COMSATS University Islamabad

Registrar Secretariat, Academic Unit (PS)

No: CUI-Reg/Notif-2380 /24/2469 October 10, 2024

NOTIFICATION

Academic Council in its 39th meeting held on August 01, 2024, on the recommendations of the 35th meeting of the Board of Advance Studies and Research (BASAR) held on June 26, 2024, approved the Scheme of Studies of Master of Science in Artificial Intelligence Engineering, effective from spring 2025.

Nomenclature of the Program: Master of Science in Artificial Intelligence Engineering

1. **MS WITH THESIS OPTION**

1(a). Duration:

1.1 Minimum Duration: 02 Years
1.2 Minimum No. of Semesters: 04
1.3 Maximum Duration: 04 Years
1.4 Maximum No. of Semesters: 08

1(b). No. of Courses and Credit Hours in MS with Thesis Option:

Sr. #	Category	SAME DISCIPLINE		INTRADISCIPLINARY	
		No. of Courses	No. of Credit Hours	No. of Courses	No. of Credit Hours
1.	**Deficiency Courses of level 6**	-	-	02-03	06-09
2.	**Core Courses**	02	06	02	06
3.	**Elective Courses**	06	18	06	18
4.	**Research Thesis**	01	06	01	06
5.	**Total**	**09**	**30**	**11-12**	**36-39**
6.	**Prerequisite**	The zero semester of an MS candidate shall not count towards the maximum study duration.			

2. **MS WITH NON-THESIS OPTION IN THE SAME DISCIPLINE / RELEVANT FIELD:** By selecting the MS with Non-Thesis option, a same/relevant discipline student can graduate by passing, in lieu of MS thesis, 02 additional elective courses and submitting a Non-Credit (NC) MS Project/Report. In such case, the course work consists of 11 courses (02 core courses, 08 electives, and 01 NC Project Report) accumulating in total 30 Credit Hours of course work.
3. **MS WITH NON-THESIS OPTION IN THE INTRADISCIPLINARY FIELD:** By selecting the MS with Non-Thesis option, an intradisciplinary student can graduate by passing 02-03 deficiency courses in the zero semester and then passing in subsequent semesters, in lieu of MS thesis, 02 additional elective courses and submitting a Non-Credit (NC) MS Project/Report. In such case, the course work consists of 13-14 courses (02-03 deficiency courses, 02 core courses, 08 electives, and 01 NC Project Report) accumulating in total 36-39 Credit Hours of course work.

This supersedes notification No: CUI-Reg/Notif-1938/24/2007 dated August 23, 2024 and issued as per the decision of 35th meeting of the Board of Faculty of Engineering held on October 10, 2024.

Dr. Muhammad Hanif (Ph.D)
Deputy Registrar

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List of Core Courses:

Sr. #	Course Code	Course Title	Credit Hours
1.	EEE610	Engineering Mathematics	3(3, 0)
2.	AIE713	Machine Learning for Engineering Design	3(3, 0)

List of Elective Courses:

Sr. #	Course Code	Course Title	Credit Hours
1.	AIC601	Statistical Learning Theory	3(3, 0)
2.	DSC606	Deep Learning	3(3, 0)
3.	AIC613	Advanced Machine Learning	3(3, 0)
4.	EEE615	Probabilistic Learning: Theory and Algorithms	3(3, 0)
5.	EEE616	Optimization Theory	3(3, 0)
6.	EEE621	Modeling and Simulation	3(3, 0)
7.	EEE632	Research Methods	3(3, 0)
8.	AIC651	Multi-Agent Systems	3(3, 0)
9.	AIC654	Advanced Pattern Recognition	3(3, 0)
10.	AIC655	Reinforcement Learning	3(3, 0)
11.	AIC662	Evolutionary Computing	3(3, 0)
12.	ECI663	Robotics	3(3, 0)
13.	AIC665	Ethical issues in Artificial Intelligence	3(3, 0)
14.	ECI670	Neural and Fuzzy Systems	3(3, 0)
15.	EEE690	Industrial Project-I	3(3, 0)
16.	AIE703	Principles of Programming for Artificial Intelligence	3(3, 0)
17.	AIE714	Hardware Arithmetic for Machine Learning	3(3, 0)

18.	AIE715	Intelligent Mechatronics Systems	3(3, 0)
19.	AIE716	Artificial Intelligence for Digital Design	3(3, 0)
20.	AIE718	Intelligent Manufacturing and Industry 4.0	3(3, 0)
21.	AIE719	FPGA design for Machine Learning Techniques	3(3, 0)
22.	EEE720	Modern Data Analysis Methods	3(3, 0)
23.	AIE721	Cyber-Physical Systems	3(3, 0)
24.	AIE722	Neuromorphic Computing	3(3, 0)
25.	AIE729	Time Series Analysis	3(3, 0)
26.	AIE731	Artificial Intelligence in Water Resources and Hydrology	3(3, 0)
27.	AIE732	Artificial Intelligence for Materials Quality Control & Monitoring	3(3, 0)
28.	AIE734	Intelligent Fault Diagnosis and Prognosis	3(3, 0)
29.	AIE735	Artificial Intelligence Applications in Healthcare	3(3, 0)
30.	AIE736	Artificial Intelligence-based Design and Manufacturing of Mechanical Systems	3(3, 0)
31.	AIE737	Applied Machine Learning for Mechanical Engineers	3(3, 0)
32.	AIE738	Intelligent Crypto Systems	3(3, 0)
33.	AIE739	Human-Robot Interaction	3(3, 0)
34.	ECI743	Computer Vision	3(3, 0)
35.	AIE746	Distributed Machine Learning	3(3, 0)
36.	AIE747	Artificial Intelligence in Smart Grids	3(3, 0)
37.	AIE749	Applied Estimation, Detection and Prediction	3(3, 0)
38.	AIE750	Autonomous Systems	3(3, 0)
39.	AIE757	Random Processes	3(3, 0)
40.	ECI761	Intelligent Control Systems	3(3, 0)
41.	AIE762	Artificial Intelligence and Renewable Energy	3(3, 0)

