

SDSC3004: COMPUTATIONAL OPTIMIZATION

Effective Term

Semester A 2024/25

Part I Course Overview

Course Title

Computational Optimization

Subject Code

SDSC - Data Science

Course Number

3004

Academic Unit

Data Science (DS)

College/School

College of Computing (CC)

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 DEC-A1 app.)		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.