ROAD SAFETY AUDIT AND ACCIDENT MODELING IN URBAN AREAS

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Abstract: In order to evaluate road safety in design stage, virtual simulation tests are proposed. The system includes the modeling of virtual road based on Creator, the development of vehicle dynamics model and 3D model, the development of real-time simulation software based on Vega and road safety evaluation model. Through the visual simulation tests, the vehicle speed inducement effect of the road can be obtained at the design stage. This system was applied to Xi’an-Hanzhong freeway and Baoshan-Longling freeway projects, the results show that this system can be used to guide the road alignment design and improving design of traffic facility, and to provide foundation for road safety audit.

1. INTRODUCTION

The number of traffic accident in China is increasing continuously in recent years. In 2005, there were 450,254 road traffic accidents, with 469,911 injuries and 98,738 deaths [1]. Most of those traffic accidents result from the harmony out-of-balance of such integrated systems inclusive as the driver, vehicle, road and traffic environment etc. To be exact, any destruction of any component’s normal function of this system may cause a traffic accident. Generally it is thought to be the driver’s fault, which results in the accident. And statistics in traffic-police department on the assertion of the accident traffic responsibility shows that over 85 percent of the accident is due to the driver mainly in China, of which nearly 70 percent resulted from the driver’s such judgment errors to the driving speed as "over speed", "careless overtaking", "not enough vertical driving interval", "negligence", etc. Take the year 2005 as an example, 52,655 accidents were caused by going over the speed limit, caused 16,015 deaths, account for 11.69% percent and 16.22% of the total number of trouble-making drivers in China.

But the profound reason for quite a few traffic accidents caused by the driver should be the very bad road and environment factors. These factors can be divided into an explicit defect and a hidden one. The former can be observed and found out directly, such as, no complete roadside guardrails, bad shoulder condition, and not timely repair after damaging of the road. The latter is not easy to be noticed, such as the straight-line section of many kilometers in succession on the freeway, dull driving environment, etc. So, in fact, in the causes of road traffic accidents, the accident resulted from “road factor” is mainly the accident that is caused by explicit defect of the road. Obviously, the statistics mentioned above have ignored the influence of the road and the traffic environment in road traffic accidents.

In the northwest and the southwest of China, national arterial highway is mainly made up of second-class auto-only highway and the mountainous expressway. Limited to the restriction of the development of the western regional economy and mountainous terrain, generally the design speed for second-class highway is only 40km/h and for the expressway only 60km/h. Corresponding with such low design speed, low standard road horizontal alignment parameter goes against the better road surface and traffic environment. This has been the main inducement of traffic accidents in mountain area of China. So such harmony problems between the road alignment parameter and the road surface and traffic environment must be solved by the means of technology.

Methods used in the road safety evaluation at present are as the following: speed-profile model [2], speed distribution [3], alignment indices, driver workload [4], etc. These methods can be roughly divided into two types. One is to get the vehicle’s operating speed through its speed investigation and test, and then to carry on the safety evaluation of the concrete highway section according to the corresponding model. The application obstacle of this kind of method lies in being difficult to get vehicle operating speed on the highway section in the design stage. Another is to find something laws in the stochastic traffic accidents by statistical method, to predict the frequency of the accident in the design highway section macroscopically and to evaluate the road’s safety. As the model has a lack of commonality and the model parameter has a considerable difference to different grades and regional highway, there are few achievements suitable for popularizing and applying of this kind of model when the safety of concrete highway section is studied. Therefore, at present, China still lacks the systematical, rational, visual road safety evaluation system that can face the road’s design scheme and safety protection project scheme.

Virtual reality technology can make vivid virtual environment through multimedia technology and simulation technology. Users can naturally experience and interact with the object in the virtual
environment and feel they are personally on the scene. Virtual reality technology has such main characteristics as immersion, interaction, multi-sensation, and autonomy. In last years, some relevant technologies are increasingly improved, especially the real-time three-dimensional graphics generation technology, sound locating and composing technology, environment modeling technology, etc. So, it is already possible to make use of virtual reality technology to carry out the systematic research of road safety evaluation.

