Virtual Kyoto

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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, we built Virtual Kyoto which is 4D-GIS that comprise a series of 3D-GIS at different points in time. Our 3D city modeling begins with the present Kyoto and then goes back to the past, 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. Creating Virtual Kyoto includes the following projects: a) archiving geo-referenced materials such as current digital maps, old topographic maps, cadastral maps, aerial photos, picture maps, street photos, landscape paintings, archaeological sites data, and historical documents; b) creating a database of all existing buildings including machiyas (traditional town houses), early modern buildings, shrines and temples including historical and cultural heritages; c) creating 3D VR models of the above buildings; and d) estimating and simulating land use and landscape changes over the study periods using aforementioned materials. Virtual Kyoto is an infrastructure to place various digitally archived materials associated with the city, and to disseminate Kyoto's subtle and sophisticated forms of cultures and arts to the world over the internet. The web-based system provides user-friendly interface to explore historical materials of cultures and arts in the geographical context of Kyoto with its historical landscapes. Virtual Kyoto should play a valuable role in the assistance for urban landscape planning of Kyoto as well as sending rich information about Kyoto to the world through the internet.

1. INTRODUCTION

Large amounts of various geo-spatial data have been accumulated since the GIS revolution of the late 1980s, supported by advances in IT technology, new survey methods, and high-resolution satellite images (Longley et al., 2001)[1]. Such evolutions in GIS environments have enhanced 3D-GIS and Virtual Reality (VR) models in terms of precision and quality. Our Virtual Kyoto project uses the cutting-edge 3D-GIS/VR technologies to restore historical urban landscapes of Kyoto (Yano et al., 2006, Yano et al., 2007)[2][3].

This Virtual Kyoto project 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) entitled "Digital Humanities Center for Japanese Cultures and Arts". It aims at reconstruction and visualization of historical landscapes in Kyoto using by 4D-GIS of Kyoto, 3D-GIS of Kyoto with a time dimension. The Virtual Kyoto is built on a 4D GIS database of Kyoto that becomes a container of digitally archived materials, such as Japanese drawings and performing arts that are being digitally archived recently. The contents of the database can be explored by a "real time" interactive system, so that users have the capability of navigating freely in the 4D space. We realize an on-line access to the virtual city of Kyoto over the internet. This paper introduces to our Virtual Kyoto and suggests the utilization of Virtual Kyoto for Digital Humanities research.

2. WHAT IS VIRTUAL KYOTO?

In this paper we define virtual cities as 3D urban models using VR technologies and having various services, functions, and information contents with realistic buildings and allowing social interactions in the same way as in real cities (Dodges et al., 1997; Fisher and Unwin, 2002)[4][5]. Crucial aspects in constructing 3D virtual cities are threefold (Shiode, 2001)[6]: (1) level of reality (amount of contents), (2) data input (retrieval of height and appearance) and (3) functionality (as practical and/or analytical tools). As intensity of geometrical content of them increases, automatic generation of the 3D models will become more difficult and cost of creation will increase. In terms of level of reality aspect, Shiode (2001)[6] defines six levels of virtual city: (1) 2D maps and orthogonalized aerial photos; (2) Image base rendering (panoramic 2D image pasted on virtual 3D space); (3) Prismatic building block models

(3D models based on building footprint and height); (4) Block modeling with image-based texture mapping (the above model with UV mapped textures); (5) Models with architectural details and roof morphology; and (6) Full volumetric CAD models (3D model using CAD data for individual buildings). In practice, it is possible to mix different levels of 3D models to create a virtual city. In this project, we have created 'prismatic building block models' for the whole city of and Kyoto, by gathering as much 2D geographical information as possible, incorporating more elaborate models with architectural details and roof morphology or full volumetric CAD models for some important architectures.

Kyoto, the historical capital of Japan founded in 794 AD, retains large number of historical architecture such as temples, shrines, machiyas (townhouses) and western buildings of the pre-war period. This is a rare case in Japan in that the city avoided the World War II damages. Unlike other restoration project, our strategy in restoring historical Kyoto is to first model the present day Kyoto as a virtual city, and then replacing the newer buildings with the previous buildings going backwards to the past. As a consequence, we created 4D-GIS (3D plus time dimension) of Kyoto. The system supports a number of new areas of geographic inquiry, especially in its ability to represent the implications of historic conditions for current and future policy in three dimensions over time.

