Development of an Urban Maglev Simulator using Virtual Reality Technology

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ABSTRACT: Korea’s Urban Maglev Program is in the final stage of project which develops a maglev transit system in the vicinity of Incheon International Airport. Because this project aims at producing a new railroad system, various requirements related to preliminary inspections of the maglev system have been raised steadily. In this study, a maglev simulator system was developed using digital mock-up and simulation technology. We used an open-source graphics engine to support rapid response to user requirements. Finally, this system was used to position the path of the demonstration line, select vehicle design and color, examine the station design, and perform other evaluations related to harmony with the city environment. Also, a VR simulator was developed to provide a virtual riding experience in the maglev.

1 INTRODUCTION

Korea’s Urban Maglev Program is in the final stage of project which develops a maglev transit system in the vicinity of Incheon International Airport in 2013[1-2]. Because this project aims at producing a new railroad system, various requirement and assessments related to preliminary inspections of the maglev system have been steadily raised.

Virtual reality technology generates realistic graphic images in real-time and provides users opportunities to interact with the virtual world through pre-defined simulation logic. Using virtual reality technology, we can simulate the maglev to run on our demonstration line in order to perform various design reviews of railway systems and evaluate environmental effects.

In this study, we developed a virtual reality based maglev simulator using DMU(digital mock-up) and simulation technology. First, we developed 3D DMUs of the maglev and railway structures using drawings and concept images of the vehicle design. Also, a 3D DMU of the demonstration area was modeled from urban planning documents of Incheon international airport and real photographs of the surrounding area. The DMUs were then loaded in the VR engine, which generates realistic graphics from DMUs, simulates the maglev’s dynamic behavior, and processes the user interactions. We used an open-source graphics engine as the VR engine to support rapid design-review responses to user requirements.

Finally, this system was utilized to position the path of the demonstration line, select vehicle design and color, examine the design of stations and perform other evaluations related to harmony with the city environment. The VR simulator was also used to promote our new maglev system to the public through the provision of a virtual riding experience of the maglev and a virtual navigation experience in the demonstration area.

2 SYSTEM DEVELOPMENT

2.1 Digital Mock-Up

For the selected demonstration areas at Incheon International Airport and Yeongjong Island, a 3DS MAX-based terrain model was developed using a 2D CAD model and aerial photographs. The airport terminal and other nearby buildings were modeled with the 2D building layout as a reference; real images were adequately mixed with those generated using the render-to-texture method to improve the quality and lifelikeness of the images.

3D modeling was also carried out on the basis of detailed 2D drawings on railroad tracks and train station buildings. The loft feature was utilized to generate tracks and rails on the section; the spacing tool was employed to arrange piers at constant intervals. The interior and exterior of the train station building were modeled separately, and selective rendering was performed under a real-time environment for improved performance.
Three design proposals were made by the institution that designed the maglev train; we selected one of the proposals and commissioned the train developer to carry out the detailed design. We initially intended to import alias files obtained from the train designer into 3DS MAX files after standard IGES file conversion. For real-time performance improvement, however, we had to redevelop the files into a 3DS MAX low-polygon file as they were comprised of 2.3 million massive mesh files. We also sought to convert the detailed 3D CAD model developed by the train developer in the same manner, but instead we referred to 2D/3D CAD drawings and reproduced it into a low-polygon model to ensure outstanding real-time performance.

![Digital mock-ups of station, rail and maglev](image)

**Figure 1. Digital mock-ups of station, rail and maglev**

### 2.2 Driving Simulation

The planned demonstration line will be built and run on double tracks on the 6.1km interval starting from Incheon International Airport Transportation Center through the Yongyu Train Base. The maglev train will be operated along the designated track, and the total distance from the point of departure was used as a parameter to develop a trajectory tracking module.

For this purpose, segments with a certain interval may be defined against the trajectory and be exported using ACE (Ascii Scene Export) when performing loft on the tracks to obtain point coordinates for each segment. The trajectory tracking module generates a spline using this point. Adequate interpolation is carried out with the total distance travelled as the basis to obtain information on the position and orientation of 10 objects in total. The results are reflected on individual components of the maglev train to undertake accurate trajectory tracking.

For one of the two train sets, acceleration was generated based on user input via a joystick or keyboard and the distance travelled was calculated using real-time numerical integration to implement a manual operation simulation. For the remaining one train set, an automatic operation simulation was performed where the train set cruised through individual train stations under predetermined conditions. For this purpose, we realized logic where stop positions in a train station building were defined in advance and acceleration was controlled automatically on the basis of intervals between train stations and maximum speed in the intervals to repeat running and dwell.

