Hybrid Active Teaching in Automatic Control Systems Course

TOORAN EMAMI
Department of Electrical Engineering and Computing,
U. S. Coast Guard Academy,
27 Mohegan Ave, New London, CT,
UNITED STATES OF AMERICA

Abstract: - This paper introduces a hybrid teaching method for an undergraduate course in automatic control systems. This approach combines traditional lectures with interactive, hands-on activities that link theoretical concepts to real-world applications. Using MATLAB and QUARC software, students apply theoretical knowledge to practical control problems, enhancing their understanding and skills. The lab sessions are aligned with lecture topics to create a cohesive learning experience that reinforces the fundamentals of classical control theory. This hybrid method boosts student engagement, improves problem-solving skills, and enhances overall learning outcomes. This framework provides valuable insights for educators looking to improve undergraduate control systems courses.

Key-Words: - Hybrid and Active Teaching, ACS Course Design, Virtual Laboratory, Hardware and Software Interface, MATLAB and QUARC Software, SRV02 DC-Motor.

Received: March 17, 2025. Revised: March 19, 2026. Accepted: June 5, 2026. Published: August 3, 2026.

1 Introduction

Active teaching helps students improve their critical thinking skills. It encourages them to experiment, simulate, and analyze different scenarios, which boosts their problem-solving abilities. Using virtual models and real systems, students learn how theoretical concepts apply to real engineering and science situations. Modern software tools help students visualize complex ideas and apply theoretical knowledge in an interactive laboratory. This paper shares insights gathered over ten years of using innovative teaching methods in an Automatic Control Systems (ACS) course.

Numerous textbooks worldwide provide comprehensive, well-structured coverage of classical control system concepts. They lay out theoretical foundations, mathematical models, and systematic problem-solving strategies that are crucial for grasping the principles of control engineering, [1], [2], [3], [4], [5], [6].

Creating a laboratory environment that emphasizes hands-on learning is essential for connecting theoretical knowledge with real-world applications. In such settings, students can interact with physical systems and witness the dynamics of various processes while experimenting with different control strategies. This practical exposure also introduces them to real-world challenges, including sensor noise, actuator limitations, and time delays. Moreover, collaborative project tasks enhance teamwork, innovation, and communication skills, which are crucial in today's engineering field. The hands-on experience gained through laboratory work is fundamental for developing practical competencies and adequately preparing students for the challenges they will face in their careers.

Active learning in practical environments is revolutionizing undergraduate engineering programs worldwide. This approach not only equips students with essential skills but also prepares them to address real-world challenges. The author in [7] established a framework of laboratory objectives, essential concepts, and key components for the laboratory apparatus used in undergraduate control systems labs. The study in [8] introduced a web-based study support system to improve study effectiveness by giving students ongoing feedback and regular guidance based on self-assessment exercises. This method helped students monitor their progress in understanding the course material.

The authors proposed significant concepts and a practical curriculum for control systems as a distinct discipline, [9]. They highlighted several issues with existing curricula, including typical laboratory setups and the importance of simulation, logic, sequencing, and real-time simulation. They also discussed the use of Computer-Aided Control Engineering (CACE) software in teaching and its potential shortcomings. Additionally, the authors considered the industry's perspective on the desirable skills required for engineering education.

The authors in [10] incorporated elements from various tutorials accessible to students through a structured, objectives-oriented project planning method. This instructional method helped student remain accountable for their learning. The research in [11] introduced the teaching of automatic control for linear time-invariant systems to undergraduate students using open-source software. Students solved control problems with a few lines of C/C++ code in the Ch Control System Toolkit software.

The authors in [12] established a professional facility evaluation service that utilized its physical space and technological resources to benefit the national industry. This method provided graduates with tools to enhance their knowledge and improve their employment prospects.

The study in [13] introduced innovative reforms in theoretical and practical teaching content to integrate theory and practice seamlessly. Simultaneously, they moved away from the conventional teacher-guided classroom model. This approach cultivated a robust sense of self-directed learning, exploration, and innovation, equipping students to become well-rounded individuals in their education, research, and application.