In order to efficiently create 3D models in the whole city of Kyoto, we adopted MAP CUBE® data for basic components of Virtual Kyoto reflecting the present day Kyoto. MAP CUBE® data is composed of prismatic building blocks that are created based on high-precision laser-profiler data (from PASCO, Co.) and building footprint data (from Increment P, Co., or iPC), by using the most up-to-date technology of automated generation of prismatic models developed by CAD Center Corp. The 3D models are created by extruding building footprint data with air-borne laser-profiler data which took height values at an interval of 2.5m within error of 15cm (Figures 1 and 2). MAP CUBE® data also has some full volumetric 3D models for buildings acting as landmarks in Kyoto.

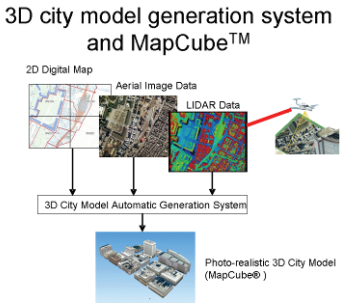


Figure 1. MAP CUBE® data generation

Figure 2. 3D city model of Kyoto

3. VIRTUAL CITY OF PRESENT KYOTO

We first modeled the present-day Kyoto before restoring the past Kyoto, because unlike other cities in Japan, Kyoto has been exempt from wartime air raid, and thus retained numerous building from pre-war period, such as machiyas, temples, shrines and western style buildings. There are four major elements of historical architectures in Virtual Kyoto for the present day as discussed below.

Figure 3. Machiyas in Kyoto

3.1 Machiyas

Machiyas or historical townhouses (Figure 3), in particular, are of special importance to our restoration project because most part of urbanized Kyoto consisted of them in the pre-modern period. Machiyas, most of which had been built in between 18th century and World War II, have been decreasing rapidly in recent decades. However, they are still dominant elements of the urban landscape of Kyoto. The research firstly aimed at the construction of 2D-GIS of those elements through large scale field surveys and then 3D-GIS were built based on them.

We use Machiya databases from 'Machiya Community-building Survey (Kyo-machiya machizukuri chosa)' (Kyoto City, 1999)[7] and 'Toyota Fund Citizen Survey of Machiyas (Toyota Zaidan niyoru Shimin Chosa)' in 1995 and 1996, for the base of 2D-GIS of Machiyas. The two database combined ('Machiya Exterior Surveys' hereafter) covers the area in central Kyoto that had been urbanized by the beginning of the 20th century. In the Machiya Exterior Surveys, investigators visited all buildings in the study area and examined whether a building is a machiya, and recorded the type, condition and use of the premise. The surveys identified about 28,000 dwelling units of machiya. Since the main aim of Machiya Exterior Surveys had been to count the existing machiyas, the geo-referencing of identified machiyas were incomplete. Therefore we matched the data to building footprint data from large scale residential maps by iPC, and we have done a supplementary survey for unmatched records with the help of Kyo-machiya Saisei Kenkyukai, an NPO who initiated the original survey (Figure 4). The changes in machiyas since 1995/8 until today are also conducted in the supplementary survey, and we will continue monitoring the changes in machiyas (Kawahara et al., 2003)[8].

Considering that there are still so many machiyas in Kyoto, a computer program for automatic generation of machiya 3D models has been developed in Microsoft Excel VBA macro. "Machiya VR Generation Macro" retrieves the coordinates and attributes of a machiya from GIS database, applies one of seven machiya type, resizes the model matching to the width and depth of the building lot, rotates and places the model in the VR space, and this is repeated for all machiyas in the database (Figure 5).

The advantage of this macro is that it is possible to visualize urban landscape with information only on building footprints and machiya types. In another words, past urban landscape can be restored according to different scenarios of past urban land use and machiya type composition (Figure 6). Although this is not a precise restoration of individual building, this would be a reasonable approximation of past urban landscape as a whole. It is also possible to model machiyas from blueprint, or laser-scanning existing machiyas, and this is done at an ad hoc basis for more important machiyas.

