A Prototype of Three Dimensional Operations for GIS†

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Abstract

According to the development of computer technology, especially in 3D graphics and visualization, the interest for 3D GIS has been increasing. Several commercial GIS softwares are ready to provide 3D function in their traditional 2D GIS. However, most of these systems are focused on visualization of 3D objects and supports few analysis functions.

Therefore in this paper, we design not only a spatial operation processor which can support spatial analysis functions as well as 3D visualization, but also implement a prototype to operate them. In order to support interoperability between the existing models, the proposed spatial operation processor supports the 3D spatial operations based on 3D geometry object model which is designed to extend 2D geometry model of OGIS consortium, and supports index based on R*-Tree. The proposed spatial operation processor can be applied in 3D GIS to support 3D analysis functions.

Key Words: 3D GIS, 3D Spatial Operation, Operation Processor, Topological Operation

1. Introduction

Recently as the necessity for 3D representation of spatial objects has been increasing in application fields such as urban planning, visibility analysis, urban engineering, and communication design, many 3D spatial data models have been developing to represent 3D spatial objects [2,5,6,7,9].

In [6], LC(Layer Combined) model which can represent each layers of building is proposed and a prototype based the model is implemented. Although they support metric functions (e.g. distance) as well as 3D visualization, they do not consider spatial topological operations between 3D spatial objects. Also in [2] 3D spatial objects model, which is designed to extend 2D geometry model of OGIS consortium, is proposed. They define various 3D spatial relationships, but they do not consider 3D visualization functions and methods, which process operations efficiently. As described the above, most of proposed models and prototypes based the models are mainly focused on 3D visualization, because of the complexity of spatial relational operations between 3D spatial objects. Those proposed models and prototypes have the problem which do not support 3D analysis functions.

Therefore in this paper, we designed not only 3D spatial operation processor supporting various spatial analysis functions as well as 3D visualization, but also implemented a prototype to operate them. The proposed

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spatial operation processor can be applied in 3D GIS which needs various spatial analysis functions between 3D spatial objects.

In order to describe the remained part, we discuss the related work regarding 3D spatial models and 3D spatial operations in section 2. In section 3 we describe the architecture of the proposed 3D spatial operation processor. Then the implementation of a prototype is described in section 4. Finally in section 5 we conclude our work and discuss future works.

2. Related works

2.1 3D spatial data models

Many 3D modeling techniques for representing 3D objects have been developed. Due to different computer-internal representations and application ranges 3D computer models, they can be distinguished into three types: wireframes, surface models and solid models. Solid models are used to create generally applicable models, not 3D models, which are only suitable for special applications, because wireframes and surface models are unapt for modeling bodies [6]. Solid models are able to answer various geometrical questions of a user using the computational geometry algorithms, and to be represented by cell models, CSG(Constructive Solid Geometry) models, and B-Rep(Boundary Representation) models depending on their character.

In a cell model, 3D objects are represented by voxels of uniform size, the three-dimensional analogue to the pixel. The voxels are arranged in a regular spatial lattice and are computer-internally represented by the coordinates of the center of the cell. It is suitable for the calculation of volumes and Boolean operations as well as visualization. On the other hand, the geometrical items such as point, edge and surface can be calculated only inaccurately since they cannot be stored explicitly.

3D objects are represented by space-primitives in a CSG model. Space-primitives are basic geometrical elements such as cuboids, cones, spheres, cylinders etc. CSG models contain neither edges nor surfaces of the modeled body in an explicit form and are therefore not directly usable for analysis. The example is edges, which are defined by an intersection of the surfaces of two space primitives. The edges will not be stored in a CSG model. They must be computed whenever they are required.

B-Rep models are frequently used a form of the three-dimensional modeling. They use three-dimensional polygon surfaces, in order to define the boundaries of an object. The surface modeling is a simple and generally accepted method for the representation of three-dimensional objects. The B-Rep model consists of four object types: nodes, edges, surfaces and bodies. Bodies are defined by surfaces, surfaces by edges, edges by nodes and nodes finally consist of three coordinates. The B-Rep is thus a logical extension of the implemented node-edge-surface data model in the most vector GIS.

