SRI SATHYA SAI INSTITUTE OF HIGHER LEARNING

(Deemed to be University)

Syllabus for
M.Sc. (Data Science and Computing)

(Effective from the batch 2018-19 onwards)

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M.Sc. (Data Science and Computing)

INTRODUCTION

Data Science has grown to be a domain of scientific study due to the deluge of data generated and acquired through various means. Data driven scientific discovery has contributed a lot to the scientific investigation. Important contributions of data acquisition, visualization and analytics with tools from Machine Learning is seen in domains like Business Intelligence, Financial services, Climate Modeling, Weather forecasting, Medical, Chemo, Bio, Onco informatics etc., and the list goes on.

It is felt that there is a need to produce manpower trained in this stream of scientific study and therefore a course is proposed.

For a Data Science graduate to be of use to the society and specific Industry or organization, he/she should be trained and equipped to develop solutions and applications using computing platform(s) of choice. Therefore, it is felt that a program for training young individuals in the area of Data Science should take care of their readiness to meet this requirement.

This programme is designed specifically for graduates in Computer Science and Computer Applications. Having Degrees like B.Sc.(Computer Science), BCA and B.Tech./B.E. in Computer Science.

In order to equip the students to continue with higher studies in academic disciplines for Ph.D., the candidates undergoing the course should also be comfortable to take the National Level qualifying examinations like UGC NET, GATE etc.

The course structure and syllabus provides good foundations and working knowledge in Statistics, Computer Science, Machine Learning, Data Visualization, Big data Analytics, Distributed Systems and Programming languages R, Python and platforms like Hadoop, SPARK etc.

All the subjects are to be awarded for 4 credits.

For some of the subjects the credits are split between Theory and Practical based on the necessity. For 1 credit of practical 2 periods are allocated.

A few subjects are purely practical as they are intended to improve programming skill of the students in a specific language or platform. Eight periods are allotted for a four credits practical course.

In order to facilitate development of skill in problem solving and to provide exposure to applications of the concepts learnt in a given Theory subject a facility for Tutorial/Practical is also provided within the curriculum. One or two periods per week is provided for Tutorial/Practical for every subject based on the requirement.

In order to cater to individual needs and preferences, electives courses are provided in the areas of Cloud Computing, Artificial Intelligence, Information Retrieval, Deep Learning, Computer Graphics, Image Processing, Computer Vision, Robotics etc. All electives are of 4 credits. Based on necessity the credits may be split between Theory and Practical.

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DEPARTMENT OF MATHEMATICS & COMPUTER SCIENCE

SCHEME OF INSTRUCTION AND EVALUATION

M.Sc. (Data Science and Computing)

(Effective 2018-19 batch onwards)

Paper Code	Title of the Paper	Credits	Hours	Modes of Evaluation	Types of Papers	Maximum Marks
Semester I						
MDSC-101	Computational Linear Algebra	**4**	5	IE2	T	100
MDSC -102	Inferential Statistics	**4**	5	IE2	T	100
MDSC -103	Multivariate Analysis	**4**	5	IE2	T	100
MDSC -104	Computer Organization and Architecture	**4**	5	IE2	T	100
MDSC -105	Design and Analysis of Algorithms	**4**	5	IE2	T	100
MDSC-106	Software lab in Python	**4**	8	I	P	100
PAWR-100	Awareness Course – I: Education for Life	**1**	2	I	T	50
		25 credits	**35** hours			**650** Marks
Semester II						
MDSC-201	Stochastic Processes	**4**	5	IE2	T	100
MDSC-202	Regression Methods	**4**	5	IE2	T	100
MDSC-203	Optimization Techniques	**4**	5	IE2	T	100
MDSC-204	Distributed Systems	**4**	5	IE2	T	100
MDSC-205	Software Engineering	**4**	5	IE2	T	100
MDSC-206	Software lab in R	**4**	8	I	P	100
PAWR-200	Awareness Course – II: God, Society and Man	**1**	2	I	T	50
		25 credits	**35** hours			**650** marks

