A STUDY OF THE VIRTUAL REALITY SIMULATION SYSTEM FOR LRT PROJECTS TOWARDS SUSTAINABLE CITY

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Abstract. Recently, many cities in Japan and in other developed nations face problems such as decadence of downtown areas, aged society with a fewer number of children, dependence on automobile transport, etc. And redesign of public transportation services (e.g. tram) is thought to be one of the solutions for these problems. The introduction of LRT is investigated in various places, however, when a public traffic system like LRT is introduced, it is necessary to consider not only the transportation oriented aspects, but also landscapes and plans for a future sustainable city. Therefore, city planners are required to promote workshop-type in the design process to deal with citizens, companies, NPOs, etc. In this research, both components of the VR system for LRT projects and the system that enables the examination from various aspects of traffic, landscapes, city planning, etc., were studied.

Keywords. VR; LRT; community development; consensus building; transport planning.

1. Introduction

Light Rail Transit (LRT), a new traffic system which the past model of tram is upgraded to, is gathering new technologies such as barrier-free, a sophisticated designed vehicle, low vibration and low noise, etc. From the economical point of view, the construction cost of LRT is cheaper than the construction cost of other complicated transportation such as subway, mainly because the railroad is built on an existing road, consequently there is no major expenditure in land expropriation compensations.

On the other hand, many cities in Japan and other developed nations face problems such as decadence of central districts, aged society with a fewer number of children, dependence on automobile transport, etc. Moreover, the society faces the global warming issue and must take measures to prevent it. The developing country will be confronted with the problem in the future, too. For that purpose, the introduction of LRT is here investigated as one of the possible solutions for the presented problems.

When a public traffic system like LRT is introduced, it is necessary to consider not only an aspect of transportation but also community development, landscapes and plans for a future city. Toyama was the first and still only city in Japan that developed a LRT system, so the entirely problem of the design process were still unknown by that time. The authors of the project then elected Virtual Reality (VR) to enable and share a concrete image of the design among the parties concerned, because of various approaches were done for construction and the city planning by VR (Lou, 2003; Sato, 2006). There is no research to examine both LRT project and a sustainable city with VR.

In this research, components of the VR system for LRT projects were studied, and the system that enables the examination integrating various aspects was studied. Furthermore, this study highlights how necessary it is to attempt the consensus with the residents in the project surrounding areas, the promotion of public audiences, and the built of a smooth VR operation and examination environment. Therefore, the system is evaluated.

2. VR System for LRT Projects

2.1. UNDERSTANDING OF THE PROJECT AND ARRANGEMENT OF REQUIREMENTS FOR VR SYSTEM

It is important to develop the VR system that suits the purpose of the project, so in order to that it becomes necessary the grasp of background knowledge concerning LRT project. Therefore, authors surveyed on successful projects in developed nations, mainly in Europe. The characteristics of LRT were analyzed, and the most relevant elements were classified into six different categories (Table 1).

Analyzing the components of the VR system, it is necessary to express the movements of LRT vehicle and cars running along the road from the character of the project concerning traffic. Moreover, it is necessary to examine the functioning of traffic system itself, and to design VR models efficiently so that this project may handle the urban area in a large range.

TABLE 1. Classification of expression element.

CLASSIFICATION	EXPRESSION ELEMENT
Street furniture	Fence, Planting, Signboard, Bench, Utility pole, Streetlight, Bollard, etc.
Architecture	House, Office building, etc.
Structure	Road, Pavement, Railway, Station, Bridge, etc.
Landmark	Symbol architecture and structure
Transportation	LRT vehicle, Car, Bicycle, Motorcycle, Human, etc.
Nature	Water, Ground, Sun light, Mountain, Sky, etc.

2.2. INVESTIGATION OF THE PROJECT AREA

It was extremely necessary the field survey, due to some practical reasons. Firstly, when examining a VR, it is necessary to select some important viewpoints for a wide-ranging project area, so that the 3D model's details degree and data composition can be decided. Secondly, information that does not exist in the map and the drawing such as a signboard can be obtained in the field survey. Thirdly, the atmosphere of the town and people's movements can be grasped, and later turn to be useful for man's model's arrangement.

