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THE DEVELOPMENT AND APPLICATION OF INFORMATION TECHNOLOGY IN TRACK CONSTRUCTION TRAINING

Quan He, Qing Zhang*
Department of Rail Transit Engineering, Sichuan Vocational and Technical College of Communications, Chengdu 611130, Sichuan, China.
Corresponding Author: Qing Zhang, Email: bunny07@qq.com

Abstract: As a core course in the rail transit specialty, practical teaching in track construction plays a crucial role in cultivating students' professional skills and qualities. However, traditional methods of practical teaching in track construction face numerous challenges, including substantial investment required for constructing practical training facilities, low student engagement, and difficulty in quantifying the effectiveness of practical training. The rapid advancement of information technology offers innovative solutions to these issues. This study investigates the development and application of information technology in track construction practice training. By establishing a track construction practice training platform leveraging BIM technology, oblique photography technology, and human-computer interaction technology, this approach achieves cost-effectiveness, high student participation, on-site training capabilities, and ease of evaluation.
Keywords: Rail transit; Practical teaching; BIM; Oblique photography; Human-computer interaction

1 INTRODUCTION

The traditional practical training teaching of track construction mainly presents the following issues: Firstly, the establishment of practical training facilities demands a substantial investment. Track construction involves a considerable amount of professional equipment and sites. Constructing a comprehensive practical training base requires a colossal infusion of funds, which poses a heavy burden for numerous colleges and universities. Secondly, students engage in more passive learning and have fewer hands-on experiences and practical operations. Due to the constraints of equipment and sites, the majority of students can merely learn by observing the demonstrations of teachers, lacking opportunities for hands-on practice. Furthermore, the depth of student participation is insufficient. Traditional practical training teaching is often conducted in classes, and the time and depth of participation for each student are limited, making it challenging to fully grasp all aspects of track construction. Finally, the practical training effect is difficult to quantitatively assess. Traditional practical training evaluations predominantly rely on the subjective judgments of teachers, lacking objective and quantitative evaluation standards and methods, and thus are hard to accurately reflect the actual skill levels of students. These problems severely constrain the effectiveness of practical training teaching of track construction and impact the professional adaptability and competitiveness of students. Therefore, exploring new practical training teaching models and methods and leveraging information technology to address the aforementioned issues have become the urgent demands for the current reform of practical training teaching of track construction.

This study proposes a design scheme for a track construction practical training platform based on information technology, with BIM technology as the core[1], in combination with oblique photography technology and human-computer interaction technology, to construct a virtual track construction practical training environment. The overall architecture of the platform encompasses the data layer, model layer, application layer, and user interface layer. The data layer is responsible for collecting and processing various data related to track construction; the model layer utilizes BIM technology and oblique photography technology to build track information models and geographic information models; the application layer realizes various practical training functions, such as construction method selection, construction sequence arrangement, site layout, etc.; the user interface layer provides an intuitive and user-friendly operation interface and supports multiple human-computer interaction approaches.

In terms of the design of platform function modules, it mainly comprises the following modules: the construction method selection module, offering detailed introductions and comparisons of various track construction methods to assist students in choosing appropriate ones; the construction sequence arrangement module, allowing students to arrange the construction sequence based on the actual circumstances of the project and view the effect in real time; the site layout module, supporting students in conducting construction site layout in the virtual environment to optimize resource utilization; the progress and resource planning module, helping students formulate construction progress plans and resource allocation schemes; the construction rehearsal module, permitting students to simulate and rehearse the entire construction process to discover potential problems; the quality, safety, and environmental protection problem judgment module, providing identifications and solutions for common problems to cultivate students' comprehensive capabilities.

2 INTRODUCTION TO BIM TECHNOLOGIES

BIM technology is a methodology for architectural design, construction and operation management that is based on digital models. Through the creation and management of three-dimensional models of construction projects, it integrates multi-dimensional data such as geometric information, time, cost and materials, and realizes collaborative management throughout the entire life cycle.

2.1 Core Features

Three-dimensional Visualization: BIM technology facilitates an intuitive three-dimensional model, enabling designers, engineers, and stakeholders to gain a comprehensive understanding of the building project's intricate details. This visualization extends beyond geometric shapes to encompass materials, colors, lighting, and other attributes, ensuring that design intent is accurately conveyed to all participants. Furthermore, three-dimensional visualization aids in identifying potential issues during the design phase, such as spatial conflicts and structural inconsistencies, thereby minimizing changes and rework during construction.

Data Integration: A BIM model integrates both geometric and non-geometric information, including time schedules, cost estimates, material specifications, and equipment data, into a unified platform. This integration enhances transparency and coordination across different project phases, improving overall project efficiency by allowing all stakeholders to access and update relevant data in real-time.