Figure 4. Distribution of machiyas by type

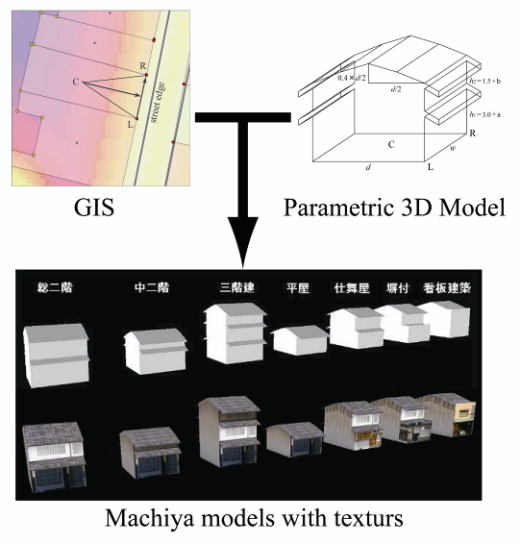


Figure 5. Machiya VR Generation Macro

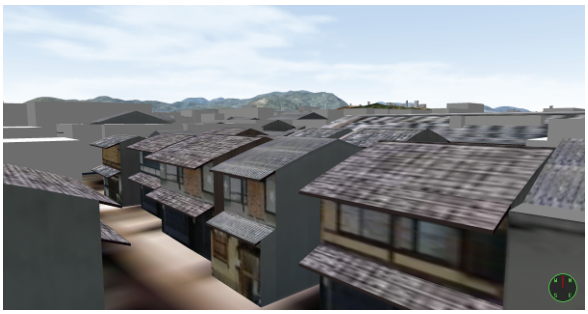


Figure 6. Machiya models in Virtual Kyoto

3.2 Architectural Heritages

Kyoto has been the cultural capital of Japan and consequently houses the largest collection of architectural heritages. There are 375 designated or registered historical buildings, and the city itself constitutes the cultural legacy. Kyoto has large number of temples and shrines: approximately 1,300 temples and 350 shrines (Figure 7). Among them, 16 temples and shrines, and the Nijo Castle are designated as World Heritage, and the areas around them are subject to development restriction to preserve the landscape.

There are also about 2,000 early modern buildings, based on the recent survey by Kyoto City. These buildings were designed and built just when Japanese architects began to incorporate Western techniques into their thinking. Representative buildings of this category are made of brick, but many different types of modern buildings including reinforced concrete buildings, wooden structures, and buildings that combined traditional wood and modern materials have also been presented in Kyoto (Figure 8).

Each individual building in these categories has its own unique character, and thus cannot be well represented by the prismatic model or automatically generated models. Several detailed VR models of those buildings are being modeled using CG/VR software (Figure 9).

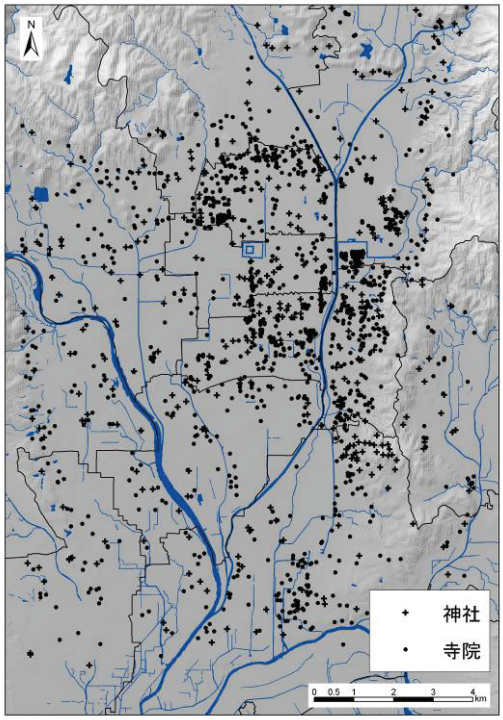
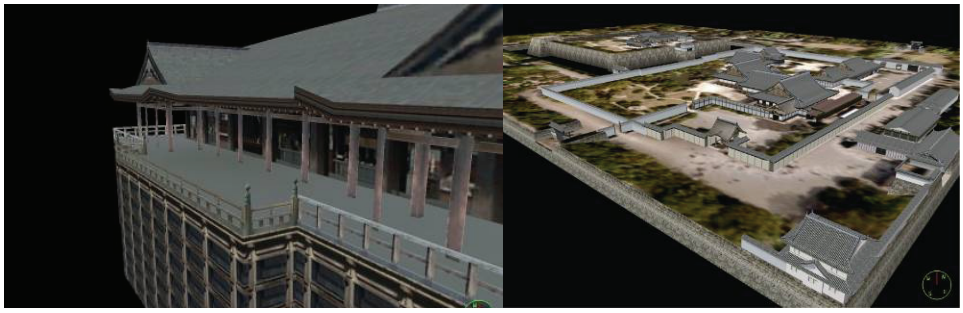


