GENERALIZATION FOR 3D GIS

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ABSTRACT

The development of Geographic Information System (GIS) has inputted new vitality for the map that has been used thousands of years as the widespread and common tool for academic and reference object. 3D GIS as the characteristic of visualization of the reality is more and more becoming an indispensable component of future's GIS thought automated generalization in 2D digital map/GIS is still the outstanding question. The future availability of automatic generalization tools has allowed us to realize our goal, namely the generalization in 3D GIS, will be the basic research in the field. The paper which is focused on the theoretical research for 3D GIS based on the characteristics of 3D GIS explores several different ways for generalization associated with simple examples: a) Levels of systems which displays different detail elements comparing to the area or scale from large scale 3D GIS to small one; b) Symbolization in both small and large scale 3D GIS, including the design of symbol; c) Refinement such as selection, aggregation and simplification etc. of features are used to generalize features according to the functions and area characteristics. Those will provide an explorative approach to the 3D GIS production in normalization and comparability to each other. Some basic algorithms and operators have been expanded from 2D GIS to 3D GIS.

INTRODUCTION

Traditional maps displaying the Earth 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 (It does not overstate that a cartographer is an artist). Semi-automated and automated generalization theories have been developed and used in variable of mapmaking.

Geographic Information System (GIS) that serves long-term, multiple-purpose applications has become a hot industry in the recent decades. GIS is as a tool that captures, stores, manages, manipulates, analyzes, models and displays information with respect to geographic space. It is the rapidly growing information technology area at today's information age.

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). Relating observation of geographic space to models of geographic phenomena converts data to knowledge. Once a model of the phenomenon has been developed, it is possible to generalize that model. Cartographic generalization may be considered to be an exercise in applied geography (Pannekoek 1962); for example, generalization of contours, coastlines, streams, and topographic surfaces should incorporate knowledge of landforms and geomorphic process. Furthermore, the cartographic character of many features is scale-dependent (Buttenfield 1989), and the use of a single database to support mapping at a variety of scale presents many research challenged (Beard 1987). Generalization in 3D GIS will become an indispensable component of future's GIS. Whatever the task, compiling data in different sources into a master database to compose an output from it for data compression, analysis, or representation, generalization is most likely involved.

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 GIS, 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 new, a set of complete theories of generalization in traditional map had been created and these theories have been transplanted to the digital map and 2D GIS. Automation or semi-automation of generalization in digital map and 2D GIS has being developed based on these basic theories even there are still some open problems needing to be found. 3D GIS as the new baby generated with the computer development will go along the different way: combination the basic theories with automation. Generalization for 3D GIS would be very valuable to support the realization of automation.

- In Market

Normalization not only for digital map or 2D GIS but also for 3D GIS is the major question in data product. How to rule a 3D GIS 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 root 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

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reference as a standard to the 3D GIS products designing and accepting according to the purpose.

METHODOLOGIES

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

1. Levels of Systems

In traditional 2D maps, also digital map/GIS, we use scales to level the different levels of systems. We normalize the features (size, symbol, etc.) for each scale. 3D GIS, however, has the different characteristics with 2D map/GIS. In the first level there are four levels normally have effects on the single steps of the project realization and have to be heeded from the data capture to the modeling up to the visualization of the feature. The four levels are distinguished as **global, area, town, feature.**

- **Global**
  The lowest step of the detail classes is used to display the large distribution from a large area to the whole world. In this case, all the elements such as cities are show as a symbol (symbolization of the features). Normally, the function of this level is used to give the index to the system. The feature is almost scaled down less than 1:100,000 and the elements of the system are made up mainly of cities and roads and other thematic features.

- **Area**
  The second level is often to describe an area including one or several first or second district of a country. At this level, a few thematic elements are emphasized and the features in the cities are more generalized to leave the main streets, main buildings and thematic features. The features are scaled from 1: 100,000 to 1:25.000.

- **Town**
  The more frequent useful level is used in the scale among 1:10,000 to 1:1,000. The level system is more detail to show the basic elements in a city, especially the buildings. Some basic characteristics are necessary such as geometrical shapes were added to the buildings that were reconstructed from ground plan and building height. In addition to this it is possible to cover the single facades with a texture. An additional presentation of streets facilities and objects of the greens are possible.

According to the scale and the size of the features (buildings), three sublevels are used to display them.

Block Model (BM): 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.

Mixed Block Model (MBM): 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.

Detail Block Model (DBM): The features are presented as alone as they are according to the applied purpose of the GIS. 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.

