Semi-Automatic Generation of 3-D Building Model by the Integration of CG and GIS

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***Abstract*— When a real urban world is projected into 3-D virtual space, buildings are major objects in this space. To realize the 3-D urban model by CG, it is important to generate building models efficiently. 3-D urban models are the important information infrastructures that can be utilized in several fields, such as landscape evaluation, city planning, civil engineering, architecture, disaster prevention simulation, etc. In this paper, we propose the system to generate 3-D building models semi-automatically by the integration of CG and GIS. Usually, urban planners design the future layout of a town by drawing the map. So, it is convenient for the urban planner who draws the future map to realize the alternative plan if the map can immediately be converted into 3-D Urban Model. The system automatically generates 3-D Urban Model so quickly that the system meets the urgent demand to realize another alternative plan.**

Keywords-3-D Urban Model, Automatic Generation, Computer Graphics, Landscape Evaluation

I. INTRODUCTION

Once urban environment is projected into virtual 3-D space, 3-D urban model can be modified and utilized for various simulations. 3-D urban model is the important information infrastructure that can be utilized in several fields, for example, landscape evaluation, city planning, civil engineering, architecture, disaster prevention simulation, etc. In addition, disclosure of information about public projects to the public in order to encourage their participation in urban planning is a new application area where 3-D urban model can be of great use. So it is necessary to create objects in 3-D urban model such as buildings, roads, bridges, towers and other utilities efficiently. The manual creation of the shapes and the texture mapping for these objects require lots of labor and time. Therefore, in our research, we aim at generating 3-D urban models, especially building models automatically. To generate 3-D urban models, the 3-D shapes and material attributes of buildings and other objects must be reconstructed. In the reconstructing process, the image data must be acquired by taking photographs of the objects in the city. But, when we think of the future of the city, we cannot take photos of the future of the city, planning road and predicted damages by disasters. Usually, urban planners design the future layout of the town by drawing the map. So, it is convenient for the urban planners who draw the future map for the city to realize the alternative idea in 3-D virtual space if the map can immediately be converted into 3-D urban model. The system automatically generates 3-D urban model so quickly that the system meets the urgent demand to realize another alternative plan.

II. FLOW OF THE AUTOMATIC GENERATION

In our system, GIS and CG integrated system automatically generates 3-D urban model, especially 3-D primitive building models. A program has been developed using 2-D GIS software components (MapObjects, ESRI Inc.) to pre-process the buildings' contours i.e. the building polygons on GIS. Another program on the side of 3-D CG receives the processed data and generates 3-D CG building model.

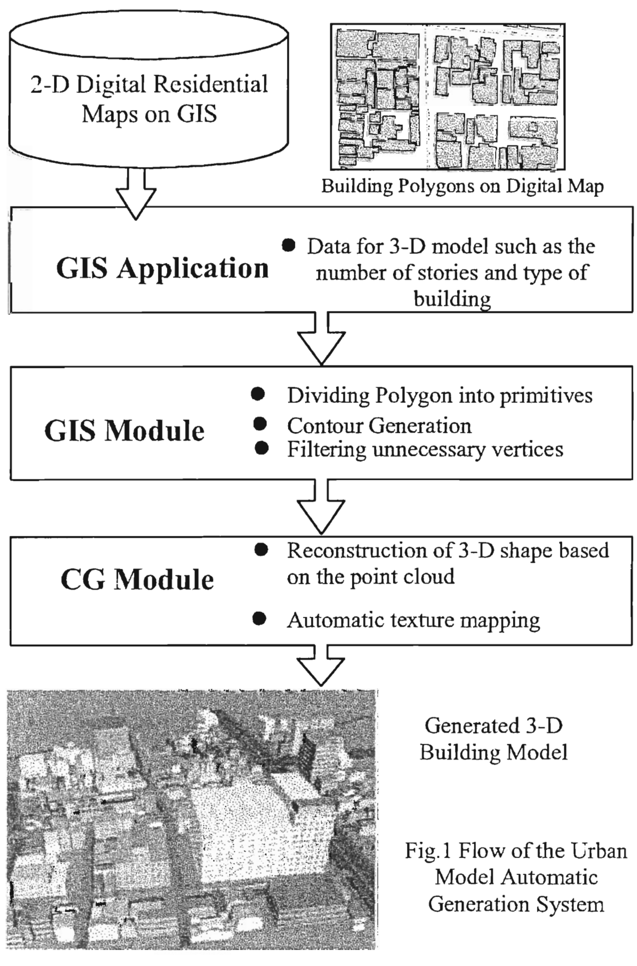
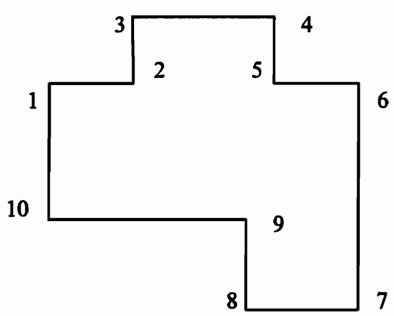