In the United States, the design consistency is used to evaluate road safety, which focus on the rural two-lane highways. The definitive study is Interactive Highway Safety Design Model (IHSDM) being developed by the Federal Highway Administration (FHWA) [5], Design Consistency Module of IHSDM estimates expected operating speeds and measures of operating-speed consistency.

The visual simulation platform for combined operation of driver-vehicle-road (environment) developed by this paper offers the visual and quantitative experimental environment for obtaining the visual effect of the driver-vehicle-road (environment) system for design or research highway section. In this virtual experimental environment, simulating the vehicle’s operation conditions, above-mentioned evaluation parameters can be obtained, for example, parameters of operating speed, of speed distribution, and of sight demand, etc., and further these models can be utilized to carry out research and appraise. So the significance of this road safety evaluation system based on virtual reality technology is to realize the implement of the concept of “people first and based on car” in highway engineering project and security protection engineering, and as a result to improve the road traffic safety and to reduce the traffic accidents in China.

2. Structure of road safety evaluation system

Road safety evaluation system consists of road model, vehicle model, virtual simulation module and road safety evaluation model.

2.1. Road model

MultiGen Creator is one of the best real-time 3D modeling tools with high fidelity. This is a special modeling tool designed for real-time simulation of the complicated virtual scene, a manual modeling tool which integrates polygon modeling, vector modeling and terrain generation in a software package. MultiGen Creator uses OpenFlight as the format of its database. OpenFlight, uses geometry hierarchy structure and attribute to describe the 3D object.

MultiGen Creator software is different from such other modeling software as mechanical CAD, etc. On the premise of satisfying real-time character it mainly considers how to generate facing simulation scene of large area with high fidelity. Its strong modeling function can offer modeling system and tool for numerous different kinds of image generator, and its advanced real-time functions such as LOD, polygon filter, draw priority makes OpenFlight format become most prevailing vision database format among the real three-dimensional field and also become the actual standard of the scene simulation field. The 3D road modeling mainly adopts MultiGen Creator software. System model mainly includes terrain model, road model, traffic engineering facility model, and environment model.

(1) Terrain modeling.

Three-dimensional terrain generating method can be divided into one on the basis of true terrain data and another based on the fractal technology.

(2) Wireframe modeling of road.

Use RoadPro tool of MultiGen Creator to set up road parameter and to produce road model, and use Tessellation tool to grid wireframe model.

(3) Vehicle system modeling.

Use MultiGen Creator to set up evaluation vehicle model, including the model of passenger car, of bus, of truck, etc.

(4) Traffic engineering facility modeling.

(5) Modeling of road structures.

(6) Plants modeling in the traffic environment based on the Billboard technology.

(7) 3-D simulation road modeling. (8) Scene modeling.

Figure 2 shows the road model of Xi'an-Hanzhong freeway of Shaanxi province of China.
2.2. Vehicle model

Vehicle model is made up of vehicle dynamics model and virtual 3D vehicle model. Vehicle dynamics model can be used to obtain the vehicle’s response to the driver’s input of manipulation order. This model mainly includes complete vehicle model, brake system model, steering system model, tire model and etc., the 3D 4-wheel vehicle model adopted by this paper, as is shown in figure 3 [6]. The tire model uses Gim tire model because of its advantages such as high computational speed, good adaptability, and precision of operating, etc [7]. The 3D vehicle model includes passenger car, bus, heavy-duty truck and so on.

The off-road vehicle model is shown in figure 4.

2.3. Virtual simulation module

The virtual simulation is the most important expression of virtual reality technology. It comprehensively applies such a great deal of new and high technology as the computer simulation technology, graphics processing and image generating technology, stereo technology, information synthetic technology, etc. It has realized direct and natural interaction between the user and environment. It demands to construct the vivid 3D model, texture and special effect, and to reproduce the realistic virtual environment at high speed and to real-time respond and operate mutually.

OpenGL Performer is one expanded real-time 3D visual simulation developing software package with high performance developed by SGI. Based on GL graphics lib, OpenGL Performer offers to the user one group of procedure interface in the form of standard C language and C++ language. Comparing with OpenGL, it is with better function and flexibility as well.