2.2 3D spatial operations

Topological relations between 2D spatial objects, such as disjoint, meet, overlap, inside and contains, are well defined by 9-intersection method that is based upon the comparison of the nine intersections between the interiors, boundaries, and exteriors of the two objects. They also are defined by DE-9IM(Dimensional Extended-9IM) and CBM (Calculus Based Method) [1,4,5].

In order to represent topological relations between 3D spatial objects, 3DE-9IM (Three Dimensional Extended –9IM) is defined in [2]. The method, which is applicable for 3D spatial objects, is based on the comparison of the nine intersections between the interiors, boundaries, and exteriors of the two 3D objects such as point, line, area and solid. The operators defined in [2], such as Disjoint3D, Touches3D, Crosses3D, Within3D, Overlaps3D, Contains3D, Intersects3D, are based on a 3D geometry objects model extending a 2D geometry objects model of OGIS.

In this paper in order to support interoperability between the existing models, we design and implement a 3D spatial operation processor based the model proposed in [2].

3. The architecture of 3D spatial operation processor

In order to process 3D spatial operation efficiently, we designed operation processor as shown in Figure 1.

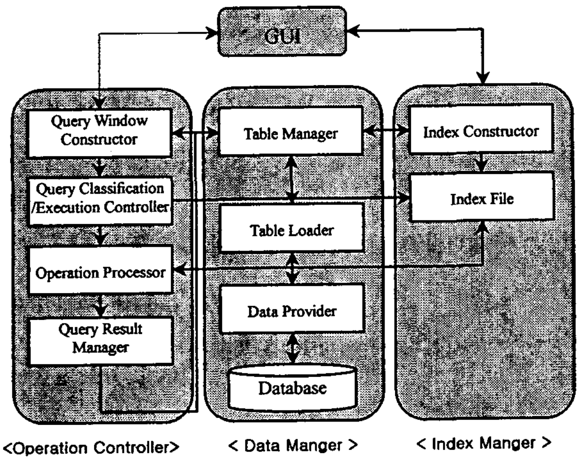

Figure 1. The architecture of operation processor

The operation processor consists of three main parts; operation controller, data manager, index manager. Their functions are following that:

■ Operation controller

The Operation controller consists of a query window constructor, a query classification/execution controller, an operation processor, and a query result manager. We describe the process in brief. User makes an area of a query window at first, and then a query window constructor makes an MBB(Minimal Bounding Box) for the area of a query window. And then a query classification/execution controller decide an operation type and whether index exists or not, and then an operation processor process the operation. A query result manager provides query result as a text or visualization form for user.

■ Data manager

The data manager consists of a table manager, a table loader and a data provider. User connects the database using the data provider at first, and then the table loader load the tables, which are registered in database into a table list. The table manager decides whether the loaded tables join on an operation. If they join on one, it informs on whether must create index for the tables to index manager.

■ Index manager

The index manger consists of an index constructor and an index file that produced from the index constructor. The index constructor creates an index file for the table, which decided by the table manger.

4. Implementation of a prototype

The 3D GIS is required in many application fields such as urban planning, virtual tourist guide, underground facility management. In this paper we used buildings located in Jung-gu, Seoul, Korea to carry out the experiment. The test data of total 10,484 is stored in 9 kinds of table such as a commercial, an education, an emergency, an entertain, a house, a lodge, a religion, a welfare, and an etc table. The relational database structure for table is shown in Table 1, and each table has the same structure. Geometry values of each table are used WKB(well-known binary) representation that provides a portable representation of a geometry value as a contiguous stream of bytes. We implemented a prototype by use of the OpenGL Graphic Library, Visual C++ 6.0 and MS SQL Server.

Table 1. The structure of building table

Column	Type	Remarks
ID	Int	Object ID
SIZE	Int	Geometry size of object
X1	Float	Min x coord' Of MBB

Y1	Float	Min y coord' Of MBB
Z1	Float	Min z coord' Of MBB
X2	Float	Max x coord' Of MBB
Y2	Float	Max y coord' Of MBB
Z2	Float	Max z coord' Of MBB
GEOMETRY	Text	Geometry info of object
NAME	Varchar	Object name
...	...	...

