# Modeling of Buildings and Roads for Urban Applications based on 2D Digital Maps

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## Summary

Three-dimensional models of urban objects play an important role in the urban applications such as urban planning, environmental concerning, or urban disaster mitigations. While the modeling of urban objects is time consuming and storage costing. This paper presents solutions for this. Buildings with regular shapes and plane roofs are constructed into computer models by identifying of graphic elements from the digital maps of urban area to get building base plane and building heights. Buildings with irregular shapes and non-plane roofs are constructed into computer models by employment of a specific system developed by the authors. Road objects and topologies are constructed into computer models by employment of specific algorithms. The solutions presented in this paper has been used in the development of urban disaster mitigation system for Shantou, China.

## 1 Introduction

Three-dimensional (3D) models of urban objects are becoming significant due to the rapid development of urban areas, and the increasing applications in urban planning, environmental concerning, virtual reality, or urban disaster mitigations. 3D computer graphics and related technologies have been developed rapidly ( Whyte and Bouchlaghem et al. 2000). Technologies facilitating 3D graphics revolution are animation tools among which Maya (Alias Wavefront), 3D Studio (Discret), Lightwave 3D (New Tek) which enables designers, architects and engineers to build 3D models based on CAD data and to create highly realistic perspective rendering and fly-through movies. While the modeling costs for urban area in China are significantly expensive due to the big population and in turn the dense covering of buildings and roads. For instance, there are more than 1,000,000 peoples in the most middle size cities in China. In turn there are about 80,000 apartments and buildings, and other urban objects in those urban areas. More than 30 persons in one year are required to construct the models into the computer for more than 80,000 apartments and buildings by employment of current available software. In order to solve the significant problem for the modeling of a mass of buildings for the development of digital disaster reduction system, this paper presents a new method for the construction of a mass of buildings and road networks from the current available digital maps for urban area. The method presented in this paper has been used in the development of urban disaster mitigation system in Santou, China

## 2 Modeling of Buildings with Regular Shapes and Plane Roofs

In general, it is not necessary that every building model should be constructed in details in many urban applications, such as landscape analysis, wind simulation, or flood simulation for urban area ( Fishwick and Paul 2000). Moreover, the large amount of calculation is time consuming and storage costing. In this case, it is necessary to work out simple but adaptable building model for urban applications. Since two dimensional (2D) digital maps were drawn by AUTOCAD which are utilized popularly in the most cities in china, it is reasonable to construct 3D models of buildings directly from those 2D digital maps, in which the base plane outlines, the plane geometry dimensions and the number of floors of buildings can be identified from the 2D maps. This saves significantly the modeling costs for buildings with regular planes and elevations.

The solutions are as follows:

(1) Selection of file format for the storage of building models which can be read and edited by a text editor, and the texture images can be pasted onto the arbitrary surfaces. Furthermore, the completed models can be roamed in a virtual reality environment.

(2) Identification of graphic elements which specify the building base plane outlines (See Figure 1).

(3) Employment of snap functions for obtaining of correct positions of the nodes in the base planes of buildings.

(4) Identification of the attributes, such as the structure types of buildings and the number of stories, of the graphic elements from the texts displayed on the digital maps.

(5) Link of attributes to the associated building base plane.

(6) Transformation of the building base plane into 3D coordinate system in a city.

(7) Construction of theoretical 3D models for the buildings in urban area. The heights of the buildings are calculated from the attribute data: the number of stories and the building type. For instance, the story height is taken as 2.9m for the apartments.

(8) Construction of practical 3D models for the buildings in urban area in which each surface in the theoretical models are shrunk in a small value from the intersection edges, so that each surface in a practical building model is independent of the building model.

(9) The surfaces in a building model are numbered in a sequence. While the texture images associated to the surfaces are numbered in the same sequence. The texture images can then be pasted automatically onto the associated surfaces (See Fig.2).

