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Development of a Cloud-Based Simulation Measurement Laboratory and Evaluation System based on Unity3D

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ABSTRACT

This paper presents the development of a virtual simulation teaching platform for measuring equipment in the mechanical industry, aimed at improving students' learning effectiveness and operational skills. Traditional teaching methods relying on physical hardware are costly and pose safety risks, while the virtual simulation platform offers a safe, repetitive, and resource-efficient learning environment. The platform is divided into four modules: measuring tool cognition, measuring tool experiment, measuring tool evaluation, and user management. Each module is meticulously designed to meet specific teaching and evaluation needs, covering everything from basic knowledge learning to practical skill development. By achieving the outlined objectives, this platform will contribute to the technological advancement and talent cultivation in the mechanical manufacturing industry, promoting the sustainable development of the industry.

KEYWORDS

Virtual Simulation; Measuring Equipment; Mechanical Industry; Teaching Platform.

1. INTRODUCTION

With the continuous development of science and technology, the mechanical manufacturing industry has increasingly high demands for precision and quality. In this process, measuring equipment such as dial gauges, micrometers, and laser interferometers play a crucial role in mechanical manufacturing. Measuring devices are essential tools in manufacturing, inspection, and maintenance, and their accuracy and effectiveness directly affect the quality and performance of mechanical products. For example, equipment like dial gauges and laser interferometers can measure minute length differences, ensuring the fitting and movement of parts. These devices have specific principles and structures, requiring students to possess theoretical knowledge and practical skills. However, the usage methods and precautions of these devices are not simple and need to be mastered through extensive practical operations[1].

Traditional teaching methods often rely on laboratory or workshop hardware facilities, which are not only costly but also pose safety risks and resource wastage[2]-[4]. For instance, laboratory or workshop space is limited and cannot accommodate all students simultaneously; the quantity and quality of equipment are also limited and cannot meet all students' needs; equipment wear and maintenance require substantial human and material resources. Therefore, developing a virtual simulation teaching platform that utilizes computer technology and interactive media to simulate real measurement scenarios and equipment, allowing students to practice and evaluate skills in a virtual environment, is an innovative and effective teaching method[5].

The virtual measurement laboratory provides a flexible and efficient learning environment for the study of measuring equipment in the mechanical industry. Compared with traditional teaching methods, the virtual simulation teaching platform has the following advantages:

1. Safety: Students learn and operate in a virtual environment, avoiding potential safety accidents during actual operations.
2. Repetitiveness: Students can practice repeatedly in a virtual environment without being affected by equipment wear.
3. Resource Sharing: The virtual simulation teaching platform can be used simultaneously by multiple students, reducing the demand for actual equipment.
4. Interactivity: Students can perform simulated operations through the virtual simulation teaching platform, enhancing the fun and engagement of learning.
5. Remote Learning: Students can learn remotely over the internet, breaking geographical limitations and improving learning efficiency.

This study aims to develop a virtual simulation teaching platform for measuring equipment (such as dial gauges and laser interferometers) in the mechanical industry to improve students' learning effectiveness and operational skills [6]-[8]. Through this research, the following objectives can be achieved:

1. Explore the application methods and techniques of virtual simulation technology in teaching measuring equipment in the mechanical industry.
2. Analyze the differences in teaching effects between the virtual simulation teaching platform and traditional physical teaching methods to provide a basis for teaching reform.
3. Provide an efficient and feasible solution for large-scale training of measuring equipment in the mechanical industry.
4. Improve students' grasp and depth of knowledge through the online evaluation system, while allowing teachers to more comprehensively and conveniently analyze students' mastery levels to understand their weaknesses and make targeted adjustments.

By achieving the above objectives, this platform will contribute to the technological advancement and talent cultivation in the mechanical manufacturing industry, promoting the sustainable development of the industry.

2. SYSTEM OVERALL STRUCTURE

The system is divided into four modules: measuring tool cognition module, measuring tool experiment module, measuring tool evaluation module, and user management, as shown in Figure 1. Through the integration of information from these four modules, various virtual measuring tools can be taught and evaluated.