Paper Code	Title of the Paper	Credits	Hours	Modes of Evaluation	Types of Papers	Maximum Marks
Semester III						
MDSC -301	Machine Learning	**3**	3	IE2	T	100
MDSC -301 (P)	Practicals: Machine Learning	**1**	2	I	P	50
MDSC-302	Big Data Analytics	**3**	3	IE2	T	100
MDSC-302(P)	Practicals: Big Data Analytics	**1**	2	I	P	50
MDSC-303	Data Visualization	**2**	2	IE2	T	50
MDSC-303(P)	Practicals: Data Visualization	**2**	4	I	P	50
MDSC-304	Hadoop Programming	**2**	2	IE2	T	50
MDSC-304(P)	Practicals: Hadoop Programming	**2**	4	I	P	50
MDSC-305	Seminar	**1**	1	I	--	50
MDSC-404	Project Interim Review*	**--**	--	I	PW	50*
PAWR-300	Awareness Course –III: Guidelines for Morality	**1**	2	I	T	50
		18 credits	**25** hours			**600** marks
Semester IV						
MDSC -401	Elective - I	**4**	5**	IE2/I	T/P	100**
MDSC-402	Elective - II	**4**	5**	IE2/I	T/P	100**
MDSC-403	Elective - III	**4**	5**	IE2/I	T/P	100**
MDSC-404	Project*	**10**	18	E2	PW	200*
MDSC-405	Comprehensive Viva voce	**1**	--	E1	V	50
PAWR-400	Awareness Course –IV: Wisdom for Life	**1**	2	I	T	50
		24 credits	**35**** hours			**600**** marks
	GRAND TOTAL	**92** credits	**130**** hours			**2500**** marks

Notes:

1. (*) Project work MDSC-404 will commence in 3rd semester and continue to 4th semester with the allocation of 50 Marks in third semester and 150 marks in the fourth semester towards the project work.

2. (*) For students undertaking project (MDSC-404), the evaluation will be based on three components, viz.

    a. A preliminary review of an interim report in respect of the project work at the end of 3rd semester will be conducted for 50 marks and the marks allocated will be carried forward to 4th semester MDSC-404 for overall grading.

b. A project Viva voce by a committee constituted by the Head of the Department as per regulations will be conducted for 50 marks in the 4th semester.
c. An E2 type evaluation of the project report at the end of 4th semester will be for 100 marks.

3. (*)Total marks for the project will be 200 marks against total credits of 10 accounted in 4th semester.

4. A number of electives have been identified and listed. These courses are identified with a special code. All these subjects are also allocated 4 credits each.

5. (**) Elective courses may have the credits split between Theory and Practical based on the chosen treatment of the subject and its requirement. Accordingly, the number of periods allocated for the subject (Th + Prac) will vary. That will influence the total number of hours allocated for the subject and the total marks for the semester too.

6. The choice of electives being offered in each semester is at the discretion of the Head of the Department.

Indicator	Legend
IE1	CIE and ESE ; ESE single evaluation
IE2	CIE and ESE ; ESE double evaluation
I	Continuous Internal Evaluation **(CIE)** only Note: 'I' does not connote 'Internal Examiner'
E	End Semester Examination **(ESE)** only Note: 'E' does not connote 'External Examiner'
E1	ESE single evaluation
E2	ESE double evaluation

Continuous Internal Evaluation (CIE) & End Semester Examination

Indicator	Legend
T	Theory
P	Practical
V	Viva voce
PW	Project Work
D	Dissertation

PS: Please refer to guidelines for 'Modes of Evaluation for various types of papers', and 'Viva voce nomenclature & scope and constitution of the Viva voce Boards'.

