

A Simulation Tool for Projection Mapping Based on Mapbox and Unity

Noriko Hanakawa, Masaki Obana

Abstract—A simulation tool is proposed for big-scale projection mapping events. The tool has four main functions based on Mapbox and Unity utilities. The first function is building three-dimensional models of real cities using Mapbox. The second function is movie projections to some buildings in real cities using Unity. The third is a movie sending function from a PC to a virtual projector. The fourth function is mapping movies with fitting buildings. The simulation tool was adapted to a real projection mapping event held in 2019. The event completed, but it faced a severe problem in the movie projection to the target building. Extra tents were set in front of the target building, and the tents became obstacles to the movie projection. The simulation tool developed herein could reconstruct the problems of the event. Therefore, if the simulation tool was developed before the 2019 projection mapping event, the problem of the tents being obstacles could have been avoided using the tool. Moreover, we confirmed that the simulation tool is useful for planning future projection mapping events to avoid various extra equipment obstacles, such as utility poles, planting trees, and monument towers.

Keywords—Avoiding obstacles, projection mapping, projector position, real 3D map.

I. INTRODUCTION

PROJECTION mapping events are popular worldwide, especially in higher education institutes, such as universities. Abilities of movie creation, music creation, and event management are essential for higher education. At first, students plan a projection mapping event with customer meetings and local field surveys. Subsequently, they develop a theme and scenarios for the movie. Further, students create movies and music using various multimedia tools. After creating movies and music, the projection mapping movies are evaluated by customers. On the event day, students prepare the equipment for projection mapping and operate the event. Moreover, because general event audiences directly evaluate the projection mapping events, the students may have more satisfaction and accomplishment. It is a high-performance interdisciplinary education in higher education [1]. However, efforts required for this education are considerable for teachers and students alike. This effort significantly influences other education. For example, we need fieldtrip for investigating the target buildings such as train stations, historic castles, and modern tower buildings. The fieldtrip should be held several times at one projection mapping event.

The first fieldtrip is a preview of the target buildings and

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surrounding environment. We should judge the availability of projection mapping to the target at the first fieldtrip. The second fieldtrip is a test of projection to the target building with real equipment such as projectors and PCs. We should move a lot of equipment to the projection area in front of the target building. The third fieldtrip is a rehearsal with actual equipment such as projectors, speakers, PCs, audio amplifiers, and actual movies and music. Then, the fourth fieldtrip is an actual performance on the event day. The four fieldtrips require much time and effort from teachers and students. In this way, projection mapping events are efficient education techniques. However, severe problems exist in projection mapping events.

Usually, we project movies onto the surfaces of real buildings. At the planning phase of the event, the developers of projection mapping must set projectors at mapping positions near the buildings. Further, they must test the projection conditions at the real projection locations. Therefore, they have excessive workload for setting up the equipment, which requires a considerable time period. Moreover, they need to examine the movie projection condition onto the building and obstacles. For example, obstacles are event stall tents, traffic lights, and utility poles. Sometimes, a movie may be interrupted by such obstacles. Furthermore, obstacles may be moveable, e.g., event stall tents. Even if no moveable obstacles are present in the previous local field survey, they may be present on the event day. However, we cannot perform the local field survey frequently because the workload and cost of previous local field surveys is very high. Therefore, we developed a simulation tool for projection mapping tests. Using the simulation tool, developers can test projection conditions onto virtual buildings and obstacles several times without a heavy workload. The requirements of equipment, transportation cost, labor cost, and the cost of renting a place for projection mapping in a real local area are eliminated. The simulation tool has four main functions: building modeling function, movie projection function, sending movie function of capturing a window, and mapping function of fitting building surfaces. Especially, the building modeling function is based on Mapbox SDK [2]. Virtual and movie projections are realized on UNITY [3].

The remainder of the paper is organized as follows. Section II presents related work. In Section III, we explain the simulation tool, including the four functions. The adaptation results of the tool are presented in Section IV. Finally, Section V presents the summary and future studies.

II. RELATED WORK

Many studies have been conducted on high-quality projection mapping. Several algorithms for analyzing

three-dimensional (3D) model techniques have been proposed [4], [5]. The proposed algorithms can decrease developers' workload by autofitting movies on complicated buildings. Although the algorithms are significant, the proposed simulation tool can be implemented with significant algorithms. The simulation tool is highly expandable with the algorithms. Moreover, Battulga and Fujimoto proposed a new method for avoiding blank areas generated by obstacles' and viewers' positions [6]. The method can generate natural views even if a viewer moves anywhere because obstacles' backgrounds are projected onto natural movies and obstacles' surface. Simizu et al. proposed a calculation method for optimizing two projectors' positions for natural views [7]. These studies are useful for achieving high-quality projection mapping and movies. Our simulation tool is related to these studies. However, our simulation tool is based on the real 3D map data of real cities. Therefore, our simulation tool can support large-Sscale projection mapping events, e.g., real building projections and real tower buildings. Further, real obstacles in the real 3D map can be reconstructed in the tool. For example, developers try projecting movies on a 3D virtual building numerous times until a good projector position can be clarified in the tool.

