International Journal of Interactive Digital Media, Vol. 2(1), ISSN 2289-4098, e-ISSN 2289-4101, www.ijidm.org

Real-Time Atmospheric Cloud Visualization Framework for Urban Simulation System

Muhamad Najib Zamri and Mohd Shahrizal Sunar

Abstract—Clouds are important aspects of any natural outdoor scene especially in urban simulation system and atmospheric analysis. However, the existing methods within computer graphics only offer the simplest of cloud representations. The problem is how to provide a means of simulating heterogeneous types of clouds and other atmospheric features that are suitable for virtual environments. Methods for cloud visualization are available within the area of urban planning, but numerical calculation of the systems are computationally intensive which give more numerical accuracy than what are required for graphics and restricted to the law of physics. Furthermore, pure physics-driven methods are not always producing the visual plausible results. Consequently, three-dimensional clouds are very difficult to model and render when considering the efficiency and visual accuracy aspects. The purpose of this research is to propose a cloud visualization framework for urban simulation system that would be able to produce high real-time rate and higher degree of visual realism. In order to solve the data representation complexity and the computation overhead problem, the generalized multiple data representations andthe cloud rendering method are proposed respectively. Combinations of ground, atmospheric, cloud and shadow models in the proposed framework is the key for realizing the real-time cloud visualization in urban simulation system.

Index Terms—atmospheric, cloud, urban simulation, visualization framework.

1 Introduction

CLOUDis a part of the important element of the atmospheric region.Cloud appearances can be useful for wide range of applications such as video games, movies, weather analysis and visual simulation. In urban simulation system, there are great demands for producing realistic cloud visualization as well as for real-time modeling, rendering and animation of clouds.

To realize the natural atmospheric clouds, there are two general problems involved. First, it is difficult to realize different types of clouds simultaneously. This is due to the complex representations of clouds in terms of shape, size, density, and formation.Fig. 1 illustrates the heterogeneous types of clouds [1] to give the general idea of clouds are look like.Based on the previous methods [2]-[11], the researchers attempted to solve for certain cloud type(s) only. Second, it lacks inclusion of atmospheric models. These models include the interaction of atmospheric scattering, indirect illumination, self-shadowing, inter-cloud shadows, and so on. Consequently, the unnatural cloud effects are yielded. Both of these problems have led to the high computation cost for rendering the objects in the system.

The aim of this paper is to propose the real-time atmospheric cloud visualization framework for urban simulation system which considers to solve the above-mentioned problems.The primary research questions that should be addressed are:

1. How to represent the heterogeneous types of clouds?
2. How to include the cloud elements into atmospheric model?

The first idea is to introduce a new data representation which can support for diverse cloud types. Generalized data structure is generated to store the cloud features in details. In order to remedy the atmospheric lackingissue, we propose the second idea which is to develop an extended atmospheric model by incorporating the previous research on sky color rendering [12] with the proposed cloud model into one system.

Urban simulation system developed in this paper can be summarized in the following way.In order to obtain the real-time cloud visualization as an output, the system needs to be input with atmospheric and terrain data. These data inputs are then pre-processed into specific data structure. The parameters from the data structure are disseminated to the corresponding modules that are ground, atmospheric, cloud, and shadow. During run-time, the parameter editing is allowed for fine-tuning the clouds to be generated. Lastly, all the objects are combined and rendered.

The remaining of this paper is organized as follows. In Section 2, we give an overview of the related work. Section 3 describes the proposed cloud visualization framework in further detail. The results obtained from this research are given in Section 4. Finally, Section 5 concludes the paper.

