ARTIFICIAL INTELLIGENCE IN ELECTROMECHANICAL ENGINEERING: THE ESPRIT MODEL

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ABSTRACT

In response to the surge of artificial intelligence (AI) in the last decade, which now spans across electromechanical sectors like automation, electricity, and maintenance, the ESPRIT approach is introduced. It emphasizes the need for engineers to diversify their skill sets to adapt to the evolving landscape. This educational paradigm integrates an AI module into the electromechanical engineering curriculum, congruent with CDIO standards, to cultivate a broad spectrum of competencies in AI. The curriculum is meticulously crafted to progress from foundational knowledge to advanced application and assessment, employing active learning strategies to enhance students' technical, problem-solving, and professional skills, ultimately encouraging a well-rounded mastery of AI in engineering. This paper describes the ESPRIT approach, a pedagogical paradigm tailored for equipping electromechanical engineers with the necessary AI competencies. The integration of a dedicated AI module within ESPRIT's electromechanical engineering curriculum aligns with the CDIO standards, marking a significant stride in engineering education. Our pedagogical contribution is threefold, encapsulating the design, execution, and evaluation of the AI module over a span of three years. The curriculum employs active learning strategies (standard 8) to immerse students in AI problem-solving, fostering an environment of practical engagement. The curriculum unfolds in a structured manner (standard 3), starting with the AI discovery phase in the third year, where students acquaint themselves with Python, AI libraries, and foundational AI concepts, including elementary classification and regression algorithms. The second phase, in the fourth year, pivots on the application and reinforcement of the knowledge acquired, with a focus on the lifecycle of an AI project. Students culminate this stage by undertaking a mini project adhering to AI project conventions. The final phase, in the fifth year, emphasizes practical application and mastery, culminating in an NVIDIA DLI workshop where students have the opportunity to earn a certificate in AI for predictive maintenance. In conclusion, the paper presents a critical analysis of this pedagogical approach, highlighting its pragmatic applications and the well-paced learning trajectory that aligns with student capability. Nonetheless, it underscores the imperative of achieving a symmetrical balance between the theoretical and practical aspects of AI to fully harness its potential in electromechanical engineering.

KEYWORDS

Artificial Intelligence, Electromechanical engineering, engineering education, Predictive maintenance, Standards: 1, 2, 3, 5, 6, 8, 11

INTRODUCTION

Integration of artificial intelligence (AI) into engineers' education across various disciplines, including mechanical, electrical, civil, electromechanical, and biological engineering, is gaining increasing significance due to the numerous advantages it brings to the industrial landscape (Chen, Chen, & Lin,2020; Lee, Bagheri, & Kao, 2015; Novatchkov & Baca, 2013). It enhances students' skills and prepare them to cope better with the world challenges (Chen et al., 2020).

In this context, our focus centers on the integration of AI into the training of electromechanical engineers. The rationale behind this imperative integration is multifold:

First and foremost, the rapid progression of AI and automation is reshaping the electromechanical industries (Lee et al., 2015), compelling engineers to acquaint themselves with these technologies to remain abreast of the latest advancements and sustain competitiveness in the job market.

AI proves instrumental in optimizing manufacturing processes, predictive maintenance, and operations management within electromechanical industries. It plays a pivotal role in proactively identifying potential failures and breakdowns, contributing to enhanced efficiency and reduced downtime. Furthermore, AI training equips engineers with the skills to apply advanced diagnostic techniques, leading to minimized downtime and maintenance costs, thereby meeting the stringent demands of the electromechanical industry (Novatchkov & Baca, 2013).

The facilitation of communication between humans and machines is another significant advantage of AI. Engineers trained in AI can design interactive and intelligent systems, resulting in the creation of more user-friendly and efficient man-machine interfaces. AI opens new avenues for innovation in the design of electromechanical products and solutions. Engineers versed in both electromechanics, and AI can introduce inventive ideas to address complex challenges and design more intelligent systems. Hence, there is a growing demand for electromechanical engineers with AI expertise to assist these companies in maintaining competitiveness on a global scale (Humble & Mozelius, 2019).

Finally, the integration of AI into the training of electromechanical engineers imparts versatility. This ensures that engineers are adept at comprehending and contributing to projects involving mechanical, electrical, and IT components (Crawley, Malmqvist, Ostlund, Brodeur, & Edstrom, 2007).

In conclusion, integrating AI into the education of electromechanical engineers is imperative for preparing the upcoming generation to confront present and future technological challenges while maximizing the benefits of these advancements within the industrial sector. Electromechanics, despite being a field with a rich history of exploration, continues to undergo constant technological advancements (Grüner et al., 2020).