The author in [14] discussed the challenges of teaching seafarers control engineering during the COVID-19 pandemic. The author emphasized the difficulties of remote instruction, the importance of practical training, and the adaptations required to maintain educational standards during these unprecedented times.

The research in [15] presented an educational project designed to introduce graduate students to autonomous navigation concepts using a small-scale model electric car. The project integrated control systems principles by providing hands-on experience in implementing and testing control algorithms practically. This approach enhanced students' understanding of control systems and their applications in autonomous vehicles.

The authors in [16] developed a teaching method for sustainable development by examining bicycle safety through lighting systems. This approach enables students to engage with control systems while actively designing and implementing lighting mechanisms.

The current paper reflects over a decade of experience in teaching classical control systems, emphasizing the vital integration of theoretical knowledge and practical laboratory experiences for undergraduate students. It advocates a comprehensive educational model that nurtures both conceptual understanding and practical skills, preparing students for real-world applications.

The work presents a structured framework for designing introductory control systems courses that blend theoretical concepts with hands-on learning. By combining theoretical problem-solving with practical experimentation, students deepen their understanding of the complexities and significance of control systems. This dual method enhances their technical skills while also cultivating critical thinking and problem-solving abilities.

This paper is organized as follows: Section 2 details the design of the hybrid active automatic control systems course, Section 3 presents the assessment framework, and Section 4 presents the conclusions.

2 Design of Hybrid Active ACS Course

The contents of a 3.5-credit course in Automatic Control Systems (ACS) include key components such as modeling, analysis, and controller design. Through engaging instructional modules, students will develop mathematical models, perform system analysis, and design controllers to achieve the system performance goals. This course bridges the traditional learning experience by incorporating modern technological tools, preparing students to tackle real-world challenges. The course is structured into three parts over one semester.

2.1 First Part of the Semester

In the first part, the course focuses on modeling system dynamics in the time and frequency domains, teaching students to apply differential equations to represent them. A key element of this modeling process is applying the Laplace transform, which is a foundation for conducting frequency-domain analyses. The system's transfer function can represent the differential equation, illustrating the relationship between input and output under zero initial conditions.

The transfer function concept is introduced through a review of complex electric passive circuits, followed by applications of active circuits utilizing operational amplifiers, including inverting and non-inverting configurations. The course then extends to derive the transfer function for purely mechanical systems, covering translational, rotational, and gear-based systems. Initial modeling efforts will focus on analyzing velocity and angular velocity, utilizing Cramer’s rule to simplify variable interactions. Students will find it straightforward to understand the relationship between velocity and position, drawing from their background in physics. The final part of the first section of the semester focuses on electromechanical systems, emphasizing mathematical modeling and real data analysis in both time and frequency domains. Table 1 outlines the topics covered during the first part of the semester, including two laboratories as active learning, highlighted in orange.

Table 1. Overview of the First Part of the Semester

Control Systems Overview
Apply Solutions of Differential Equations, Laplace Transform Theorems
Apply Inverse Laplace Transform and Transfer Functions for Complex Circuits
Lab 1: Apply Introduction to Control Systems Toolbox and Simulation to Antenna Azimuth Position Control
Electrical Network Transfer Functions for Operational Amplifier
Translational Mechanical System Transfer Functions
Rotational Mechanical System Transfer Functions
Transfer Functions for a System with Gears
Electromechanical System Transfer Functions
Apply Electromechanical Systems Dynamics to the Mathematical Modeling of SRV-02 DC Motor
Apply Electromechanical Systems Modeling to Real Data Collection of SRV-02 DC Motor
Lab 2: Apply First-Order System Identifications to DC-Motor Hardware

Source: created by the author

The objectives of the first lab, which focuses on active learning, are outlined as follows:

- Introduction to MATLAB Simulink Libraries.
- Creation of continuous Simulink models for an antenna azimuth control system. The case study for this laboratory involves an antenna angle position control system, where the antenna's angular output tracks the angular input from a potentiometer, as illustrated in Figure 1, [1].
- Introduction to the Symbolic and Control Toolboxes in MATLAB.
- Review the fundamentals of linear algebra, as well as an understanding of the theory behind linear least-squares estimation.
- Solving fundamental linear algebra problems and performing linear least-squares system identifications using MATLAB on the input and output data in the lab handout.

