New Arts, Commerce & Science College
Ahmednagar

Post Graduate Diploma
In
Industrial Mathematics

Syllabus

Post Graduate Diploma in Industrial Mathematics

First semester forms the foundation and second semester follows with specialized areas in industrial mathematics. There will be 2-months industrial training at the end of the program.

Sem-I :

101. Numerical Methods for Scientific Computing
102. Partial Differential Equations and Finite Element Methods
103. Distributions and Transforms

104 (A): Computational Statistics and Numerical Optimizations

or

104(B) Introduction to System and Control Theory

105 Design and Analysis of Algorithms

106.Programming Language Lab

Sem-II :

201. Mathematical Modeling and Numerical Simulation
202. Software Systems Lab

Electives (any 2 from Group A)

Electives (any 2 from Group B)

Two months Industrial Training.

Elective Group-A :

203. Parallel Processing and Grid Computing
204. Computational Mechanics
205. Cryptography and Network Security
206. Artificial Intelligence
207. Mathematics of Finance
208. Fuzzy Sets and Applications

Electives Group-B :

209. Computational Fluid Dynamics
210. Topics in Systems and Control
211. Methods in signal and image Processing
212. Artificial Neural Networks
213. Scientific Visualization
214. Computational Biology

101. <u>Numerical Methods for Scientific Computing</u>

1. Number Systems and Errors
   Representation of integers and fractions, errors in Numerical Computations, loss of significance.
2. Linear Equations
   Gauss elimination, maximum pivotal strategy, triangular decomposition algorithms, error analysis, evaluation of determinant, ill conditioning, improvement schemes, iterative methods.
3. Algebraic eigen-value problem
   The characteristic polynomial, power method, conversions consideration, Jacobi and Givens methods, practical considerations, Lanczos and House holders algorithms.
4. Curve fitting and functional approximation
   Fitting curves to discrete data, Least square methods, fitting to a straight line, polynomial fitting, polynomial wiggle problem, ill-conditioning, polynomial and rational function approximations, orthogonal polynomials, Chebyshev polynomials, FFT algorithm.
5. Numerical differentiation and integration
   Numerical differentiation, Richardson's formula, Approximations for k^{th} derivative, numerical quadrature for equispaces, composite rules, Rhomberg integration, Gauss-Quadrature multiple integration
6. Numerical methods for ordinary differential equations.
   Existence and uniqueness of solution, Eulers and Taylor Series method, Runge-Kutta method, multistep methods (Predictor-Corrector), Procedures with error analysis, Stiff differential equations, methods based on numerical integration
7. Optimization
   Golden search methods, Brent's procedure, methods using derivatives, minimization in several dimensions, Quasi-Newton methods, direction set method.

References:

1. Brian Braide - A Friendly Introduction to Numerical Analysis (Pearson)
2. Froberg C. E. – Numerical Analysis (McGraw Hill) 1979
3. Maron M. J. – Numerical Analysis: A practical Approach (Mc Millan) 1982
4. Carnhan B., Luter H. A., Wilkes J. O. – Applied Numerical Methods (John Wiley) 1969
5. Antia H. M. – Numerical Methods for Scientists and Engineer (TMH) 1991

102. <u>Partial Differential Equations and Finite Element Methods</u>

1. Hyperbolic systems of PDE
2. Systems of conservation laws, method of characteristics
3. Shock waves, weak solutions, entropy conditions
4. Elliptic equations
5. Green function, Dirichlet principle, Maximum principle
6. Parabolic problems
7. Variational Problems, existence, uniqueness
8. Conformal FE, nonconformal FE, mixed and hybrid FE, h- and p-adaptivity
9. Conjugate gradient methods, multigrid, applications from PDE.

References :

1. E. DiBenedetto, Partial Differential Equations, Birkhauser, Boston, 1995.
2. L.C. Evans, Partial Differential Equations, Graduate Studies in Mathematics, Vol. 19, AMS, Providence, 1998.
3. F. John, Partial Differential Equations, 3rd ed., Narosa Publ. Co., New Delhi,1979.
4. E. Zauderer, Partial Differential Equations of Applied Mathematics, 2nd ed., John Wiley and Sons, New York, 1989.
5. K.E. Brenner and R. Scott, The Mathematical Theory of Finite Element Methods, Springer- Verlang, Berlin, 1994.
6. P.G. Ciarlet, The Finite Element Methods for Elliptic Problems, North Holland, Amsterdam, 1978.
7. C. Johnson, Numerical solutions of Partial Differential Equations by Finite Element Methods, Cambridge University Press, Cambridge, 1987.
8. C. Mercier, Lectures on Topics in Finite Element Solution of Elliptic Problems, TIFR Lectures on Mathematics and Physics Vol. 63, Narosa Publ. House, New Delhi, 1979

103. <u>Distributions and Transforms</u>

1. Distributions
   Test Functions, generalized derivatives, convolutions, compactly supported and tampered distributions
2. Fourier transforms
   Fourier Series, Fourier Integrals, applications to ODE and PDE.
3. Time Frequency analysis and Gabor Transforms
4. Introduction to Hilberts Spaces, Orthonormal basis and frames
5. Wavelet transform :
   Continuous wavelet transform and its inversion formula, discrete wavelet transform, multi resolution analysis and orthonormal wavelet bases, Shannon, Meyer and Daubechies wavelets, Byorthogonal wavelets.
6. Radon transform, Hough transform. Basic theory and applications. Hilbert Transform.