Several papers discussed the integration of AI in Engineering according to CDIO framework (Cao & Sun, 2020; Edström & Kolmos, 2014; Tsai, Wang, Peng, Huang & Tsai, 2018). While traditional training for electromechanical engineers covers fundamental aspects of electricity and mechanics, the evolving demands of the contemporary industry necessitate a broader skill set.

In recognition of this need for a more comprehensive skill set, ESPRIT Private school of Engineering and Technology has been proactive in updating its electromechanical curriculum since 2018. The curriculum overhaul specifically addresses the imperative of integrating artificial intelligence (AI) into the skill repertoire of electromechanical engineers.

This novel module is distinctive in its approach, considering prerequisites in essential areas such as basic mathematics, numerical analysis, probability, and statistics, as well as algorithmics and computer science. Moreover, the module is strategically structured over a three-year duration, aligning with the CDIO (Conceive, Design, Implement, Operate) reference framework.

The CDIO framework, an educational approach emphasizing Conceive-Design-Implement-Operate, serves as the guiding principle for the development of the Artificial Intelligence module at ESPRIT. This approach entails a strategic three-year plan that aligns with the CDIO framework, facilitating a gradual and systematic integration of AI-related knowledge and skills throughout the curriculum.

This strategic update aims to equip electromechanical engineers not only with traditional mechanical and electrical skills but also with the cutting-edge proficiency in artificial intelligence. By incorporating AI into the curriculum, ESPRIT aims to produce operational electromechanical engineers who can effectively address the evolving needs of industry and contribute to technological innovation in the field.

The AI module spans three years, with each year's students engaging in a module encompassing 21 hours of instruction. The schedule unfolds as follows:

During the third year of the electromechanical engineer training program, the initial module titled ”Introduction of Artificial Intelligence” is scheduled. This module aims to empower students to design and explore the fundamental concepts of AI.

In the fourth year of the electromechanical engineer training program, the subsequent module, labelled ”Machine Learning 1”, is incorporated. The primary objective of this module is to solidify AI knowledge and introduce new insights into machine learning. Throughout the course, students apply this knowledge to address challenges within the electromechanical domain.

Advancing to the fifth year of electromechanical engineer training, the third module, named ”Machine Learning 2”, is outlined. In this module, students deepen their understanding of AI and leverage this expertise to tackle real-world problems. Successful completion of this module results in the attainment of an AI certificate.

The paper will be organized as follows, we will explain why we have planned the AI over three years, then the methodology used according to the CDIO referential, then we will detail each module by explaining the objectives, pedagogy adopted, evaluation, etc.

METHODOLOGY AND JUSTIFICATION

Artificial intelligence is the overarching system. Machine learning is a subset of AI. Deep learning is a subfield of machine learning, and neural networks make up the backbone of deep learning algorithms. It’s the number of node layers, or depth, of neural networks that distinguishes a single neural network from a deep learning algorithm, which must have more than three.

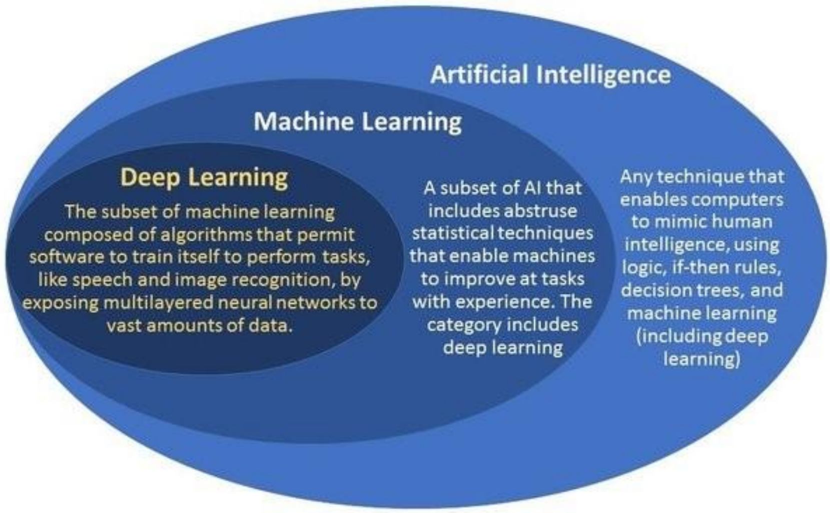

Figure 1. 3 faces of artificial intelligence: IA VS ML VS DL

The depicted Figure 1 illustrates these incorporations. Drawing inspiration from this representation, we conceived a strategy to integrate three artificial intelligence modules into the electromechanical curriculum, commencing from the third year onward. The primary objective of the initial module is to lay the groundwork for the AI domain and delve into the machine learning subdomain. In the subsequent module, the emphasis shifts to the machine learning subdomain, specifically on its creation and implementation. Upon completion of this module, students are expected to execute a mini machine learning project, showcasing a well-defined pipeline. The third module homes in on the deep learning subdomain of machine learning, where all acquired knowledge is put into practice. A workshop, resulting in a certificate, serves as the culmination of this module.