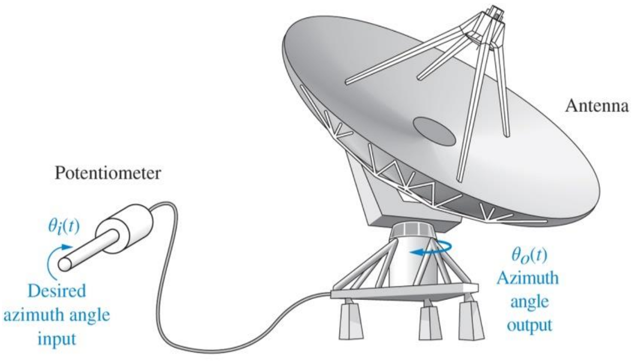

Fig. 1: Antenna azimuth position control
Source: [1]

Laboratory Two focuses on the ideologies of active learning and identifying electromechanical first-order systems through hardware and software interfaces. Its primary objective is to facilitate a comprehensive understanding of modeling processes of a real system via simulations, verifications, and validations, utilizing the SRV02 DC motor from Quanser Inc., [17].

The modeling process commences with the acquisition of frequency- and step-response measurement data from the system. The experimental setup is depicted in Figure 2.

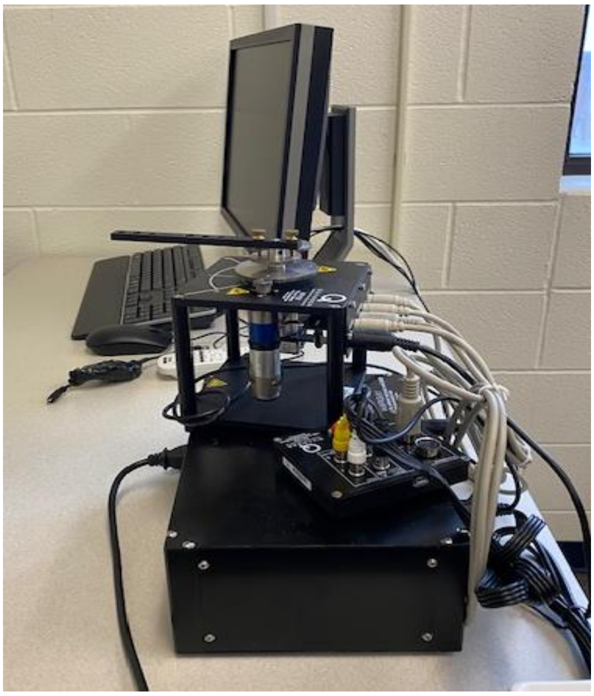

Fig. 2: Hardware and software interface of the DC motor
Source: created by the author

Data collection is performed using MATLAB in conjunction with QUARC software Simulation, enabling real-time observation of data acquisition alongside hardware integration. The MATLAB environment facilitates the complete characterization and representation of the acquired data, setting the stage for subsequent analysis.

In the verification phase, students typically determine the system's mathematical model, ensuring that the implemented QUARC software model accurately reflects the system's dynamics. Validation involves comparing the derived transfer functions against the actual system performance, achieved by interfacing the hardware with the software of the Servo motor. This process confirms that both the measurement models from the simulation QUARC software and the mathematical analyses represent the dynamics of the physical system.

2.2 Second Part of the Semester

In the second part of the course, students are presented with an overview of modeling dynamic systems utilizing state-space representations and output equations, with a particular focus on multiple-input, multiple-output (MIMO) systems with and without disturbance. This section underscores the adaptability and applicability of state-space modeling, illustrating how it can be derived from differential equations and transfer functions, and vice versa. By examining these diverse methodologies, students understand how to represent and analyze complex systems within both time and frequency domains.

After state-space modeling, the course continues with standard second-order system modeling. This concept examines system dynamics, including poles, zeros, and oscillatory responses. Students use analytical techniques to assess and predict system performance, with a focus on second-order system identification. The active learning of 2nd-order system identification and visualization is assessed in the laboratory, [18].

Students learn about Masson's gain rule and the Routh-Hurwitz criterion to enhance their analytical skills. These concepts are demonstrated through the application of Antenna azimuth position control in an active-learning setting, providing students with practical experience in a laboratory, [19].

