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Interdisciplinary project-integrated teaching method in control and drive courses for robotics engineering oriented students

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Abstract: Robot engineering education plays an important role in shaping the future of automation and robotics. Among the core subjects, control systems and drive technologies stand as fundamental pillars, demanding innovative teaching methodologies to ensure comprehensive learning outcomes. This paper investigates the efficacy of interdisciplinary approach in enhancing student understanding and practical application of control and drive concepts in robot engineering courses. It highlights the implementation methods such as integrated projects and laboratory sessions, as well as other techniques including project-based learning. Through a comparative analysis of these methods, key factors influencing student engagement, knowledge retention, and skill development can be identified. This paper also explores the benefits and the real-world application of this method of teaching, highlighting its potential to revolutionize the teaching of control and drive courses. By synthesizing insights from existing literature and empirical studies, this research offers a valuable recommendation for educators seeking to optimize teaching strategies in robot engineering education.

1. Introduction

At the core of robot engineering lies the study of control and drive systems, which are essential for the operation, autonomy, and efficiency of robotic devices [1]. Mastery of these concepts is imperative for engineers who design, develop, and deploy robotic solutions that address real-world challenges and opportunities. The effective teaching of control and drive courses in robot engineering education is paramount to equipping students with the knowledge and skills necessary to excel in this rapidly evolving field. However, with the proliferation of new technologies and methodologies, educators face the challenge of selecting and implementing the most effective teaching methods to engage students, facilitate learning, and foster critical thinking and problem-solving abilities.

One of the main challenges and issues encountered in teaching control and drive courses in robot engineering is mainly lack of interdisciplinary project-integrated approach and an outdated curriculum. These courses often require knowledge from various disciplines such as electrical engineering, mechanical engineering, and computer science. Failing to integrate these disciplines cohesively can lead to a fragmented understanding of the subject matter. In addition, rapid advancements in robotics and automation technologies necessitate frequent updates to the curriculum to keep pace with industry trends. Outdated course materials can hinder students' preparedness for real-world applications.

Various researchers have tackled these challenges and succeeded in coming up with several solutions to the existing challenges. One approach taken by different researchers in regards to this included the addition of play-based elements such as games as a method of instruction to increase student engagement [2]. Virtual laboratories were used engaging students in building and guiding robots remotely with a range of tools.

The interdisciplinary method in robotics education offers numerous advantages that enrich students' learning experiences and equip them for success in the field. By integrating insights from various disciplines such as computer science, electrical engineering, and mechanical engineering, this approach provides students with a holistic understanding of robotics [3, 4]. The use of content from various disciplines and integrating it into robotics education has become increasingly important [5]. Through interdisciplinary projects and activities that mirror real-world collaboration, students gain practical experience and develop skills directly relevant to industry settings, laying a strong foundation for careers in robotics engineering. Moreover, the interdisciplinary project-integrated method fosters innovation and creativity by challenging students to think innovatively and develop novel solutions to complex robotics challenges, thus cultivating a culture of ingenuity essential for pushing the boundaries of robotics technology. Furthermore, interdisciplinary collaboration is a key component of the interdisciplinary method, as robotics projects often require teamwork among experts from diverse fields. By engaging in interdisciplinary projects, students learn effective communication, collaboration, and appreciation for diverse perspectives, preparing them for success in interdisciplinary teamwork both academically and professionally. Additionally, the interdisciplinary project-integrated approach promotes adaptability and flexibility by equipping students with versatile skills that enable them to navigate the rapidly evolving landscape of robotics technology [6]. With proficiency in multiple disciplines, students become adept problem-solvers who are ready to tackle the dynamic challenges of the field, contributing to the advancement of robotics technology and shaping the future of the industry. In one study discussing the review of a robotics course in the faculty of mechatronics at a Korean university, Jung, et al. [7] raised the need to combine theory and practice by integrating knowledge in Manipulator robots with hands-on experiences in laboratory practical. The course incorporated interdisciplinary theoretical content covering robot kinematics, dynamics, path planning and control, while the laboratory practical experience made use of a range of robot applications, experimental kits, Lego robots and humanoid robots to develop student skills in motor control.

Through this research, we aim to contribute to the ongoing discourse surrounding pedagogy in robot engineering education and provide educators with valuable insights and recommendations for optimizing their teaching strategies. By empowering students with the knowledge and skills needed to navigate the complexities of control and drive systems, we can cultivate a new generation of adept and innovative engineers capable of driving forward progress in the field of robot engineering. This presentation will pave the way for revolutionizing higher education robotics courses and assist students and teachers in identifying pedagogical tools for autonomous learning development and teacher curriculum development.