Figure 7. Distribution of shrines and temples in Kyoto

Figure 8. Distribution of early modern buildings in Kyoto by type



a) Kiyomizu-temple b) Nijo castle

Figure 9. Detailed VR model examples

3.3 Minamiza theater

Minamiza 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 theatres along Shijo Street in 17-18th century, Minamiza theatre solely remains on the street today.

In order to situate digitally archived traditional dance in the digitally constructed landscape, modeling the theater has been an important issue in our project, A detailed 3D model that includes the interior of the building was created based on blue prints. Along with the theatre, we also created a detailed model of the street to the theatre (Shijo Street), allowing walk-through experience of the street toward the entrance of the theater, the reception and into the hall of Minamiza (Figure 10). In this VR environment, it is planned to stage virtual Kabuki performance or traditional dance, created by 'motion captures' of real performers.

Figure 10. Minamiza Theater

3.4 Gion Festival and Yamahoko float

The visual element that consist historical urban landscape is not limited to buildings, we attempt to model landscapes of Gion festival that originate in the mid 9th century, which has evolved to take the current form by the mid 14th century and continued until today with minor interruptions. During the festival, 32 Yamahokos (floats) representing each local neighborhood parade in the city centre, including Shijo Street. Yamahoko parade of Gion Festival becomes a symbolic landscape of Kyoto during the festival period. Yamahokos of similar scale have been enshrined over the centuries (Ashikaga, 1994)[9], and thus are one of the important visual elements that existed throughout our study period.

At present, four VR models of Yamahokos (Kankoboko, Funeboko, Naginataboko and Kitakannonyama) have been created by laser scanning detailed miniatures and digital images of the real Yamahokos taken by digital cameras during the festival, as well as by manual modeling based on blue prints (Figure 11). These 3D Yamahoko models placed in the VR space would become a reference object to the changes in urban landscape over the years.

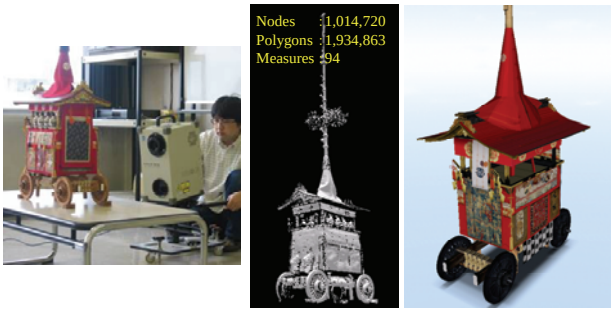


Figure 11. Laser scanning of the miniature Yamahoko and its VR model

4. THREE DIMENSIONAL RECONSTRUCTION OF KYOTO OF THE PAST

In this research, 3D reconstructions of Kyoto at various time slices have been and 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 era (17th to late 19th century), and finally up to Heian era (late 8th to 12th century). The 5 time slices are discussed in turn below.

4.1 Landscape changes before and after World War II

We examine aerial photographs to trace the changes of the distribution of machiyas in the center of the City since the late 1920s. Machiyas employ gable roof covered with roof tile. The observation of aerial photographs makes possible identifying machiyas as different 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 12). The photos were scanned and rectified to fit to surveyed maps. Then gable roofs were traced to create the building footprint data of machiyas. Using GIS, we first traced machiyas row by row against 1928 and 1946 photograph. We then examined photographs of later years and eliminated the machiyas which no longer existed. In this way, we identified the changes of the machiyas distributions for each year for which we had photographs. The result indicates the rapid changes of machiyas distribution in six stages since 1928. Approximately 7,400 machiyas existed in this central area in 1928, 6,200 in 1946, 5,900 in 1961, 4,500 in 1974, 2,900 in 1987 and 1,800 in 2000 (Figure 13).