Semester I

[MDSC-101]- Computational Linear Algebra 4 Credits

	Course Objective: The course focuses on iterative techniques for solving large sparse linear systems of equations which typically stem from the discretization of partial differential equations. In addition, computation of eigenvalues, least square problems and error analysis will be discussed.	
	Course Outcome: Develop the skill set to ● explain and fluently apply fundamental linear algebraic concepts such as matrix norms, Eigen- and singular values and vectors; ● estimate stability of the solutions to linear algebraic equations and eigenvalue problems; recognize matrices of important special classes, such as normal, unitary, Hermitian, positive definite and select efficient computational algorithms based on this classification;	
Unit	**Topic**	**Hrs.**
1	Matrices and Gaussian Elimination, Matrix Notation, Matrix Multiplication Triangular Factors, Row Exchanges, Inverses and Transposes, Special Matrices and Applications	8
2	Vector Spaces, Subspaces, Solving Ax = 0, and Ax = b, Linear Independence, Basis and Dimension, Four Fundamental Subspaces, Graphs and Networks, Linear Transformations	10
3	Orthogonality - Orthogonal Vectors and Subspaces, Cosines and Projections onto Lines, Least Squares, Orthogonal Bases and Gram - Schmidt, Fast Fourier Transform	10
4	Determinants - Properties of Determinant, Formulas for the determinant, Application of Determinants.	8
5	Eigenvalue Problems: Overview of eigenvalue problems – Diagonalization of a Matrix, Difference Equations and Powers, Differential Equations, Complex Matrices, Similarity Transformations, Positive Definite Matrices - Minima, Maxima, Saddle Points, Tests for Positive Definiteness, SVD, Minimum Principles, Finite Element Method	10
6	Computation with Matrices - Matrix Norms, Condition Numbers Computation of Eigenvalue, Iterative Method for Ax = b	6

Key Text Linear Algebra and Its Applications - by Gilbert Strang, 4th Edition, Thomson Brooks/Cole.		
REFERENCES 1. Numerical Linear Algebra, Allaire, Grégoire, Kaber, Sidi Mahmoud, Springer (2008) 2. Applied Numerical Linear Algebra, by James W. Demmel, SIAM (1997) 3. Numerical Linear Algebra, by Lloyd Trefethen and David Bau III, SIAM, 1997. [Lectures 1-29, 32-35 covered in chapter 1-6 of the Text Book]		

[MDSC-102] – Inferential Statistics 4 Credits

	Course Objective: ● To make students understand and make inferences based on relations found in the sample, to relations in the population. ● For each individual statistical test students should be able to understand how it works, for what data and design it is appropriate and how results should be interpreted.		
	Course Outcome: Develop the skill set to ● Acquire an understanding of the concepts of sampling distribution, statistical reliability and hypothesis testing, as well as the principles and procedures of the various tests of significance. ● Write python program to carry out data analyses; ● Interpret the output of such analysis.		
Unit	**Topic**	**Details**	**Hrs.**
1	Central Limit Theorem	Expectations of Continuous Random Variables, General Definition of Expectation, Moments of Continuous Random Variables, Conditional Expectation, Central Limit Theorem - Normal Approximation, Applications to Sampling	10
2	Basic Principles & Estimation	Types of Problems, Risk Function, Mean Risk, Choice of Loss functions, Unbiased Estimates, Efficiency, Asymptotic Efficiency, Maximum Likelihood Estimation, Vector Parameters, Confidence Intervals	12
3	Testing Hypotheses	Neyman-Pearson Lemma, Composite Hypotheses, Sequential Tests, Likelihood ratio tests, Goodness of fit tests	10
4	Linear Models - Estimation	Linear Regression, Nonlinear Regression, Multiple Linear Regression, Matrix Methods, Properties of Least Squares Estimators, Analysis of Variance mode	10
5	Linear Models - Testing	General Linear Hypothesis, Confidence Intervals for regression coefficients, Simple Linear Regression, Multiple Linear Regression, Analysis of Variance	10
***Bayesian Methods are excluded throughout**			
Key Text(s): Introduction to Probability Theory by Paul G. Hoel, Sidney C. Port, Charles J. Stone Chapter: 7: Houghton Mifflin Company, BOSTON Introduction to Statistical Theory by Paul G. Hoel, Sidney C. Port, Charles J. Stone Chapters: 1, 2.1 - 2.7, 3.1 - 3.5, 4.1 - 4.7, 5			