This structured progression equips students with a solid theoretical foundation while developing practical skills in analyzing and designing effective control systems. Furthermore, the course covers steady-state error analysis by exploring open- and closed-loop system responses. Students learn to detect steady-state errors and classify system types, which are crucial for designing controllers to enhance system performance. The final topic in this part of the semester focuses on steady-state error analysis of systems affected by disturbances. By examining how systems respond to external disturbances, students gain valuable insights into improving the robustness and resilience of controller designs. Table 2 provides a detailed overview of the topics covered during the second part of the semester.

Table 2. Overview of the Second Part of the Semester

Converting a Transfer Function to State Space Equations
Converting from State Space Equations to a Transfer Function
General First-Order
Standard Second-Order Systems, Undamped, Underdamped, Damped, Overdamped Responses
Standard Second-Order Performance Specifications
Lab 3: Apply Second-Order System Identifications to an RLC Circuit and a Ship
Reduction of Multiple Subsystems: Introduction to Signal Flow Graphs
Signal Flow Graphs and Mason's Rule
Apply Reduction of Multiple Subsystems: Signal Flow Graphs and Mason's Rule
LHP and RHP Poles, Modes, Introduction to Routh-Hurwitz Criterion
Analysis of Routh-Hurwitz Criterion
Apply the Routh-Hurwitz Criterion
Steady State Error for Unity Feedback Systems in Terms of T(s)
Lab 4: Apply Mason's Rule and Routh-Hurwitz Criterion to Antenna Azimuth Position Control
Steady State Error for Unity Feedback Systems in Terms of G(s), Static Error Constants, and System Types
Steady State Error for Systems with Disturbances

Source: created by the author

During this part of the semester, two laboratories are dedicated to active teaching. In these labs, students use MATLAB to model and analyze various systems, applying the concepts they have learned. The third laboratory aims to teach the standard identification of second-order systems. The objectives of active learning in this laboratory are: 1) Determine the transfer functions of the resistor-inductor-capacitor (RLC) series connection circuit. 2) Compare the RLC circuit transfer function with those of standard 2nd-order systems. 3) Analyze the effect of changing the damping ratio and natural frequency on the step and frequency responses and the pole location of the RLC circuit. 4) Apply the standard 2nd-order system identification to a given measurement heading angle response of a ship to a disturbance step input in Figure 3, [1]. 5) Determine the state space and output equations from a ship's heading-angle response to a constant disturbance.

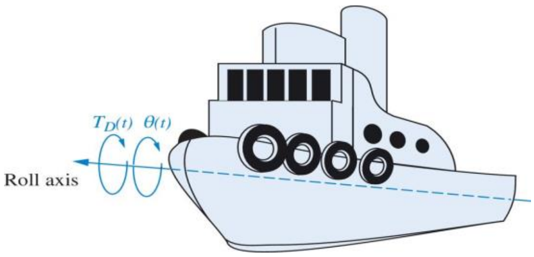

Fig. 3: A ship at sea
Source: [1]

The Fort laboratory aims to apply the Routh-Hurwitz criterion to antenna azimuth heading position control, [19]. This lab aims to create an active learning environment for students to apply signal flow graphs, Mason's gain rule, and the Routh-Hurwitz criterion. The objectives of this laboratory are: 1) The mathematical modeling and signal flow graph for an Antenna Azimuth Heading Position Control system. 2) Apply the Routh-Hurwitz criterion to find all proportional gains for the antenna controllers that stabilize the heading angle. 3) Find the proportional controllers that meet the specific output response for the antenna angular position response. 4) Understand the concepts of closed-loop poles, stability, marginal stability, and instability.

The case study in this Lab begins by modeling the schematic and parameter data of an antenna azimuth heading position control, as shown in Figure 1. Next, students define the transfer function of each subsystem based on the given system configuration data, the antenna azimuth heading position control diagram in Figure 4. In the second part of this lab, students apply Mason's gain rule and Routh-Hurwitz's criterion to find all proportional gains that make this system stable and analyze the system performance in MATLAB. Finally, virtual MATLAB programming teaches them about the antenna control system's instability and marginal stability concepts, [19].