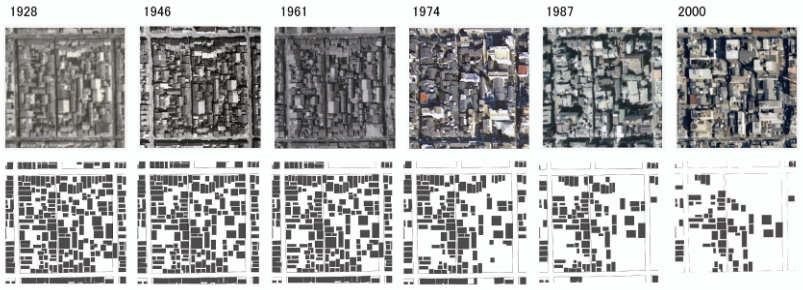


Figure 12. Identification of machiyas in the aerial photographs

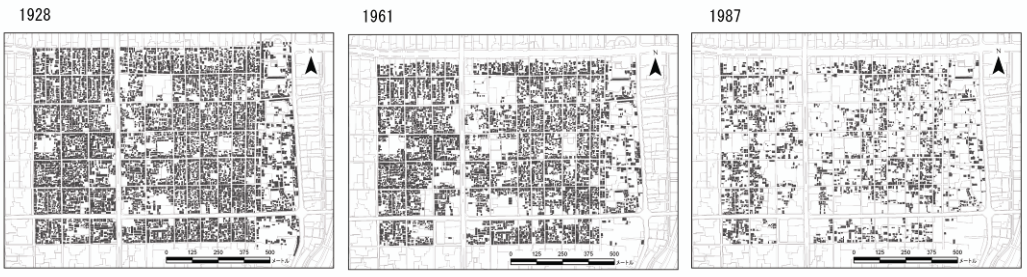


Figure 13. Changes in number of machiyas in central Kyoto, 1928-1987.

4.2 Kyoto during the Meiji and Taisho eras

Information on allocation of urban land in the past is obtained from past cadastral maps. The oldest cadastral map available is that of 1884 owned by the Kyoto Prefectural Library and Archive, but it lacks the register. Therefore, we have used cadastral map 1912 (scale 1/1,500 – 1/1,300), owned by the Ritsumeikan University Library. We have matched the past cadastral maps to current map based on the shape of neighborhood community, rather than basing on streets and intersections. This is because streets in Kyoto are substantially broadened and thus unsuitable for referencing. After this process we traced each parcel to examine the land division in the beginning of the last century (Figure 14).

The landscape in 1910's has been visualized based on digitized cadastral maps of 1912 and "Machiya VR Generation Macro." Figure 15 presumes that one house is built on one plot and constructs a virtual image of streets built up with nothing but machiyas and we get a good sense of how different the Kyoto of Taisho was compared to the present day.

