Usage, Usability, and Utility of 3D City Models, 03001 (2012)
DOI: 10.1051/3u3d/201203001

Web based hybrid volumetric visualisation of urban GIS data

Integration of 4D Temperature and Wind Fields with LoD-2 CityGML models

J. Congote[1,3,a], A. Moreno[1,b], L. Kabongo[1], J.-L. Pérez[2], R. San-José[2] and O. Ruiz[3]

[1]*Vicomtech-IK4 Research Centre, Spain*
[2]*Environmental Software and Modelling Group, Technical University of Madrid (UPM), Spain*
[3]*EAFIT University, Colombia*

Abstract. City models visualisation, buildings, structures and volumetric information, is an important task in Computer Graphics and Urban Planning. The different formats and data sources involved in the visualisation make the development of applications a big challenge. We present a homogeneous web visualisation framework using X3DOM and MEDX3DOM for the visualisation of these urban objects. We present an integration of different declarative data sources, enabling the utilization of advanced visualisation algorithms to render the models. It has been tested with a city model composed of buildings from the Madrid University Campus, some volumetric datasets coming from Air Quality Models and 2D layers wind datasets. Results show that the visualisation of all the urban models can be performed in real time on the Web. An HTML5 web interface is presented to the users, enabling real time modifications of visualisation parameters.

1. INTRODUCTION

Scientific visualisation of city scale models, such as geometry, terrain, volumetric data and others are a big challenge in Computer Graphics. These models are represented in several markup languages such as CityGML, X3D, COLLADA or DEM for geometry; NetCDF or Raw data for volumetric datasets; or special compressed as JPEG and GeoTIFF formats for images. Some of these formats are rarely used and only some specialized software can deal with them. The Web with the new standards as XML or HTML5 allows the inclusion of different models into a common framework, but the restrictions presented in the Web architecture difficult the implementation of the algorithms necessary for the correct visualisation of these models.

Volume rendering is a model of scientific visualisation. The methodology is used in several areas like medical imaging, geo-visualisation, engineering, and almost any other field that deals with n-Dimensional datasets. The method renders an image of a volume using the metaphor of passing light through semi-transparent objects. This allows the identification of internal structures, which are occluded by the external levels of the volume. The colour of the object is normally arbitrary and generated by a false colour model that is user assigned for each dataset and the region of interest of the volume.

Our contribution is the visualisation of air quality models, wind fields and buildings in a common framework using Declarative 3D technologies such as X3DOM and MEDX3DOM (see Figure 1). Modification over the frameworks are proposed to work with these datasets, including some brief

[a]e-mail: `jcongote@vicomtech.org`

[b]e-mail: `amoreno@vicomtech.org`

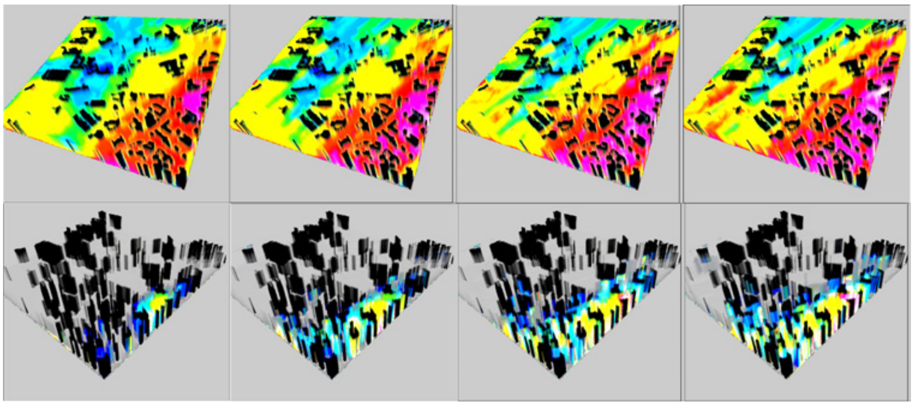

Figure 1. Two temporal series of the same dataset with different transfer function and window level configuration.

description of the volume rendering techniques utilised. Then, the followed methodology to load AQM datasets into a volume rendering web application and integrated with georeferenced geometry.

2. RELATED WORK

In Computer Graphics, ray-casting is a well known direct volume rendering technique. Traditionally, three dimensional objects have been created by using surface representations, drawing geometric primitives that create polygonal meshes [1]. In addition to the great amount of methodologies to visualise vector fields which have been developed in the last decades, the visualisation of volumes on the Web had been implemented recently by Congote et al. [2]. An up-to-date survey on geometric-based approaches is presented by [3]. However, in terms of the calculation of those trajectories for determined points in the field, the procedures usually compute for each point the integrals, and therefore the procedures are computationally expensive for highly dense data sets. Visualisation of flows in the web had been implemented by Aristizabal et al. [4].