2.3. MODELING OF BUILDING AND STRUCTURE

Table 2 shows the software applications used in the process. The model of the buildings and the structures were made referred to Table 1.

It was thought that the examination of the place along railway-tracks environment by simulating the LRT vehicle running on it was important, and the shape of a road and street furniture such as streetlight and bollard are set up the policy of making it for details. Furthermore, landmark and symbolical buildings were modeled in detail. To treat wide-ranging data, peripheral buildings are made suppressing the details degree.

TABLE 2. The software applications

OS	Microsoft® WindowsXP® Professional SP2
3DCG Modelling software	Autodesk® 3ds Max® 8
VR software	UC-win/Road version 3.03
Graphics API	Open GL 2.1.1

2.4. SET UP VR SOFTWARE

The model of current erected buildings and structures are imported to the VR software, so that the current state and the project plan can be faithfully reproduced on VR. Traffic density, traffic signals, shade, and important viewpoints are set. Afterwards, the VR designer makes arrangements with the project team, and can modify and develop new function at any time.

3. Application the VR System to the LRT Project in Sakai City

3.1. OUTLINE OF SAKAI CITY AND THE LRT PROJECT

Sakai City is located in south of Osaka city, Japan, with an estimated population of about 830,000 people in an area of 150km^2. The construction of a new factory of major company is decided to take place in Sakai's seaside. The cited company does an advanced approach on environmental problems such a photovoltaic generation etc. Along with it, Sakai also advocates the label of the Sustainable City of Japan.

The LRT project in Sakai is scheduled to be opened in 2010. Figure 1 shows the introduction schedule section. The section of Sakai Station and Sakai-Higashi Station (about 1.7km), located in the downtown, is to be finished in the first phrase.

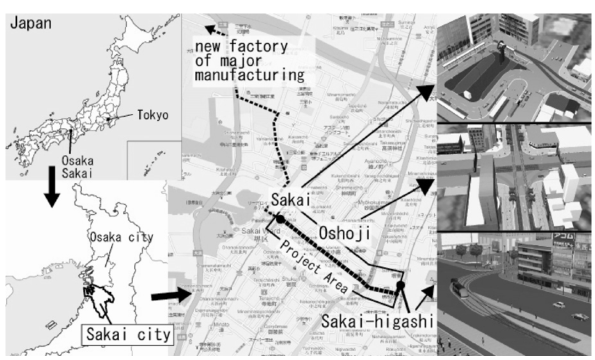

Figure 1. LRT project map

3.2. AIMS OF VR SYSTEM

Firstly, in the earliest stages of the project a VR was made aiming at the examination of the project outlines to the developer's team. Secondly, it was proposed not only a traffic viewpoint but also a sustainable city image that would drive the future of Sakai on VR. Thirdly, the solution was examined altering the traffic lanes disposal and paved areas to accommodate the trails (Figure 2). It was also necessary to consider the parking area and designed sites for load/unloading vehicles. The system could cause major traffic impact, mainly around the station, and the local residents would be inconvenienced for the traffic jams, if some parking areas were not given. It was later requested some changes in the current traffic design.

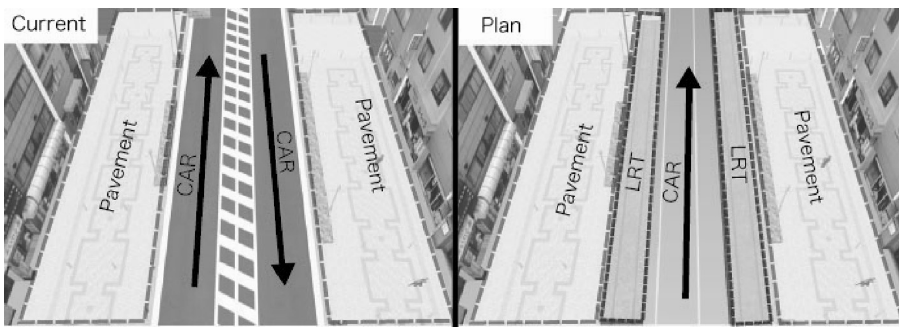

Figure 2. Current state and project plan of road

3.3. TECHNIQUE TO ACHIEVE THE AIMS

To understand the project area, a bird's-eye view image of the route was set to the section from Sakai Station to Sakai-Higashi Station. It was made to facilitate the visualization of the main intersections and also the pedestrian viewpoint and a bird's-eye view perspective, the most important ones. They were later compared with the whole plan visualization, and the presentation scenario was made.

