

Generalization of Three-Dimensional City Maps

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ABSTRACT

Three-Dimensional city map as the characteristic of visualization of the reality is becoming more and more important for 3D GIS applications. The paper is focused on the theoretical research for generalization of 3D city maps associated with simple examples: a) Levels of systems which displays different detail elements comparing to the area or scale from large scale 3D city maps to small one; b) Symbolization in both small and large scale 3D city maps; c) Refinement of features based on the functions and area characteristics. Those will provide an explorative approach to the 3D city map production in normalization and comparability to each other.

1. INTRODUCTION

Traditional maps displaying the geographic objects in 2D have been used thousands of years. Human beings had been not realized their dream of displaying the real world as it is in 3D and more until the invention of computer. The mapping industry has taken the revolutionary move of replacing 2D, traditional manual work by 3D and computer-driven processes. Generalization, the art and theory with which cartographer describes the world by selecting and drawing elements on the map, has been developed at high level in 2D mapping. Semi-automated and automated generalization theories have been developed and used in variable of mapmaking.

Generalization is the simplification of observable spatial variation to allow its representation on the map (Goodchild, 1991). It is an information-oriented process intended to universalize the content of a spatial database for what is of interest (Muller, 1991). Map generalization. One of the greatest challenges to cartographers working with digital systems has been automating the map generalization process (Robert, W 1999). Manual generalization, as the traditional means, is extremely subjective and time consuming. Cartographers draw a reduced map by hand. They eliminate unimportant features, simplify lines and boundaries, combine area features, and resolve conflicts as they draw. The result is, no doubt, operator-dependent. As geographical databases are constantly built, the request for automation of generalization capability for multi-purpose output is in demand. The field of generalization has extended to include 3D GIS applications. Noticeable efforts have been made by researchers and some GIS/mapping software vendors defined digital generalization problems and developed solutions. However, none of the existing 2D GIS/mapping systems has provided a set of tools that fully satisfies digital generalization needs. Aspects as automation of generalization are still open problems.

The age movement forward is carried by both the existing problems solved and new matters found. The future availability of automatic generalization tools has allowed us to realize our goal, namely the generalization for 3D city maps, will be the basic research in the field.

For the main topic of the paper, there are two niches in the research and market.

- In Research

Up to now, a set of complete theories of generalization in traditional map had been created and these theories have been transplanted to the digital map. Automation or semi-automation of generalization in digital map has been developed based on these basic theories even there are still some open problems needing to be found. 3D city map as the new baby generated with the computer development will go along the different way: combination the basic theories with automation. Generalization for 3D city map would be very valuable to support the realization of automation.

- In Market

Normalization for 3D city maps is the major question in data product. How to rule a 3D city map product is reasonable or not for its data, detail and selection of elements, etc.? A building, for instance, can be displayed as a symbol, a sketch with only the walls and the roof or the almost real one that has windows, doors, even the pattern of the wall. Which one is the better to the user and which one is fair to the investment. The research can be a reference as a standard to the 3D city map products designing and accepting according to the purpose.

2. METHODOLOGIES

Methodologies of generalization for 3D city maps are studied from four aspects in this paper.

2.1. Levels of Systems

In traditional 2D maps, we use scales to level the different levels of systems. We normalize the features (size, symbol, etc.) for each scale. 3D city maps, however, has the different characteristics with 2D map. According to the scale and the size of the features (buildings), three sublevels are used to display them.

City Model (CM): Presentation of the buildings as block with or without shape of roofs, texture, spacing between buildings and functions, mainly street texturing and greens. The scale is about from 1:10,000 to 1:5,000.

Detail City Model (DCM): The middle sublevel presents different buildings using the four kinds of symbols. Some of the main buildings are separated alone from the block. The scale is from 1:5,000 to 1:2,000.

Block Model (BM): The features are presented as alone as they are according to the applied purpose of city maps. The main buildings (presenting as Pictographic symbol) contain additional presentation of building facades and further single objects. The facilities of the street are displayed completely. The scale is from 1:2,000 to 1:500.

Detail Block Model (DBM): In this most detail class the area is defined in special range such as a park, a temple or a round of buildings and the buildings are generated with a

high level of realism. These objects are supplied with a photo-texture. The scale is from 1:500 and 1:50.

