# DEVELOPMENT OF A LANDSCAPE SIMULATION SYSTEM FOR HISTORICAL AND CULTURAL HERITAGE OF THE REGION

YASUO KAWAI
[1]*Bunkyo University*
[1]*kawai@bunkyo.ac.jp*

**Abstract.** In this study, we developed a historical and cultural landscape simulation system for Fujisawa-juku, a post town of the old Tokaido road. A game engine was used to recreate the landscape of the past by referring to old documents to inherit the history and culture of the region. Subsequently, an enhanced system was developed for changing the representation of time, season, and weather, and another system was developed for recreating the landscape using Ukiyo-e-style rendering. The developed system was exhibited at permanent installations in public facilities and at community events, and feedback from users led to major updates to the system. With the new information, we reviewed the shape of the model of the spatial components of the system and updated it to be more accurate. The digital model of this system can be updated with information that is not possible in a real model, such as a diorama. We will generalize this system through the unitization of spatial components to create a platform for historical cultural landscape simulation systems that can be used in other regions.

**Keywords.** Landscape Simulation; Historical Landscape; Local Cultural Inheritance; Ukiyoe; Game Engine.

## 1. Introduction

In recent years, the preservation of local history and culture has become a challenge for many ordinary towns in Japan because of rapid urbanization and depopulation, declining birthrates, and aging population (Yamauchi, 2009). Measures based on the Law for the Protection of Cultural Properties (1950) have been undertaken for each category including tangible cultural property, intangible cultural property, folk cultural property, historical sites, important cultural scenery, and areas for the preservation of traditional buildings, according to the characteristics of each category. However, the general historical culture of the region, which has cultivated in the lives of the locals over a long period of time, has been buried and lost to society without being designated as a cultural asset and without its value being discovered.

In 2007, the Agency for Cultural Affairs of Japan proposed the "Basic Concept of History and Culture," which provides a policy for the comprehensive inheritance and utilization of cultural properties, whether designated or undesignated, that exist widely in the region, including the surrounding

*PROJECTIONS, Proceedings of the 26th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2021*, Volume 2, 489-498. 

environment, within the society as a whole. In this project, a self-sustaining and continuous regional design that exploits the characteristics of the region is required in terms of history and culture; it is expected that the historical and cultural resources of the region will be strategically used to revitalize the region and disseminate information as regional tourism resources. We focused on the general historical and cultural landscape of the region and developed a landscape simulation system for inheriting the historical and cultural landscape of the region by visualizing it in an easily understandable approach.

The digital reproduction of historical cultural landscapes has been attempted in various places in the past. Sundstedt et al. (2004) recreated the ancient Egyptian temple of Kalabsha, which was dismantled, on a computer. El-Hakim et al. (2007) used a combination of 3D digitizing and laser scanner modeling, photogrammetry, and computer-aided architectural design to recreate a castle in northern Italy. Although these studies are based on detailed recreations of buildings, they are limited in their scope to famous temples and castles and to the level of buildings. Further, there is a problem with the massive amount of data required to create a 3D model at the town scale; however, there have been a few prior attempts at large-scale landscape simulation. Virtual city reconstruction using procedural modeling methods was performed by Dylla et al. (2008) in the Rome reborn project. Yano et al. (2008) developed a virtual Kyoto using geographic information data and virtual reality to reconstruct past and present urban landscapes. In addition, Fukuda et al. (2015) studied the level of detail and representation of natural objects in a digital recreation project of Azuchi Castle and the Old Castle Town. These are city-level simulations of past landscapes with interactive elements. However, owing to the need for a dedicated and expensive system, it is a large-scale project for a famous historical heritage site. In this study, a system that can recreate the townscape of the past was developed using a low-cost development environment based on a game development system. By using this system, it is possible to create and manage the landscape of each ordinary town in the past that is not a famous heritage or tourist attraction at the local government level.