References:

1. R. Strichartz, A Guide to Distributions and Fourier Transforms, CRC Press.
2. E.M. Stein and R. Shakarchi, Fourier Analysis: An Introduction, Princeton University Press, Princeton 2003.
3. I. Richards and H. Youn, Theory of Distributions and Non-technical Approach, Cambridge University Press, Cambridge, 1990.
4. Y.T. Chan, Wavelet Basics, Kluwer Publishers, Boston, 1993.
5. I. Daubechies, Ten Lectures on Wavelets, Society for Industrial and Applied Mathematics, Philadelphia, PA, 1992.
6. C. K. Chui, An Introduction to Wavelets, Academic Press Inc., New York, 1992.
7. Gerald Kaiser, A Friendly Guide to Wavelets, Birkhauser, New York, 1995.
8. P. P. Vaidyanathan, Multirate Systems and Filter Banks, Prentice Hall, New Jersey, 1993.
9. A.N. Akansu and R.A. Haddad, Multiresolution signal Decomposition: Transforms, Subbands and Wavelets, Academic Press, Oranld, Florida, 1992.
10. B.Boashash, Time-Frequency signal analysis, In S.Haykin, (editor), Advanced Spectral Analysis, pages 418--517. Prentice Hall, New Jersey, 1991.

104 (A): Computational Statistics and Numerical Optimizations

Part – I : "Computational Statistics Optimization"

1. Introductory Statistics and Probability Concepts:

   Motivation, Data & Decisions, Measurements Uncertainties, Random Processes, Various Statistical Measures. Basic Probability, Sample Space, Events, Axioms of probability, Sample Space with Equal likely outcomes, Conditional Probability, Independent Events.

   Random Variables, Continuous/Discrete Random variables, Exception Variance, Covariance, Conditional distributions, Generating functions.(Moment, Cumulant, Factorial, Probability)
2. Distributions: Bernoulli, Binomial, Uniform Poisson, Normal, Exponential, Chi-square, T and F relationship between them.
3. Regression: Linear, non linear, multiple regression, forward and backward stepwise regression, Logistic, exponential, parabolic regression.
4. Estimation and testing: Point and interval estimation, method of moments, maximum likelihood, Pivotal quantity, Interval estimates, Hypothesis Testing , Significance Levels, Test for testing means, proportion, variance, goodness of fit
5. Simulation: Need of simulation, concept of simulation, random number generation, Monte carlo method, sampling from normal distribution using Box Muller transformation.
6. Industrial and Applied Statistics:

   Statistical Quality Control: control charts – X ¯, R, P, C. Acceptance sampling, Single and Double sampling Plan, Multivariate Analysis, time series analysis., Marko chains.

Part – II : Numerical Optimization

7. Unconstrained Optimization: Optimality conditions, Properties fo Quadratic functions, Simple methods: Direct search, Alternating directions, Steepest Descent, Line Search Algorithms, Conjugate direction and Conjugate gradient methods.

8. Linear constrained Optimization: LPP, Simplex methods, Big - M method, Duality Sensitivity Analysis, Transportation and Assignment problem.
9. Non Linear constrained Optimization: Theory and optimality conditions for equality and inequality constraints, Direct search method, Penalty function methods, Augmented Lagranian method, Sequential LP and QP methods.

References:

1. S. P. Gordon and F. S. Gordon: Contempory Statistics: A Computer Approach. 1994
2. Gentle: Elements of Computational Statistics Springer Vering : New Delhi 2002
3. Milton J. S. and Arnold J. S. : Introduction to Probability and Statistics 3rd Edition MeGraw Hill inc. 1997
4. Ross S. M. : Introduction to Probability and Statistics for Engineers, John Wiley Publishing, 1987
5. Jorge Nocedal and Stephen J: Wright Numerical Optimization, Springer-Verlag, New York 1999
6. R. Fletcher; Practical Methods of Optimization, Wiley, Second edition 1987
7. Douglas C. Mongomery: Introduction to Statistical Quality Control, 4th edition, John Wiley and Sons 2001
8. D. C. Montgomery, G. C. Ranger and N. F. Hubele: Engineering statistics, John Wiley and sons 2000
9. H. M. Wadsworth, K. S. Stephans, B. Godgrey: Modern Methods for Quality Control and Improvement, Wiley, 1986
10. K Deb: Optimization of Engineering Design Algorithms and Examples, prentice Hall of India. 2000
11. S. S. Rao: Engineering Optimization Theory and Practice, Third Edition, John, Wiley and Sons, 1996.
12. R. K. Sundram: First Course in Optimization Theory, Cambridge University Press, 1996

Practical: As a Part of Internal Assessment

Introduction to SAS, SPSS, R, Minitab, Matlab, OM Software.

