Development and application of a driving simulation platform adapted to the teaching of students under the influence of COVID-19

Tao Zhao[1*], Chuan Wang[2], Ning Zhang[3], Xianglong Meng[4], Xinming Guo[5]

[*] Corresponding author: 202215419@mail.sdu.edu.cn

[1]Shandong University, School of Qilu Transportation & Shandong University, Suzhou Research Institute, Shandong Univ, Sch Qilu Transportat & Shandong Univ, Suzhou Res Inst Jinan, China & Suzhou, China

[2]Shandong Hi-Speed Construction Management Group Co., Ltd
Shandong Hi-speed Construct Management Grp Co Ltd Jinan, China

[3]Shandong Hi-Speed Construction Management Group Co., Ltd, Jinan, China

[4]Shandong Hi-Speed Construction Management Group Co., Ltd
Shandong Hi-speed Construct Management Grp Co Ltd Jinan, China

[5]Shandong University, School of Qilu Transportation & Shandong University, Suzhou Research Institute, Shandong Univ, Sch Qilu Transportat & Shandong Univ, Suzhou Res Inst Jinan, China & Suzhou, China

Abstract—Due to the COVID-19, offline driving simulation practice teaching is not possible. In order to let students intuitively understand the knowledge about freeway diverging and merging areas, this paper develops a driving simulation platform for teaching based on Unity 3D. The terrain and road models were established based on real scenarios. The vehicle dynamics model is used to simulate the motion of the controlled vehicle. A simulation platform with adjustable traffic volume and weather conditions is implemented. The validity of the driving simulation system was verified by comparing the experimental data with actual experience. Students are given hands-on experience in the teaching process to experience the driving characteristics in the diverging and merging areas. Quantitative analysis of driving behavior in different situations in different scenarios. After subjective evaluation and objective evaluation based on questionnaires, the teaching effect is good.

Keywords- driving simulation; teaching; diverging and merging area; Unity 3D

1 INTRODUCTION

Since the occurrence of the COVID-19 in December 2019, the location and form of teaching activities implemented in universities have been greatly restricted, which to some extent affects the effectiveness of teaching and learning. In teaching in traffic safety, in order to make students understand freeway diverging and merging areas and the various risk conflicts in them, students need to be taken to a partner organization that has a driving simulator for hands-on practice.

ITEI 2022, December 23-25, Harbin, People's Republic of China

DOI 10.4108/eai.23-12-2022.2329102

However, due to the epidemic, it was not possible to go out and participate in hands-on driving simulator instruction.

One of the most important reasons affecting the safety of freeway traffic is the driving behavior of vehicles in the freeway diverging and merging areas[1]. The acceleration and deceleration of vehicles, lane changes, and other behaviors are likely to cause drivers to make errors in judgment and operation, causing traffic chaos and more likely to lead to accidents. Freeway entrance and exit area kilometer accident rate is generally 4 to 6 times higher than other road sections, belonging to the accident-prone area[2]. The implicit association between driving behavior and traffic safety is the core of the problem, and the multi-factor, uncertainty and personalization characteristics of traffic safety accident formation present a challenge for solving such problems.[3] Therefore, this paper develops an interactive driving simulation platform based on Unity 3D for diverging and merging areas scenarios. Unity 3D software is easy to operate, easy to develop, and highly interactive[4]. The software is simple to install and configure the environment so that all students can operate it on their own computers[5, 6]. You can adjust parameters such as steering sensitivity, brake sensitivity, and the maximum speed of the car driving according to your own operating habits. There is no safety risk in the driving simulation in practice, it is less costly, less time -consuming, and more efficient.

