City University of Hong Kong
Course Syllabus

offered by School of Data Science
with effect from Semester A 2024/25

Part I Course Overview

Course Title:	Stochastic Optimization for Machine Learning
Course Code:	SDSC6015
Course Duration:	One semester
Credit Units:	3
Level:	P6
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

Stochastic optimization plays a vital role in machine learning where the full batch of data is either unavailable or too large to process in practice. This course introduces the theoretical foundations and algorithmic development in this area. The topics will start form the basic convex optimization theories as well as numerical methods, and we then focus on the stochastic approximation for stochastic optimization and its various accelerations in many statistical and machine learning models, supplemented with the most recent progress from research literature. Basic theoretic understanding of these stochastic optimization algorithms will also be explained. After this class, the students with some preliminaries of classic optimizations and probability theories are expected to transit into the new optimization world in the machine learning, in which significant progresses have been made during the past decades.

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.	Describe the methodologies and the underlying mathematical structures in optimization	20%	✓		
2.	Identify the essential principles and nature of stochastic approximation for modern machine learning optimization problem	25%		✓	
3.	Analyze basic forms of stochastic optimization and learning algorithms across various machine learning models.	30%		✓	
4.	Design and analyze the practical algorithms for related optimization problems.	25%			✓
		100%			

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		
Lecture	Students will engage in formal lectures and demonstrations in class to gain knowledge about the stochastic optimization theories and algorithms.	✓	✓	✓	✓		26 hours/semester
Tutorial	Students will engage in tutorial sessions to develop their skills about computer programming of implementing algorithms, and the in-depth interpretation of numerical results.		✓	✓	✓		13 hours/semester

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			
Continuous Assessment: 60 %							
Test/Quiz Students need to participate actively in in-class quizzes and tests designed to facilitate their understanding of knowledge taught in class.	✓	✓	✓			30%	
Take-home Assignment Students will critically analyze, apply and develop the theoretical concepts and quantitative skills by solving the individual samples of questions and exercises.		✓	✓	✓		30%	
Examination: 40 % (duration: 2 hours, if applicable)							
Examination Students will be assessed via the examination their understanding of concepts learned in class, textbooks, reading materials and their ability to apply subject-related knowledge.	✓	✓	✓	✓		40%	
						100%	

For a student to pass the course, at least 30% of the maximum mark for the 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)
1. Test/Quiz	Demonstrate the continuous learning process, the intellectual ability and achievements of understanding the materials in lecture time.	High	Significant	Moderate	Basic	Not even reaching marginal levels
2. Take-home Assignment	Show the capability to apply the knowledge and methods to practical exercises and the generalization to new context.	High	Significant	Moderate	Basic	Not even reaching marginal levels
3. Examination	Present the overall academic performance in understanding fundamentals and achieving measurable progress in the taught discipline.	High	Significant	Moderate	Basic	Not even reaching marginal levels

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)
1. Test/Quiz	Demonstrate the continuous learning process, the intellectual ability and achievements of understanding the materials in lecture time.	High	Significant	Moderate	Not even reaching marginal levels
2. Take-home Assignment	Show the capability to apply the knowledge and methods to practical exercises and the generalization to new context.	High	Significant	Moderate	Not even reaching marginal levels
3. Examination	Present the overall academic performance in understanding fundamentals and achieving measurable progress in the taught discipline.	High	Significant	Moderate	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.)

- Machine Learning models for optimization.
- Convex optimization theory : gradient and sub-gradient descent, mirror descent, acceleration; constrained optimization; primal-dual; ADMM.
- Stochastic convex optimization: stochastic gradient descent; Nesterov acceleration; stochastic momentum method: Adagrad, RMSprop, Adam; stochastic mirror descent; noise-reduction technique.
- Python programming for related algorithms.
- Selected Topics that arise from stochastic optimization in adversarial training, reinforcement learning, etc.

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 note

2.2 Additional Readings

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

1.	First-Order and Stochastic Optimization Methods for Machine Learning Author(s): Guanghui Lan Series: Springer in the Data Sciences Publisher: Springer Nature, Year: 2020
2.	Optimization Methods for Large-Scale Machine Learning. SIAM Review Vol. 60, No. 2, pp. 223–311, 2018
3.	ADAM: a method for stochastic optimization, Diederik P. Kingma, Jimmy Ba, ICLR 2015