The measuring tool cognition module includes a video teaching sub-module and a recognition sub-module. The video teaching sub-module provides video teaching content for various measuring tools, helping students learn how to use the measuring tools through visual and auditory means. The recognition sub-module helps students learn the recognition and assembly skills of parts through exercises and tests.The measuring tool experiment module is divided into a measuring tool experiment sub-module and a data collection sub-module. The measuring tool experiment sub-module guides students to use assembled tools to measure the errors of workpieces, enhancing their understanding of tool usage methods. The data collection sub-module records the common mistakes students make during operations and stores these data in a database for further analysis.The measuring tool evaluation module includes an evaluation sub-module, a data collection sub-module, and a data analysis sub-module. The evaluation sub-module consists of an exam system and an evaluation system that assesses students' mastery of tool knowledge through tests. The data collection sub-module records students' test results into a database, and the data analysis sub-module analyzes these data and provides feedback to students and teachers. The user management sub-module includes an information management sub-module and an information analysis sub-module. The information management sub-module manages user information, including students' personal data and learning records. The information analysis sub-module analyzes user information, helping teachers better understand students' learning situations and needs. This assists teachers in better guiding students and providing personalized teaching support.

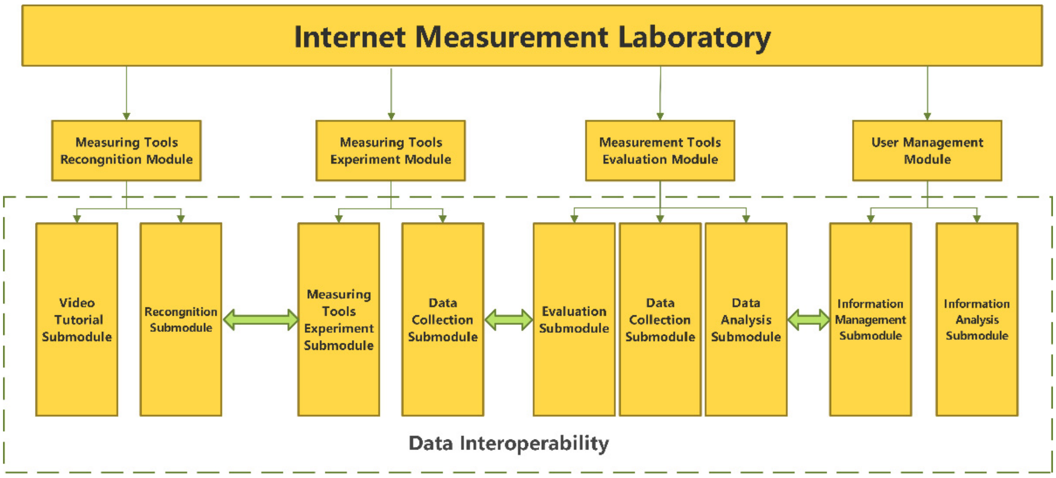

Figure 1. System Overall Architecture

3. SYSTEM FUNCTIONAL UNIT DESIGN

3.1 Measuring Tool Cognition Module

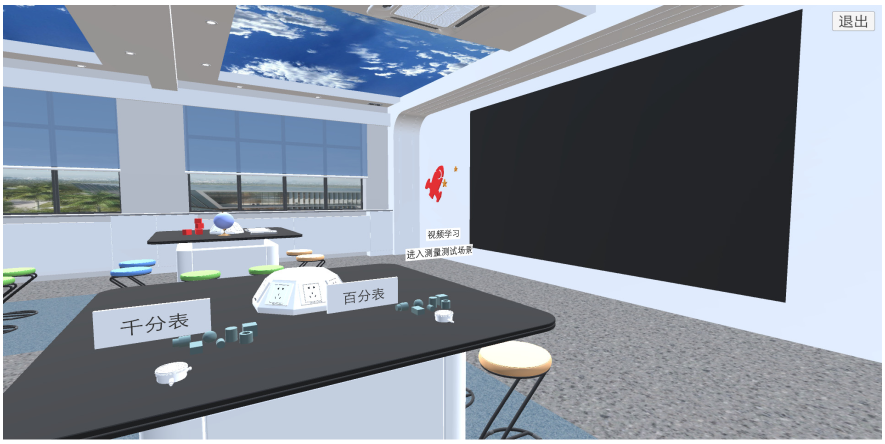

Figure 2. Video Learning Interface

The measuring tool cognition module primarily functions to teach the usage process and basic knowledge of measuring tools and assess parts assembly capabilities. This module includes specific video teachings for each measuring tool and the necessary knowledge base, as shown in Figure 2. Clicking the video learning button opens and plays the corresponding video for learning, with the video playback scene shown in Figure 3. The recognition sub-module requires entering the corresponding measuring tool measurement test scene to proceed with recognition, as shown in Figure 4. Clicking to enter the measurement test scene brings the students to the scene where different parts of the measuring tool are automatically generated. On the left side is the sequence of part extraction, and students are to follow this sequence for assembly. Each recognition and assembly failure is recorded in the database for data analysis, allowing teachers to understand the difficult points of each measuring tool in depth. As shown in Figure 5, we also provide an internal model question interface for students to search for questions.

