City University of Hong Kong
Course Syllabus

offered by College/School/Department of _Mathematics______
with effect from Semester __A____ 20_20_ / _21_

Part I Course Overview

Course Title:	**A Mathematical Introduction to Machine Learning for Data Sciences**
Course Code:	**MA4550**
Course Duration:	**1 semester**
Credit Units:	**3**
Level:	**B4**
Proposed Area: *(for GE courses only)*	☐ **Arts and Humanities** ☐ **Study of Societies, Social and Business Organisations** ☐ **Science and Technology**
Medium of Instruction:	**English**
Medium of Assessment:	**English**
Prerequisites: *(Course Code and Title)*	**MA2503 Linear Algebra / MA1503 Linear Algebra with Applications; and MA3518 Applied Statistics**
Precursors: *(Course Code and Title)*	**Nil**
Equivalent Courses: *(Course Code and Title)*	**Nil**
Exclusive Courses: *(Course Code and Title)*	**Nil**

Part II Course Details

1. Abstract

(A 150-word description about the course)

Machine learning is the science of getting computers to learn the hidden patterns from the massive size of data and it is the most important methodology run on computers for artificial intelligence. The theoretic core of the machine learning consists of three elements: the mathematics to characterize the hidden structures and relations of the data, the statistical learning theories to build the correct models and assessment tools, and lastly, the computational algorithms to practically solve the final numerical problems.

This elective course is to provide the elementary mathematical and numerical theories relevant to the machine learning for data sciences. The basic knowledge of linear algebra, probability theory and statistical models is required and the familiarity of basic numerical methods and one programming language (Python or R or MATLAB or C or SAS, etc) is also preferred or required. The course will discuss fundamental rules, major classes of models, and principles of standard numerical methods. There will be a careful balance between heuristic vs rigorous, simple vs general. The perspective is from the applied and computational mathematics rather than an attitude of "alchemy". This course is a highly integrated undergraduate course for computational math major and it has a wide spectrum in various math knowledge and computational techniques. It can be also a companion theoretic course to a hands-on-experience-oriented machine learning course, for engineering major students with an exceptional math background.

This course will introduce the basic concepts of machine learning (supervision and unsupervised learning) and review the popular models used in machine learning and explain the underlying mathematical theories behind these models: linear regression, logistic regression, support vector machine, Gaussian process regression, model reduction, etc. Besides, this course also focuses on the neural network models. The machine learning algorithms such as unsupervised learning, stochastic gradient descent and deep learning techniques will be also an important part of this course. The examples of specific application will be given as exercises which require some programming work. During this course, the students are encouraged to apply the techniques to solve some realistic appreciations in the framework of Discovery&Innovation Curriculum. The students who complete this course are expected to be prepared for the modern development of more advanced machine learning theories and practical techniques.

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.	Explain the basic math models and concepts in learning theory and understand the functionalities of mathematics.	20%	√	√	
2.	Understand the statistical models and their properties used in the machine learning methods	30%		√	
3.	Understand the fundamental principles in numerical algorithms used in machine learning	30%		√	
4.	Write computer programming to implement, illustrate and test the simple versions of numerical methods.	10%	√	√	
5.	Solve one practical problem by applying certain machine learning methods to datasets from open source or real problems	10%	√	√	√
	** If weighting is assigned to CILOs, they should add up to 100%.*	100%			

[#] Please specify the alignment of CILOs to the Gateway Education Programme Intended Learning outcomes

(PILOs) in Section A of Annex.

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 self-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. Teaching and Learning Activities (TLAs)

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

TLA	Brief Description	CILO No.						Hours/week (if applicable)
		1	2	3	4	5		
Lectures	Learning through **teaching** is primarily based on lectures	√	√	√	√			39 hours in total
Assignment	Learning through **take-home assignments** helps students understand basic concepts and theory, and develop the ability of thinking both heuristically and rigorously.	√	√	√	√			After-class
Group project	Learning through **computer-programming-based group projects** helps students gain the deeper understanding of the theories and helps students develop the skills of solving real problems.		√	√	√	√		After-class

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: __50__%								
Assignments (3 or above)	√	√	√	√			20	
Group project		√	√	√	√		20	
Test	√	√	√				10	
Examination: _50___% (duration: hrs, if applicable) 2hours								
** The weightings should add up to 100%.*							100%	

5. Assessment Rubrics

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

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Assignments	demonstration of the understanding of the basic materials	High	Significant	Moderate	Basic	Not even reaching marginal levels
2. Project reports	demonstration of the ability of hands-on experience in applying machine learning methods	High	Significant	Moderate	Basic	Not even reaching marginal levels
3. Test	demonstration of the understanding of basic theoretic knowledge.	High	Significant	Moderate	Basic	Not even reaching marginal levels
4. Examination	demonstration of the understanding of basic theoretic knowledge.	High	Significant	Moderate	Basic	Not even reaching marginal levels

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.)

classification, linear regression, logistic/softmax regression, support vector machine, Gaussian process regression, deep neural network; bias-variance trade-off, regularization, model complexity, Rademacher complexity, VC-dimension, generalization error; estimation of approximation error, reproducing Kernel Hilbert spaces, probability inequalities; empirical risk minimization, convex optimization, K-means, EM algorithm, stochastic gradient descent

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.	Lecture notes distributed in class
2.	
3.	
…	

2.2 Additional Readings

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

1.	The "Machine Learning" course of Andrew Ng at the website: https://www.coursera.org/learn/machine-learning
2.	Cucker, F., & Zhou, D. (2007). Learning theory: An approximation theory viewpoint (Cambridge Monographs on Applied and Computational Mathematics). Cambridge: Cambridge University Press.
3.	Mohri, M., Rostamizadeh, A., & Talwalkar, A. (2012). Foundations of machine learning (Adaptive computation and machine learning). Cambridge, MA: MIT Press.
3.	Pattern Recognition and Machine Learning, by *Christopher M. Bishop. Springer, 2006*
4.	MATLAB Machine Learning *by Michael Paluszek and Stephanie Thomas. Apress © 2017 , ISBN:9781484222492*
5.	An Introduction to Statistical Learning with Applications in R, by *Gareth James, Daniela Witten, Trevor Hastie and Robert Tibshirani*. http://www-bcf.usc.edu/~gareth/ISL/