VIRTUAL KYOTO: VISUALIZATION OF HISTORICAL CITY WITH 4D-GIS, VIRTUAL REALITY AND WEB TECHNOLOGIES

Y. Takase[a+c], K. Yano[a], T. Nakaya[a], Y. Isoda[b], T. Kawasumi[a], K. Matsuoka[a], T. Seto[a], D. Kawahara[a+c],
A. Tsukamoto[a], M. Inoue[a] and T. Kirimura[a]

takaseyutaka@yahoo.co.jp, (yano@lt., nakaya@lt., isoda-y@apu., kawasumi@fc.) ritsumei.ac.jp
[a] Ritsumeikan University, 56-1, Tojiin-kitamachi, Kita-ku, Kyoto, Japan 603-8677
[b] Ritsumeikan Asia-Pacific University, 1-1, Jumonjibaru, Beppu-shi, Oita, Japan 874-8577
[c] CAD Center Corporation, 2-3-21, Kouraku, Bunkyo-ku, Tokyo, Japan 112-0004

KEY WORDS: GIS, City, History, Visualization, Cultural Heritage, Three-dimensional, Internet/Web, Virtual Reality

ABSTRACT:

Virtual Kyoto is a virtual time-space created on a computer for the purpose of investigating the past, present and future of the historical city of Kyoto. Using the cutting-edge technologies in GIS and VR (virtual reality), the authors have been constructed Virtual Kyoto as 4D-GIS that comprises a series of 3D-GISs for different eras. The 3D modeling of the city began with the present Kyoto, and has gone back to the past eras, including those soon after and before the World War II, the Taisho and Meiji eras, pre-modern Edo era and finally back to Heian era when the city of Kyoto was founded in the late 8th century. The aims of the creation of Virtual Kyoto include; 1) to archive geo-referenced materials such as current digital maps, old topographic maps, cadastral maps, aerial photographs, picture maps, street photographs, landscape paintings, archaeological sites data, and historical documents; 2) to create a database of all existing buildings including machiyas (traditional townhouses), modern heritage buildings, shrines and temples including historical and cultural heritages; 3) to create VR models of the abovementioned buildings; and d) to estimate and simulate the land use and landscape changes over the studied periods using aforementioned materials. Virtual Kyoto is an infrastructure to place a variety of digitally archived materials associated with the city, and to disseminate varieties of sophisticated styles of culture and art of Kyoto to the world over the Internet. The web-based system provides user-friendly interface to explore comprehensive information on culture and art of Kyoto with its historical landscapes. Virtual Kyoto will play significant roles in assistance for urban landscape planning of Kyoto as well as sending rich information on Kyoto to the world through the Internet.

1. INTRODUCTION

Kyoto, an old capital of Japan which was founded more than 1,200 years ago, and eluded damage from World War II, retains a great number of historical architecture such as temples, shrines, machiyas (traditional townhouses) and modern heritage buildings.

The research aims at reconstruction and visualization of the historical landscapes of Kyoto in different eras, which provides Kyoto's 3D-GIS starting from the present, based on automatically generated 3D city model, going back to the past, including those soon after and before World War II, Taisho and Meiji eras (early 20th to late 19th century), Edo era (late 19th to 17th century), and finally up to Heian era (12th to the end of 8th century). And the research also aims at making Virtual Kyoto open to the public through VR and internet (Yano *et al*., 2006, 2007).

Virtual Kyoto has been a part of "Kyoto Art Entertainment Innovation Research (2002-2006)" at Ritsumeikan University driven by the 21st Century COE (Center of Excellence) program funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), and now handed over to the Global COE program (2007-2011) titled "Digital Humanities Center for Japanese Cultures and Arts".

This paper introduces our Virtual Kyoto and suggests the utilization of Virtual Kyoto for Digital Humanities research.

2. VIRTUAL KYOTO

Virtual Kyoto is 4D-GIS including time dimension to conventional 2D-GIS and 3D VR models. It is capable of accommodating various geographical information of different eras. This feature has been crucial from the outset of the research because the goals of Virtual Kyoto project were to represent the history of the city and to reconstruct the city's past urban landscapes.

