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Reform of the Teaching Model for Automotive Control System Courses through AI-Enhanced Project-Based Learning

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Abstract: The rapid evolution of intelligent connected vehicle (ICV) technology has exposed limitations in traditional lecture-based teaching models, which struggle to equip students with the practical engineering competencies and AI-driven innovative capabilities demanded by the industry. While project-based learning (PBL) enhances knowledge integration and application skills, its implementation in automotive engineering curricula faces challenges such as knowledge gaps in interdisciplinary projects and mismatches between diverse solution approaches and student capabilities. Artificial intelligence (AI) offers a transformative pathway to address these issues. Developed through the project-based course Automotive Control System Analysis and Practice, a systematic AI-enhanced framework has been introduced, incorporating specific strategies for refining learning objectives, optimizing project structures, improving evaluation mechanisms, and redefining instructors' roles. This initiative establishes an integrated curriculum and assessment system that provides continuous support throughout the PBL process. The ultimate goal is to cultivate a new generation of exceptional engineers in the AI-enhanced ICV sector, capable of effectively leveraging artificial intelligence to solve complex, project-based engineering challenges.

1. Introduction

To address the urgent demand for interdisciplinary and innovative talents in the intelligent era, exploring a new pathway of project-based learning (PBL) supported by artificial intelligence (AI) in the course Automotive Control System Analysis and Practice has become a critical task. Characterized by task-driven learning and collaborative inquiry, PBL can effectively facilitate the integration of theoretical knowledge and engineering practice, and it is particularly aligned with the teaching objectives of courses such as Automotive Control System Analysis and Practice.

In the field of international educational research and practice, considerable experience has been accumulated regarding the integration of project-based learning. For instance, Hassane Benlaghrissi and L.Meriem Ouahidi[1] combined PBL with mobile-assisted language learning (MALL) in teaching English as a foreign language (EFL) speaking skills. Their research indicates that this integrated approach can enhance students' listening and reading skills, as well as problem-solving abilities. However, such studies exhibit clear limitations: mobile devices are constrained by limited algorithmic capabilities, and the integration of technology remains superficial, serving mainly as a tool rather than enabling deep learning or providing precise instructional guidance.

Domestically, project-based learning has been progressively incorporated into teaching reforms within the field of vehicle engineering. Using actual business cases as teaching examples, Wang Cuicui and Hou Qingqing[2]combined PBL with the case-based learning (CBL) approach in an automobile defect diagnosis course. Empirical findings demonstrate that this paradigm considerably enhances students' proficiency in cooperation, inquiry awareness, and fault analysis. However, the existing model relies on traditional case-driven approaches and manual guidance, which limits its effectiveness in simulating complex faults intelligently and providing personalized instruction. As a result, students often struggle to develop a systematic understanding of fault diagnosis logic.

In conclusion, although the fact that previous research conducted both domestically and abroad has encouraged the incorporation of project-based learning, issues such a lack of depth in technological integration and an inadequate instructional support system still persist. The AI-enhanced project-based learning model put out in this research has clear advantages over models that only use standard pedagogical combinations or single-technology integration. Artificial intelligence has a great deal of promise to support PBL because of its strong ability to interpret information in a personalized fashion and its creative approaches to problem-solving. This paper systematically explores the application of an AI-enhanced PBL model in the Automotive Control System Analysis and Practice. By establishing a new teaching environment that enables precise process guidance and visualization of collaborative workflows, we aim to enhance the effectiveness of project-based teaching and provide valuable insights for pedagogical reform in the cultivation of application-oriented talents in the field of vehicle engineering.

2. Significance of AI-Based Project-Based Learning in the "Automotive Control System Analysis and Practice" Course

Project-based learning (PBL) places a strong emphasis on solving real-world issues, and the addition of artificial intelligence gives students access to an even more individualized and engaging learning environment. This strategy not only encourages student initiative but also more successfully develops creative thinking and problem-solving abilities than standard teaching approaches. Specifically, extremely lifelike virtual driving scenarios can be produced during the course using automobile simulation software for autonomous driving systems. This approach enables students to intuitively observe the real impacts of control tactics by converting abstract theoretical information into visual, three-dimensional dynamic models. Students' motivation and inquisitive interest are successfully piqued by such immersive experiences, which promote more active participation throughout the project. Additionally, problems in the vehicle simulation models and control tactics created by students during PBL can be examined using artificial intelligence technologies. The system can make intelligent recommendations for pertinent theoretical materials and simulation instances based on this analysis[3]. Through real-world problem-solving, this type of individualized instruction helps students get past technical obstacles, boosting their technical confidence and internal motivation.

The teaching objectives of the "Automotive Control System Analysis and Practice" course extend beyond the learning of basic automotive and control theory to include the development of students' comprehensive collaborative abilities. The introduction of artificial intelligence holds significant importance in fostering teamwork and communication skills among students. Teams can be built scientifically and rationally by utilizing AI, and work can be assigned according to individual learning profiles. For instance, in the "Vehicle Cruise Control" project, students with a solid foundation in control theory and vehicle dynamics are responsible for building the vehicle dynamics model. Those skilled in algorithm design and programming lead the controller design and coding. Students familiar with simulation tools and methods undertake the verification of control strategies. By grouping students with diverse skill sets within the same team, each group is assured the capabilities required to complete projects. This AI-driven team formation guarantees structured complementarity of skills, fundamentally transforming the randomness and subjectivity of traditional grouping methods. Within such an environment of complementary skills and mutual dependence, students naturally cultivate teamwork spirit and communication coordination abilities while accomplishing specific project tasks.