III. A SIMULATION TOOL FOR PROJECTION MAPPING

A. An Overview of the Simulation Tool

Fig. 1 shows an overview of the simulation tool. The simulation tool has four main functions, and it was constructed based on Mapbox and Unity. The following sections explain the details of the functions.

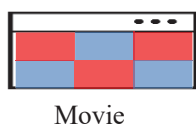
B. A Building Modeling Function

The building modeling function is based on Mapbox SDK for Unity. Mapbox can generate 3D models of real cities using map data. Fig. 2 shows a 3D model of a San Francisco city generated automatically using the Mapbox SDK for Unity. In the function, longitude and latitude values on the map data indicate the views of reproducing the cityscape.

C. An Overview of the Simulation Tool

Unity supports a standard projector component. The movie projection function is developed using the projector component in Unity. However, the projector component of Unity cannot project movies when there is an obstacle in front of the building. Fig. 3 shows the failure projection case in the projector component in Unity.

(3) A sending movie function to projector

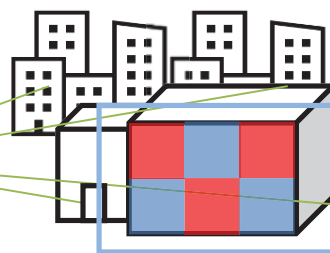


Movie



Virtual Projector

(2) A movie projection function



(1) A building modelling function

(4) A mapping function of fitting building

Fig. 1 Overview of the simulation tool

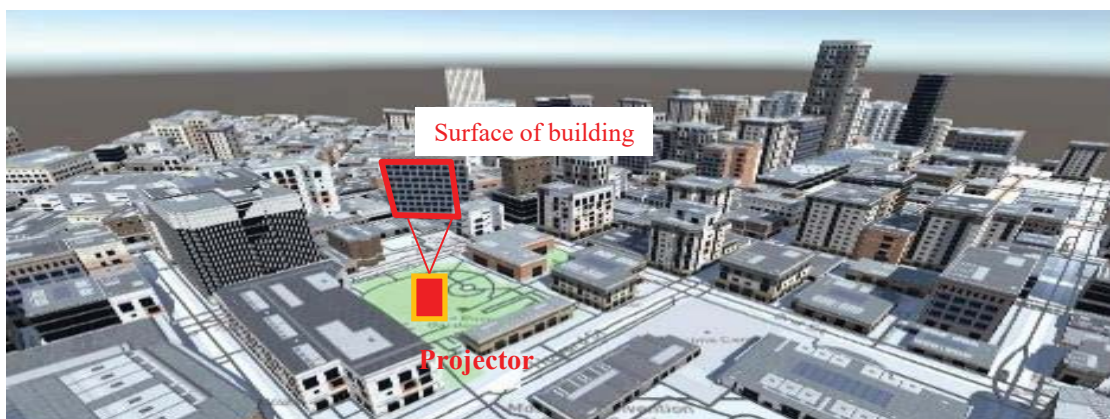


Fig. 2 3D model of a San Francisco town

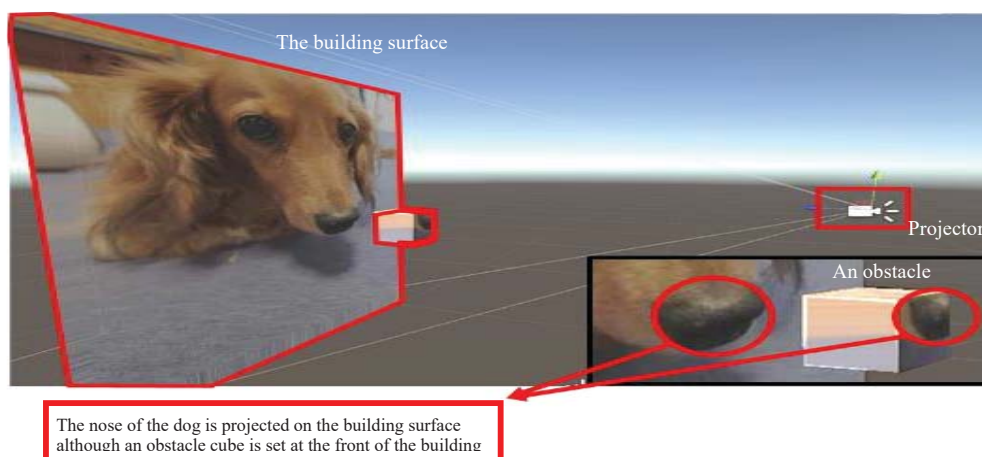


Fig. 3 Problem of the projector component of Unity

The reason for the problem is a difference in the projection method in Unity. Naturally, the projector in Unity should project using the perspective projection method. The perspective projection method involves a natural view using a perspective. It implies that a different perspective can be a different building view. Therefore, the behind building surface by a cube obstacle also projected the dog nose image. Therefore, the projection method was changed from the perspective projection method to the orthographic projection method that can generate a 2D view like camera images. Additionally, the orthographic projection method can generate the shadows of the obstacle on the building surface. The shadows are calculated through the depth information, i.e., the distance between the projector and surfaces.

D.A Sending Movie Function to Projector

The projector in Unity project movies captured the images of a PC window. Usually, movies are directly set to the projector component in Unity. However, the projector projects images of a PC window because various image and movie types are supported in our simulation tool. We developed a window image capturing tool with User Interface (see Fig. 4). The image capturing tool runs on a desktop computer. The images of the selected window of the computer are captured. Subsequently, the images are sent to the projector component in Unity. In this way, the projector in Unity can project various movies or images like various application software images and movies.

E. A Mapping Function of Fitting Building

