City University of Hong Kong
Course Syllabus

offered by College/School/Department of Mathematics
with effect from Semester A 2024/25

Part I Course Overview

Course Title:	Machine Learning and Data Analysis
Course Code:	MA8028
Course Duration:	One semester
Credit Units:	3
Level:	R8
Medium of Instruction:	English
Medium of Assessment:	English
Prerequisites: *(Course Code and Title)*	Nil
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

This course develops an up-to-date analysis of machine learning and data analysis from the mathematical and experimental viewpoints. Its topics will be selected in collaboration with the students and will focus on the most relevant and recent mathematical contributions to the understanding of machine learning: mathematical models of optimal networks, performance limits, probabilistic interpretation and Bayesian models. The usage of deep learning will be the main focus. Students will be invited to propose topics and papers of their current research interest, in particular applications to signals, images or other data types, so that participation to the course will foster their own research and in depth understanding of their own research topic. Classic signal and image and data analysis and their interaction with deep learning will be also discussed on demand, for example image denoising and deblurring, motion analysis, image comparison, anomaly detection, object classification, image or signal based medical diagnosis etc. Since the goal of the course is to help students develop their own research, they will be invited to select one paper or several papers of their particular interest and will commit themselves to an oral exposition and to a written report. If the report reaches sufficient level, publication at IPOL (www.ipol.im) will be considered or submission to a conference or journal will be considered and the instructor will help the student to complete it after the course. The main evaluation criterion is the production of a good public exposition and a good essay on the topic of interest for the student.

2. Course Intended Learning Outcomes (CILOs)

No.	CILOs[#]	Weighting* (if applicable)	Discovery-enriched curriculum related learning outcomes (please tick where appropriate)		
			A1	*A2*	*A3*
1.	Understanding the current development of deep learning from the theoretical viewpoint based on the weekly lectures of the instructor, active participation to the class by questions and comments, submit own readings of interest to the group.	25%	✓		
2.	Understanding the current development of deep learning form the practical viewpoint, making experiments on a topic of the student's choice, potentially using online demos such as IPOL to assess quickly the value of a method.	25%	✓	✓	
3.	Being able to present, analyse and criticise a recent deep learning method by theoretical and practical analysis based on experiments on data in an oral presentation with slides, on a topic chosen by the student and agreed by the instructor.	25%		✓	
4.	Being able to present, analyse and criticise a recent deep learning method by theoretical and practical experimental analysis on well-chosen data in a short review paper with bibliographical analysis on a topic chosen by the student and agreed by the instructor.	25%		✓	✓
		100%			

3. Learning and Teaching Activities (LTAs)

LTA	Brief Description	CILO No.						Hours/week (if applicable)
		1	2	3	4			
ML theory	Courses on recent mathematical arguments analysing deep learning methods. In addition to the courses, reference papers will be recommended to read either by the instructor or on suggestion of one of the students.	✓	✓	✓	✓			1 hour/week
Deep learning applications	Courses on recent deep learning applications, in particular in data analysis and imaging, illustrated by commented experiments. Students will be invited to perform online experiments and submit their critical analysis.	✓	✓	✓	✓			2 hours/week
Talk by student and discussion	By agreement with the course leader, papers of interest for the student's research will be chosen and exposed in front of the other students			✓				After-class
Review report by student on a machine learning method	The same papers selected by the student will be the object of a written review written by the student and corrected by the course leader. This may lead to an IPOL publication (www.ipol.im). Note: if the topic is judged adequate, work in group of two will be allowed, provided the parts assigned to each student be clearly identified. Particularly of the end goal is the publication of a review paper.				✓			After-class

4. Assessment Tasks/Activities (ATs)

Assessment Tasks/Activities	CILO No.						Weighting*	Remarks
	1	2	3	4				
Continuous Assessment: _100_%								
Oral participation to the course and its theoretical and practical discussion	✓	✓	✓	✓			30	Presence and participation are important to discuss recent advances of this fast evolving topic.
Oral exposition of selected paper during the course			✓				30	Papers preferably proposed by the student and relevant for his/her research.
Written review of selected paper that will be corrected by the course leader and followed by an individual interview with each student.				✓			40	This might lead to a publication.

Examination: _0___% (duration: , if applicable)								
							100%	

5. Assessment 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)
1. Oral participation to the course and its theoretical and practical discussion	Attendance and reactivity to scientific discussion during the course, reported readings, questions.	High	Significant	Moderate	Basic	Not even reaching marginal levels
2. Oral exposition of selected paper during the course	Quality and completeness of exposition, quality of the slides, interest of the public	High	Significant	Moderate	Basic	Not even reaching marginal levels
3. Written review of selected paper	Report's good organisation, quality of the theoretical analysis, and completeness of the bibliographical analysis, experimental design and quality of the experimental analysis.	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

Deep learning, image and data science, Bayesian interpretation of deep learning, tangent kernel interpretation of deep learning, denoising interpretation of deep learning, image processing and image analysis classic algorithms and their DL version.

2. Reading List

2.1 Compulsory Readings

1.	Lecture notes provided by the course leader
2.	Recent papers supporting the topics elected
3.	Paper(s) proposed by the student for her (his) report
4.	I enclose in Additional Readings some examples of papers that may be exposed

2.2 Additional Readings

1.	Zhang, K., et al. (2021). Plug-and-play image restoration with deep denoiser prior.
2.	Miyasawa, K. (1961). An empirical Bayes estimator of the mean of a normal population.
3.	Zhang, K., et al. (2021). Plug-and-play image restoration with deep denoiser prior.
4.	Kadkhodaie, Z., & Simoncelli, E. P. (2020). Solving linear inverse problems using the prior implicit in a denoiser
5.	Blau, Y., & Michaeli, T. (2018). The perception-distortion tradeoff. In Proceedings of the IEEE conference on computer vision and pattern recognition (pp. 6228-6237).
6.	Courtois, A., Morel, J. M., & Arias, P. (2023). Can neural networks extrapolate? Discussion of a theorem by Pedro Domingos. Revista de la Real Academia de Ciencias Exactas, Físicas y Naturales. Serie A. Matemáticas.
7.	Courtois, A., Morel, J. M., & Arias, P. (2022). Investigating neural architectures by synthetic dataset design. In Proceedings of the IEEE/CVF CVPR conference.