Fig.1 Flow of the Urban Model Automatic Generation System

III. ALGORITHM FOR ASSIGNING BUILDING MODELS TO POLYGON

For most of building polygons, the angles of vertices of polygon are almost 90 degrees and the number of vertices is limited. The building polygon that has limited num. of vertices and only almost 90 degrees angles can be replaced by a combination of rectangles. When creating 3-D CG building models, 3-D CG primitives such as box, prism and the combination of these are placed on this building polygon. When following the segments of the polygon clockwise, any segment will have a bending angle of 90 degrees to the right or to the left relative to a preceding segment. So, it is possible to assume that the building polygon with right angles can be expressed as a set of changes of the segments' direction.

An example of a building polygon expressed as a set of changes of the segments' direction is shown in the Fig. 2. The vertices and segments of the polygon are numbered clockwise.



This polygon can be expressed as RLRRLRRRLR.

R and L mean a change of the segments' direction to the right and to the left.

Fig.2 Expression of a building polygon as a set of changes in the direction of its segment

The algorithm for assigning buildings and roofs to polygon is started with the algorithm for assigning to the polygon that has 6 vertices (L-shaped polygon). L-shaped polygon will be divided into two rectangles. Two boxes (Box1, Box2) are formed on these two rectangles shown at Fig.3. Also, the two roofs (roof1, roof2) are formed and placed on the two boxes. The length and direction of the rectangle are supposed to be these of the longer edge of the rectangle.

The algorithm for assigning to L-shaped polygon is as follows:

1) After finding the longest edge(Lmax) among 6 edges, it will be the length and direction of Box1.

2) Between the two edges that are adjacent to Lmax, longer edge will be the length(L_box2) and direction of Box2.

3) Between the two edges that are adjacent to Lmax, shorter edge will be the width(W_box1) of Box1.

4) The edge that is adjacent to L_box2 and is not Lmax will be the width of Box2(W_box2).

5) The length of Box2 will be reduced to (L_box2 – W_box1).

6) In case that W_box1 >= W_box2

The length of the roof for Box2 (Roof2) will be (L_box2 – 0.5*W_box1).

Roof1 will be a main roof while Roof2 is a sub roof.

In case that W_box1 < W_box2

The length of the roof for Box1 (Roof1) will be (Lmax – 0.5*W_box2).

Roof1 will be a sub roof while Roof2 is a main roof.

There are two cases: W_box1 >= W_box2 and W_box1 < W_box2. In each case, a main roof is differently assigned. A main roof has almost the same size as box to be placed, while a sub roof is the roof reduced in length.