Collaborative Work: BIM technology provides a collaborative platform that enables seamless cooperation among all project stakeholders, including designers, engineers, contractors, owners, suppliers, and regulatory authorities. This collaborative environment fosters mutual understanding of each party's needs and constraints, reducing misunderstandings and conflicts while enhancing project efficiency.

Simulation and Analysis: BIM technology supports advanced simulations and analyses, such as energy consumption analysis, structural analysis, and daylighting studies. These tools assist designers in optimizing their plans, leading to improved building performance in terms of energy efficiency, occupant comfort, and safety. For instance, energy consumption analysis can guide the selection of more sustainable materials and systems; structural analysis can refine designs for enhanced safety; and daylighting studies can optimize natural light distribution within the building.

Full Lifecycle Management: BIM technology extends its application from the design and construction phases to the operation and maintenance stages of buildings. Through BIM models, facility managers can access critical information about building systems and components, such as equipment specifications and maintenance records, thereby improving operational efficiency. Additionally, BIM models can support end-of-life decisions, such as demolition and reconstruction, extending the building's lifecycle.

2.2 Application Areas

Architectural Design: BIM technology plays a pivotal role in architectural design, supporting scheme development, detailed construction drawings, and clash detection. During the conceptual design phase, designers can rapidly generate and compare multiple design options using BIM models. In the detailed design phase, BIM models facilitate the creation of precise construction documents and enable clash detection , which identifies conflicts between different disciplines (e.g., piping and structure) early in the process, reducing errors and rework during construction.

Construction Management: BIM technology significantly enhances construction management by supporting schedule management, cost control, and quality assurance. Project teams can develop detailed construction schedules and track progress using BIM models. Cost management benefits from accurate quantity takeoffs and cost estimates derived from BIM models. Quality management is bolstered by the ability to perform inspections and ensure compliance with design standards through BIM-based documentation.

Facility Management: BIM technology is instrumental in facility management, aiding in equipment management, maintenance planning, and space utilization. Facility managers can access comprehensive information about building systems and components, such as equipment models, installation dates, and maintenance histories, improving operational efficiency. Maintenance plans can be generated and tracked using BIM models, ensuring timely upkeep. Space management is also enhanced by leveraging BIM models for efficient space planning and allocation.

Urban Planning: BIM technology is increasingly applied in urban planning to enhance infrastructure planning and management. Planners can utilize BIM models for road design, bridge engineering, drainage systems, and other urban infrastructure projects, improving planning efficiency. Moreover, BIM models provide a powerful tool for three-dimensional visualization of urban environments, facilitating better communication of planning concepts to government officials and the public.

2.3 Advantages

Improved Efficiency: BIM technology streamlines collaboration by providing a unified platform that reduces information silos and enhances work efficiency. The technology also supports various simulations and analyses, helping designers optimize their schemes, reduce errors, and improve design efficiency.

Cost Reduction: BIM technology assists in controlling project costs through precise quantity calculations and cost estimations. Collision detection capabilities further minimize changes and rework during construction, leading to cost savings.

Enhanced Quality: BIM technology supports the optimization of design schemes through advanced simulations and analyses, resulting in higher-quality buildings. Additionally, it facilitates quality inspection and control during construction, ensuring adherence to design standards.
Improved Collaboration: BIM technology fosters effective collaboration among all project stakeholders by providing a unified platform that reduces misunderstandings and conflicts, thereby enhancing overall project efficiency.

3 INTRODUCTION TO BIM TECHNOLOGIES

Oblique Photogrammetry is an advanced photogrammetric technique that generates high-precision three-dimensional (3D) models by capturing images of a target area from multiple angles, including vertical and oblique perspectives. This technology has gained widespread application in recent years, particularly in urban planning, land management, disaster monitoring, and cultural heritage preservation. Oblique Photogrammetry not only provides high-resolution imagery but also produces accurate 3D geographic information models, offering comprehensive spatial data support for decision-makers.

3.1 Technical Principles

Data Acquisition: Oblique Photogrammetry typically employs unmanned aerial vehicles (UAVs) or aircraft equipped with multi-camera systems for data collection. These systems usually include one nadir camera and four oblique cameras, capturing images from different angles. The nadir camera acquires top-down views of the target area, while the oblique cameras capture side views from front, back, left, and right directions.
Image Processing: The collected image data undergoes a series of processing steps, including image matching [2], aerial triangulation [3], and 3D reconstruction [4]. Image matching utilizes computer vision algorithms to align images from different angles and identify corresponding ground control points. Aerial triangulation calculates the exterior orientation parameters of the images using a large number of control points and image data, determining their spatial position and orientation. 3D reconstruction then integrates multi-view images to generate a detailed 3D model of the target area.
Model Generation: After image processing and 3D reconstruction, Oblique Photogrammetry can produce high-precision 3D models. These models incorporate both geometric shapes and high-resolution texture information, enhancing their realism and utility. The generated models are applicable in various fields such as urban planning, land management, and disaster monitoring.