2. Interdisciplinary project-integrated teaching method

2.1. Fundamentals of the teaching method

This method emphasizes collaboration across different disciplines, such as computer science, engineering, and mathematics, to address real-world problems through practical application. In this approach, students work in teams to tackle complex projects that require a combination of skills and knowledge from multiple fields. This approach, known as interdisciplinary adaptation, can enrich the educational experience by blending insights from various disciplines and equips students with a holistic skill set necessary for navigating the complexities of robotics engineering. Because of the popularity of robotics as a discipline and its cross-disciplinary nature, new methodologies and content need to be developed to allow students to combine hardware and software implementation and to prepare future engineers to handle unfamiliar and complex problems. The case above obeys and complies with the current education principles which encourage a thorough analysis of the context and needs of students to design relevant and student-centered courses. [8] Teachers and learners will therefore embrace a culture where different disciplines are blended to bring up a unifying course that comprises of the relevant information needed by students studying robotics. Below is a detailed outline how the relevant major disciplines can contribute to a comprehensive robotics course.

As illustrated in Fig. 1, incorporating interdisciplinary project-integrated teaching methodologies into robotics education serves not only to diversify students' skill sets but also to replicate the collaborative essence of real-world robotics projects.

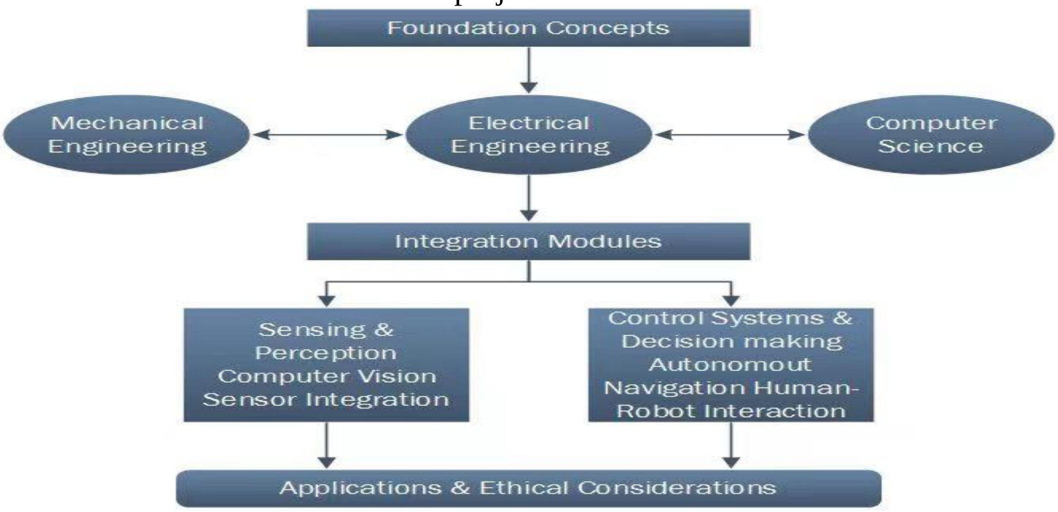

Figure 1: Illustration of method for interdisciplinary project-integration

This instructional approach not only equips students with a broad array of capabilities but also reflects the interdependent relationships among different fields within the professional sphere. By emphasizing collaboration across disciplines like computer science, electrical engineering, and mechanical engineering, educators prepare students for seamless integration into interdisciplinary teams prevalent in industry contexts. Such preparation is invaluable, as it mirrors the collaborative dynamics required to navigate the complexities of real-world robotics challenges effectively. Furthermore, interdisciplinary teaching fosters a culture of innovation and adaptive problem-solving, traits critical for addressing the multifaceted obstacles inherent in real-world robotics applications. Through exposure to diverse academic domains, students develop a versatile mindset that enables them to devise creative solutions drawing from insights across various disciplines. This approach not only nurtures students' ability to think critically but also cultivates their capacity to adapt to novel challenges, essential qualities in the rapidly evolving field of robotics. Moreover, hands-on interdisciplinary projects within the classroom provide practical experience reflective of real-world scenarios, empowering students to synthesize knowledge from different fields to address complex robotics problems effectively. In addition to enhancing technical proficiency, interdisciplinary teaching in robotics education instills ethical awareness and entrepreneurial acumen in students. [10] Discussions surrounding ethical considerations in robotics, such as privacy, safety, and autonomy, encourage students to develop a holistic understanding of the societal implications of their work. Moreover, integration of business and entrepreneurship principles into the curriculum equips students with the skills necessary to leverage their interdisciplinary knowledge for innovative ventures. By nurturing ethical consciousness and entrepreneurial spirit alongside technical expertise, interdisciplinary robotics education prepares students to make meaningful contributions to society while thriving in diverse professional roles within the field.