### 2.3 Real-time Rendering Engine

As we were developing Korea’s first maglev transit system, prompt support for decision making and quick responses in the initial design stage were essential. Against this backdrop, we comprehensively examined costs incurred, duration of development, and utilization of development outputs upon the addition of features and decided to leverage an open source-based graphics engine. In order to provide the most efficient development environment and ensure the quality of outputs, we analyzed the features of commercial toolkits and wide-ranging open source graphics engines. Ultimately, we selected and employed OGRE3D [3], which proved outstanding in terms of reflection of the latest graphic rendering technology, documentation of source codes, implementation of additional features, and the development and execution of license policies.

### 3 APPLICATIONS

#### 3.1 Demonstration Line Selection

We utilized this system to determine the routes of the demonstration line surrounding Incheon International Airport and to review the selected line and provide promotion support.

#### 3.2 Vehicle Design Decision

As illustrated in Figure 3, we supported the final decision making process by enabling real-time comparative assessment both indoors and outdoors on three design options developed by the train designer. Among the three types, Type B was
selected. We also implemented the feature of changing the train’s colors to support optimal color selection. The selected Type B was later modified to be developed into the final design shown in Figure 4.

3.3 Environmental Congruence Assessment

The railroad line for the maglev transit system was designed as elevated ground tracks, which have a slimmer and simpler shape than elevated tracks in other light rail transit systems. As pointed out in Figure 5, the urban surroundings were fully leveraged to support a comprehensive environmental congruence assessment encompassing not only train design but also elevated tracks.

3.4 Emergency Evacuation Route Selection

Given the characteristics of elevated tracks, the design of an emergency evacuation route was imperative to prepare for breakdown and other potential emergencies. The evacuation route should be set at a high level to facilitate evacuation from the train, but this would bring about a perception of visual disparity from the tracks. For this reason, we sought to determine the optimal format between the two design proposals illustrated in Figures 6 and 7 and ultimately selected Type B.

3.5 Track Format Review

The tracks of a maglev are comprised of girders, rails, and rail ties connecting the two; mono-block and twin-block formats may be applied to rail ties.
Through real-time switching of these rail ties, the system enabled passengers to visually assess the shape of rail ties, as illustrated in Figure 9.

3.6 Station Design Review

Using the drawings provided by the station designer, we assessed the levels of crowdedness at the waiting room and platform of the train station. Based on the maximum number of passengers for the maglev, we examined the flow of passengers while boarding/alighting and obstacles ahead of them and modified the location and operational direction of stairways and escalators.

3.7 Turnout Location Selection

A maglev is run with its bogies covering the tracks, and thus the implementation of a turnout is very complicated and related structures are huge compared to the general tracks. The turnout had to be installed between the starting station (Transportation Center) and the second station (ground parking lot intersection). However, because the turnout structure was huge in size, a wide variety of preliminary verification works were carried out before determining its final location.

3.8 Application to Daejeon Urban Railway Line 2

The Korean city of Daejeon has the plan of adopting the maglev transit system for the second line of its urban railway. The simulator developed in this study was utilized to perform a virtual driving simulation around the area of the Daejeon Government Complex and to explain the project to local residents.

3.9 Virtual Riding Experience Simulator

Using this system, we developed a simulator offering a virtual maglev riding experience. The system enables wide-ranging experiences such as train operation and opening/closing of doors via a joystick; a 10-channel DLP cube and a 3D stereo system were developed to provide a strong sense of immersion to the virtual environment. The same simulator is being run in the maglev promotion center on the first floor of the Incheon International Airport Transportation Center.
4 CONCLUSIONS

This study has developed a simulation system using digital mock-up and real-time virtualization technology and introduced application examples to support preliminary inspection of and decision making on an urban maglev transit system that is drawing keen attention as a next-generation means of transport. Real-time review and simulator technology may play a crucial role in the conceptual or initial design stage of the new system; a more systematic approach and in-depth research will be necessary for the development of virtual rapid prototyping technology.

5 ACKNOWLEDGEMENT

This research was supported by a grant from the Maglev Realization Program, funded by the Korean Ministry of Construction & Transportation.

6 REFERENCES

3. OGRE3D (Object-oriented Graphics Rendering Engine) project. URL: http://www.ogre3d.org