42.	AIE764	Intelligent Power Transmission and Distribution Systems	3(3, 0)
43.	AIE766	Path Planning and Motion Control	3(3, 0)
44.	ECI770	Intelligent Systems	3(3, 0)
45.	ETN789	Internet of Things (IoT)	3(3, 0)
46.	AIE782	Explainable Artificial Intelligence	3(3, 0)
47.	AIE784	Advanced Topics in AI Engineering I	3(3, 0)
48.	AIE785	Advanced Topics in AI Engineering II	3(3, 0)

MS with Thesis Option:

Sr. #	Course Code	Course Title	Credit Hours
1.	AIE800	MS Thesis	6(0, 6)

MS with Non-Thesis Option:

Sr. #	Course Code	Course Title	Credit Hours
1.	AIE600	MS Project/Report*	3(0, 3)

* For students choosing the MS with Non-Thesis option, the MS Project Report is a Non-Credit mandatory requirement for degree completion.

Tentative Semester Plan:

Semester	Course Title	Credit Hours
1st Semester	Machine Learning for Engineering Design	3(3, 0)
	Modeling and Simulation	3(3, 0)
	Elective-I	3(3, 0)
2nd Semester	Elective-II	3(3, 0)
	Elective-III	3(3, 0)
	Elective-IV	3(3, 0)
3rd Semester	Elective-V	3(3, 0)
	Elective-VI	3(3, 0)
	MS Thesis	6(0, 6)
4th Semester	MS Thesis (Continued)	6(0, 6)

COURSE CONTENTS

Course Code: AIE703
Course Title: Principles of Programming for Artificial Intelligence
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course provides an in-depth exploration of programming principles and techniques relevant to artificial intelligence (AI) applications. Students will learn foundational programming concepts, data structures, algorithms, and best practices essential for developing AI systems. The course will cover state of art programming paradigms commonly used in AI, with an emphasis on practical implementation and real-world applications.

Course Description:

Introduction to AI Programming, data types and structures, functional programming such as lambda techniques, recursion and iteration, symbols and symbol manipulation, macros. Modern Programming for AI: data structures for AI, algorithms for AI including searching and sorting, graphs, optimization, object-oriented Programming concepts including classes and objects, inheritance and polymorphism, encapsulation and abstraction, functional programming for AI, concurrency and parallelism in AI, threading and multiprocessing, synchronization and communication between threads, testing and debugging AI programs, Integration with AI libraries and frameworks.

Recommended Books:

1. Xiao, Perry. Artificial intelligence programming with Python: from zero to hero. John Wiley & Sons, 2022.
2. Charniak, Eugene, Christopher K. Riesbeck, Drew V. McDermott, and James R. Meehan. Artificial intelligence programming. Psychology Press, 2014.
3. Raschka, Sebastian. Python Machine Learning. United Kingdom: Packt Publishing, 2015.

Course Code: AIE713
Course Title: Machine Learning for Engineering Design
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course is designed to give students exposure to the basic concepts used in machine learning, neural networks and Artificial Intelligence aiming to apply these tools across diverse engineering landscapes. This beginner course will teach you the fundamentals of machine learning and how to use these techniques to build real-world Artificial Intelligence applications and solving complex engineering problems. The course focuses on algorithms and models that can learn from data, identify patterns and relationships in the data and make decisions on these patterns.

Course Description:

In this course we will start with fundamental concepts of machine learning such as classification, regression, supervised and unsupervised machine learning approaches and then move to e.g. regression, Bayesian classification, multilayer perceptron and basic concepts of neural networks. The steps involved in a machine learning process like data collection, data pre-processing, feature selection, model selection, model training and evaluation. This course will also cover topics such as clustering, principal component analysis, support vector machines and introduction to deep learning and reinforcement learning techniques, dimensionality reduction, neural networks. In this course, students will delve into the applications of Artificial Intelligence and Machine Learning in engineering design, focusing on the creation of new products and addressing engineering design challenges.

Recommended Books:

1. Ryan G. McClarren. Machine Learning for Engineers: Using Data to Solve Problems for Physical Systems. Springer., 2021.
2. Shalev-Shwartz, Shai, and Shai Ben-David. Understanding machine learning: From theory to algorithms. Cambridge university press, 2014.

Course Code: AIE714
Course Title: Hardware Arithmetic for Machine Learning
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course focuses on the hardware implementations of arithmetic operations tailored specifically for machine learning applications. It explores the fundamental principles of arithmetic algorithms and their efficient realization in hardware architectures to support various machine learning tasks. Students will gain hands-on experience with designing, analyzing, and optimizing arithmetic units for accelerating machine learning computations. For each circuit introduced, we will develop techniques and present theory for evaluating their functionality and speed. Other methods will be described for analyzing a circuit's power consumption, testability, silicon area requirements, correctness, and cost. In addition, we will utilize various CAD tools to evaluate the circuits described. Finally, advanced timing and clocking concepts will be investigated. For example, the notion of clock skew will be introduced and its impact on clock period for sequential circuits will be analyzed.

Course Description:

Number systems and digital arithmetic, basic arithmetic circuits, complex adders (carry-look-ahead, carry-skip, carry-bypass, etc.), multipliers, dividers, and floating-point units, analyzing circuit's power consumption, testability, silicon area requirements, correctness, and cost, CAD tools to evaluate the circuits, timing and clocking, asynchronous circuits, arithmetic aspects of various machine learning algorithms (K-nearest neighbors, neural networks, decision trees, and support vector machines), Co-Design, Data Orchestration, Sparsity.

Recommended Books:

1. Cavanagh, Joseph. Computer Arithmetic and Verilog HDL Fundamentals. United States: CRC Press, 2017.
2. Deschamps, Jean-Pierre. Hardware Implementation of Finite-Field Arithmetic. United Kingdom: McGraw Hill LLC, 2009.