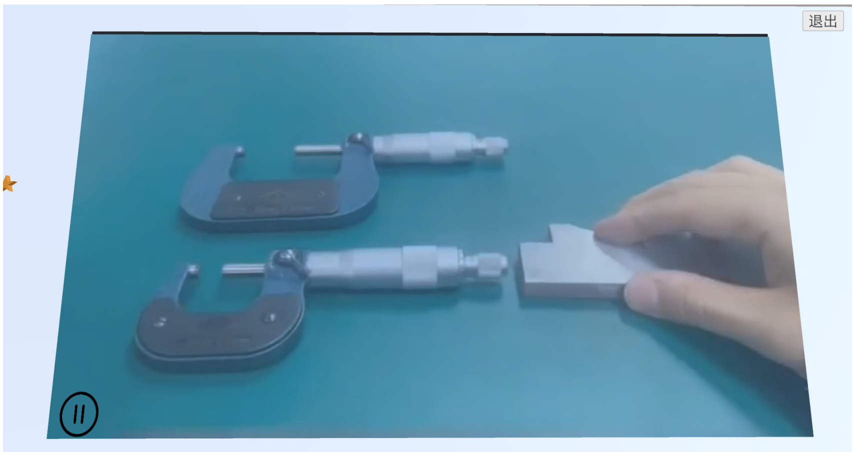

Figure 3. Video Playback Interface

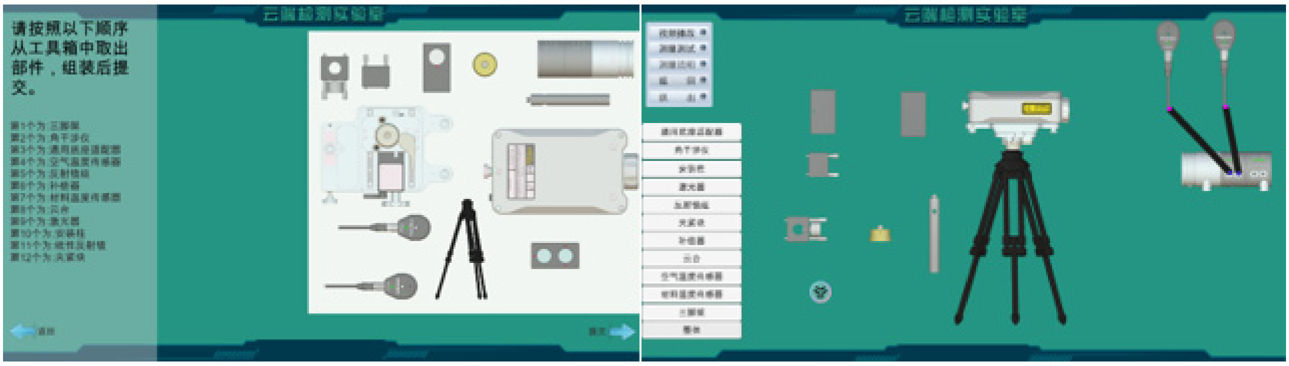

Figure 4. Measuring Tool Recognition Scene

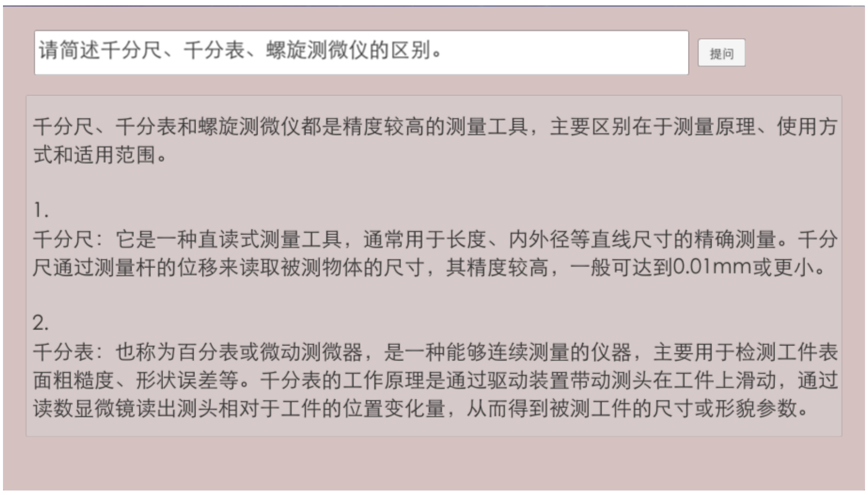

Figure 5. AI Q&A Scene

3.2 Measuring Tool Experiment Module

This module includes the measuring tool experiment sub-module and the data collection sub-module. Depending on the tool, such as a micrometer, entering the measurement test scene directly brings up the experiment scene, as shown in Figure 6. In the scene, users select instructions like watching teaching videos, usage instructions, and measurement tests from the top left corner, then click the measurement test button to start measuring. The experiment results are recorded by the data collection sub-module into the database. Analyzing the database captures which part of the experiment is prone to errors and which user has a high error rate. The success interface is shown in Figure 7.

