URBAN SPACE SIMULATION SYSTEM FOR TOWNSCAPE ORDINANCE

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

Abstract. In this study, a game engine-based urban space simulation system for townscape ordinance was developed and evaluated. For accurate evaluation of a townscape, it is important for the townscape simulation to be as close to reality as possible from various perspectives. The proposed system employs a freely moving first-person viewpoint with different height and origin variations; the building height and exterior wall color can also be changed. To evaluate the system, the simulation and photographic images were compared. The photographic images exhibited a higher gaze rate on spatial components; high gaze rates were also observed for vehicle and pedestrian in the photographic images. Therefore, we recreated dynamic spatial components such as vehicles and pedestrians. Additionally, we successfully reproduced the night townscape via a switchable light source and enabled the control of the numbers of poles and signs. The townscape reproduced by the proposed system could contribute to townscape planning. In the future, a more versatile urban space simulation system that combines various sources of urban information can be developed.

Keywords. Landscape Simulation; Game Engine; Urban Planning; Gaze Elements; Sequence.

1. Introduction

We developed an urban space simulation system for townscape ordinance using a game engine. The urban space comprises various spatial components, such as buildings, facilities, and signs, which can be controlled to create the desired townscape. In a townscape, humans recognize environmental information and evaluate it sensitively; consequently, formulating a townscape plan based on objective evaluation is not easy. However, with the promulgation of the Japanese Landscape Act in 2004, the townscape has become an essential element in urban planning. Local governments have established various townscape ordinances to create a pleasant urban space.

While the interest in townscapes is increasing, it is difficult for citizens and developers to imagine the urban space characteristics and changes affected by townscape planning. To create an urban space image, models and composite photographs have been used. Models have been widely used to share townscape images during the planning stage; they are still being used because they enable

PROJECTIONS, Proceedings of the 26th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2021, Volume 2, 479-488.

the study from multiple angles (Bosselman, 1987; Feimer, 1984). However, modeling requires considerable time and cost, and design changes are difficult to reflect immediately. Composite photographs and montages have been used for a long time to evaluate the impact of new architectural plans on the townscape (Lange, 2001; Rekittke and Paar, 2008). In recent years, digital image processing has enabled the generation of realistic predictive images (Rohrmann and Bishop, 2002; Wergles and Muhar, 2009). However, the output of a still image is limited to a fixed viewpoint. In particular, it is possible to minimize the effects on the surrounding environment, and therefore, it is necessary to be careful when planning and evaluating the townscape. Recently, a computer visualization system using 3D shape data created during the design stage was also observed (Portman, Natapov and Fisher, 2015; Azhar et al., 2008). However, these systems were often developed as dedicated systems that require specific systems to be developed for each project, thereby making them expensive and lack versatility.

In this study, we developed a general-purpose urban space simulation system for a townscape using a game engine, which is used as a development environment for digital content, such as games, to experience a reproduced townscape at a low cost. There are various types of game engines, but Unity was used for the development environment in this study. Unity has a lighter editor than those of other game engines, and it can be programmed directly in C sharp script, making it suitable for developing complicated systems with large-scale models. Although previous studies have been conducted on urban space simulations using game engines that have exhibited their potential, they focused on a small limited area, such as a single building and so on, and did not simulate an entire city. (Herwig and Paar, 2002). Only a few dedicated systems can examine the townscape of a real city in a large-scale model at the city block level owing to the large amount of data to be handled (Lim, Honjo and Umeki, 2006; Santosa, Ikaruga and Kobayashi, 2014). We developed an urban space simulation system for townscape planning in which a large-scale urban model can be displayed in a light-weight game development environment, and the elements necessary for townscape planning, such as the building height, exterior wall color, nighttime views, and number of signs, can be changed accordingly in real time.