Course Code: AIE715
Course Title: Intelligent Mechatronics Systems
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course explores the integration of artificial intelligence (AI) techniques with mechatronics systems, combining principles from mechanical engineering, electrical engineering, and computer science. Students will learn how to design, develop, and optimize intelligent mechatronics systems that can perceive, reason, and act autonomously in real-world environments. The course will cover topics such as sensor integration, control algorithms, machine learning, and robotics.

Course Description:

Introduction to intelligent mechatronics, Bond graph modeling, modeling of actuators, sensors and electronic circuits, MEMS, sensor integration and data fusion, control systems for intelligent mechatronics: model-based and model-free control algorithms, adaptive and learning control methods for dynamic environments, machine learning for mechatronics: overview of machine learning techniques, training and deployment of machine learning models in embedded systems, computer vision and perception: depth sensing and 3D perception using stereo vision, integration of computer vision algorithms with mechatronics systems, neural networks and fuzzy systems, robotics and autonomous systems: autonomous navigation and path planning, robotic manipulators, human-robot interaction, modeling and control of space robots, vehicle mechatronic systems, intelligent transport systems, model-based fault diagnosis and fault-tolerant control and manufacturing technology.

Recommended Books:

1. Bradley, David Allan, Derek Seward, David Dawson, and Stuart Burge. Mechatronics and the design of intelligent machines and systems. CRC Press, 2018.
2. Merzouki, Rochdi., Samantaray, A. Kumar., Pathak, Pushparaj Mani., Ould, Bouamama B. Intelligent Mechatronic Systems: Modeling, Control and Diagnosis. United Kingdom: Springer London, 2012.
3. Braga, Newton C. Robotics, Mechatronics, and Artificial Intelligence: Experimental circuit blocks for designers. Newnes, 2002.

Course Code: AIE716
Course Title: Artificial intelligence for Digital Design
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course is intended to familiarize the students with the role of AI in manufacturing digital systems, especially in the context of improving efficiency and quality of manufacturing processes.

Course Description:

The course will include basics of digital design and manufacturing, basics of CAD, introduction to AI and machine learning, optimization, design for manufacturability and sustainability, AI-enabled process scheduling, quality control and defect detection, predictive maintenance, introduction to digital twin and its application in manufacturing, computer vision and NLP in industries, role of IoT in manufacturing, smart manufacturing 4.0, reinforcement learning in manufacturing, and emerging trends.

Recommended Books:

1. H. Ren, J. Hu. Machine Learning Applications in Electronic Design Automation. Switzerland: Springer International Publishing, 2022.
2. Moons, Bert., Bankman, Daniel., Verhelst, Marian. Embedded Deep Learning: Algorithms, Architectures and Circuits for Always-on Neural Network Processing. Germany: Springer International Publishing, 2019.

Course Code: AIE718
Course Title: Intelligent Manufacturing and Industry 4.0
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

The course addresses on one hand the current state of the art in smart automation and on the other hand provides an outlook on new technologies, businesses and opportunities arising out of digitalization, use of smart devices and in conclusion in Industry 4.0. The concerted objective of the lectures is the basic knowledge for smart automation and Industry 4.0 within production. The trend towards industrial automation and Industry 4.0 will change production significantly in the future. Therefore, it is imperative to understand basic principles of automation and Industry 4.0 to meet the challenges facing production in the future.

Course Description:

Introduction to automated production systems, sensors, controls and drive technology, handling systems and industrial robots, advanced automation in smart manufacturing, fundamentals of industrial internet of things, data analytics basics, artificial intelligence (AI) and machine learning (ML) in smart manufacturing systems, automated quality control, manufacturing and assembly technology, multi machine systems design and planning of automated production facilities, use cases: Industry 4.0 in industry

Recommended Books:

1. Molina A, Ponce P, Miranda J, Cortés D,. Enabling Systems for Intelligent Manufacturing in Industry 4.0. Springer: Berlin/Heidelberg, Germany; 2021.
2. Kandasamy J, Muduli K, Kommula VP, Meena PL,. Smart manufacturing technologies for industry 4.0: integration, benefits, and operational activities. CRC Press; 2022.

Course Code: AIE719
Course Title: FPGA design for Machine Learning Techniques
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

The development of neural networks has now reached the stage where they are employed in a large variety of practical contexts. However, to date most of such implementations have been in software. While it is generally recognized that hardware implementations could, through performance advantages, greatly increase the use of neural networks. This course provides an introduction of hardware implementation of machine learning algorithms and models on FPGAs.

Course Description:

In the course 'FPGA Design for Machine Learning Techniques,' students will explore advanced concepts at the intersection of field-programmable gate arrays (FPGAs) and machine learning. Beginning with an overview of approximate and stochastic computing for machine learning, students will delve into the VLSI architecture tailored for deep neural networks, learning to optimize performance and efficiency. The course will also cover computing in/near memory techniques, enabling faster processing and reduced energy consumption. Advanced design techniques for deep neural networks will be discussed, alongside emerging paradigms such as adiabatic Ising and quantum computing. Additionally, students will explore the application of machine learning and artificial intelligence (AI) in the Internet of Things (IoT) domain, known as AIOT. VLSI architecture and circuit design for machine/deep learning will be examined, emphasizing hardware acceleration for efficient inference and training. Furthermore, the course will explore machine learning-based techniques for Electronic Design Automation (EDA), thermal modeling, analysis, and control, as well as reliability analysis and modeling, empowering students to develop innovative solutions for next-generation FPGA-based machine learning systems.

Recommended Books:

1. Anuradha D. Thakare, Sheetal Umesh Bhandari. Artificial Intelligence Applications and Reconfigurable Architectures. United Kingdom: Wiley, 2023.
2. AR Omondi. FPGA Implementations of Neural Networks. Germany: Springer US, 2006.

Course Code: AIE721
Course Title: Cyber-Physical Systems
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

The course provides an introduction to cyber-physical systems (CPSs), i.e., dynamical systems composed of logical components (driven by event occurrences) interacting with physical components (described by time-driven models). From a control system perspective CPSs are hybrid systems, combining discrete events and continuous dynamics. The course is structured into two parts. The first part presents discrete event systems and supervisory control. The second part is devoted to the modeling and analysis of hybrid systems and introduces some approaches for formal modeling and verification.