## 2. Method

We developed a system that recreated the landscape of a post town in the late Edo period. Post towns were developed along major national roads during the Edo period in Japan, and were places where transportation of goods occurred and where travelers could rest on their journey across the country. In this study, Fujisawa-juku, a post town on the old Tokaido route (Fujisawa City, Kanagawa Prefecture, Japan) was selected as the target area. Fujisawa-juku is the sixth post town, which is about 50 km away from Edo-Nihonbashi (located in Tokyo), which is the starting point of Old Tokaido. Originally, Fujisawa-juku developed as a town for the Yugyo-ji Temple, the head temple of the Jishu Buddhist sect, which was founded in 1325; in 1601, it was developed as one of the first post towns. However, in 1887, when the railway network was built in the southern part of Fujisawa-juku, the center of the city was shifted to the station area. Currently, there are no buildings from the Edo period. This system simulates Fujisawa-juku

at the end of the Edo period-in the vicinity of the Daigiri Bridge over the Sakai River-which was the central part of Fujisawa-juku from the Yugyo-ji Temple, which is the northeastern part of the town, to Maita Honjin, which is the western part (Figure 1).

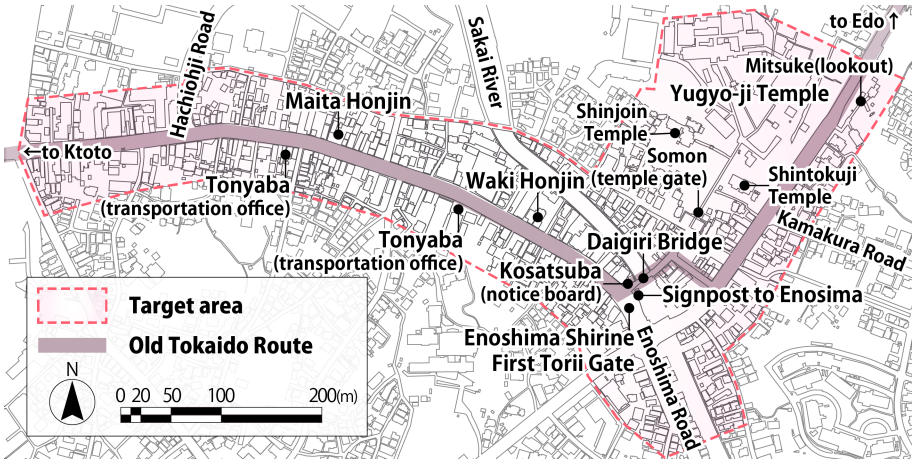


Figure 1. Fujisawa-juku, a post town on old Tokaido.

In 1843, the population of the post town was 4,089 and the number of houses was 919: with one main-Honjin (Maita Honjin) as an inn officially designated as a lodging for a daimyo in the Edo period; one sub-Honjin (Waki Honjin); and 45 inns (Kodama 1970).The Unreal Engine was used as the development environment, and materials such as three-dimensional models, material maps, and sound data were consolidated on the game engine. We modeled buildings such as shops, inns, and temples, urban installations such as tori (gateway), guideposts, and notice boards, trees, and small household items based on ancient documents (Figure 2). The modeling was based on Ukiyo-e, and the types and shapes of spatial components were studied (Utagawa 1832, 1840, 1847). Ukiyo-e is a picture (color print) of everyday life in the Edo period. The spatial components of Ukiyo-e, such as signposts and plantings, are deformed; therefore, the shapes of signposts, tree species, and bridge girders were studied separately, referring to historical documents and other literature (Hirano and Ichikawa, 2017).


Figure 2. View of the Fujisawa post town in the past: a) inn, b) shop, and c) notice board.

In addition to static spatial components, the human model is placed as a

nonplayer character (dynamic spatial component) that encourages gazing. We arranged human models on the streets of the town based on the behaviors of the people who lived in Fujisawa-juku, such as townspeople and monks, and the people who visited the post town, such as samurai and travelers. In addition, as an auditory element, natural sounds such as birds and insects were included in the objects as sound effects to create soundscapes that differed according to their positions.

