SDSC6015: STOCHASTIC OPTIMIZATION FOR MACHINE LEARNING

Effective Term
Semester A 2025/26

Part I Course Overview

Course Title
Stochastic Optimization for Machine Learning

Subject Code
SDSC - Data Science
Course Number
6015

Academic Unit
Data Science (DS)

College/School
College of Computing (CC)

Course Duration
One Semester

Credit Units
3

Level
P5, P6 - Postgraduate Degree

Medium of Instruction
English

Medium of Assessment
English

Prerequisites
Nil

Precursors
Nil

Equivalent Courses
Nil

Exclusive Courses
Nil

Part II Course Details

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.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Describe the methodologies and the underlying mathematical structures in optimization	20	x		
2	Identify the essential principles and nature of stochastic approximation for modern machine learning optimization problem	25		x	
3	Analyze basic forms of stochastic optimization and learning algorithms across various machine learning models.	30		x	
4	Design and analyze the practical algorithms for related optimization problems.	25			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	Students will engage in formal lectures and demonstrations in class to gain knowledge about the stochastic optimization theories and algorithms.	1, 2, 3, 4	30 hours/semester

2	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.	2, 3, 4	9 hours/semester

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks ("-" for nil entry)	Allow Use of GenAI?
1	Test/Quiz: Students need to participate actively in in-class quizzes and tests designed to facilitate their understanding of knowledge taught in class.	2, 3	20	-	No
2	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.	2, 3, 4	30	-	Yes
3	Course Project: Students will be evaluated through course projects, which will assess their ability to comprehend and analyze advanced stochastic optimization algorithms in machine learning.	1, 2, 3, 4	10	-	Yes

Continuous Assessment (%)

60

Examination (%)

40

Examination Duration (Hours)

2

Minimum Continuous Assessment Passing Requirement (%)

30

Minimum Examination Passing Requirement (%)

30

Additional Information for ATs

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.

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

Assessment Rubrics (AR)

Assessment Task

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

Criterion

Demonstrate the continuous learning process, the intellectual ability and achievements of understanding the materials in lecture time.

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

Take-home Assignment (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Show the capability to apply the knowledge and methods to practical exercises and the generalization to new context.

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

Criterion
Demonstrate a solid understanding of stochastic optimization algorithms, showcase the ability to critically analyze and compare them, and provide evidence of effective implementation and experimentation.

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

Criterion
Present the overall academic performance in understanding fundamentals and achieving measurable progress in the taught discipline.

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

Criterion
Demonstrate the continuous learning process, the intellectual ability and achievements of understanding the materials in lecture time.

Excellent
(A+, A, A-) High

Good
(B+, B) Significant

Marginal
(B-, C+, C) Moderate

Failure
(F) Not even reaching marginal levels

Assessment Task
Take-home Assignment (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Show the capability to apply the knowledge and methods to practical exercises and the generalization to new context.

Excellent
(A+, A, A-) High

Good
(B+, B) Significant

Marginal
(B-, C+, C) Moderate

Failure
(F) Not even reaching marginal levels

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Course Project (for students admitted from Semester A 2022/23 to Summer Term 2024)

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Part III Other Information

Keyword Syllabus

- 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.

Reading List

Compulsory Readings

	Title
1	Lecture note

Additional Readings

	Title
1	Convex Optimization: Algorithms and Complexity, by Sébastien Bubeck
2	Convex Optimization, by Stephen Boyd and Lieven Vandenberghe
3	Introductory Lectures on Convex Optimization, by Yurii Nesterov