RULE-BASED MODELING FOR 3D GIS

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ABSTRACT

One popular approach for modeling 3D geo-features is to create 3D CAD model manually. In particular, manual 3D geo-feature modeling approach provides a high quality of visualization for 3D GIS features. However, this approach can be time consuming to generate 3D models being created manually and requires high costs.

We introduce a novel modeling concept; so-called, Rule-based modeling (RBD) that can model 3D geo-features using 2D profiles and 3D feature attributes. By using rule-based engine and model library, we are able to create 3D geo-features automatically. The RBD component combines a synthetic modeler with efficient LOD (level-of-detail) control for real-time rendering.

In addition to, describing the details of our component, we present the comparison result between manual modeling and proposed rule-based modeling in terms of the following criteria: input data domain, interoperability, reusability and modeling cost.

Keywords: 3D GIS, geometric modeling, data reuse, software components

1 INTRODUCTION

As geographical information is still strongly 2D oriented, which is mostly due to data capture capabilities, a 3D GIS must allow to import, process, visualize and export 2D data. A traditional GIS provides only 2D representation of the spatial entities using simple primitives of points, lines and polygons.

2.5 D data consist of 2D topology and 3D feature geometry. A 2.5D GIS add a third dimension to the display by adding a third dimension using one of the attribute information such as elevation, land use, land cover, rain fall, etc. The attribute property of the object remains constant along the third dimension.

The present trend is to build a truly 3D GIS (Virtual GIS). Current research developments include navigation in a virtual environment and simple querying of the attribute database.

The input, storage, and 2D output of GIS data have seen remarkable progress, the analysis of GIS data in a 3D setting still requires significant development in order to yield new insights into the relationship between 3D data.

The purpose of this paper is to model the 3D geo-feature by using the existing 2D data with additional 3D attributes, same as 2.5D data. In this paper, we present a design method for scene modeler component that can create three-dimensional geo-feature models by using existing 2D-based GIS data.

We present design and analysis results of scene modeler component that can create 3D models according to the level-of-detail requests at the 3D scene rendering phase.

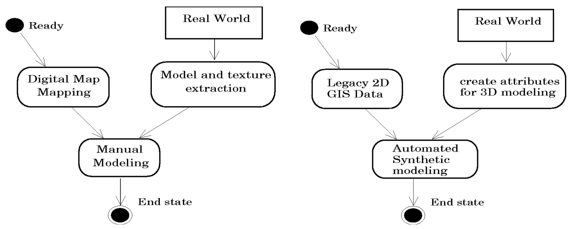
2 RELATED WORKS

Recently, component-oriented programming is receiving increasing amounts of interest in the software engineering community. The goal is to create a collection of reusable components that can be used for component-based application development[Bosch97].

Bachmann *et al.* presented the Architecture Based Design (ABD) method. The ABD method provides structure in producing the conceptual architecture of a system[Bachmann00].

Murer introduced the method to motivate for a

broader interdisciplinary discussion about components including technical aspects, but also organizational, social and even marketing aspects[Murer97].
Outhred indicated to the difficulty for programming for evolution or adaptation by using Microsoft's COM(component object model) that is representative component-based frameworks[Outhred98].
Trott presented the development of ISO 19107 compliant prototype vector data using object-oriented extensions to Vector Product Format (VPF)[Trott00]. These prototypes demonstrate both the feasibility and the utility of 3D topology for analytical applications, particularly with respect to modeling and simulation.
Currently, it is not formally defined the 3D GIS but the GIS system is developed according to each application goal[Dollner00].
Characteristics of representative 3D GIS software are constructing spatial information system, spatial analysis, visualization quality improvements and so on.



(a) manual modeling approach (b) our proposed approach

Figure 1: Two approaches for 3D modeling

There are two approaches for constructing a 3D GIS system. One is a *manual modeling approach* that creates the 3D model manually according to the 2D vector map. The other is an *automated modeling approach* which can model 3D models automatically and uses minimum 3D attributes (i. e, building height, road width) and a 2D vector map to build a 3D model. We present the *synthetic modeling* method that is based on automated modeling approach. We design the 3D scene modeler component that could level-of-detail (LOD) control for facility models according to the user requests[Hoppe96, Hoppe97]. The figure 1 shows two activity diagrams of these two approaches, which describe the overall 3D modeling concept.

