City University of Hong Kong
Course Syllabus

offered by School of Data Science
with effect from Semester A 2019/20

Part I Course Overview

Course Title:	**Computational Optimization**
Course Code:	**SDSC3004**
Course Duration:	**One Semester**
Credit Units:	**3**
Level:	**B3**
Proposed Area: *(for GE courses only)*	☐ Arts and Humanities ☐ Study of Societies, Social and Business Organisations ☐ Science and Technology
Medium of Instruction:	**English**
Medium of Assessment:	**English**
Prerequisites: *(Course Code and Title)*	**SDSC2002 Convex Optimization**
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

(A 150-word description about the course)

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.

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.	State the various types of optimization problems and models and their features.	10%	√		
2.	Explain the basic concepts and main ideas of various optimization algorithm and techniques.	20%	√	√	
3.	Elaborate the properties and application domains of different optimization methods.	30%	√	√	
4.	Illustrate the mainstream algorithms by numerical tests and obtain practical experience from numerical experiments	30%		√	√
5.	Apply the correct algorithm to solve certain optimization problems from the application domains.	10%		√	√
		100%			

** If weighting is assigned to CILOs, they should add up to 100%.*

[#] Please specify the alignment of CILOs to the Gateway Education Programme Intended Learning outcomes (PILOs) in Section A of Annex.

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 self-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. Teaching and Learning Activities (TLAs)

(TLAs designed to facilitate students' achievement of the CILOs.)

TLA	Brief Description	CILO No.					Hours/week (if applicable)
		1	2	3	4	5	
Lectures	Learning through teaching is primarily based on lectures.	√	√	√	√	√	3 hours/ week
Take-home assignments	Learning through **take-home assignments** helps students understand basic concepts and theories of computational optimization.	√	√	√	√		after-class

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	5		
Continuous Assessment: 40%							
Test	√	√	√	√		10%	
Assignments		√	√	√	√	30%	
Examination: 60% (duration: 2 hours)							
Examination	√	√	√	√	√	60%	
** The weightings should add up to 100%.*						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.)

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Test	2-hour test to assess students' understanding of computational optimization methods and algorithms.	High	Significant	Moderate	Basic	Not even reaching marginal levels
2. Assignments	Students' ability to correctly apply computational optimization methods to solve given problems.	High	Significant	Moderate	Basic	Not even reaching marginal levels
3. Examination	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.	High	Significant	Moderate	Basic	Not even reaching marginal levels

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

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.)

- Review of convex optimization: gradient descent method, line search, quadratic programming; primal and dual
- 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

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.	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.