Course Description:

Classification of dynamical systems, time-driven systems, discrete-event systems, hybrid systems, automata models for discrete event systems, formal languages, supervisory control of discrete event systems, supervisory design for language specifications, supervisory design for state specifications, hybrid systems and hybrid automata, reachability analysis of hybrid systems, state transition systems

Recommended Books:

1. Taha Walid, M. Taha, Abd-Elhamid M., Thunberg Johan. Cyber-Physical Systems: A Model-Based Approach. Germany: Springer International Publishing, 2020.
2. Houbing Herbert Song, Danda B. Rawat, Sabina Jeschke, Christian Brecher. Cyber-Physical Systems: Foundations, Principles and Applications. Netherlands: Elsevier Science, 2016.

Course Code: AIE722
Course Title: Neuromorphic Computing
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This Neuromorphic Computing course aims to equip students with a comprehensive comprehension of the interdisciplinary domain that integrates ideas from neurology with hardware and software engineering. The objective of this course is to provide students with the essential knowledge and abilities to investigate the boundaries of neuromorphic computing. This will enable them to make contributions to the progress of brain-inspired computing systems. The program encompasses a wide range of subjects, spanning from fundamental principles in neurology to the creation and utilization of neuromorphic hardware and software.

Course Description:

Introduction to neuromorphic computing, its history, goals and comparison with traditional methods. Fundamentals of neuroscience, neurotransmitters, neural circuits and network dynamics. Basics of ML and ANN, learning algorithms, and limitations. Neuromorphic algorithms, and principles of neuromorphic hardware, memristor, spiking neural networks, spike-based coding, and processing. Neuromorphic programming, simulation tools, and interfaces. Ethical and societal implications, privacy, and security concerns. Research trends, and future directions. Industry and academia perspectives on the future of neuromorphic computing.

Recommended Books:

1. Elishai Ezra Tsur. Neuromorphic Engineering. CRC press, 2023
2. Yang (Cindy) Yi, Hongyu An. Neuromorphic Computing. IntechOpen, 2023.

Course Code: AIE729
Course Title: Time Series Analysis
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

The objective of this course is to teach students with the main concepts of Time Series theory and methods of analysis. Time Series consist of values of a variable recorded in an order over a period of time. Such data arise in just about every area of science and the humanities, including econometrics and finance, engineering, medicine, genetics, sociology, environmental science. This course provides an introduction to time series analysis using current methodology and software.

Course Description:

In this course students will explore foundational concepts and advanced techniques for analyzing and predicting time series data. Beginning with an examination of stochastic processes and their main characteristics, students will learn about autoregressive-moving average models (ARMA) and the Box-Jenkins approach for coefficient estimation in ARMA processes. The course will cover forecasting methodologies within the framework of the Box-Jenkins model, as well as the challenges posed by non-stationary time series and the unit root problem. Students will delve into regressive dynamic models, vector autoregression models, and co-integration, exploring their applications in analyzing multivariate time series data. Additionally, the course will address causality in time series and covers machine learning-based approaches for time series forecasting, enabling students to leverage advanced computational techniques for accurate and efficient prediction tasks.

Recommended Books:

1. Montgomery, Douglas C.., Jennings, Cheryl L.., Kulahci, Murat. Introduction to Time Series Analysis and Forecasting. Germany: Wiley, 2011.
2. Gridin, Ivan. Time Series Forecasting Using Deep Learning: Combining Pytorch, RNN, TCN, and Deep Neural Network Models to Provide Production-ready Prediction Solutions. India: BPB Publications, 2021.

Course Code: AIE731
Course Title: Artificial Intelligence in Water Resources and Hydrology
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course explores the application of Artificial Intelligence (AI) techniques in the field of water resources and hydrology. Students will learn how AI methods can be used to model, analyze, and manage water-related processes, from flood prediction to groundwater management. The course will equip students with the skills to address complex water resource challenges using advanced AI tools and approaches.

Course Description:

In the "AI in Water Resources and Hydrology" course, students will explore the integration of Artificial Intelligence (AI) in the management of water resources, addressing crucial challenges in this field. The course begins with an introduction to the pivotal role of AI in water resource management and sets the stage for a comprehensive exploration of key topics. Students will delve into data collection and preprocessing, then proceed to apply AI models for hydrological forecasting, groundwater management, water quality analysis, and optimization of water resource systems. The course also examines the impact of climate change on water resources and introduces ethical considerations in the use of AI in this context. The capstone project allows students to apply their knowledge, and discussions on future prospects and trends provide insights into the evolving landscape of AI in water resources and hydrology, equipping students with the skills to address complex water-related challenges.

Recommended Books:

1. Govindaraju RS, Rao AR,. Artificial neural networks in hydrology. Springer Science & Business Media; 2013.
2. Hsieh WW. Machine learning methods in the environmental sciences: Neural networks and kernels. Cambridge university press; 2009.

Course Code: AIE732
Course Title: Artificial Intelligence for Quality Control & Monitoring
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course includes teaching modern methods of artificial intelligence and machine learning applied to problems in industrial manufacturing. There, is an introduction to monitoring manufacturing processes and the quality control chain. The specific focus is on machining operations and subsequent quality control. The idea of predictive quality control will be explained and presented in the industrial example. Students will learn the recent innovations in metrology processes using AI for improvement the overall process productivity.

Course Description:

Machining operations, data transformation, predictive quality control and AI in industrial metrology, harnessing AI for enhanced productivity, AI system architecture and design principles, AI quality model: safety, security, legal compliance, ethics, and performance, Application of AI quality frameworks in daily operations, Supply Chain Management, Root Cause Analysis, Machine Vision

Recommended Books:

1. Pengzhong Li, Paulo Pereira, Helena Navas. Quality Control: Intelligent Manufacturing, Robust Design and Charts. United Kingdom: IntechOpen, 2021.
2. Pham, Duc T., Oztemel, Ercan. Intelligent Quality Systems. Switzerland: Springer London, 2012.