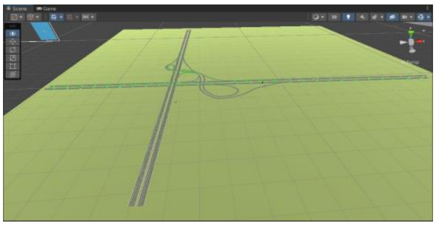
In this paper, we developed a driving simulation platform for teaching based on Unity 3D for freeway diverging and merging areas. The terrain and road models are established based on real scenarios. The simulation motion of the controlled vehicle is realized based on the vehicle dynamics model. Innovative ray detection in the driving process is realized, and the following distance data is recorded. And the simulation platform with adjustable traffic volume and weather conditions is realized.

Driving simulation technology has now been applied to a variety of traffic scenarios. Firstly, it has an important role in promoting the development of intelligent transportation and ensuring the safety of road traffic, and secondly, it has an important role in student education. This paper first introduces the driving simulation platform based on Unity 3D. The types of scenario design and the process of script development are elaborated. The important and difficult issues in the driving simulation are introduced. Secondly, this paper elaborates on the specific teaching process and experimental operation process as well as the basic ideas of data analysis. Third, the subjective and objective evaluation of teaching effectiveness is presented. Finally, the content of this paper is summarized and prospected.

2 UNITY 3D-BASED DRIVING SIMULATION PLATFORM DEVELOPMENT

2.1 Design of simulation scenarios

Currently, 12 scenarios are designed based on three main types of merge zones for teaching purposes. The first is the interchange scenario, which is divided into six scenarios based on weather conditions and traffic volume, namely, clear day normal traffic volume scenario, rainy day normal traffic volume scenario, clear day medium traffic volume scenario, rainy day medium traffic volume scenario, clear day high traffic volume scenario, and rainy days high traffic volume scenario. The overall scenario diagram and part of the first view diagram (taking the rainy days low traffic volume scenario as an example) are as follows.



(a) Overall design of interchange scenario

(b) The first view of normal traffic volume on rainy days

Figure 1. interchange scenario

The second is the bypass front bridge pier scenario, which is divided into 3 scenarios according to the traffic volume, including normal traffic volume scenario, medium traffic volume, and high traffic volume scenario, the overall scenario map and part of the first view map (medium traffic volume scenario as an example) are as follows.

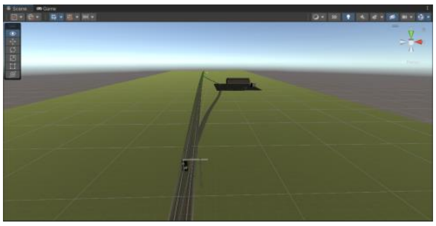
(a) Overall design of the bypass front bridge pier scenario

(b) The first view of medium traffic volume

Figure 2. the bypass front bridge pier scenario

The third is the service area scenario, which is divided into 3 scenarios according to the traffic volume: low traffic volume scenario, medium traffic volume, and high traffic volume scenario.

The overall scenario diagram and part of the first view diagram (taking the high-density scenario as an example) are as follows.



(a) Overall design of service area scenario

(b) The first view of the high-traffic volume

Figure 3. service area scenario

Among them, in the above three scenarios of merging zone, the traffic volume in normal density is designed according to the actual traffic volume of the freeway, in order to make students get the driving feeling of different traffic volumes, the medium traffic volume and high traffic volume scenarios are designed.

2.2 Script Development

Using the Unity 3D development environment, this paper first uses the Easyroads3D plug-in for preliminary road model building according to the actual road situation. The specific details of road markings and merge zones were adjusted to form the final road simulation model. Then the UTS plug-in was used to set up the traffic flow, including setting and adjusting the route, density, and speed of the traffic flow.

After the road simulation model and traffic flow are set up, the vehicle appearance model and wheel model are created first. According to the vehicle dynamics model, the code is implemented for vehicle control, including the design of the vehicle's collision model, the design of acceleration and deceleration range, and the design of the steering system. Then, we add the Camera to the overall vehicle model and adjust its position, and realize the following rotation of the camera view through the code. Through code design and Unity internal settings, effective control of the vehicle by external input devices is realized.