This system is a walkthrough that allows users to move freely in the post town. The system can be operated using a gamepad as well as a keyboard and mouse. The input to the system is based on viewpoint and gaze control with an analog pad, and various actions are operated by buttons. Actions, such as talking, horse riding, and money offering, are based on the relative distance from other objects in the system. In addition, a head-mounted display is used as an output interface to enable an immersive experience.

This system is permanently displayed in a public facility in Fujisawa City. In the exhibition, the system is projected onto a 40-inch monitor and controlled by a gamepad. In addition, the system is not network dependent, and is a PC startup program that automatically starts when the power is turned on, enabling the system to be operated without any special operations.

## 3. Enhancements to the Historical and Cultural Landscape Simulation System

### 3.1. DEVELOPMENT OF A HISTORICAL AND CULTURAL LANDSCAPE SIMULATION SYSTEM THAT REPRODUCES THE TIME, SEASON, AND WEATHER

Based on the development of these systems, time and weather designing systems have been developed. The impression of a landscape changes considerably depending on the time of day, whether it is morning, noon, or night, even in the same place (Kawai and Furuyama, 2001). In addition, the image of the landscape changes with the intensity of sunlight and changes in plantings, depending on the season. Furthermore, the landscape looks different even at the same time depending on whether it is sunny, cloudy, rainy, or snowy. Therefore, we decided to develop a system to represent changes in landscape images according to time of day, season, and weather conditions. The target area was Fujisawa-juku, which is similar to that in a previous study. By referring to the records provided by local temples of weather conditions at that time, we could recreate the weather at a specific date and time in the Edo period. In this system, we recreated the weather conditions for one year, 1862.

The location of Fujisawa-juku is at latitude 35°20 min north and longitude 139°30 min east; therefore, the location of the solar source was used to reproduce the time (Figure 3). In the night-time landscape, a light source using the moon was prepared to reproduce the variation in brightness during the night such as at the time of the new moon and full moon. The position of the sun and the moon varies with the seasons. Therefore, the position of the light source was set in conjunction with the time data of the sun and the moon. In addition, four weather patterns were

prepared: sunny, cloudy, rainy, and snowy. When it was raining and snowing, we created particles to indicate raining or snowing, and when it was snowing, we modified the surface layer of the model with a material by shaders to represent snowfall (Figure 4). The number of the human models of nonplayer characters varied according to the environment, such as time of day and weather. In addition, as the behavioral pattern of the human model, we added actions such as holding an umbrella when it rains and snows, and carrying a lantern at night.

This system is designed to change the time of day, season, and weather by changing light sources, effects, and materials. It was found that the impression of the landscape was greatly affected by these changing elements.

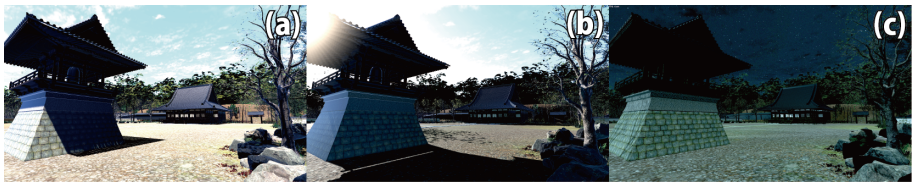


Figure 3. Changes in time: a) day, b) evening, and c) night.


Figure 4. Changes in weather: a) sunny, b) rainy, and c) snowy.

