Research and Implement of 3D Data Integration between 3D GIS and 3D CAD

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SUMMARY

3D GIS and 3D CAD system describe the same real-world objects but they belong to different domains. The data involved in the two systems are therefore quite different. Along with the evolution of information technology and 3D representation of geospatial information, more and more 3D applications demand both of them to be used together.

This paper focuses on how to integrate the 3D data of 3D GIS and 3D CAD. This paper describes 4 approaches for the data integration, i.e. direct data import, shared access to database, formal semantic and integrated data management and file translation. Based on the last approach, this paper designs the scheme of data integration. This scheme focuses on two aspects: geometry exchange and the information loss due to file translation.

On geometry exchange, after this paper points out the how-to of translating between the complex geometric description in 3D CAD and the simple description in GIS of some graphical primitives, e.g. line, surface and polygon, it focuses on the translation of 3DSOLID. In 3D CAD, geometric information of 3DSOLID cannot be read from DXF (Data eXchange Format) file directly. This paper researches three approaches for this problem: (a) making a plug-in using ObjectARX (an AutoCAD API) to extract the geometric information from the 3D CAD environment; (b) converting 3DSOLID to appropriate representation (such as POLYFACE MESH) in 3D CAD; and (c) inserting 3DSOLID into GIS environment as a point

The information loss is discussed next. This paper stresses on how to resolve the information losing during data translation between 3D GIS and 3D CAD systems. This paper gives the approaches for two types of information loss - the boundary point loss (from GIS to 3D CAD) and the accuracy of curve loss (from 3D CAD to GIS). According to this scheme, and based on VGEGIS software platform developed by LIESMARS (State Key Laboratory in Information Engineering, Surveying, Mapping and Remote Sensing) of Wuhan University and the AutoCAD by Autodesk, a prototype system is developed to demonstrate the 3D data integration of 3DGIS and 3D CAD. Finally, the conclusions and recommendations are presented.

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1. INTRODUCTION

GIS (Geographic information system) and CAD (Computer Aided Design) systems have evolved over the past 30 years. In its original concept, CAD software was designed for geometric models of relatively small in size vis-à-vis model of geographical scale. In contrast, GIS software was primarily designed to deal with geospatial models covering relatively vast extent in area. Its fundamental feature is to create and maintain spatial (the graphics) and non-spatial (attribute information) data. GIS is used to represent existing objects and it places emphasis on spatial analysis whilst CAD is used to represent non-existing objects and it generally lacks the capability in spatial analysis.

As 3D CAD has developed into AEC (Architecture, engineering, and construction) solutions and GIS has developed into 3D solutions, there is a renewed interest in large-scale geo-information among the diverse set of AEC and GIS end users (Zlatanova and Prosperi, 2005). To optimize the use of land resources which is limited in an island-state like Singapore, extending the utilization of land resource to subsurface is very important. Thus land resource could no longer be treated as two-dimensional, so there is a need to create a 3D GIS system and also to synergize it with design-based CAD/AEC system. Successful integration of 3D GIS and CAD/AEC is crucial to an intelligent spatial information management system which is not limited to the efficient and effective archiving and management of land resources, but also the planning and design of infrastructure - both above surface and subsurface.

2. OBJECT CHARACTERISTIC OF 3D GIS and 3D CAD

3D CAD has been identified with powerful precision data entry and editing tools. These tools enable users to create precise geometric objects which can be moved and edited with no loss of precision. Because 3D CAD comes from a world where engineering tolerances of fractions of a centimetre or an inch are important, full attention is given to manage data without losing precision (Curry, 2003).

GIS system was primarily aimed at mapping and spatial analysis, not precision design for construction and management of real-world objects. If a GIS system is to be used as a CAD system, the models in GIS can approximate the geometry of designed objects, e.g. building, tunnel, cavern, but it is difficult to represent them with the geometric precision required of by engineers.

For CAD system (Lattuada, 2004):

- The mathematical description of the design object is well known;
- Well-known, simple-shaped objects, with a corresponding efficient mathematical descriptions, are often used in the modelling process to build more complex structures (for example, in Constructive Solid Geometry);
- The final object is well defined, to any required degree of precision.