Usually, projection mapping must perform mapping operations. The mapping operation implies that a movie is fit to building surfaces. For example, a building surface is a trapezoid although the shape of a movie is rectangular. Therefore, the shape of the movie is changed to a trapezoid. Changing the movie shape represents a "mapping operation".

The changing movie shape function was developed using "OPENCVSharp getPer-spectiveTransform()" method. Our simulation tool users perform the mapping operations. The mapping operation is essential for users because it is essential

training in real projection mapping events.

Fig. 5 shows an image of the mapping operation in the mapping function. Users operate various mapping trials to fit the surface of the target building in the tool. The movie of the mapping operation is projected obstacles. Therefore, users can train the mapping operation in a virtual 3D building without visiting the real building.

IV. ADAPTATION OF THE SIMULATION TOOL AND DISCUSSION

A. Adaptation

The simulation tool was adapted to a real projection mapping event. The event was held in November 2019 in Osaka, Japan. The event finished, but it faced a significant problem. Several event stall tents were set up in front of the target surface of the building. It implies that the event stall tents were obstacles to the movie projection to the target surface of the building. Fig. 6 shows a real projection mapping picture and a screenshot image of the simulation tool. In the real event, the tent roofs of the stores were obstacles to the movie projection. The tent roof obstacles were unexpected. The tent roof obstacles were found on the event day. These obstacles were clearly simulated (see the (2) image of Fig. 6); and had we run the simulation before the projection mapping event, we could have prepared a projector position and projection ways to avoid these obstacles.

Here, a procedure of adaptation of the simulation tool is explained. First, we prepared the 3D city map data in Mapbox (see Fig. 7). The target city is Matsubara-shi, Osaka. The city is near Hannan University. Inset (1) of Fig. 7 is a real picture of the mapping building. Image (2) of Fig. 7 is a screenshot of the mapping building in the 3D city, and it shows the position of the real projector at the event. The projector position can move everywhere. However, to reconstruct the projection condition at the event, the projector position in the simulation tool is at the real position of the event. Therefore, the problem of the tent roof obstacles could be reconstructed in the simulation tool, as shown in Fig. 6. Further, the projector position moves in the simulation tool. As shown in Fig. 8, the projector moves from (a) position to (b) position. The projector moves by the x-axis, y-axis, and z-axis. Thereafter, the movie projection starts. We

can confirm the projection condition of the movies in the simulation tool. Here, we confirmed that the tent roof obstacles did not influence the projection. However, the position of the

projector repeatedly moves until the projection condition is good. Finally, the position of the projector was decided through the simulation run in the tool.