Two future plans were designed to think about the future of Sakai. The first was a transit mall plan (Figure 3). Transit mall is a space in which only public transportation facilities have free access, such as buses and trams and pedestrian, by installing the traffic limitation system. This transit mall was made for the space in front of City Hall. The possible pedestrian uses were then simulated, in a scenario that when the LRT does not pass, the road can be used as a plaza. The second is a greenery plan proposed by citizens that was considered. We simulated a rooftop gardening and greening on the wall of the buildings, and the tree planting along the road space has been enhanced. Also, a cafe installed on the first floor of the building, and a space to relax offered to people (Figure

4-LEFT).

When the plan accomplished, cars will not be possible to park on the road anymore. Therefore, it was thought to use parking facilities along the railway facilities instead. The authors surveyed the current parking capacity, and then it was simulated in VR (Figure 4-RIGHT). The parking capacity was expressed according to height and the color of 3D model. As a result, the parked vehicle measures can be easily understood in VR.

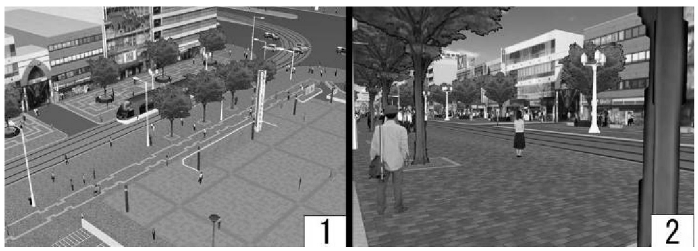

Figure 3. VR capture image of transit mall: (1) Bird's-eye view, (2) Pedestrian viewpoint

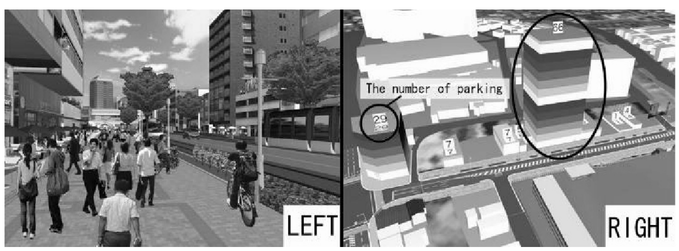

Figure 4. VR capture image of (1) a greening plan, (2) visualization of parking capacity

4. Evaluation

The measurement of frames per second (fps) and the loading time were selected as an evaluation of the performance. The purpose of fps is to promote a comfortable simulation. The purpose of the loading time is to smoothly switch data. The same laptop computer was used for all experiments. Table 3 shows a specification for the computer, and, Table 4 shows a specification for the data.

TABLE 3. Specification for the computer

CPU	Intel(R) Core(TM)2 Duo CPU T7800 2.60GHz
Memory	DDR2 667 2GB(×1)
Graphic Accelerator	nVIDIA GeForce 8400M GS 256MB
Display	1024×768

TABLE 4. Specification for the data

Volume of data	Number of polygons	Number of texture	Texture data	Number of model
714MB	683,222	1,706	456MB	281

4.1. MEASUREMENT OF FPS

Fps is a number of still pictures displayed in one second. When a smooth simulation by real-time rendering is done, 10fps or more is demanded (Fukuda, 2007).

4.1.1. fps in viewpoint fixation

While the LRT car running, even when the viewpoint is fixed, this movement should be smooth. Three main intersections (Sakai Station, Oshoji, Sakai-Higashi Station) were selected as measured viewpoint (Figure 6). Moreover, it was measured according to the presence of the traffic simulation. Table 5 shows the measurement result, where the decrease in the performance by the traffic simulation can be confirmed.

