Applications of Virtual Reality to Civil and Architectural Engineering Projects

Deyin JIN[1], Feng YAN[2] and Yuji ITO[1]

[1] Forum8 Co., Ltd., 2-1-1 Nakameguro GT Tower 15F,
Kami-Meguro, Meguro-ku, Tokyo 153-0051, Japan
[2] NEPOCH & FORUM8 Technology Development (Shanghai) Co., Ltd.
Room 706, Eton Place, 69 Dongfang Road, Shanghai 200120, China

ABSTRACT

Virtual Reality (VR) is an emerging technology to simulate the real world on the computer and is being applied to many fields of industries like Civil and Architectural Engineering (CAE). The uses of Virtual Reality not only make us transverse the time and space to feel a planning project but also avoid a design miss and have project-related persons a quickly understanding on any complex project. As the development of computer technology of

software and hardware, VR shows a great perspective and will be widely applied to engineering projects. In this paper we will first introduce some VR knowledge and its properties as a computer program system, and then present the relative problems in civil engineering field, finally give some examples of the VR applications from project discussion to constructional process preview, from traffic flow simulation to predicted disaster demonstration in CAE fields by our VR tool of UC-win/Road.

KEYWORDS

Virtual Reality, Civil Engineering Projects, Traffic Simulation, Disaster Simulation, Construction Simulation

1. INTRODUCTION

The computer has been intensively applied to CAE from traditional numerical calculation of structural responses under external forces to automatic safety checks basing on specific design criteria, from draft drawings of plan and structures to CG image of a space or a scene. With those applications in design and calculation, CAE projects can be finished more efficiently, safely and in a large-scale within a short period. However, the works involving CAE projects are not limited to design and safety check, the planning, construction and management are very important to a complex project.

VR as a new innovative technology appeared recently accompanying with computer performance improvement of hardware and software, like CPU, memory, video card and 3 dimensional graph system technologies. It can present the real world including objects and phenomena in a compact environment in 3D format and make users transport time and space to feel a virtual world. The VR technology presents an applicable perspective in all social aspects including CAE.

The more early description about VR application to civil engineering can be found in paper (1, 2). Retik(1) applied VR to develop an approach to share collaborative visual planning of the construction process while Xie(2) dealt with the application of VR to natural disaster presentation. Since then there are a mount of papers to discuss the VR application in the CAE.

Here we will give a simple introduction to the VR technology and then describe its application to the CAE in various aspects. Some applying facts by our tool UC-win/Road in recent years are presented too. And finally we will conclude the some points about VR applications.

2. VIRTUAL REALITY TECHNOLOGY

Virtual Technology can be defined as to show a real world environment on a PC monitor and user can operate it or interact with it by some utilities. Due to the real world complex, the data size to reflect the real object is very large and PC capability of speed, memory and disk is ultimately used to reach a realistic effect. Since the limit of PC capacity in the past, the VR system did not perform well to represent a scene realistically and its application was limited too. But now PC technology development has made running a VR system available on a common PC machine. Reference 3 gives a general description about VR technology.

VR system can be divided into desktop VR and Immersive VR according to the interaction interface, Single PC VR and Distribution VR (DVR) connecting by internet according to attendee number. DVR is widely used in some game and training system while VR systems used in CAE at present mainly concentrated to the desktop, single machine type corresponding to the CAE task characteristics. The moving and natural phenomenon simulation is the necessary requirement of VR System of CAE.

For a VR system, its contents are generally composed of the following parts :

a. Geometrical grid (3 dimension points <x, y, z> on the base of a certain coordinate system)

b. 3 dimension models composed of frame and texture

c. Nature phenomenon like rain, cloud, snow etc.

d. Motion simulation of objects, scenes

e. Texture treatment and memory manager

For a vivid, realistic scene presentation, many CG technologies are needed such as LOD, Rendering, etc. Especially when the data become large, the memory manager technique to run a huge data is necessary. An advancing video card is necessarily installed for smoothly dynamic showing. With the advancing of PC technology on hardware, software and internet, VR system will be created more powerfully.

