Visualisation of 3-D city model on the Internet

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Abstract
In conventional GIS (Geographical Information System) technology and applications, the third dimension in reality is either ignored or treated as an attribute. Based on this methodology, only terrain surface can be incorporated and managed. However, urban planning and environment management demand the incorporation of, and interaction with man-made objects on top of the terrain, such as buildings in a GIS environment. The interaction and the analysis afterwards can only be best performed through effective 3-D visualisation.

This article applies advanced Internet-based 3-D visualisation technologies in visualising 3-D city model. In order to reach an effective visualisation, buildings should first be modelled in geometry, topology and appearance. This is done by using VRML, an advanced 3-D graphics standard for Internet-based visualisation and virtual reality. Textures and background images are also added to reach a photo-realistic effect. Because of the platform independence of VRML standard, any Web browser supporting VRML can be used to render the created world through the Internet.

In this article, a brief conceptual introduction to the 3-D city model is made, followed by an overview of visualisation technologies, where VR on the Internet and its development tool VRML are addressed. Methodology for modelling buildings with VRML in terms of geometry, topology and appearance are described with detailed examples. A virtual city environment for the campus of University College Gavle, Sweden is created and can be manipulated through the Internet. Further development towards an Internet-based desktop VR environment for virtual city is prospected.

Keywords: 3-D city model, GIS, IT, visualisation

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1. Introduction

Geographical Information System (GIS) is nowadays widely applied in urban planning and environmental management, and is becoming essential in many quantitative analyses in these areas [1][5][6]. However, conventional GIS technique uses the 2-D map as a basis for managing 3-D geographical data and planning decision. In this methodology, the third dimension is either ignored or treated as an attribute. Though this is sufficient for describing physical terrain surface, man-made objects on top of the terrain in urban environment, such as buildings, traffic networks, i.e., a 3-D city, can not be managed. Advances in 3-D computer graphics and visualisation technologies are making it possible to model, manage and visualise the reality in a true 3-D mode.

The emerging of Internet technology and its spreading application are making the distribution, query, display and processing of geographical data possible through and on the Internet. The demand on visualising geographical data on the Internet environment is becoming higher. Although the geographical data can be visualised through the Internet via using different image formats (in 2-D), the interaction with the data and the stereoscopic effect are not possible without using advanced 3-D graphical tools running on the Internet.

This article applies advanced Internet-based 3-D visualisation technologies in visualising 3-D city model. A virtual city environment for the campus of University College Gävle, Sweden is created and can be manipulated through the Internet. The remainder of this article is organised as follows. Section 2 gives a brief conceptual introduction to the 3-D city model, followed by an overview of visualisation technologies in section 3, where VR (Virtual Reality) on the Internet and its development tool VRML (Virtual Reality Modelling Language) are addressed. Section 4 describes the methodology for modelling buildings with VRML in terms of geometry, topology and appearance. Sample results together with discussions are given in section 5, before this article is summarised in section 6.

2. 3-D city model

3-D city model is a three-dimensional digital description of an urban environment. Instead of conventional phenomena in physical geography depicted on topographical maps, such as terrain, vegetation area, water bodies, a 3-D city model is mainly composed of man-made objects, especially buildings, culture constructions, and traffic networks.

In order to establish a 3-D city model and manipulate it effectively, three fundamental issues are involved, namely constructing the models or modelling, managing the model based on database technologies so that spatial query is possible, and visualising the model [3][5][6]. Once the modelling process is completed, visualisation will be served as an interface for effective spatial query and analysis. This article will mainly discuss the modelling and visualisation issues.

A complete modelling should include geometric, topologic and thematic issues of the 3-D city. Geometry determines the size, shape and local or global location of any object in the 3-D city. The relative relationship among objects is described by
Thematic modelling assigns the geographic objects with attributes. Besides, for visualisation purpose, objects in a 3-D city model will be given colour, texture, image etc. to model their appearance.

3-D city model is used in diverse areas. Urban planning needs 3-D city model for city development. Telecommunication industry is in need of 3-D city model to best locate mobile transmission stations in urban environment. A realistic virtual 3-D city can help architects with designing new buildings in an interactive mode. Tourists may experience the virtual 3-D scene before the on-site visiting.

3. Visualisation technologies

As a subject of computer graphics, visualisation has dynamically been changing its technologies in the past decades. 3-D graphical display and processing capabilities are now as a standard function in desktop environment, such as on workstation and high-end PCs. Industrial graphic libraries, like Open GL and Open Inventor, have functions to perform complex graphic processing tasks, such as shading and hidden element removal, which would otherwise be done only with lengthy codes.

