DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY PATNA

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CS74144: Optimization Techniques

L-T-P-Cr: 3-0-0-3

Pre-requisites: Linear algebra, Probability theory

Objectives/Overview:

- To introduce various techniques of mathematical optimization along with their applications.
- To develop the basic understanding of applying various optimization techniques in various fields of Computer Science

Course Outcomes (COs):

At the end of the course, a student will be able to understand the following:

Sr. no.	CO
CO1	Basic concepts of Optimization Process, Derivatives and Gradients, Local Descent, and First-Order Methods. Applications of various Optimization techniques, Derivatives and Gradients, Local Descent, and First-Order Methods to solve various problems.
CO2	Basic concepts and applications of Elementary probability, Probability measures, Probabilities on finite and denumerable sets, Conditional probability, Bayes probability theorem, Discrete and continuous Random variables, Probability density functions---Gaussian, Uniform, Exponential, Chebyshev inequalities, Bernoulli process, Poisson distribution. The method of solving/evaluating various problems of probabilities, Bernoulli process, Poisson distribution, Gaussian density function, Uniform density function, Exponential density function, etc.
CO3	Basic concepts, features, and applications of Stochastic processes and Discrete time Markov chains. The method of solving/evaluating various problems of Markov chains.

CO4	Basic concepts and applications of various Constraint Optimization techniques. The method of solving/evaluating various problems using Constraint Optimization techniques.

CO-PO mapping:

CO/ PO	PO1	PO 2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Unit I: Lectures: 10 hours

Introduction:

Optimization Process, Basic Optimization Problem, Constraints, Critical Points, Conditions for Local Minima, Contour Plots

Derivatives and Gradients:

Derivatives, Derivatives in Multiple Dimension, Numerical Differentiation, Automatic Differentiation

Local Descent:

Descent Direction Iteration, Line Search, Approximate Line Search, Trust Region Methods, Termination Conditions

First-Order Methods:

Gradient Descent, Conjugate Gradient, Momentum, Nesterov Momentum, Adagrad, RMSProp, Adadelta, Adam, Hypergradient Descent,

Unit II: Lectures: 15 hours

Probability measures:

Elementary probability, Basic facts, Events, Probability measures, Continuity of measures, Integral with respect to a measure, Probabilities on finite and denumerable sets, Probabilities on denumerable sets, Probabilities on uncountable sets, Conditional probability, Bayes formula, Inclusion–exclusion principle, Random variables, Random variables, Expected value, Functions of random variables, Cavalieri formula, Variance, Markov and Chebyshev inequalities, Variational characterization of the median and of

the, expected value, A few discrete distributions, Bernoulli distribution, Binomial distribution, Hypergeometric distribution, Negative binomial distribution, Poisson distribution, Geometric distribution

Unit III Lectures: 09 hours

Discrete time Markov chains:

Stochastic matrices, Oriented graphs, Markov chains, Stochastic processes, Transition matrices, Homogeneous processes, Markov chains, Canonical Markov chains, some characteristic parameters, Steps for a first visit, Probability of (at least) r visits, Recurrent and transient states, mean first passage time, hitting time and hitting probabilities,

Population Methods:

Initialization, Genetic Algorithms, Differential Evolution, Particle Swarm Optimization, Firefly Algorithm, Cuckoo Search, Hybrid Methods

Unit IV: Lectures: 08 hours

Constraints Optimization:

Constrained Optimization, Constraint Types, Transformations to Remove Constraints, Lagrange Multipliers, Inequality Constraints, Duality, Penalty Methods, Augmented Lagrange Method, Interior Point Methods,

Linear Constrained Optimization

Problem Formulation, Simplex Algorithm, Dual Certificates,

Multiobjective Optimization

Pareto Optimality, Constraint Methods, Weight Methods, Multiobjective Population Methods, Preference Elicitation

Text book:

1. Algorithms for Optimization, Mykel J. Kochenderfer and Tim A. Wheeler, MIT Press.
2. A First Course in Probability and Markov Chains by Giuseppe Modica, Laura Poggiolini, Wiley publication.