3. CIVIL ENGINEERING PROBLEMS AND SOLUTION BY VR

Even though the computer gives us a lot of helps as mentioned above in load-acting responses, safety checks and CAD draft drawings, with civil engineering trend to complex and requirement to project contents rises, it cannot satisfy our needs sometime like a large project to require several side participants to act coordinately. The problems that met in CAE projects can be summarized as below.

- The whole image about complex and large-scale projects cannot be easily grasped by 2D drawings or verbal description. Some table scaled-models are very limited.
- Planned projects are frequently modified to satisfy the need of all the aspects.
- Project management during construction becoming difficult because of complex process.
- Multi-system running in city need a more feasible tool to display.
- Landscape and environment evaluation trend toward a high level and cannot be realized only by imagining.
- Underground projects increase so that the unseen components arranging crowdedly.

As a solution, the VR tool, UC-win/Road, had been developed and VR technology is used to solve these problems. By working in the last several years, VR has been successfully to apply to the CAE fields as listed in Table1 and its details can refer to the web page (4).

Table 1: Application aspects of our tool UC-win/Road by now

Catalogues	Application Details	Solved Problems
Road	Speed-way, lamp and skip road line simulation, The four corners cotton thread distribution with the design which moves towards, The charge stands design	Lane design, facility design
Transportation	Traffic state simulation, Driving, Traveling on road, Flight on an air route Signal Light State simulation	Traffic congest
Tunnel	Alignment examination, an underpass road, a subway, a canal, mountain tunnels, compound tunnels	Design
Bridge	Arch bridges, bridge type comparison, bridge construction, suspension bridges	Shape Design
Rivers	River rebuilding, river mouth, river improvement, waterway	Sight View check
Architecture	Architecture planning, an apartment project, a housing room planning, a parking area planning, a sunshine time and area check	Decorating, outside view
Railway	Railroad crossing, underpass, station house, pedestrian deck, station house repairing, LRT	Sight view running
Harbor&Airport	Haneda Airport, Yokohama Port, Scene design of the seaside	Sight view
Park	A park planning, Park facility Check	Design Check
Underground Infrastructures	Station taxi pool，pedestrian deck and surrounding roads	Spatial position grasp
Construction	Grade separation construction, viaduct execution, a new tunnel constructing method, temporary construction, station expansion	Simulation, organization
Disaster	A mount road disaster, a city disaster, a traffic accident, a flood, hazard map data, a tsunami	Preview
Education	Teaching arrangement, The imaginary project creation	Lecture excise

4. APPLICATION EXAMPLES OF VR

In the followings we introduce 5 specific application fields or examples to use VR in the project creation and project presentation with the captured pictures from our VR system.

4.1 Project Checks and Demonstrations

As a project presentation tool, VR has a great advantage over any traditional method such as the table scaled-model. It has many characteristics such as easily modified and digital-saved format. The model data can be repaired whenever necessary and be displayed in any world places. Here we show a specific case of VR application to the whole project planning of Fuji International Speedway in Figure 1.