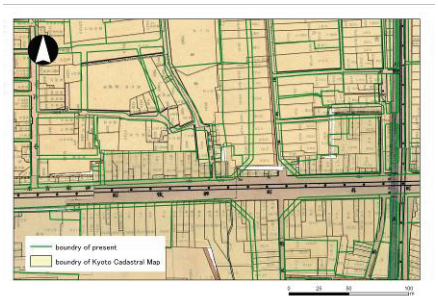


Figure 14. GIS based Kyoto cadastral map in 1912

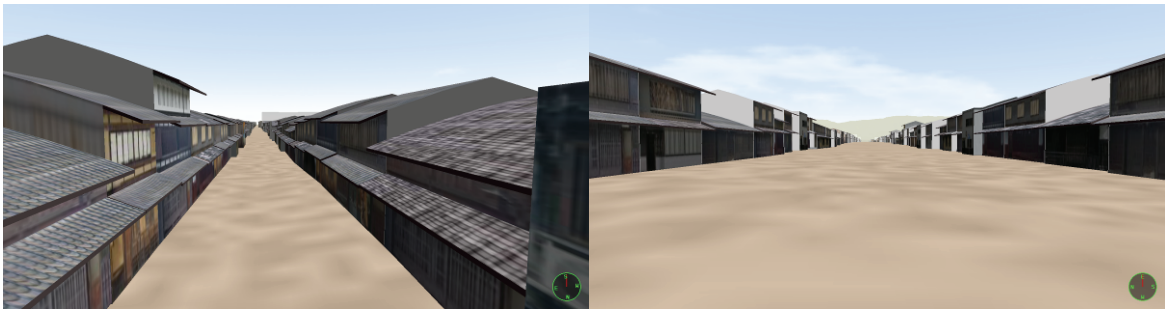


Figure 15. Urban landscapes in the early 20th century based Kyoto cadastral map

4.3 Kyoto in early Edo era

No photographs or charts exist to provide us with objective measures of Kyoto in the Edo era. However, the Edo era was a time when culture flourished, and many paintings, drawings and documents from that era survive. Some Ukiyoe woodblock prints depict landscapes of Edo era Kyoto. The series of paintings called Rakuchu-Rakugai-Zu (Views Inside and Outside Kyoto) produced in the late 14th century and after give us a detailed account of the bustling city.

Kan'ei-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. So we reconstruct early 17th century Kyoto based on this old maps. The map was scanned, and rectified to fit to the modern map (Tsukamoto and Isoda, forthcoming)[10]. After these geometrical adjustments, streets, blocks and major building lots were traced, and their attribute data were input on a 2D-GIS system (Figure 16). We reconstruct the street scenes of Edo period Kyoto by placing machiya 3D models where Rakuchu-Ezu indicated townsmen's district and lord's mansions on the lord's parcels, and on temples in the temple lands. Moreover we were able to reconstruct a model of the Nijo castle keep, which no longer exists, based on remained blueprints (Figure 17).

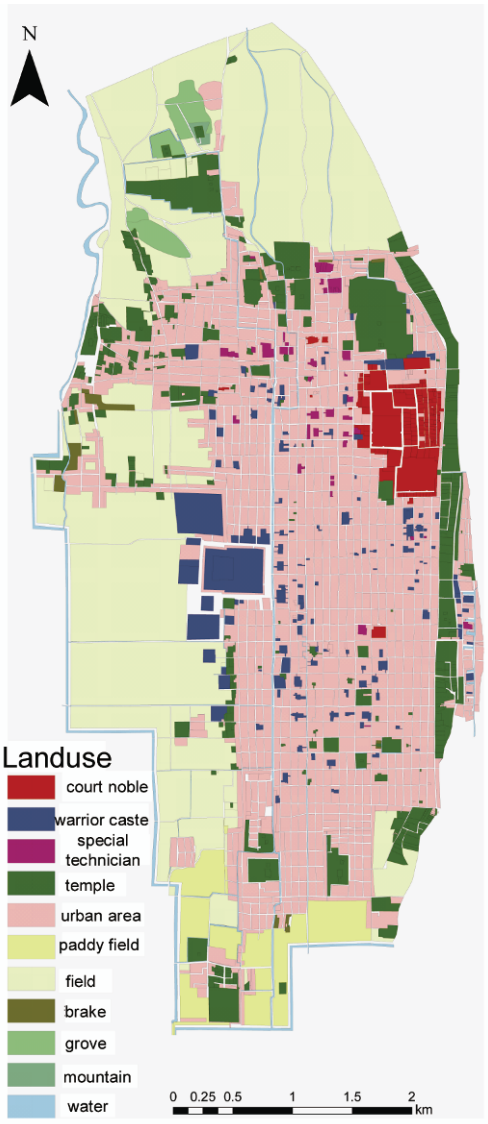


Figure 16. Kyoto Land use map in 17th century based on Rakuchu-Ezu

Figure 17. Kyoto street scene in the early Edo era.

4.4 Virtual Heiankyo

When Kyoto was founded in A.D. 794 as the capital of Japan, the city was called Heiankyo. It was built based on a rectangular street grid extending 4km from East to West and 5km from North to South. Extended excavations of Heiankyo archaeological sites have led to the accumulation of much information on the city's early environment and scenery. Many historical documents of Heian era Kyoto remain, providing valuable resources on which to base a reconstruction of Heiankyo. Based on all of the archaeological evidence and historical manuscripts collected, scholars have compiled a number of analog databases of the Heiankyo's environment and land use. The authors have started the reconstruction of Heiankyo, 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 blueprints for miniature model of Heiankyo which was made by the Kyoto City celebrating its 1200th anniversary. The 3D CAD models have been automatically located according to the land use of the time (Figure 18).