Matlab/ Minitab Statistical Toolbox

- Graphical representation of data: Bar diagram, Histogram, Pi Gharts, Frequency polygon
- Computation of various measures of central tendency and measures of dispersion
- Random number generation
- Generation a random sample using various sampling techniques
- Compute correlation coefficient between two sets of data points, and plot regression lines.
- Fitting of curves
- Multiple regression techniques to linear and Non linear problems
- Testing of hypothesis – practical Examples Type I and Type II error.
- Computation of Confidence intervals for mean, proportion etc.

- Simulation of Poisson, Binomial, and Normal Distribution
- Examples with small samples and large samples.
- Testing with Chi square, t-distribution, and F-ratio application.

Use of Matlab and /or OM toolbox for numerical optimization

104(B): <u>Introduction to System and Control Theory</u>

1. Existence and uniqueness of Solutions of ODE's, Systems of ODE's
2. Introduction to stability, phase space analysis, Liapunov methods, Asymptotic methods for singularly perturbed equations
3. Boundary value problems, shooting methods for boundary value problems.
4. Continuous and discrete time control systems, stability, controllability, observability, state space description, observers, feedback and dynamic compensators, realization theory, transfer functions, behaviors.

References :

1. J.C. Doyle, B.A. Francis and A.R. Tannenbaum, Feedback Control Theory, Maxwell Macmilan International Edn., 1992.
2. C.L. Phillips and R.D. Harbour, Feedback Control Systems, Prentice Hall, 1985
3. B.C. Kuo, Automatic Control Systems, 4th Edn., Prentice Hall of India, New Delhi, 1985.
4. G. Franklin, J.D. Powell and A. Emami-Naeini, Feedback Control of Dynamic Systems, Addison Wesley, 1986.
5. I.J. Nagrath and M. Gopal, Control System Engineering, 2nd Edn., Wiley Eastern, New Delhi, 1982.

105. <u>Design and Analysis of Algorithms</u>

1. Algorithm Analysis. Methodologies for Analyzing Algorithms. Asymptotic Notation.
2. 2. Basic Data Structures. Stacks and Queues. Vectors, Lists, and Sequences. Trees. Priority Queues and Heaps. Dictionaries and Hash Tables.
3. Search Trees. Ordered Dictionaries and Binary Search Trees. AVL Trees. Bounded-Depth Search Trees.
4. Sorting. Merge-Sort. Quick-Sort. A Lower Bound on Comparison-Based Sorting. Bucket-Sort. Comparison of Sorting Algorithms.
5. Fundamental Techniques. The Greedy Method. Divide-and-Conquer. Dynamic Programming.
6. Graphs. Graph Traversal. Directed Graphs. Depth-First Search. Weighted Graphs. Single-Source Shortest Paths. All-Pairs Shortest Paths. Minimum Spanning Trees.
7. Network Flow and Matching. Flows and Cuts. Maximum Flow. Maximum Bipartite Matching. Minimum-Cost Flow.
8. NP-Completeness. P and NP. NP-Completeness. Important NP-Complete Problems. Approximation Algorithms. Backtracking and Branch-and-Bound.

References :

1. R. Sedgewick, Algorithms in C++, Addison-Wesley, 1992.
2. T. Cormen, C. Leiserson, R. Rivest and C. Stein, Introduction to Algorithms, MIT Press, 2001.
3. M.A. Weiss, Data Structures and Algorithms Analysis in C++, Addison-Wesley, 1999.

106. <u>Programming Language Lab</u>

1. Introduction to C Programming Language : Syntax, data types, pointers, functions, scope rules, bindings, parameter transmission mechanism, storage management, command line arguments.

2. Introduction to C++ : Object Oriented Concepts, classes and objects, constructors and destructors, polymorphism, Inheritance, virtual functions, file handling.

201. <u>Mathematical Modeling and Numerical Simulation</u>

Part-A: (50%)

1. Fundamentals of modeling : Langrange and Eulerian models, basic conservation laws, stress strain and strain rate, constitutive equations.
2. Growth and decay models: population growth (lotka-volterra model), bacteria growth and decay, Interacting species and chemical reactions, satellite problems
3. Network Analysis : Mechanical models, electrical network, Fluid flow including blood flow problem, traffic flow.
4. Diffusion and air pollution models.

Part-B: (50%)

1. Review of continuum model, transport phenomena, air quality modeling, furnace reaction analysis, de-icing helicopter blades (free and moving boundary problems), modeling microwave heating, food contamination from packaging, electron beam lithography, color negative film development, photo copy machine,
2. Selected case studies.

