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ARTICLE

Railway Engineering Experimental Teaching Research Based on the Combination of Field Experiment and Virtual Reality (VR) Technology——Taking Central South University as an Example

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ABSTRACT

At present, rail transit is developing rapidly in the world, and this means new and changing requirements for the training of talents in railway engineering experiments. Given the current problems of limited laboratory/field instruments for railway engineering experimentsand the safety/administrative difficulties of going to the frontline of railway lines to teach railway engineering experiemnts in the field, the Department of Railway Engineering of Central South University tried to introduce virtual reality (VR) technology to teach students experiments in the field of railway engineering. Through the virtualized experimental methods, students can carry out railway engineering experiments such as; vehicle wheel pair off-axis experiments, track geometry and position detection, etc. by immersive means. It was observed that after performing virtual simulation experiments, students appeared conversant in subsequent field experiments. Thus, VR greatly improves the teaching efficiency of railway engineering experiments.

1. Introduction

The Field/laboratory experiment is an important process for students to realize the theoretical knowledge, and enable students to fully understand the specific content that they cannot master in the classroom. The Railway Engineering experiments course for students of Railway Engineering in Central South University (CSU), China is arranged after the third grade. Since the professional courses such as "Railway Engineering" have been completed at this stage, the students' are presumed to have an overall understanding of railway engineering knowledge and have formed the professional thinking of railway engineering system, thus, it is necessary to carry out railway engineering-related experiments at this time, to achieve the consolidation of knowledge [1].

Through railway engineering experiments, students can integrate theory with practice, combine book knowledge with practical application on the field, diligently investigate and carry out field studies as well as, cultivate students' ability to analyze and solve problems; have the basic qualities of engineering and technical personnel [2]. At the same time, because the students' first impression

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will play a decisive role in the later understanding and learning process, a good railway engineering experiment process can also further improve the enthusiasm of railway engineering students to learn.

At present, VR technology is widely used in teaching and training in various types of rail transportation network.

In order to cope with the lack of work experience and practical skills of newly recruited railway employees in the Nanjing East Depot of the Shanghai Railway Bureau, virtual reality technology was proposed for integration into relevant on-the-job training, so that the maintenance work of related rolling stock can be immersed in virtual reality. The successful application in the distributed environment solved the time and space limitations of the new employee training and achieved good results. The practical operation ability of the employees who have been trained in virtual reality showed significant improvement.

During the construction of the Shanghai Metro Line, the project virtual simulation system developed by Tongji University played an important role in the training of construction workers. It was found that the technical level of related operators does not only greatly improved, but also, effective cooperation with the daily management staff was achieved.

Zhang Jiali, Department of Electrical Engineering, Tongji University also introduced VR simulation technology into the training of subway train maintenance focusing on virtual reality simulation of train equipment failure maintenance. The aim was to equip relevant personnel with knowledge of train failures and corresponding solutions.

Jiangsu Normal University has established a virtual simulation center for rail traffic signal and control which is mainly aimed at computer interlocking, electric multiple units simulation driving, fault diagnosis, vehicle overhaul, traction power supply dynamic simulation and fault analysis, high-speed rail comprehensive scheduling, Virtual simulation experiments and special practice Training.

Hunan High-Speed Railway Times Digital Technology Co., Ltd. has carried out virtual simulation research on rail transit passengers, signals, vehicles, power supply and other aspects.

To enhance students understanding of the railway engineering system and consider the comprehensive conditions of various aspects, we chose a virtual railway engineering experiment as the experimental background. The experimental background involves the knowledge of railway tracks, fasteners and tunnel structures. These experiments will enable students to fully understand the operation process of railway engineering experiments, the composition of track structures and disease detection methods, and the process of railway and rail traffic vibration test experiments. However, the teaching the experiments in situ on the railway line is very feasbile due to difficulties in obtaining administrative approvals. At the same time, if the experiments are only carried out through the teacher's explanation, the entire experiment will be relatively simple and boring, resulting in low student enthusiasm [3]. Therefore, VR (Virtual Reality) technology can be introduced to allow students to intuitively understand the composition of each structure. Herein,we discuss the feasibility of using VR technology in teaching railway engineering experiments by describing the advantages and development process of VR technology, in addition to the characteristics of the operation and implementation of railway engineering experiments.

2. The Advantages and Development Process of VR Technology

VR technology is an advanced simulation technology that serves as an interface device to connect the real world and the virtual world. It mainly uses the computer's graphics system to make the users of VR devices immersive, thereby, providing users with visual, auditory, and even tactile sensory simulation [4].