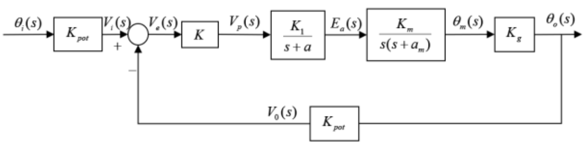

Fig. 4: Block diagram of antenna azimuth position control
Source: [1]

2.3 Third Part of the Semester

The third part of the course focuses on classical controller design. The analysis begins with a traditional sketch of the root locus and continues with a more detailed examination of its properties. The controller design begins with proportional controller design via root locus, as described in traditional textbooks, [1], [2], [3], [4], [5], [6], [20]. The overview of the course concepts in this part of the semester is shown in Table 3.

Table 3. Overview of the Third Part of the Semester

Root Locus Techniques: Sketching and Properties of Root Locus
Design Via Root Locus: Proportional (P) Controller Design
Design Via Root Locus: Proportional Derivative (PD) Controller Design
Design Via Root Locus: Apply Proportional Derivative (PD) Controller Design
Design Via Root Locus: Proportional Integral (PI) Controller Design
Design Via Root Locus: Apply Proportional Integral (PI) Controller Design
Lab 5: Apply Root Locus Techniques to Position Control of DC Motor
Frequency Response Techniques: Stability, Gain Margin, and Phase Margin Via Bode Plots
Design Via Frequency Response: Performance Analysis
Design Via Frequency Response: Proportional (P) Controller Design
Design Via Frequency Response: Apply Proportional (P) Controller Design
Design Via Frequency Response: Proportional Integral (PI) Controller Design
Design Via Frequency Response: Apply Proportional Integral (PI) Controller Design
Design Via Frequency Response: Proportional Derivative (PD) Controller Design
Design Via Frequency Response: Apply Proportional Derivative (PD) Controller Design
Lab 6: Apply Bode Design to Angular Velocity Control of DC Motor

Source: created by the author

After students learned controller design in the lecture, the course continued by designing proportional, proportional-derivative, and proportional-integral controllers using root locus. Next, the analysis of frequency domains, including gain and phase margins, gain and phase crossover frequencies, is introduced. Following this, the Bode compensator design and the algorithms that guide students through this design process are introduced.

The final part of the semester focuses on active learning through two hands-on hardware laboratories. Lab five is designed to apply root locus techniques for the position control of the SRV02-DC Motor. The objectives of this lab are as follows: 1) Utilize the root locus technique to develop MATLAB code for designing a controller for shaft position control based on the mathematical model of the SRV02-DC motor. 2) Implement the chosen controllers on the real-time SRV-02 DC motor to effectively regulate the shaft position, as depicted in Figure 2. 3) Compare the closed-loop step responses of the real-time SRV-02 motor with the responses predicted by the mathematical model.

The last lab of the semester is applying Bode design to angular velocity control for the SRV02-DC Motor. In this laboratory, Bode techniques are employed to design a compensator that regulates the angular velocity of the SRV-02 DC motor. The input to the motor is voltage, and the output is the angular velocity. The only information provided to students for the system is the magnitude-frequency response plot of the motor's angular velocity and the system's specifications for the gain margin and phase crossover frequency.

3 Assessment Framework

The assessment framework implemented in this course evaluates students' understanding, analytical skills, problem-solving abilities, and their capacity to apply control systems concepts. This comprehensive approach employs a diverse range of assessment tools, ensuring a thorough evaluation of both theoretical knowledge and practical competencies. By integrating these elements, the framework prepares students for real-world challenges in the field.

Weekly quizzes are a continuous assessment tool, reinforcing key concepts covered during lectures while providing students with regular feedback on their progress. These quizzes assess fundamental understanding and promote consistent engagement with the material, thereby supporting long-term retention.

Pre-laboratory quizzes assess students' readiness for hands-on experiments. These quizzes confirm that students understand the theoretical principles before participating in practical activities, helping to build clear connections between abstract ideas and real-world use. This proactive approach improves the efficiency and effectiveness of lab sessions, enabling students to engage in experiments and gain an understanding.