Recent advances in computer graphics lead to a demanding research and application subject - virtual reality (VR) [4], which presents a compelling concept: a natural and effective interaction between user and computer through visualisation. The display of a 3-D city model, integrated with possible interaction, is called virtual city. Through an effective interface one can walk-through the city, go shopping and even chat with other people who are visiting the virtual city at the same time [5]. Thematic information about the current visiting place is available by clicking the mouse button on any interesting area. Once the 3-D city model is geo-referenced, it will act as a 3-D map with accuracy and realism, shared and connected locally and globally.

The integration of Internet and visualisation technology makes it possible to render the 3-D city model over the Internet. For this purpose, the VRML is developed, which is now acknowledged as an industrial standard for VR development over the Internet. The created VRML file can then be rendered via a browser, such as Cosmo Player, to get three dimensional effect and perform man-machine interaction. The current (1997.12) version VRML 2.0, released in August 1996 and revised as VRML97 in April, 1997, is capable of handling animation and integrating multimedia, such as sound, movie and image [2].

4. Modelling buildings with VRML

4.1 Introduction to VRML

VRML uses a hierarchical scene graph to describe the 3-D world [2]. Entities in the scene graph are called nodes. Nodes store their data in fields. Nodes can contain other nodes and may be contained by more than one nodes. By organising the nodes and specifying their values, one can model the geometry and topology of the geographical data. Illumination and appearance of the world can be defined by corresponding nodes.
as well. In addition, image textures can be transformed and added on top of the geographical surface, such as terrain and urban area. Another distinct characteristic of VRML is LOD (Levels Of Detail). The world is first defined in different versions of detail. VRML browser will automatically choose and display the appropriate version of the world based on the distance from the viewer.

One can interact with the view so that any part of the world, as long as it is modelled by VRML, can be examined in any path at any orientation and at any scale. Textures can be pasted on the surface of the world as to obtain a photo-realistic result. In such a way one can experience the immersion into the geographical environment through navigating the virtual reality.

4.2 Modelling buildings

Modelling is to establish a description of the world based on a grammar which is interpretable for a visualisation system. It is the first step in visualisation. A comprehensive description should minimum include the geometry, topology and appearance of the world, illumination condition and viewer attitude.

Buildings should be modelled in geometry as well as in topology. In addition to giving the coordinates of vertices composing a building, their connectivity, namely how the faces are formed by which vertices, should also be specified. Following VRML codes are used to describe the building beside

```
Shape {
  geometry IndexedFaceSet {
    coord Coordinate {
      point [ 0 0 0
      0 0 0, 0 0 5, 0 2 0, 0 2 5, 0 3 2.5,
      15 0 5, 15 2 5, 15 3 2.5, 15 2 0, 15 0 0, ]
    }
    CoordIndex [1,2,3,-1,4,5,3,-1,2,6,7,4,-1,6,10,9,7,-1,7,9,8,-1,1,3,10,-1,3,5,8,9,-1,5,7,8,5,-1,1,10,6,2,-1]
  }
}
```

4.3 Modelling the appearance

The appearance will affect the final effect of visualisation. There are various optional parameters to choose in VRML, such as the location, direction and type of illumination, reflection properties of the world, types of colour and texture, scale etc. To simulate the reality and the circumstances one views the object, directional light from upper-left (north-west) is chosen. The surface of the world is often chosen as
having diffuse reflection. Initial attitude of viewing location is also carefully 
determined so that a proper initial view can be obtained.

5. Sample results and discussion

A VRML world for the campus of University College Gävle, Sweden is created. It 
includes buildings, trees and grasslands. The file is composed by text editor based on 
the building blueprint and aerial photographs. Sample results are given in following 
figures.

![a. Back-left view](image1.jpg) ![b. Back-right view](image2.jpg)
![c. Back bird-view](image3.jpg) ![d. Front bird-view](image4.jpg)

Geometric primitives, colours and textures are used in the creation of the virtual 
world. Cosmo Player and World View are chosen as browsers. By clicking interesting 
location on the view one can examine that spot at a larger scale, animate the scene via 
panoramic view and fly through the view.

There are optional parameters in the VRML for a programmer to choose proper 
appearance such as colour, intensity, illumination, initial view etc., however, they are 
hardly to determine with minor efforts. Creative author tool for this purpose is thus 
recommended to obtain optimal visualisation result.
6. Summary

3-D city model can be applied in, among others, urban planning, tele-communication, tourism, transportation, architecture and environment management. The integration of visualisation technologies and Internet enables the Internet-based visualisation. VRML offers powerful functions to model the 3-D city, which can then be rendered through a browser over the Internet. As for the future work, a VR system for integrating modelling, rendering and querying the 3-D city is expected to be developed in a desktop environment.

References

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