A 3D Visualization Framework for Real-time Distribution and Situation Forecast of Atmospheric Chemical Pollution

Haibo Wang[1], Jingeng Mai[1], Yi Song[2], and Chaoshi Wang[1], Lin Zhang[1], Fei Tao[1], and Qining Wang[2]

[1] School of Automation Science and Electrical Engineering, Beihang University, Beijing 100191, China
[2] Intelligent Control Laboratory, College of Engineering, Peking University, Beijing 100871, China

Abstract. The visualization system of pollutant distribution contributes to scientific decision-making in the emergency pollution affairs. In this paper, we propose a framework which supports 3D visualization for real-time distribution and situation forecast of atmospheric chemical pollution. The core of our framework is a distributed system infrastructure, which is designed for massive data storage and parallel computing. The stored data includes terrain elevation, vector maps, satellite maps, meteorological data and concentration data from gas sensors. High-performance computing generates gridded data for visualization. Web-based 3D visual applications with B/S structure support cross-platform terminal access.

Keywords: visualization, distributed system, situation forecast, web-based, chemical pollution.

1 Introduction

The atmospheric chemical pollution has a significant hazard to human health. The system for real-time monitoring, forecast and visualization of the pollution level in urban areas is an important tool for evaluating the atmospheric environment and dealing with the emergency pollution accidents.

James J.Q. Yu *et al.* developed a method of collecting data from gas sensors deployed on the public traffic system[1]. Jinqiu Xiao *et al.* also attempted to monitor the atmospheric chemical pollution via the telecommunication network [2]. In addition, many other methods have been used to realize real-time monitoring [3].

Besides real-time data, the system needs the support of more information, including terrain elevation, satellite maps and vector maps, to estimate pollutant distribution around 3D space and forecast the diffusion situation [4].

Displaying the pollution level in 2D view is a common environment evaluation method at present [5]. Many people have attempted 3D visualization with terrain data [6-8].However, the combination of real-time pollution distribution and situation forecast with 3D terrain remains a great challenge.

G. Tan et al. (Eds.): AsiaSim 2013, CCIS 402, pp. 415–420, 2013.

Łukasz Kamiński *et al.* proposed a web-based GIS visualization architecture and indicated that the system integrated with sensors providing current on-line data containing measurement results was practical[9].

We propose a 3D visualization system for atmospheric chemical pollutant real-time distribution and situation forecast. The gas sensors are deployed on a mobile blimp with a large monitoring range for real-time measurement. The distributed system infrastructure is used to realize massive data storage and parallel computing. The pollutant distribution and situation forecast are estimated according to the diffusion model and real-time measurement data, and displayed on the cross-platform terminals to realize web-based 3D visualization.

The rest of the paper is organized as follows. The architecture of the system is described in Section 2, and the infrastructure of data processing is shown in Section 3. In Section 4 and 5, the diffusion model and structure of 3D visualization platform are discussed. We conclude in Section 6.

2 Architecture

As shown in Fig.1, the system consists of three parts: flight platform for sensors deployment, ground station for data storage and processing, and access terminals for 2D and 3D view. And as shown in Fig.2, the data access layer provides the storage, access and management interfaces for structured data (e.g. GPS, velocity, temperature, humidity, atmospheric pressure, wind speed, wind direction and chemical concentration) and unstructured data (e.g. video and images); in the business logic layer, a variety of data modeling methods are taken for data gridding Based on the pollution data of discrete points from gas sensors, and various visual structured data are generated from visualization mapping of gridded data, such as points, lines and planes; in the user interface, the contour lines and planes are drawn and rendered according to visual structured data to display atmospheric chemical pollution distribution, and the cross-platform visualization applications are realized based on WebGL technology.

