

Subject Description Form

Subject Code	DSAI5104
Subject Title	Optimization for Machine Learning
Credit Value	3
Level	5
Pre-requisite/ Co-requisite/ Exclusion	Nil
Objectives	To equip students with more advanced optimization algorithms for machine learning applications
Intended Learning Outcomes	Upon completion of the subject, students will be able to: (a) Gain deep understanding of optimization in the context of machine learning. (b) Apply (deterministic and stochastic) first-order and second-order algorithms to unconstrained/constrained convex optimization, and large scale distributed optimization problems. (c) Conduct computational complexity and convergence analysis and understand optimality and duality theory widely used for machine learning applications. (d) Formulate some machine learning problems in terms of optimization and solve them.
Subject Synopsis/ Indicative Syllabus	<u>Mathematical Background</u> Applied linear algebra, theory of convex functions, convex and nonconvex optimization, sparse optimization. Examples include SVM, regression and convex clustering. <u>First-order Methods</u> Gradient descent and accelerated variants, projected and proximal gradient descent, stochastic gradient descent, Frank-Wolfe algorithm <u>Second-order Methods</u> Newton's method, quasi-Newton methods, Semismooth Newton method <u>Dimensionality Reduction Methods</u> Principle component analysis and multidimensional scaling, ISOMAP, t-SNE. <u>Introduction of Duality Theory for Structural Optimization Problems</u> Karush-Kuhn-Tucker conditions, Fenchel duality theory, Alternating Direction Method of Multipliers (ADMM), distributed optimization algorithms.
Teaching/Learning Methodology	The subject will be delivered mainly through lectures and tutorials. The teaching and learning approach are mainly problem-solving oriented. The approach aims at the development of mathematical techniques and how the techniques can be applied to solving problems. Students are encouraged to adopt a deep study approach by employing high level cognitive strategies, such as critical and evaluative thinking, relating, integrating and applying theories to practice.

Assessment Methods in Alignment with Intended Learning Outcomes	Specific assessment methods/tasks	% weighting	Intended subject learning outcomes to be assessed			
			a	b	c	d
	1. Mid-term test/ Assignments	30%	√	√	√	√
	2. Examination	70%	√	√	√	√
	Total	100 %				
	Explanation of the appropriateness of the assessment methods in assessing the intended learning outcomes: Continuous Assessment comprises of a mid-term test. A written examination is held at the end of the semester.					
Student Study Effort Expected	Class contact:					
	▪ Lecture				26 Hrs.	
	▪ Tutorial				13 Hrs.	
	Other student study effort:					
	▪ Case study on t-SNE method				21 Hrs.	
	▪ Self-study				60 Hrs.	
	Total student study effort				120 Hrs.	
Reading List and References	Nocedal and Wright: Numerical Optimization (2 nd), Springer, 2006					
	Boyd and Vandenberghe: Convex Optimization, Cambridge University Press, 2004					
	Luenberger and Ye: Linear and Nonlinear Programming (4 th), Springer 2016					
	Ghojogh, Crowley, Karray, and Ghodsi: Elements of Dimensionality Reduction and Manifold Learning, Springer, 2023.					
	Bottou, Curtis, and Nocedal: Optimization Methods for Large-Scale Machine Learning, SIAM Review, 60 (2018), 223—311.					