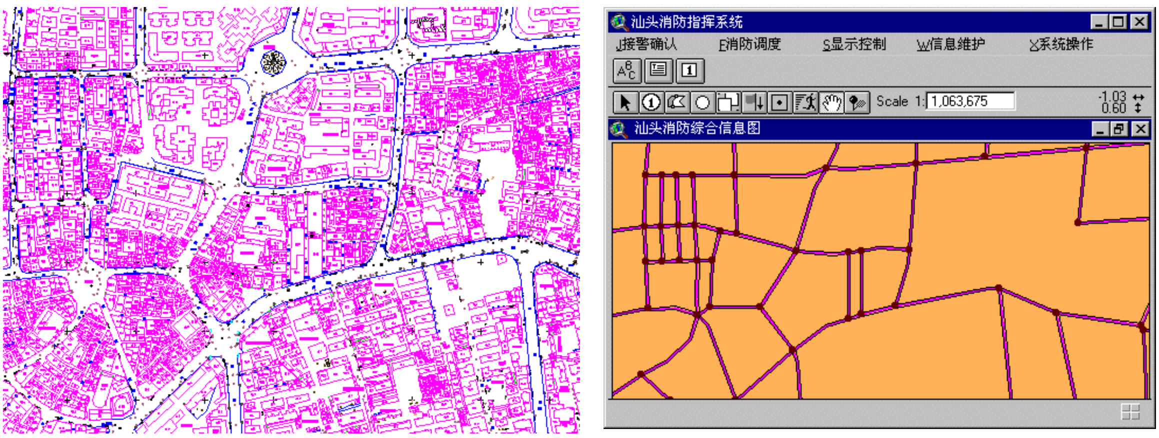


Fig. 1 A digital map of an urban area

For the buildings without texture images, a color table is employed to indicate the height of the buildings with regular shapes and plane roofs (See Figure 3).

Fig. 2 The texture images can be pasted automatically onto the the building

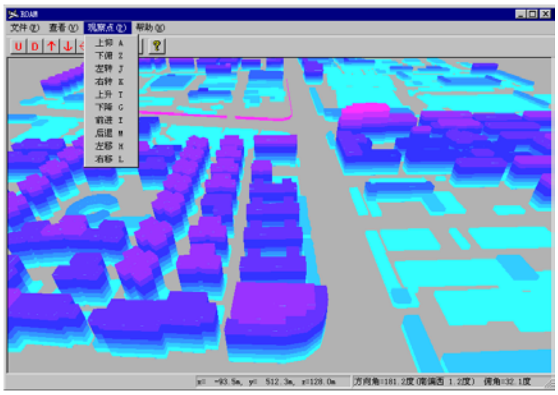

Fig. 3 Color is used to display the heights of the buildings

## 3 Modeling of Buildings with Irregular Shapes and non-Plane Roofs

For the buildings with irregular shapes and non-plane roofs, the method presented in section 2 is no longer suitable. A specific modeling system was developed by the authors for the constructing of irregular building models. The components in a building are specified in details as a 3D CAD model which can then be inserted into the urban model (See Fig.4). This is time consuming and storage costing. But in some urban applications, it is not necessary to specify the all components in a building. In this case, the modeling costs will be decreased. And the system also provides the expert clone functions, lofting functions and a component data base which save significantly the modeling costs.

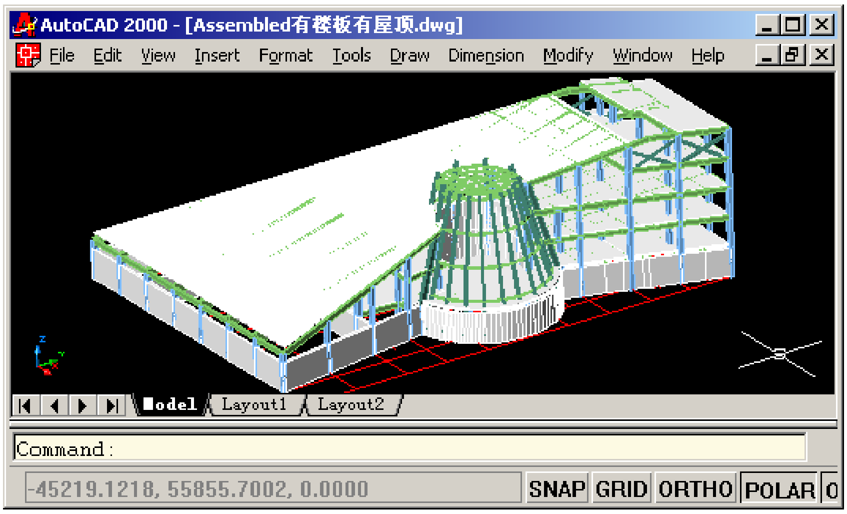


Fig. 4 A 3D CAD model which can be inserted into the urban model

A lofting function was developed by the authors(Aizhu Ren and Yang Wen 2002). The lofting function indicates that, an arbitrary organized component group can be placed along a specific path with variable scale, so that the modeling process is simplified. The lofting function (See Fig. 5) includes “uniform lofting” and “variable scale lofting” which speeds up the modeling process for irregular and complicated structures significantly.