2. Method

2.1. SIMULATION SYSTEM THAT ALLOWS FOR CHANGES IN BUILDING CONDITIONS

2.1.1. Development

We developed an urban space simulation system that allows users to change the architectural conditions. The Shonandai Townscape Formation Area in Fujisawa City, Kanagawa Prefecture, Japan, was selected as the study site (Figure 1). The Shonandai Townscape Formation Area, which is the urban hub of the northern part of the city, comprises a terminal station connected by three railway lines, a commercial area around the station, a neighborhood residential area, and a traffic terminal for the nearby industrial and educational districts. Target areas and townscape control standards are defined as part of the city's townscape plan, which has been in operation since 2012. The area imposes restrictions on wall location, architectural form and design, color standards, outdoor advertising, planting, and nighttime views. In accordance with Article 16, paragraph 1 of the Japanese Landscape Act, developers are required to notify any new construction, extension, renovation, or relocation, repairs, redecoration, or color change of a building or structure that can change its appearance.

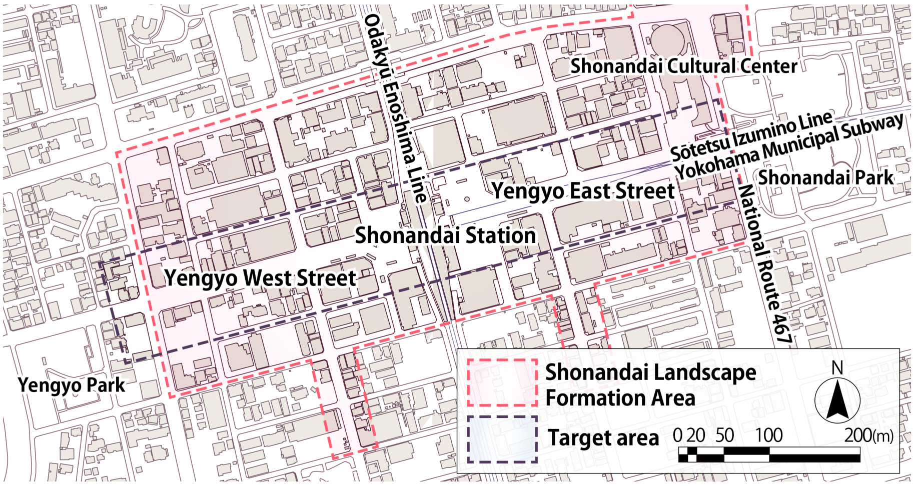

Figure 1. Shonandai Landscape Formation Area.

Three-dimensional shape models were created for the spatial components of buildings and urban facilities in the study area. An entire city, owing to the excessive number of polygons, is difficult to model; therefore, we created a model for each building site, imported it into the game engine, prefabbed it, and then accurately placed it on a mapped model with geographic information data. Furthermore, we created a first-person walkthrough on the game engine that allows the user to move freely. The initial viewpoint height was set at 1500 mm, which was changed to simulate views from not only the street level but also from the interiors of the middle and upper floors of a building (Figure 2). Changing the viewpoint height enables the user to view the townscape from both the public street level and from each private residential unit.

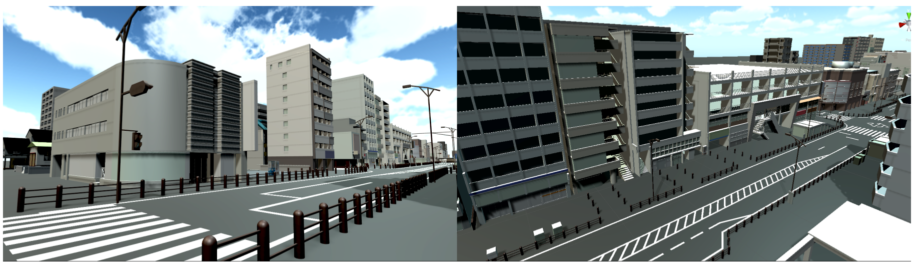

Figure 2. Street view (left) and view from middle/upper floors of a building (right).

Various spatial parameters, including building height and setback, can be changed (Figure 3); building wall material and color can also be changed (Figure 4). A touch-screen display enables the real-time study of building heights and setbacks using an intuitive drag-and-drop operation.