In Virtual Kyoto we adopted MAP CUBE® (CAD Center Co., Ltd). The data consists of 3D geometry models of buildings based on building footprint and height, for the whole city of Kyoto (Figure 1). The 3D geometry models are automatically generated by extruding building footprint data with air-borne laser-profiler data which took height values at an interval of less than 2.5m within error of 15cm as illustrated in Figure 2. Kyoto, a historical capital of Japan founded in 794 AD, retains large number of historical architecture such as temples, shrines, machiyas and modern western buildings of the pre-war period. Fortunately, the city suffered no serious damages in the World War II. Starting from the 3D models of Kyoto at present, more and more 3D models of the city in the past have been reconstructed, resulting in VR models and associated information of Kyoto in different eras. As a consequence, the authors have created 4D-GIS (3D-GIS with time dimension) of Kyoto.

The system now supports a number of new areas of geographic inquiries, and gives us rich and significant findings, with its comprehensive 3D visualization of historical contexts and varieties of useful information of Kyoto through time.
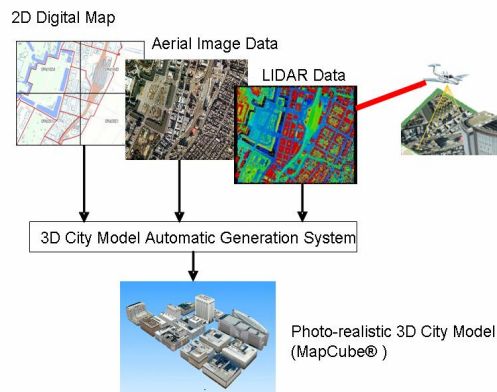

Figure 1. 3D city model of Kyoto

Figure 2. Automatic generation of 3D city model (MapCube®)

3. KYOTO AT PRESENT

The authors first modeled the present-day Kyoto before reconstructing the past Kyoto. Kyoto was exempt from air raids in the war, and thereby retained numerous pre-war buildings, such as machiyas, temples, shrines and western style buildings. Machiyas, or traditional townhouses, in particular are of special importance to the reconstruction of Kyoto because most urban areas of Kyoto consisted of machiyas in the pre-modern period (Figure 3).

The landscape of Kyoto characteristically consists of natural elements such as the mountains surrounding the city and the rivers, as well as the built elements including machiya, temple, shrine and modern heritage building. Therefore, the research firstly aimed at the construction of 2D-GIS of those elements and then the 3D-GIS were built based on them.

3.1 Machiya

Machiyas (Figure 4), traditional townhouses of Kyoto, most of which had been built in between the 18th century and World War II, have been decreasing rapidly in recent decades. Today, it is a very important issue how to evaluate machiya and to

hand their historical and cultural value to the future generations.


Figure 3. Distribution of machiyas by type

Figure 4. Typical machiyas in Kyoto
(left: So-nikai or full 2 story, right: Chu-nikai or lower 2 story)

However, they still are dominant elements of the urban landscape of Kyoto, and there are approximately 22,000 units today. Considering that there still are many machiyas in Kyoto, a computer program for automatic generation of machiya 3D models has been developed as a macro package of Microsoft Excel. "Machiya VR Generation Macro" retrieves the coordinates and attribute data of machiyas from GIS database, applies one of machiya library models for each lot, resizes the model matching to the width and depth of the building lot, and places the model in the VR space (Figure 5).
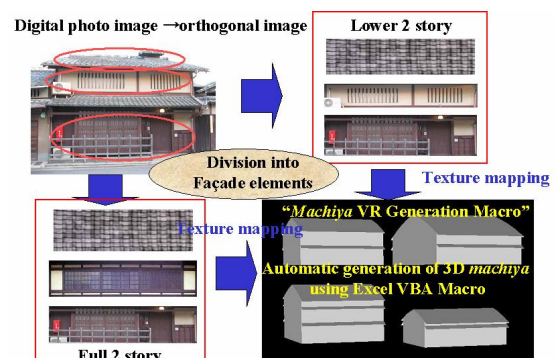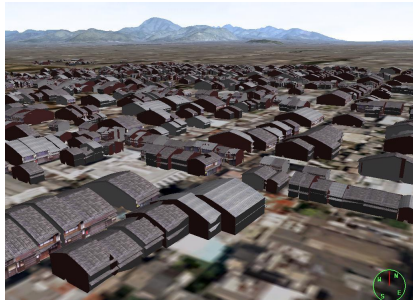
Figure 5. Automatic generation of machiya VR model (upper)
and machiya models in Virtual Kyoto (lower)

