City University of Hong Kong
Course Syllabus

offered by Department of Computer Science
with effect from Semester A 2022/23

Part I Course Overview

Course Title:	Topics in Optimization and its Applications in Computer Science
Course Code:	CS6491
Course Duration:	One semester
Credit Units:	3 credits
Level:	P6
Medium of Instruction:	English
Medium of Assessment:	English
Prerequisites: *(Course Code and Title)*	CS4335 Design and Analysis of Algorithms AND (MA2170 Linear Algebra & Multi-variable Calculus <u>or</u> MA2176 Basic Calculus and Linear Algebra)
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

The goal of this course is to expose students to modern and fundamental developments of optimization theory, algorithms and applications in computer science. The course focus is on various topics including the conceptual and algorithmic sides of convex optimization as well as dynamic programming. We will cover cone programming including linear, quadratic and semidefinite programming, geometric programming and dynamic programming whose rich expressive power makes it suitable for a wide spectrum of important optimization problems arising in mathematics and computer science. On the algorithmic side, the course covers efficient methods including optimization decomposition, convex relaxation and iterative methods, e.g., proximal algorithms, to address large-scale problems and non-convex problems. Emphasis will also be placed on the software aspect of convex optimization and dynamic programming. A variety of applications in computer science will be selectively drawn from combinatorial graph problems, Internet and wireless networks, online social networks, machine learning, statistical inference, compressed sensing and artificial intelligence.

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.)

At the end of the course, students are expected to be able to:

No.	CILOs	Weighting (if applicable)	Discovery-enriched curriculum related learning outcomes (please tick where appropriate)		
			A1	*A2*	*A3*
1.	analyze and explain topics in theory of optimization;		✓	✓	
2.	apply algorithms and techniques learned to solve practical problems;		✓	✓	✓
3.	conduct scientific investigation in these areas.		✓	✓	✓
		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 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	
Lecture	Lecture to teach basic concepts in optimization theory, teach problem-solving skills to analyse optimization problems and design algorithms to compute the solution, and to guide students on applying optimization theory and algorithms to a variety of applications in computer science.	✓	✓	✓	2 hours/ week
Tutorials	Tutorials for students to learn basic concepts in optimization theory, problem-solving skills to analyse optimization problems, design algorithms to compute the solution, and to conduct scientific investigations of applying optimization theory to computer science and other practical applications.	✓	✓	✓	1 hour/ week
Homework Assignment	Homework assignment which includes analytical and numerical tasks covering basic concepts in optimization theory as well as problem-solving skills to analyse optimization problems and design algorithms as part of scientific investigation for practical applications of optimization theory.	✓	✓	✓	
Midterm Examination	Midterm exam which includes analytical tasks covering basic concepts in optimization theory as well as problem-solving skills to analyse optimization problems and design algorithms to compute the solution.	✓	✓		

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		
Continuous Assessment: 40%					
Homework Assignment	✓	✓	✓	20%	2 weeks to complete
Midterm Examination	✓	✓		20%	2 hours closed book
Final Examination Assessment^: 60% (duration: 2 hours)					
Final Examination	✓	✓		60%	Closed book
				100%	

^ For a student to pass the course, at least 30% of the maximum mark for the examination must 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 in Semester A 2022/23 and thereafter

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B)	Marginal (B-, C+, C)	Failure (F)
1. Homework Assignment	Able to solve analytical and numerical tasks related to optimization theory and algorithms with a number of computer programming tasks satisfying CILOs 1 2, and 3.	Excellent if the assignment has completely correct solution with correct workings and a working computer program for numerical tasks in the scientific investigation to apply optimization theory.	Good if final answer is correct with partially correct workings and a working computer program for numerical tasks in the scientific investigation to apply optimization theory.	Marginal if feeble attempt is made in assignment and no computer programming for numerical tasks in the scientific investigation to apply optimization theory.	Not even reaching marginal levels.
2. Midterm Examination	Able to solve analytical tasks related to optimization theory and algorithms satisfying CILOs 1 and 2.	Excellent if the midterm exam has completely correct solution with correct workings.	Good if final answer is correct with partially correct workings.	Marginal if feeble attempt is made in midterm exam.	Not even reaching marginal levels.
3. Final Examination	Able to solve analytical tasks related to optimization theory and algorithms satisfying CILOs 1 and 2.	Excellent if the final exam has completely correct solution with correct workings.	Good if final answer is correct with partially correct workings.	Marginal if feeble attempt is made in final exam.	Not even reaching marginal levels.