There are several models to combine polygonal geometry and volume rendering. Some methods identify the intersection between the casted rays, the volume rendering process and the geometry [5]. Ray-casting is a flexible algorithm that allows the implementation of acceleration methods, such as *Empty Space Skipping* [6] or *Early Ray Termination*. Early ray termination is an optimization process that establishes certain limitations in the volume [7]. Novel techniques for hybrid visualisation on web had been proposed by Ginsburg et al. [8].

X3DOM presents a framework for integrating X3D nodes into HTML5 DOM content [9]. Complementing this iniciative, other alternatives like XML3D [10] have been developed, leading to a standardization process for X3D in the MedX3D volume rendering model [11, 12]. The MEDX3DOM proposal has been presented by Congote [13] to visualize volumetric datasets in a declarative model.

3. METHODOLOGY

MEDX3DOM implements the standard *MEDX3D* in *X3DOM*. The implementation is based on the generation of the nodes for two components: *Texturing3D* and *VolumeRendering*. *Texturing3D* nodeset define the tags to work with the information of 3D data, specific readers for file formats such as *DICOM*, *NRRD* and raw data are part of the standard. 3D texture data is normally stored in a **Texture3D** structure which is part of common 3D APIs like *OpenGL*. This structure is not available in WebGL and a mapping between a Texture3D and Texture2D entities was defined in order to overcome this limitation.

The file format is presented in the Figure 2, where a snippet of a HTML5 file displays a volume in a web page. A new style is proposed for the visualisation of vector fields, the *StreamLineFlowStyle* enables

```
<html>
<head> ... </head>
<body>
<h1>Volume Rendering</h1>
<X3D xmlns='http://www.web3d.org/specifications/x3d-namespace'
  showStat='true' showLog='true' width='500px' height='500px'>
  <Scene>
    <Background skyColor='0 0 0'/>
    <Viewpoint description='Default' zNear='0.0001' zFar='100'/>
    <Transform>
     <Shape>
         <Inline url="buildings.x3d"> </Inline>
     </Shape>
     <VolumeData id='volume' dimensions='4.0 4.0 4.0'>
        <ImageTexture containerField='voxels' url='aqm/aqm_frame0.png'/>
      <OpacityMapVolumeStyle>
       <ImageTexture url='aqm/transferFunction.png'/>
      </OpacityMapVolumeStyle>
     </VolumeData>
     <VolumeData id='volume' dimensions='4.0 4.0 4.0'>
        <ImageTexture containerField='voxels' url='aqm/aqm_wind_frame0.png'/>
      <StreamLineFlowStyle />
     </VolumeData>
    </Transform>
  </Scene>
</X3D>
</body>
</html>
```

Figure 2. HTML/X3DOM proposed file fragment to visualize the first frame of a AQM volumetric dataset using *MEDX3DOM*. The texture image is defined in atlas format (Figure 3).

the visualization of vector fields such as wind information by transforming the information to a geometry representation known as stream lines. These lines are modeled internally as geometrical entities for the MEDX3DOM extension. The visualisation of geometry and volumetric datasets in a common render pass is known as Hybrid Visualisation but other flow visualisation styles can be implemented with no generated geometry acting as proxy. For completeness, composition methods for visualisation of several volumes simultaneously should be implemented.

4. RESULTS

We have selected some dataset provided by the Madrid Technical University (UPM). In this section, we will describe the process of transforming the AQM dataset into the required images for the volume rendering engine, enhancing the significant differences of such datasets. The HTML interface for the web application will be described, including the hardware and software platform used for the tests.

4.1 Dataset description and loading stage

Turbulent urban flow simulations require Computational Fluid Dynamics models. In this research the datasets have been obtained from large scale numerical experiments to simulate turbulent fluxes for urban areas with the EULAG (UCAR, US) [14] CFD model, which was modified to include an energy balance equation to obtain the urban fluxes. In the Figure 3 we can see a sequence of 2D map of the Potential Temperature (K) simulated by the EULAG model.

