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Integration of Artificial Intelligence and Machine Learning in Computer and Electrical Engineering Programs

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Abstract

Artificial Intelligence (AI) is the branch of computer science dedicated to creating systems or machines that can perform tasks that typically require human intelligence. These tasks include problem-solving, reasoning, understanding natural language, recognizing patterns, learning from experience, and making decisions. AI systems aim to mimic or simulate cognitive functions such as thinking, learning, and decision-making. AI is the science of building machines or software that can think, learn, and act in ways that seem intelligent, often simulating human-like behavior.

Machine learning (ML) is the study of computer algorithms that can improve automatically through experience and by the use of data. Machine learning is a subset of Artificial Intelligence. Machine learning algorithms build a model based on sample data, known as training data, in order to make predictions or decisions without being explicitly programmed to do so. Machine learning algorithms are used in a wide variety of applications, such as in medicine, email filtering, speech recognition, and computer vision, where it is difficult to develop conventional algorithms to perform the tasks needed [1-3].

ML is an emerging area of importance for a wide range of applications. ML has become a revolutionary modern engineering tool to solve real-world engineering problems. It is essential for engineers to know how to apply machine learning algorithms to their large amount of data that is generated by the sensors. Because of the availability of computing power, more and more engineering problems have been reformulated and solved using this data-driven approach.

The field of machine learning is growing rapidly. It is essential that the emerging field of machine learning be integrated into the electrical and computer engineering curricula. This paper is a study of different approaches that are used by different institutions of higher education around the world to integrate machine learning in their electrical and computer engineering curricula.

Introduction

Artificial Intelligence (AI) refers to the creation of machines or software systems that can perform tasks that would normally require human intelligence. These tasks include reasoning, problem-solving, understanding natural language, recognizing patterns, and learning. The goal of AI is to create systems that can simulate human-like cognitive functions. AI is a broad field that encompasses various approaches, including rule-based systems, expert systems, and optimization algorithms, as well as machine learning and neural networks. Chess-playing programs, voice assistants like Siri, and self-driving cars are all AI systems [1-3].

AI is rapidly transforming industries, automating tasks, and enabling new innovations in almost every field. The integration of AI in various domains has revolutionized traditional systems, enhancing efficiency and effectiveness.

Machine Learning is a subset of AI that focuses on creating algorithms and models that enable machines to learn from data and improve over time without being explicitly programmed for every task. In ML, the system uses historical data to identify patterns and learn from examples. Over time, the system improves its performance by adjusting its internal parameters based on

new data. ML is a specific approach to AI that involves training a model on data so that it can make predictions or decisions based on that data. Spam filters, recommendation systems (like those on Netflix or Amazon), and predictive analytics are all examples of machine learning in action.

Machine learning (ML) is a powerful tool with applications in many industries and fields. Following is a list of some of the applications of machine learning: Healthcare (Disease Diagnosis, Predictive Analytics, and Personalized Treatment Drug Discovery); E-Commerce and Retail (Recommendation Systems, Price Optimization, Customer Segmentation, and Inventory Management); Autonomous Vehicles (Self-Driving Cars, Object Detection and Tracking, and Route Optimization); Manufacturing (Predictive Maintenance, Quality Control, and Supply Chain Optimization); Energy (Energy Consumption Forecasting, Smart Grids, and Renewable Energy Forecasting); Sports and Fitness (Performance Analytics, Injury Prediction and Prevention, and Fan Engagement); Education (Personalized Learning, Automated Grading, and Intelligent Tutoring Systems); and Entertainment (Content Recommendation, Content Creation, and Audience Analysis) [1-3].

Recently, machine learning has gained widespread attention and is being implemented across nearly every part of society, including data mining, automation, entertainment, healthcare, business, and engineering. This technology is driving a major shift in problem-solving, moving from traditional analytical approaches to more powerful, data-driven techniques. Through computer programs that learn from training data and predict outcomes based on new data, machine learning is revolutionizing various industries and fields. It is rapidly becoming an essential tool in modern engineering, fueled by the explosive growth in data and the increasing availability of high-performance computing resources. However, the rapid expansion of machine learning technology has created a shortage of skilled engineers capable of developing and optimizing these tools to address real-world challenges [1-3].

The field of machine learning is growing rapidly. This rapid development in ML related technological areas requires future engineers to learn and master the essential elements of these domains during their undergraduate curriculum. However, the electrical and computer engineering curricula is still catching up with the rapid growth in technology. Many institutions of higher education lack adequate laboratory facilities and expert faculty in this area. It is essential that the emerging field of machine learning be integrated into the electrical and computer engineering curricula. The following are examples of how various universities are integrating machine learning into their curricula.