We describe the process of INTERSECT3D operation as an example query that involves the previously defined functions in [2].

(Example) Query: Search all commercial buildings intersected with query window area (Q). This query is expressed in SQL as follows:

Select ID, GEOMETRY From Commercial c WHERE INTERSECT3D (c.GEOMETRY, Q)

If given a query window on GUI, the query window should be constructed as MBB. If it does not constructed as MBB, no operations are possible. So in order to construct MBB, a user should input Z coordinate value, since a query window rectangle that is captured by mouse on 2D screen does not have 3D coordinate values. The example of query window is shown in Figure 2.

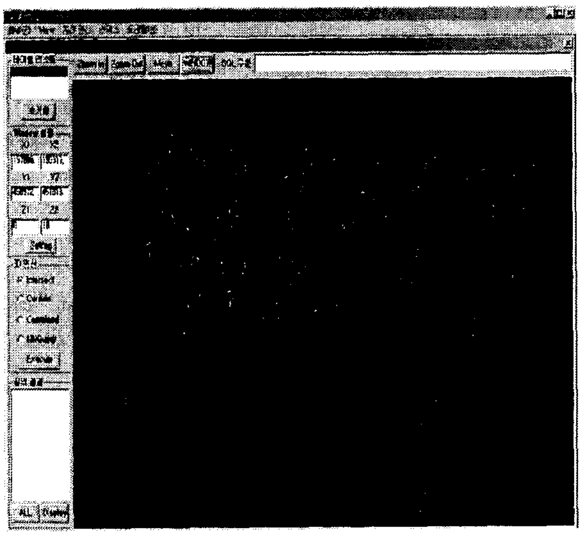

Figure 2. An example of query window

An operation is processed after constructed MBB for query window. Operation processing is performed in two steps. The first step, called filter step, selects the objects whose MBB satisfies the spatial predicate. This step consists of traversing the index, applying the spatial test on the MBB. In a second step, called refinement step, the spatial test is done on the actual geometries of objects whose MBB satisfied the filter step. The results that performed Intersect3D operation and Zoom-In are shown in Figure 3.

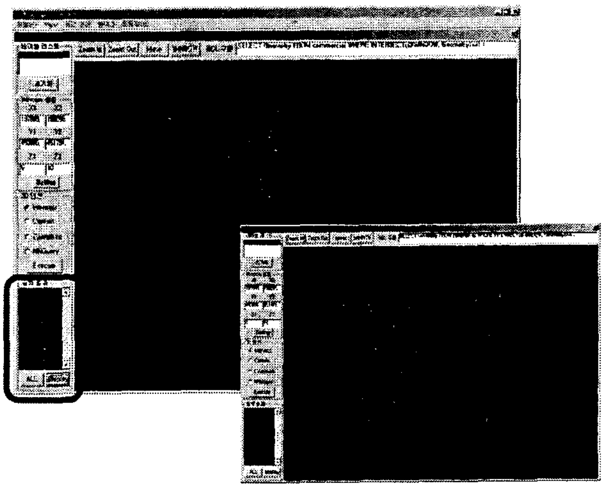

Figure 3. The result of operation and Zoom In

The proposed operation processor can provide not only text form, but also visualization form of query results. It can also support basic functions such as Zoom-In, Zoom-Out, and Panning on 3D visualization.

5. Conclusion and future works

Recently in order to represent 3D spatial objects efficiently, many spatial data models are proposed, and many prototypes based these models are developed. However, since most of existing prototypes are focused on visualization of 3D spatial object, they can not support spatial analysis functions such as topological spatial relationship between 3D spatial objects.

Therefore in this paper, we designed 3D spatial operation processor, which can support various spatial operations as well as the visualization of 3D spatial objects and implemented a prototype. Also in order to process 3D spatial analysis functions efficiently, we used R*-Tree as spatial index. The proposed operation processor for 3D operations can be applied to 3D GIS which need various spatial analysis functions between 3D spatial objects.

The future work includes the development of various spatial operations between complex 3D objects. It will also include techniques for improving operation performance, and for developing an operation processor based components.

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