The dataset represents the temperature and winds fields over a region of Madrid, which includes some buildings. The coverage of the data is around 1 km $\times$ 1 km., with a spatial resolution of 4m, giving a 250 $\times$ 250 regular grid. Also, the dataset covers 100 m. in altitude with the same spatial resolution,

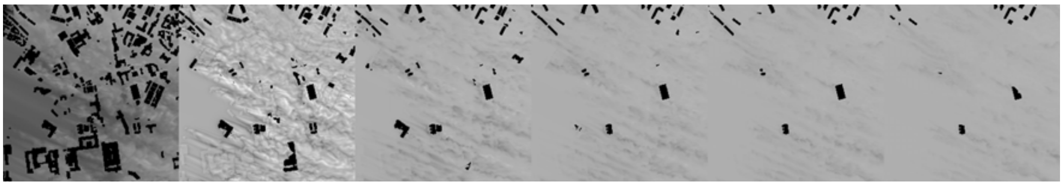

Figure 3. Grayscale texture atlas with the volume data for the AQM dataset.

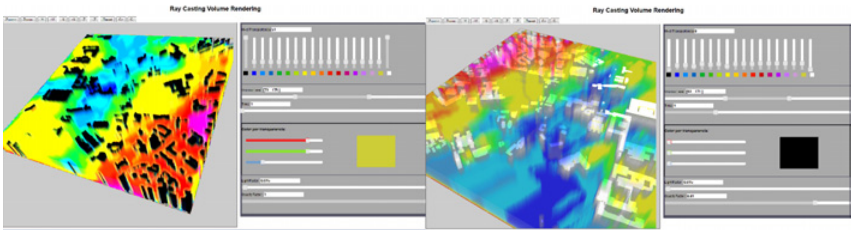

Figure 4. Different configurations of the HTML5 user interface and the achieved visual output.

resulting in a volumetric dataset of $250 \times 250 \times 25$ values for each variable. Temperature is a scalar value and wind is a vector field with two components horizontal (u) and vertical (v).

4.2 HTML Interface description

We implemented a HTML5 user interface using jQuery (see Figure 4) to interact with the AQM datasets, providing standard functionality to navigate the datasets at different levels. First, we provide mouse interaction in the HTML5 canvas through X3DOM custom navigation techniques. Also, some buttons in the upper part of the web page are used to navigate inside the volume (zooming and panning). The time navigation is provided through a slider, used to select the frame of the volume datasets (see Figures 1 and 5). The animation can be configured to be manual or automatic, iterating continously between the frames of the datasets.

The buildings model has been reconstructed from tagged SHP files, where each building corresponds to a 2D polygon, having their height specified as a feature in the DBF file. The reconstructed 3D model is equivalent to the LoD 2 proposed in the CityGML specification, although a X3D file was created to be later inlined in the X3D scene (see Figure 2).

The wind information, provided as u and v components for each voxel in the dataset, were processed with the methods presented by Aristizabal et al. [4]. The result is a set of geometric streamlines, converted to X3D file format. The final step involved the integration of such X3D model as an inline node into the X3D scene (see Figure 2).

The integration of the streamlines with the volume dataset has been performed in the same way as the buildings, as they are not conceptually different, but some precautions had to be taken into account. A full reconstruction of the complete vector field is so dense that the visualisation turns to be not usable and therefore, not practical. A simplification was performed to produce a smaller set of streamlines. Even with such reduction, we have reduced it even more to achieve better graphical results for the Figure 5.

5. CONCLUSIONS AND FUTURE WORK

This work has presented a Volume Rendering Web application to visualize 3D scalar and vector fields coming from AQM. An HTML5 interface has been provided to enable the users to configure the parameters of the visualisation and to navigate through the datasets (spatial and temporal navigation).

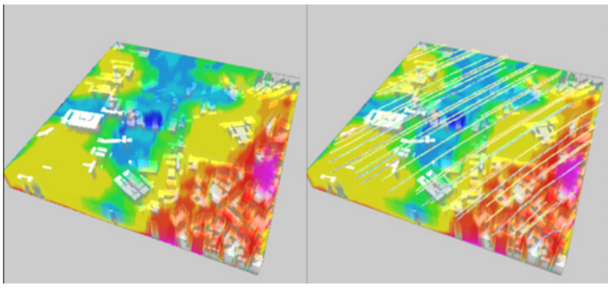

Figure 5. Hybrid visualisation of temperatures dataset (on the left, just the volume rendering and the buildings are shown) and wind information, reconstructed as colored geometric lines. For clarity purposes, only a small subset of wind flow lines have been added to the image (right).

For such operations, the key point is how users can deal with the heterogeneity of the multivariate scenarios. Transfer functions are a fundamental tool for the correct visualisation of such volumes. Some of the future work can be oriented to the generation of transfer functions by visual clues, known as Visual Volume Attention Maps (*VVAM*) [15]. Some preliminary results has been already researched and these methodologies are going to be tested in *MEDX3DOM*.