### 3.2. DEVELOPMENT OF A HISTORICAL AND CULTURAL LANDSCAPE SIMULATION SYSTEM USING UKIYO-E STYLE RENDERING

In addition, a system was developed with Ukiyo-e style rendering (Figure 5). This system provides not only realistic rendering, but also Ukiyo-e style rendering, thereby allowing users to experience the old landscape in the world of Ukiyo-e in three dimensions. As a base for Ukiyo-e style rendering, we used the style of Hiroshige Utagawa as the basis for the rendering of buildings and other structures. Hiroshige was a Ukiyo-e artist who excelled in the painting of landscapes; his representative work includes the "Fifty-three Stages of the Tokaido." People painted by Hiroshige are depicted as supplementary landscapes, and therefore, they are not suitable for human models. Therefore, the human models are designed based on the style of Kunisada Utagawa. Hiroshige and Kunisada collaborated on Fifty-three stations by Two Brushes, a collaboration of their Ukiyo-e works (Utagawa and Utagawa 1854). The figures and background are painted by different artists, and we decided to use the same method for this system.

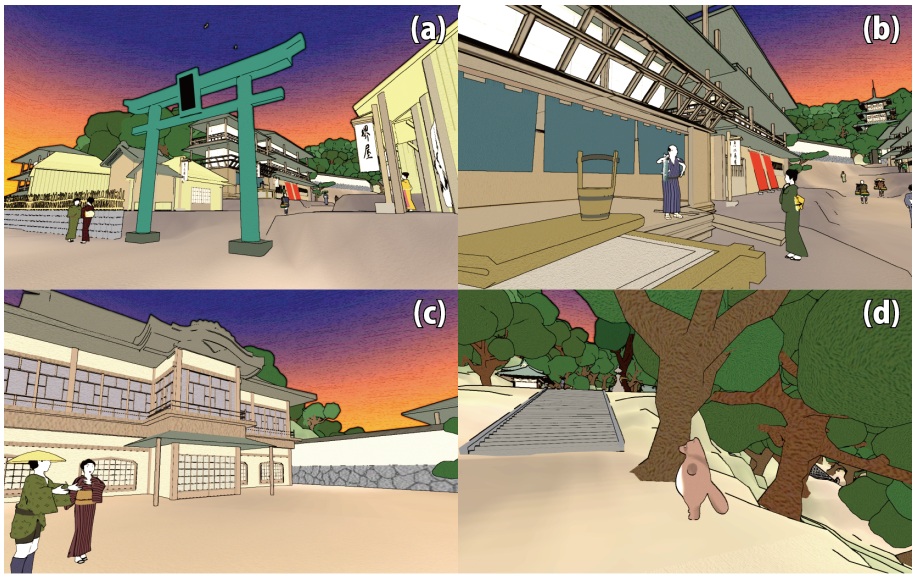


Figure 5. View with Ukiyo-e style reading: a) torii gate, b) shop, c) inn and d) yōkai.

Ukiyo-e style rendering was represented by detecting the edges of objects in the spatial components and by emphasizing the borders of the objects. Edge rendering was added to the objects using edge detection in Unity, the game engine. The values of depth sensitivity, normal sensitivity, and sampling distance were set by the mode filter. A script that automatically adjusts the width of the edges of the foreground and background based on the distance from the viewpoint was created. The adjustments of the edge line segments were introduced through a comparative evaluation of Ukiyo-e style renderings by subjects to make them more Ukiyo-e like. The objects are given the texture of Japanese traditional paper in terms of the material. We prepared an image with a screen size of 1024 × 1024 pixels on an image processing software, filled it with the color of the object on a layer, and we created a paper-quality black-and-white image with a filter on another layer; then, we set the opacity of the layer to 50%. The material was colored with a color gradient, and background elements such as the sky were created.

In Ukiyo-e style rendering, as dynamic elements, we prepared human models, and several yōkai as traditional Japanese ghosts. In the late Edo period, many Ukiyo-e prints depicting yōkai were published. We added a monster cat to the shopping mall, a raccoon dog and a giant snake to the temples and shrines, and a fox to the woods as yōkai. Based on the data from the stories in which the yōkai are said to have appeared, we made the yōkai appear only in the world of Ukiyo-e style rendering of the place where the yōkai are said to have appeared. Further, we made them a characteristic element of the world of Ukiyo-e.