Course Code: AIE734
Course Title: Intelligent Fault Diagnosis and Prognosis
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

The area of intelligent maintenance and diagnostic and prognostic–enabled CBM of machinery is a vital one for today's complex systems in industry, aerospace vehicles, military and merchant ships, the automotive industry, and elsewhere. The industrial and military communities are concerned about critical system and component reliability and availability. The objective of this course is to acquire knowledge and apply methods on intelligent fault diagnosis and prognosis for engineering systems. During the course discuss historical perspective, system requirements, design and functional layers of fault diagnostic and prognostic systems, in addition of recognize the system approach to CBM/PHM that includes trade studies, FMECA, system CBM test-plan design, performance assessment, impact on maintenance and operations and control and contingency management. At the end, apply fault diagnosis procedures and methods as well as fault prognosis performance metrics.

Course Description:

In this course students will embark on a comprehensive journey through the theoretical foundations and practical applications of diagnostic and prognostic systems. Beginning with a historical perspective and an exploration of diagnostic and prognostic system requirements, students will delve into the intricacies of designing fault diagnostic and prognostic systems, including the functional layers involved. The curriculum covers Failure Modes and Effects Criticality Analysis (FMECA), as well as the design and assessment of System CBM Test Plans. Through case studies, students will examine the impact of CBM/PHM on maintenance and operations, including its role in control and contingency management. The course also delves into sensor strategies, signal processing techniques, and database management systems tailored for CBM/PHM applications. Students will explore various fault diagnostic methods, including data-driven and model-based approaches, alongside prognosis techniques such as physical model-based and data-driven prediction methods. Emphasis is placed on performance metrics for fault diagnosis and prognosis, as well as the logistical aspects of supporting systems in operation.

Recommended Books:

1. Hamid Reza Karimi, Fault Diagnosis and Prognosis Techniques for Complex Engineering Systems. United Kingdom: Elsevier Science, 2021.
2. Vachtsevanos, George J. Intelligent Fault Diagnosis and Prognosis for Engineering Systems. United Kingdom: Wiley, 2006.

Course Code: AIE735
Course Title: Artificial Intelligence Applications in Healthcare
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course explores the intersection of artificial intelligence (AI) and the healthcare industry, focusing on the applications, challenges, and ethical considerations of using AI to enhance medical practices, improve patient care, and streamline healthcare operations. Students will gain a deep understanding of medical data, AI algorithms, and their real-world deployment in areas such as medical image analysis, clinical decision support, natural language processing, and telemedicine. Additionally, the course will address the critical issues of ethics, privacy, and regulatory compliance in the context of healthcare AI.

Course Description:

This course provides a comprehensive exploration of the integration of artificial intelligence (AI) in healthcare. It begins with an introduction to the significance and applications of AI in medicine and healthcare. The course then delves into the complexities of medical data, the role of machine learning in healthcare, the use of natural language processing (NLP) for healthcare text analysis, and the application of AI in medical image analysis. Students also explore clinical decision support systems (CDSS) and the ethical and regulatory considerations within healthcare AI. The course further examines telemedicine, healthcare robotics, and emerging technologies such as genomic medicine and wearable devices. Throughout, students gain a comprehensive understanding of how AI is transforming the healthcare landscape, from diagnostics to patient care, and are encouraged to share their insights on these exciting developments.

Recommended Books:

1. Davenport T., Glaser, John Patrick., Gardner, Elizabeth. Advanced Introduction to Artificial Intelligence in Healthcare. United Kingdom: Edward Elgar Publishing, 2022.
2. Panesar A. Machine learning and AI for healthcare. Coventry, UK: Apress; 2019.

Course Code: AIE736
Course Title: Artificial Intelligence based Design and Manufacturing of Mechanical Systems
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course provides an introduction to developing end-to-end AI-based design and manufacturing workflows. In this course students will explore how AI methods are advancing digital manufacturing and the entire design ecosystem. Also, students will learn how AI methods can be used in a manufacturing workflow for process optimization and control.

Course Description:

In this course students will focus on cutting-edge methodologies and technologies shaping modern design and manufacturing workflows. Beginning with an overview of computational design and manufacturing workflows, students will delve into digital design representations, including parametric modeling and procedural modeling techniques. The curriculum covers geometric deformation methods and provides an overview of advanced manufacturing processes, emphasizing the transition from geometry to hardware abstraction languages. Through simulation, students will learn to predict design performance and bridge the gap between simulation and reality. The course explores inverse methods and performance-driven design, introducing optimization techniques and topology optimization. Additionally, students will be introduced to AI and machine learning, exploring symbolic AI methods and machine learning methods tailored for computational design. Advanced AI tools such as deep neural networks and convolutional neural networks will be covered, along with their applications in representing design spaces, evaluating performance, and inverse design. The course concludes with a focus on intelligent manufacturing systems and advanced AI tools for manufacturing process optimization, including Bayesian optimization methods.

Recommended Books:

1. Christopher Tong, Duvvuru Sriram. Artificial Intelligence in Engineering Design: Volume III: Knowledge Acquisition, Commercial Systems, And Integrated Environments. United States: Elsevier Science, 2012.
2. Kaushik Kumar, Divya Zindani, J. Paulo Davim. Artificial Intelligence in Mechanical and Industrial Engineering. United States: CRC Press, 2021.

Course Code: AIE737
Course Title: Applied Machine Learning for Mechanical Engineers
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course covers how to apply techniques from Artificial Intelligence and Machine Learning to solve mechanical engineering problems and design new products or systems. It covers machine learning fundamentals and focuses on case studies of mechanical systems. Through a combination of theoretical lectures, hands-on exercises, and practical projects, students will learn how to apply machine learning techniques to analyze complex mechanical systems, predict system behavior, optimize designs, and enhance decision-making processes.