Software Support : Mathematica, LSODE, GNUPLOT, MATLAB

References :

1. M. Braun, C. S. Coleman and D. A. Draw, - Differential Equation Models, Modules in Applied Mathematics, Vol. 1, Springer Verlag, 1978.
2. C. L. Dym and E. S. Ivey, Principles of Mathematical Modeling, Academic Press, 1980. A. Friedman, Mathematics in Industrial Problems, Part 1-9, MA Series, Springer-Verlag, 1991.
3. Y. C. Fung, Biomechanics, Springer Verlag, 1981.

4. J. Keener and J. Sneyd, Mathematical Physiology, Springer-Verlag, 1998.
5. M.S. Klamkin (ed.), Mathematical Modelling. Class Room Notes in Applied Mathematics, SIAM, 1987.
6. E. N. Lightfoot, Transport Phenomenon and Living Systems, John Wiley & Sons, 1974.
7. H. J. White and S. Tauber, System Analysis, W.B. Saunders Company, 1969.
8. J. Crank, Free and Moving Boundary Problems, Oxford Univ. Press, 1987.
9. A. Friedman, Mathematics in Industrial Problems Part 1 – 9, IMA Series, Springer-Verlag, 1991.
10. A. Friedman and W. Littman, Industrial Mathematics for Under- graduates. SIAM Publ. 1994.
11. Y.C. Fung, A First Course in Continuum Mechanics, Prentice-Hall, 1969.
12. A. James (Ed.), An Introduction to Water Quality Modelling, Wiley Pub. 1984.
13. Lecture Notes on Heat and Mass Transfer : A Problem driven approach, M.Sc. in Industrial Mathematics. Univ. Strathclyde, U.K., 1995.

202. <u>Software systems Lab</u>

1. Introduction to Linux operating system, shell programming, programming in awk, introduction to world wide web (HTML,CGI/perl)
2. Programming using JAVA, Graphical User Interface programming using JAVA
3. Document processing using LATEX.
4. Mini-project.

<u>Electives Group A</u> :

203. <u>Parallel Processing and Grid Computing</u>

1. Introduction
   Need for high speed computing, need of parallel computers, features of parallel computers, hardware requirements

2. Solving problem in parallel
   Temporal parallelism, data parallelism, comparison of temporal and data parallelism with specialized processors, inter-task dependency.
3. Structure of parallel computers
   Pipelined parallelism computers, array processors, a generalized structure of parallel computer, shared memory multiprocessors ,message passing multi computers, multi link multi dimensional computing systems
4. Programming Parallel Computers
   Programming message passing multi computers, Programming shared memory parallel computers, Programming vector computers

5. Case studies
   Matrix multiplication, graph theory, n-body simulation, computer vision and image processing applications
6. Grid Computing
   Introduction, grid architecture, resource sharing and allocation, job scheduling, grid security, globas, open grid service architecture.

References :

1. Ananth Grama, Anshul Gupta, George Karypis, Vipin Kumar – Introduction to Parallel Computing (Pearson Edu), 2004 II Ed.
2. V. Rajaraman, C. Siva Ram Murthy – Parallel Computers – Architecture and Programming (PHI) 2000
3. Ian Foster – Designing and building parallel programs (Addison Wesley) 1995
4. V. Rajaraman – Elements of Parallel Computing (PHI) 1990
5. Bart Jacob, Michael Brown, Kentarofukui, Nihar Trivedi – Introduction to Grid Computing (IBM Red Book) 2005

204. <u>Computational Mechanics</u>

1. Introduction to Modern computational mechanics, mapping and iterative methods, stability conversions consistency
2. Numerical and symbolic solutions of ordinary and partial differential equations
3. Finite Difference methods, spectral methods
4. Applications to problems in solid mechanics, fluid mechanics and dynamics

References :

1. Anderson, Tannehill and Pletcher, *Computational Fluid Mechanics and Heat Transfer*, New York: Hemisphere (1984)
2. Wilson and Turcotte, *Advanced Mathematics and Mechanics Applications Using MATLAB*, CRC (1994)

205. <u>Cryptography and Network Security</u>

1. Conventional encryption : Classical Systems, Conventional Encryption: DES, AES, Contemporary Symmetric Ciphers: 3DES, RC4, RC5
2. Public-key encryption : Introduction to Number Theory, Public-Key Cryptography. RSA, Key Management, Message Authentication and Hash Functions, Hash and Mac Algorithms, Digital Signatures and Authentication Protocols
3. Authentication : MAC, Hash and message digests, Digital signatures, Passwords, Kerberos
4. Network security: Authentication Applications, Electronic Mail Security, IP Security, Web Security
5. Other issues: Intruders and Viruses, Firewalls, Digital cash, Secret sharing schemes, Zero-knowledge techniques, Folklore

References :

1. William Stallings -Cryptography and Network Security, 4/E (Prentice Hall) 2006
2. Neal Koblitz, A Course in Number and Theory and Cryptography, Graduate Texts in Mathematics No.114, Springer-Verlag, New York/Berlin/Heidelberg, 1987