This system uses the Ukiyo-e style to recreate the landscape of the past. In Japan, there is a traditional expression of depth painting called Yamato-e, which is represented by an oblique projection from a bird's-eye view (Suguhara 2011).

It is said that geometric perspective was introduced in the mid-18th century, but the use of perfect perspective was not widespread in Japan. In Ukiyo-e, imperfect perspective projection, orthographic projection, and traditional overhead oblique projection were used (Kishi 1994). Although Ukiyo-e is deformed in terms of depth representation and the arrangement of spatial components, this system provides accurate depth representation using a three-dimensional perspective based on geographic information data. Therefore, even if the location is the same as that depicted in Ukiyo-e, the system image shows a different landscape. Because of this difference in the way of viewing, it is not possible to simply compare the scene reproduced by the system with the original Ukiyo-e, but we have created the Ukiyo-e style rendering system based on user evaluation.

This system was designed for viewing of images on a head-mounted display; however, many cases of virtual reality sickness were observed. Flat materials such as Ukiyo-e may cause confusion in spatial cognition because of the loss of depth cues other than the binocular parallax. In addition, it was found that the movement method, which is the main cause of virtual reality sickness, needs to be considered.

## 4. Major Update to the Historic and Cultural Landscape Simulation System

These historical and cultural landscape simulation systems were opened to the public and received considerable feedback from the public. In addition, various local materials were provided by nearby temples and regional historians, and we referred to the records of houses in those days. Based on this new information and materials, a major system update was introduced (Figure 6).

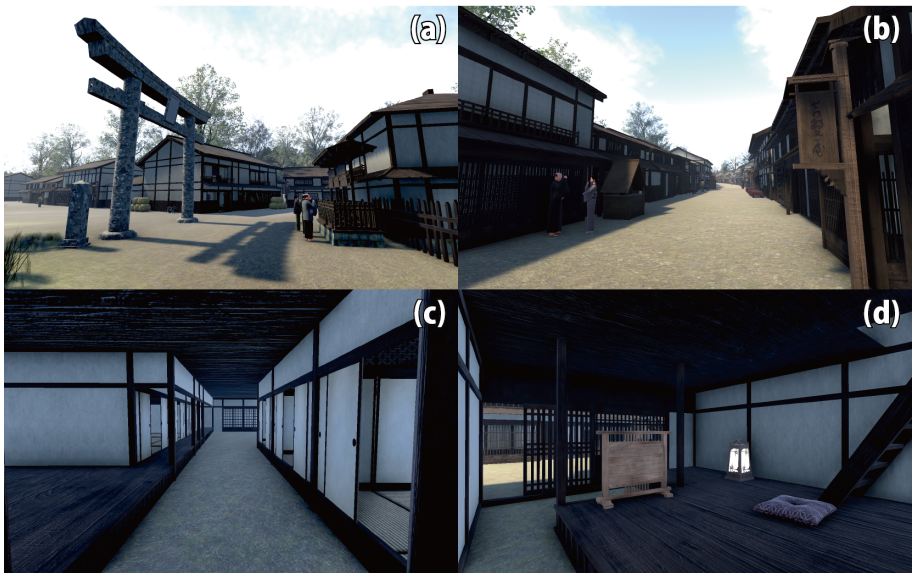


Figure 6. View with updated system: a) torii gate and notice board, b) shop sign and main street, c) inside the Honjin, and d) inside the inn.

The building model was reviewed and remodeled. For the modeling of the townhouse, the building was unitized with walls, entrances, openings, and other components, and these components were combined to reproduce various facades. The buildings were assembled based on the frontage and depth of the buildings from the archives, and these were arranged against the old maps. In addition, there were records of shop names for inns and shops. Therefore, signboards of the shops were reproduced, and interior spaces were recreated to enter the ground floor of the building including earthen floors within a certain range. Further, the road width was changed because it various data indicated that the road was considerably narrow. The depth of the river was also reexamined, as it was used for logistics by boat at that time. For the trees, some species were newly identified in the data, and changes were introduced to more reproduce the landscape of the time faithfully. The trees in this system were based on photogrammetric models generated from photographs. This tree model has a massive number of polygons, and therefore, the level of detail is set up to control the accuracy of the tree model and depict only the range of view. In particular, if the frames per second value falls during the display with the head-mounted display, virtual reality sickness may occur.