TABLE 5. Measurement result of fps (fixation)

		Without Traffic Simulation (fps)	Traffic Simulation (fps)
Place	Sakai Station	112	29.8
	Oshoji	112	19.9
	Sakai-higashi Station	111	9.9

4.1.2. fps in viewpoint movement

This was measured by a bird's-eye view of the route (Figure 5) from Sakai Station to Sakai-Higashi Station.

Figure 5. Bird's-eye view route

It was measured according to the presence of the traffic simulation, and the traffic simulation without the street furniture (Table 6). It was understood that the load by the viewpoint in movement is larger than the load of traffic simulation because there is no difference in the result with or without the traffic simulation. The system performance enhancement when the street furniture was non-displayed was confirmed. So it was thought that the load of the processing of culling and mipmap influences fps.

TABLE 6. Measurement result of fps (fly through)

	Without Traffic Simulation (fps)	Traffic Simulation (fps)	Traffic Simulation No Street furniture (fps)
Average	12.0	11.6	13.4
Maximum	31	30	31
Minimum	6	5	7

4.2. MEASUREMENT OF LOADING TIME

We will have to do presentation by using two or more data due to the advances of related research in the future. However, it takes long time to start data and it always interferes with smooth presentation, making the opposite opinion side audience more concerned about the application use. The factor that influences at the loading time of the VR system was though extracted and reflected in the VR system designing. The data of some patterns was prepared, and the loading time was measured (Table 7). It was clarified that both numbers of polygons and the texture volume of data influenced the loading time. However, it was detected no influence of either especially. Moreover, it is difficult to reduce the loading time greatly, and therefore, would need measures like the improvement of the system and the division of data, etc.

TABLE 7. Measurement result of loading time.

	Case1 Former data	Case2 No texture	Case3 Reduction in number of polygons No texture	Case4 Reduction in texture	Case5 Reduction in number of polygons
Volume of data(MB)	714	310	220	550	617
Number of polygons	683,222	683,222	375,657	683,222	367,789
Number of textures	1,702	0	0	1,702	1,702
Texture data(MB)	456	0	0	293	456
Data reduction rate(%)	0	56.6	69.2	23.0	13.6
Polygon reduction rate(%)	0	0	45.0	0	46.2
Texture data reduction rate (%)	0	100	100	35.7	0
Average loading time (second)	105.3	50.2	40	90.7	89.7

4.3. EVALUATION FROM THE LRT ENTREPRENEUR

A positive evaluation was able to be obtained through VR use. For instance, the well expression of traffic facilitates explanations and comprehensions, in a wish that the making of a sustainable city can be considered. There was an opinion of one of the participants concerned to parking and load/unloading vehicles, and it turned to be another consideration for the future. The authors already began to working on it, as cited previously.

5. Conclusions

It can be said that this VR system was effective in understanding the project and facilitation of the promotion of a sustainable city, and in this specific case this opinion was stated by LRT entrepreneurs. In addition, it succeeded in making the parking capacity clearly visible on VR, the main added consideration.

The system occasionally fell below the 10fps needed by a real-time rendering in part when the measurement result of fps was considered. However, it was confirmed that the performance improved by non-displaying small but load objects like the street furniture. In summary, it was thought that the switch of the display and non-display of the model is effective depending on the displayed viewpoint.

When the measurement result at the loading time was considered, it has been understood that it requires to start loading data for one or more minute. On the other hand, it turned out that the reduction in the texture data and the number of polygons was effective to promote so. However, there is a limit in those reduction techniques, and when not possible, is necessary to improve the system and to divide data.

As a future work and challenge, the authors think that it is necessary to make visible the effects of the reduction of greenhouse gas emissions and the consumption energy by VR. Then, more system developments and improvements are demanded. In this research, the rendering technologies such as Culling and Mipmap were not directly target, but the authors consider it necessary to improve those technologies for better performances in the future.

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