2.2. Continuous improvement mechanism

Teachers should regularly solicit feedback from students throughout the course to identify areas for improvement and ensure that interdisciplinary content is effectively integrated. They should regularly review and update course materials to reflect advances in robotics technology and interdisciplinary research. This iterative process involves updating curriculum materials, integrating new technologies, and refining interdisciplinary projects to align with industry trends and emerging technologies in robotics [9]. By prioritizing continuous improvement, educators ensure that the course remains dynamic and responsive to the evolving demands of robotics education.

Table 1: Relevant topics for robotic course in terms of different disciplines

Discipline	Relevant Topics for Robotics Course
Mechanical Engineering	Mechanics and dynamics Kinematics and kinetics Materials science and engineering Mechanical design and CAD (Computer-Aided Design) Robotics mechanisms and manipulators
Electrical Engineering	Circuit theory and analysis Digital and analog electronics Control systems theory Signal processing Power electronics and motor control
Computer Science	Algorithms and data structures Programming languages (e.g., Python, C++) Artificial intelligence and machine learning Computer vision and image processing Robotics software frameworks (e.g., ROS - Robot Operating System)
Physics	Classical mechanics Electromagnetism Optics Thermodynamics and heat transfer Quantum mechanics (for advanced robotics applications)

In parallel, feedback mechanisms are established to gather input from students about their learning experiences, enabling educators to gauge the effectiveness of interdisciplinary approaches and make necessary adjustments. Students are encouraged to provide constructive feedback through course evaluations, surveys, focus groups, or one-on-one sessions. This feedback is collected regularly, allowing educators to identify trends and patterns over time and make informed decisions about curriculum design, teaching strategies, and the integration of interdisciplinary content. By listening to students' perspectives and incorporating their feedback, educators demonstrate responsiveness to student needs, fostering a collaborative learning environment where both educators and students contribute to the ongoing improvement of the robotics course.

Table 1 highlights some of the relevant concepts teachers can use to formulate and come up with a robust and fully inclusive robotics course for their learners. The disciplines span from engineering courses to biology course and even the ethics part where robots are required to live and co-exist peacefully with humans.

3. Implementation of the Approach

An interdisciplinary approach to robotics education involves integrating insights, methodologies, and perspectives from various academic disciplines to create a comprehensive learning experience. Implementing different disciplines to create a comprehensive robotics course requires careful planning and integration of various topics and methodologies. The following are the direct steps the teachers and the learners should adhere to while blending different disciplines.

3.1. Designing Curriculum with Interdisciplinary Modules

The educators should identify key learning objectives for the robotics course, considering both technical skills and interdisciplinary understanding. After carefully obtaining the learning objectives, he/she should map out the course structure, breaking it down into modules or units that cover different aspects of robotics. Finally, the teacher should determine which disciplines will contribute to each module based on the learning objectives and topics covered. The modules developed which will include the insights from multiple disciplines may include the following:

- ➢ Module 1: Foundations of Robotics (Integrating computer science, electrical engineering, and mathematics)
- ➢ Module 2: Robot Mechanisms and Dynamics (Mechanical engineering and physics)
- ➢ Module 3: Sensing and Perception (Computer science, electrical engineering, and biology)
- ➢ Module 4: Control Systems and Decision Making (Electrical engineering, computer science, and mathematics)
- ➢ Module 5: Applications and Special Topics (Drawing from various disciplines to explore specific applications or emerging trends)

3.2. Integrated Projects and labs

Instructors should design hands-on projects and laboratory exercises that require students to apply concepts from multiple disciplines to solve real-world robotics problems, encourage interdisciplinary collaboration among students, and assign group projects that involve designing, building, and programming robots using a multidisciplinary approach. In integrated projects, students work together in teams to design, build, and program robots to perform specific tasks or solve challenges. These projects typically span multiple phases, including conceptualization, design, prototyping, testing, and refinement. By integrating concepts from computer science, electrical engineering, mechanical engineering, and other relevant fields, students gain a holistic understanding of the robotics development process and develop skills in problem-solving, critical thinking, and project management.