3. Application of AI-Based Project-Based Learning in the "Automotive Control System Analysis and Practice" Course

3.1 Defining Teaching Objectives

The clear definition of teaching objectives is a primary step in project-based learning and serves as a key benchmark for evaluating teaching effectiveness[4]. It is essential for encouraging students' initiative and a dynamic, inquiry-based learning environment. Teaching objectives must incorporate fundamental concepts from the "Automotive Control System Analysis and Practice" course, such as PID control algorithms and model predictive control (MPC), while emphasizing proficiency in algorithm design, simulation verification, and physical debugging. This is in line with the training requirements of vehicle control. The use of virtual reality technology in the classroom improves the attainment of learning goals. Specifically, the purpose of the lesson is to help students use path-following control for autonomous cars, which will enhance their capacity to create intricate control schemes. The significance of virtual reality technology lies in its capacity to transform abstract algorithm verification into observable vehicle behavior, addressing the common issue of disconnection from practical application in conventional teaching. On the one hand, students have an unique educational experience owing to the immersive virtual worlds that VR technology simulates. Students can immediately witness changes in driving stability and vehicle attitude by modifying PID and MPC control techniques. On the other hand, student awareness of control tactics goes beyond what they learn in the classroom. They gain an improved comprehension of the intricate coupling links between vehicle dynamics and control theory through iterative "parameter adjustment-vehicle validation" cycles.

3.2 Intelligent Project Framework

Through the integration of artificial intelligence across the project workflow, this method seeks to create a more dynamic and effective learning environment while encouraging student initiative and intrinsic drive. The pedagogical process is guided by an AI-constructed framework, as demonstrated by the "MPC-Based Path Tracking Control for Autonomous Vehicles" project. Based on specified learning objectives, the AI platform automatically creates a variety of instructional materials at project initiation, such as code templates, simulation demonstrations, and technical documentation. This results in an easy-to-understand contextual introduction that increases preparation effectiveness and ignites student interest. As students independently study MPC algorithms and vehicle dynamics modeling during the theoretical exploration phase, the AI system offers tailored assistance when conceptual challenge—like constraint handling or receding horizon optimization—occur by precisely identifying knowledge gaps and suggesting specific explanatory materials to fortify theoretical underpinnings. The AI platform helps identify problems like excessive path-tracking error and provides specific tuning recommendations like modifying prediction horizons or optimizing weighting matrices during practical development, where student teams use MATLAB/Simulink and CarSim for controller design and simulation testing. Students gradually gain multifaceted analytical skills and methodical debugging abilities by contrasting and validating different solutions. Following groups' presentation of simulation videos, error analysis reports, and peer evaluations during the final demonstration and reflection phase, the AI system creates customized learning reports based on full-process data, highlighting both practical competency and knowledge acquisition strengths and weaknesses and offering specific improvement strategies. In addition to encouraging group learning, this integrated mechanism directs students toward ongoing optimization and reflection practice, eventually developing engineering skills that can handle challenging problems in intelligent and connected vehicles [5].

3.3 AI-Powered Evaluation

In the "Automotive Control System Analysis and Practice" course, one of the main factors influencing the enhancement of teaching quality is the evaluation method. Compared to traditional evaluation models, the application of AI plays a vital role in promoting students' engineering practical ability and innovative thinking skills. It expands course evaluation beyond the final simulation report to cover the entire process from algorithm design, system modeling, simulation verification, to physical debugging. AI can produce precise and thorough analytical reports in class practice by evaluating the logic of students' modeling techniques, parameter modification plans, and problem-solving reasoning. This facilitates timely adjustment of teaching strategies and optimization of the learning process by instructors. Analyzing the stability of the final simulation model algorithms and system response characteristics, it promotes student reflection and improvement, thereby stimulating their innovative potential.

3.4 Transformation of the Instructor's Role

The Automotive Control System Analysis and Practice curriculum's use of artificial intelligence in project-based learning is fundamentally changing the role of educators. The complex demands of engineering practice and innovation can no longer be met by traditional teaching techniques. With AI-powered platforms, educators must now shift from being unilateral knowledge transmitters to facilitators of the learning process, creating open-ended, inquiry-based activities that suit students' needs and interests[6]. This change places higher-dimensional demands on the professional competencies of teachers in the field of vehicle control. In addition to having a thorough understanding of core algorithmic logic, model coupling mechanisms, and data processing techniques, teachers are required to be experts in vehicle dynamics, control algorithm design, and simulation software application. Meanwhile, they should make use of contemporary technology like artificial intelligence (AI) to create learning environments that are highly interactive, diversified in form, and rich in content. Establishing a methodical teacher development structure is necessary to facilitate this shift. To improve their competence using simulation technologies and AI-enhanced teaching, educators should first participate in organized training and cooperative exchanges. Second, enrolling in specialist MOOCs—like those on integrating AI with project-based learning offered via China's University MOOC platform—and taking part in official MATLAB/Simulink certification programs helps strengthen pertinent technical and instructional competencies. To guarantee that the curriculum stays innovative and useful and that high-quality instruction is ultimately achieved, United Automotive also frequently hosts exchange seminars in which real-world company case studies are turned into instructional materials.

4. Conclusions

This course has effectively closed the traditional gap between theory and practice in engineering education, allowing students to improve their engineering competence and comprehensive skills through active exploration and innovation. This is made possible by the deep integration of artificial intelligence and project-based learning. Future initiatives will concentrate on further integrating virtual simulation technologies—like digital twin vehicle platforms—and real-world industrial scenarios into the curriculum in order to build upon and expand these accomplishments. By refining an integrated "teaching-learning-practice-application" educational ecosystem, this ongoing development seeks to produce exceptional engineers with core competitiveness for the automotive engineering sector.

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