3.2 Architectural Heritage

Kyoto city has been the cultural capital of Japan and consequently houses the largest collection of architectural heritage including famous temples, shrines and western-style modern buildings, which were built before World War II. There are 375 designated or registered cultural heritage buildings (Figure 6), and the city itself constitutes the cultural legacy.
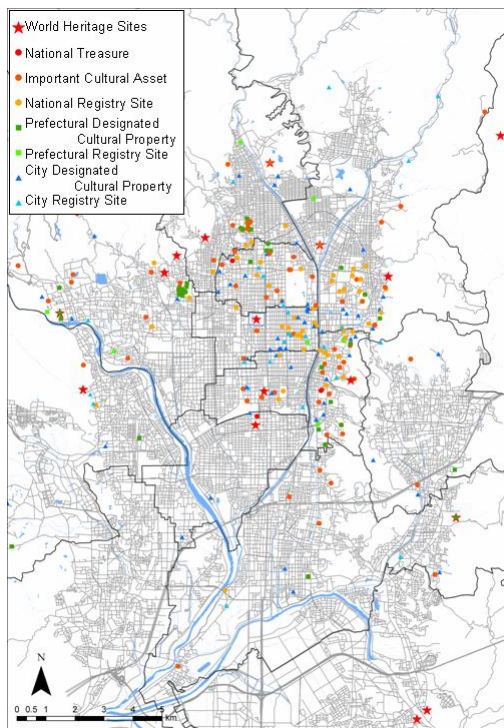

Figure 6. Distribution of designated and registered cultural
heritage buildings, Source: Kyoto city

There are approximately 2,000 modern heritage buildings, based on the recent survey by the city of Kyoto. These buildings were designed and built when architects in Japan started to incorporate western design in their works. Typical western-style buildings are made of brick. However, we can also find many modern buildings with other structures including reinforced concrete, wood, and the combination of wood and modern structures (Figure 7).

Needless to say, Kyoto has large number of temples and shrines: approximately 1,300 temples and 350 shrines. Among them, 16 temples and shrines, and the Nijo Castle are designated as World Heritage sites, and the areas around them are subject to the restriction against real estate developments to preserve the urban landscape of Kyoto.

In addition to 3D geometry model of Kyoto, 3D models of well-known buildings such as those in World Heritage sites have been made with detailed geometry and texture (Figure 8).
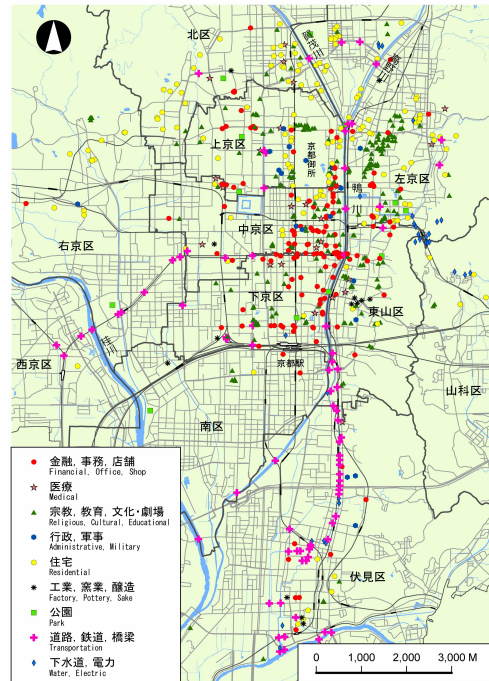

Figure 7. Distribution of modern heritage buildings
by type (Source: the field survey by the authors)

Figure 8. Detailed VR model examples
(left: Kiyomizu-dera, right: Kinkaku-ji)

3.3 Minami-za theatre and Shijo Street

Minami-za theater was originally constructed in 17th century on Shijo Street, which was close to the place where the first Kabuki was performed in early 17th century. Although there were seven major theaters along Shijo Street in 17-18th century, Minami-za theater solely remains on the street today. The creation of 3D model of the theater has been an important issue in the project. A detailed 3D model including interior space of the building was also created based on architectural drawings.

A detailed 3D model of Shijo Street, on which Minami-za theater is located, has also been created, allowing walk-through of the street and interior space of Minami-za theater (Figure 9). In the VR environment, it is planned to show virual Kabuki performance or traditional dance, created by motion capture techniques applied to real performances.