[MDSC-103]	Multivariate Analysis	4 Credits
	Course Objective: To learn multivariate statistical methods that uncover surprising but valid linkages between variables and explain and predict their measured values.	
	Course Outcome: Develop the skill set to ● select appropriate methods of multivariate data analysis, given multivariate data; ● Write python program to carry out multivariate data analyses; ● Interpret the output of such analysis.	
Unit	**Chapters**	**Hrs**
0	Bivariate: Binomial, Poisson , exponential and normal distributions, conditional and marginal distributions	6
1	Matrix algebra, random vectors and random sampling	6
2	Multivariate normal distribution, (singular and non-singular) marginal and conditional distributions; linear transformations, characteristics function; maximum likelihood estimators of the parameters and their sampling distributions.	10
3	Tests of hypothesis about the mean vector of normal distribution, Hotelling's T^2- statistics, its distribution and applications; Wishart distribution and its properties	10
4	Introduction to principle components, Graphing the Principal Components; factor model and estimations; canonical correlation and canonical variables;	10
5	Cluster analysis; classification of populations.	10

Key text: Applied Multivariate Statistical Analysis (AMSA) by Richard Johnson and Dean Wichern, (6th edition). Pearson Publications
Chapters: 2.1-2.6, 3.3-3.6, 4.1-4.4, 5.1-5.5, 8.1-8.4, 10.1-10.4, 10.6, 12.3, 12.4, 12.7

Reference books:

1. Anderson, T. W., An Introduction to Multivariate Statistical Analysis, Wiley, 2003.
2. Kshirsagar, A. M., Multivariate Analysis, Marcel Dekker, 1972.

[MDSC-104] – Computer Organization and Architecture 4 Credits

	Course Objective: To study and understand the basic of computer organization and architecture (CPU, memory, I/O).		
	Course Outcome: Develop the skill to ● Evaluate the merits and pitfalls in computer performance measurements ● Evaluate impact of ISA on cost/performance of computer design. ● Enhance the performance and take advantage of Instruction Level Parallelism and using this with minimum hazards. ● Understand memory hierarchy and its impact on computers performance. ● Experience of executing programs in simulator.		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	Introduction	Performance, the Power Wall, the Switch from Uniprocessors to Multiprocessors, Historical Perspective.	6
2	Instruction Set Design	Operations of the Computer Hardware, Operands of the Computer Hardware, Signed and Unsigned Numbers, Representing Instructions in the Computer, Logical Operations, Instructions for Making Decisions, Supporting Procedures in Computer Hardware, MIPS Addressing for 32-Bit Immediates and Addresses, Parallelism and Instructions.	12
3	Arithmetic for Computers	Addition and Subtraction, Multiplication, Division, Floating Point representation, Computer Arithmetic.	8
4	The Processor	Logic Design Conventions, Building a Datapath, Pipelining, Pipelined Datapath and Control, Data Hazards: Forwarding vs. Stalling, Control Hazards, Exceptions	12
5	Memory Hierarchy	The Basics of Cache, Measuring and Improving Cache Performance, Virtual Memory, A Common Framework for Memory Hierarchies, Parallelism and Memory Hierarchies: Cache Coherence	14
Key Text(s): Computer Organization and Design: The Hardware/Software Interface by Patterson, David A. and Hennessy, John L, MIPS - Fourth Edition, Elsewhere Publications			
Chapters: 1, 2, 3, 4, 5			

REFERENCE BOOKS:

1. Randal E. Bryant and David R. O'Hallaron, Computer Systems: A Programmer's Perspective, Prentice Hall, 2011 (Second Edition).
2. Computer Architecture And Organization – John P. Hayes, McGraw Hill Edition.