2.1 The Advantages of VR Technology

Interactivity, immersion and imagination are the three major characteristics of VR technology, as well as its three major advantages. The interactivity of VR technology is achieved through sensor devices. Through sensor devices, users can experience sensory simulation in a virtual environment. For example, when a user touches an object in the virtual environment, there will be a real tactile sensation, and even a feel of the specific outline of the item. Because VR technology creates a virtual environment for users through the computer's three-dimensional graphics system, users will experience VR products as if they are in the real objective world, which is the immersive embodiment of VR technology. The imagination of VR technology is that when users experience VR products, they can not only improve their rational knowledge but also enhance their perceptual knowledge, which can stimulate users 'new associations and exercise of creative mind [5].

2.2 The Development of VR Technology

The development process of VR technology is mainly

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divided into three stages, namely the initial stage, technology accumulation stage and technology promotion stage. VR technology first originated in 1960. Due to the limitation of technological level and technology, most of the VR equipment at the initial stage was huge. The technology accumulation stage of VR technology was from 1980 to 1990 and at this time, computer technology has made great progress. Consequently, display technology was improved, that promoted the production of VR glasses and VR helmets and other convenient devices to improve the user's experience. From 2013 to the present stage of the promotion of VR technology, due to the improvement of computer 3D modeling capabilities, advances in various aspects of technology such as display resolution improvements have gradually made VR devices more convenient, refined, and lightweight, thus, VR technology has been widely used in various industries.

3. VR Application Feasibility Analysis of Railway Engineering Experiments

Railway engineering is a major with complex composition, involving multiple majors and strong technical requirements. Due to the relatively weak professional knowledge base of students participating in railway engineering experiments and different levels of knowledge, students 'interest in basic railway knowledge is not sufficient, and this results in a difference in the degree of mastery of course [6]. To solve this problem by means of increasing students' participation and enthusiasm in the experiment, the introduction of VR technology is undoubtedly a good choice.

First of all, the closed-display mode of VR technology can reduce the impact of the external environment such as; the effects of external light, noisy sounds, etc., on the viewing experienceso that VR product users can better substitute for the virtual environment to create a deeper immersive experience. Secondly, VR technology has a much higher degree of simulation than other multimedia technologies, and 3D surround stereoscopic images provide users with a more realistic experience. Again, when VR technology is used in teaching, it can provide users with more observation angles, and can also add some interesting items to the VR product to increase the fun of the teaching process. Finally, VR technology is also targeted and operable. In experimental teaching, Corresponding operation items can be set according to the knowledge points that the students want to master so that the students can carry out targeted learning. Also, because the operation is relatively simple when applying VR products, students can easily perform operations that are very difficult in real life. So, VR technology has strong operability. Figure 1 shows a virtual simulation laboratory scene of our university's rail transportation.

Figure 1. Virtual simulation experiment of rail vehicle collision and crashworthiness of Central South University

In summary, the application of VR technology in railway engineering experiments will result in the following; firstly, this innovative teaching method will arouse students' interest in learning and enhance students' enthusiasm for learning. Secondly, with VR student experience 360-degree panoramic images, and can be immersive in the process through the sound, and overall impact feeling atmosphere, so that the students' sense of substitution and participation are stronger. Finally, the high-dimensional performance of VR technology will allow students to receive more information and make them master knowledge. Also, students of deficiency in knowledge can quickly bridge the knowledge gap. After the completion of the virtual experiments, the students are brought into the real experimental scene as shown in Figure 2, which can make the students deepen their understanding of basic knowledge, Figure 2 is the drop weight impact test site of our university's railway engineering laboratory.

Figure 2. The site of the drop hammer impact test at the Railway Engineering Laboratory of Central South University

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4. Design of VR Technology Application Scheme for Railway Engineering Experiment

4.1 Features of Railway Engineering Experiment

The railway engineering major is mainly focused on training high-quality talents engaged in railway engineering design, construction, management and scientific research. In recent years, China's railway construction has been progressing rapidly, and the demand for railway engineering professionals by railway units is also relatively high. The job market requires graduates to have engineering experiment application capabilities and corresponding engineering qualities in the railway engineering industry [7].

Relying on virtual simulation technology, carrying out innovative experiments can enable students to fully experience and understand the engineering-related problem-solving process, which is conducive to inspiring students' ability to find and solve problems. It also helps to fully realize the innovative ability and personalized training goals.

The railway engineering major is one of the backbone majors in the transportation engineering discipline. Railway engineering experiments have the following characteristics.