2.2. Symbolization

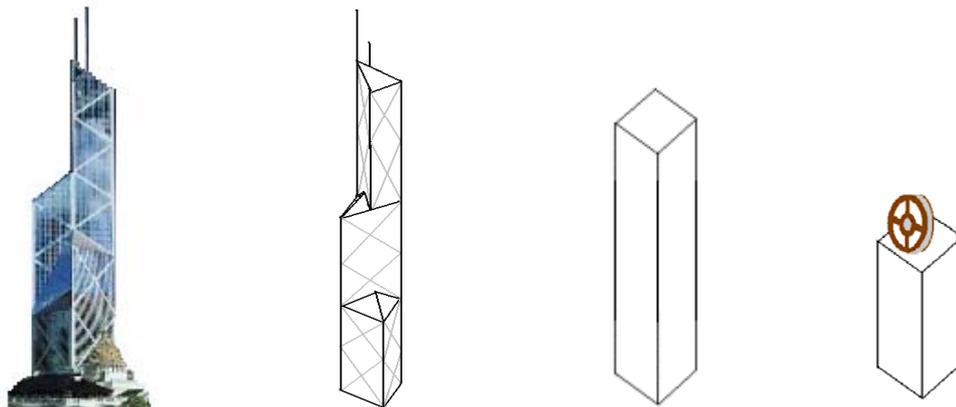
Symbolization is concerned with choosing the symbols, line weights, marks, colors, etc. used to present feature information. This component relates directly to aspects of production, and focuses on the manifestation of the graphic representation.

City map itself is a collection of symbols to display the multi-dimension world. There are some kinds of conditions we use symbol to show the feature, such as:

- The feature is so small that be displayed as symbol.
- The feature is too small to be displayed as real dimension but it is very important for the purpose of the city map, we use a symbol to show it on a city map.
- We want to emphasis or display feature such as gas station in a transportation map, but unnecessary to separate the building to around environment, for example, we do not need separate a restaurant from a round of buildings.

There are 3+1 kinds of symbols using in GIS:

- **Pictographic symbol** describes the enlarged outside volume model of the object and encoding on geographic and space phenomena.
- **Abstract symbol** is the sketch chosen have a “natural”(or at least readily learned) relation to the objects and categories being symbolized.
- **Authentic symbol** is the conceptual constrains symbol that operate directly upon the graphic depiction to maintain a natural semiotic relation between the manifest symbol and the visual expectations of the GIS user.
- **Collecting symbol** is the collection of abstract symbol and authentic symbol, and that shows the special object.



2.3. Refinement

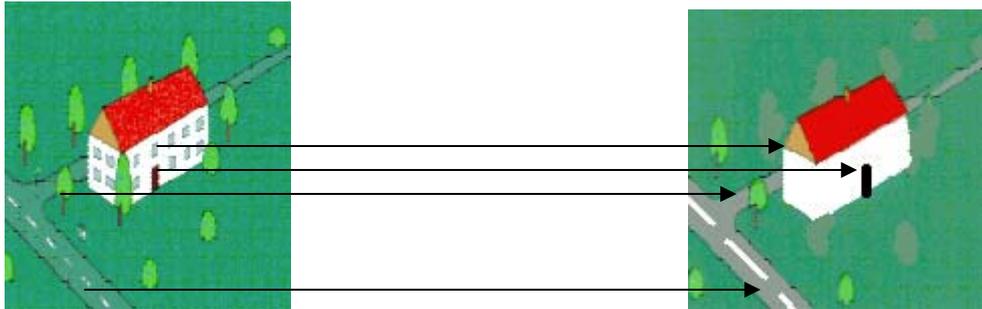
- **Selection and Elimination**

Selecting certain features or its elements into the final 3D city maps. What to be selected depends on the target scale and purpose, for instance, visual clarity. The selected features will participate further generalization operations. In the phase, we normally identify which feature will be selected and which class of one kind of feature will be selected roughly. In another

hand, selectively eliminating features that are insignificant or impossible to be presented in a city map. These features or their details must be eliminated. The progress is the opposite one to the selection. The left features must to be displayed as probably as detail depending on the purpose and scale.