206. <u>Artificial Intelligence</u>

1. Definition and introduction to A.I. and A.I. techniques, Problem definition- problem definition as state space search, production system, control strategies, problem characteristics.
2. Problem solving methods: forward and backward reasoning, matching, indexing, search techniques: DFS, BFS. Adding heuristics, hill climbing search techniques, problem reduction, and constraint satisfaction, game playing.
3. Knowledge representation: knowledge representation in Predicate and prepositional logic, resolution in predicate and prepositional logic. Deduction and theorem proving, question answering, structured representation of knowledge, declarative representation, semantic networks, conceptual dependencies, frames and scripts, procedural representation
4. Implementing AI systems: AI languages and their important characteristic.
5. Overview of LISP and Prolog.
6. Introduction to Expert Systems.

References :
1. E. Charniak and D. McDermott. Introduction to Artificial Intelligence , Addison-Wesley, 1985.
2. E. Rich. Artificial Intelligence , McGraw-Hill, 1983.
3. J. Sowa. Conceptual Structures , Addison-Wesley, 1984

207. <u>Mathematics of finance</u>

1. Introduction to options and markets : types of options, interest rates and present values.
2. Black Scholes model : arbitrage, option values, pay-offs and strategies, putcall parity, Black Scholes equation, similarity solution and exact formulae for European options, American options, call and put options, free boundary problem.
3. Binomial methods : option valuation, dividend paying stock, general formulation and implementation.
4. Monte carlo simulation : valuation by simulation
5. Finite difference methods : explicit and implicit methods with stability and conversions analysis, methods for American options - constrained matrix problem, projected SOR, time stepping algorithms with convergence and numerical examples.

6. Lab component : implementation of the option pricing algorithms and evaluations for Indian companies.

References :

1. D.G. Luenberger, Investment Science, Oxford University Press, Oxford, 1998.
2. J.C. Hull, Options, Futures and Other Derivatives, 4th ed., Prentice-Hall, New York, 2000.
3. J.C. Cox and M. Rubinstein, Options Market, Englewood Cliffs, N.J.: Prentice Hall, 1985.
4. C.P Jones, Investments, Analysis and Measurement, 5th ed., John Wiley and Sons, New York, 1996

208. <u>Fuzzy Sets and applications</u>

PART ONE

1. Introduction

History of fuzzy logic, Motivation

2. Basic Concepts of fuzzy logic

- 2.3 Fuzzy Sets
- 2.4 Linguistic Variables
- 2.5 Possibility Distributions
- 2.6 Fuzzy Rules

3. Fuzzy Sets

- 3.2 Fuzzy Sets
- 3.3 Operations of Fuzzy Sets
- 3.4 Properties of Fuzzy Sets
- 3.5 Geometric Interpretation of Fuzzy Sets
- 3.6 Possibility Theory (3.6.1)

4. Fuzzy Relations, Fuzzy Graphs, and Fuzzy Arithmetic

- 4.1 Fuzzy Relations
- 4.2 Composition of Fuzzy Relations
- 4.3 Fuzzy Numbers
- 4.4 Fuzzy Graph
- 4.5 Extension Principle
- 4.6 Arithmetic Operations on Fuzzy Numbers

5. Fuzzy If-Then Rules

- 5.1 Basics
- 5.2 Types of Fuzzy Rules
- 5.3 Fuzzy Rule based Models for Function Approximation (Fuzzy Partition, Defuzzification)
- 5.5 Types of Fuzzy Rule based Models
- 5.6 The Mamdani Model
- 5.7 The TSK Model

6. Fuzzy Implications and Approximate Reasoning

- 6.3 Fuzzy Logic

PART TWO

8. Fuzzy Logic in Control Engineering

10. Analytical Issues in Fuzzy Control

11. Fuzzy Logic and Artificial Intelligence

11.1 Artificial Intelligence
11.3 Fuzzy Logic in Expert Systems
11.4 Intelligent Agents
11.5 Fuzzy Logic in Intelligent Agents
11.6 Fuzzy Logic in Mobile Robot Navigation
11.7 Fuzzy Logic in Emotional Intelligent Agents

12. Fuzzy Logic in Database and Information Systems

12.1 Fuzzy Information
12.2 Fuzzy Logic in Database Systems
12.3 Fuzzy Relational Data Models
12.4 Operations on Fuzzy Relational Data Models

13. Fuzzy Logic in Pattern Recognition

13.1 Introduction
13.2 Unsupervised Clustering
13.3 Fuzzy C-mean Algorithm
13.5 Knowledge based Pattern Recognition
13.6Applications in Medical Image Segmentation

16. Neuro -Fuzzy Systems

Basics of Neural Networks
Neural Networks and Fuzzy Logic
Supervised Neural Network Learning of Fuzzy Models
16.6 Neuro-Fuzzy Modelling Examples.