For a comprehensive overview of the final planning of these three modules and their alignment with the CDIO framework, please refer to the detailed Figure 2 provided below.

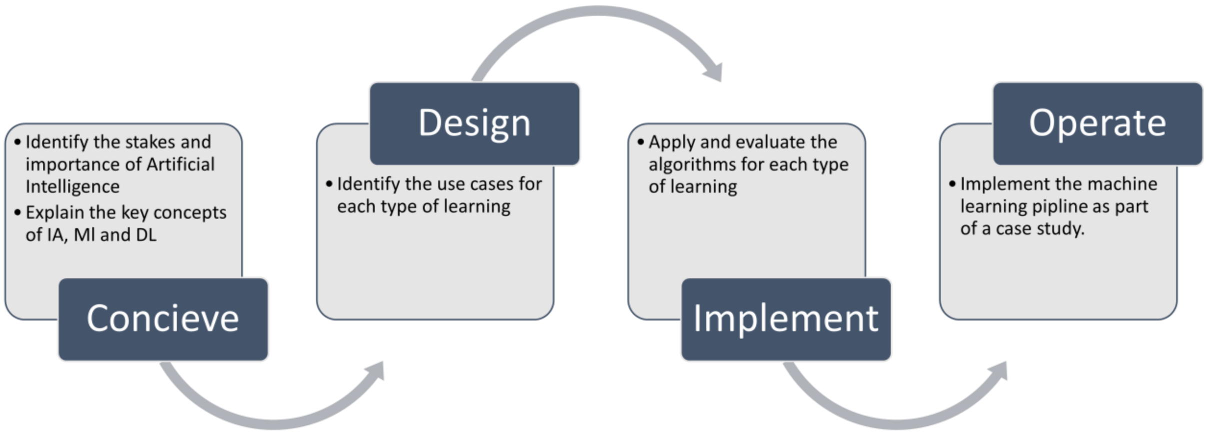

Figure 2. Learning outcomes and CDIO framework

CDIO APPROACH IN INCORPORATION OF ARTIFICIAL INTELLIGENCE (AI) FOR ELECTROMECHANICAL ENGINEERS

The integration of AI unfolds in three distinct phases, each spanning a year and implemented through the design of a dedicated module.

Introduction of artificial intelligence (AI)

In the third year of the electromechanical engineering course, the inaugural module focusing on artificial intelligence is scheduled. This module spans a duration of 7 weeks, carrying a credit value of 2 ECT. It signifies the initiation of the AI design phase for electromechanical engineering students. Throughout this module, students delve into the fundamental concepts of AI through a combination of theoretical lectures. Their comprehension of these concepts is evaluated through a multiple-choice questionnaire (MCQ). Subsequently, students apply their acquired knowledge by leveraging digital tools, notably utilizing the Python programming language and AI libraries to implement practical aspects of AI (see Figure 4).

Figure 3. AI libraries and tools

Next, the student focuses on solving supervised and unsupervised learning problems using ready-to-use databases. This phase is approached through practical work guided by theoretical notions. Assessment for this module consists of a continuous assessment grade, representing 40% of the final grade, and an examination comprising theoretical and practical MCQs, awarding 60% of the total grade. We begin by providing the Table 1, correlating the learning objectives with the CDIO reference framework.

Table 1. Learning outcomes and CDIO framework

Learning outcomes	CDIO
Identify the stakes and importance of Artificial Intelligence	Conceive.
Explain the key concepts of AI , ML and DL	Conceive.
Distinguish between the different types of machine learning	Conceive.
Identify the use cases for each type of learning	Design.
Apply the algorithms of each type of learning	Implement.
Evaluate the performance of different learning algorithms	Implement.

A summary of this first module is given in the Table 2.