Applicable to students admitted before Semester A 2022/23

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Homework Assignment	Able to solve analytical and numerical tasks related to optimization theory and algorithms with a number of computer programming tasks satisfying CILOs 1 2, and 3.	Excellent if the assignment has completely correct solution with correct workings and a working computer program for numerical tasks in the scientific investigation to apply optimization theory.	Good if final answer is correct with partially correct workings and a working computer program for numerical tasks in the scientific investigation to apply optimization theory.	Fair if a weak attempt is made in assignment and computer programming for numerical tasks in the scientific investigation to apply optimization theory.	Marginal if feeble attempt is made in assignment and no computer programming for numerical tasks in the scientific investigation to apply optimization theory.	Not even reaching marginal levels.
2. Midterm Examination	Able to solve analytical tasks related to optimization theory and algorithms satisfying CILOs 1 and 2.	Excellent if the midterm exam has completely correct solution with correct workings.	Good if final answer is correct with partially correct workings.	Fair if a weak attempt is made in midterm exam.	Marginal if feeble attempt is made in midterm exam.	Not even reaching marginal levels.
3. Final Examination	Able to solve analytical tasks related to optimization theory and algorithms satisfying CILOs 1 and 2.	Excellent if the final exam has completely correct solution with correct workings.	Good if final answer is correct with partially correct workings.	Fair if a weak attempt is made for final exam.	Marginal if feeble attempt is made in final exam.	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.)

Convex optimization, Lagrange duality, Linear programming, Quadratic programming, Semidefinite programming, Geometric programming, Parallel and distributed computation methods, First-order and second-order optimization methods, Regularisation, Proximal algorithms, Convex relaxation, Optimization decomposition, Network utility maximization problems, Dynamic programming, Algorithms for combinatorial graph problems, Approximation algorithms in computer science, Algorithms for Internet and wireless networks, Algorithms for machine learning, Algorithms for online social networks, Algorithms for statistical inference and artificial intelligence, Disciplined convex programming and convex optimization software.

Syllabus

1. Overview of optimization theory and algorithms
   a. Theoretical structures
   b. Duality approach
   c. Computational algorithms
2. Basic theory: Convex functions and convex sets
3. Basic theory: Linear programming and quadratic programming
4. Convex optimization theory: conic programming and semidefinite programming
5. Convex optimization theory: geometric programming
6. Lagrange duality of convex optimization and decomposition
7. Primal and dual decomposition and theory of iterative methods
8. Disciplined convex programming and convex optimization software
9. Application: Algorithms for Internet and wireless network utility maximization
10. Proximal algorithms for parallel and distributed computation
11. Application: Approximation algorithms in computer science
12. Convex relaxation for non-convex optimization
13. Application: Regularization-based algorithms in machine learning
14. Application: Optimization-based algorithms in artificial intelligence
15. Dynamic programming and Bellman's principle of optimality
16. Application: Graph algorithms in online social networking and artificial intelligence

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.	*Boyd, S. and Vandenberghe. Convex Optimization. Cambridge University Press.* Free e-Book online at: *http://www.stanford.edu/~boyd/cvxbook*

2.2 Additional Readings

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

1.	*Bertsekas, D. and Tsitsiklis, J. N. Parallel and Distributed Computation: Numerical Methods. Athena Scientific, 2015.*