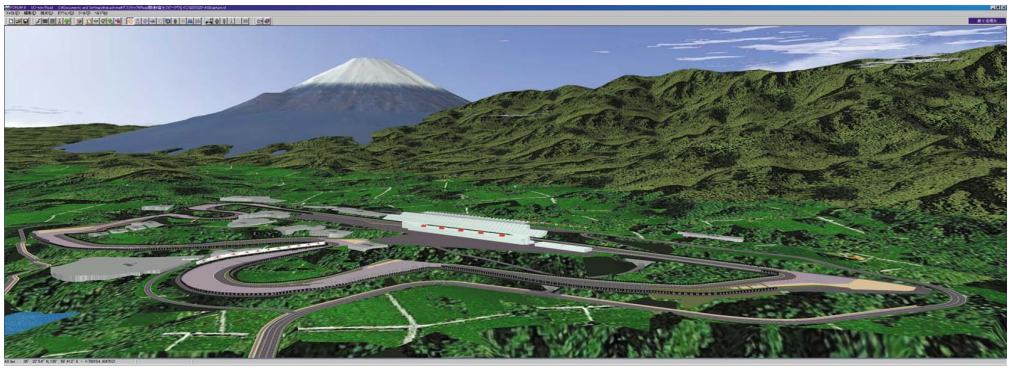


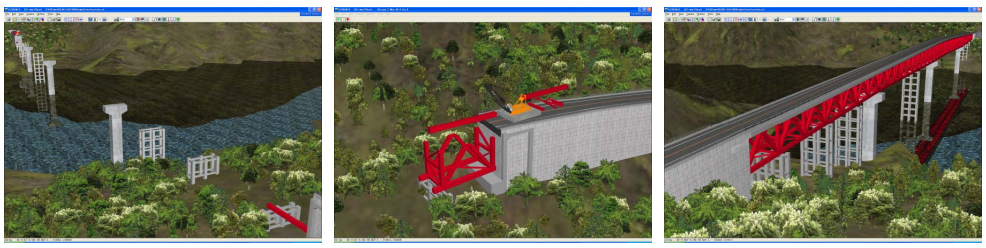
Figure 1: A bird view for the planning landscape

Mt. Fuji is the most important landmark in Japan and hope to be seen from any places. For obtaining a good view from different points, the VR technology by the tool, UC-win/Road, was used to adjust the position and height of each part of the project. Mt Fuji, as a large 3D model, was placed 16km distant in the data. Scene examination was performed from every position that overlooked Mt. Fuji and a simulation of driving along the management road was carried out. VR was also used to model exhibition booths and displays in the open area during event and even to check the views of billboards from TV camera positions.

The Fuji speedway project involved many international companies in a variety of business categories, including course designers, drivers, construction engineers, TV Companies, sponsors and race officials. UC-win/Road provided a common language to assist communications between these organizations.

4.2 Constructional Stage Simulations

Construction processes of any large-scaled CAE project are not easily organized and mastered by designers and constructors only relying on the drawing and specifications. Any mistake will result in the whole project delaying and cost increasing. By using VR, the construction stage is simulated so that components or parts assembling and machine using can be checked in time and spatial position. Therefore, construction can go congruously based on VR simulation images among all the participants. The following three graphs in Figure 2 are VR application to the truss bridge construction process.



a) Before construction b) Being constructing c) After construction

Figure 2: A construction stage simulation of truss bridges

4.3 Transportation Simulations

The traditional traffic simulation was done on the 2D plane in which the moving cars can be modelized as a point or mark, the roads and buildings are only presented by line and box, lack of real impression. VR application to transportation simulation makes simulation more realistic and more impressive as the following two pictures in Figure 3. Besides of the traffic flow, vehicle type, intersection signal and car driving can be realized as a real world. According to the traffic flow state, the effects to lessen traffic congestion can be viewed easily and simultaneously by changing road lane division, redesigning road crossings and resetting the signal light period. VR can be used to simulate the traffic flow state too for some repair or emerging cases. Except for the traffic flow simulation, the road marks and signals can be tested from the driver viewing points. By driving simulation on a road of VR,

the environment around roads can be familiarized with.

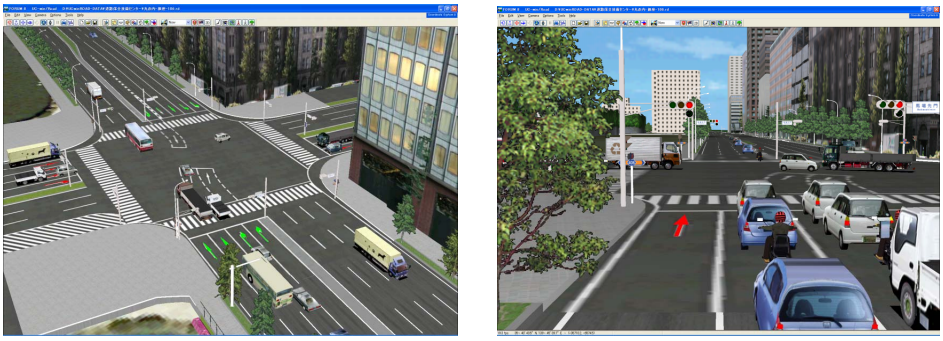


Figure 3: Transportation simulation from different view points

4.4 Predicted Disaster Demonstrations

Natural disaster happen can be heard of nearly every day from TV or newspaper. Disaster prediction and reduction are a very important activity now around the world, especially for a populated city. The success of disaster prediction and loss reduction depends not only on the researchers' precise forecast to the possible damage, but also on the government and citizen consciousness on the potential dangers. Therefore how to present the future disaster to the related persons can decide the success of disaster reduction activity.