3.2 Technical Characteristics

Multi-angle Shooting: Oblique Photogrammetry captures images from multiple angles to obtain comprehensive image data of the target area. This multi-angle approach not only captures the top information of objects but also their side details, resulting in more complete and accurate 3D models.
High Precision: Oblique Photogrammetry achieves high-precision 3D models through multi-view imaging and precise image processing techniques. The accuracy of these models can reach the centimeter level, meeting the stringent requirements of various high-precision applications.
High Efficiency: Oblique Photogrammetry leverages UAVs or aircraft for rapid data collection over large areas. Compared to traditional ground-based measurement methods, this technology offers significantly higher efficiency.
Realistic Texture Information: The models generated by Oblique Photogrammetry include not only geometric shapes but also high-resolution texture information, making them highly realistic and suitable for visualization applications.
Wide Application Fields: Oblique Photogrammetry finds extensive use in urban planning, land management, disaster monitoring, and cultural heritage preservation. By generating high-precision 3D models, it provides comprehensive spatial data support for decision-makers.

3.3 Application Fields

Urban Planning: Oblique Photogrammetry plays a crucial role in urban planning. High-precision 3D models enable planners to better understand the spatial structure of cities and make informed decisions regarding layout and development. Additionally, it facilitates 3D visualization of urban environments, aiding government officials and the public in comprehending urban planning schemes.
Land Management: Oblique Photogrammetry supports efficient land management by generating high-precision 3D models. These models assist in conducting land surveys, cadastral mapping, and land use planning. Moreover, they enable timely detection and prevention of illegal land use through change monitoring.
Disaster Monitoring: Oblique Photogrammetry is vital for disaster monitoring. High-precision 3D models aid in disaster risk assessment, early warning systems, and emergency response planning. For instance, after natural disasters like earthquakes, floods, and landslides, Oblique Photogrammetry can rapidly generate 3D models of affected areas, helping rescue teams assess the situation and formulate effective rescue plans.
Cultural Heritage Protection: Oblique Photogrammetry holds significant value in cultural heritage protection. High-precision 3D models allow for digital preservation of historical structures and archaeological sites, providing essential data for conservation and restoration efforts. Furthermore, it enables virtual display and dissemination of cultural heritage, enhancing public awareness and appreciation.

4 APPLICATION OF VARIOUS INFORMATION TECHNOLOGIES IN THE PLATFORM

4.1 Application of BIM Technology in the Construction of Track Information Models

BIM (Building Information Modeling) technology plays a pivotal role in constructing track information models. In data acquisition and processing, BIM integrates multi-source data such as design drawings, survey data, and material specifications into a comprehensive, multi-dimensional information model. This integration encompasses both geometric and non-geometric data, including time schedules, cost estimates, and material properties, providing robust support for subsequent construction simulations and decision-making processes.

In model construction and optimization, BIM enables the creation of highly accurate three-dimensional models of track structures, including roadbeds, bridges, tunnels, and other components. Parametric design allows for rapid modifications and optimizations to meet diverse construction scenarios. Furthermore, BIM models can be integrated with models from other disciplines (such as architecture and mechanical and electrical engineering), ensuring seamless coordination across specialties.

In construction simulation and visualization, BIM offers advanced 4D (3D + time) and 5D (4D + cost) simulation capabilities [5]. These features allow students to simulate entire construction processes in virtual environments, observe the effects of different construction plans, and identify potential conflicts and issues. Visualization tools make complex construction processes more intuitive and comprehensible, aiding students in better understanding construction principles and methods. Additionally, BIM models can be linked with project schedules and resource allocation data to achieve dynamic management and optimization of the construction process.

4.2 Application of Oblique Photography Technology in Geographic Information Model Construction

Oblique photography technology is instrumental in the construction of geographic information models. For data acquisition and processing, oblique photography utilizes UAVs or aircraft equipped with multi-angle cameras to capture high-resolution images of target areas from various perspectives. After processing, these images generate high-precision three-dimensional geographic information models. Compared to traditional surveying methods, oblique photography offers advantages such as higher efficiency, lower costs, and richer detail, making it particularly suitable for large-scale and complex terrain data collection.

In model construction and optimization, the three-dimensional models generated by oblique photography are characterized by their realism and detailed representation. Professional software can integrate these models with BIM models to form a complete virtual construction environment. This integration enhances model accuracy and realism while providing a reliable basis for construction site layout and machinery path planning.

In scene visualization and analysis, oblique photography-generated models support multi-perspective observation and analysis. Students can navigate virtual environments freely, observing construction sites and surrounding areas from different angles. This immersive experience aids in better understanding the construction environment and making informed decisions. Moreover, oblique photography models can be combined with GIS systems for terrain analysis, line -of-sight analysis[6], and solar radiation analysis, supporting the optimization of construction plans.