The main camera mainly displays the front view and loads a ray detection script to detect the distance to the vehicle in front, setting the depth of the main camera to 0. The left and right cameras mainly act as left and right mirrors to get the rear view of the vehicle, setting the depth of the left and right cameras to 1. The other camera is rotated 180° so that its main direction faces backward. The other camera will be rotated 180° so that its main direction is towards the rear, mainly to mount the ray detection script to detect the distance to the vehicle in front, set the depth of the main camera to -1 so that it does not show the field of view and only plays the role of distance detection.

Design the "Speed" script, mount it to the controlled vehicle, calculate and store the speed and acceleration of the vehicle at the current moment, and extract and store the distance information of the vehicle's position at the current moment. Design a script named "scene control" to transfer the speed, acceleration, distance, and position data stored in the Speed script to this script, create an empty object "control" in the scene, and mount it. Create an empty object "control" in the scene, mount the "scene control" script, and use the code to realize that this object will not be destroyed when the scene changes, so as to provide a basis for the subsequent script transfer process.

In order to view the run data easily after the run, set the button to view the run data in the main scene. Design the code to realize the transition between the main and secondary scenes, and mount this script under the button to realize the transition between the main and secondary scenes when the operator clicks the button.

Design the data export scene (sub-scene), and design the UI interface, mainly including velocity image drawing, acceleration image drawing, "Data Export" button design, and "Data Export to Local" button design. The design code gets the running data from the undestroyed empty object "control". Then pop up the save text file data screen, select the save location and fill in the file name. The script will be mounted under the "Export Data to" button to export the runtime data to the text file.

2.3 Important issues in system development

In response to the problems in the process of scene design and script development, the key issues in the process are summarized as follows.

(1) Using Unity 3D to model the road diverging and merging areas.

(2) Setting the traffic flow route, density, and speed according to the actual situation.

(3) Code design for vehicle control based on the vehicle dynamics model.

(4) Code design for recording data transferring data, and exporting data.

(5) Design of linkage between scenarios.

3 TEACHING PROCESS

3.1 Teaching Method

In the teaching process, firstly, we teach the basic knowledge about the freeway diverging and merging areas, so that students can master the basic theoretical knowledge. Secondly, we teach the download and installation process of Unity 3D, let students complete the download and installation, and then send the built scene model to each student. Thirdly, the Unity 3D-based modeling process, the important and difficult issues in the script development process, and the basic operation of conducting driving simulations were generally explained[7, 8]. And then students were allowed to conduct driving simulation experiments on their own computers. Finally, at the end of the driving simulation, students will be asked to summarize the risky nature of the diverging and merging areas, driving characteristics, and the problems they need to pay attention to during the driving process and the direction of improvement of the freeway diverging and merging areas that they have experienced during the driving process in 12 different scenarios. If there is room for learning, the data can be analyzed at the end of the driving simulation to uncover deeper driving characteristics[9, 10].

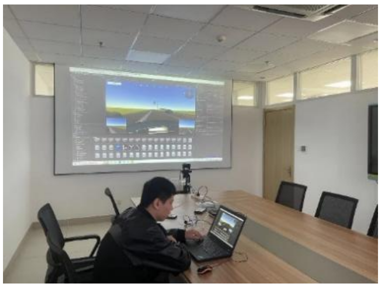
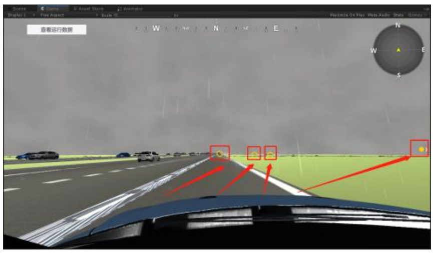