Loyola Marymount University (LMU)

At LMU, to introduce ML concepts to freshman engineering students, they have combined active learning and authentic learning into an integrative learning tool to introduce machine learning to freshman engineering students. The labware that has been created is a web-supported and mobile-enabled cyber-learning tool, which allows their students to learn anywhere, anytime. Their labware is open source and open access to the public. The labware has two components: A public Google Site repository and a final project associated with website in a MATLAB based programming course (a required course for all first-year undergraduate engineering students). Their Google Site has three sections: fundamental concepts of machine learning, modules of different machine learning algorithms, and real-world applications.[4]

Arizona State University

At the Arizona State University School of Electrical, Computer, and Energy Engineering, to integrate machine learning concepts early in the engineering curricula, they have implemented a web-based machine learning simulation lab exercise in their online sophomore signals and systems I course. Their signals & systems I course is a 3-credit hour required course for sophomore electrical engineering students. They have introduced fundamentals of ML techniques (supervised learning, classification, regression) alongside core signal processing concepts in that course. They linked ML to signal processing methods like feature extraction, filtering, and system identification, enabling students to apply ML models for signal classification and prediction. The authors emphasized using real-world data sets and projects that integrate both signal processing and ML techniques to reinforce learning. Their students responded positively to the integration of ML, finding it engaging and practical. Their students showed improved problem-solving skills and a deeper understanding of both signal processing and ML, enhancing their ability to analyze systems. Their approach effectively bridged traditional engineering principles with cutting-edge technology, prepared students for the evolving demands of modern engineering [5].

Central State University

Central State University is an institution with a large diverse population of undergraduate students. In 2017, they integrated deep learning as a learning topic into their CSS 4420 Software Engineering course which is a required course for their junior and senior students. They had two objectives for integrating deep learning into that course. One was to introduce deep learning to their undergraduate students as a modern topic and the second reason was to train research assistants for their research team. Students enrolled in the course had no experience with Python programming and deep learning. They had to introduce Python and deep learning. Another major challenge was their students' limited programming skill. To address this, they gave the following reference links for their students to explore [33]:

- Installing Tensorflow on Windows (windows user), by Tensorflow team [34]
- Build a TensorFlow Image Classifier in 5 Min (Mac User) [35]

About 40% of their students were able to use the references and other supplements on their own and the rest needed help from faculty. They hired those students that were able to follow the instructions on their own as research assistants for their project [33].

Northeastern University

At Northeastern University, they have introduced the concepts of machine learning in their EECE 2160 – Embedded Design: Enabling Robotics course which is designed to introduce their students to the different areas in computer engineering at their sophomore or freshman years. This course is a project-based course, and the students work on nine projects. They are using ZedBoard with MATLAB and Simulink to introduce the basic concepts of machine learning to their students. In the final project, students will simulate a mini golf course featuring a windmill and a clear pipe that functions as a path for a ping-pong ball to travel from its initial position to

the back of the windmill. This project gives their students exposure to Reinforcement Learning [36].

Models Used to Integrate AI and ML Concepts in Curricula

Table 1 provides a study of AI and ML course offerings of selected universities in the world. The course offerings of thirty-seven universities were studied. From this study universities are using six models to integrate AI and ML concepts into their computer science, computer engineering, and electrical engineering curricula:

1. Offering undergraduate courses in AI and machine learning
2. Offering graduate courses and research opportunities in machine learning and AI for their master's and Ph.D. students
3. Offering an undergraduate machine learning degree
4. Offering a master's degree in machine learning
5. Providing certificates in ML and AI
6. ML modules and projects in Undergraduate courses

Model 1 is used by several universities such as Carnegie Melon University, University of Washington, ETH Zurich, and University of Toronto. Out of thirty-seven universities studied, seventeen (46%) are offering an undergraduate course on ML or AI.

Massachusetts Institute of Technology, University of Michigan, Ann Arbor, and University of Utah utilize Model 2 by offering a graduate course on ML. Ten universities (27%) are offering one or more graduate courses on ML. Some universities offer a variety of specialized research opportunities in the field of ML and AI across disciplines such as computer science, robotics, natural language processing, and big data analytics

Model 3 is used by Carnegie Mellon University where they are offering a BS in AI and ML and University of Amsterdam offering a Bachelor of Science in Artificial Intelligence. Fifteen universities are offering a Bachelor of Science in Computer Science, Computing, or Informatics with an emphasis in AI and ML such as University of Cambridge, Technical University of Munich, and University of Sydney.