[MDSC-105] – Design and Analysis of Algorithms 4 Credits

Course objective:

- to develop problem solving skills by analyzing various problems and learning the techniques for implementation.
- Analyze the asymptotic performance of algorithms.
- Write rigorous correctness proofs for algorithms. Demonstrate a familiarity with major algorithms and data structures. Apply important algorithmic design paradigms and methods of analysis. Synthesize efficient algorithms in common engineering design situations.

Course outcome:

Develop the skill to

- Analyze the problem.
- Implement various problem solving methods.
- Write algorithms for implementing solutions.
- Discriminate between different problem solving approaches.
- For a given algorithms analyze worst-case running times of algorithms based on asymptotic analysis and justify the correctness of algorithms .

Unit	Unit Title	Unit Contents	No. of Periods
1	Introduction	Algorithm, Algorithm Specification, and Performance Analysis. Randomized Algorithms. Basic Data Structure: Stacks and Queues, Trees, Dictionaries, Priority Queues, Sets and disjoint Set Union, Graphs.	8
2	Divide and Conquer	Binary search, Finding MIN and MAX, Merge sort, Quick sort, Selection, Strassen's Matrix Multiplication, convex Hull.	6
3	The Greedy method	Knapsack problem, Tree vertex splitting, Job Sequencing with deadlines, minimum cost spanning Trees, optimal merge patterns, single source shortest path.	8
4	Dynamic Programming	General Method, Multistage Graph, All pairs shortest path, single source shortest path, Optimal Binary Search Trees, 0/1 Knapsack, reliability design, the traveling salesperson problem.	8
5	Basic traversal and Search Techniques	Techniques for Binary Trees, graphs, spanning tress, DFS	6

6	Backtracking	General Method, 8-queens problem, sum of subsets, Graph coloring, Hamiltonian cycles, Knapsack problems. Branch and Bound: the general method, 0/1 Knapsack problem, TSP	8
7	NP-Hard and NP-Complete Problems	Basic concepts, Cooks theorem, NP-Hard graph problems, NP-Hard Scheduling problem, NP-Hard code generation problems, some simplified NP-Hard problems	8

Key Text:

E Horowitz, S Sahani S Rajasekaran, "Fundamentals of Computer Algorithms",
2E, Universities Press. Chapters: 1,2,3,4,5,6,7 and 11.

Reference Texts:

1. AHO, Hopcraft, Ullman, "The Design Analysis of Computer Algorithms".
2. Thomas H. Cormen, Charles E. Leiserson, R.L. Rivest, Algorithms, Prentice Hall of India Publications, New-Delhi.
3. Sara Baase and Allen Van Gelder, Computer Algorithms: Introduction to Design and Analysis, Pearson education (Singapore) Pte. Ltd, New Delhi.
4. Alfred V. Aho, John E. Hopcroft, Jeffrey D. Ullman, The Design and Analysis of Computer Algorithms, Pearson Education (Singapore) Pte. Ltd New Delhi.

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[MDSC-106]- Software Lab in Python 4 Credits