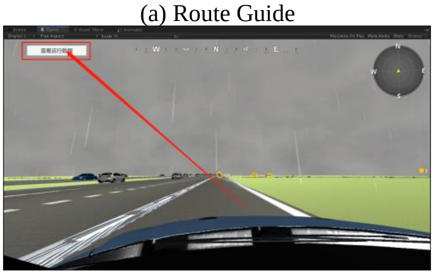
Figure 4. Practical operation for students

3.2 Driving simulation experiment operation process

First, open the scene you want to test and click the Start button on top. Use the "WSAD" key on the keyboard to manipulate the car (W forward, S backward, A to the left, D to the right). Then run the set route according to the guidelines, and click "View Run Data" after running the set route to view and export the run data.



(a) Route Guide



(b) View data button

Figure 5. Operation-related images

3.3 Data Analysis

The data exported at the end of the student's operation includes data on the speed, acceleration, 3D coordinates, mileage, distance to the front vehicle, and distance to the rear vehicle of the vehicle being operated. These data are collected at an interval of 1s. This paper introduces an idea of data analysis that can be innovatively used by students to do research in different directions in the actual teaching process.

First, the data from all testers are aggregated to extract important metrics, such as average speed, the standard deviation of acceleration, and minimum following distance. Then the data were standardized and subjected to principal component analysis to achieve data dimensionality reduction[11, 12]. Second, the principal components were subjected to cluster analysis to classify all testers into different driving styles, such as aggressive driving style, average driving style, and cautious driving style. Subsequently, a driving style prediction model was built using machine learning algorithms to make accurate predictions of driving styles[13, 14]. Finally, the different driving styles were analyzed for driving characteristics, such as acceleration length, deceleration length, and lane change locations[15, 16].

In this paper, the data of one of them were statistically analyzed, as shown in Table 1.

As can be seen from the table, compared to low traffic volume, the high traffic volume condition has a lower average driving speed, a higher frequency of rapid acceleration and deceleration, and a shorter minimum following distance. Compared with a clear day, the average driving speed of in a rainy situation is lower, the frequency of rapid acceleration and deceleration is higher, and the minimum following distance is longer. The main reason is the restricted vision on rainy days and less information on the situation ahead. To ensure driving safety, one must reduce the speed of the vehicle. Secondly, the driving process is more cautious and keeps a longer following distance. The overall speed is reduced at high density when it is more influenced by the surrounding vehicles. Because of the more congested traffic volume, the following distance is closer and the frequency of emergency braking and rapid acceleration behavior is higher.

From the results, it is clear that the results of the driving simulation match the actual experience. It shows low speed and high frequency of sharp deceleration during rainy days and high traffic volume, etc. The validity of the driving simulation system is relatively verified.

Table 1 Comparison of driving behavior in different scenarios

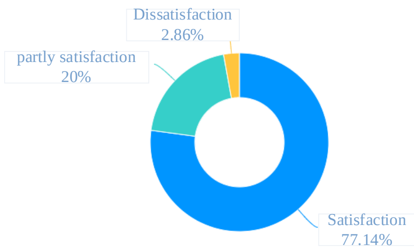
Scenarios	Conditions	Average speed (km/h)	Minimum following distance (m)	Rapid acceleration frequency	Emergency deceleration frequency
Scenarios 1	Clear days and low traffic volume	119.07	32.528	0.174344	0.153741
	Rainy days and low traffic volume	112.20	54.564	0.181855	0.173293
	Clear days and high traffic volume	99.21	15.306	0.182475	0.171935
Scenari	low traffic	141.09	36.82	0.064206	0.038968

os 2	volume				
	high traffic volume	130.19	24.85	0.069235	0.082201
Scenari os 3	low traffic volume	113.06	49.028	0.104681	0.078852
	high traffic volume	112.41	25.164	0.132107	0.090592

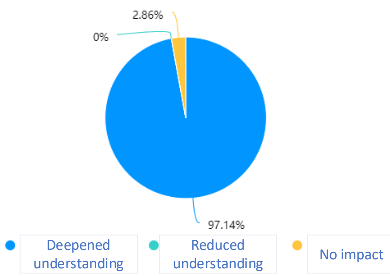
4 TEACHING EFFECTIVENESS EVALUATION

Compared with theoretical knowledge learning, students were more motivated and involved in the driving simulation practice. At the same time, the teaching mode of combining theory with practice made students a deeper understanding of the freeway diverging and merging areas instead of floating on the surface. 12 different scenarios also gave students a broader understanding.

