

Course 2: UMAM-502 - Optimization for Machine Learning

L – T – P – C	3 – 0 – 2 – 4	Total Periods: 70
Prerequisites	10+2 Mathematics, Python programming, Calculus, Probability and Statistics	

Course Objectives

- Modeling and discussion of documented real-world applications.
- Study of mathematical programming algorithms for optimization.
- Apply the mathematical results and numerical techniques of optimization theory to concrete engineering problems.

Course Outcomes

- Discover, study and solve optimization problems.
- Investigate, study, develop, organize and promote innovative solutions for various applications.
- Apply mathematical skills to model optimization problems.
- Critically analyze theoretical principles and choose the relevant optimization techniques for a specific problem.
- Get exposed to solutions for various types of optimization problems and be enabled to adopt them for the situation at hand.

Syllabus

Unit	Topic	Contents	Periods
1	Introduction	Mathematical Review – Lines – Hyperplanes and linear varieties – convex sets – neighborhoods – polytopes and polyhedra – derivative matrix – level sets and gradients – Taylor's series	6
2	Unconstrained Optimization	Conditions for local minimizers – one-dimensional search methods including golden section, Fibonacci, bisections and Newton's method – Gradient methods including steepest descent methods, Newton's method and its analysis.	8
3	Linear Programming	Modelling with Linear Programming, the Simplex method and Duality	8
4	Non-Linear Constrained Optimization	Problems with equality constraints – Lagrange condition – second-order condition – minimizing quadratics subject to equality constraints – problems with inequality constraints – Karush-Kuhn-Tucker conditions – second-order conditions.	8
5	Convex Optimization	Convex Optimization Problems – Convex Functions – Convex Optimization Problems	6
6	Machine Learning View for Optimization	Gradient Descent, properties of optimization in ML, computing gradients with respect to vectors, linear regression, and optimization models for binary targets.	6
		Total	42

UMAM-502: Practicals – Optimization for Machine Learning

Unit	Topic	Contents	Periods
1	Unconstrained Optimization	Implementation of unconstrained optimization using Python: Newton–Raphson method; implementation of Gradient Ascent and Gradient Descent methods.	10
2	Solving LPP	Solving LP problems using Excel Solver; sensitivity analysis using Excel Solver; solving LP problems using <code>scipy.optimize.linprog</code> .	10
3	Python Library <code>scipy.optimize</code>	Univariate function minimization; constrained and unconstrained minimization of multivariate scalar functions; global optimization; least-squares optimization; custom minimizers.	8
		Total	28

Practicals — Key Text(s)

- SciPy Reference Guide. Retrieved July 7, 2022 from <https://docs.scipy.org/doc/scipy-1.7.1/scipy-ref-1.7.1.pdf> — Section 2.4 (Optimization – `scipy.optimize`)
- Christian Hill, Learning Scientific Programming with Python, 2nd Edition, Cambridge University Press, 2020.
- Edwin K. P. Chong and Stanislaw H. Zak, An Introduction to Optimization, 4th Edition, Wiley Inter-Science Publication, John Wiley and Sons Inc., 2013.
- Hamdy A. Taha, Operations Research – An Introduction, 10th Edition, Pearson Education, 2017.

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- Edwin K. P. Chong and Stanislaw H. Zak, An Introduction to Optimization, 4th Edition, Wiley Inter-Science Publication, John Wiley and Sons Inc., 2013.
- Hamdy A. Taha, Operations Research – An Introduction, 10th Edition, Pearson Education, 2017.

Suggested / Additional Readings

- L.R. Foulds, Optimization Techniques, Springer, UTM, 1981.
- Numerical Optimization video lectures: <http://freevidelectures.com/Course/3072/Numerical-Optimization>
- Hamdy A. Taha, Operations Research, Pearson Publication, 9th edition (2014).
- Boyd, Stephen, and Lieven Vandenberghe, Convex Optimization, Cambridge University Press, UK, 2004.