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Semester –II

<table>
<tr><th colspan="3">[MDSC-201] -Stochastic Processes 4 Credits</th></tr>
<tr><td></td><td colspan="2">Course Objective:
Stochastic models are among the most widely used tools in operations research and management science. Stochastic processes and applications can be used to analyse and solve a diverse range of problems arising in production and inventory control, resource planning, service systems, computer networks and many others.</td></tr>
<tr><td></td><td colspan="2">Course Outcome:
Develop the skill set to
• elucidate the power of stochastic processes and their range of applications;
• demonstrate essential stochastic modelling tools including Markov chains and Gaussian processes;
• formulate and solve problems which involve setting up stochastic models</td></tr>
<tr><th>Unit</th><th>Topic</th><th>H.rs</th></tr>
<tr><td>1</td><td>Markov Chains : classification of states, transition functions, existence and uniqueness of stationary distribution, expected time between successive visits to a state - positive recurrent states,</td><td>14</td></tr>
<tr><td>2</td><td>Convergence to the stationary distribution, Birth and death chains, Branching and queuing chains.</td><td>12</td></tr>
<tr><td>3</td><td>Markov Processes: Continuous time discrete state Markov processes, Poisson processes, birth and death processes</td><td>12</td></tr>
<tr><td>4</td><td>Gaussian processes, The Wiener process; continuity of the mean, covariance and sample functions.</td><td>14</td></tr>
<tr><td colspan="3">Key text: Introduction to Stochastic Processes by Paul G. Hoel, Sidney C. Port and Charles J. Stone, Houghton Mifflin Company, BOSTON, 1972.
Chapters: 1-4.</td></tr>
<tr><td colspan="3">References:
1. Ross, S., Stochastic Processes, second edition, John Wiley, 1996.
2. Goswami, A. and Rao, B. V., A Course in Applied Stochastic, Processes, Hindustan Book Agency, 2006.</td></tr>
</table>

[MDSC-202] - Regression Methods 4 Credits			
	Course Objectives: Regression methods is one of the most powerful methods in statistics for determining the relationships between variables and using these relationships to forecast future observations. Regression models are used to predict and forecast future outcomes. Its popularity in finance is very high; it is also very popular in other disciplines like life and biological sciences, management and engineering.		
	Course Outcome: Develop the skill set to ● develop a deeper understanding of the linear regression model and its limitations; ● diagnose and apply corrections to some problems with the generalized linear model found in real data;		
Unit	**Topic**	**Details**	**Hours**
1	Simple Linear Regression	Model, Least Squares Estimation, Hypothesis Testing, Interval Estimation, Prediction of new observations, Coefficient of Determination, Regression through Origin, Estimation by Maximum Likelihood, Application examples	10
2	Multiple Linear Regression	Models, Estimation of model parameters, Hypothesis Testing, Confidence Intervals, Prediction of new observations, Hidden Extrapolation, Standardized Regression Coefficients, MultiCollinearity, Application examples	10
3	Model Adequacy Checking	Residual Analysis, Press Statistic, Detection and treatment of Outliers, Lack of fit	10
4	Model Adequacy Correction	Variance stabilizing transformations, Transformations to Linearize, Analytical methods for selecting a transformation, Generalized and Weighted Least squares	10
5	Generalized Linear Models	Logistic Regression, Poisson Regression, Generalized Linear Model	12

Key Text: Introduction to Linear Regression Analysis by Douglas C. Montgomery, Elizabeth A. Peck and G. Geoffrey Vining, 5th Edition, Wiley. Chapters: 1 - 5, 13.

References: Applied Regression Analysis - Norman Draper and Harry Smith, 3rd Edition

