This research integrates GIS and virtual reality (VR) technologies to develop a 4D GIS, "Kyoto Virtual Time-Space," in which we can virtually travel over space and time in the Japanese historical city of Kyoto. For this purpose, a database of elements that comprise urban landscapes in Kyoto is created starting from the present going back to the past through the 20th to 17th centuries, and finally to the Heian period (12th to 8th centuries, when Kyoto was founded) based on available historical documents, maps and other information. Locations are identified on a 2D GIS and a 3D VR technique is employed to visualize the urban landscapes. Finally, the 3D GIS is created for several time slices to form the 4D GIS. The "Kyoto Virtual Time Space" will be made public as a Web GIS on the Internet.
Virtual Kyoto

**Time Periods Setting**

- **Heisei era** (1990s - present)
- **Showa era** (1920s - 1980s)
- **Taisho era** (1910s)
- **Meiji era** (late 19thC - early 20thC)
- **Edo era** (17thC - late 19thC)
- **Heian era** (late 8thC – 12thC)

**OUTLINE of PRESENTATION**

1) 3D city model of Kyoto at Present
2) Urban landscape changes during Showa era
3) Restoring urban landscape of Taisho & Meiji eras
4) Restoring urban landscape of Edo era
5) Restoring urban landscape of Heian era
6) Kyoto virtual time-space using 4D-GIS and VR technologies
3D city model generation system and MapCube™

2D Digital Map  
Aerial Image Data  
LiDAR Data  
3D City Model Automatic Generation System  

Photo-realistic 3D City Model (MapCube™)

Textured models of existing buildings

Actual Kyoto

Virtual Space

Kyo-machiya (Traditional town-house in Kyoto)
**Kyo-machiya**

*Kyo-machiya* has its origin in the Heian era. After the 14th century, all merchant houses were called machiya. Later, the traditional private houses within the central city were also referred to as Machiya.

Almost of extant *kyo-machiya* (now about 28,000) were originally constructed between the late Edo era and early Showa era.

*Kyo-machiya* are built to be extremely narrow and deep because years ago property taxes were determined by the width of the street frontage.

The layout of *Kyo-machiya* is simple, and they have several traditional exteriors.

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**Several Types of Kyo-machiyas**

<table>
<thead>
<tr>
<th>Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sonikai</td>
<td>47.0%</td>
</tr>
<tr>
<td>Chunikai</td>
<td>19.3%</td>
</tr>
<tr>
<td>Sankai</td>
<td>13.6%</td>
</tr>
<tr>
<td>Hiraya</td>
<td></td>
</tr>
<tr>
<td>Simotaya</td>
<td></td>
</tr>
<tr>
<td>Haitsuki</td>
<td></td>
</tr>
<tr>
<td>Kanban</td>
<td></td>
</tr>
</tbody>
</table>

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**Real space**

*Kyo-Machiyas (Townhouses)*

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**Sheets of Kyo-machiya exterior surveys**


Recording:
- Types
- Exteriors
- Building conditions and so on.
About 28,000 Kyo-machiya were identified in this study area in 1998.

Survey organisation

Type-specific distribution

Gion area

Condition-specific distribution

3D VR models of Kyo-machiya

Automatic generation of Kyo-machiya VR models

Automatic generation of 3D-VR models of Kyo-machiya

Procedure

1) Getting the following data from GIS:
   - Centroid of house shape
   - Vertices of house shape
   - Distances from street edge

2) Identifying
   - Nearest vertex from street edge
   - Line of frontage

3) Calculating
   - Normal direction
   - Length of frontage
   - Length of depth

4) Identifying
   - Type of Kyo-machiya

Each part is divided

Sonikai-type

Chunikai-type

Sonikai

Chunikai

Sankaidate

Hiraya
Western-style modern buildings

Western-style modern buildings built between late 19th century and World War II.