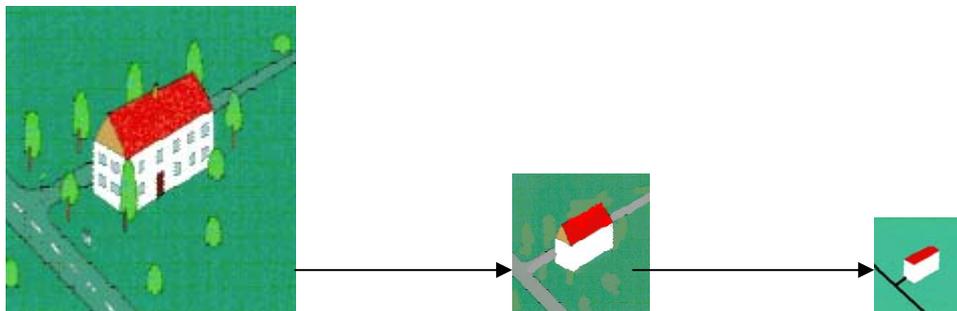
Purpose

Any city map is used for some thematic fields or purposes. In the case, some features are very important to the users and the others are not. For example, a city map is used for transportation and then the roads, even pedestrians are important to be displayed in a city map. Oppositely, Some trees, windows, chimney, even the roof of the buildings are unimportant to be display in a city map.



Scale

When the scale changes we can not present all the features or their details that are necessary (scale change smaller) or oppositely. In the case, we have to eliminate some features or their detail that are not only unnecessary but also very important.

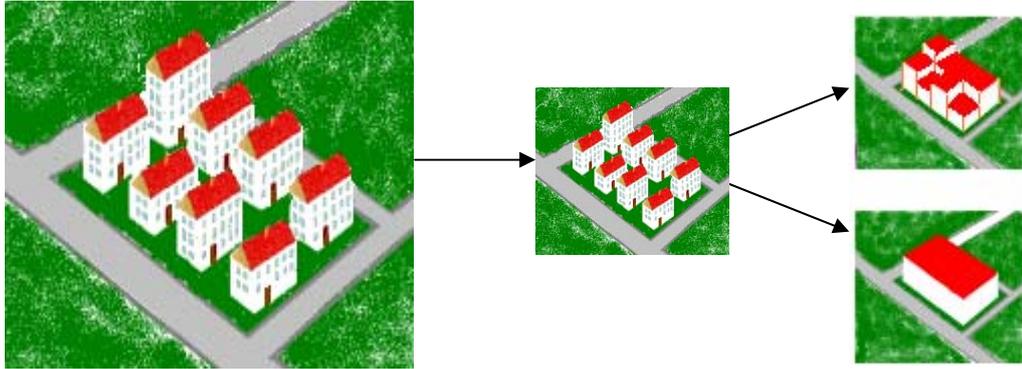


- **Bunching and Injoining**

Bunching the features with the same characteristic and close proximity each other together, Displaying as a feature that presents the volume, fill up the spaces among them and average (e.g. highest or lowest) high.

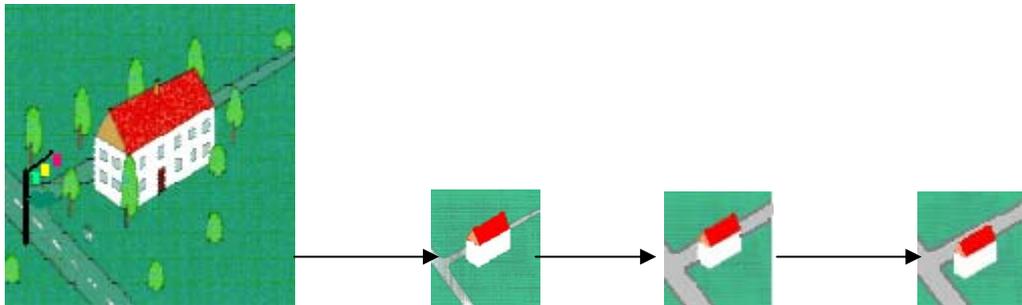
There are two main reasons we use bunching for generalization:

- The features are too small to be display as the real shape. We use bunching to show that there are features in the space and tell the reader the extent of the space.
- We do not need to display these features one by one.