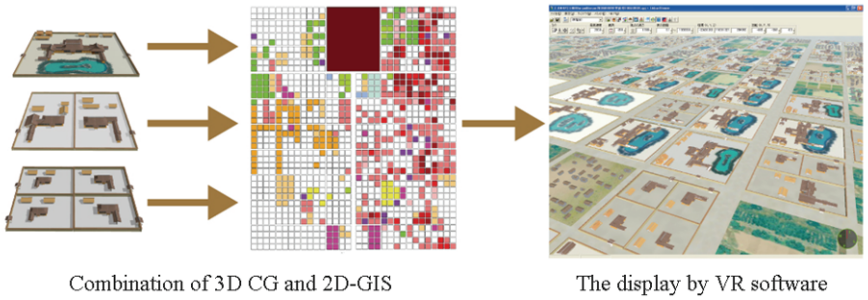


Figure 18. Virtual Heiankyo

5. TIME TRAVELLING IN VIRTUAL KYOTO

So far we created 3D-VR models of urban landscapes of Kyoto for each of several time periods. In this section we would time travel in the virtual time-space of Kyoto as 4D GIS.

5.1 Urban Landscape changes through Virtual Kyoto

We can watch the change of urban landscape through Virtual Kyoto. Based on the data of machiyas identified by aerial photographs in section 4.1, VR data of machiyas of different years were automatically generated by "Machiya VR Generation Macro" were placed in to the Virtual Kyoto (Figure 19). It shows the ways in which machiyas were replaced with modern buildings during the post-war period. 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.

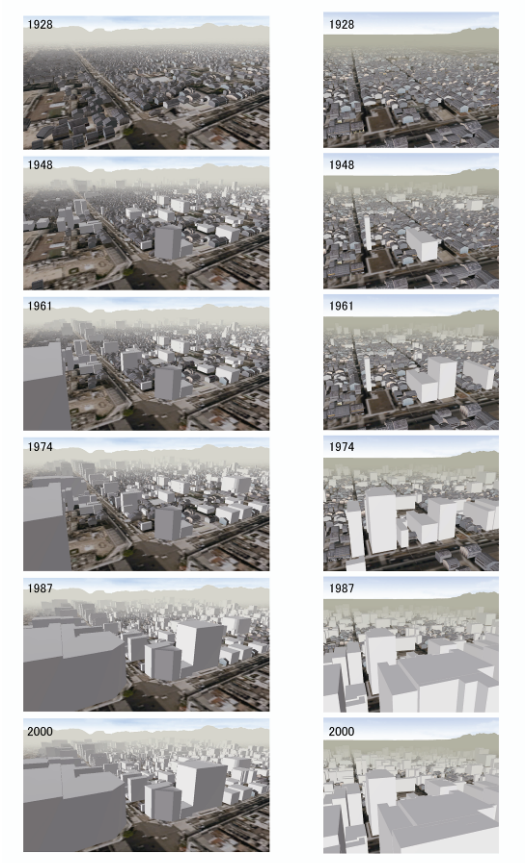


Figure 19. Changes of the urban landscape in the central Kyoto

5.2 Virtual Gion Festival

The models of Yamahoko floats were placed in the virtual time and space of Kyoto streets. We then place floats in a virtual early 20th century scene, parading them from the West, with Higashiyama Mountains as a background, and allowing us to see their huge size against the backdrop of low buildings (Figure 20). It clearly demonstrates that Yamahoko, buried among the high-rise buildings today, had been an extremely salient object in the pre-modern days. The visibility of the mountains surrounding Kyoto had been also very different. We also lined up and paraded some floats through the streets of Kyoto (Figure 21).

Figure 20. Landscape changes of Gion Festival between the present and early 20th century

Figure 21. Virtual Gion festival

5.3 Fly through over Virtual Kyoto at the different time slices

Drawing on leading edge GIS and VR technologies, we took up the challenge of creating 3D maps of Kyoto for several time slices. As a result the Virtual Kyoto we produced is a 4D GIS that includes two and three dimension GISs of various historical ages. By adding a time dimension to our GIS we created an unprecedented GIS time machine allowing travel within time and space in a manner not heretofore possible.