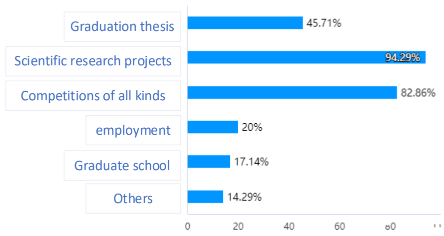
In order to get an objective evaluation from students, this paper made a questionnaire survey for 35 students who participated in the course, and the results are as follows. In terms of satisfaction with the scenario design, 77.14% of students were satisfied, 20% were partly satisfied, and 2.86% were dissatisfied. 97.14% of the students thought that the driving simulation experiment deepened their knowledge of the diverging and merging areas. Most students thought it helped them in their research projects and competitions, and enhanced their practical hands-on skills and analytical problem-solving abilities.



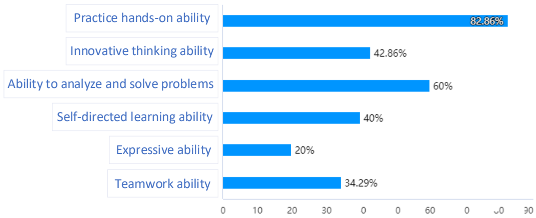
(a) Scenarios design satisfaction



(b) Awareness of diverging and merging areas



(c) What it can help yourself



(d) What has empowered you

Figure 6. Questionnaire results

In summary, the students said that they had a basic concept of freeway diverging and merging areas during the process of learning theoretical knowledge. Through the driving simulation, they had a deeper understanding of the riskiness of the diverging and merging areas by personally controlling the vehicle in the diverging and merging areas. The teaching mode based on Unity 3D driving simulation practice was highly evaluated, and the effectiveness was obvious and the teaching effect was good.

5 CONCLUSION

This paper is based on the background that students could not go out and practice intensively under the influence of the epidemic. In order to provide students with a deep understanding of freeway diverging and merging areas, a complete driving simulation platform was developed using Unity 3D. 12 simulation scenarios were designed by combining different working conditions, different weather, and different traffic volumes to let students understand different forms of merge zones. Secondly, the teaching mode and teaching process of combining theoretical knowledge with Unity 3D-based driving simulation are elaborated. Finally, the teaching effectiveness was evaluated by subjective and objective summaries for this teaching model. In addition, there are some shortcomings in this paper. No complete experimental verification and comparative validation has been performed on the validity of the driving simulation system. Only the experimental results were compared with the actual experience, and its validity needs to be further investigated. Subsequent comparative analysis should be performed with the field observation data in the diverging flow area to verify the validity of the system.

Acknowledgment. This research was funded part by the National Natural Science Foundation of China, grant number 52002224, part by the National Natural Science Foundation of Jiangsu Province, grant number BK20200226, part by the Program of Science and Technology of Suzhou, grant number SYG202033, part by the Key Research and Development Program of Shandong Province, grant number 2020CXG010118.

REFERENCES

[1] M. Wang, Y. Mao, S. Di, and W. Zhang, "Study on Length of Speed-change Lane in Diverging and Merging Areas of Urban Underground Road," Journal of Highway and Transportation Research and Development, Article vol. 37, no. 1, pp. 104-114, 2020.