Table 2. Introduction of IA roadmap

	Course content	Duration	Report	Assessment
Week 1	Introduction to Artificial Intelligence	3 hours	No report	MCQ
Week 2	Background on the Python language	3 hours	Notebook	No assessment
Week 3	AI libraries and tools/ Pandas, Seborne	3 hours	Notebook	MCQ
Week 4	Manipulate supervised learning methods: Classification	3 hours	Notebook	No assessment
Week 5	Manipulate supervised learning methods: Classification	3 hours	Notebook	practical work
Week 6	Manipulate supervised learning methods: Regression	3 hours	Notebook	No assessment
Week 7	Manipulate supervised learning methods: Regression	3 hours	Notebook	practical work

Machine learning 1

In the fourth year of the electromechanical engineering course, the second module entitled "Machine Learning 1" is scheduled. This module extends over a period of 7 weeks, with a value of 2 ECT credits. It represents the creation and realization phase. The module begins with a reminder of artificial intelligence (AI) and an update of information, presented through lectures and practical work. This part is validated by questions and MCQs. The main objective of this module is to master the pipeline of a machine learning project, from data exploration to data preparation and data modelling. The examples covered come from the field of electromechanics. To validate the module, a mini project is launched during the second-class session.

This mini project involves solving a machine learning problem from A to Z. Students are divided into groups of 6 for this project, with the choice of groups left to the students. Tasks are divided between the groups, and students receive coaching at each class session. The module is validated through this project, and students must submit a final report organized according to a Data Science work methodology (project pipeline), well-commented source code (Notebooks), and an oral presentation. The Figure 4 shows the pipeline used by the students to create the mini project.

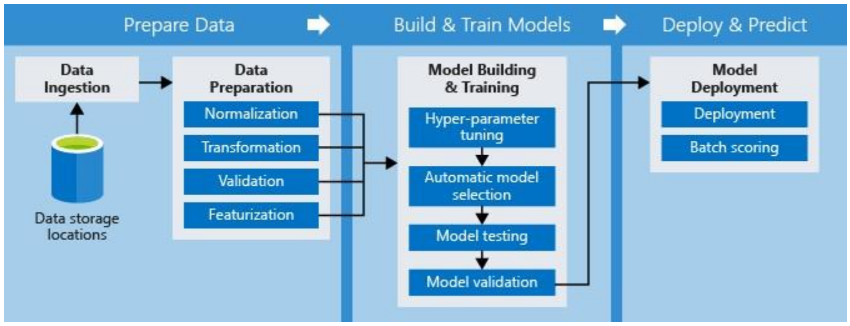

Figure 4. Pipelines for mini project

We begin by providing the Table 3, correlating the learning objectives with the CDIO reference framework.

Table 3. Learning outcomes and CDIO framework

Learning outcomes	CDIO
Identify the stakes and importance of machine learning	Conceive.
Differentiate between the main phases of a machine learning project	Conceive and Design.
Distinguish and identify the use cases for the different types of machine learning	Conceive.
Apply the algorithms of each type of learning	Design and Implement.
Interpret the performance of different learning algorithms	Implement.
Interpret the models resulting from machine learning	Implement.
Suggest improvements to the various learning models	Implement

The table 4 below summarizes the details of this module.

Table 4. Machine Learning 1 roadmap

	Course content	Duration	Report	Assessment
Week 1	Introduction to machine learning	3 hours	Presentation	oral presentation
Week 2	project pipeline and project launch	3 hours	No report	No assessment
Week 3	Ensemble learning: Bagging	3 hours	Notebook	practical work
Week 4	Ensemble learning: Bagging	3 hours	Notebook	practical work
Week 5	Unsupervised learning	3 hours	Notebook	practical work
Week 6	Neural network: Regression	3 hours	Notebook	practical work
Week 7	Project validation	3 hours	Notebook and report	oral presentation

Machine Learning 2

In the fifth year, the final stage of the electromechanical engineering education, the "Machine Learning 2" module is scheduled to last 7 weeks. The first five weeks will be dedicated to lectures consisting of a combination of theoretical sessions, tutorials and practical work. During this period, the students will consolidate their knowledge of classical machine learning, while discovering a subfield, deep learning. The pedagogy favors an active approach where the student is at the center of the learning process. The last two sessions will be combined in a single day in the form of a workshop. The aim of this workshop is to explore the use of AI in a real-life context, specifically in the field of electromechanics. Entitled "Applications of AI for Predictive Maintenance," the workshop is run by the NVIDIA DLI INSTITUTE NVIDIA (n.d.).

The Prerequisites of this workshop are:

- Experience with Python.
- Basic understanding of data processing and deep learning.

The learning Objectives of this workshop are:

- Use AI-based predictive maintenance to prevent failures and unplanned downtimes.
- Identify key challenges around detecting anomalies that can lead to costly breakdowns.
- Use time-series data to predict outcomes with XGBoost-based machine learning classification models.
- Use an LSTM-based model to predict equipment failure.
- Use anomaly detection with time-series autoencoders to predict failures when limited failure-example data is available.