Many universities are offering graduate programs on AI and ML and using Model 4 such as Massachusetts Institute of Technology, University of Oxford, University of Toronto, and Australian National University. Out of thirty-seven universities studied, twelve (32%) are offering a master's degree in ML, or have a master's degree with focus in ML and AI through the School of Computer Science, the College of Engineering, and other interdisciplinary programs.

Seven universities are using Model 5 by offering a certificate in AI or ML such as Stanford University, University of California, Berkly, Purdue University, and Columbia University. Offering a certificate in ML and AI provides an excellent opportunity for professionals and

students to gain specialized knowledge in these cutting-edge fields. These certificates can often be earned through online or hybrid formats, giving flexibility to those who may not be able to attend full-time academic programs.

Some institutions are using Model 6 and integrating machine learning concepts and projects into their existing courses. For example, Loyola Marymount University, Beihang University, Arizona State University, Northeastern University, and Clarkson University.

University	BS Degree in ML	Undergraduate ML Course	Graduate Degree or Course in ML	ML Projects and Modules in other Courses	Comments
Carnegie Mellon University [6]	BS in AI and ML	10-601 – Introduction to ML 10-701 – Machine Learning	10-701 – Machine Learning		
Standford University [7]	Bachelor of Science in Computer Science (with a concentration in Artificial Intelligence)	CS229 - Machine Learning EE 364A - Introduction to Machine Learning EE 364B: Advanced Machine Learning	MS in CS with focus on AI and ML		Artificial Intelligence Graduate Certificate
Massachusetts Institute of Technology [8]	BS in CS and Engineering with a focus on AI and ML	EECE 6.036 - Introduction to Machine Learning	Master of Engineering in Artificial Intelligence and Machine Learning EECE 6.867 - Machine Learning		MIT's EECS department integrates ML deeply into its graduate curriculum. MIT Professional Education - Machine Learning for Big Data and Text Processing
University of California, Berkeley [9]	BS in EE and CS with a focus on AI and ML	CS189 - Introduction to Machine Learning EECS 227A - Statistical Learning			Berkeley is one of the leading institutions in machine learning research, and its graduate programs offer many opportunities to specialize in ML and AI applications in engineering Certificate in Machine Learning and Artificial Intelligence

University of Illinois Urbana-Champaign (UIUC) [10]	BS in CS with AI/ML emphasis	CS 498 - Machine Learning ECE 445 - Introduction to Machine Learning	ECE 549 - Machine Learning ECE 549 - Machine Learning		Course in Machine Learning Specialization (Coursera)
University of Washington [11]	BS in Data Science	CSE 446 - Machine Learning	CSE 546 - Machine Learning		U. Wash's Data Science program offers a machine learning concentration that covers statistical methods, algorithms, and data modeling techniques. Machine Learning Certificate Program
University of Michigan, Ann Arbor [12]	Bachelor of Science in Computer Science (with AI and Machine Learning)	EECS 445 - Introduction to Machine Learning	EECS 598 - Machine Learning		
University of Oxford [13]			MSc in Advanced Computer Science (with options in Machine Learning and Artificial Intelligence)		Oxford Artificial Intelligence Programme
University of Cambridge [14]	Bachelor of Science in Computer Science (with a focus on AI and Machine Learning)		Master of Philosophy (MPhil) in Machine Learning and Machine Intelligence		
Imperial College London [15]	Bachelor of Science in Computing (with a focus on Artificial Intelligence and Machine Learning)		MSc in Computing (Artificial Intelligence and Machine Learning)		
ETH Zurich (Switzerland) [16]	Bachelor of Science in Computer Science (with a focus on Artificial Intelligence)	151-0001-00L - Introduction to Machine Learning	Master of Science in Computer Science (with specializations in Machine Learning and AI)		
Technical University of Munich (Germany)[17]	Bachelor of Science in Informatics (with a focus on Machine Learning and AI)		Master's in informatics (with a focus on Machine Learning and Artificial Intelligence)		
University of Amsterdam (Netherlands) [18]	Bachelor of Science in Artificial Intelligence		MSc in Artificial Intelligence		
University of Toronto [19]	Bachelor of Science in Computer Science (with a focus on Artificial Intelligence and Machine Learning)	ECE 443 - Machine Learning for Engineers	Master of Science in Applied Computing (with a focus on Machine Learning ECE 589 - Machine Learning for Engineers		