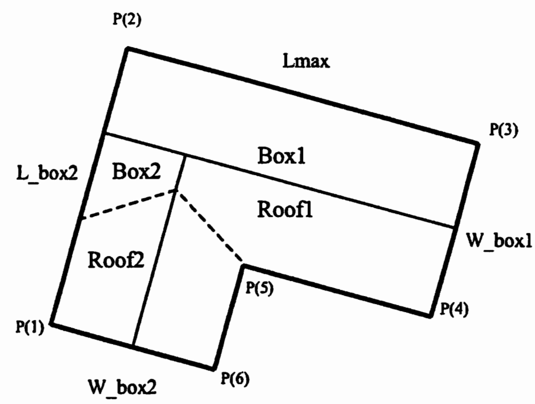


Fig.3 L-shaped polygon in case that W_box1 >= W_box2
Roof1 will be a main roof while Roof2 is a sub roof.

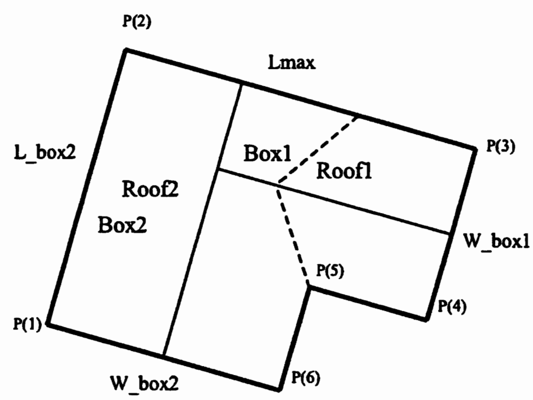
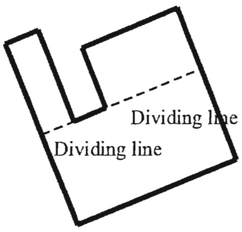
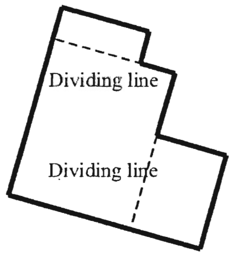


Fig.4 L-shaped polygon in case that W_box1 < W_box2
Roof1 will be a sub roof while Roof2 is a main roof.

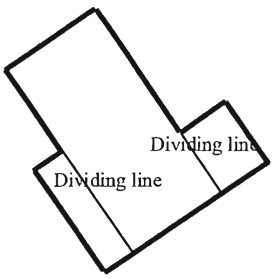
As for the polygon consists of more than 8 vertices, it will be divided into the center area and attached branches. The polygon with right angles is supposed to be expressed as a dataset of turning direction of its segments. In case that dataset take L (Left turn) after or before consecutive R (Right turn), we assume this pattern as the branch. In other words, we take notice of the vertex that turns conversely. From this vertex, the dividing line will be drawn. For example, '*RRL*' pattern will be recognized as the branch. From 'L' vertex, the dividing line will be drawn to the backward direction in terms of the clockwise numbered vertices. Also,'*LRR*' pattern will be recognized as the branch. From 'L' vertex, the dividing line will be drawn to the forward. After the polygon being broken down to L-shaped polygon and rectangles, the algorithm for assigning to L-shaped polygon will be applied to broken-down L-shaped polygon. We have applied this dividing algorithm to the polygon with 8 vertices (8 vertices polygon). Since 8 vertices polygon takes 4 kinds of shape according to RL expression, the algorithm has been applied to 4 cases respectively.



LLRRRRRR type



LRLRRRRR type



LRRLRRRR type

Fig 5. 3 shape types of 8 vertices polygon that have no reiteration pattern

These 3 types have no reiteration pattern. In these types, the module looks up the vertex that turns to the left ('L') after the consecutive vertex that turns to the right ('RR'). From this vertex, the dividing line will be drawn to the backward direction. From the next vertex that turns to the left, the dividing line will be drawn to the forward direction. After the intersections between the edge and the dividing line are calculated, the branches are divided from the center area. The coordinates of six vertices of pruned polygon are given as the candidate coordinates set. The algorithm for assigning to L-shaped polygon will be applied to this coordinates set. Here are the examples that the algorithm is applied to 8 vertices polygon.