Course Description:

The course "Applied Machine Learning for Mechanical Engineers" covers a comprehensive range of topics aimed at equipping students with the skills necessary to integrate machine learning techniques into mechanical engineering applications. Beginning with an introduction to machine learning concepts and their relevance in mechanical engineering, the course proceeds to explore essential data preprocessing techniques tailored for mechanical datasets. Supervised and unsupervised learning algorithms, including regression, classification, and clustering, are examined in detail alongside dimensionality reduction methods such as PCA and SVD. Time series analysis methods and optimization techniques are introduced, with a focus on their application in mechanical systems. Reinforcement learning basics are covered, followed by real-world case studies and hands-on projects in predictive maintenance, design optimization, and control system tuning. Ethical considerations surrounding the application of machine learning in mechanical engineering are also discussed. Through a combination of theoretical knowledge and practical exercises, students gain the expertise to leverage machine learning effectively in various facets of mechanical engineering, positioning them at the forefront of innovation in the field.

Recommended Books:

1. Ulrich KT, Eppinger SD, Yang MC. Product design and development. Boston: McGraw-Hill higher education; 2008.
2. Kaushik Kumar, Divya Zindani, J. Paulo Davim. Artificial Intelligence in Mechanical and Industrial Engineering. United States: CRC Press, 2021.

Course Code: AIE738
Course Title: Intelligent Crypto Systems
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

The area of cryptography focuses on various problems pertaining to secure communication and computation. It entails the study of models that express security properties as well as the algorithms and protocols that are the implementation candidates for satisfying these properties. An important dimension of modern cryptography is the design of security proofs that establish security properties using classical and modern-day advance tools like AI and machine learning. Students will learn to model security problems, design protocols, and prove them secure under precisely formulated system and computational assumptions using AI.

Course Description:

Cryptography is the formal study of the notion of security in information systems. The course will offer a thorough introduction to modern cryptography focusing on models and proofs of security for various basic cryptographic primitives and protocols including key exchange protocols, commitment schemes, digital signature algorithms, oblivious transfer protocols and public-key encryption schemes. Applications to various problems in secure computer and information systems will be briefly discussed including secure multiparty computation, digital content distribution, e-voting systems, digital payment systems, cryptocurrencies. Use of AI based tools in cryptography.

Recommended Books:

1. Ferguson, Niels, Bruce Schneier, and Tadayoshi Kohno. Cryptography engineering: design principles and practical applications. John Wiley & Sons, 2011.
2. Chio, Clarence, and David Freeman. Machine learning and security: Protecting systems with data and algorithms. " O'Reilly Media, Inc.", 2018.

Course Code: AIE739
Course Title: Human-Robot Interaction
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course will focus on the emerging field of Human-Robot Interaction (HRI). This multidisciplinary research area draws primarily from: robotics, AI, human-computer interaction, and cognitive psychology. The primary goal of HRI is to enable robots to successfully interact with humans. This course will cover a variety of topics related to social intelligence: learning, teamwork, planning, dialog, emotion, embodied intelligence, among others. For each topic, readings and lectures will cover (1) what's known about how this ability arises in human intelligence, and (2) state-of-the-art approaches to building computational systems with this type of social intelligence. The motivation for using HRI systems for an application where humans and robots can interact and cooperate is to reap the benefits of both worlds.

Course Description:

This course offers a comprehensive overview of the principles and methodologies underlying interactions between humans and robots. Beginning with an introduction to Human-Robot Interaction (HRI), students are introduced to various types of physical, cognitive, and social interactions through illustrative examples. The course delves into the architecture for social interaction, detailing each stage of interaction and incorporating non-verbal communication techniques. Key aspects of HRI systems are explored, along with different metrics used to characterize them, including human and robot metrics, interaction effort, attention demand, and collaborative metrics. Design concepts for HRI systems are discussed, covering autonomy levels, information exchange, task definition, and team structure. Additionally, the course addresses the taxonomy and design guidelines for HRI systems, as well as the role of human factors such as workload, situational awareness, and reliance on automation. Further topics include social robots, anthropomorphism, intentions, perception of other minds, and collaboration dynamics within human-robot teams, providing students with a comprehensive understanding of the complex interplay between humans and robots in various contexts.

Recommended Books:

1. Bartneck C, Belpaeme T, Eyssel F, Kanda T, Keijsers M, Šabanović S. Human-robot interaction: An introduction. Cambridge University Press; 2020.
2. Gholamreza Anbarjafari, Sergio Escalera. Human-Robot Interaction: Theory and Application. United Kingdom: IntechOpen, 2018.

Course Code: AIE746
Course Title: Distributed Machine Learning
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course provides an in-depth understanding of distributed systems for ML and Deep Learning using CPU, GPU and TPU clusters.

Course Description:

This course provides an in-depth understanding of distributed systems for ML and Deep Learning using CPU, GPU and TPU clusters. It starts with foundations of Map-reduce framework and in-memory distributed and resilient data structures that form the backbone of Spark. Students will learn the architectural details of these distributed system platforms and how they can be leveraged to perform data analysis and model training on petabyte scale datasets. We cover how distributed training is achieved for popular ML algorithms on Spark by understanding the internal working of SparkML Lib. The module then focuses on understanding distributed graph processing using GraphX. Students move on to Deep-Learning algorithms and how distributed algorithms can be designed for them when we have GPU or TPU clusters at our disposal. We also dive deep into how TensorFlow archives distributed computing for popular Deep Learning algorithms. Students will study distributed data stores and how they can be used for ML using popular datastore systems like Hive and SparkSQL. The module concludes by discussing state of the art distributed, low-latency approximate nearest neighbor algorithms along with their implementations in ElasticSearch.

Recommended Books:

1. Tang, Yuan. Distributed Machine Learning Patterns. United Kingdom: Manning, 2024.
2. Jiang, Jiawei., Cui, Bin., Zhang, Ce. Distributed Machine Learning and Gradient Optimization. Singapore: Springer Nature Singapore, 2022.

Course Code: AIE747
Course Title: Artificial Intelligence in Smart Grids
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course focuses on artificial intelligence and its application to power and energy systems. The main goal of the course is to apply machine learning algorithms in smart grid.