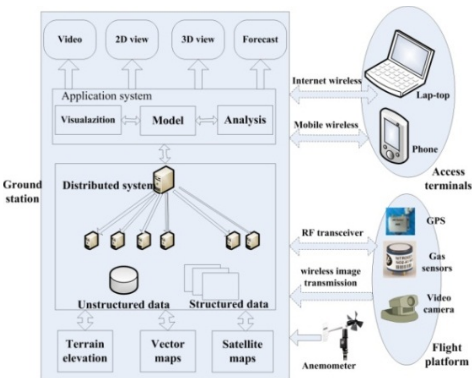

Fig. 1. Functional Structure

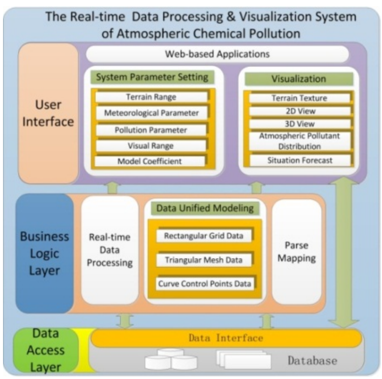

Fig. 2. Hierarchical Structure

3 Data Processing Infrastructure

As shown in Fig.3, the data processing infrastructure consist of three parts:1) Data source The terrain data in the system includes terrain elevation, satellite maps and vector maps. The terrain elevation data is about 30GB from SRTM (Shuttle Radar Topography Mission). The satellite maps data is about 3TB in total. The vector maps data in the form of MapInfo is about 3GB, including the coordinate information of landmarks, such as buildings, roads, etc. The real-time monitoring data is divided into two types according to the format. One is video image in the form of streaming media; the other is structured data, including GPS, velocity, temperature, humidity, atmospheric pressure, wind speed, wind direction and chemical concentration, etc. 2) Data storage The distributed system based on Hadoop includes one NameNode and several DataNodes. The data of terrain elevation and satellite maps, which is not frequently read and written, is stored in the DataNodes of Hadoop system. The vector maps data is stored in the NameNode. Besides, the structured data, video data and visualization data from the model computing within a given period (e.g. one month) are all stored in the NameNode. The outdated data will be immigrated to the DataNodes of Hadoop system as historical data. 3) Data interface The data of terrain elevation and satellite maps are provided in the form of web map service, while the vector maps data is provided by the MapX. The real-time database supports ODBC interface, and the real-time video data supports video streaming playback interface. The historical data stored in Hadoop system can be accessed via historical data service.

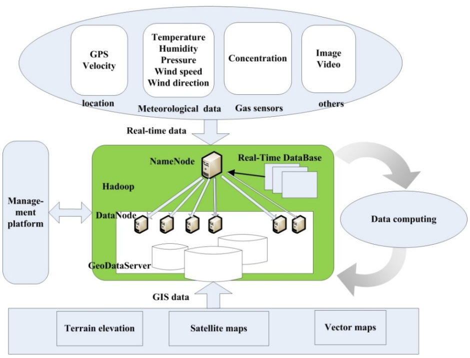

Fig. 3. Data Processing Infrastructure

4 Diffusion Model

After comprehensive comparison among Gaussian plume model [10,11], RIMPUFF (Lagrange atmospheric diffusion smoke model) [12], ATSTEP (the mixture of Gaussian model and Segmented plume model) [13,14], and CALPUFF (three-dimensional unsteady Lagrange smoke diffusion system) [15], Gaussian plume model is chosen as the diffusion and situation forecast model of the system. The model can not only simulate current distribution of atmospheric pollutants diffusion concentration in the leeward direction, but also forecast pollutant distribution sometime in the future according to real-time and historical data [16-19]. Headwind diffusion is considered and added to Gaussian plume model for optimization [20, 21]. The optimized model is more suitable for continuous point source diffusion. Pasquill diffusion parameter determination method combined with atmospheric parameters is taken to determine the diffusion coefficient. Subsequently, the concentration distribution of chemical pollutant and diffusion trend are visualized via model computing to realize diffusion analysis and situation forecast.

5 3D Visualization

As shown in Fig.4, 3D real-time visualization displays real-time distribution of chemical pollutant and provides the reference for situation forecast. It is related to the construction of 3D terrain platform, real-time data processing and visualization technology.