The student validates the Machine Learning 2 module by obtaining a certificate and taking an MCQ exam covering both theoretical and practical aspects. The Table 5 summarizes the details of this module.

Table 5. Machine Learning 2 roadmap

	Course content	Duration	Report	Assessment
Week 1	Overview of Machine learning and introduction to deep learning	3 hours	Presentation	oral presentation
Week 2	Classification and regression using an artificial neural network	3 hours	Notebook	practical work
Week 3	Convolutional Neural Network	3 hours	Notebook	practical work
Week 4	Convolutional Neural Network	3 hours	Notebook	practical work
Week 5	Recurrent Neural Network and LSTM	3 hours	Notebook	practical work
Week 6,7 Week 7	NVIDIA DLI Workshop: Applications of AI for Predictive Maintenance	6 hours	Certificate	MCQ and practical work

ALIGNMENT WITH CDIO STANDARDS

In the electromechanical engineering curriculum at ESPRIT Private School of Engineering, the incorporation of Artificial Intelligence (AI) is aligned with the CDIO (Conceive, Design, Implement, Operate) standards (Malmqvist et al., 2019), ensuring a comprehensive and application oriented educational experience.
The Learning Outcomes (Standard 2) are specific and designed to help students acquire skills through all AI courses integrated in their curriculum.

The curriculum's alignment with Standard 3, Integrated Curriculum, begins with the third year's ”Introduction of Artificial Intelligence” module, where foundational AI concepts are introduced alongside Python AI libraries. It is exemplified in the third year's ”Introduction of Artificial Intelligence” module, where foundational AI concepts are seamlessly blended with practical Python AI libraries. This approach lays a solid groundwork for advanced learning, adhering to the CDIO initiative of integrating theoretical knowledge with practical skills.

Transitioning to Standard 5, Design-Build Experiences, the curriculum peaks in the fifth year with ”Machine Learning 2.” Here, students engage in hands-on experiences, notably through the NVIDIA DLI workshop on AI for predictive maintenance, which bridges the gap between classroom learning and real-world applications. This standard emphasizes the importance of experiential learning, enabling students to conceive and design solutions to actual engineering challenges.

Active Learning, as per Standard 8, is a cornerstone of the fourth year's ”Machine Learning 1” module. This phase of the curriculum involves an interactive and engaging learning process, highlighted by a mini project. This project allows students to implement their learning and fosters a deep understanding of AI's practical applications, crucial for future engineers.

Lastly, Standard 11, Learning Assessment, is integral to the AI module. Continuous and varied assessments, including project -based evaluations, ensure that students acquire theoretical knowledge and also develop the practical skills necessary in the electromechanical industry. This standard guarantees that the learning outcomes are in line with both academic and industry standards, thereby producing well-equipped engineers.

CONCLUSION

This paper has explored the integration of Artificial Intelligence (AI) into the electromechanical engineering curriculum at ESPRIT Private School of Engineering, highlighting a forward-thinking approach in engineering education. In an era where AI is increasingly becoming a cornerstone in various sectors, notably in electromechanical fields like automation, electricity, and maintenance, ESPRIT's initiative stands as a testament to the necessity and effectiveness of incorporating advanced technologies into educational frameworks. The ESPRIT approach in not limited to the inclusion of AI concepts into the curriculum; it represents a paradigm shift in engineering education. By aligning with the CDIO standards, particularly focusing on Standards 2, 3, 5, 8, and 11, this curriculum ensures a comprehensive educational process. From the initial stages of acquiring foundational knowledge to the advanced stages of application and mastery, the curriculum is designed to build both technical and professional competencies. The use of active learning strategies, as emphasized in Standard 8, and a structured progression in learning, as per Standard 3, are integral to this process. Moreover, the ESPRIT model's pedagogical contribution extends beyond traditional educational models. It represents an approach to designing, executing, and evaluating the AI module. This threefold methodology, spread over three years, allows students to discover AI concepts, reinforce and apply their knowledge, and achieve practical application and mastery. This approach ensures that students are well-equipped in AI theories and become proficient in applying these concepts in real-world scenarios, a crucial skill in the ever-evolving field of electromechanical engineering. In conclusion, the ESPRIT Private School of Engineering's approach in integrating AI into its electromechanical engineering curriculum can serve as an example for other institutions. It demonstrates the importance of evolving curricula to include emerging technologies and methodologies, preparing students to be adept engineers who can contribute to the complex technological landscapes of the future.

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