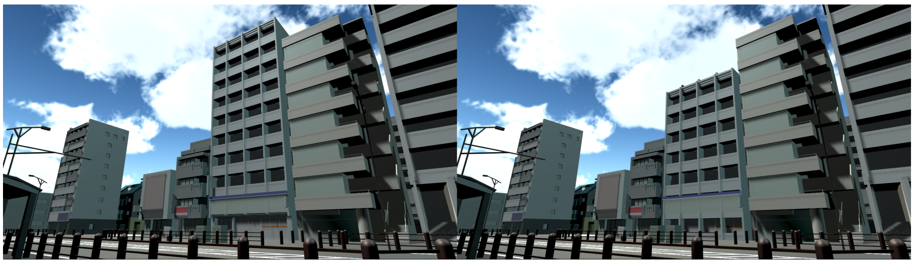

Figure 3. Changes in building height and setback.

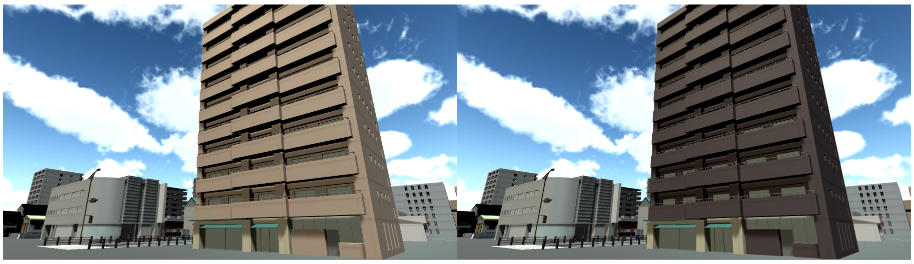

Figure 4. Changes in building external wall material and color.

Input interfaces for free movement in the virtual urban space are designed to be operated by a gamepad, along with a keyboard and a mouse. The left-handed analog pad is used for viewpoint movement, whereas the right-handed analog pad is used for viewpoint rotation to enable intuitive operation. As an output interface, a head-mounted display could be used to enhance the immersion experience.

2.1.2. Evaluation

Methods such as subjective psychological measurement have been used to evaluate townscapes (Reeve, Goodey and Shipley, 2007). However, these are evaluations of the overall impression of the townscape, and the specific spatial components that are affected by these evaluations are not clear. Vision directs the attention by illuminating a specific area of the visual field such as with a spotlight (Posner, Snyder and Davidson, 1980). Here, we pay attention to specific objects in the visual field rather than the entire visual field area (Cave and Bichot, 1999). There have been studies that use eye tracking to analyze the gazing behavior of real townscapes (Simpson et al., 2019; Spanjar and Suurenbroek, 2020). We developed a simple evaluation system to measure gazing objects without using special equipment, such as eye tracking, to determine what is being gazed at in the reproduced townscape and images.

The developed urban space simulation system was evaluated by comparing system images with photographic images (i.e., Street View images from Google Maps). Yengyo West Street was selected as the evaluation area. In Google Maps, 23 points were identified at 10-m intervals from Street View in the evaluation area. The same viewpoint field as the shooting point of each Street View was used in the game engine. In this experiment, a 1280 × 720 image was used. The image was divided into 100 segments, and HTML files for each segmented image were prepared. In this study, the access analysis of each HTML file was used to identify the segmented images that were clicked. The subjects were instructed to click on any number of points of interest on the image displayed on a monitor. This evaluation method is a way to make a conscious choice among the objects in the line of vision. A total of 115 subjects, who frequently visit the places around this area, participated in this experiment.

2.1.3. Results and Discussion

The results indicate that the gaze frequency of the photographic images was higher than that of the system images for each viewpoint field (Figure 5). To evaluate the townscape, we classified images used in the experiments into five spatial components: sky, building and facility, commercial sign, traffic sign, and road.

Gaze rates for each spatial component were measured and compared. The gaze rate was calculated by dividing the total number of gazes clicked on each image by the number of participants; the click rate per image was used. In the case of multiple spatial component species coexisting in the same segmented image, the spatial components are classified based on the percentage of the screen occupied by each spatial component. The results show similar trends for the sky, buildings, and facilities. In contrast, the gaze rates for commercial signs in system images are lower than those in photographic images. It was found that commercial signs, which are small but require attention in the townscape, require more detailed representations (e.g., the preparation of high-resolution textured material). A similarly low gaze rate was observed for roads in the system images. Roads are a background element of the townscape, and they are a spatial component with a high level of screen share.