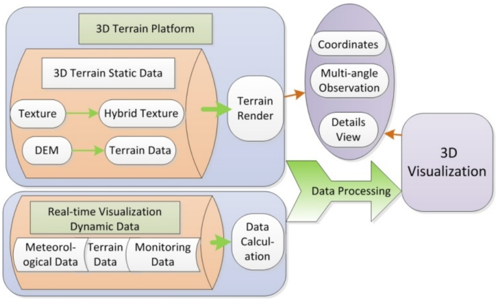

Fig. 4. 3D Real-time Visualization Platform

The construction of 3D terrain platform can be divided into 3 steps. Firstly, 3D terrain static data is retrieved from the database and calculated with corresponding texture data for the hybrid textures. Secondly, terrain elevation is used to divide terrain blocks according to terrain multi-resolution structure [22], and terrain data is obtained from building Quad-tree Spatial Data Model [23]. Finally, the hybrid texture and terrain data are used in the construction of 3D terrain platform via Semi-CLOD (Semi-Continuous Level Of Details) algorithm [24] and Surface Rendering technology[25]. The 3D terrain platform can realize location, paranoma roaming, multi-angle observation, multi-resolution and multi-level detail view.

Real-time data processing calculates three categories of real-time sensing data (meteorological data, geographical data, and monitoring data) stored in the database via the established model, and it processes the calculated data via the parsed mapping algorithm and interpolation method to display current pollution level and range in the targeted area. Recent diffusion trend of chemical pollution can be predicted via relevant parameters setting and historical data analysis. And the pollution level and range can be displayed via paranoma roaming.

6 Conclusions

In this paper, we propose a 3D visualization system for atmospheric chemical pollutant analysis. The main idea of the system is summarized as follows.

1. Build a distributed system for massive data storage and parallel computing.
2. Estimate gas concentrations around 3D space according to optimized diffusion model, terrain data, and real-time sensor data.
3. Display real-time distribution and situation forecast efficiently in 3D view.

We will research the massive unstructured data access and optimize the diffusion model. In addition, web-based 3D visualization will also be an important object to research.

Acknowledgement. This work was financially supported by the National Key Technology Research and Development Program (No. 2011BAK16B00) in China.

References

1. Yu, J.J.Q., Li, V.O.K., Lam, A.Y.S.: Sensor Deployment for Air Pollution Monitoring Using Public Transportation System. In: 2012 IEEE World Congress on Computational Intelligence, WCCI 2012, pp. 1–7 (2012)
2. Xiao, J., Ying, W.: Monitoring System of Regional Environmental Pollution Index Based on Telecommunication Network. In: 2011 International Conference on Electrical and Control Engineering, ICECE 2011, Yichang, China, pp. 254–256 (2011)
3. Chen, W., Chen, S.: Application of GIS Technology in the Emergency Monitoring of Sudden Air Pollution Accident. In: 2010 2nd International Conference on Information Science and Engineering, ICISE 2010, Hangzhou, China, pp. 3550–3555 (2010)
4. Wang, C., Wan, T.R., Palmer, I.J.: Automatic Reconstruction of 3D Environment Using Real Terrain Data and Satellite Images. Intelligent Automation and Soft Computing 18(1), 49–63 (2012)
5. Narashid, R.H., Mohd, W.M.N.W.: Air Quality Monitoring Using Remote Sensing and GIS Technologies. In: 2010 International Conference on Science and Social Research, CSSR 2010, Kuala Lumpur, Malaysia, pp. 1186–1191 (2010)
6. Sequeira, V., Wolfart, E., Bovisio, E., et al.: Hybrid 3D Reconstruction and Image-Based Rendering Techniques for Reality Modeling. In: Conference on Videometrics and Optical Methods for 3D Shape Measurement, San Jose, CA. SPIE, vol. 4309, pp. 126–136 (2001)
7. Hou, H.-D., Zhang, J.-F.: Research on Real-Time Visualization of Large-scale 3D Terrain. In: 2012 International Workshop on Information and Electronics Engineering, IWIEE 2012, Harbin, China, vol. 29, pp. 1702–1706 (2012)
8. Hu, Y., Li, D., He, X., Sun, T., Han, Y.: The Implementation of Wireless Sensor Network Visualization Platform based on Wetland Monitoring. In: 2009 Second International Conference on Intelligent Networks and Intelligent Systems, ICINIS 2009, Tianjin, China, pp. 224–227 (2009)
9. Kamiński, L., Kulawiak, M., Ciżmowski, W., Chybicki, A.: Web-based GIS dedicated for marine environment surveillance and monitoring. In: IEEE Oceans 2009-Europe, Oceans, Bremen, Germany, vol. 1-2, pp. 1247–1253 (2009)