Course Description:

The main topics will be introduction and literature review of the basics concepts of a smart grid and applications of machine learning, deep learning to control problem of power systems and smart grid. The application of machine learning for predicting user preferences in optimal scheduling of smart appliances. Topics covered in the course include fundamental concepts related to smart and sustainable energy and transport systems, such as demand response, energy management, energy informatics, electric mobility and energy efficiency, and applications of deep learning algorithms and advanced machine learning concepts to solve typical decision-making problems in smart grids, designing high-performance green solutions, perform forecasting, improve network management.

Recommended Books:

1. Mehdi Rahmani-Andebili. Applications of Artificial Intelligence in Planning and Operation of Smart Grids. Switzerland: Springer International Publishing, 2022.
2. Miltiadis D. Lytras, Kwok Tai Chui. Artificial Intelligence for Smart and Sustainable Energy Systems and Applications. Switzerland: MDPI AG, 2020.

Course Code: AIE749
Course Title: Applied Estimation, Detection, and Prediction
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

The purpose of this Applied Estimation, Detection, and Prediction course is to provide students with advanced expertise and abilities in statistical signal processing and data-driven decision-making. The program integrates theoretical principles with real-world implementations, equipping graduates for professions in fields such as telecommunications, finance, healthcare, and sensor networks.

Course Description:

Introduction to signal processing, time and frequency domain analysis, Fourier analysis and transforms. Maximum likelihood estimation (MLE) and Bayesian estimation. Cramer-Rao lower bound, Kalman filtering for state estimation. Binary and multi-hypothesis testing, Neyman-Pearson criterion, seasonal decomposition and ARMA models. Linear and nonlinear prediction methods. LMS and NLMS algorithms. Recursive least squares (RLS) algorithms. Markov Chains and random walks, Poisson Process, Gaussian processes and their applications. Advanced detection techniques, MIMO systems, space-time coding and decoding. Short-time Fourier transform, Wavelets and Gabor Transform and its applications. Machine learning for estimation and prediction, ensemble methods, and multi-carrier modulation techniques.

Recommended Books:

1. Ye Wang. Advances in State Estimation, Diagnosis and Control of Complex Systems, Springer International Publishing, 2021.
2. Arthur Gelb. Applied Optimal Estimation. MIT press, 2010.

Course Code: AIE750
Course Title: Autonomous Systems
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

The course covers introduction and design of autonomous systems, introduction to sensors for autonomy, data fusion algorithms from multiple sensors, introduction to motion sensing, state estimation and localization, modelling and control of autonomous ground, aerial and underwater vehicles, and machine and deep learning applications in autonomous operations.

Course Description:

This course offers a comprehensive exploration of autonomous systems and intelligent solutions, emphasizing all kinds of vehicles such as AGVs (autonomous ground vehicles), AUVs (autonomous under water vehicles), UAVs (unmanned aerial vehicles) and Robots. The course covers diverse modules including an introduction to autonomous and intelligent systems. The course also introduces different types of sensors used in autonomous and intelligent systems such as IMUs, visual sensors, Lidars, Radars and GNSS in addition to comprehensive details on sensor fusion models for data fusion from multiple sensors. Moreover, practical skills in handling various sensors, sensor fusion techniques and AI applications in developing intelligent autonomous systems. The curriculum also encompasses advanced topics such as simultaneous localization and mapping (SLAM), deep learning for perception, predictive modeling, path planning algorithms, control systems, and reinforcement learning for decision- making. A crucial aspect of the course involves introduction to the Robotic Operating System (ROS) and its application through practical case studies. Introduction to Autonomous Vehicle Technology provides insights into policy and regulatory aspects. These resources collectively equip students with the essential knowledge and skills for developing intelligent solutions in the realm of autonomous systems.

Recommended Books:

1. Mahtani, Anil., Sanchez, Luis., Fernandez, Enrique., Martinez, Aaron. ROS Programming: Building Powerful Robots. United Kingdom: Packt Publishing, 2018.
2. Anderson, JamesM., Nidhi, Kalra., Stanley, Karlyn, Sorensen, Paul., Samaras, Constantine., Oluwatola, Oluwatobi A. Autonomous Vehicle Technology: A Guide for Policymakers. United States: RAND Corporation, 2014.
3. Jitendra R. Raol, Ajith K. Gopal. Mobile Intelligent Autonomous Systems. United Kingdom: CRC Press, 2016.

Course Code: AIE757
Course Title: Random Processes
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course will acquaint students with the basic elements of probability theory, random variables, and random processes, probabilistic descriptions of signals and noise, including joint, marginal and conditional densities, autocorrelation, cross-correlation and power spectral density. Linear and nonlinear transformations, linear least-squares estimation and signal detection.

Course Description:

The following topics will be covered in this course: Probability Review: Random variables, expected value, moment generating functions, conditional distribution, conditional expectation. Sequences of Random variables, modes of convergence and limit theorems. Random vectors, orthogonality principle, minimum mean square estimation. Random processes: Definitions and basic properties. Counting processes, Poisson process, renewal processes. Discrete and continuous time Markov chains. Martingales: Definitions, properties and inequalities. Basic Calculus of random processes, continuity, mean square differentiation, integration. Random processes in linear systems, spectral analysis, Fourier transforms, power spectral density. Wiener Filtering, causal functions and spectral factorization, causal Wiener filtering problem.

Recommended Books:

1. Grimmett, G. and Stirzaker, D.,. Probability and random processes. Oxford university press. 2020
2. John A. Gubner. Probability and Random Processes for Electrical and Computer Engineers – (first edition), 2006

Course Code: AIE762
Course Title: Artificial Intelligence and Renewable Energy
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course focuses on the integration of artificial intelligence (AI) techniques into power systems engineering. Students will learn how AI can be used to optimize power generation, distribution, and consumption, improve grid stability, and enhance energy efficiency. Students will gain insights into smart grid technologies, demand-side management, and energy storage systems. They will learn how AI can be applied to manage and control energy flows, balance supply and demand, and improve grid resilience in the face of changing conditions and evolving energy landscapes.

Course Description:

Introduction to power systems engineering and fundamentals of renewable energy, technologies and systems for solar, wind, hydroelectric and geothermal power generation, conversion technologies and applications of biomass energy, energy storage systems: batteries, capacitors, and flywheels, demand-side management and demand response, power electronics for renewable energy systems, AI techniques for power system optimization, predictive maintenance and condition monitoring, energy management systems and energy efficiency.