17. Genetic Algorithms and Fuzzy Logic

17.1 Basics of Genetic Algorithms
17.2 Design Issues in Genetic Algorithms
17.5 Genetic Algorithms based Fuzzy Model Identification
17.6 An Application to Metabolic Modelling
17.7 Industrial Applications

BOOKS:

(i) Fuzzy Logic:Intelligence, Control, And Information
John Yen, Reza Lengari, Prentice Hall Publication

(ii) Fuzzy Sets, Logic and Its Applications
Maria & George Bodjaziev, World Scientific Publ.

(iii) Fuzzy Sets and its Applications
M.Ganesh,

Electives Group-B :

209. <u>Computational Fluid Dynamics</u>

1. Background: Fluid Mechanics
2. Background: Numerical Methods
3. Numerical Methods in Fluid Mechanics
4. System of Equations: Elliptic Problems
5. Unsteady Problems: Viscous diffusion terms: Heat Equation
6. Unsteady Problems: Convection terms: Wave Equation
7. Advanced numerical analysis
8. Boundary layers
9. Incompressible Navier Stokes methods
10. Compressible Euler equation methods

References :

1. Tannehill, Anderson, and Pletcher : Computational fluid mechanics and heat transfer, 2nd Ed.
2. John David Anderson : Computational Fluid Dynamics: The Basics with Applications (McGraw Hill) 1995 Edition: 6
3. Joel H. Ferziger and Milovan Peric: Computational Methods for Fluid Dynamics **(Springer Verlag): 1999 Edition: 2**

210 <u>Topics in Systems and Control</u>

1. Geometric control, general first order representations of linear systems (descriptor systems etc.); behaviors
2. Multidimensional systems
3. Nonlinear systems
4. H-∞ control
5. Robust control.

References :

1. Kwakernak and Sivan Linear Optimal Control, jon Wiley, 1972.
2. Anderson and Moore Linear Optimal Control_Prentice-Hall 1990 B.A.
3. Francis A Course in Hoo Control Theory-Springer Verlag 1987
4. S. S. Sastry. Nonlinear Systems: Analysis, Stability, and Control. Springer-Verlag, 1999.
5. A. Isidori. Nonlinear Control Systems, 3rd Edition. Springer, 1995.
6. M. Vidyasagar. Nonlinear Systems Analysis, 2nd Edition. Prentice-Hall, 1993.
7. H. K. Khalil. Nonlinear Systems, 3rd Edition. Prentice-Hall, 2002.

211. <u>Methods in Signal and image Processing</u>

1. Signal analysis: Multirate signal processing and filter bank theory, signal denoising.
2. Multiscale analysis of images: pyramids, wavelets, anisotropic diffusion; data reduction: fractal image compression, filters; segmentation: thresholds and optimizing

of energy functionals; stochastic geometry, statistical description: Markov random fields, stochastic grammars, incorporation of semantics

3. Pattern Recognition
Classification and description, Patterns and Features extractions with examples, Supervised learning in PR systems, PR approaches, other approaches to PR.

References :

1. A. K. Jain, Fundamentals of digital image processing, Prentice Hall of India, 1989.
2. R.M. Haralick, and L.G. Shapiro, Computer and Robot Vision, Vol-1, Addison Wesley, Reading, MA, 1992.
3. R. Jain, R. Kasturi and B.G. Schunck, Machine Vision, McGraw-Hill International Edition, 1995.
4. W. K. Pratt, Digital image processing, Prentice Hall, 1989.
5. A. Rosenfold and A. C. Kak, Digital image processing, Vols. 1 and 2, Prentice Hall, 1986.
6. H. C. Andrew and B. R. Hunt, Digital image restoration, Prentice Hall, 1977
7. A.V. Oppenheim and Schafer, Discrete Time Signal Processing, Prentice Hall, 1989.
8. John G. Proakis and D.G. Manolakis, Digital Signal Processing: Principle, Algorithms and Applications, Prentice Hall, 1997.
9. L.R. Rabiner and B. Gold, Theory and Application of Digital Signal Processing, Prentice Hall, 1992.
10. J.R. Johnson, Introduction to Digital Signal Processing, Prentice Hall, 1992.
11. D. J. DeFatta, J. G. Lucas and W. S. Hodgkiss, Digital Signal Processing, J Wiley and Sons, Singapore, 1988.
12. Robert J. Schalkoff - Pattern Recognition : Statistical, Structural and Neural Approaches (John Wiley) 1992.

212. <u>Artificial Neural Networks</u>

1. Introduction : biological neurons and memory, structure and functions of single neuron.
2. Artificial neural networks : typical applications of ANN, classification, clustering, vector quntisation, pattern recognition, function approximation, forecasting, control, optimization.
3. Basic approach of working of ANN : training, learning and generalization. Supervised learning : single layer networks, perception – linear seperability, training algorithms, limitations. Multiplayer networks, architecture, training propogation algorithms, applications.
4. Adaptive multiplayer networks : architecture, training algorithms.
5. Recurrent netwoks, Feed forward networks, Radial basis functional networks
6. Unsupervised learning : winner-takes-all-networks, hamming networks, max net, simple competitive learning, vector quantization, counter propogation networks, adaptive resonance theory, kohonen's self organizing maps, principle component analysis.

