# VR AND WEB3D-GIS APPLICATIONS USING 3D CITY MODELS

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**Abstract.** For the recent years the authors have developed techniques for automatic generation of 3D city models using LIDAR data, 2D digital map and aerial photograph, as well as a virtual reality (VR) viewer software with high-speed graphic engine which can deal with a large area of 3D city models on VR. The authors also have developed Web3D-GIS system which can provide transmission and reception of a great amount of urban information with interactive manipulation of detailed 3D city models linked with geographic information systems (GIS), on ordinary internet infrastructure such as DSL. Using those techniques and systems the authors have been conducting a research project called "Kyoto Virtual Time-Space" which aims at reconstruction and visualization of Kyoto at different eras on VR and on the internet, starting from the present and finally up to Heian era.

## 1. Development of Techniques

### 1.1. AUTOMATIC GENERATION OF 3D CITY MODELS AND VR APPLICATIONS

Traditional modeling method of 3D city models usually had required enormous amount of works. Especially, manual modeling with 3D CAD software was most time-consuming and required operators' expertise.

Therefore, it had not been applicable for the production of great area of 3D city models in a short period of time.

The automatic generation system of 3D city models developed by the authors has realized surprising reduction of production time for modeling of 3D city models. The material data for the automatic generation system includes LIDAR data with elevation accuracy of 15cm, aerial images, and 2D digital maps. With the material data, accurate 3D city models are automatically generated with developed software.

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. Through the application of 3D automatic generation program, accurate "geometry model" of terrain and buildings are automatically generated. Presently geometry models of 14 major cities of Japan are available on the market (MAPCUBE®), which are revised annually (Figure 1, left). And 3D models of other cities are also available on project basis. In addition to geometry model, 3D models of well-known buildings/objects called "landmark models" are being produced with detailed geometry and texture. Approximately 2,000 landmark models are presently available.

*Figure 1.* 3D Kyoto (left), and an urban renewal simulation on VR (right)

## 1.2. VR VIEWER

Applications for VR using wide areas of 3D city models are becoming indispensable in a variety of fields. However, VR viewer software for popular use, such as VRML, often has difficulty in terms of drawing speed when it is applied for a wide area of 3D city model. To solve the problem, VR viewer software that can easily deal with wide areas of 3D city models has been developed by the authors, and is presently available on the market (UrbanViewer™). It is used in a variety of fields including urban design, real estate development, hazard prevention, tourism and urban navigation (Figure 1, right).

### 1.3. WEB3D-GIS

The authors also have developed a Web3D-GIS system that makes possible transmission and reception of a great amount of urban information with interactive manipulation of detailed 3D city models linked with GIS on ordinary internet infrastructure such as DSL (Figure 2, left). New techniques have been developed for the system, including; (a) reduction of data, (b) level of detail (LOD) and streaming, and (c) linkage between 3D city model and GIS.

The system also can deal with topographical 3D data of wide areas. To make this possible a technique to change density of meshed DEM (Digital Elevation Model) according to the distance between viewpoint and viewed topography.

The system has recently started to be used on the internet homepages for tourism and real estate sales (Figure 2, right). And its uses are expected to expand rapidly.

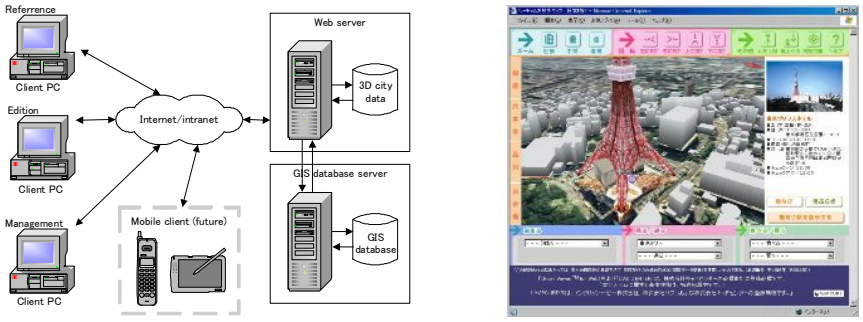


*Figure 2.* System structure (left), and a web site for tourism on the system (right, ©Nippon Travel Agency Co., Ltd.)

