# AUTOMATIC GENERATION OF 3D CITY MODELS AND RELATED APPLICATIONS

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**KEY WORDS:** 3D City model, Automatic generation, Laser profiling, VR, Viewer software, 3D-GIS

**ABSTRACT:**

The needs for 3D city models are growing and expanding rapidly in a variety of fields. In a steady shift from traditional 2D-GIS toward 3D-GIS, a great amount of accurate 3D city models have become necessary to be produced in a short period of time and provided widely on the market. The authors have developed a system for automatic generation of 3D city models, using laser profiler data, 2D digital map, and aerial image, which are processed by the software newly developed. MapCube, the 3D city models generated by the system, has already covered all major cities of Japan at the end of 2002. Applications for virtual reality (VR) that deal with accurate and photo-realistic 3D city models are becoming indispensable in many fields. However, there had been no VR viewer that can appropriately deal with a great amount of 3D city data in real time. In order to solve the problem the authors have developed a new VR viewer called UrbanViewer that can make best use of 3D city models, especially MapCube. VR applications used on display devices should provide easy interactive operation. The authors have developed a new type of VR display device with optical sensors called NEXTRAX, which users can operate as easily as touch-panel display, with more accuracy of operation and much more durability. NEXTRAX also provides simultaneous display of co-related information including 3D city model, 2D digital map and varieties of multi-media information.

## 1. INTRODUCTION

The needs for 3D city models are growing and expanding rapidly in a variety of fields. In a steady shift from traditional 2D-GIS toward 3D-GIS, a great amount of accurate 3D city models have become necessary to be produced in a short period of time and provided widely on the market.
The authors have developed a system for automatic generation of 3D city models, using laser profiler data, 2D digital map, and aerial image, which are processed by the software newly developed.
MapCube, the 3D city models generated by the system, has already covered all major cities of Japan at the end of 2002. MapCube with texture provides photo-realistic and accurate virtual urban space for a variety of uses including 3D-GIS, urban planning, design and redevelopment, hazard prevention, broadcasting, navigation and TV game (Fig 1,2).

Fig 1. Photography of Ginza

Fig 2. 3D model of Ginza

## 2. AUTOMATIC GENERATION SYSTEM OF 3D CITY MODEL

Traditional modeling method of 3D city models had required enormous amount of time for manual works. Ordinary modeling method of 3D city used to be:

1. Scan map and get digital image,
2. Trace digital image of map with 3D CAD software resulting in 2D data of buildings outlines,
3. Manually make 3D modeling of buildings with 3D CAD by extruding 2D outlines to building height, and/or modeling manually detailed 3D geometry referring to drawings and photographs also with 3D CAD.

Especially, manual modeling with 3D CAD software was most time-consuming and required operators' expertise. Therefore the old method was not applicable for production of great area of city model in a short period of time.
The system development of automatic generation of 3D city model aimed great saving of production time. The new method has realized surprising reduction of time in production of 3D city model through automatic generation programs. Moreover, efficiency in texture mapping as well as quality and accuracy of 3D city model has been greatly improved.

### 2.1 3D City Model Automatic Generation System

The material data for the automatic generation system includes laser profiler data, aerial image, and 2D digital map (Table 1).
With the material data, detailed and accurate 3D city model is automatically generated. Fig. 3 shows the process of automatic generation of 3D city model.

| Material data | Specification |
|---|---|
| Laser profiler data | -Point cloud data obtained by airborne laser profiler, which offers elevation of terrain and buildings.<br>-Distance of points: approx. 1m<br>-Elevation accuracy: 15cm<br>-Horizontal accuracy: 30cm<br>-Each point has latitude and longitude information. |
| Aerial image data | -Digital aerial image data and standardized local coordination information.<br>-Resolution: 20-40cm per pixel. |
| 2D digital map | -Vector data based on 2D map of 1/2,500.<br>-Outlines and attribute data of objects including buildings, roads, railroads. |