3 3D GIS SOFTWARE COMPONENT DESIGN

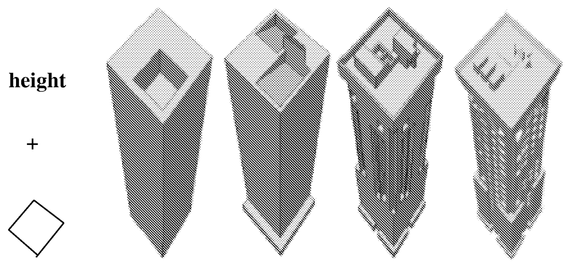
3.1 Design Philosophies

The important parts of scene modeler component that considers in design phase are as following:

interoperability By designing and embodying a standardized data provider, we can solve the problem resulted from different aspect of data format and database that used in current commercial GIS product.
standardization The geometry model specified in the OpenGIS simple features specification.
reusability We can improve the software reusability by constructing several core components for 3D GIS application such as data provider, data graph, scene graph and viewer component.
performance We also use the *Well Known Binary* (WKB) format to store geometry information as in Open GIS Consortium (OGC) simple features specification for geometry provides a portable representation of a Geometry value as a contiguous stream of bytes[OGC99].

3.2 Scene Modeler Component

The scene modeler component is composed of the *scene graph package* and *LOD modeler package*. The scene graph package creates the scene graph for 3D rendering by using the given data in preprocessing step for 3D geo-feature visualization. The LOD modeler package coarsens or fines the 3D geo-features (i.e. building, road) according to the user request. The major functionality of LOD modeler achieves three-dimensional modeling of various detailed geo-features rendering by using 2D geometric information and 3D additional attributes.
There are two important system elements to model the static LOD geo-feature model efficiently. One is the *rule-based modeling engine* and the other is the *model library*. For example, in case of a building, our proposed modeling system can create 3D polygonal model to process 2D profile geometry of a building and height attributes as an input by using the rule-based modeling engine and model library. The figure 2 shows an example of a result of synthetic modeling concept according to the LOD level τ.



(a) input (b) τ=1 (c) τ=3 (d) τ=5 (e) τ=10

Figure 2: Synthetic modeling concept [Gran99]

The scene modeler component is consisted of *dynamic modeler package* that manage dynamic three-dimensional scene by user interaction after the scene rendering performed and *static modeler package* that performs the rule-based modeling according to user LOD requests.

The *meta scene graph* can be defined in three-dimensional scene graph which is consisted of information from data graph only.
First, the dynamic modeler composes a meta scene graph by using information about whole scene which is receiving from initial data graph component. Then system performs the refinement process of the scene graph, determines the LOD state according to user view parameter and requests to static modeler a relevant LOD model.

3.3 Ruled-Based Modeling

We present novel modeling concept so-called *rule-based modeling* that can model the 3D geometry model by using 2D profiles and additional 3D attributes. The detail system elements for the rule-based modeling are *rule-based modeling engine*, which creates geometry information by referring facilities attributes in modeling phase, and *model library*, which has preprocessed models and appearance data in order to create detailed model. The rule-based modeling engine is the reasoning engine that already defines geometry components and rules beforehand to model 3D facilities according to their classified features in GIS. The model library is composed of geometry components (i.e. window, roof, parapet) and appearance components (i.e. texture, terrain texture), which is constructed in the preprocessing phase. The data, which is provided by model library, don't match exactly geometries and attributes of real-world models but the modeling engine can create similar models to real-world models. Moreover, the rule-based modeling engine includes the rule parameter database (RPD) that can edit the modeling rule. Table 1 shows an example of RPD according to LOD level.

LOD level	Modeling elements	Model library
LOD 1	SE	None
LOD 2	EB, R	RT
LOD 3	EB, R, W, P	WT
....	....	....
LOD n	EB, R, W,P, ...	RDT,WDT, ...

Table 1: An example of RPD according to the LOD level. (SE:simple extrusion, EB:extrusion body, P:parapet, R:roof, RT:roof texture, WT:window texture, RDT:roof detail texture, WDT:window detail texture)

For given input (a) with an example of figure 2, the rule based modeler can create a simple extrusion of input data according to 2D profile geometry and additional 3D attributes (the story of building, height). After we get modeling rules according to facility features in rule-based modeling engine, modeler performs the three-dimensional synthetic modeling to create a detailed model.

