MNE6128: ADVANCED MACHINE LEARNING AND QUANTUM COMPUTATION FOR ENGINEERING

Effective Term
Semester B 2024/25

Part I Course Overview

Course Title
Advanced Machine Learning and Quantum Computation for Engineering

Subject Code
MNE - Mechanical Engineering

Course Number
6128

Academic Unit
Mechanical Engineering (MNE)

College/School
College of Engineering (EG)

Course Duration
One Semester

Credit Units
3

Level
P5, P6 - Postgraduate Degree

Medium of Instruction
English

Medium of Assessment
English

Prerequisites
Nil

Precursors
Linear Algebra

Equivalent Courses
MNE8121 Advanced Machine Learning and Quantum Computation for Engineering

Exclusive Courses
Nil

Part II Course Details

Abstract

Computers have been the workhorses of modern society in every aspect. And mechanical engineers always use computer to do many kinds of computational work including control, robotics, fluid mechanics, heat transfer, …etc. However, with the ever-changing technology, there are more and more numerical methods and algorithms been developed, and even a new type of computer structure is invented – quantum computer. Therefore, this course aims to equip our students to better understand these new tools and to face the coming challenges in the future. This course will introduce two most advanced topics in the computational field, namely, machine learning and quantum computation.

Machining learning and artificial intelligence play more and more important roles in current engineering disciplines. This course will introduce the basics of machine learning and explore how such advanced techniques can be applied in the mechanical engineering field. Students will learn the art and science of Machine Learning from the fundamentals to state-of-the-art models. A strong emphasis is put on the principles of problem solving, and how machine learning techniques can be used to tackle practical engineering problems. The students will complete the course with the confidence to explore these topics further and apply them to other areas of interest themselves.

Students should have linear algebra knowledge and some programming background to understand the course content. We will use Matlab/Python as a medium to implement the machine learning models.

Quantum computer can perform computations much faster than classical computer on certain type of problems, which starts a new page in computation history. Many problems that are intractable on classical computers may be tractable with the aid of quantum computing. This course will introduce different quantum computer hardware designs and mainly focus on quantum computing algorithms. We will start from the basic knowledge of qubits to fundamental quantum algorithms such as quantum Fourier transform, Shor's algorithm, Grover's algorithm…etc. Recent developed algorithms will be introduced as well, such as quantum machine learning, imaginary time control, quantum chemistry applications…etc. Especially quantum machine learning as a new rising topic will serve as connecting bridge between classical machine learning and quantum computing. With these new tools and knowledge, quantum computers will become a powerful tool for our students to face the rapid changing challenges in this whole new era.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Identify the nature of engineering problems that can be solved through machine learning and quantum computation.		x	x	
2	Describe the principles of machine learning/ quantum computation and core models.		x	x	
3	Apply the basic concepts of machine learning/ quantum computation and models to a specific engineering problem.			x	x
4	Analyze the machine learning/quantum computation model and evaluate its accuracy and applicability.			x	x
5	Use Matlab and Qiskit to implement the basic machine learning/quantum computation models.			x	x

A1: Attitude
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: Accomplishments
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

Learning and Teaching Activities (LTAs)

	LTAs	Brief Description	CILO No.	Hours/week (if applicable)
1	Lecture	Lecture on the topics of advanced structured rationale.	1, 2, 3, 4	30 hrs
2	Presentation	Students presenting and defending their work.	3, 4	3 hrs
3	Lab	Students hands-on training with practical ML models.	5	6 hrs

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks (e.g. Parameter for GenAI use)
1	Test/Assignments	1, 2, 3, 4, 5	30	
2	Presentation	1, 2, 3, 4, 5	10	
3	Final project	2, 3, 4, 5	20	

Continuous Assessment (%)

60

Examination (%)

40

Examination Duration (Hours)

2

Additional Information for ATs

For a student to pass the course, at least 30% of the maximum mark for both coursework and examination should be obtained.

Assessment Rubrics (AR)

Assessment Task

Test/Assignments (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Capacity to understand and implement a particular model in engineering problems.

Excellent

(A+, A, A-) 75%-100%

Good

(B+, B, B-) 60%-74%

Fair

(C+, C, C-) 45%-59%

Marginal
(D) 40%-44%

Failure
(F) <40%

Assessment Task
Presentation (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
Capacity of self-directed learning to conceptualise a solution to a given problem.

Excellent
(A+, A, A-) High

Good
(B+, B, B-) Significant

Fair
(C+, C, C-) Moderate

Marginal
(D) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Final project (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
Demonstrate the mastery of all CILOs.

Excellent
(A+, A, A-) High

Good
(B+, B, B-) Significant

Fair
(C+, C, C-) Moderate

Marginal
(D) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Final Examination (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
Ability to understand the key concepts of machine learning/quantum computation.

Excellent
(A+, A, A-) 75%-100%

Good
(B+, B, B-) 60%-74%

Fair
(C+, C, C-) 45%-59%

Marginal
(D) 40%-44%

Failure
(F) <40%

Assessment Task
Test/Assignments (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Capacity to understand and implement a particular model in engineering problems.

Excellent
(A+, A, A-) 75%-100%

Good
(B+, B) 65%-74%

Marginal
(B-, C+, C) 50%-64%

Failure
(F) <50%

Assessment Task
Presentation (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Capacity of self-directed learning to conceptualise a solution to a given problem.

Excellent
(A+, A, A-) High

Good
(B+, B) Significant

Marginal
(B-, C+, C) Moderate

Failure
(F) Basic

Assessment Task
Final project (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Demonstrate the mastery of all CILOs.

Excellent
(A+, A, A-) High

Good
(B+, B) Significant

Marginal
(B-, C+, C) Moderate

Failure
(F) Basic

Assessment Task
Final Examination (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Ability to understand the key concepts of machine learning/quantum computation.

Excellent
(A+, A, A-) 75%-100%

Good
(B+, B) 65%-74%

Marginal
(B-, C+, C) 50%-64%

Failure
(F) <50%

Part III Other Information

Keyword Syllabus

Machine learning, artificial intelligence, deep learning, supervised learning, non-supervised learning, classification, regression, data gathering, preprocessing, data visualization, probability theory, neural network, kernel methods, model training, validation, and testing, advanced manufacturing, robotics, dynamic systems, energy systems, product quality control.

Qubits, quantum Fourier transform, Shor's Algorithm, Grover's algorithm, quantum machine learning, imaginary time control, linear and nonlinear control, optimization.

Reading List

Compulsory Readings

	Title
1	Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer.
2	Tom Mitchell, Machine Learning, McGraw Hill.
3	Stuart Russell, Peter Norvig, Artificial Intelligence: A Modern Approach, Prentice Hall.
4	Quantum Computation and Quantum Information, Isaac Chuang and Michael Nielsen, Cambridge University Press.

Additional Readings

	Title
1	Richard Sutton and Andrew Barto, Reinforcement Learning: An Introduction, MIT Press.