For GIS system (Lattuada, 2004):

- Requires to build statistical description of object with not well known shape;
- Linkages must be maintained between the spatial and the non-spatial data;
- A degree of uncertainty is always present both in the initial data and in the result of modelling process, so the final object is not necessarily well defined and is subject to further analysis, simulation, and interpretation;
- Many models may be created for a particular project, and they should be filed and managed with their respective source data and modelling parameters

3 . METHODS OF DATA INTEGRATION

CAD and GIS systems traditionally focus on different domains and purposes. There are a number of different approaches for integrating 3D data of 3D GIS and 3D CAD, i.e. direct data import, shared access to database, formal semantic and integrated data management and file translation.

3.1 Direct Data Import

Direct data import (Maguire, 2003) means that data is read and converted on the fly into memory. It does not require intermediate format, just an in-memory representation in the 3D GIS or 3D CAD. For example, ArcView can read MicroStation DGN files directly so the 3D CAD data can be visualized, queried, and printed in the same map as other 3D GIS data.

3.2 Shared Access to Database

An alternative to data conversion is shared access to a database. Technically, one system embeds an application programming interface (API) that allows access to data on the fly. ESRI's CAD Client extension to ArcSDE allows MicroStation or AutoCAD users to store and retrieve 3D CAD elements and 3D GIS features in a DBMS (ESRI, 2003a, 2003b). The ArcSDE access API is embedded inside the 3D CAD system. The API shows up as tools in the 3D CAD user interface (Maguire, 2003).

3.3 Formal Semantic and Integrated Data Management

Another efficient solutions to integrate 3D GIS and 3D CAD should cover formal semantics and integrated data management (Oosterom et al., 2004).

First, the semantics (of geometry and other information) within a domain need to be formalized, i.e. domain ontology has to be developed. Next, these domain ontologies have to be matched against each other in order to have meaningful exchange of information between the two worlds. After solving the semantic differences, the next step is to create an integrated model that can serve multiple purposes. The integrated model is managed in a way that maintains consistency during updates or when model data is added to the data base management system (DBMS).

3.4 File Translation

File translation (Maguire, 2003) involves conversion of data from one file format to another, i.e. converts 3D CAD data to a 3D GIS data format and vice versa. DXF can be used as intermediate file format. Because of the differences in 3D CAD and 3D GIS data models and file formats, users need to specify the syntactic and semantic mapping. Unfortunately, the process is not flawless, and data is often lost. The loss of information due to the translation cannot be ignored but, with careful attention, it can be minimized.

In this paper, file translation is chosen to achieve the data integration of the 3D GIS and 3D CAD. The file translation involves conversion of data from one file format to another. First, we need to choose the platform of 3D GIS and 3D CAD. Then intermediate file for file translation between these two systems are needed to chosen.

3.4.1 <u>The Platform of 3D GIS and 3D CAD</u>

The 3D GIS platform used is VGEGIS, which is developed by LIESMARS (State Key Laboratory in Information Engineering, Surveying, Mapping and Remote Sensing) of Wuhan University. The major characteristic of this software is the automatic generation of large 3D city model with 3D coding data, GIS data, CAD data etc. And it provides advanced tool for three dimensional visualization, analysis and surface generation.

The 3D CAD platform used is AutoCAD, which is the product of Autodesk. AutoCAD is the 2D drafting and detailing and 3D designing software that enable one to create with speed, share with ease and manage with efficiency.

3.4.2 <u>Intermediate File for File Translation</u>

This paper uses DXF (Data exchange Format) file as the intermediate file. A DXF file contains 2D and 3D drawing components. Those components are known as Entities. The DXF file can represent almost any CAD drawing using those entities and can connect a group of entities together (such as windows, doors, etc.) and use them later in the file.

4. GEOMTRY CONVERSION

Geometry is the very important part of the CAD and GIS systems. Both are information systems that involve geometry for many different purposes. One could classify CAD as one system which deal with both moveable objects (tables, cars, airplanes, etc.) and unmovable objects (plants, buildings, houses, railways, roads, bridges, tunnels, etc.). Likewise, unmovable objects are the sole domain of GIS system. So, geometry conversion between CAD and GIS on unmovable objects is essential in the integration of these two systems.