7. Associated models : hop-field networks, brain-in-a-box network, boltzmann's machine
8. Optimization methods : hop-field networks for TSP, Solution of simultaneous linear equations, iterated gradient descent simulated annealing genetic algorithm

References :

1. K. Mehrotra, C.K. Mohan and Sanjay Ranka, Elements of Artificial Neural Networks, MIT Press, 1997 - [Indian Reprint Penram International Publishing (India), 1997]
2. Simon Haykin, Neural Networks - A Comprehensive Foundation, Macmillan Publishing Co., New York, 1994.
3. A Cichocki and R. Unbehauen, Neural Networks for Optimization and Signal Processing, John Wiley and Sons, 1993.
4. J. M. Zurada, Introduction to Artificial Neural Networks, (Indian edition) Jaico Publishers, Mumbai, 1997

213. <u>Scientific Visualization</u>

1. Introduction to Computer Graphics
   Examples of Graphics applications, Key journals in Graphics, Input and Output Graphics devices, World so-ordinate systems, viewports and world to viewport mapping.
2. Raster Graphics techniques
   Line drawing algorithms, scan-converting circles and ellipses, polygon filling with solid colors and filling patterns, half toning and dithering techniques.
3. Vectors and their use in Graphics
   Operations with vectors, adding, scaling subtracting lineat spaces, dot product, cross product, scalar triplr product, application of dot product, cross product and scalar triple product, applications of vectors to polygons
4. Transformation of pictures
   2D-affine transformations, use of homogeneous co-ordinates, 3-D affine transformation

5. 3-D viewing with synthetics camera.
   Synthetic camera approach, describing objects in view co-ordinates, Perspective and Parallel projections, 3-D clipping.
6. 3-D Graphics, Write frame models
   marching cube algorithms for contour generations and surface generationo from a given data over 2-D / 3-D grid.
7. Hidden line and surface removal, Backface culling
8. Light and shading models, rendering polygonal masks flat, Gauraud, Phone shading
9. Ray tracing
   Overview intersecting ay with plane, square, cylinder, cone, cube and sphere. A drawing shaded pictures of scenes, Reflection and transparency
10. Introduction to multimedia and animation

References :

1. H. Harrington – Computer Graphics, A Programming approach (McGraw Hill) 1986
2. F. S. hill Jr. – Computer Graphics (McMillan) 1990
3. D. F .Rogers – Procedural elements for Computer Graphics (McGraw Hill) 1995.

214. <u>Computational Biology</u>

1. Introduction : Comparative genomics: genomes (DNA and protein sequence), protein structures (geometry), gene regulation (logic, systems), immunology (systems). The nature and complexity of bio-molecular data. The intertwining of algorithms and statistics in the design of genomics tools. The “Gold-Bug” – a metaphor for Bioinformatics.
2. Genomics : Alignment of two bio-molecular sequences. Local and global alignment. Dynamic Programming algorithms. Edit graph theory and visualization of alignments. The fundamental Dynamic Programming recurrence. The Smith-Waterman algorithm. Probability and statistical significance. Evolutionary models. Information theory and the genetic code. The PAM matrices of Margaret Dayhoff, the “mother and father” of Bioinformatics. Statistical assumptions for bio-molecular data. Statistics hypothesis testing. How Sir R.A. Fisher caught Mendel “cheating.”

3. BLAST: An outline of the BLAST statistical theory. Algorithmic speed up: a linear time approximation of the quadratic Smith-Waterman algorithm.
4. Gene prediction. Hidden Markov Model algorithms. Genome Assembly. Assembly algorithms. Comparing assemblies: Of Mice and Dogs and Chimps and Men. Genomic Regulation. Regulatory motifs. Transcription factors. Position weight matrices algorithms. Sea urchin - the First Genome of genomic regulation. A visit to the Sea Urchin.
5. Assembly: Suffix trees data structure and algorithms. Compressing genomic regulatory information. Designing DNA arrays.
6. Protein folding : The computational protein folding problem. Secondary structure prediction algorithms. Classification of protein folds. Protein structure alignment algorithms. Protein missfolding and the Mad Cow Disease.
7. Genetic variation. Single Nucleotide Polymorphism. Haplotypes. Informative SNPs. The Minimum Informative Subset Problem. Guilt by association. Statistical power and disease associations.
8. Systems Biology : Biological complexity. Complex systems and Herbert Simon.s Hora and Tempus problem.
9. Human and pathogens. Comparative immuno-peptidomics of human and their pathogens. A tale and a tour of two genomes: the virus genome and the bacteria genome. Do pathogens evolve their proteome to evade the human immune system?
10. Cancer genomics : Tumor complexity.
11. Gene regulatory networks : Logic functions of genomic cis-regulatory code. Davidson vs. von Neumann: an information processing parallel between the genomic regulatory system and the nervous system.