Figure 9. Shijo Street and Minami-za theater

3.4 Gion Festival and Yamahoko float

Gion Festival, held in every July in Kyoto, is one of the most famous festivals in Japan. It originated in the mid 9th century, evolved to be the current style by the mid 14th century and continues until today. During the festival, 32 Yamahoko floats representing neighborhoods parade on the streets of downtown Kyoto, including Shijo Street. Yamahoko parade of Gion Festival becomes a symbolic landscape of Kyoto during the festival period. At present, four VR models of representative Yamahokos have been created by laser scanning of detailed miniatures and digital images of the real Yamahokos taken by digital cameras during the festival, as well as by manual modeling with reference so architectural drawings of the floats (Figure 10).
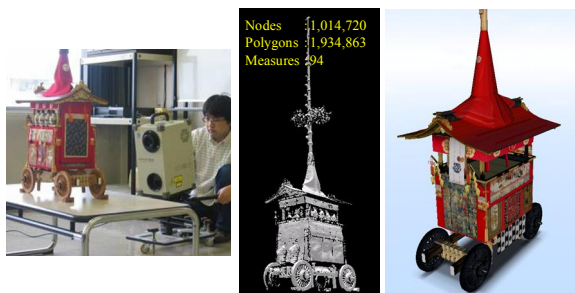

Figure 10. Laser scanning of miniature Yamahoko and VR model

4. 3D RECONSTRUCTION OF KYOTO OF THE PAST

In the research, 3D reconstruction of Kyoto at different eras have been and are being conducted, starting from the present to the past, including times of soon after and before World War II, Meiji and Taisho eras (late 19th to early 20th century), Edo era

(17th to late 19th century), and Heian era (late 8th to 12th century).

4.1 Landscape changes before and after World War II

Machiyas employ gable roof covered with roof tile. The observation of aerial photographs makes possible identifying machiyas distinguishing from other type of houses. Six sets of aerial photographs taken after World War II at approximately 13 years of intervals since the 1928 have been used (Figure 11). The photographs are from the city of Kyoto; 1928, US Army Air Force; 1946, Geographical Survey Institute; 1961, 1974, 1987, and Nakanihon Airline; 2000. The photographs were scanned and rectified to fit to the map. Then gable roofs were traced to make the building footprint data of machiyas. Based on the distribution data of machiyas identified by aerial photographs, VR data of machiyas automatically generated by "Machiya VR Generation Macro" were placed into the Virtual Kyoto. It clearly shows that machiyas facing major streets disappeared first, and the disappearance gradually expanded inward the street blocks. Modern high-rise buildings have become more and more dominant in urban landscapes (Figure. 12).
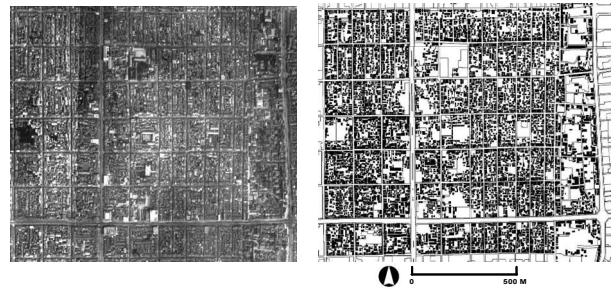

Figure 11. Identification of machiyas in the aerial photograph as of 1928 (left: aerial photograph of Kyoto (Source: Kyoto University Library), right: identified machiyas input in GIS)
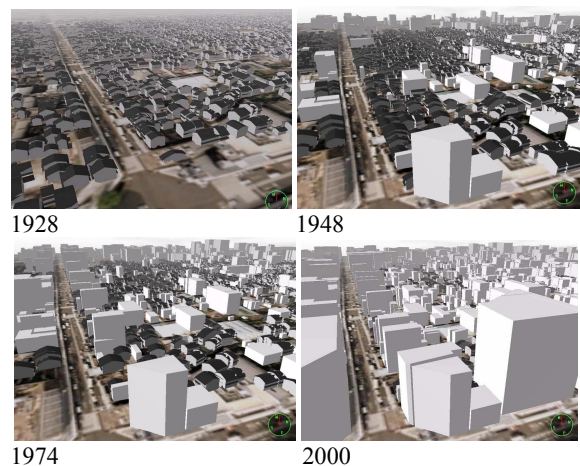

1928   1948

1974   2000

Figure 12. Changes in urban landscape of Kyoto

4.2 Kyoto during Meiji and Taisho eras

Figure 13 shows landscapes of Shijo Street at present and that in 1910's. The landscape at present has been visualized based on MAP CUBE® of Kyoto with additional textured models of the buildings along the street. The landscape in 1910's has been visualized based on digitized cadastral maps of 1912 and

"Machiya VR Generation Macro." In addition, Yamahoko floats were placed on Shijo Street in order to reconstruct Gion Festival at different times. The figure shows that Yamahoko floats look as very big objects in 1910's though they look smaller at present surrounded by high buildings. The visible ranges of mountains were much greater in older times.