4.1 Line

In AutoCAD, one can create a variety of lines such as single line, and multiple line segments - with and without arcs - known as Line, Polyline, 3D Polyline and Multiline (Fig. 1).

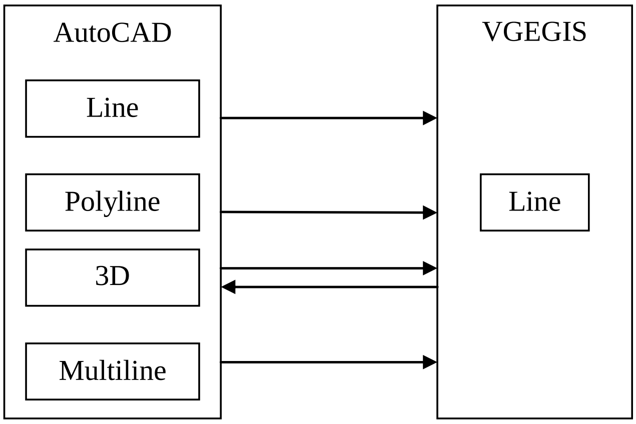

Fig. 1. Line conversion between CAD and GIS

In VGEGIS, there is only one type of line - comprising vertexes and segments. The simplest line composes of two vertexes and one segment. Since the line types of these two systems are very different, the difficulty thus lies in translating between the multitude of lines in AutoCAD and the simple line type in VGEGIS. With the inherent constraint, all line types in AutoCAD are translated into VGEGIS as lines. Some of the lines in AutoCAD, e.g. Polyline, do not have z values in their vertex coordinates, their elevation attributes, if any, will be used as the z values for the vertexes of the line. So after extracting the geometric information and other properties of the line, e.g. color, width, style, from AutoCAD drawing files, all kinds of lines can be imported to the VGEGIS system according to the data structure of VGEGIS.

Conversely, in translating lines from VGEGIS to AutoCAD, the problem of how to insert the lines into AutoCAD arises because there are several kinds of lines in AutoCAD. 3D Polyline, having x, y, z coordinates and comprising several vertexes and multi segments, is the equivalent of the line in VGEGIS. So it is the adopted line type in the translation.

4.2 Surface

In AutoCAD, the surface modeler defines faceted surface using a polygonal mesh. Because the faces of the mesh are planar, the mesh can only approximate curved surfaces. There are several types of surfaces in AutoCAD, i.e. 3D face, Ruled surface, Tabulated surface, Revolved surface, Edge-defined surface, Predefined 3D surface and General surface meshes, etc. In drawing database, these surfaces are recognized as 3DFACE, POLYFACE MESH or POLYGON MESH (Fig. 2).

In VGEGIS, there are two kinds of surfaces. One is the generic surface and the other is the vertical surface. Generic surface can be used to represented road, lake, geological surface or any other surface object. Vertical surface can be used to represented billboard, wall and etc. Generic surface can be either concave or convex. Each facet of the generic surface consists of 3 vertices. And the drawing file records the boundary points of this surface for doing further spatial analysis. Vertical surface, on the other hand, consists of 4 vertices.

Since vertical surface is a special surface in VGEGIS, surfaces from AutoCAD are imported as generic surfaces to VGEGIS. The AutoCAD surface, having more than 3 vertices, has to be triangulated before importing since the generic surface consists of facets with 3 vertices each.

In translating a surface from VGEGIS to AutoCAD, POLYFACE MESH which consists of facets with three or four vertices - similarly to VGEGIS generic surface - was adopted as the most suitable type for representing the VGEGIS surface.

