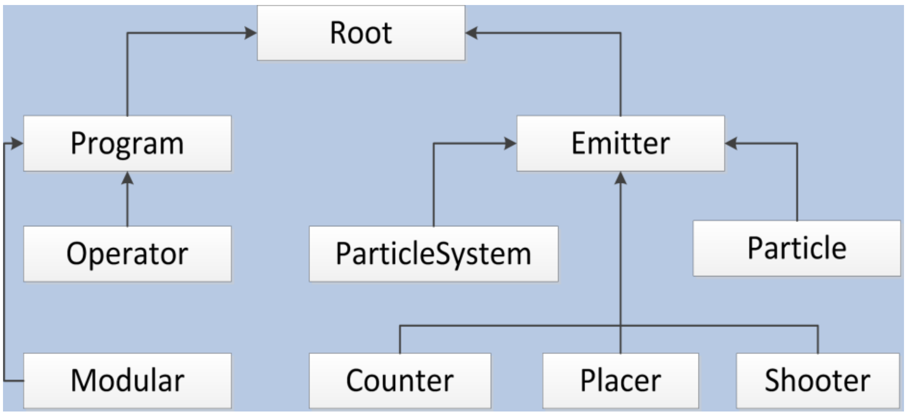

Figure3. Custom Particle System

5. References

DING Xinwei, WANG Shulan, XU Guoqing. 1999. A Review of Studies on the Discharging Dispersion of Flammable and Toxic Gases. Chemical Industry and Engineering, 16(02): 118-122.

Kari J. Eidsvik. 1980. A Model for Heavy Gas Dispersion in the Atmosphere. Atmospheric Environment, 14: 769-777.

PAN Xuhai, JIANG Juncheng. 2003. Numerical Simulation Research on Instantaneous Release Dispersion of Heavy Gases. Chemical Engineering, 31(01):35-39.

SANG Haiquan, KANG Rongxue, WEI Lijun. 2009. Safety Monitoring and Emergency Platform for Chemical Industry Parks. China Academy of Safety Science and Technology, 27(22): 81-85.

XIE Binyu, et al. 2011. Research on the On-line Monitoring Platform Design of Environmental Risk Sources in Chemical Industrial Zone. Environmental Monitoring in China, 27(01): 60-63.

ZHANG Qiping, MA Dexian. 1998. Effect of heavy gas of dangerous material in diffusion process. Journal of Beijing University of Chemical Technology, 25(03):86-90.