[2] D. Eustace, A. Aylo, and W. Y. Mergia, "Crash frequency analysis of left-side merging and diverging areas on urban freeway segments - A case study of 1-75 through downtown Dayton, Ohio," Transportation Research Part C: Emerging Technologies, Article vol. 50, pp. 78-85, Jan. 2015.

[3] M. Sarhan, Y. Hassan, and A. O. A. El Halim, "Saftey performance of freeway sections and relation to length of speed-change lanes," Canadian Journal of Civil Engineering, Article vol. 35, no. 5, pp. 531-541, May. 2008.

[4] P. Smith, T. P. Hartley, and Q. H. Mehdi, "C# interpreter and unity 3D for educational programming games," 2013 18th Internat Conf on Comp Gam: AI, Animat, Mob, Interact Multim, Educat & Seri Gam (CGAMES) , pp. 41-7, 2013.

[5] G. Lu, G. Xue, and Z. Chen, "Design and Implementation of Virtual Interactive Scene Based on Unity 3D," Equipment Manufacturing Technology and Automation, PTS 1-3, 2011.

[6] Y. Kuang and J. Jiang, "The Designing of Training Simulation System Based on Unity 3D," 2011 Internat Conf on Intelli Computat Techn and Automat (ICICTA) , pp. 976-8, 2011

[7] Y. Zhou, W. Liu, Y. He, and X. Liu, "Design of Flash Point and Ignition Point Virtual Teaching System," 2019 Internat Conf on Virtl Reali and Intelli Syst (ICVRIS). Proceedings) , pp. 9-12, 2019

[8] U. Wolz, G. Carmichael, and C. Dunne, "Learning to Code in the Unity 3D Development Platform" SIGCSE '20: Proceedings of the 51st Techn Sympos on Comput Sci Edu, pp. 1387 (1 pp.)-1387 (1 pp.), 2020.

[9] G. Kortemeyer, "Game Development for Teaching Physics," Journal of Physics: Conference Series, Conference Paper Journal Paper vol. 1286, pp. 012048 (7 pp.)-012048 (7 pp.), 2019.

[10] J. Duran and S. Villagrasa, "Teaching 3D arts using game engines for engineering and architecture," Virt, Augm and Mix Reali. Syst and Applicat. 5th Internat Conf, VAMR 2013 Held as Part of HCI International 2013. Proceedings, Part II: LNCS 8022, pp. 113-21, 2013.

[11] J. Q. Wu, H. Xu, R. J. Sun, and P. Z. Zhuang, "Road Boundary-Enhanced Automatic Background Filtering for Roadside LiDAR Sensors," IEEE Intelligent Transportation Systems Magazine, vol. 14, no. 4, pp. 60-72, Jul-Aug 2022.

[12] X. G. Song, J. Q. Wu, H. B. Zhang, and R. D. Pi, "Analysis of Crash Severity for Hazard Material Transportation Using Highway Safety Information System Data," SAGE Open, vol. 10, no. 3, Jul 2020.

[13] J. Q. Wu, Y. Tian, H. Xu, R. Yue, A. B. Wang, and X. G. Song, "Automatic ground points filtering of roadside LiDAR data using a channel-based filtering algorithm," Optics and Laser Technology, vol. 115, pp. 374-383, Jul 2019.

[14] J. Q. Wu, H. Xu, Y. Tian, R. D. Pi, and R. Yue, "Vehicle Detection under Adverse Weather from Roadside LiDAR Data," Sensors, vol. 20, no. 12, JUN 2020.

[15] J. Q. Wu, Q. F. Wang, Z. Y. Li, and Y. Tian, "Review on risk conflict identification and early warning for Interchange," Journal of Shandong University (Engineering Science, pp. 1-19, 2022.
[16] J. Q. Wu, X. G. Song, " Review on smart highways critical technology," Journal of Shandong University(Engineering Science), vol.50, no.04, pp. 52-69, 2020.