- *Muhamad Najib Zamri is with the UTM VicubeLab Research Group, Department of Software Engineering, Universiti Teknologi Malaysia, Malaysia, Johore 81310. E-mail: najibzamri@ utm.my*
- *Mohd Shahrizal Sunar is with the UTM-IRDA Digital Media Centre, Media and Game Innovation Centre of Excellence, Universiti Teknologi Malaysia, Malaysia, Johore 81310. E-mail: shahrizal@ magicx.my*

2 Related Work

Computer graphics research usually follows two different approaches on developing the cloud modeling and visualization system, which are known as "physics-

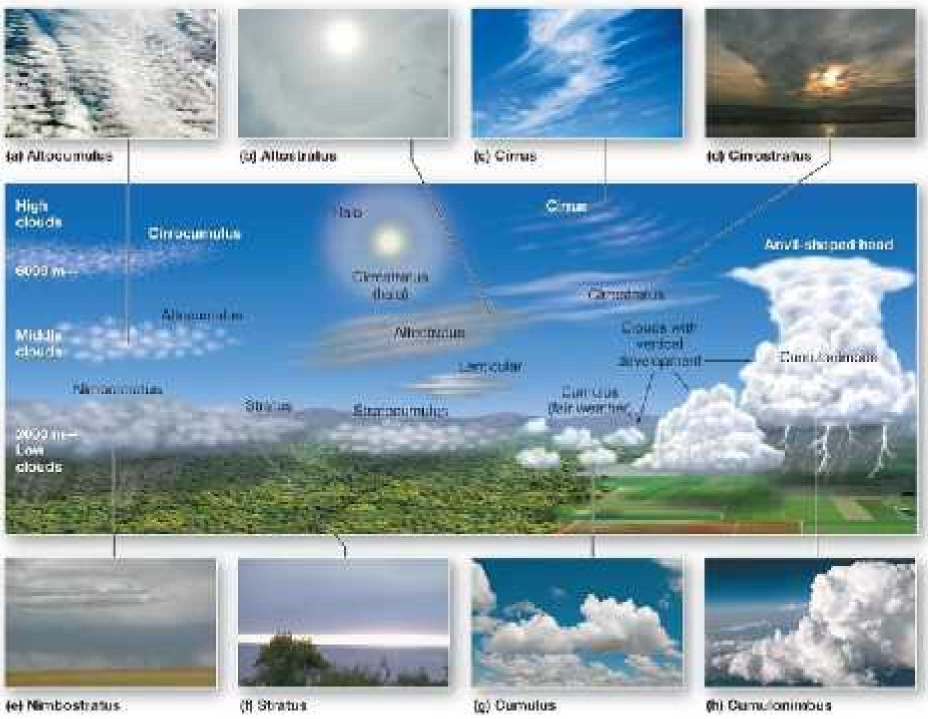

Fig. 1. Types of clouds (source: Pearson Education 2013 [1]).

driven" approach and "model-driven" approach.A comprehensive survey on clouds has been done by Hufnagel and Held [2]. The next subsections will explain the overview of the relevant research work.

2.1 Physics-Driven Approach

The physics-driven approach involves the use of physics law to model and compute the clouds. Yang et al [3] has modeled the clouds based on weather forecast data, whileKol [4] developed the cloud physics by manipulating the graphics processing unit (GPU) for real-time purpose. These methodsconsist in reproducing the law of physics in a computationally efficient way and use them to render an image.

The advantages of this approach is that it relies on numerous works and studies on related matters. There are some drawbacks. First, the laws of physics are themselves approximations of real phenomenon that correspond to ideal cases. For instance, geometric optics assume the objects are much larger than the wavelength of light and thus fail completely at determining the optics of a cloud droplet. Second, these physical laws rely on boundary conditions, initial conditions and numerous parameters, which are usually very complex in real cases. Finally, it is difficult for a human to predict the results of a method relying on multiple microphysical parameters whereas an artist needs understandable meaningful parameters.

2.2 Model-Driven Approach

The model-driven approach (cumulus cloud model [5]; atmospheric effect model [6]; cellular automata model [7]; photon mapping model [8]; volumetric instance model [9]; optimization model [10]; line integral convolution model [11]) rather uses an inverse approach which consists in finding a computational model capable of reproducing an observed phenomenon, regardless of the underlying physics that cause it.

The drawback of this method is that the more complex the phenomenon is, the more difficult it is to analyze and reproduce. Second, there does not currently exist criteria for the quality of the result. Third, this inductive strategy is also the one used by physicists to establish some equations, the current state of the art being the result of centuries of research. Thus, it seems unproductive to start from scratch and try to rediscover in a few months all that was found by physicists.