Table 1. Material data

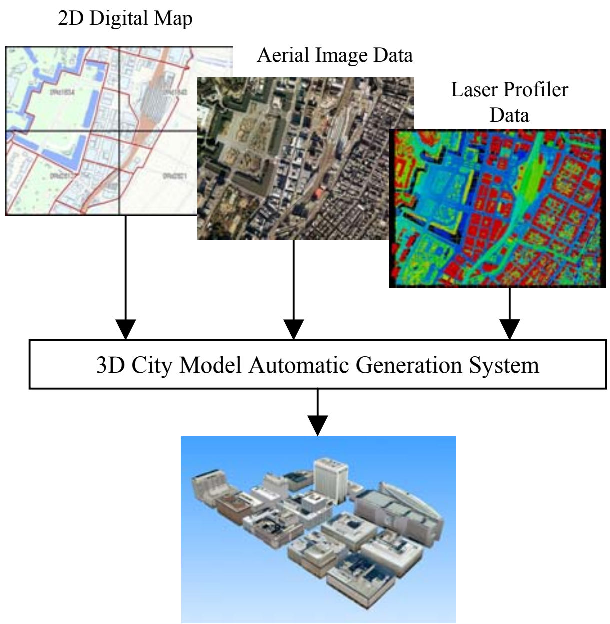


Fig 3. 3D city model generation system

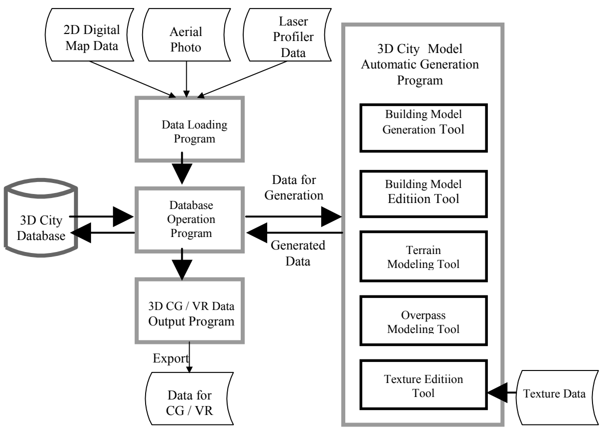


Fig 4. Program structure of the system

The system consists of several programs including 3D city model automatic generation program, database management program, material data input program, and 3D CG/VR data output program (Fig 4).

**3D city model automatic generation program**

3D city model automatic generation program generates geometry data of building, terrain, and overpass and elevated object, using input material data including laser profiler data, aerial image and 2D digital map data as input data.
The program consists of several tool programs (Table 2).

| Tools of 3D city model automatic generation | |
|---|---|
| Building model generation | It produces geometry data of building automatically, using their outlines on 2D digital map and laser profiler data within the outlines (Fig 5). |
| Building model edition | Building model generation tool solely cannot model all geometry of building and penthouse. The program helps edition of generated building model through supplementary modeling (Fig 6). |
| Terrain modeling | It provides automatic generation of terrain model using laser profiler data, resulting in TIN model (Fig 7). |
| Overpass and elevated object modeling | The program produces geometry of overpass and elevated object such as highway, railroad and bridge, using their polygon data on 2D digital map and laser profiler data (Fig 8). |
| Texture edition | It helps attach texture data to surface of geometry model (Fig 9). |