a)Flood disaster b) Geological disaster c) Earthquake disaster

Figure 4: Presentation of natural disasters

By using VR technology, the predicted potential disasters can be displayed intuitively as the 3 pictures in Figure 4. Figure 1 a) is flood disaster due to the bank breaking, Figure 1 b) is

mountain slope slide disaster and the road traffic is blocked, and Figure 1 c) is building collapse due to earthquake attacking. Beside of 3 special scenes, the dynamic phenomenon like fire and sound can be shown too. The impressive disaster scenes arouse viewers the disaster prevention awareness.

4.5 Structures and Response

VR technology can be used to display the structural components, details, and load-acting responses. The 3D visual images not only give a quick understanding to the structural inner parts but also give a mechanical state under external forces and even the possible damage part. College students, project design can benefit from those 3d Images and get a visual concept that only be created by imagination when using 2D drawing or numerical figure. Those graphs can also be used as a project presentation.

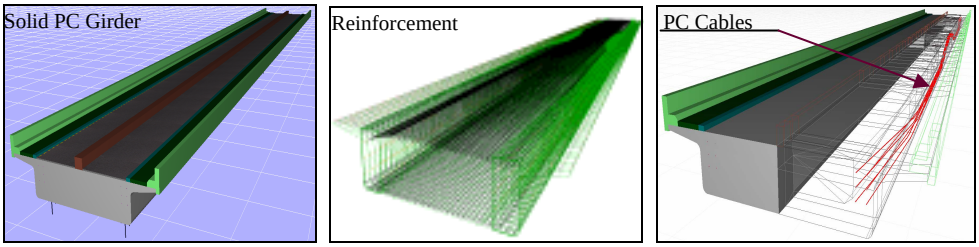


Figure 5: PC girder of a bridge superstructure

The 3 graphs in Figure 5 show a PC superstructures and its arrangement of reinforcement and PC Cable. By item selecting or object operating, the concrete and steel are separated shown clearly.

The three graphs in Figure 6 show the responses of rigid frame bridge under Level 2 transverse earthquake. The step solid deformation response with original wire frame model is displayed on the left. Pier parts are modelized as fiber elements and its section defined strain damage accompanying with the whole frame displacements is shown in the middle. Frame element internal forces (red line: moments, green line: shear forces) and supported nodal

reaction at each step is displayed on the right.

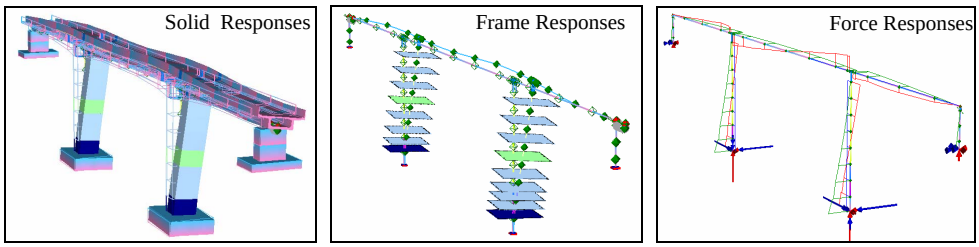


Figure 6: Bridge responses acted by an earthquake

5. CONCLUSIONS

The VR application to civil and architectural engineering projects is described here based on our engineering application facts by to now. By introducing the VR to the CAE projects, we can summarize the following points about VR as a presentation tool.

1). A quick perception to complex projects.
2). Make project design more reasonable, low cast, and sometimes good idea.
3). Before project is carried out, the intuitively visual understanding.
4). Visual simulation make problem solving more quick.
5). Reach a good communication among the participants for the project.
6). Have a good education effect

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