3 Proposed Framework

In this paper, we are proposing a cloud visualization framework that comprises of both physics- and model-driven methods. We integrate our proposed framework with the chosen sky color and shadow research work by Kolivand [12] (our research group's member) in order to see the interaction between our cloud model and sky effects for more realistic visualization.

3.1 Overview of the System

In this section, the system overview is explained briefly. The outcome of this research is the real-time visualization system which takes into account the atmospheric elements especially the relationship between clouds and sky colors. Fig. 2 shows the proposed research framework for our urban simulation system.This system requires three types of input data: (i) atmospheric data, (ii) terrain data, and (iii) city data. Sky color, sun position and cloud profiles are obtained in the atmospheric data; while mountain and hill landscapes; and

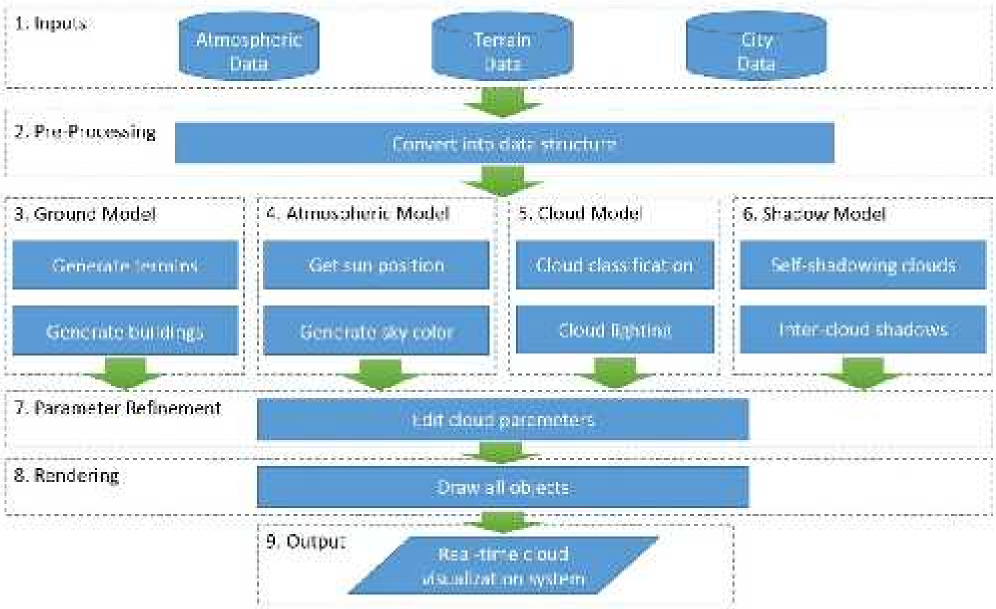

Fig.2. Proposed framework.

buildings are referred to as ground data. In this framework, different types of data formats can be used as the inputs. The important thing is to understand the specific file format thoroughly.

The proposed framework consists of seven consecutive steps that need to be followed. In pre-processing step, data conversion is done here. The input data collected earlier are then converted into generalized data structure whereby each specific data are stored separately based on our designed data representation. The converted data are then spread to four corresponding modules which we called them as "ground model", "atmospheric model", "cloud model", and "shadow model". These four modules are run in parallel during run-time. Next, the system allows the user to edit the cloud parameters in order to get the desired cloud appearances. Finally, all the data including sky color, cloud, terrain, and buildings are rendered in run-time. The next subsections will explain the steps in further detail.

3.2 Pre-Processing

In this paper, the pre-processing step is referred to as the data conversion process.This process is needed because the input data can be in different formats and form. Therefore, it is a need to standardize these inputs so that it can be easy for the system to retrievecertain data for the next processes.

Atmospheric datais transformed into two data structure: (i) cloud profile and (ii) sky and sun profile.The cloud profile is characterized in terms of shape, size, density, altitude, and formation. The second profile is featured based on sky color, sun position, single and multiple scattering.

Terrain data can be an image file format or digital elevation map (DEM).It is converted into three-dimensional (3D) Cartesian coordinate system which consists of X-, Y-, and Z-axis. X- and Z-axis are set to be the horizontal terrain dataand Y-axis is represented for terrain height values. In addition, the size of terrain data is stored into the terrain data structure.