12. Gene finding in eukaryotes : HMMs, Markov chains, neural nets, and decision trees for gene finding.
13. Protein structure prediction : Secondary structure prediction methods. Signal peptide recognition. Introduction to structure threading.
14. Genome databases and annotation : Representations of sequence data and functional information.

References :

1. J. Setubal and J. Meidanis - Introduction to Computational Molecular Biology (PWS Publishing Company, Boston) 1997.
2. Durbin, Richard, Sean R. Eddy, Anders Krogh, and Graeme Mitchison. *Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids.*(Cambridge University Press), 1999.

104 (A): Computational Statistics and Numerical Optimizations

Part – I : "Computational Statistics Optimization"

1. Introductory Statistics and Probability Concepts:

   Motivation, Data & Decisions, Measurements Uncertainties, Random Processes, Various Statistical Measures. Basic Probability, Sample Space, Events, Axioms of probability, Sample Space with Equal likely outcomes, Conditional Probability, Independent Events.

   Random Variables, Continuous/Discrete Random variables, Exception Variance, Covariance, Conditional distributions, Generating functions.(Moment, Cumulant, Factorial, Probability)
2. Distributions: Bernoulli, Binomial, Uniform Poisson, Normal, Exponential, Chi-square, T and F relationship between them.
3. Regression: Linear, non linear, multiple regression, forward and backward stepwise regression, Logistic, exponential, parabolic regression.
4. Estimation and testing: Point and interval estimation, method of moments, maximum likelihood, Pivotal quantity, Interval estimates, Hypothesis Testing , Significance Levels, Test for testing means, proportion, variance, goodness of fit
5. Simulation: Need of simulation, concept of simulation, random number generation, Monte carlo method, sampling from normal distribution using Box Muller transformation.
6. Industrial and Applied Statistics:

   Statistical Quality Control: control charts – $\bar{X}$, R, P, C. Acceptance sampling, Single and Double sampling Plan, Multivariate Analysis, time series analysis., Marko chains.

Part – II : Numerical Optimization

7. Unconstrained Optimization: Optimality conditions, Properties fo Quadratic functions, Simple methods: Direct search, Alternating directions, Steepest Descent, Line Search Algorithms, Conjugate direction and Conjugate gradient methods.

8. Linear constrained Optimization: LPP, Simplex methods, Big - M method, Duality Sensitivity Analysis, Transportation and Assignment problem.
9. Non Linear constrained Optimization: Theory and optimality conditions for equality and inequality constraints, Direct search method, Penalty function methods, Augmented Lagranian method, Sequential LP and QP methods.

References:

1. S. P. Gordon and F. S. Gordon: Contempory Statistics: A Computer Approach. 1994
2. Gentle: Elements of Computational Statistics Springer Vering : New Delhi 2002
3. Milton J. S. and Arnold J. S. : Introduction to Probability and Statistics 3rd Edition MeGraw Hill inc. 1997
4. Ross S. M. : Introduction to Probability and Statistics for Engineers, John Wiley Publishing, 1987
5. Jorge Nocedal and Stephen J: Wright Numerical Optimization, Springer-Verlag, New York 1999
6. R. Fletcher; Practical Methods of Optimization, Wiley, Second edition 1987
7. Douglas C. Mongomery: Introduction to Statistical Quality Control, 4th edition, John Wiley and Sons 2001
8. D. C. Montgomery, G. C. Ranger and N. F. Hubele: Engineering statistics, John Wiley and sons 2000
9. H. M. Wadsworth, K. S. Stephans, B. Godgrey: Modern Methods for Quality Control and Improvement, Wiley, 1986
10. K Deb: Optimization of Engineering Design Algorithms and Examples, prentice Hall of India. 2000
11. S. S. Rao: Engineering Optimization Theory and Practice, Third Edition, John, Wiley and Sons, 1996.
12. R. K. Sundram: First Course in Optimization Theory, Cambridge University Press, 1996

Practical: As a Part of Internal Assessment

Introduction to SAS, SPSS, R, Minitab, Matlab, OM Software.

Matlab/ Minitab Statistical Toolbox

- Graphical representation of data: Bar diagram, Histogram, Pi Gharts, Frequency polygon
- Computation of various measures of central tendency and measures of dispersion
- Random number generation
- Generation a random sample using various sampling techniques
- Compute correlation coefficient between two sets of data points, and plot regression lines.
- Fitting of curves
- Multiple regression techniques to linear and Non linear problems
- Testing of hypothesis – practical Examples Type I and Type II error.

- Computation of Confidence intervals for mean, proportion etc.
- Simulation of Poisson, Binomial, and Normal Distribution
- Examples with small samples and large samples.
- Testing with Chi square, t-distribution, and F-ratio application.

Use of Matlab and /or OM toolbox for numerical optimization