4.3 Application of Human-Computer Interaction Technology in Construction Training Operations

Human-computer interaction (HCI) technology enhances construction training operations through interaction method design, operation process design, and user experience optimization. In interaction method design, the platform supports multiple interaction methods, including traditional mouse and keyboard operations, touchscreen interactions, and emerging technologies like virtual reality (VR)and augmented reality (AR) . These methods provide diverse operational experiences, catering to different learning styles and needs. Particularly, VR and AR technologies create highly immersive training environments, making students feel as if they are on an actual construction site, significantly enhancing engagement and learning outcomes.

In operation process design, the platform adheres to principles of intuitiveness, simplicity, and efficiency. Each training module includes clear operation steps and prompts, guiding students through tasks systematically. The platform also offers functions such as undo, redo, and save, allowing students to experiment and refine their skills. For complex operations, the platform provides step-by-step instructions and detailed explanations to facilitate understanding and mastery.

In user experience optimization, the platform focuses on interface design and feedback mechanisms. The interface features a clean and intuitive layout, with critical information and functions prominently displayed to reduce cognitive load. Real-time feedback functions, such as operation prompts, error warnings, and progress displays, help students promptly understand their performance and address issues. Additionally, the platform supports personalized settings, such as customizable themes and operation preferences, enhancing user comfort and satisfaction.

4.4 Implementation and Application of the Track Construction Training Platform

The implementation of the track construction training platform involves system development and integration. This includes selecting appropriate development platforms and tools, designing the system architecture, coding, and integrating various functional modules into a unified system. During development, emphasis is placed on system stability, scalability, and compatibility to ensure long-term stable operation and adaptability to future technological updates and functional expansions.

Platform testing and optimization are critical to ensuring system quality. Testing encompasses functional testing, performance testing, compatibility testing, and user experience testing. Through rigorous testing, bugs are identified and fixed, system performance is optimized, and user experience is enhanced. During testing, feedback from students and teachers is collected to further improve the system.

Case analysis and effect evaluation are essential for verifying the platform's effectiveness. By applying the platform in real teaching scenarios, collecting student learning data and feedback, and comparing outcomes between users and non-users, the platform's impact on teaching effectiveness can be assessed. Controlled experiments can be designed to evaluate differences in knowledge acquisition and skill improvement. Additionally, surveys and interviews can gather insights into teacher and student satisfaction and suggestions for improvement.

5 THE IMPACT OF INFORMATION TECHNOLOGY ON TRACK CONSTRUCTION PRACTICAL TRAINING TEACHING

The impact of information technology on track construction practical training teaching is primarily reflected in three key areas: reform of teaching models, innovation in teaching methods, and innovation in assessment approaches.

In terms of teaching model reform, information technology liberates practical training from the constraints of physical space and time. Students can engage in virtual practical training anytime and anywhere, significantly enhancing learning flexibility and efficiency. Virtual practical training platforms can simulate a wide range of construction scenarios and conditions, offering students richer and more diverse learning experiences. This not only broadens the scope of practical training but also allows for repeated practice under different conditions, thereby improving students' adaptability and problem-solving skills.

Regarding teaching method innovation, information technology supports personalized and collaborative learning. The platform tailors learning content and difficulty levels based on individual student progress and abilities, promoting personalized learning paths. Additionally, it facilitates collaborative practical training for multiple participants, enabling students to divide tasks and work together in a virtual environment to complete complex construction projects. This collaborative learning model not only improves learning efficiency but also fosters students' teamwork and communication skills, which are essential in real-world construction environments.

Concerning assessment method innovation, information technology enables more objective, comprehensive, and timely evaluations. The platform automatically records students' operational processes and outcomes, generating detailed assessment reports. This data-driven evaluation approach enhances the objectivity of assessments and allows for the timely identification of learning issues, providing teachers with targeted guidance. Moreover, the platform supports formative assessment through real-time feedback and continuous progress tracking, helping students adjust their learning strategies promptly and improve overall learning outcomes. The integration of quantitative and qualitative assessment methods ensures a holistic evaluation of students' performance.

6 CONCLUSION

This study effectively addresses numerous challenges in traditional practical training by developing an information technology-based track construction practical training platform. Utilizing BIM technology, oblique photography technology, and human-computer interaction technology, the platform creates a highly realistic virtual training environment. It provides students with abundant practical opportunities and immersive learning experiences. Research findings indicate that this platform significantly enhances student engagement and learning outcomes while reducing the costs associated with practical training and enabling quantitative evaluation of training effectiveness. The platform's ability to integrate various advanced technologies demonstrates its potential for broader application in engineering education and professional development.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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