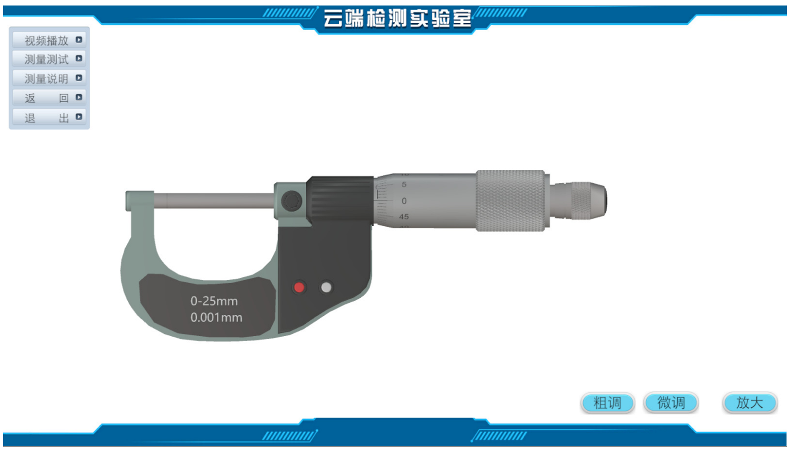

Figure 6. Micrometer Experiment Scene

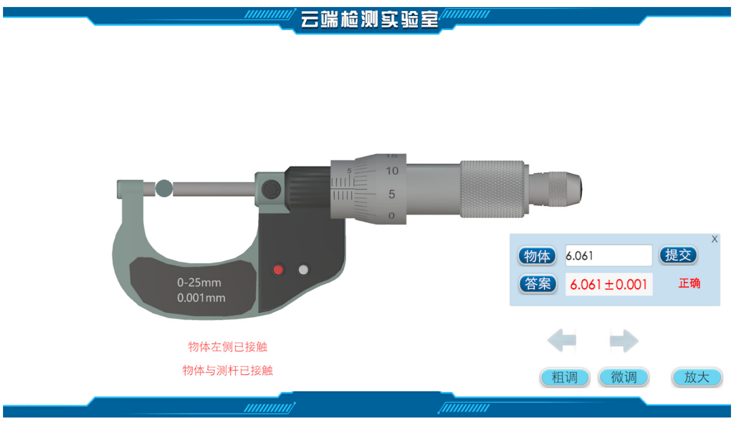

Figure 7. Success Interface

3.3 Measuring Tool Evaluation Module

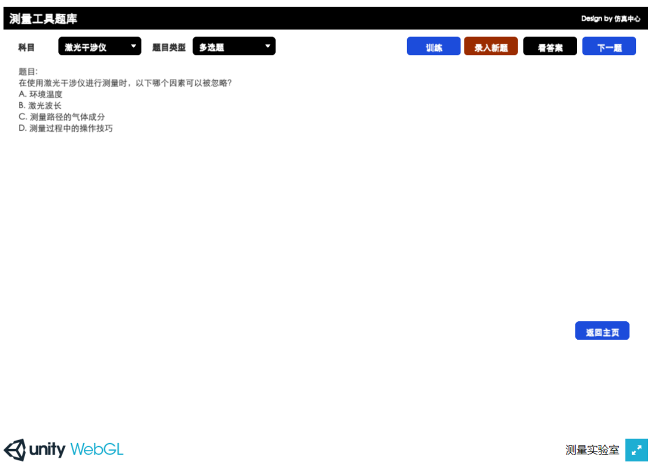

Figure 8. Question Bank Scene

The measuring tool evaluation module includes the evaluation sub-module, data collection sub-module, and data analysis sub-module. The evaluation sub-module is mainly for student exams and grade evaluation. Students can select the measuring tool type and click the start button to enter the scene, as shown in Figure 9. After submission, students receive error feedback, and the wrong questions are recorded in the user's database. The data collection sub-module collects user data, while the data analysis sub-module analyzes the error rates, time spent, and other data for all students or individual students or specific tools, as shown in Figure 10.