Recommended Books:

1. Vyas AK, Balamurugan S, Hiran KK, Dhiman HS. Artificial Intelligence for Renewable Energy Systems. John Wiley & Sons; 2022.
2. Ehrlich R, Geller HA, Cressman JR. Renewable energy: a first course. CRC press; 2022.
3. Demirel Y, Rosen MA. Sustainable Engineering: Process Intensification, Energy Analysis, and Artificial Intelligence. CRC Press; 2023.

Course Code: AIE764
Course Title: Intelligent Power Transmission and Distribution Systems
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

The course prepares students to integrate AI techniques with power transmission and distribution systems, allowing them to leverage data analytics, machine learning, and optimization algorithms to enhance grid operation, manage energy flows, and improve system performance. This interdisciplinary approach equips students with the skills to address real-world challenges in energy management and grid optimization. Students gain a comprehensive understanding of power transmission and distribution systems, which are fundamental components of energy infrastructure. This knowledge allows them to appreciate the interplay between AI technologies and critical energy systems, enabling them to develop innovative solutions for optimizing energy efficiency, reliability, and sustainability.

Course Description:

Introduction to Artificial Intelligence in power systems, Artificial Intelligence for power system monitoring and control, predictive maintenance and condition monitoring, optimization techniques in power systems, data analytics for grid integration of renewable energy, smart grid management and energy efficiency, Artificial Intelligence-enabled fault diagnosis and self-healing grids, cybersecurity in Artificial Intelligence -driven power systems.

Recommended Books:

1. Almoataz Y. Abdelaziz, Shady Hossam Eldeen Abdel Aleem, Anamika Yadav. Artificial Intelligence Applications in Electrical Transmission and Distribution Systems Protection, CRC Press; 2021.

Course Code: AIE766
Course Title: Path Planning and Motion Control
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

The course is intended to provide a comprehensive introduction to motion planning and control related to autonomous vehicles. This course will cover the major topics of motion planning including (but not limited to) planning for manipulation with robot arms and hands, mobile robot path planning with non-holonomic constraints, multi-robot path planning, high-dimensional sampling-based planning, and planning on constraint manifolds.

Course Description:

Motion planning involves the study of models and algorithms used to generate sequences of motions for many kinds of robots, AUVs (autonomous under water vehicles), AGVs (autonomous ground vehicles), UAVs (unmanned aerial vehicles). Historically, robot motion planning deals with the design of algorithms that can find collision free paths (if they exist) to take a robot from an initial point to a goal point. Due to recent interests in developing autonomous robotic systems, the subject has become extremely broad and covers not only the traditional areas of finding collision free paths, but automatic assembly, warehouse automation, multi robot cooperation, robotic surgery, etc. The course would cover the fundamental concepts and mathematics required to understand, analyze, and design algorithms required for motion planning of serial robotic arms and mobile robots. In this course, students will learn fundamental concepts in motion planning, sampling-based methods in motion planning, combinatorial motion planning, motion planning and feedback control, polygonal workspaces and construction of obstacles in configuration space, robot and obstacle representations, constructing C-Obstacles, and representing C-Obstacles, path planning framework, introduction to roadmap methods, and introduction to Graphs, Graph Search Methods for Planning, Configuration Spaces & cell decompositions.

Recommended Books:

1. Kala, Rahul. Autonomous Mobile Robots: Planning, Navigation and Simulation. Netherlands: Elsevier Science, 2023.
2. Mahulea, Cristian., Kloetzer, Marius., Gonzalez, Ramon. Path Planning of Cooperative Mobile Robots Using Discrete Event Models. United Kingdom: Wiley, 2020.

Course Code: AIE782
Course Title: Explainable Artificial Intelligence
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

Explainable AI (XAI) is a specialized area within artificial intelligence (AI) that specifically aims to enhance the transparency, interpretability, and comprehensibility of AI models for human users. An XAI course will familiarize you with the fundamental principles and methodologies of XAI. The students will acquire knowledge regarding many categories of explanation techniques, including local explanations, global explanations, and model-specific explanations. You will acquire the skills to assess and implement explanation techniques in practical scenarios.

Course Description:

Introduction to Explainable Artificial Intelligence (XAI), its types and importance. Interpretable models and algorithms, decision trees, linear models, and rule-based systems. Explainability in deep learning, challenges, layer-wise relevance propagation, saliency maps, and gradient based methods. Local, global and model-based explanations. Introduction to LIME, SHAP, Partial dependence plots, and Anchors. Ethical considerations in XAI, fair and unbiased explanations, privacy and data protection. Used cases in industry and research, and human - AI collaboration.

Recommended Books:

1. Pradeepta Mishra. Practical Explainable AI Using Python: Artificial Intelligence Model Explanations Using Python-based Libraries, Extensions, and Frameworks, 1st ed. 2021.
2. Christopher Molnar. Interpretable Machine Learning – A guide for Making Black Box models Explainable, Munich, 2023.

Course Code: AIE784
Course Title: Advanced Topics in AI Engineering I
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course introduces the advanced topics in Artificial intelligence engineering that will assist students to gain state-of-the-art knowledge.

Course Description:
This course is intended to expose students to state-of-the-art knowledge of advanced topics in Artificial intelligence. The course contents will be accordingly devised by the course instructor at the time of offering this course.

Recommended Books:

Latest research papers/articles, patents, and conference publications.

Course Code: AIE785
Course Title: Advanced Topics in AI Engineering II
Credit Hour: 3(3, 0)
Prerequisites: None

Course Objectives:

This course introduces the advanced topics in Artificial intelligence engineering that will assist students to gain state-of-the-art knowledge.

Course Description:
This course is intended to expose students to state-of-the-art knowledge of advanced topics in Artificial intelligence. The course contents will be accordingly devised by the course instructor at the time of offering this course.

Recommended Books:

Latest research papers/articles, patents, and conference publications.