City data are translated into 3D box representation which consists of width, depth, and height.

3.3 Ground Model

Ground model is designed to set up the landscape features of the 3D urban simulation system. This module is divided into two processes: (i) terrain generation and (ii) building generation.Although there are many types of objects can be inserted as landscape objects, we only choose terrain and building because they usually appearin urban simulation system.

For generating a terrain, the regular grid representation is exploited. This is due to the simple representation and easy to implement approach. By retrieving the terrain size (resolution) and height value from our designed data structure, each horizontal position (X-axis and Z-axis) can be calculated automatically.The distance between two adjacent terrain vertices is 10 pixels for easy computation.

For generating the building objects,the height and the lateral positions of the buildings are determined randomly or using real position data.

3.4 Atmospheric Model

Atmospheric model is a module that formulates the atmospheric profiles. It includes the determination of son position and sky color generation, which are the most prominent elements of the atmospheric region. We use Kolivand's model [12] as a base of our atmospheric model.

Sun position is determined based on specific location, date and time using coherent mathematical formation. This position is crucial in order to simulate the sky effects during daytime and day night.

Based on the sun position information, the sky color is generated and computed by using Perez sky diffuse model.The colors obtained from this approximated model are mapped onto sky dome in the form of a hemisphere for visualization and navigation purposes.

3.5 Cloud Model

Cloud model is a main important module in this paper. It has closely mutual connection with atmospheric model due to their interaction as a part of the atmospheric appearance.This model is decomposed of two activities: (i) cloud classification and (ii) cloud lighting.

Cloudsneed to be categorized due to complex nature and different representations of cloud types.In this paper, we classify the clouds into cumulus, cumulonimbus, stratus, and cirrus which are the most noticeable form of clouds. We propose a multiple representations of clouds depending on the cloud characteristicssuch as shape, size, density and formation. Each cloud is assigned with different representation that matches its features. The representations used in this research include the particle system, the image-based method, and the layered-based method.

For generating the cloud lighting, we apply the acceleration-based method. This selection are made in order to achieve high frame rate for real-time purpose.

3.6 Shadow Model

Shadow model is created for realizing the cloud effect to be more realistic.It can be done by imposing the self-shadowing clouds and the inter-cloud shadows into the cloud itself.By integrating the cloud model with shadow model, the resulting effects would be much resemble to the natural atmospheric phenomena.

Self-shadowing clouds are generated by computing the cloud particles considering the cloud lighting and the sun position. Inter-cloud shadowsare generated by first detecting the neighbors of the current clouds and then calculating the exact shadows after considering the lighting properties and scattering effects.

3.7 Parameter Refinement

Parameter refinement is provided for user to edit the cloud parameters such as the size, density, and form.User would be able to do the editing process by manipulating a simple user interface provided by the system.

3.8 Rendering

Rendering is the last step for realizing the real-time cloud visualization system. All the objects from ground, atmospheric, cloud and shadow models are rendered together in run-time.

For real-time purpose, scene managementmethod takes into account.This involves view-frustum culling and polygon reduction techniques in order to speed up the system performance.

4 Results

The real-time cloud visualization system has been developed to test the proposed framework.Fig. 3 illustrates the results obtained. USGS DEM data (Arizona region) was used as a terrain data. Cloud data are procedurally generated. City data were not used for the experiment in this paper.

Fig. 3. Screenshot of the system.

5 Conclusion

We have presented an extended framework for real-time atmospheric cloud visualization in urban simulation system. We proposed a generalized data structure so as to represent heterogeneous data types of the system. We also introduced the cloud model in order to investigate the interaction between clouds and sky color effects.

For future work, we are going to focus on enhancing the rendering method so that it can be used for broad range of virtual applications such as flight simulator, video games, edutainment-based applications, and so forth. Furthermore, we are planning to develop an intuitive user interface which is based on keystroke manipulation for user editing.

Acknowledgment

We thank to Dr. Hoshang Kolivand from UTM-IRDA Digital Media, Universiti Teknologi Malaysia for assisting and providing related research materials. This research was supported in part by a Research University Grant Scheme (RUG Flagship Research Group) from Universiti Teknologi Malaysia (Ref. No.: PY/2014/02465).