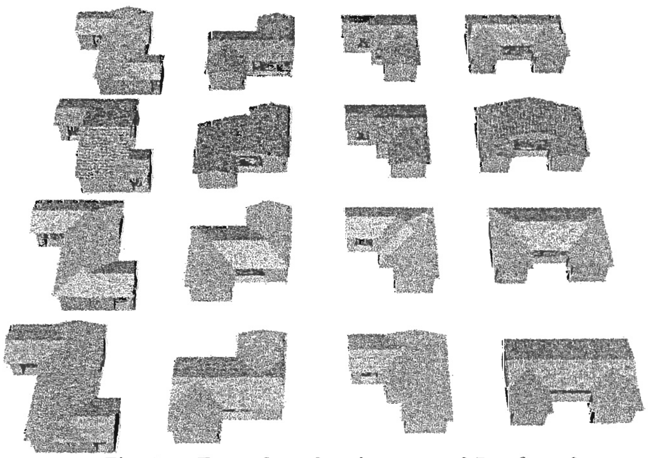


Fig 6. Examples of assignment of Roofs and Boxes to 8 vertices polygon

IV. CONCLUSION

In this paper, we proposed the system that automatically generates 3-D building model, integrating GIS and CG. The system consists of two modules, GIS module and CG module. Main roles of GIS module are to break down the building polygon to primitive polygons. CG module executes producing 3-D shape model by generating 3-D primitives and boolean operation of these, texture mapping to these objects, rotating and positioning these objects for building model, based on the preprocessed data from GIS module.

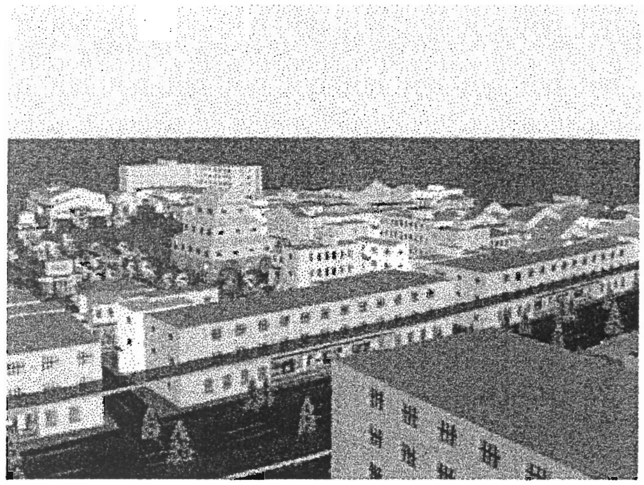


Fig 7. Automatically generated 3-D Urban Model (Ogaki castle, Ogaki city Gifu Prefecture)

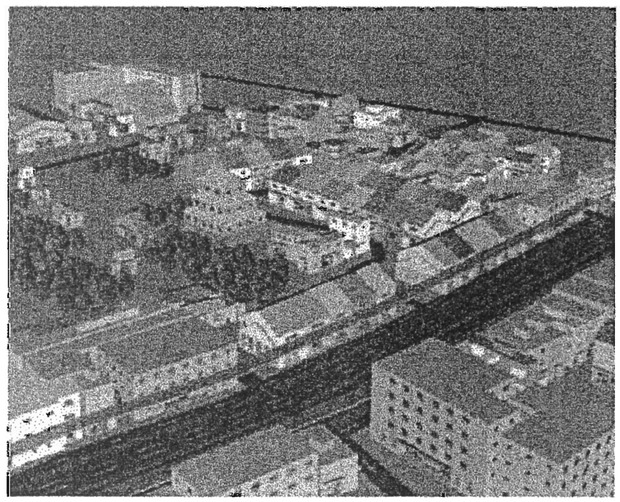


Fig 8. Proposed 3-D Urban Model (Ogaki castle surrounded by 2 stories houses so as to be seen from the area around the castle)

Here is the example of 3-D urban model for urban planning proposal. Fig.7 shows 3-D urban model of the present state of the center area of the middle size city where a castle is surrounded by buildings and not outstanding. Fig8 shows the castle is surrounded by the 2 stories houses with roofs so as to be seen from the area around the castle. The road to the castle is widened so that people can easily reach the castle.