4.1.1 Wide Range of Knowledge

Generally speaking, railway engineering mainly refers to various civil engineering facilities on the railway, and also refers to the technology used in the construction of the railway at various stages (survey design, construction, maintenance, and reconstruction). Railway engineering initially included civil engineering (tracks, subgrades, bridges, tunnels, and stations), machinery (locomotives, vehicles) and signals related to railways. With the development of construction and the further division of technology, some of these projects have gradually become independent disciplines, such as locomotive engineering, vehicle engineering, and signal engineering. Other projects are gradually included in their respective disciplines, such as bridge engineering and tunnel engineering. The term railway engineering narrowly refers to railway route selection, railway tracks, subgrades and railway stations and hubs.

4.1.2 High Degree of Integration with Engineering Experiments

The construction, operation and management of high-speed railway, heavy-duty transportation and urban rail transit engineering are all closely related to railway engineering, so engineering-oriented experiment is the training goal of railway engineering. The selection of railway engineering experiment was sorted out based on the combined considerations of the current background of China's railway development, and real life/actual projects.,. In recent years, the railway engineering experimental projects sponsors of Central South University are subway design institutes, subway operating companies, China Railway Engineering Bureau, fastener manufacturers and other first-line railway departments. Students can participate in the analysis and experiment to understand specific engineering problems, which deepens students 'professional recognition, cultivate students 'comprehensive coordination ability, experimental ability and knowledge, comprehensive application ability, and engineering thinking.

4.1.3 New Structures and Technologies Are Updated Quickly

Since the founding of New China, China has attached great importance to the development of railway construction, especially since the beginning of this century making China's railway have achieve leapfrog development. Railway engineering technology is constantly updated with the development of railway construction. From the perspective of design methods, since the 1990s, major design units have successively implemented computer-aided design. After years of development, we have developed unique design software systems, and the degree of automation of the design process is becoming more and more precise. At the same time, foreign advanced survey and design integration systems have also been continuously applied, and the design methods have become more abundant. Currently, the design system is developing in the direction of intelligence and networking.

From the perspective of engineering structure, to meet the transportation needs of high-speed and heavy-load railways, the service performance of line structural components has been continuously improved [8]. From the perspective of track structure, in recent years, China has continuously developed CRTS Ⅰ, CRTS Ⅱ, and CRTS Ⅲ slab ballastless tracks to meet the needs of high-speed railways. To meet the requirements of vibration and noise reduction of urban rail transit, new types of vibration damping rails such as steel spring floating slab rails, vibration damping floating slab rails, and trapezoidal sleepers have been widely adopted. With the continuous development of railway technology, we can foresee that engineering structures with superior performance will continue to emerge. Railway engineering experiments

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should focus on the integration of new structures and new technologies in the current project, strive to advance with the times, and improve the competitiveness of students in future work or research work [9].

4.2 Implementation Process of the Railway Virtualization Experiment

Combining the expertise of railway engineering and the characteristics of railway engineering experiments, through the data acquisition, 3D virtual environment modeling, real-time 3D graphics generation technology and stereoscopic display and sensor technology, a scientific and interesting VR product was produced. Railway engineering experiment VR products mainly realize the following processes:

(1) Use of railway track geometry detection equipment. The instruments include rail rulers, square rulers, rail wear testers, electronic straightness meters and other commonly used instruments in railway maintenance and repair. Students need to have a better grasp of their operating steps and details. Through VR technology, students can observe the railway track geometry and position detection instruments from multiple angles and use precautions, so that they can have a more vivid understanding of the railway track geometry and position detection instruments.

(2) Demonstration of the experiment process of track crawling, falling axis and falling hammer impact. In the virtual experiment, students need to paste concrete strain gauges and install displacement sensors as shown in the layout of the measuring points according to the system prompt, and connect them to the dynamic acquisition system. To finish the mission in the VR atmosphere, they should install jacks and force sensors according to the layout of the loading device. The strain gauges, displacement sensor and force sensor should be cleared after the load is applied to achieve preload so that all parts of the instrument are closely fitted. Also, they need to debug the instrument and check whether the strain gauge is in good condition, before using the calibration device to calibrate the vertical force of the wheel-rail, and then clear the strain gauge, displacement sensor and the force sensor before the formal loading test begins as shown in Figure 3. During loading, the double stiffening beam is used for static stiffness test, and then the acceleration sensor is arranged as shown in the arrangement diagram of the acceleration measuring point. With the VR technology, students can use the impact performance test of the track slab or the fastener to carry out the off-axis testing, simulate the manual switch and observe the working process of the switch in the VR video. Additionally, calculate the various mechanical performance indicators of the rails, sleepers, and ground under different fasteners as shown in Table 1. Students need to use the data obtained by the VR platform to evaluate the experimental results, and the specific values are generated by random numbers.

