SRI SATHYA SAI INSTITUTE OF HIGHER LEARNING

(Deemed to be University)

Department of Mathematics and Computer Science

SYLLABUS: UMAM-502: Optimization Techniques 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	8

Unit	Topic	Contents	Periods
		equality constraints – problems with inequality constraints – Karush-Kuhn-Tucker conditions – second-order conditions.	
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 scipy.optimize.linprog.	10
3	**Python Library scipy.optimize**	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.

Key Text(s)

- Edwin K. P. Chong and Stanislaw H. Zak, An Introduction to Optimization, 4th Edition, Wiley Inter-Science Publication, John Wiley and Sons Inc., 2013. — Chapters: 4, 5 (5.3–5.6), 6, 7 (7.1–7.5), 8 (8.1–8.2), 9 (9.1–9.2), 20, 21, 22 (22.1–22.3)
- Hamdy A. Taha, Operations Research – An Introduction, 10th Edition, Pearson Education, 2017. — Chapters: 2, 3, 4

Suggested / Additional Readings

- L.R. Foulds, Optimization Techniques, Springer, UTM, 1981.
- Numerical Optimization video lectures: http://freevideolectures.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.