In photographic images, a high gaze rate was observed for plants, vehicles, and pedestrians, which were not represented in the system. Plants are visually informative elements with complex edges. Vehicles and people are temporary and dynamic elements, and typically, these elements are noisy during townscape evaluation, and our system could remove them. However, these elements were found to be spatial components that were the focus of many gazing behaviors in townscape evaluation. The actual townscape is composed of vehicles and pedestrians, and therefore, these elements are essential in townscape evaluation in the actual urban space.

Figure 5. Gaze rates for photographic and system images.

2.2. SIMULATION SYSTEM THAT ALLOWS FOR CHANGES IN DAYTIME AND NIGHTTIME VIEWS

2.2.1. Development

We developed an urban space simulation system that represented day and night townscapes and dynamic elements such as vehicles and pedestrians. A light source is embedded in an object that emits light at night. These point light sources can be switched to light sources representing sunlight to reproduce daytime and nighttime townscapes. The agent models of vehicles and pedestrians acting autonomously were also prepared.

The Special Townscape Community Planning around the North Exit of Chigasaki Station Area in Chigasaki City, Kanagawa Prefecture, Japan, was selected as the study site. The area around the north exit of Chigasaki Station is the urban center of Chigasaki City. It is composed of three characteristic districts: a commercial district with commercial buildings, a governmental district with public buildings, and the Tokaido district along the national road. Chigasaki City has been devoting efforts to create a pleasant townscape even before the enforcement of the Japanese Landscape Law. These efforts include the formulation of the Chigasaki City Townscape Basic Plan in 1998 and enactment of the Chigasaki City Townscape Ordinance in 2000. In 2001, the Special Townscape Community Planning around the North Exit of Chigasaki Station Area was designated as an area that focuses on townscape development. Any new construction, extension, relocation, repair, redecoration, color change, or other development activity that results in the construction of a new building or structure within this area will change the appearance of the building or structure that will be planned to conform to the townscape control standards and must be notified to that effect. Further, it is necessary to evaluate the impact on the surrounding environment and the building size that will appear as a result of the development by creating a simulated scenario using composite photographs, models, and balloons, prior to implementation subject to notification.

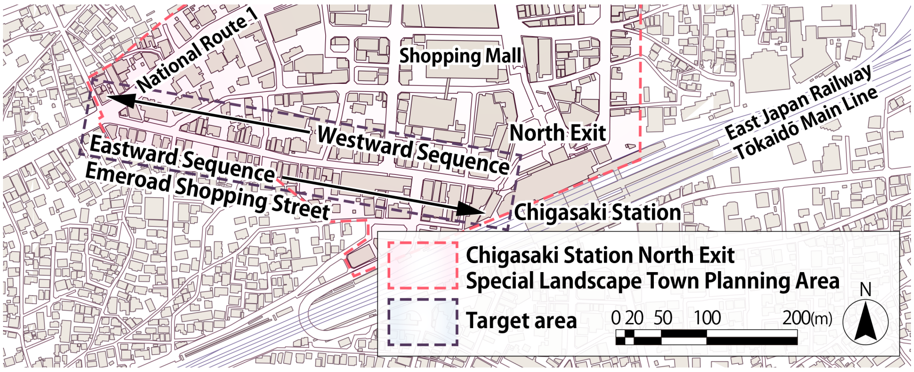

Figure 6. Chigasaki Station North Exit Special Landscape Town Planning Area.

Figure 7. Day and nighttime views of system image.

In this study, the Emeroad shopping street located northwest of Chigasaki Station was selected as the target area (Figure 6). In addition to the detailed modeling of the existing 76 buildings and their related facilities facing north and south, point light sources were inserted into spatial components, such as commercial signs, shop eaves, and streetlights that emit light autonomously. These light sources can be switched between daytime and nighttime townscapes (Figure 7). In this system, planting was reproduced, and models of autonomous vehicles and pedestrians were prepared.