Vega, developed by MultiGen-Paradigm Inc. to be used in real-time simulation and virtual reality high-performance software environment and tool, is the most fundamental environment made up of the graphic user interface called Lynx and Vega API lib. The function of Vega can be expanded through the additional special effect module. The module expands user interface and offers a large number of customized C function lib.

The simulation 3D engine of virtual road evaluation system adopts Vega and OpenGL performer and the developing platform of this system uses Visual C++ integrated development environment. Fully utilizing the embedded scene simulation function of Vega, visual simulation control can be realized using API function library of Vega in Visual C++. Scene simulation procedure is designed on the basis of multi-processes and multi-thread.

2.4. Road safety evaluation model

The key issue of road safety evaluation is how to obtain the road safety evaluation index. Road safety evaluation model is set up on the basis of combined operation of driver-vehicle-road (environment). The foundation of the evaluation system is the record data when the driver drives on the virtual road in visual simulation. Eq. (1)~Eq. (4) show the calculating model.

$$\Delta V_{od} = (V_{85i} - V_d)$$  \hspace{1cm} (1)

$$\Delta V_{se} = V_{85i} - V_{85(i - 1)}$$  \hspace{1cm} (2)

$$SRC = \frac{V_{85i}}{V_{85(i - 1)}}$$  \hspace{1cm} (3)

$$\Delta S_{Fod} = \frac{od_{od} \cdot od_{i-1}}{127R}$$  \hspace{1cm} (4)

Where:

$\Delta V_{od}$ is the difference between the operating speed and the design speed, km/h.

$\Delta V_{se}$ is the difference of the operating speed on adjacent highway sections, km/h.

$SRC$ is the speed reduction coefficient.

$V_d$ is the design speed, km/h.

$V_{85i}$ is the 85% operating speed on i highway section, km/h.

$V_{85(i - 1)}$ is the 85% operating speed on (i-1) highway section, km/h.

$R$ is the radius of horizontal curve.

$\Delta S_{Fod}$ is the variation of lateral force coefficient.
3. The course of simulation evaluation

Utilizing the driver-vehicle-road (environment) visual simulation platform (DVRSP), the steps of road safety evaluation are as follows:
(1) To input horizontal, vertical, cross-section parameters of road and traffic environmental ones to build road model;
(2) To set up the 3D models of vehicle, terrain, and environment;
(3) To utilize semi-physical model to carry out the simulation test on DVRSP to obtain data for evaluation model;
(4) To produce the speed-profile figure of operating speed;
(5) To make safety evaluation on the road section according to safety evaluation model;
(6) To evaluate and optimize the design scheme. The design should be revised when appraised to be “bad”, be optimized when “good”.

The hardware system includes vision simulation graphics workstation, vehicle dynamics solution station, three-channel reality center (RC), simulated driving test stand, and etc.

The basic process of visual simulation experiment is: the major controlling vision station sends the collection signals; data collection module of the of secondary computer passes the obtained signal from the driver to the major controlling workstation of vision simulation through serial communication; by means of local network, the major controlling station of vision simulation sends the vehicle driving parameter and momentary state parameter of driver operating to the system of vehicle dynamics solution, which sends back the calculation result to the major controlling station; combined with sound system, the major controlling station generates 3D vision, and sends the synchronous signal to another two stations of vision simulation, three controlling stations of vision simulation pass graphics signal to three projection controlling channels of RC by which the vision is projected to the cylinder screen in the front after blending and correction; thus producing a high immersion simulated environment.

The system was applied to evaluate safety of the alignment and traffic engineering facilities of Xi’an-Hanzhong freeway of Shaanxi province and Baoshan-longling freeway of Yunnan province projects in China. Fig. 5 shows the simulation photo for Xi’an-Hanzhong freeway.

4. Conclusion

The application shows that virtual simulation is a good method to develop road safety evaluation system. MultiGen Creator and Vega are high-efficient developing tools, which can be used to set up 3D simulation model and vision rendering.

References