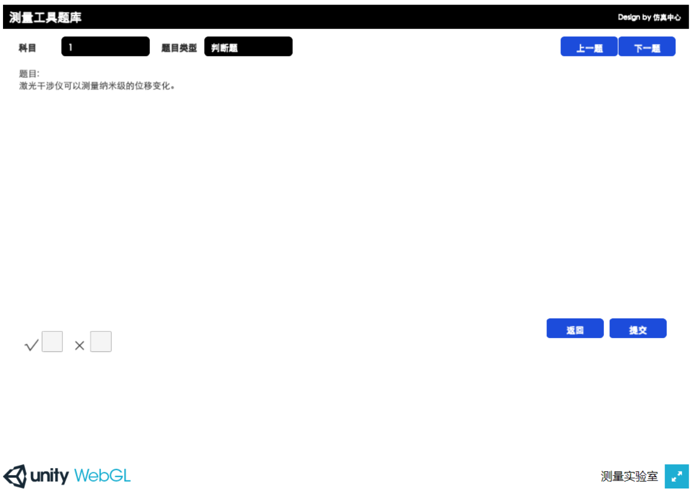

Figure 9. Test Scene

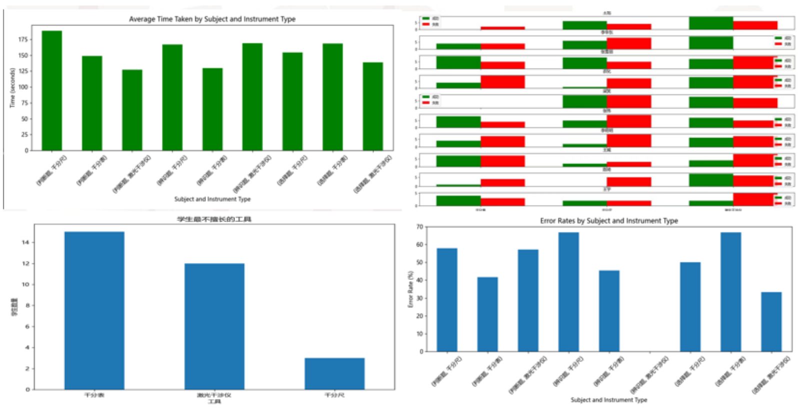

Figure 10. Data Analysis Interface

3.4 User Management Module

The user management module includes the user management sub-module and the user information analysis sub-module. Users can manage their information and view their question records and error types data on the right side, as shown in Figure 11. For administrators, the program backend uses the Django+MySQL solution. Administrators can log in to the backend to manage database information. The user information analysis sub-module uses Python packages like Pandas, Numpy, and Matplotlib and provides interfaces to teachers. Teachers can select the corresponding tools and students for analysis and display the analyzed data and charts on the teacher's interface, as shown in Figure 10.