10. Ebrahimi, M., Jahangirian, A.: New Analytical Formulations for Calculation of Dispersion Parameters of Gaussian Model Using Parallel CFD. Environmental Fluid Mechanics 13(2), 125–144 (2013)
11. Leroy, C., Maro, D., Hebert, D., et al.: A study of the atmospheric dispersion of a high release of krypton-85 abovea complex coastal terrain, comparison with the predictions of Gaussian models (Briggs, Doury, ADMS4). Journal of Environmental Radioactivity, 937–944 (2010)
12. Roberti, D.R., Souto, R.P., de Campos Velho, H.F., et al.: Parallel Implementation of a Lagrangian Stochastic Model for Pollution Dispersion. In: Proceedings of the 16th Symposium on Computer Architecture and High Performance Computing, Foz dolguacu, PR, Brazil, pp. 142–149 (2004)
13. Hao, Y., Yu, Q., Qu, J.: Application of ATSTEP in Decision Support System for Nuclear Emergency Management. Nuclear Power Engineering 23(4), 102–107 (2002)
14. Yao, R., Hao, H., Hu, E., Cao, J.: Comparison of Two Kinds of Atmospheric Dispersion Model Chains in RODOS. Radiation Protection 23(30), 146–155 (2003)
15. Bo, X., Ding, F., Xu, H., Li, S.-B.: Review of Atmospheric Diffusion Spersion Model CALPUFF Technology. Environmental Monitoring Management and Technology 21(3), 9–13 (2009)
16. Cai, X., Chen, J., Kang, L.: An Atmospheric Diffusion Model for Conditions of Nuclear Accident. Radiation Protection 23(5), 293–299 (2003)
17. Yang, B., Gu, X.-M., Zhang, F., Zhang, F.: Development of Simulated Evaluation and Decision Support System of Atmospheric Pollution Dispersion. Science of Surveying and Mapping 36(3), 147–149 (2011)
18. Cheng, Y.: Gaussian Model Used Gas Pipeline after the Gas Leak Spread. Petroleum Chemical Industry of Inner Mongolia (14), 49–51 (2010)
19. Li, H., Deng, J., Wang, X., Zhang, L.: Calculation of Diffusion of Radionuclides Cloud in Atmospheric Using the Gaussian Model. Radiation Protection 24(2), 92–99 (2004)
20. Dvorak, R., Zboril, F., Kapoun, M., Masek, I.: Modeling of Atmospheric Dispersion from Point Source. In: Second UKSIM European Symposium on Computer Modeling and Simulation, Liverpool, England, pp. 46–51 (2008)
21. Briant, R., Seigneur, C., Gadrat, M., Bugajny, C.: Evaluation of roadway Gaussian plume models with large-scale measurement campaigns. Geoscientific Model Development 6(2), 445–446 (2013)
22. Tong, X., Ben, J., Zhang, Y.: Design and Quick Display of Global Multi-Resolution Spatial Data Model. Science of Surveying and Mapping 31(1), 72–74 (2006)
23. Zhang, L., Tang, L.-W.: Study of Organizing Seamless Great Capacity Spatial Data Based on Quad-tree. Computer Technology and Development 21(1), 77–80 (2011)
24. Hoppe, H.: Smooth View-dependent Level-Of-Detail Control and its Application to Terrain Rendering. In: 9th Annual IEEE Conference on Visualization, VIS 1998, Research Triangle Park, NC, USA, pp. 35–42 (1998)
25. John, D.: A Novel Technique for Visualizing High-Resolution 3-D Terrain Maps. In: Conference on Stereoscopic Displays and Virtual Reality Systems XIV, San Jose, CA. SPIE, vol. 6490, pp. 49003–49013 (2007)