This system obtains the time from the clock in the computer and reflects it in real time in the recreated landscape. The position of the sun, which is the main light source of the system, is calculated in terms of longitude and latitude, and the brightness of the sun and the speed of sunset are accurately implemented by referring to the total solar radiation measured by the Japan Meteorological Agency. The cloud cover was measured and divided into finer, cloudless, scattered, partly cloudy, moderately cloudy, and all-sky cloudy. In addition, rainfall depiction in rainy weather is slow in processing if rainfall effects are placed in all locations. Therefore, rainfall is depicted only in the area near the player, and it is possible to represent the rainfall with light processing. Moreover, as a ground system, we simulated changes that the ground undergoes because of weather conditions such as when walking in the rain, the ground is muddy, when it is snowing, and when footprints are marked on the snow.

Further, we used a method of instantaneous movement of the viewpoints by a blackout at the moment of movement, instead of continuous walking. Using this movement method, we suppressed the phenomenon of the difference in the feeling of virtual reality sickness when the user does not move but the screen moves. The input interface allows the user to move by simply pressing and releasing a button, and we checked that even first-time users have no problem using it.

## 5. Result and Discussion

We developed a historical and cultural landscape simulation system for Fujisawa-juku, a post town in old Tokaido, using Ukiyo-e, old documents, and maps to recreate a past landscape with a game engine for inheriting the historical culture of the region. Further, we developed a system that can change the expression of time (e.g., day and night), seasons (e.g., spring, summer, fall, winter), and weather (e.g., sunny, cloudy, rainy, snowy). Additionally, we studied the reproduction of the landscape using Ukiyo-e style rendering. The developed system has been open to the public through permanent exhibitions in

public facilities and local events. There is no major operational problem, and the operation is stable. We received feedback from users about these exhibits, and it motivated us to create major system updates. Specifically, we examined and updated the shapes of the models of the spatial components to be more accurate.

The updated system was also made open to the public, and we received feedback from various regional information reflected in a more accurate post-town model. The digital model was updated to reflect new information, which is not possible with models such as dioramas. In addition, this system is an interactive system, which differs from animations, as it allows users to roam the streets of the past freely. The digital models are not suitable for long-term exhibitions because the execution environment changes rapidly. It also took much work to create many digital detailed models accurately. We hope to reduce the modeling costs by unitizing the model so that it can be used in the production of past landscapes in other areas. We will continue to update the system periodically and develop a general-purpose system that can be used in other regions.

## 6. Conclusion

In this study, we developed a historical and cultural landscape simulation system using a game engine and made it available to the public; the system considers elements such as time and weather and rendering methods. Further, it can reflect the information collected after publication. However, we found that creating various models to reflect the past landscape accurately requires much time. Previous studies have attempted to digitally recreate the landscape of the past, but most of them were limited in scope to few buildings, famous heritage sites, or tourist sites and used specialized systems. Based on these studies, we attempted to recreate the past landscape of a general ordinary town using an open and inexpensive development environment such as a game engine. In addition, by collecting and referencing materials provided by local archives and temples, we were able to recreate past townscapes and create a system that visually conveys the historical culture of the region. By making this system open to local citizens, the community of citizens discussed how to reproduce the past landscape more accurately. With the new materials provided by the citizens who experienced the system, the system could be easily updated for accurate recreation of the past townscape by this system because this is digital content. Based on this effort, we will rediscover materials related to local history, and connect them to each other to link local history to the next generation in various regions by generalizing the system. In the future, as an extension of the system to the exhibition environment, we will add functions to explain various urban elements and compare them with the current landscape. Further, based on the findings from the recreation of the historical cultural landscape in the target area, we will generalize this system through the unitization of buildings and urban installations, and we plan to create a platform for a historical cultural landscape simulation system that can be used in other areas.