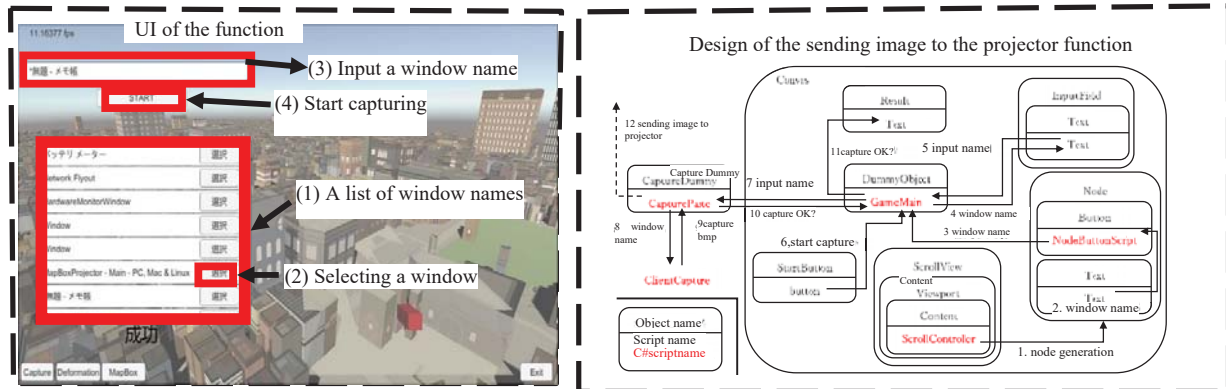


Fig. 4 Design of the sending image function

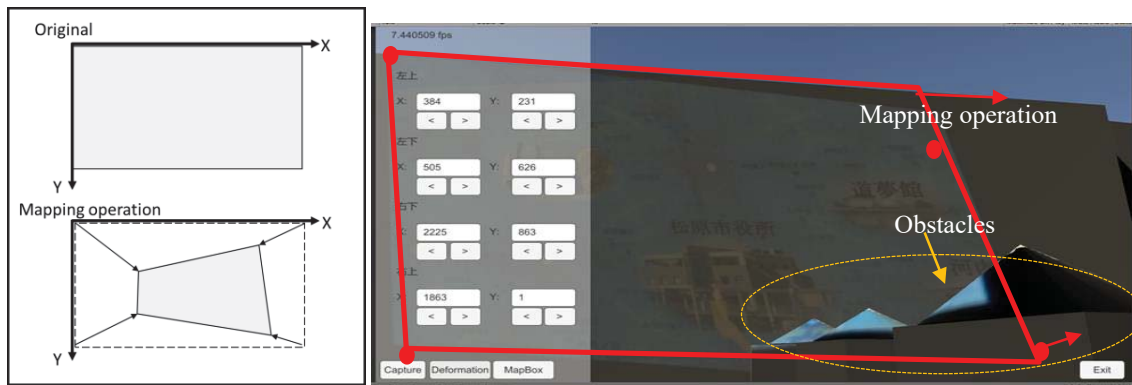


Fig. 5 Example of the mapping operation

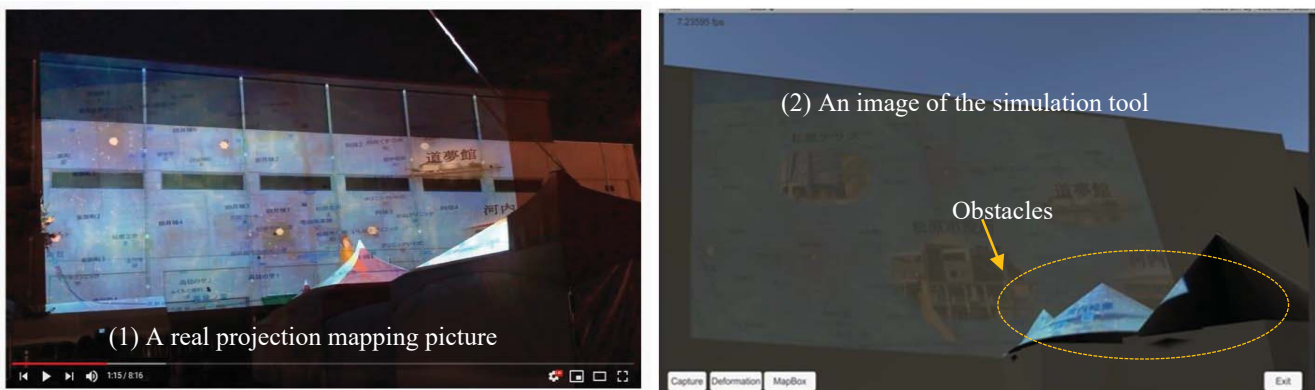


Fig. 6 Comparing the real projection mapping and an image of the simulation tool



Fig. 7 3D city map and the projector position in the tool

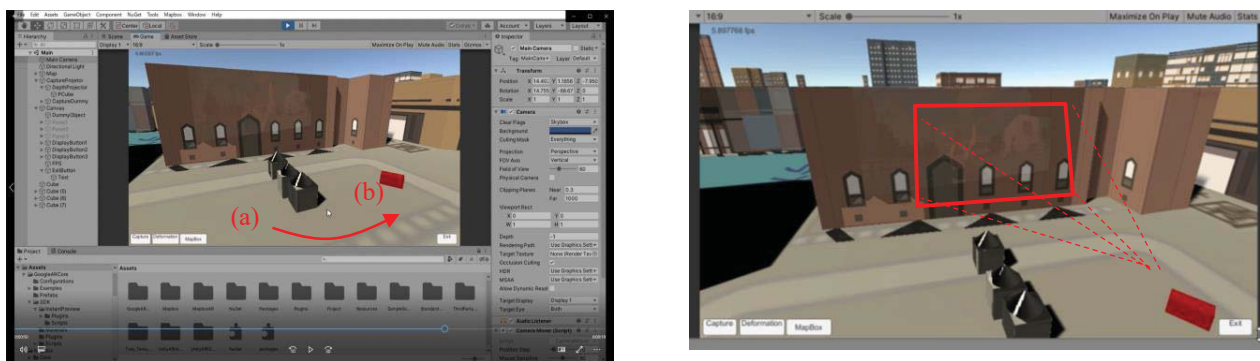


Fig. 8 Moving the projector in the tool for avoiding the obstacles

The simulation details of the projection moving are presented on YouTube [8], [9]. Refer to the links for more details. In this manner, we can simulate the condition of the movie projection on the projection mapping event. Thus, the projector moving can be simulated without the workload and cost of developers. The simulation tool is useful to reconfirm the projection conditions.

B. Discussion with Performance of a Projector

Usually, we use a high-level projector in the real event because the high luminance and resolution of a projector are required. The high-level projector has various high-performance functions, such as lens-shift, automapping, and multiprojection. We often use such high-performance functions of a high-level projector. However, a projector component of Unity does not have such high-performance functions. The difference between a projector component of Unity and a real high-level projector is a significant problem in useful projection simulations. Especially, the lens-shift function is essential for determining projector position. The lens-shift function implies that the projection angle can be moved up, down, left, and right by approximately 40% with only lens angles. This function is very useful when the projector position is limited by various obstacles, such as fences, trees, and utility poles. Therefore, we must implement the lens-shift function in the simulation tool. Further, the angles of the projector body and lens differ. The maximum value of the lens-shift angle differs for each projector. Therefore, the simulation tool will implement a lens-shift function so that the maximum angle of the lens-shift can be set to various values.

C. Discussion with 3D City Map Model