2.2.2. Evaluation

An identifier was assigned to each model placed on the game engine. The 76 buildings were divided into 'walls,' which represent the outer building walls; 'openings' such as windows; and 'temporary structures,' such as storefront products and vending machines, with 228 identifiers as buildings. In addition, there were 194 identifiers for 'traffic signs' including road traffic signs; 'commercial signs' such as permanent signs; and 'temporary signs' such as flag- and stand-type signs. Moreover, 'street trees,' including trees along the road, and 'plants,' including plants or planters, were designed as 96 identifiers of 'planting'; 'street lamps,' 'utility poles,' 'electric wires,' 'car stops,' and 'manholes' were designed as 210 identifiers of 'urban facilities.' They were made to be a model with 728 identifiers in total.

This urban space simulation system has two functions: townscape mode and evaluation mode. In the townscape mode, reconstruction and large-scale repairs were simulated for existing buildings by replacing the building model and changing the outer wall texture, respectively, via mouse clicks. In addition, changes to urban properties related to the townscape, such as the undergrounding of wires and poles and signage control, are possible. In the evaluation mode, the object on the marker displayed in the center of the screen is recorded by clicking the mouse. When the marker is clicked, it acquires the identifier of the object to which the polygon on the line of the marker belongs and stores it in a log file. Using this evaluation mode, the gaze tendencies in the daytime and nighttime townscapes are used to determine spatial component characteristics in the urban space represented in the system.

A total of 404 subjects participated in this evaluation experiment. In the evaluation experiment using the evaluation mode of this system, the participants were instructed to click on an interesting spatial component, and their gazing elements were analyzed in the log. To recognize the townscape as a continuous sequential scene, two routes are prepared: a westward sequence from the station to the shopping street and an eastward sequence from the shopping street to the station.

2.2.3. Results and Discussion

The gaze rate in the westward sequence was plotted in a scatter plot of spatial components, with daytime and nighttime on the horizontal and vertical axes, respectively (Figure 8). The gaze rate is the number of times a spatial component is clicked divided by the number of participants. When the slope of the line connecting each point and the origin is less than 1, the tendency to gaze during the daytime is high; when the slope is greater than 1, the tendency to gaze during the nighttime is high. For example, the commercial sign located in the upper right corner on the westward figure has high gaze rates in both daytime and nighttime; however, because it is an autonomous light-emitting sign, its gaze rates at nighttime and daytime are 2.09 and 1.10, respectively. The average gaze rates of all the spatial components are higher at nighttime than at daytime. With regard to the types of spatial components, the gaze rates of signs and plantings were high, especially at nighttime.

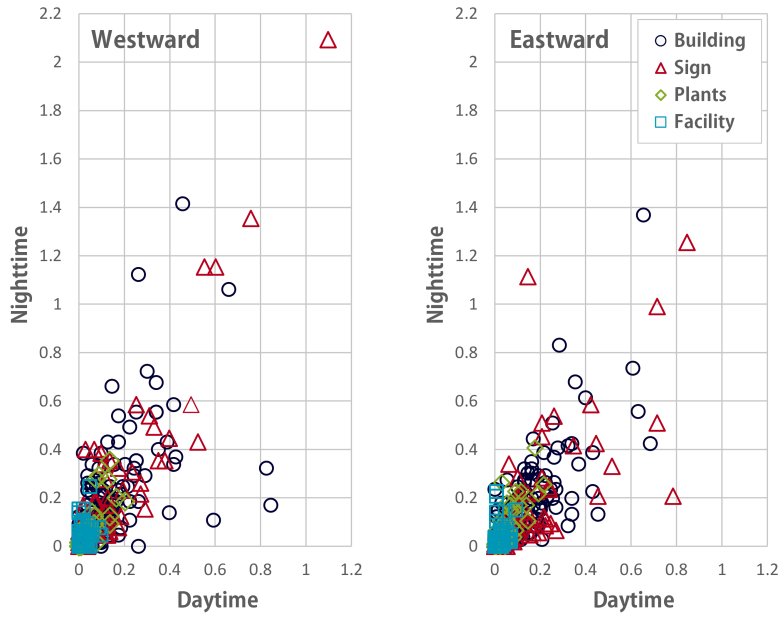

Figure 8. Day and nighttime gaze rates in westward (left) and eastward (right) sequences.