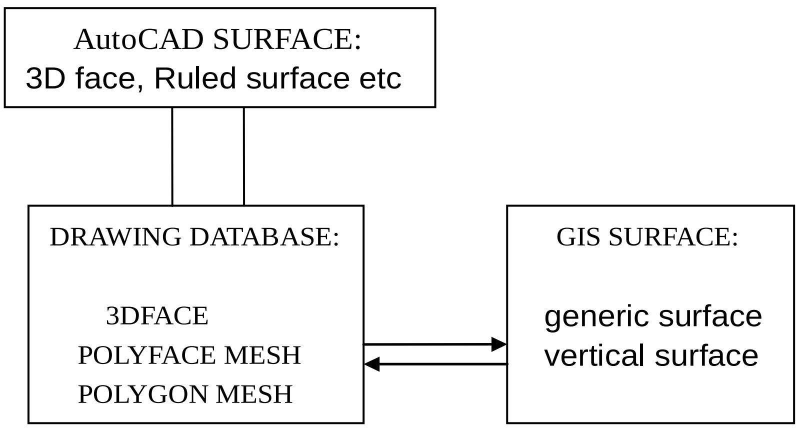

Fig. 2. Surface conversion

4.3 Solid

A solid object represents the entire volume of an object. Complex solid shapes are easier to construct and edit than wireframes and meshes. There are several types of solid in AutoCAD, including basic solid shape (box, cone, cylinder etc), solid torus, solid wedge, extruded solid, revolved solid and composite solid.

All these kind of solids are represented as 3DSOLID in the drawing database of AutoCAD. In VGEGIS, there are four kinds of solid, namely polygon volume, rectangle volume, sphere and column. The top surface of a polygon volume is a polygon and that of a rectangle volume is a rectangle. They can be used to describe all kinds of buildings, bridge, court etc.

In DXF file, the 3DSOLID is encoded in a proprietary format, this paper uses these methods to resolve this problem. One method is converting 3DSOLID to appropriate representation (such as POLYFACE MESH) in 3D CAD. Another is inserting 3DSOLID into VGEGIS as a point, i.e. as a single object. The third is making a plug-in using ObjectARX (an AutoCAD API) to extract the geometric information from the 3D CAD environment;

Fig. 3. Solid translation

5. INFORMATION LOSS

In this paper, data translation is done by "mapping" data from one format to another. Because formats are different, there's rarely a one-to-one match for every object, resulting in information loss.

For example, although AutoCAD package supports a mathematical arc, VGEGIS does not. A precise, three-point arc drawn in AutoCAD is typically converted to a series of straight-line segments in VGEGIS. In order to reduce this kind of information loss, we can increase the density of the straight-line segments. That is to say to use more straight-line segments to describe the arc. The more straight-line segments the arc has, the more precise it is.

In VGEGIS, the drawing file records the boundary points of each surface. These points are very useful for spatial analysis and other operations. Such as in Fig.4, A, B, C and D are boundary points. But in AutoCAD package, there is no information about the boundary points as the CAD package is for design and drafting, not for analysis. So, when converting a surface drawn in GIS to a surface in CAD, the boundary points is lost.

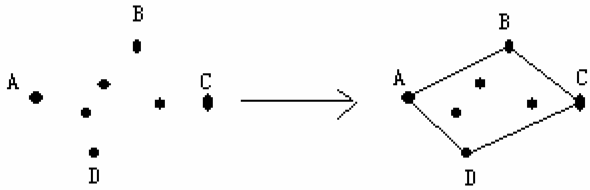

Fig. 4. Convex hull

One method can be used to resolve this problem. It begins with a point known to be on the convex hull, e.g., the leftmost point A (Fig.4), and selects the point B such that all points are to the right of the line AB. This point B may be found by comparing slope of straight line which is determined by A and the other one point. Repeating with B and so on until one reaches A again to yield the convex hull.

Algorithm of getting convex hull is as follow:
Convex (P, n)
/* P = set of n points */
/* store vertices of Convex Hull in clockwise order in array A */
1. A [0] ← leftmost point in P;
2. K ← 1;
3. Repeat
4. Compare the slope
5. A[k] ← first point in clockwise order around A[k-1];
6. Until (A[k] = A[0])

6. IMPLEMENTATION

The implementation of the approach of using data exchange format to achieve GIS-CAD integration is achieved using a programming code written in C++. First, it is necessary to identify (a) the object types that are going to be modeled in 3D CAD and 3D GIS; (b) the functionalities and (c) the output that are expected from each system.

The architecture of the approach is illustrated in Fig. 5 and an example of the two-way transfer of terrain surface, lines and 3D buildings between AutoCAD and VGEGIS is displayed in Fig. 6.