This work was supported by COST Action TU0801 "Semantic Enrichment of 3D City Models for Sustainable Urban Development", the Basque Government's ETORTEK research programme, the EAFIT University and the Colombian Council for Science and Technology (COLCIENCIAS). The authors thankfully acknowledge the computer resources, technical expertise and assistance provided by the Centro de Supercomputación y Visualización de Madrid (CESVIMA) and the Spanish Supercomputing Network. The authors also acknowledge the ESPAÑA VIRTUAL CENIT project funded by the Spanish Ministry of Science and Technology.

References

[1] M. Levoy, IEEE Comput. Graph. Appl. **8**, 29 (1988)

[2] J. Congote, A. Segura, L. Kabongo, A. Moreno, J. Posada, O. Ruiz, *Interactive visualization of volumetric data with WebGL in real-time*, in *Proceedings of the 16th International Conference on 3D Web Technology* (ACM, New York, NY, USA, 2011), Web3D '11, pp. 137–146, ISBN 978-1-4503-0774-1, `http://doi.acm.org/10.1145/2010425.2010449`

[3] T. McLoughlin, R. Laramee, R. Peikert, F. Post, M. Chen, *Over Two Decades of Integration-Based, Geometric Flow Visualization*, in *Computer Graphics Forum* (Wiley Online Library, 2010), Vol. 29-6, pp. 1807–1829

[4] M. Aristizabal, J. Congote, A. Segura, A. Moreno, H. Arriegui, O. Ruiz, *Hardware-accelerated Web Visualization of Vector Fields. Case Study in Oceanic Currents*, in *IVAPP-2012. International Conference on Computer Vision Theory and Applications*, edited by R.S.L. Paul Richard, Martin Kraus, J. Braz, INSTICC (SciTePress, Rome, Italy, 2012), pp. 759–763, ISBN 978-989-8565-02-0

[5] M.R.M. Silva, I.H. Manssour, C.M.D.S. Freitas, *Optimizing Combined Volume and Surface Data Ray Casting*, in *WSCG* (2000)

[6] J. Kruger, R. Westermann, *Acceleration Techniques for GPU-based Volume Rendering*, in *VIS '03: Proceedings of the 14th IEEE Visualization 2003 (VIS'03)* (IEEE Computer Society, Washington, DC, USA, 2003), p. 38, ISBN 0-7695-2030-8

[7] M. Hadwiger, P. Ljung, C.R. Salama, T. Ropinski, *Advanced illumination techniques for GPU-based volume raycasting*, in *ACM SIGGRAPH 2009 Courses* (ACM, 2009), pp. 1–166

[8] D. Ginsburg, S. Gerhard, J.E. Congote, R. Pienaar, Frontiers in Neuroinformatics (2011)

[9] J. Behr, P. Eschler, Y. Jung, M. Zöllner, *X3DOM: a DOM-based HTML5/X3D integration model*, in *Proceedings of the 14th International Conference on 3D Web Technology* (ACM, New York, NY, USA, 2009), Web3D '09, pp. 127–135, ISBN 978-1-60558-432-4, `http://doi.acm.org/10.1145/1559764.1559784`

[10] K. Sons, F. Klein, D. Rubinstein, S. Byelozyorov, P. Slusallek, *XML3D: interactive 3D graphics for the web*, in *Proceedings of the 15th International Conference on Web 3D Technology* (ACM, New York, NY, USA, 2010), Web3D '10, pp. 175–184, ISBN 978-1-4503-0209-8, `http://doi.acm.org/10.1145/1836049.1836076`

[11] N.W. John, M. Aratow, J. Couch, D. Evestedt, A.D. Hudson, N. Polys, R.F. Puk, A. Ray, K. Victor, Q. Wang, Studies In Health Technology And Informatics **132**, 189 (2008)

[12] N. Polys, A. Wood, P. Shinpaugh, Departmental Technical Report 1177, Virginia Tech, Advanced Research Computing (2011)

[13] J. Congote, *MEDX3DOM: MEDX3D for X3DOM*, in *To be pusblish in Proceedings of the 17th International Conference on 3D Web Technology* (ACM, New York, NY, USA, 2012), Web3D '12

[14] P.K. Smolarkiewicz, L.G. Margolin, *On forward-in-time differencing for fluids An Eulerian semi Lagrangian nonhydrostatic model for stratified flows.* (1997), Vol. 35, pp. 127–152

[15] A. Beristain, J. Congote, O. Ruiz, Studies in Health Technology and Informatics **173**, 53 (2012)