Table 2. Tools of automatic generation program

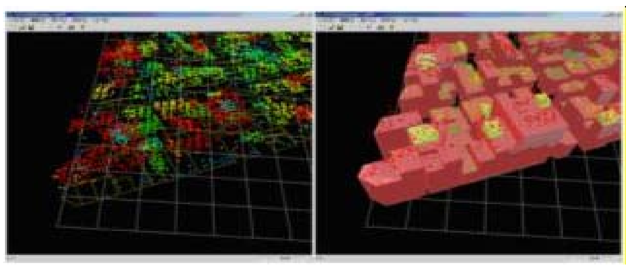

Fig 5. Building model generation tool

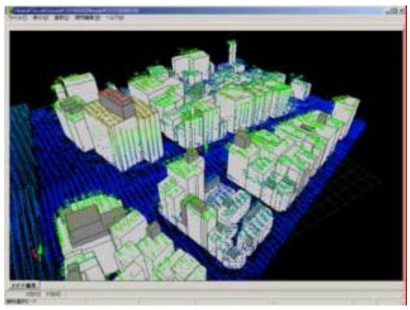

Fig 6. Building model edition tool

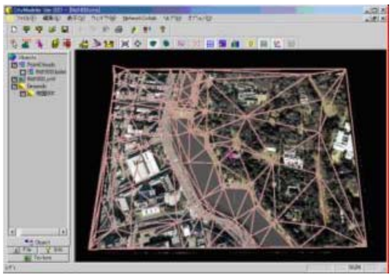

Fig 7. Terrain modeling tool

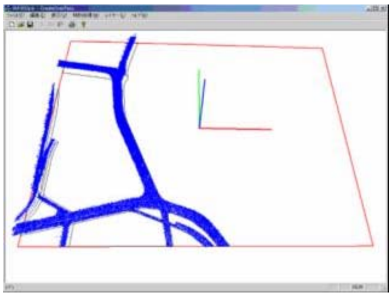

Fig 8. Overpass and elevated object modeling tool

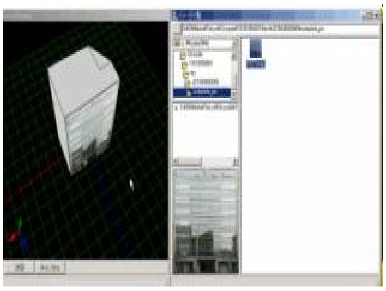

Fig 9. Texture edition tool

**Database operation program**

Database Operation Program controls transfer of various data between 3D city database and 3D city model generation program. Its functions include registration of various input data to 3D city database, extraction of geometry, texture and attribute data within selected area, as well as registration of generated geometry and texture data to the database. Building data is managed by its address using 2D digital map interface. On the other hand, terrain and overpass and elevated object are managed using digital map of Geographic Survey Institute of Japan (Fig 10, 11).

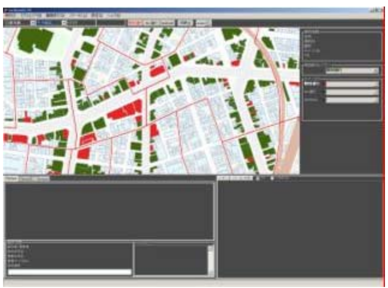

Fig 10. Operation interface for edition of building model

Fig 11. Operation interface for edition of terrain and overpass

**Material data input program**

The program controls reading of material data into database operation program. Its functions include checking and co-ordination of material data and reassignment of directory and file names for registration.

**3D CG/VR data output program**

The program receives 3D city model data from 3D city database intermediated by database operation program, and give output in ordinary CG/VR format such as Wavefront OBJ format. This function is defined in all tool programs.

## 2.2 MapCube: 3D City Model

Through the application of 3D automatic generation program, accurate geometry model of terrain and building are automatically generated. Then, photo-realistic 3D city model with façade texture on geometry model, which is called textured model, is generated (Fig 12).

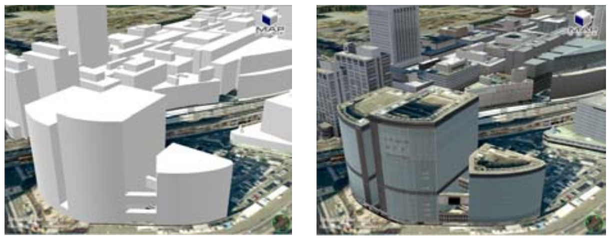

Fig 12. Geometry model and textured model
(left: geometry model, right: textured model)

The 3D city model, which is called MapCube, is already available on the market.
At the time of January 2003, geometry model of all major cities of Japan including Tokyo, Yokohama, Kawasaki, Osaka, Nagoya, Kyoto, Kobe, Fukuoka, Hiroshima, Sendai and Sapporo are available. MapCube geometry model is revised annually based on revision of 2D digital map data for car navigation systems.
Texture model is being produced along major roads of major cities with priority. It presently covers total length of 500km.
It will take considerable amount of time to produce texture model of all buildings of major cities of Japan. And it may not be very indispensable. Then, for the time of being, the authors have prepared virtually textured building model, where buildings are textured with randomly selected façade texture from the texture library according to their building uses.
In addition to geometry model and textured model, 3D models of well-known buildings/objects, which is called landmark model, are being produced with more detailed geometry (Fig

13). Approximately 1,000 landmark models are presently available.

Fig 13. Examples of landmark models
(Budoh-kan, City Hall, and Tokyo Tower in Tokyo)

## 3. VR VIEWER

Applications for virtual reality (VR) that deal with accurate and photo-realistic 3D city models are becoming indispensable in many fields. However, there had been no VR viewer that can appropriately deal with a great amount of 3D city data in real time. In order to solve the problem the authors have developed a new VR viewer called UrbanViewer that can make best use of 3D city models, especially MapCube.
VR viewer software for popular use on the market has often difficulties when it is applied for specific purposes in terms of easy operation or drawing speed. It is also often hard to put additional functions in the software. It was true too in the case of displaying 3D city model. To solve this problem, the authors have developed new VR viewer software that can easily deal with wide areas of 3D city models, and named it UrbanViewer (Fig 14). UrbanViewer has been available on the market since 2002.