## 2. "Kyoto Virtual Time-Space"

"Kyoto Virtual Time-Space" is a part of "Kyoto Art Entertainment Innovation Research" by Ritsumeikan University, a 21st Century COE (Center of Excellence) program funded by Ministry of Education, Culture, Sports, Science and Technology of Japan during the period from 2002 to 2006. It aims at reconstruction and visualization of "4D-GIS" of Kyoto, which means that it provides 3D-GIS of Kyoto, starting from the present going back to the past through 20$^{th}$ century to Heian period (12$^{th}$ to 8$^{th}$ century, when Kyoto was the capital), based on 3D city model and available historical documents and information, employing new visualization technologies

including VR and Web3D-GIS. Since early stage of the research, "Kyoto Virtual Time-Space" has employed MAPCUBE® of Kyoto, and UrbanViewer™ has been employed as VR viewer for it. All 3D data and information are installed and handled on VR, and they are transferred on to Web3D-GIS in succession.

## 2.1. 3D MODEL OF KYOTO AT PRESENT

*Kyo-machiyas*, or *machiyas*, traditional townhouses of Kyoto, most of which had been built in between 18th century and World War II, have been decreasing rapidly in recent decades. However, they still are dominant elements of urban landscape of Kyoto. Since 1995, community surveys covering the central area of Kyoto were conducted by the city of Kyoto, an NPO, and Ritsumeikan University. In the surveys, the surveyers visited all buildings within the area and identified *machiyas*, as well as recorded the types, conditions and uses of them. The surveys identified 21,820 units of *machiyas* within the area and a 2D-GIS of *machiya* was built up.

Considering that there are so many *machiyas* in Kyoto, a method for automatic generation of *machiya* 3D models has been developed. That is, an Excel VBA Macro has been developed for the purpose, which retrieves the coordinates and attribute data of *machiyas* from GIS database, applies one of *machiya* library models, resize the model matching to the width and depth of the building lot, and place the model in the VR space (Figure 3).

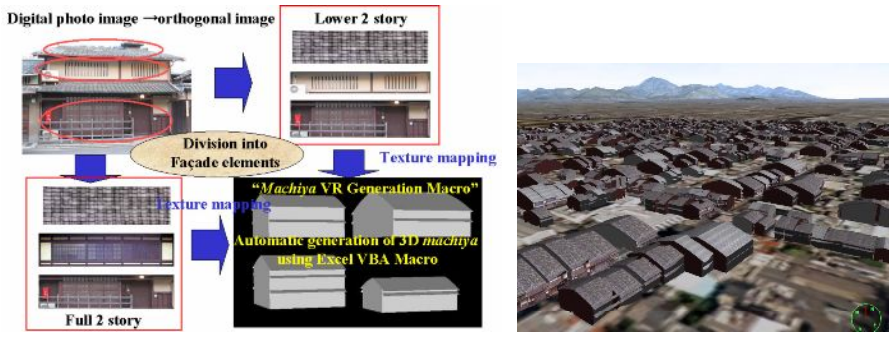


*Figure 3.* Automatic generation of *Machiya* VR model

Additional 3D modeling and texture mapping of buildings/streets for walk-through visualization have been done with priorities by using CG/VR software which can output the data in OBJ format such as MultiGen Creator and form.Z RenderZone. For example, the detailed VR model of Shijo Street is even to be extended from the street to the entrance and theater space of Minami-za (Figure 4), and on the stage Kabuki or traditional dance is

performed. Motion capture technique is to be applied to those performances on VR. Furthermore, the authors have built up 2D-GIS of 1,308 temples and 352 shrines of Kyoto based on "Digital Map 10,000" by Geographical Survey Institute of Japan, as well as that of approx. 2,000 western-style heritage buildings based on the survey in 2003 by the city of Kyoto. Their detailed VR models are to be modeled one after another.