The equation (1) denotes the creation process of synthetic model for the rule-based modeling where $S_{x,y,z}$ denotes geometry information of the model, $P_{x,y}$ denotes the 2D profile and $R_{x,y,z}(\tau)$ denotes the geometry information obtain through performing the rule-based modeling at specific LOD level τ.

$$S_{x,y,z} = P_{x,y} + R_{x,y,z}(\tau) \qquad (1)$$

The static modeler is the package which performs the rule-based modeling.

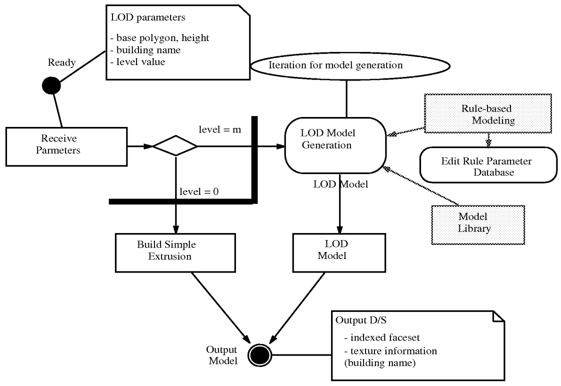


Figure 3: The activity diagram of the static modeler

As shown in figure 3, the static modeler package creates a LOD model obtained from performing iterative modeling procedures by using a 2D profile and a requested LOD level value.

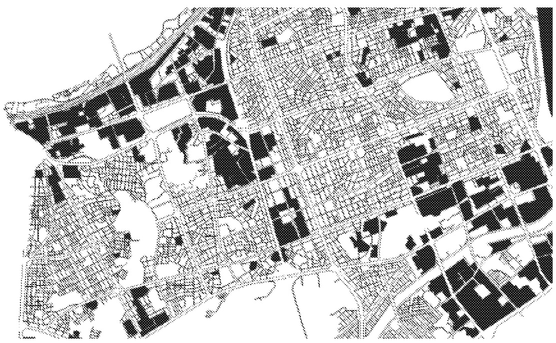
4 RESULTS AND ANALYSIS

The comparison criteria of modeling schemes, such as manual modeling, synthetic modeling (rule-based modeling), are input data, manual CAD object modeling, interoperability, reusability, initial modeling cost and so on.

Manual Modeling Approach
This modeling approach uses two-dimensional vector map with huge polygonal data set which is result from manual CAD modeling. The CAD models which is result from manual modeling depend on data format (e.g. 3D studio max, Maya). Therefore, the data interoperability among 3D GIS systems cannot be supported. The main advantages of this approach is that this can provide a fairly high and realistic visual quality of 3D models due to use manual CAD modeling. However, It requires big cost to initial manual modeling for 3D CAD data sets. In addition to, the these 3D CAD data size is too huge to manage and to visualize.

Automated Synthetic Modeling
This modeling approach uses two-dimensional vector

map with minimum attributes for automated 3D modeling such as height or story of buildings. This approach does not need a manual modeling for creating 3D CAD data. Therefore, the initial cost is only cost related to client application software developments. If we adopt the Object Linking and Embedding (OLE) database access architecture, we easily achieve the data interoperability. The main advantage of synthetic modeling approach is that it can provide the automatic modeling by using legacy two dimensional GIS data set with 3D additional attributes. Therefore, we can minimize the cost for modeling. However, it requires additional modeling procedures to provide realistic modeling.
Shown in figure 4 are snapshots of a 2D map and its synthetic modeling result where LOD level value is 1.



(a) 2D map

(b) synthetic modeling result

Figure 4: 2D map and its synthetic modeling result

5 CONCLUSION

We have presented the synthetic modeling approach so called rule-based modeling which can perform the modeling procedure for automatic 3D facility modeling such as buildings, roads and so on. Our proposed scene modeler component is better than manual modeling schemes in terms of several criteria such as component reusability, automated modeling, interoperability, initial data construction costs and system performances.
Possible ideas for future work include:
Improvement to synthetic model quality Since we use automated synthetic modeling approach, we might have intermediate quality of generated model. Therefore, we should improve the visual quality of synthetic models by using better modeling algorithms.
New applications An extension of our proposed scene modeler component could enable a class of next-generation applications such as car navigation systems, firehouse management systems.

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