Fig 14. User interface of UrbanViewer

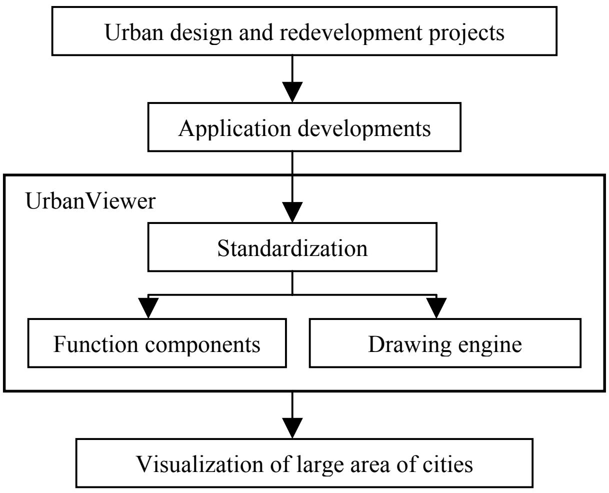


Fig 15. Development outline of UrbanViewer

UrbanViewer has been developed based on originally developed VR applications for urban design and planning on project basis. That is, before the development of UrbanViewer, VR applications for urban design and redevelopment projects used to be achieved by development of required function programs project by project.
The development included standardization of programs, development of function components and that of original drawing engine. (Fig 15).
The standardization of programs has brought great benefits including reduction of development time and cost and easy management of license.
And the development of function components also has gave us benefits such as easiness in development of additional function programs without great revision of basic application programs, as well as easiness in application development toward new fields.
Originally developed drawing engine has realized real time operation of 3D city model with a great amount of geometry and texture (MapCube).
UrbanViewer provides a variety of functions that are useful and indispensable in urban design, real estate development, hazard prevention, urban navigation 3D-GIS and so on (Fig 16). They include:

- -Seamless display of wide area of city
- -Fly-through and walk-through
- -Jump to arbitrary viewpoint
- -Control of movement speed
- -Registration of viewpoints
- -Measurement of height, distance and area
- -Edition of objects

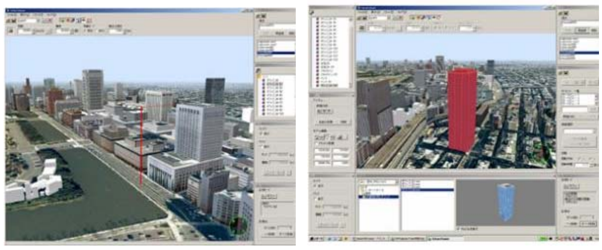

Fig 16. Example functions of UrbanViewer
(left: measurement of height, right: edition of objects)

## 4. MULTIMEDIA DISPLAY

The display device for VR applications should provide easy interactive operation. The authors have developed a new type of VR display device with optical sensors called NEXTRAX, which users can operate as easily as touch-panel display, with more accuracy of operation and much more durability. NEXTRAX also provides simultaneous display of co-related information including 3D city model, 2D digital map and varieties of multi-media information (Fig 17).
The employment of optical sensor has made possible display of VR contents on a variety of monitors, including CRT, TFT liquid crystal, projector and plasma display. Furthermore, a transparent plastic cover panel guarantee far greater durability of the device than that of touch-panel.
NEXTRAX can display on monitor screen both VR city model and 2D digital map, which are co-related each other, user can operate on either side. Furthermore, every object has unique ID both in VR and 2D map and linked to the attribute database.


Fig 17. NEXTRAX
(left: 15 inch TFT display, right: 50 inch plasma display)

NEXTRAX has been available on the market since the middle of 2002, and approximately 30 units are being in operation, mainly in the field of real estate development for the sales of condominiums (Fig 18).


Fig 18. User interface of NEXTRAX

**References from Journals**:

Takase, Y., Sho N., Sone A., Shimiya K., 2003. Generation of Digital City Model. *Journal of the Visualization Society of Japan*, *Vol.23 No.88*, pp. 21-27

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