- **Feature**
  In this most detail class the area is defined in special rang such as a park, a temple or a round of buildings and the buildings are generated with a high level of realism. Additionally, in comparison with **Town level**, more detailed street objects (e.g. traffic-lights) and a more detail objects of the greens (e.g. detail vegetation objects) are presented. These objects are supplied with a photo-texture. Due to large data quantities only a project related visualization of small areas in this detail class is realized. The scale area for these models lays between the 1:500 and 1:50.

Besides the defined levels above, a mixture of those is possible, depending on the description of the task. Within a certain frame, a flexible design of the respective detail class is possible.

2. Symbolization

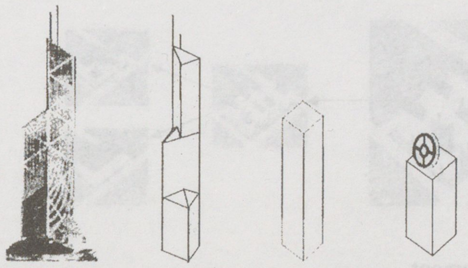
Symbolization is concerned with choosing the symbols, line weights, marks, colors, etc. used to present feature information. This component relates directly to aspects of production, and focuses on the manifestation of the graphic representation.

GIS 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 GIS, we use a symbol to show it in the GIS.
- We want to emphasis or display feature such as gas station in the transportation GIS, 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.



3. Refinement

- **Selection and Elimination**

Selecting certain features or its elements into the final 3D GIS. 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

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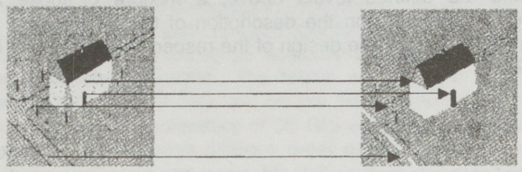
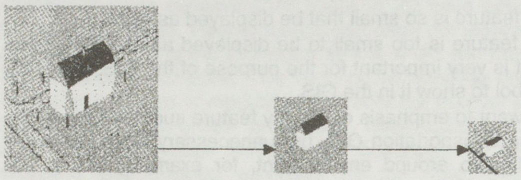
impossible to be presented in the GIS. These features or their details must be eliminated. The progress is the opposite one to the selection. The left features must to be displayed as probably as detail depending on the purpose and scale.

Purpose
Any GIS 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 GIS is used for transportation and then the roads, even pedestrians are important to be displayed in the GIS. Oppositely, Some trees, windows, chimney, even the roof of the buildings are unimportant to be display in the GIS.



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.

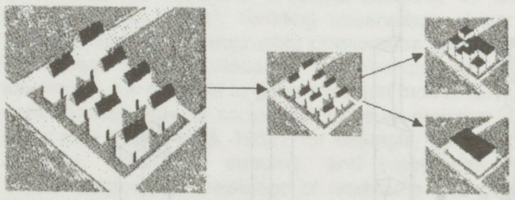


- **Bunching and Injoining**

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.

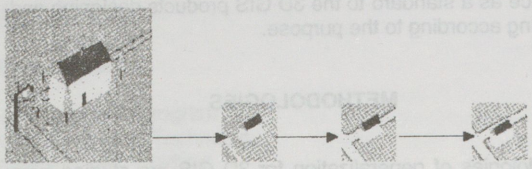
There are two main reasons we use bunching for generalization:

- 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.



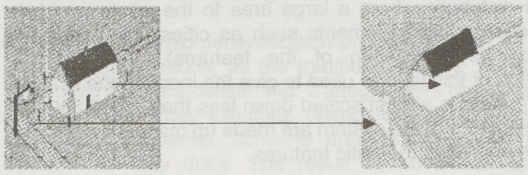
- **Displacement**

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 read was exaggerated.



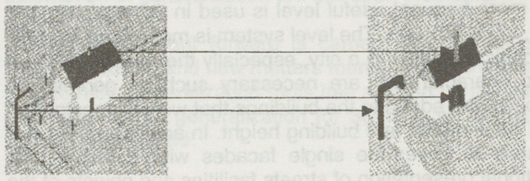
- **Simplification**

In one word, 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, 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, GIS 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.



CONCLUSION AND FUTURE

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 GIS 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 GIS hold?

- <u>Short-term Plans</u>
  - ➢ Improving the algorithms of 3D GIS generalization in more examples and conditions;
  - ➢ Suitable normalization for 3D GIS products;
  - ➢ Comprehensive library of standard 3D symbols and possibility to create new ones;

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- Comprehensive library of standard 3D text placement algorithms.

- <u>Long-term Goals:</u>
- Creation of user-defined 3D GIS with arbitrary parameters;
- Semi-automated or automated generalization.

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