Laboratory reports are essential for assessing students' ability to analyze experimental data, draw meaningful conclusions, and communicate technical findings. These reports not only improve students' skills in engineering analysis but also develop important technical writing and documentation skills, which are key to a successful career in engineering.

Exams provide comprehensive assessments of students' critical thinking, problem-solving skills, and mastery of the subject. These tests challenge students to apply their knowledge across various situations, fostering a deeper understanding.

These assessment tools work together to create a balanced evaluation system that fosters both theoretical understanding and practical skills. Beyond mere academic achievement, the consistent use of quizzes, laboratory reports, and exams equips students with vital analytical, problem-solving, and communication abilities essential for success in professional engineering careers. This comprehensive assessment strategy not only evaluates students' knowledge but also prepares them to tackle the real-world challenges they will encounter as future engineers.

4 Conclusions

This paper presents a comprehensive, active teaching methodology for undergraduate control systems education. By combining traditional lectures with hands-on laboratory experiences, it bridges the gap between theoretical knowledge and practical application. The use of MATLAB and QUARC software enables students to apply theoretical concepts to real-world situations, thereby deepening their understanding of classical control principles.

The laboratory exercises, integrated with lecture content, foster a cohesive learning experience. This structured integration reinforces essential concepts while nurturing critical thinking, problem-solving skills, and practical competence. Moreover, active participation in this approach enhances student engagement.

The notable improvements in student learning outcomes from this hybrid model highlight its effectiveness. This approach offers educators an opportunity to refine their teaching strategies and prepare students for successful careers in engineering and system automation. By adopting this model, organizations can cultivate a more engaged and skilled workforce, ultimately benefiting both students and the industry.

Acknowledgment:
The author expresses sincere gratitude to the United States Coast Guard Academy for its support over the past decade in developing this course. The opinions expressed by the author are her own and not necessarily those of the U.S. Coast Guard or the U.S. Government.