Figure 11. User Information Interface

4. PROGRAM DESIGN AND SPECIFIC SOLUTIONS

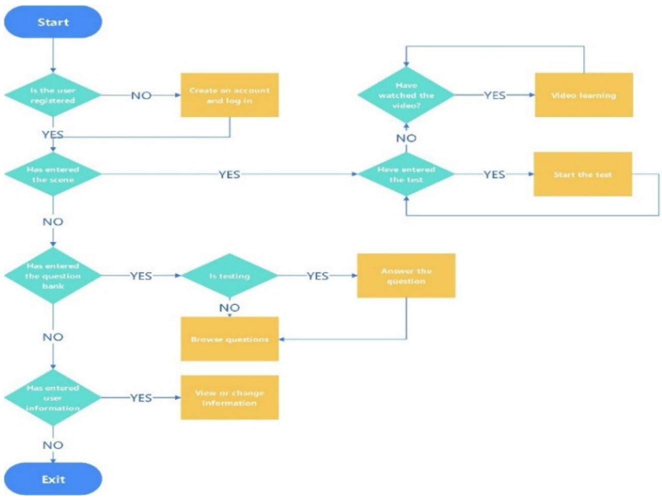

Figure 12. Program Flowchart

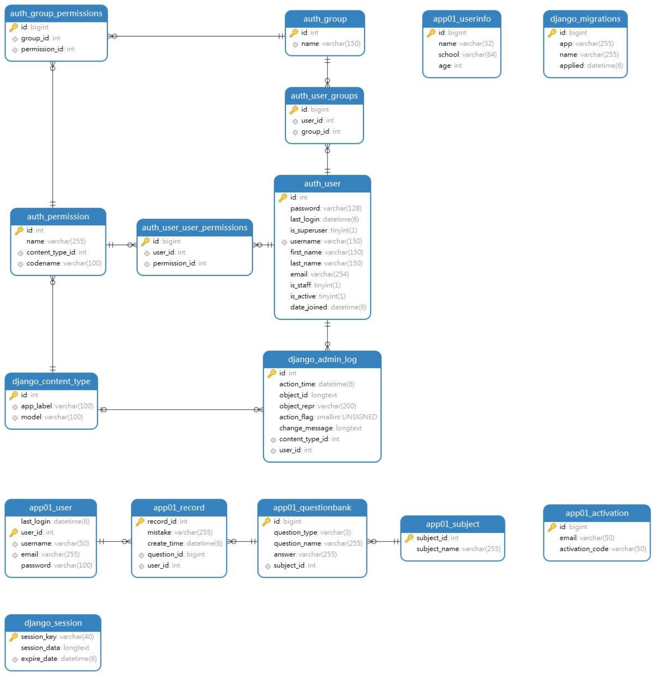

Figure 13. Database Structure

The front-end system development and program design are based on the Unity3D platform, leveraging its powerful physics engine to achieve realistic simulation effects. Development materials come from laboratory resources and online free resources. Using Unity3D's WebGL framework packaging function, the virtual simulation laboratory can be deployed on the cloud. Specifically, we upload the packaged WebGL program to the cloud server, deploy the website on the cloud server, and integrate it with the WebGL program. The backend technology solution mainly adopts WebGL+ Nginx+ Django+MySQL. For the data analysis module, we create analysis scripts using Python and create interfaces in the backend to associate with it. This allows direct calls to database data for analysis, then returns the data to the front-end interface. The large model interaction function provided in the system uses the Tongyi Q&A API service. The overall program flowchart is shown in Figure 12. The backend database design is shown in Figure 13.

5. CONCLUSION

This study successfully developed a cloud-based simulation measurement laboratory and evaluation system based on Unity3D, aiming to provide an innovative and efficient solution for learning and teaching measuring equipment in the mechanical industry. By utilizing virtual simulation technology and computer graphics, this system enhances traditional teaching methods on multiple levels, achieving a combination of safety, repetitiveness, resource sharing, interactivity, and remote learning. The system features clear overall structure, divided into measuring tool cognition module, measuring tool experiment module, measuring tool evaluation module, and user management module. Each module is meticulously designed to meet specific teaching and evaluation needs, covering everything from basic knowledge learning to practical skill development.

With continuous technological advancement and growing educational needs, this system will continue to be optimized and upgraded. Future work will focus on the following aspects:

1. Function Expansion: Further enrich the system's teaching resources and experiment projects, adding more types of measuring tools and experiment scenarios.
2. User Experience Optimization: Continuously improve the user interface and interaction design based on user feedback, providing a more intuitive and friendly learning experience.
3. Data Analysis Enhancement: Strengthen data analysis and learning effect evaluation functions, providing deeper insights and feedback for teachers and students.
4. Technical Iteration: Keep up with the latest virtual simulation technology to continuously improve the simulation accuracy and interaction performance of the system.

Overall, this system not only provides an efficient and innovative solution for education and training in measuring equipment for the mechanical industry but also offers valuable experience and reference for virtual simulation teaching in other fields. With the continuous development and deepening application of technology, we believe this system will have a positive and far-reaching impact on the innovation of educational models and the cultivation of industry talent.---This translation maintains the original structure and details of the document, ensuring clarity and coherence.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

ACKNOWLEDGMENTS

This is the place to fill in information about funds, sponsors, etc. that need to be thanked.

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