The simulation tool depends on the 3D map model. The real buildings and real city equipment are important to the simulation. In reality, some projection mapping events cannot be simulated in the tool. The reason is that the 3D city model was not adapted to the simulation model. For example, if the building surface is curved, the 3D city model from the Mapbox does not fit the simulation tool and the curved surfaces of the buildings are omitted from the 3D city model. It implies that the projection mapping areas with curved surfaces cannot be adapted to the simulation tool. The 3D city map model from Google is supported to the curved surfaces of buildings. However, the cost of the 3D city model of Google is high. Although famous tourist spots are available in the 3D city model in Google, the local areas that are not famous tourist spots are not available to the simulation tool. Therefore, we should construct a 3D city model with real buildings. There are several software that can construct a 3D model from the pictures and movies a user takes. The function of making a 3D model from original pictures and movies will be embedded in the simulation tool to improve the generality of the tool.

V. SUMMARY

We propose a simulation tool for projection mapping using Mapbox and Unity. The simulation tool has four main functions: the building modeling function, movie projection function, sending movie function from PC to the projector, and mapping function of fitting building surfaces. The characteristics are using a real city 3D model from Mapbox and the virtual projector moving in the simulation tool.

The tool was adapted to a real projection mapping event held in November 2019. The tent roof obstacles could be reconstructed in the simulation tool. The virtual projector component moved to the other position that avoided the tent roof obstacles in the simulation tool. We can try setting the projector in the tool to investigate good positions without visiting the real target building. Moreover, the simulation tool is useful for reconfirming movie projection conditions even with various obstacles, such as planting trees, utility poles, and event stall tents.

In future, the projector component will be added to the new functions of a real high-level projector, such as lens-shift, automapping, and multiprojections. Moreover, the original 3D map model-generating function will be implemented using the original photos and movies of target buildings.

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