References:
[1] Norman S. Nise, *Control Systems Engineering*, John Wiley & Sons, 2019, [Online]. https://www.wiley.com/en-us/shop/general-introductory-electrical-electronics-engineering/control-systems-engineering-8th-edition-p-9781119474227 (Accessed Date: January 10, 2026).
[2] Farid Golnaraghi, Benjamin C. Kuo, *Automatic Control Systems*, McGraw-Hill, 2017, [Online]. https://www.mheducation.com/highered/mhp/product/automatic-control-systems-tenth-edition.html?viewOption=student (Accessed Date: January 10, 2026).
[3] Richard C. Dorf, Robert H. Bishop, *Modern Control Systems*, Pearson, 2022, [Online]. https://www.pearson.com/en-us/subject-catalog/p/modern-control-systems/P200000003484/9780137307098?srsltid=AfmBOorhWSMN2g8qM39j1dB_Qfa59_FdP77rRRGviG8RDPVaTCkyI51p (Accessed Date: January 10, 2026).
[4] Gene F. Franklin, J. David Powell, Abbas Emami-Naeini, *Feedback Control of Dynamic Systems*, Pearson, 2010, [Online]. https://www.pearson.com/en-us/subject-catalog/p/feedback-control-of-dynamic-systems/P200000003343/9780137516834 (Accessed Date: January 10, 2026).
[5] Katsuhiko Ogata, *Modern Control Engineering*, Pearson, 2009, [Online]. https://www.pearson.com/en-us/subject-catalog/p/modern-control-engineering/P200000003521/9780137551064?srsltid=AfmBOooWtu0Nxdv-qpktSURurlNBaYsLF1MVm7TQm2SijzmuzMDqSLWK (Accessed Date: January 10, 2026).
[6] Katsuhiko Ogata, *System Dynamics*, Pearson, 2003, [Online]. https://www.pearson.com/en-us/subject-catalog/p/system-dynamics/P200000003209/9780131424623?srsltid=AfmBOorHYJUKHjxDu3Ll3fepTVrxmmQUIHw6GJhgHQjSqq0_HB-KHiNa (Accessed Date: January 10, 2026).
[7] R. M. Reck, Common Teaching Objectives for Undergraduate Control Systems Laboratories. *IEEE Transactions on Education*, Vol. 60, No. 4, 2017, pp. 257-264. doi: 10.1109/TE.2017.2681624.
[8] G. J. C. Copinga, M.H.G. Verhaegen, and M.J.J.M. van de Ven, Toward a Web-based Study Support Environment for Teaching Automatic Control, *IEEE Control Systems Magazine*, Vol. 20, No. 4, 2000, pp. 8-19. doi: 10.1109/37.856175.
[9] N. A. Kheir, Karl Johan Åström, D. Auslander, K. C. Cheok, Gene F. Franklin, M. Masten, and M. Rabins, Control Systems Engineering Education. *Automatica*, Vol. 32. No. 2, 1996, pp. 147-166. https://doi.org/10.1016/0005-1098(96)85546-4.
[10] J. El Khakdi, H. Wertani, L. Bouslimi, J. Ben Salem, M. N. Lakhoua, The Need for a Systemic Approach to Specifying a Robotics Tutorial, *WSEAS Transactions on Advances in Engineering Education*, Vol. 21, 2024, pp. 170-173. doi: 10.37394/232010.2024.21.19.
[11] Bo Chen, Yu-Cheng Chou, Harry H. Cheng, Open Source Ch Control System Toolkit and Web-based Control System Design for Teaching Automatic Control of Linear Time-invariant Systems, *Computer Applications in Engineering Education*, Vol. 21, 2013, pp. 95-112. https://doi.org/10.1002/cae.20454.
[12] John Milton, Ramírez Romero, Andrés Esteban Murillo Moreno, Sergio Rivera, Assessment Tools for Improving Hard Skills in a Virtual Laboratory (Electrical Machine Case Study), *WSEAS Transactions on Advances in Engineering Education*, Vol. 21, 2024, pp. 47-53, https://doi.org/10.37394/232010.2024.21.7.
[13] Hua Fan, Mingyu Liang, Combining Theory with Practice in Circuits and Systems Education, *WSEAS Transactions on Advances in Engineering Education*, Vol. 20, 2023, pp. 91-96, https://doi.org/10.37394/232010.2023.20.12.
[14] Ahmed Ekashlan, Challenges of Teaching Control Engineering to Seafarers According to IMO – STCW 2010 Convention During the Mutated Corona Virus (COVID–19) Pandemic, *WSEAS Transactions on Advances in Engineering Education*, Vol. 18, 2021, pp.

152-155, https://doi.org/10.37394/232010.2021.18.14.

[15] Y. Ilam, T. Marie, Ph. Dondon, A Didactical Electronic Project for Graduated Students: Initiation to Autonomous Navigation using a Small-Scale Model Electric Car, *WSEAS Transactions on Advances in Engineering Education,* Vol. 16, 2019, pp. 28-35.

[16] A. Sivert, F. Betin, B. Vacossin, Ph. Dondon, Innovative Sustainable Development Teaching at University: Study of Lighting Systems for Safety Bicycle Rides, *WSEAS Transactions on Advances in Engineering Education,* Vol. 16, 2019, pp. 49-62.

[17] Jacob Apkarian, J., Michel Lévis, Hakan Gurocak, User Manual SRV02 Rotary Servo Base Setup Configuration, [Online]. http://ece.ucf.edu/~abehal/eel4612/lab/General/SRV02_Workbook.pdf (Accessed Date: January 10, 2026).

[18] Tooran Emami, "Apply Second Order System Identifications," *Proceedings of the 124 ASEE Annual Conference & Exposition*, Columbus, Ohio, 2017, [Online]. https://peer.asee.org/apply-second-order-system-identifications (Accessed Date: January 10, 2026).

[19] Tooran Emami and Joseph Benin, "Computer Support for Teaching Routh-Hurwitz Criterion," *Proceedings of the 2016 American Control Conference,* Boston, MA, 2016. https://doi.org/10.1109/ACC.2016.7525102.

[20] Richard T. O'Brien Jr. and John M. Watkins, "A Unified Approach for Teaching Root Locus and Bode Compensator Design," *Proceedings of the 2003 American Control Conference,* Colorado, 2003. https://doi.org/10.1109/ACC.2003.1239092.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The author contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The author has no conflicts of interest to declare that are relevant to the content of this article.