McGill University [20]	Bachelor of Science in Computer Science (with a focus on Artificial Intelligence)		Master of Science in Computer Science (with a focus on Artificial Intelligence and Machine Learning)		
Australian National University (ANU) [21]	Bachelor of Advanced Computing (with specialization in Machine Learning and AI)		Master of Machine Learning and Computer Vision		
University of Melbourne [22]	Bachelor of Science (with a major in Computing and Machine Learning)		Master of Data Science (with focus on Machine Learning)		
University of Sydney [23]	Bachelor of Information Technology (with specializations in Machine Learning and AI)				
Harvard University [24]		CS181 - Machine Learning			
California Institute of Technology (Caltech) [25]		CMS/EE 118 - Introduction to Machine Learning			
University of California, San Diego (UCSD) [26]		CSE 255 - Machine Learning			
Princeton University [27]		COS 402 - Machine Learning			
Utah Valley University [28]		ECE 4850 – Machine Learning			
University of Utah [29]			CS 5710 – Machine Learning CS 6770 – Deep Learning CS 6760 – Reinforcement Learning		AI Lab and Institute for Artificial Intelligence
University of Oklahoma [30]		CS 4533: Artificial Intelligence CS 4573: Machine Learning	CS 5513: Advanced Machine Learning CS 5763: Deep Learning CS 5773: Reinforcement Learning		AI and Machine Learning Research Group Robotics and Intelligent System Lab Natural Language Processing Lab Computational Biology and Bioinformatics Research
Purdue University [31]			ECE 50024 – Machine Learning		Data Science and Artificial Intelligence Certificate
Columbia University [32]			Neural Networks and Deep Learning		Machine Learning for Data Science and

					Analytics Certificate
University of Toronto [33]					Artificial Intelligence (AI) Certificate Program
University of Michigan [34]		ECE 4850 – Machine Learning Elective Course			Artificial Intelligence and Machine Learning Specialization (Coursera)
Georgia Institute of Technology [35]					Machine Learning Certificate
Loyola Marymount University [4]				Projects in Several Courses	
Arizona State University [5]				ML Projects in Signals and Systems Course	
Northeastern University [39]				ML Projects in EECE 2160 – Embedded Design: Enabling Robotics	
Xiamen University [40]		Undergraduate ML Course			
Beihang University [41]				ML Concepts in Data Structure Course	
Clarkson University [42]				ML Concepts and Projects in Signals and Systems Course	
Anderson University [43]		ENGR 370 – Machine Learning for Engineers			

Table 1: A Survey of Selected Universities with Regards to AI and ML Offerings

Summary and Concluding Remarks

Artificial intelligence and machine learning has attracted tremendous attention and has many applications in every sector of our society. AI and machine learning is becoming increasingly more important in society today and in the future, especially due to the growing possibilities of gathering data and the need for intelligence systems. AI and ML deal with nature-inspired computational methodologies and approaches to solve complex problems for real world challenges to which traditional approaches are ineffective or infeasible.

Machine learning technology is enabling a paradigm shift in problem-solving from analytical to data-driven approach. Even though interest in ML has been increasing amongst engineers in recent years, institutions that offer courses dedicated to the topic are still in minority. The courses that are offered in this area are mostly designed and taught at the graduate level.

The integration of machine learning concepts into undergraduate engineering curricula has been gradually adopted by universities worldwide. While undergraduate electrical and computer

engineering students can often take ML courses which are offered by computer science or data science programs as electives, these courses present significant challenges to the ECE students. One major difficulty is the extensive theoretical foundation required for ML, including advanced mathematics, linear algebra, statistics, and probability, which students typically do not complete until the later stages of their academic programs. Another difficulty is that ML courses demand high levels of computing and programming proficiency, skills that are not often emphasized in traditional electrical engineering programs. Additionally, for engineering students, it is more relevant to learn machine learning as a modern engineering tool rather than focusing on computing and mathematical theories to solve real-world engineering problems.

When should ML-AI concepts, tools and technology platforms be introduced into engineering curricula? Some scientists believe that it should be introduced as early as possible, which is the approach taken by Loyola Marymount University [1]. Some believe that it should be offered as a senior level required course. The second option might be harder to implement, since adding a new course to the curriculum is not an easy task, as often eliminating another course would be necessary. Offering it as an elective course is also not ideal, as not all students would have the opportunity to benefit from the experience. It seems that adding the concepts slowly as modules and projects to existing courses is a good solution for integration of the ML concepts into the electrical and computer engineering curricula, which is the approach taken by Arizona State University [2].

We hope this work sparks further discussion on the importance of providing electrical and computer engineering students with education in the fields of machine learning and artificial intelligence.

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