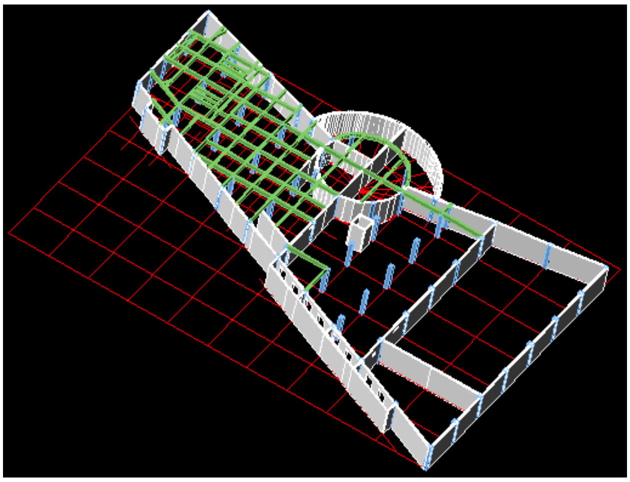

Fig.5 Lofting function to speed up modeling process

As soon as a 3D CAD model has been constructed, the model is inserted into the urban model according to the base plane outline of the building which is obtained automatically from the digital urban maps.

## 4 Automatic Modeling of Road System Based on Digital Urban Maps

In the urban applications such as transportation system planning or emergency response system planning, road topologies are required which can not be obtained directly from the digital maps. (Guoshuai and Aizhu 2003) In the constructing of road topologies, a segment of road is simplified as a line segment which is extracted from the digital maps of urban area. There are a start node and an end node in a road segment. For some nodes, they may be end nodes for certain road segments while at same time the start nodes for another road segments. Therefore, the nodes are specified as normal nodes, pseudo nodes or dangling nodes. A pseudo node is an intersection of the adjacent two road segments with the same road name (See Fig.6). A dangling node is a node which belongs only one road segment. When a node is neither a pseudo node nor a dangling node, it is then specified as a normal node.

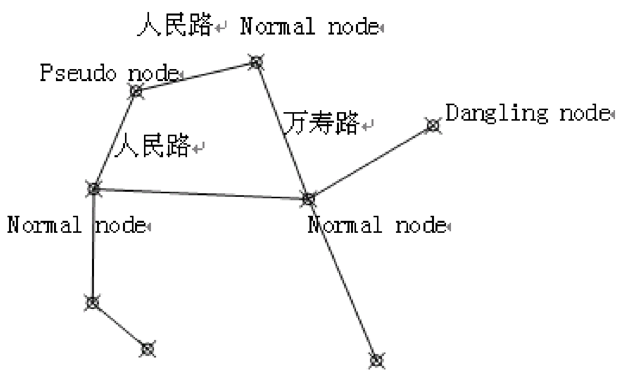


Fig.6 Pseudo nodes, dangling nodes and normal nodes

Line segments specified as road segments are digitized in interactive mode. There may be the following two problems:

(1) A specific node may be picked up more than once, i.e., one node may be specified as several nodes.

(2) Because of the picking error, a specified node may not at the exact point.

The solutions for the above two problems are as follows:

(1) Combine the nodes within a very small circle into one node which is the theoretical intersection of the adjacent line segments.

(2) Move the nodes with picking errors to the exact points. The coordinates of the exact points can be calculated according to certain rules.

Solutions to generate road topologies are as follows:

(1) Start from the first node in the road system up to the end node, and distinguish its node type to see if it is a normal node, a pseudo node or a dangling node.

(2) For the road segments which are composed of pseudo nodes (in Fig. 7), start from a pseudo node, and go along the adjacent line segment until a normal node or a dangling node is reached. The passed pseudo nodes should be marked.

(3) For the road segments which are composed of normal nodes or dangling nodes, start from a line segment, the start node and the end node can be recorded in sequence.

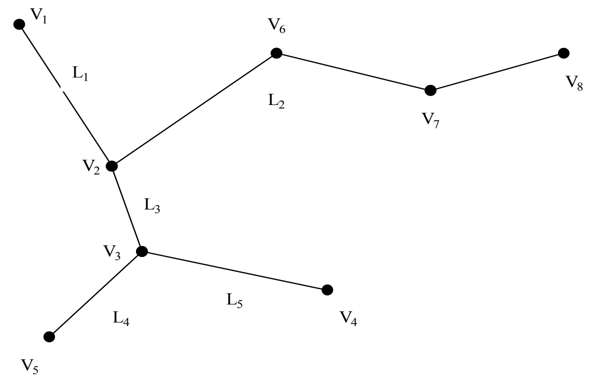


Fig. 7 Generation of road topologies

## 5 Conclusions

From the work presented in this paper, the authors have the following points to be presented:

(1) In the constructing of 3D models of urban objects for urban applications, the digital maps of a city can be used if the building base planes are drawn in correct way.

(2) Simplification of buildings with regular shapes and plane roofs is reasonable for the urban applications such as disaster mitigation systems for a city.

(3) Employment of the practical models can decrease the storage space significantly.

(4) In this paper, a specific system is employed to construct the model for the buildings with irregular shapes and non-plane roofs, this solutions should be further improved.

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