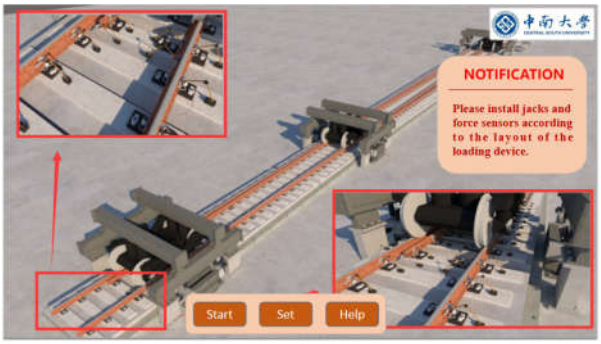

Figure 3. Demonstration of the experiment process of crawling and off-axis impact of large-scale turnouts in subway

Table 1. Dropping hammer impact test and analysis results of ordinary split fasteners and vibration-absorbing fasteners

Sample serial number	Rail acceleration（g）	Sleeper acceleration（g）	Ground acceleration（g）	Ground vertical vibration Z vibration level VL_Z（dB）	Damping effect（dB）
Ordinary fastener1#	428.85	19.84	12.8	129.27	8.30
Damping fastener1#	374.57	8.57	9.44	120.97	
Ordinary fastener2#	454.03	20.64	13.24	130.65	9.63
Damping fastener2#	380.24	8.57	9.77	121.02	
Ordinary fastener3#	432.27	19	12.36	128.2	7.11
Damping fastener3#	365.6	8.68	10.47	121.09	
Z vibration level VL_Z average value of vibration reduction effect（dB）					8.35

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(3) The scene of the vibration test experiment in subway shield tunnel. Because the vibration test of subway shield tunnels is often in the early hours of the night, the corresponding experimental scenarios cannot be provided during the normal teaching process. In the VR video, students can choose the layout of the sensors and visit in the shield tunnel. The video will simulate the layout of the displacement sensors and acceleration sensors of the rails, track slabs, tunnel walls. At the same time, students can set the vibration data when the train passes, and choose to redo or export the data, to enable them understand the the vibration test experiment in subway shield tunnel more visually.

4.3 Advantages of Applying VR Technology

(1) Make up for the lack of experimental teaching conditions. VR technology can simulate the experimental environment. To achieve the simulation effect, one only need to build a virtual instrument and a virtual experimental platform on the computer. The teaching cost of using VR technology to simulate the experimental processes is low and can achieve good teaching ouputs/outcomes. In the virtual world, the same effect as those in real/actual life can be obtained, and network level teaching can also be achieved.

(2) Teaching experiment with complex operation, high risk or high cost can be conducted. There may be some projects with complicated operations, high risks, or high costs in railway engineering experimental teaching. These projects are difficult to meet the teaching requirements of a large number of students in real life, but the application of VR technology can solve this problem well. Through VR technology, students can simulate all kinds of track detection instruments, use sensors to complete the test of various performance indicators, and experience the process of manually operating the equipment. At the same time, in VR products, students can also realize the process of vibration test in the shield tunnel, and the experiment process in the shield tunnel can be experienced through a simple operation.

(3) Repeated experimental teaching can be realized. In virtual reality, teaching can be repeatedly organized without limitation, and this process is not limited by time and space. At the same time, in VR teaching, experimental content in different periods can be displayed from multiple angles to achieve repeated experience. Because the experimental environment established by VR technology is virtual, when it needs to be updated to a new experimental base, it only needs to be regenerated in the virtual reality computer software and hardware environment, to ensure that the experimental teaching can keep up with the needs of the course teaching and technological development.

5. Conclusion

Theoretical and experimental teachings are two important aspects of talent training in colleges and universities, and the two complement each other. Railway engineering experiment is an important process for students to realize theoretical connections with experiments. Through railway engineering experiment, students can effectively and systematically obtain the required knowledge/expertise of railway engineering. At the same time, good railway engineering experiment experience will improve student's enthusiasm for studying railway engineering. Through comprehensive consideration of various prevailing conditions and in order to reform a single viable teaching model, VR technology was introduced as a new teaching method for railway engineering experiments.

VR technology is a new technology with far-reaching potential applications. The use of "software is the experimental base" to efficiently build a virtual reality experimental teaching platform. This innovative experimental teaching model is the only way for the reform of the railway engineering experimental course teaching.

By analyzing the advantages of VR technology and its advantages in the application of railway engineering professional experiments, it can be concluded that; it improves the sense of substitution and participation of students in the learning process, arouse students' interest in learning, and can make up for the lack of experimental teaching conditions, and ultimately, VR technology is feasible in the railway engineering experimental teaching field.

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