Figure 13. Landscape changes of Gion Festival
(left: in 1910s, right: at present)

4.3 Kyoto in early Edo era

Kanei-go-Manji-mae-Rakuchu-Ezu, drawn in 1640's and presently owned by Kyoto University, is known as a considerably accurate map of Kyoto. It has the size of 636cm by 282cm and shows names of towns and streets, land use, widths of streets, widths and lengths of blocks and major building lots and names of landowners. The map was scanned, and rectified to fit to the modern map. After these geometrical adjustments, streets, blocks and major building lots were traced, and their attribute data were input on a 2D-GIS system. Using the GIS database 3D reconstruction of Kyoto in 17th century was conducted (Figure 14).
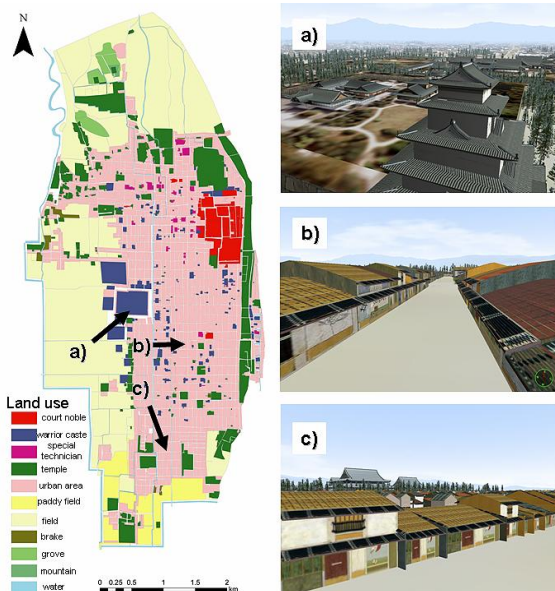

Figure 14. Land use map of Kyoto in 1640's and the reconstructed landscapes in the era
(Landscape images on the right are the views from the points of a), b), and c) in the map. Source: Kyoto University Library).

4.4 Virtual Heian-kyo

When Kyoto was founded in A.D. 794 as the capital of Japan, the city was called Heian-kyo (Heian capital). 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 geological and archaeological results. Street blocks and buildings have been modeled using 3D CAD based on blue prints for miniature model of Heian-kyo, which was made by the Kyoto City celebrating its 1200th anniversary. The 3D models have been automatically located according to the land use map of that time (Figure 15).
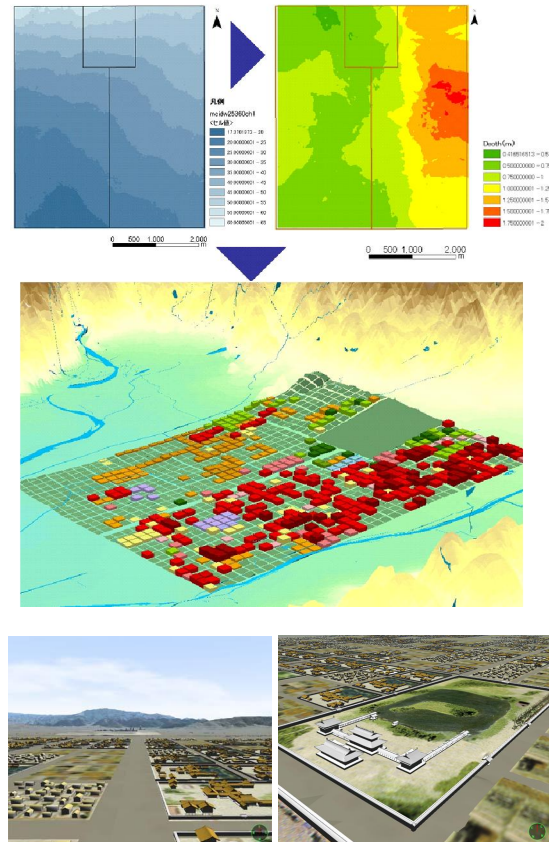

Figure 15. 3D Reconstruction of Heian-kyo

5. VIRTUAL KYOTO ON THE WEB

With the rapid expansion of the broadband communication environment through the world, the transmission of 3D city models and associating information on the internet is gaining reality. However, some relatively narrow broadband communication environments such as DSL, which is popular in Japan, cannot smoothly transmit a great amount of 3D data.