References

[1] F.K.Lutgens and E.J. Tarbuck,"The Atmosphere: An Introduction to Meteorology," 12th edition, USA, Prentice Hall (Pearson), 2013.

[2] R. Hufnagel, and M. Held,"A Survey of Cloud Lighting and Rendering Techniques,"*Proceedings of the 20th WSCG International Conference on Computer Graphics, Visualization and Computer Vision 2012 (WSCG'12)*,pp. 53-63, 2012.

[3] G. Yang, C. Yuan, S. Hao and X. Liang,"Modeling of Clouds from Weather Forecast Data,"*Proceedings of the IEEE Visual Analytics Science 2013 (IEEE VIS 2013)*, 2013.

[4] T.R. Kol,"Real-Time Cloud Rendering on the GPU," Master's thesis, Utrecht University, NETHERLANDS, 2013.

[5] S. Abdessamed, D. Noureddine and S. Amina, "Real-Time Realistic Illumination and Rendering of Cumulus

Clouds,"*International Journal of Multimedia & Its Applications (IJMA)*,vol. 5, no. 5, pp. 29-44, 2013.

[6] L. McLoughlin, "Realistic Natural Atmospheric Phenomena and Weather Effects for Interactive Virtual Environments,"PhD Dissertation, Bournemouth University, UK, 2012.

[7] W. Hailong and M. Fanjun, "Real-time Simulation of Dynamic Clouds Based On Cellular Automata,"*International Journal of Hybrid Information Technology*,vol 6, no. 5, pp. 171-182, 2013.

[8] O. Elek, T. Ritschel, A. Wilkieand H.P. Seidel, "Interactive Cloud Rendering using Temporally-Coherent Photon Mapping,"*Proceedings of Graphics Interface 2012 (GI '12)*,pp. 141-148, 2012.

[9] G. Wang, Z.Z. Jiand Z.X. Zhang, "Using Instance for Large Scale Volumetric Clouds Rendering in Real-Time,"*International Journal of Innovative Computing, Information and Control*,vol. 8, no. 6, pp. 4407-4420, 2012.

[10] Y. Dobashi, W. Iwasaki, A. Ono, T. Yamamoto, Y. Yueand T. Nishita,"An Inverse Problem Approach for Automatically Adjusting the Parameters for Rendering Clouds using Photographs,"*ACM Transactions on Graphics*,vol. 31, no. 6, Article 145, 2012.

[11] C.M. Yuand C.M. Wang, "An Effective Framework for Cloud Modeling, Rendering, and Morphing,"*Journal of Information Science and Engineering*,vol. 27, no. 3, pp. 891-913, 2011.

[12] H. Kolivand, "Shadow and Sky Color Rendering Technique in Augmented Reality Environments,"PhD Dissertation,Universiti Teknologi Malaysia, MALAYSIA, 2013.

Muhamad Najib Zamriis a PhD candidate from the Faculty of Computing, Universiti Teknologi Malaysia. He has received the Degree of Bachelor of Science (Computer) and Master of Science (Computer Science) from Universiti Teknologi Malaysia in 2003 and 2006 respectively. His research interests have broadened to include computer games, real-time visualization, computer animation, virtual reality, augmented reality, geographic information system, medical visualization image and video processing, and mobile application development.

Mohd Shahrizal Sunarobtained his PhD from National University of Malaysia in 2008. His major research fieldsare computer graphics and virtual environment. He received his MSc in Computer Graphics and Virtual Environment (2001) from University of Hull, United Kingdom and BSc degree in Computer Science majoring in Computer Graphics (1999) from Universiti Teknologi Malaysia. Currently, he is a Director of Media and Game Innovation Centre of Excellence (MaGIC-X) in Universiti Teknologi Malaysia. He leads several research projects including the driving simulator, augmented reality, natural interaction and creative content technology. He had published numerous articles in international as well as national journals, conference proceedings and technical papers including article in magazines. Dr. Shahrizal is an active professional member of ACM SIGGRAPH. He is also a member Malaysian Society of Mathematics and Science.