City University of Hong Kong
Course Syllabus

offered by
Department of Mechanical Engineering
with effect from Semester A 2024 / 25

Part I Course Overview

Course Title:	Advanced Machine Learning and Quantum Computation for Engineering
Course Code:	MNE8121
Course Duration:	1 semester
Credit Units:	3 credits
Level:	R8
Medium of Instruction:	English
Medium of Assessment:	English
Prerequisites: *(Course Code and Title)*	Nil
Precursors: *(Course Code and Title)*	Linear Algebra
Equivalent Courses: *(Course Code and Title)*	MNE6128 Advanced Machine Learning and Quantum Computation for Engineering
Exclusive Courses: *(Course Code and Title)*	Nil

Part II Course Details

1. 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.

2. Course Intended Learning Outcomes (CILOs)

(CILOs state what the student is expected to be able to do at the end of the course according to a given standard of performance.)

No.	CILOs	Weighting (if applicable)	Discovery-enriched curriculum related learning outcomes (please tick where appropriate)		
			A1	*A2*	*A3*
1.	**Identify** the nature of engineering problems that can be solved through machine learning and quantum computation.		✓	✓	
2.	**Describe** the principles of machine learning/quantum computation and core models.		✓	✓	
3.	**Apply** the basic concepts of machine learning/quantum computation and models to a specific engineering problem.			✓	✓
4.	**Analyze** the machine learning/quantum computation model and evaluate its accuracy and applicability.			✓	✓
5.	**Use** Matlab and Qiskit to implement the basic machine learning/quantum computation models.			✓	✓
		N.A.			

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.

3. Learning and Teaching Activities (LTAs)

(LTAs designed to facilitate students' achievement of the CILOs.)

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

4. Assessment Tasks/Activities (ATs)

(ATs are designed to assess how well the students achieve the CILOs.)

Assessment Tasks/Activities	CILO No.					Weighting	Remarks
	1	2	3	4	5		
Continuous Assessment: 60%							
Test/Assignments	✓	✓	✓	✓	✓	30%	
Presentation	✓	✓	✓	✓	✓	10%	
Final project		✓	✓	✓	✓	20%	
Examination: 40% (duration: 2 hours)							
Final Examination	✓	✓				40%	
						100%	

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

5. Assessment Rubrics

(Grading of student achievements is based on student performance in assessment tasks/activities with the following rubrics.)

Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
Test/Assignments	Capacity to understand and implement a particular model in engineering problems.	75%-100%	60%-74%	45%-59%	40%-44%	<40%
Presentation	Capacity of self-directed learning to conceptualise a solution to a given problem.	High	Significant	Moderate	Basic	Not even reaching marginal levels
Final project	Demonstrate the mastery of all CILOs.	High	Significant	Moderate	Basic	Not even reaching marginal levels
Final Examination	Ability to understand the key concepts of machine learning/quantum computation.	75%-100%	60%-74%	45%-59%	40%-44%	<40%

Applicable to students admitted from Semester A 2022/23 to Summer Term 2024

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B)	Marginal (B-, C+, C)	Failure (F)
Test/Assignments	Capacity to understand and implement a particular model in engineering problems.	75%-100%	65%-74%	50%-64%	<50%
Presentation	Capacity of self-directed learning to conceptualise a solution to a given problem.	High	Significant	Moderate	Basic
Final project	Demonstrate the mastery of all CILOs.	High	Significant	Moderate	Basic
Final Examination	Ability to understand the key concepts of machine learning/quantum computation.	75%-100%	65%-74%	50%-64%	<50%

Part III Other Information (more details can be provided separately in the teaching plan)

1. Keyword Syllabus

(An indication of the key topics of the course.)

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.

2. Reading List

2.1 Compulsory Readings

(Compulsory readings can include books, book chapters, or journal/magazine articles. There are also collections of e-books, e-journals available from the CityU Library.)

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.

2.2 Additional Readings

(Additional references for students to learn to expand their knowledge about the subject.)

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