*Figure 4.* Shijo Street and Minami-za Theater

## 2.2. 3D RECONSTRUCTION OF KYOTO IN THE PAST

In the research varieties of 3D reconstructions of Kyoto are being done, starting from the present to the past, including times of soon after and before World War II, Taisho and Meiji eras (early 20th to late 19th century), Edo and Muromachi eras (late 19th to 16th century), and finally up to Heian era (12th to the end of 8th century).

### *2.2.1. Landscape Changes in the 20th Century*

Based on the distribution data of *machiyas* identified by aerial photographs in 1928, 1948, 1961, 1974, 1987 and 2000, VR data of *machiyas* automatically generated by "Machiya VR Generation Macro" were located on MAPCUBE® of Kyoto. The types of *machiya* were randomly selected.

It clearly shows that *machiyas* facing major streets disappeared first, then the disappearance gradually expanded inward the street blocks. As the result, modern high-rise buildings have become more and more dominant in urban landscapes (Figure 5).


*Figure 5.* Changes of landscape (left), and Gion Festival (right)

*2.2.2. Reconstruction of Heian-kyo*

When Kyoto was founded in A.D. 794 as the capital of Japan, the city was called Heian-kyo. The authors have started the reconstruction of Heian-kyo, based on available historical documents and information. The topographical data has been reconstructed using excavation and boring survey results. Street blocks and buildings have been modeled using 3D CAD based on design drawings for miniature model of Heian-kyo which was made by the city of Kyoto celebrating 1200$^{th}$ anniversary. Those models have been automatically located according to the land use plan at that time (Figure 6).

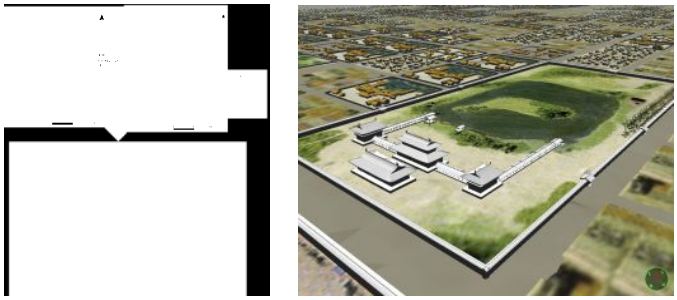

*Figure 6.* 3D Reconstruction of Heian-kyo

## 3. Concluding Remarks

The research will continue to reconstruct historical city of Kyoto starting from the present going back to the past while making varieties of digital contents which constitute the landscapes at different times. We continue

adding VR models based on all available historical information and documents. At the final phase we intend to employ "Kyoto Virtual Time-Space" as a platform to integrate a large collection of digital archives of arts and entertainment in geographical context of Kyoto with its historical landscapes. And it should play a very important role in the assistance for urban planning, cultural preservation, and tourism promotion of Kyoto, as well as sending rich information on Kyoto to the world through the internet.

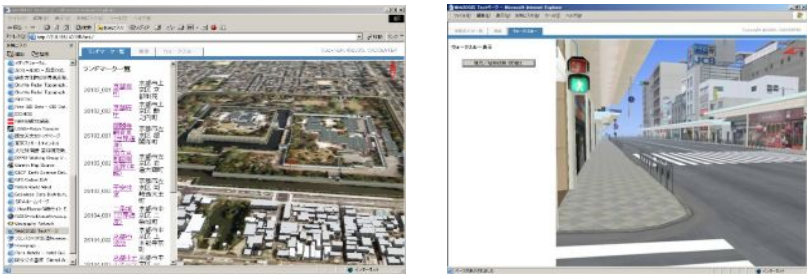

*Figure 7.* "Kyoto Virtual Time-Space" on web

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