Spatial components with high gaze rates at nighttime were commercial signs that emit light autonomously, openings that allow interior light to leak out, and architectural elements that are illuminated by streetlights. In contrast, spatial components with high gaze rates during daytime were the exterior walls of characteristic buildings and storefronts. These are spatial components that do not emit light at night, and therefore, objects that are figures in daylight become the ground at night and background for other spatial components.

The scatter plot for the gaze rate in the eastward sequence is also shown. The average gaze rates for all spatial components tended to be higher at nighttime than at daytime in the westward moving sequence; however, the slope was relatively low. Spatial components with high gaze rates at nighttime were slightly more modest in comparison to the westward sequence. The westward sequence goes from the station to the shopping street, whereas the eastward sequence goes in the opposite direction. Because commercial signs and shops are spatial components that encourage pedestrians to gaze from the station, nighttime townscapes of the eastward sequence tend to have low gaze rates. Thus, westward and eastward sequences showed different gaze-rate trends during daytime and nighttime.

3. Conclusion

In this study, we developed and evaluated an urban space simulation system for townscape evaluation. These systems, which use a game engine, are easy to operate and represent a useful tool for townscape planning. Using the game engine as a development environment enables the development of high-quality simulation systems at low cost without the need to develop an expensive dedicated system. Further, it is possible to consider environmental condition changes from the private space of the residence and from a public space at the street level, which have been the centers of evaluation in past townscape planning. The evaluation results indicate that vehicles and pedestrians were spatial components that were lacking in the system. Therefore, we recreated the dynamic spatial components. In addition, the townscape impression changes significantly with time. Therefore, we decided to create a system that can switch between the daytime and nighttime. The urban space simulation system using the game engine developed in this study is relatively inexpensive and easy to operate, and it can be used by various organizations and local governments. In the future, we will develop a more versatile urban space simulation system by combining various sources of urban information.

Acknowledgments

This work was supported by JSPS KAKENHI Grant Number JP 19K12665, and the foundation for the fusion of science and technology.

References

Azhar, S., Nadeem, A., Mok, J.Y. and Leung, B.H.: 2008, Building Information Modeling (BIM): A new paradigm for visual interactive modeling and simulation for construction projects, *First International Conference on Construction in Developing Countries*, 435-446.

Bosselman, P.: 1987, Times Square, *Places*, **4**(2), 55-63.

Feimer, N.R.: 1984, Environmental perception: The effects of media, evaluative context, and observer sample, *Journal of Environmental Psychology*, **4**(1), 61-80.

Herwig, A. and Paar, P.: 2002, Game engines: tools for landscape visualization and planning, *Trends in GIS and Virtualization in Environmental Planning and Design*, 161-172.

Lange, E.: 2001, The limits of realism: perceptions of virtual landscapes, *Landscape and Urban Planning*, **54**, 163-182.

Lim, E.M., Honjo, T. and Umeki, K.: 2006, The validity of VRML images as a stimulus for landscape assessment, *Landscape and Urban Planning*, **77**(1), 80-93.

Portman, M.E., Natapov, A. and Fisher-Gewirtzman, D.: 2015, To go where no man has gone before: Virtual reality in architecture, landscape architecture and environmental planning, *Computers, Environment and Urban Systems*, **54**, 376-384.

Rekittke, J. and Paar, D.P.: 2008, Real-time collage in landscape architecture, *Digital Design in Landscape Architecture*, Dessau, 88-95.

Rohrmann, B. and Bishop, I.: 2002, Subjective responses to computer simulations of urban environments, *Journal of Environmental Psychology*, **22**(4), 319-331.

Santosa, H., Ikaruga, S. and Kobayashi, T.: 2014, Development of Landscape Planning Support System using Interactive 3d Visualization: A case study in Malang, Indonesia, *Journal of Architecture and Planning*, **79**(706), 2699-2709.

Wergles, N. and Muhar, A.: 2009, The role of computer visualization in the communication of urban design—A comparison of viewer responses to visualizations versus on-site visits, *Landscape and Urban Planning*, **91**(4), 171-182.