To solve the problem, the authors have employed a Web3D-GIS system called UrbanViewer for Web™ (CAD Center Co., Ltd.), 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. 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.

When internet users visit the website of Virtual Kyoto provided by Ritsumeikan University, and download UrbanViewer for Web™, they can enjoy 3D-GIS of Kyoto at present as well as in the past in interactive ways. It provides

fly-through of the 3D city viewing detailed models of cultural heritage including temples, shrines, castles and modern heritage buildings, with associated information. It also provides walk-through of detailed streets and sites with associated information.

The authors have created detailed models of the buildings and streets along Shijo Street that visitors can enjoy walk-through and even enter the Minami-za theater. A reconstruction of Shijo Street in 1930s has been also created. They also can enjoy walk-through and fly-through of Heian-kyo. Actually the visitors to the site can enjoy Kyoto in different eras switching one and another just by cricking buttons on monitor screens (Figure 16, Figure 17).
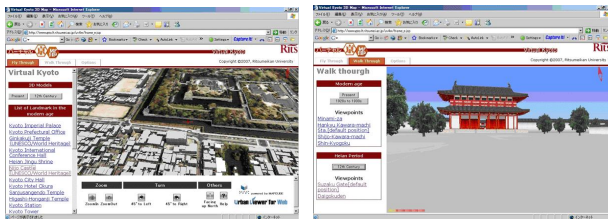

Figure 16. Virtual Kyoto on the internet
(left: fly-through of Kyoto at present, right: walk-through of Heian-kyo)

Figure 17. Walk-through in Shijo Street
(upper: at present, lower: in 1930s)

6. CONCLUSION

The research will continue to reconstruct the historical city of Kyoto starting from the present going back to the past while making more varieties of digital contents which constitute urban landscapes of Kyoto at different eras. At the final phase of the research, the authors intend to employ Virtual Kyoto as a platform to integrate a large collection of digital archives of arts and cultures in Kyoto. We expect that Virtual Kyoto will be a base for a newly launched research project, "Digital Humanities Center for Japanese Arts and Cultures" at Ritsumeikan University.

The growth of the web-based 4D-GIS of Virtual Kyoto will form a new base for museology (museum studies). We can put various digital contents on our 4D-GIS. The system would provide user-friendly interface to explore historical materials of arts and entertainments in the geographical context of Kyoto. This system also will play significant roles in the assistance for urban landscape planning of Kyoto. Now in Kyoto we have

serious issues concerning historical landscape conservation. Virtual Kyoto will support greatly making important decisions regarding those issues through clearly contextualizing the historical settings of Kyoto.

References from Journals:
Yano, K., Isoda, Y., Nakaya, T., Kawasumi, T., Matsuoka, K., Takase, Y., Kawahara, D., Kawahara, N., Inoue, M., Tsukamoto, A. and Kirimura, T., 2006. Creating virtual time-space of Kyoto. *E-journal GEO*, **0**(0), pp.12-21.

References from Books:
Yano, K., Nakaya, T. and Isoda, Y. eds., 2007. *Virtual Kyoto*. Nakanishiya.

References from Other Literature:
Takase, Y., Sho, N., Sone, A. and Shimiya, K., 2003. Automatic Generation of 3-D City Models and Related Applications, *International Workshop on Visualization and Animation of Reality-based 3D Models*, CD-ROM, Tarasp-Vulpera, Switzerland.

Takase, Y., Sone, A., Hatanaka T. and Shiroki, M., 2004. A Development of 3D Urban Information System on Web, *International Workshop on Processing and Visualization using High-Resolution Imagery,* CD-ROM, Pitsanulok, Thailand, 2004.

References from websites:
Virtual Kyoto by Ritsumeikan University.
http://www.geo.lt.ritsumei.ac.jp/webgis/ritscoe.html
CAD CENTER Corporation.
http://www.cadcenter.co.jp