According to Directory of Japanese Modern buildings, there are 570 heritage buildings in Kyoto. However, a recent survey by Kyoto city government identified no less than 2,000 western-style modern buildings in Kyoto.
3D-VR models of modern heritage buildings (1)

Minami-za theater in Map Cube™

Parade of Yamahokos in Gion festival at 17th July
How to create 3D VR models of Yamahokus

1. Laser scanning for detailed miniatures of Yamahokus
2. Getting digital images of real Yamahokus
3. 3D models from digital images
4. Data processing

3D VR models
(from detailed one to thirteen size miniatures possessed by Kyoto chuo Shikin bank)

Kanko-hoko
函谷鉾

Fune-hoko
船鉾

Nodes: 2,034,739
Polygons: 3,934,863
Measures: 94

Nodes: 1,014,720
Polygons: 1,934,863
Measures: 74

GIS/VR of Shrines and Temples
352 Shrines
1,308 Temples
Examples of identifying *Kyo-machiyas* through aerial photos

**Construction of Spatio-temporal *Kyo-machiya* GIS database**

- Geometrical adjustments
- Identifying *kyo-machiyas* and vectorising them
- Creating GIS database of *Kyo-machiyas*

Changes of urban landscapes Urban landscape simulation

**Old topographic maps**

To identify the streets blocks
1:10000, 1:25000, 1:25000 old topographic maps during 1922 - present

**Aerial photos**

- From 1928 to 2000
- 1928
- 1930
- 1948
- 1961
- 1974
- 1987
- 2000

2D

3D

**Heian-jingu** 平安神宮
**Sanjusanken-do** 三十三間堂
Spatio-temporal database of Kyo-machiya
Virtual Kyoto in Taisho and Meiji eras

Kyoto Cadastral Map in 1912
1 : 1,300

Old street photos

Box of Kyoto Cadastral Map in 1912
357 sheet maps and about 65,000 registers (landlords)

Sample of a sheet map of Kyoto Cadastral Map in 1912
27cm
20cm

3D
2D
Contents of Kyoto Cadastral maps in 1912

Lot number

Number of Cadastral maps

Tram line

River/canal

National rail

Town boundary

Lot boundary

Boundary of wards

Area (tan or tsubo)

Direction

Jigsaw puzzling of Kyoto Cadastral sheet maps on ArcGIS

Contents of Kyoto Cadastral register

Town name

Lot number

Grade of lot

Land category

Area (tan)

Land prices

Address of landlord

Name of landlord

1: 20000 Topographic map in 1912

Land price map in 1912
Time Periods Setting

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- **Heian era** (late 8thC – 12thC)

**World War II**

**Ancient Capital**

**Modern age**
Archaeological sits data from geographical stratums from archaeological excavations and old documents.

2D

1: 20000 Topographic map in 1912

3D

Heian-kyo in 794

Architectural plans of houses by historians

Restoration of the ground surface in Heian era

Land use of Heian-kyo (late 8th – 12th C) from old documents

DEM at present - Depth of sediment deposition = DEM in Heian era
3D/VR modelling of a house in Heian era

- Cypress thatching
- Facade & wall surface

Allocation of houses within blocks

Allocation of houses based on landuse

Other buildings model

Land use database

 allocation

Allocation of houses based on landuse

神泉苑北から法勝寺
Time traveling in Kyoto Virtual Time-Space

Urban Landscape changes in 1928 in 1948 in 1961 in 1974
Time traveling in Kyoto Virtual Time-Space II

Landscape changes of the Gion Festival in 1987 and in 2000.
Kyoto Virtual Time-Space on the web

http://www.geo.lt.ritsumei.ac.jp/uv4w/frame.jsp

3D WebGIS (Urban Viewer for Web)

Client PC

Web server

GIS database

3D city data

Database server

Mobile client (future)

Edition

Management

Reference

Client PC

Internet

Internet

Client PC

2D

3D
Urban Viewer for Web

Time Slip

Kyoto Virtual Time-Space
(4D GIS + WebGIS technologies)

- Reconstructing the historical city of Kyoto starting from the present going back to the past by digitally archiving urban landscapes at different times.
- Time travelling through the historical landscapes in Kyoto
- Platform to integrate a large collection of digital archives of arts and entertainments of Kyoto.

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http://www.ritsumei.ac.jp/acd/cg/lt/geo/coe/index.html

Authors information