Lecture Series on
Machine Learning, Statistical Regression and Numerical Optimization

Instructor: Professor Biswa Nath Datta, IEEE Fellow

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Objective: The purpose of this lecture series is first to give a brief overview of the subject of Machine Learning, emphasizing how and what sort of regression problems arise in the study of Machine Learning, then discuss in some details viable numerical techniques of optimization.

Intended Audience : Students and Researchers in Mathematics, Computer Science, Statistics, Medical and Health Sciences, Signal and Image Processing Engineering, and others.

Title: **Machine Learning, Statistical Regression and Numerical Optimization**
Speaker: **Prof. Biswa Nath Datta, IEEE Fellow, Northern Illinois University, USA**
Duration: **12 hours of lectures (2hours of lectures on January 14, 16, 21, 23, 29, 30)**
Time: **3:30-5:30pm**
Venue: **N325, Department of Mathematics**

Participants: Maximum of 40 students (UG 3rd/4th/5th year, MSc (2 years), MTech, PhD) belonging to various departments of IIT Kgp will be selected. Interested students much express and confirm their interest for participation in the course by writing an email to **bibhas.adhikari@gmail.com** by January 12, 2020. The students must mention their departments. The subject of the email should be MLRO.

Machine Learning is a scientific study of algorithms and statistical models that computer systems use to effectively predict a specific task without using specific human instructions. It is an emerging area of study and research, and has found applications in solutions of a variety of real-life problems, arising in, for instance, computer vision, handwritten recognition, image and speech recognitions, medical diagnosis, health care, social media, manufacturing , and many more.

Regression is a well-known statistical modeling technique to establish a meaningful relationship between independent and dependent variables. The development of machine

leaning algorithms with real or continuous output data gives rise to regression problems, which in turn, requires numerical techniques of optimization for their solutions.

The purpose of this introductory , interdisciplinary course is first to give a brief overview of the subject of Machine Learning, emphasizing how and what sort of regression problems arise in the study of Machine Learning, then discuss in some details viable numerical techniques of optimization.

Syllabus :

PART A : A Brief Introduction to Machine Learning :

(I) Machine Learning vs. Traditional Computing

(II) Some Motivating Practical Life Examples of Machine Learning

(III) Basic Steps of Development of Machine Learning Algorithms

(IV) Types of Machine Learning Algorithms – Supervised, Unsupervised and Reinforced Learnings.

(V) Discussion of how Machine Learning gives rise to Statistical Regression and Optimization Problems

N.B. – The above concepts will be illustrated by Real-life Examples arising in Machine Learning.

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Part B : Required Numerical Linear Algebra Background :

(I) Basic Concepts of Round-off Errors, Efficiency and Stability.

(II) LU, Cholesky, QR and SVD Decompositions.

(III) Solutions of Linear and Nonlinear Systems of Equations.

(iv) Characterization of Matrix Definiteness in terms of Matrix Factorization and Eigenvalues

Part C: Numerical Optimization

(I) Unconstrained Optimization :

Mathematical Definition of Unconstrained Optimization Problem

Conditions for Existence

Convex Optimization

Steepest Descent Method

Newton and Quasi-Newton (BFGS) Methods

Conjugate Gradient Method for Large-Scale optimization

Stochastic Gradient Descent Method for Large-Scale Optimization

(II) Constrained Optimization :

Mathematical definition of Constrained Optimization

Conditions for Existence

Lagrange Multipliers and Karush-Kuhn-Tucker (KKT) Conditions

Penalty and Barrier Methods

Part D : Statistical Regression :

(I) Linear Regression :

Linear Least-Squares Estimator

Properties of Least-Squares Estimator

Normal Equations for Linear Least-Squares and Numerically Effective Solutions using QR and SVD

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Efficacy of Regression Models

Illustrations using Examples from Machine Learning.

(II) Nonlinear Regression :

Least-Squares Estimation of Nonlinear Regression by Normal Equations

Logistic Regression

Gauss-Newton Method

Levenberg-Marquardt Method

Illustrations using Examples from Machine Learning

(iv) Dimension Reduction Techniques

Principal Component Analysis (PCA) : Computing PCA by SVD

Optimization of PCA

Applications of PCA to Image Compression and Data Visualization

Intended Audience : Students and Researchers in Mathematics, Computer Science, Statistics, Medical and Health Sciences, Signal and Image Processing Engineering, and others.

Reference Books :

(i) Numerical Linear Algebra and Applications by Biswa Nath Datta, 2nd Edition, SIAM, 2010 (Indian Paperback Edition by Prentice Hall of India)

(ii) Numerical Optimization by J. Nocedal and S. J. Wright , Springer Series in Operations Research, New York, 1999

(iii) Machine Learning Refined by J. Watt, R. Borhani, and A. Katsaggelos , Cambridge University Press, 2016.

(iv) An Introduction to Machine Learning by Gopinath Rebala, Ajay Ravi, Sanjay Churiwala, Springer, 2019