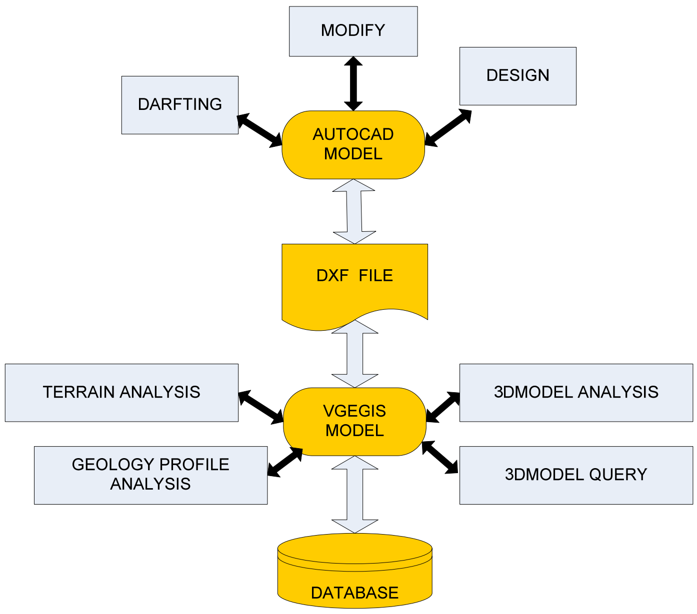

Fig. 5. The architecture

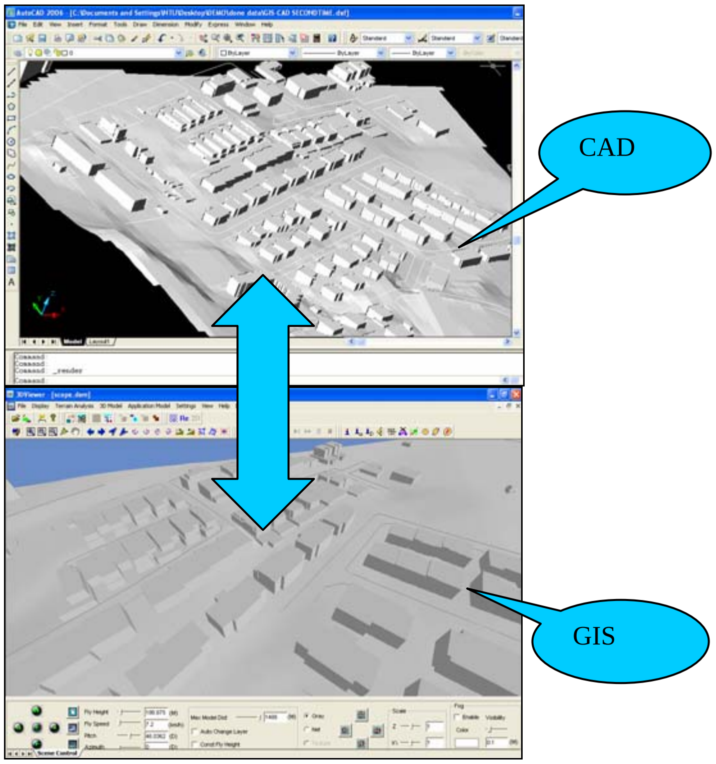

Fig. 6. Model translation between AutoCAD and VGEGIS

7. CONCLUSION

This paper focuses on how to achieve the data integration of 3D GIS and 3D CAD. Among the 4 methods of integration, this paper chose the file translation method. Using this method, this paper implements the geometry translation, including line, surface and solid, between 3D GIS and 3D CAD and resolves largely the technical differences in the geometry. This shows that the file translation is a pragmatic and efficient approach in integrating the two systems.

A tight integration will require a combined solution at the data representation level. Currently, CAD-GIS integration projects tend to be project specific and case-by-case. But model conversions are seldom based on pure geometric "translations", so semantics is important. One of the efficient solutions to integrate two different systems is to achieve interoperability between them. So the future work is to achieve semantic interoperability.

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BIOGRAPHICAL NOTES

Ms LI Juan graduated from Wuhan University with a M.Sc. degree in June 2006. While in attachment to Nanyang Technological University (NTU), Singapore, from May 2005 to May 2006, she investigated the data integration between 3D GIS and 3D CAD. She is currently a project officer researching on a 3D Geological Information System in NTU.

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