We can freely fly through the Virtual Kyoto. Figure 22 shows the urban landscapes of Kyoto from the same view point at present, Edo era and Heian era.

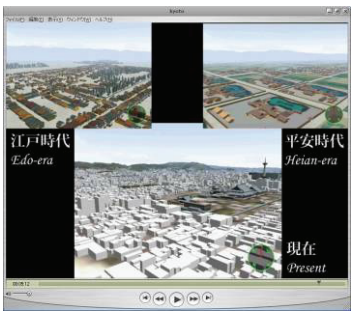


Figure 22. Fly-through in Virtual Kyoto

6. VIRTUAL KYOTO 3D MAP ON THE WEB

With the rapid expansion of the broadband communications through the world, the potential for a web-based Virtual Kyoto has been greatly increased. At its foundation, Virtual Kyoto is constructed from a 3D GIS that links the present and the past and displays the city in a high-resolution virtual reality, but on the web this kind of material needs to be displayed using 3D web-based GIS technology.

To develop a web-based 3D we use UrbanViewer^{TM} for Web (CAD Center Corp.) which is specifically designed to distribute a 3D urban model on the web. This system allows users of DSL-level broadband to view Virtual Kyoto and to interact actively using widely available browsers like Internet Explore. Users can enjoy very realistic walk-through of Kyoto neighborhoods as well as experience fly-through of the city from a bird's-eye perspective. Further, it includes functionality to search for geographic sites by place name or building types..

The model of Kyoto consists of building, landform and other shapes, and texture files; together this results in an extremely large amount of data. In order to distribute this huge data we need to use the following techniques: Data compression, Scalable topographic data, Texture files efficiently archived for application at different resolutions, Level of Detail (LOD) displayed relative to scale and Data streaming. Incorporation of these techniques allowed to distribute Virtual Kyoto over the Web.

We have constructed a web-based 3D model that demonstrates the unique characteristics of Kyoto scenery, including the landform with texture that can make use of LOD technology. We have also created a detailed model of the buildings and streets along Shijo high street that visitors can walk through and even enter the interior of the Minamiza Theater. In addition, we created a reconstruction of the same area of the 1930s. This version of Virtual Kyoto works together with the 3D city model of Heian era Kyoto, "Virtual Heiankyo on the Web". Keeping the same geographical position, users can switch the time period for the walk through scene just by clicking a button

The web-based version of Virtual Kyoto presents detailed models of temples, shrines, castles and other monuments that are UNESCO world heritage sites. A list of famous places of Kyoto is prepared on the left side of the screen so that users can instantly move their view points to the specified places. Users can also view the city from the selected site. Choosing a building on the map, viewer can call up web-search results that provide more information about it (Figure 23).

Figure 23. Web based Virtual Kyoto

7. CONCLUSION: TOWARDS THE USE OF GIS IN DIGITAL HUMANITIES

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

According to Gregory (2007)[11], Digital Humanities (also known as Humanities Computing or Computing in the Humanities), is a broad and rapidly growing inter-disciplinary field. It is concerned with using computational techniques to do the followings: (1) Create databases concerned with documents or artifacts relevant to the humanities. This involves capturing, structuring, documenting, preserving and disseminating such data; (2) Develop generic methodologies to provide new insights into these datasets; and (3) Conduct new scholarship on these databases to increase our understanding

of disciplines across the humanities. The last is the most important of the three but also perhaps the most neglected as it required inter-disciplinary collaboration between experts in technologies and methodologies on the one hand, and academics with specific research questions that they want to use information techniques to help answer. GIS with the time-dimension would provide a key tool in Digital Humanities because GIS can deal with any theme with spatial and temporal dimensions.

The capability of our web-based 4D-GIS would 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. Our experience to date with Virtual Kyoto revealed great demand for assisting urban landscape planning of Kyoto. Kyoto has serious issues concerning historical landscape conservation. Our virtual Kyoto which delivers location-based historical knowledge would effectively support a decision making for alternative futures of Kyoto by contextualizing planning in its historical settings.

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