SDSC3004: COMPUTATIONAL OPTIMIZATION

Effective Term
Semester A 2024/25

Part I Course Overview

Course Title
Computational Optimization

Subject Code
SDSC - School of Data Science

Course Number
3004

Academic Unit
School of Data Science (DS)

College/School
School of Data Science (DS)

Course Duration
One Semester

Credit Units
3

Level
B1, B2, B3, B4 - Bachelor's Degree

Medium of Instruction
English

Medium of Assessment
English

Prerequisites
SDSC2002 Convex Optimization

Precursors
Nil

Equivalent Courses
Nil

Exclusive Courses
Nil

Part II Course Details

Abstract
This course introduces students to algorithms and techniques for optimization and nonlinear programming problems. Students will learn important numerical optimization methods such as the gradient descent, the Newton’s method, the

quasi-Newton's methods for unconstrained optimization, and the methods for constrained optimization. The classic methods for machine learning such as the stochastic gradient descent and its acceleration techniques, will be covered as well.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	State the various types of optimization problems and models and their features.	10	x		
2	Explain the basic concepts and main ideas of various optimization algorithm and techniques.	20	x	x	
3	Elaborate the properties and application domains of different optimization methods.	30	x	x	
4	Illustrate the mainstream algorithms by numerical tests and obtain practical experience from numerical experiments	30		x	x
5	Apply the correct algorithm to solve certain optimization problems from the application domains.	10		x	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	Lectures	Learning through teaching is primarily based on lectures.	1, 2, 3, 4, 5	3 hours/ week
2	Take-home assignments	Learning through take-home assignments helps students understand basic concepts and theories of computational optimization.	1, 2, 3, 4	after-class

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks (e.g. Parameter for GenAI use)
1	Test	1, 2, 3, 4	30	
2	Assignments	2, 3, 4, 5	30	

Continuous Assessment (%)

60

Examination (%)

40

Examination Duration (Hours)

2

Additional Information for ATs

Note: To pass the course, apart from obtaining a minimum of 40% in the overall mark, a student must also obtain a minimum mark of 30% in both continuous assessment and examination components.

Assessment Rubrics (AR)

Assessment Task

Test

Criterion

2-hour test to assess students' understanding of computational optimization methods and algorithms.

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

Assignments

Criterion

Students' ability to correctly apply computational optimization methods to solve given problems.

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

Criterion
Examination questions are designed to assess student’s level of achievement of the intended learning outcomes, with emphasis placed on understanding and correct application, mostly through mathematical exposition, clear explanation, and numerical calculation, of the various computational optimization techniques.

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

Additional Information for AR
The test and assignments will be numerically-marked, while examination will be numerically-marked and grades-awarded accordingly.

Part III Other Information

Keyword Syllabus

- Review of convex optimization: gradient descent method, line search, quadratic programming; primal and dual
- Non-differentiable optimization: subgradient descent method, proximal gradient descent method
- Nonlinear Programming: Conjugate gradient method; Newton’s method and quasi-Newton’s method, BFGS method
- Constrained optimization: gradient projection, penalty method, Augmented Lagrange method/multiplier; ADMM; splitting methods;
- Stochastic optimization method: sample average approximation, stochastic approximation, Robins-Monro method, stochastic gradient Descent, ADAM methods;
- Applications: back-prop in training neural network, shrinkage and regularization, LASSO, L1 minimization in compressed sensing, image denoising
- Basics of convergence rate, computational complexity, acceleration techniques

Reading List

Compulsory Readings

	Title
1	Lecture note

Additional Readings

	Title
1	Convex Optimization Algorithms by Dimitri P. Bertsekas. Publisher: Athena Scientific; 1 edition (February 10, 2015)
2	Nonlinear Programming by Dimitri P. Bertsekas, 3rd Edition. Publisher: Athena Scientific; 3rd edition (June 27, 2016)
3	Numerical Optimization: Theoretical and Practical Aspects by Joseph-Frédéric Bonnans, Jean Charles Gilbert, Claude Lemarechal, Claudia A. Sagastizábal. 2nd Edition. Springer 2006.
4	Numerical Optimization by Jorge Nocedal and Stephen J. Wright, 2006. Springer Series in Operations Research and Financial Engineering.