## Acknowledgments

This work was supported by JSPS KAKENHI, Grant Number JP19K12665, and the Foundation for the Fusion of Science and Technology. I would like to thank Naoshige Togashi, Kohki Dote, Ryuta Suzuki, Yuta Terayama, Kazuma Numata, Ken Fujii, Youhei Obuchi, Yurika Tsuchiya, Shoko Nihei, Natsumi Kobayashi, Masumi Kiyokawa, Ayaka Enzaka, Sae Itoh, Kie Tsuchiya, and Shusei Yoshida, graduates of our laboratory, for assistance with this study.

## References

Dylla, K., Frischer, B., Müller, P., Ulmer, A. and Haegler, S.: 2008, Rome reborn 2.0: A case study of virtual city reconstruction using procedural modeling techniques, *Computer Graphics World*, **16**(6), 62-66.

El-Hakim, S., Gonzo, L., Voltolini, F., Girardi, S., Rizzi, A., Remondino, F. and Whiting, E.: 2007, Detailed 3D modelling of castles, *International Journal of Architectural Computing*, **5**(2), 199-220.

Fukuda, T., Ban, H., Yagi, K. and Nishiie, J.: 2015, Development of high-definition virtual reality for historical architectural and urban digital reconstruction: A case study of Azuchi castle and old castle town in 1581, *International Conference on Computer-Aided Architectural Design Futures*, 75-89.

Hirano, M. and Ichikawa, K.: 2017, *Reconstruction Map of the Tokaido Fujisawa Post Town 1862*, Fujisawa Post Town Exchange Center.

Kawai, Y. and Furuyama, M.: 2001, The space constituent elements of stimulated gazing on sequential street in the daytime and nighttime at Gion Area in Kyoto, *Journal of the City Planning Institute of Japan*, **36**, 757-762.

Kishi, F.: 1994, *Perspective in Edo: The Vision of Ukiyoe*, Keiso shobo.

K. Kodama (ed.): 1970, *Tokaido Syukuson Taigai-cho [Tokokaido Post Town Abstract Book], Kinsei Kotsu Shiryo-shu [Traffical Materials in Early Modern Japan], 4*, Yoshikawa Kobunkan.

Suguhara, F.: 2011, Visual dynamics in the illustrated tale of Genji-"Equivalent Statics" and "Organized Dynamics", *Journal of Human Environmental Studies*, **2**, 117-142.

Sundstedt, V., Chalmers, A. and Martinez, P.: 2004, High fidelity reconstruction of the ancient Egyptian temple of Kalabsha, *Proceedings of the 3rd International Conference on Computer Graphics, Virtual Reality, Visualisation and Interaction in Africa*, 107-113.

Utagawa, H.: 1832, *Fujisawa in the Fifty-three Stations of the Tokaido (Hoeido edition)*, Hoeido.

Utagawa, H.: 1840, *Fujisawa in the Fifty-three Stations of the Tokaido (Tokaido with Kyoka edition)*, Kikakudo.

Utagawa, H.: 1847, *Fujisawa in the Fifty-three Stations of the Tokaido (Clerical script Tokaido edition)*, Jyukakudo.

Utagawa, H. and Utagawa, K.: 1854, *Fifty-three Stations by Two Brushes*, Marukyu.

Yamauchi, K.: 2009, The role of communities in the era of low fertility and aging: Reviving local communities, *Legislation and Investigation*, **288**, 189-195.

Yano, K., Nakaya, T., Isoda, Y., Takase, Y., Kawasumi, T., Matsuoka, K., Seto, T., Kawahara, D., Tsukamoto, A., Inoue, M. and Kirimura, T.: 2008, Virtual Kyoto: 4DGIS comprising spatial and temporal dimensions, *Journal of Geography*, **117**(2), 464-478.