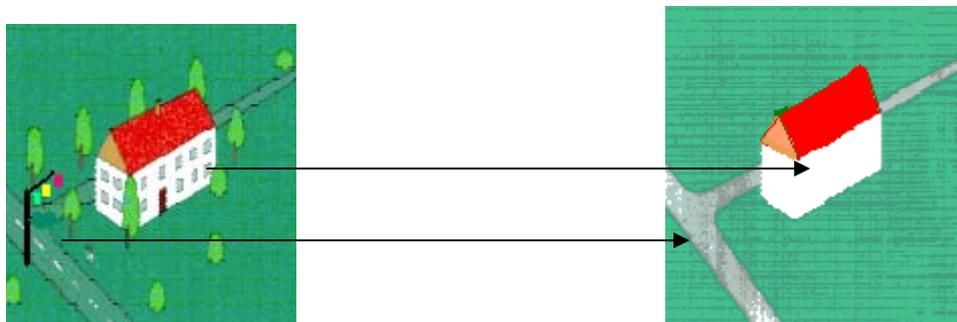
- **Displacement**

Detecting feature conflicts, removing the less important conflicting features, adjusting feature extents to satisfy the threshold of separation and keeping the relationship. In the example, the building has been removed to maintain the relationship between the road and the building when the road was exaggerated.



- **Simplification**

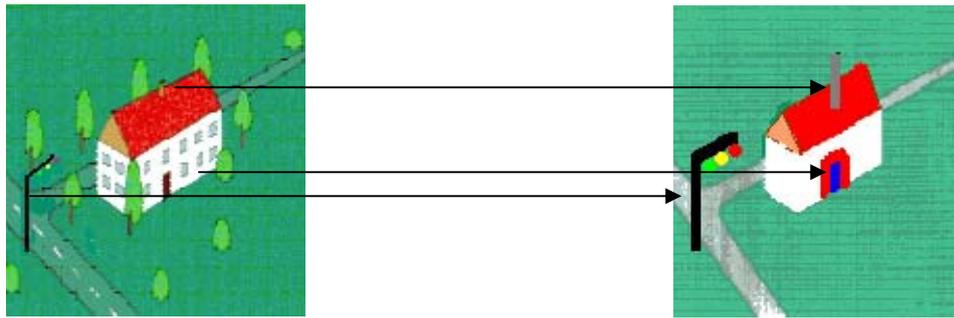
In one hand, we can not display very detail about the feature as the scale changing smaller. In the other hand, it is unnecessary to display so detail for certain purpose. The third, a city map itself is a scientific and artistic work, we must follow not only the reality but also inputting artistic elements when we display it using the GIS way. We must keep its position, shape, etc. correctly as possible as we can. At the same time, we try to make the work beautiful and easily understanding without destroying its essential shape.



- **Exaggeration**

Increasing the spatial extent of a feature representation for the purpose of emphasis and legibility; for example, enlarging the high of a chimney and the size of the door of the

example building, which are the main parts of the building. The chimney will be the obvious object for drivers, the traffic light is very important object for the transportation system.



3. CONCLUSIONS

In the study, the basic algorithms were given assistant with simply examples. It is the first step for the future research, and also these algorithms need testing under more conditions.

To enhance 3D GIS software solutions such that the users can produce multiple-scale and multiple-subject output more efficiently, both the semi-automation or automation digital 3D spatial data generalization and semi-automated and automated 3D data capture in real time must be addressed. Urban facilities (on ground, under ground, in spatial) generalization capability into the 3D GIS product environment will be a challenging and main task in general usage. Special usage such as in building structure project design in 3D or 4D will be widely used in the future.

What does the future of generalization for 3D city map hold?

- Short-term Plans
 - Improving the algorithms of 3D generalization of city maps in more examples and conditions;
 - Suitable normalization for 3D city map products;
 - Comprehensive library of standard 3D symbols and possibility to create new ones;
 - Comprehensive library of standard 3D text placement algorithms.
- Long-term Goals:
 - Creation of user-defined 3D GIS with arbitrary parameters;
 - Semi-automated or automated generalization.

REFERENCES

- [1]. D.R.FRASER TAYLOR, 1991, Geographic Information System. The Microcomputer and Modern Cartography. Pergamon Press Plc. Pp 136-150.
- [2]. F. MICHAEL WORBOYS, Introduction in GIS 1, 1994 Taylor & Francis Ltd. pp 54-63.
- [3]. X.Y.CHEN, 1998, 3D GIS: The State of the Art and Applications in Japan. Journal of Surveying, Japan. Vol.47, No.1, pp.17-24.
- [4]. X.Y.CHEN, S. Murai, 1998 , Integration of Image Analysis and GIS for 3D City Modeling. SPRS Com.IV Symposium, Stuttgart, Germany