Integrated labs complement theoretical learning with hands-on experimentation and practical skills development. These labs provide students with access to robotics hardware, software, and tools, allowing them to gain proficiency in areas such as robot assembly, sensor integration, programming, and control systems implementation. Through guided exercises and open-ended projects, students learn to troubleshoot technical issues, optimize robot performance, and iterate on design iterations, enhancing their practical skills and confidence in working with robotic systems.

3.3. Interdisciplinary Project-integrated Assignments and Assessments

Teachers should create assignments and assessments that assess students' understanding of interdisciplinary concepts and their ability to integrate knowledge from different disciplines. These assignments go beyond traditional assessments by requiring students to apply concepts learned in computer science, electrical engineering, mechanical engineering, and other relevant fields to real-world robotics scenarios. One clear example of an interdisciplinary assignment could be a project where students are tasked with designing and building a robot capable of navigating through an obstacle course autonomously. This project would require students to apply principles of computer vision to recognize obstacles, algorithms from computer science to plan a path, control systems from electrical engineering to steer the robot, and mechanical design principles to construct a robust and efficient robot. Assessments for such interdisciplinary assignments may include a combination of written reports, presentations, and demonstrations.

Other interdisciplinary assessments may involve collaborative problem-solving exercises, where students work in teams to tackle open-ended robotics challenges that require diverse expertise. These exercises not only assess students' technical proficiency but also their ability to communicate and collaborate effectively across disciplines, reflecting the interdisciplinary nature of real-world robotics projects.

3.4. Organizing Field Trips and Industry Visits

Incorporating field trips and industry visits is a pivotal aspect of fostering interdisciplinary project-integrated learning in a robotics course. To initiate this process, educators should first begin by meticulously identifying suitable organizations and companies within the robotics industry that correlate with the course's interdisciplinary objectives. This entails reaching out to potential hosts to gauge their willingness to accommodate student visits, providing comprehensive details about the course's aims, the number of participants, and any logistical requirements such as transportation and lodging. Once arrangements are made, coordination with the host organization ensues to ensure the visit aligns seamlessly with the course schedule and objectives. When visiting, students are afforded the invaluable opportunity to explore various facets of robotics firsthand. They engage in guided tours of facilities, witness live robotics demonstrations, and partake in insightful discussions with industry professionals. Active participation is encouraged, with students encouraged to ask questions and delve into the interdisciplinary aspects of robotics projects. Additionally, hands-on experiences, such as interactive demos or simulations, allow students to gain practical insights into how interdisciplinary concepts manifest in real-world robotics applications. Post-visit, students are prompted to reflect on their experiences and insights gleaned from the field trip or industry visit. These reflections are integrated into classroom discussions, assignments, or projects to reinforce interdisciplinary connections and underscore the practical relevance of the visit. Through reflective essays, reports, or presentations, students articulate their observations, analyse interdisciplinary connections, and critically evaluate industry practices. These assessments gauge students' ability to comprehend and articulate the contributions of different disciplines to robotics projects, facilitating deeper learning and understanding.

The continuous improvement is integral to the process, with feedback from students informing refinements in future field trip plans. By gathering insights on strengths and areas for enhancement, educators can fine-tune the visit experience to better align with the course's interdisciplinary objectives. Through this iterative approach, field trips and industry visits serve as invaluable tools for exposing students to real-world applications of interdisciplinary concepts in robotics, fostering a deeper understanding of the field and preparing them for future endeavours.

4. Conclusions

The research on teaching methods for control and drive courses in robot engineering education underscores the importance of innovative pedagogical approaches in preparing students for careers in robotics. Traditional methods have laid the foundation for understanding fundamental concepts, but their limitations in engaging students and fostering active learning necessitate the exploration of alternative approaches. Interdisciplinary project-integrated approach or simply blending of concepts from different fields offer promising avenues for enhancing student engagement, promoting critical thinking, and fostering collaborative problem-solving skills. By leveraging these innovative methods, educators can create dynamic and immersive learning experiences that empower students to excel in the rapidly evolving field of robot engineering. Moving forward, continued research and experimentation are needed to further refine teaching methods, assess their effectiveness, and adapt them to meet the evolving needs of students and the demands of industry. By embracing innovation and collaboration, educators can collectively advance the pedagogy of control and drive courses, ultimately empowering students to become proficient and innovative practitioners in the field of robot engineering.

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