	[MDSC-203] – Optimization Techniques 4 Credits		
	Course Objective: To study of model formulation and discussion of documented real-world applications. Study of mathematical programming algorithms. Apply the mathematical results and numerical techniques of optimization theory to concrete Engineering problems.		
	Course Outcome: Develop the skill set to ● become a mathematical translation of the verbal formulation of an optimization problem; ● discovery, study and solve optimization problems; ● Investigate, study, develop, organize and promote innovative solutions for various applications.		
Unit	**Title**	**Contents**	**Hrs**
1	Introduction	Introduction to Linear Programming Problem (LPP), Graphical method, simplex method, Two Phase method, degeneracy, alternative optima, Graphical sensitivity analysis	10
2	Linear Programming	LP-Duality And Sensitivity Analysis: Definition of Dual, Primal-Dual Relationships, Dual Simplex Sensitivity or Post Optimal Analysis.	8
3	Advanced Linear Programming	Revised Simplex Method, Bounded-Variable Algorithm, Duality, Parametric programming	10
4	Integer Programming	Formulation and Applications-Cutting Plane Algorithm-Branch and Bound Method.	8
5	Deterministic Inventory models	EOQ models, EOQ with price breaks, Multi-Item EOQ with storage limitation.	8
6	Queuing Systems	Pure birth and Pure death models, generalized Poisson queuing model, single server models.	8
Key Text(s): Operations Research- An Introduction, by Hamdy A.Taha , 9th Edition, Pearson Education - 2012.			
Chapters: 2 to 4, 7.1-7.6, 9, 13.1-13.3, 18.1- 18.6.2			
REFERENCE BOOKS: Optimization Techniques , by L.R.Foulds, Springer ,Utm , 1981			

[MDSC-204] – Distributed Systems 4 Credits

<table>
<tr><td></td><td colspan="3">Course Objective:
• To provide students with contemporary knowledge in parallel and distributed systems.
• To equip students with skills to analyze and design parallel and distributed applications. 3. To provide master skills to measure the performance of parallel and distributed algorithms</td></tr>
<tr><td></td><td colspan="3">Course Outcome:
Students will be able to
● Apply the principles and concept in analyzing and designing the parallel and distributed system
● Reason about ways to parallelize problems.
● Gain an appreciation on the challenges and opportunities faced by parallel and distributed systems.
● Understand the middleware technologies that support distributed applications such as RPC, RMI and object based middleware.
● Improve the performance and reliability of distributed and parallel programs.</td></tr>
<tr><td>Course Code: 204</td><td>Unit</td><td>Description</td><td>No. of Periods</td></tr>
<tr><td></td><td>I</td><td>Characterization of Distributed Systems: Introduction, Examples of Distributed Systems, Trends In Distributed Systems, Focus On Resource Sharing, Challenges, Case Study: The World Wide Web. System Models: Physical Models, Architectural Models, Fundamental Models</td><td>10</td></tr>
<tr><td></td><td>II</td><td>Networking and Internetworking: Types Of Network, Network Principles, Internet Protocols, Case Studies: Ethernet, Wifi And Bluetooth. Interprocess Communication: The API For The Internet Protocols, External Data Representation And Marshalling, Multicast Communication, Network Virtualization: Overlay Networks, Case Study: MPI</td><td>10</td></tr>
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	III	Remote Invocation: Request-Reply Protocols, Remote Procedure Call, Remote Method Invocation, Case Study: Java RMI Indirect Communication: Group communication, Publish-subscribe systems, Message queues, Shared memory approaches Web Services: Web services, Service descriptions and IDL for web services, A directory service for use with web services, XML security, Coordination of web services, applications of web services.	10
	IV	Coordination and Agreement: Distributed mutual exclusion, Elections Coordination and agreement in group communication, Consensus and related problems Name Services: Name services and the Domain Name System, Directory services, Case study: The Global Name Service, Case study: The X.500 Directory Service. Time and Global States: Clocks, events and process states, Synchronizing physical clocks, Logical time and logical clocks, Global states, Distributed debugging	11
	V	Distributed Transactions: Flat and nested distributed transactions, Atomic commit protocols, Concurrency control in distributed transactions, Distributed deadlocks. Replication: System model and the role of group communication, Fault-tolerant services, Case studies of highly available services: The gossip architecture, Bayou and Coda, Transactions with replicated data Mobile And Ubiquitous Computing: Association, Interoperation, Sensing and context awareness, Security and privacy, Adaptation, Case study: Cooltown	11

Text Book:

1. George Coulouris, Jean Dollimore, Tim Kindberg, Gordon Blair, Distributed Systems - Concepts and Design (Unit I-Unit VI) Publisher: Addison Wesley - 2012

References:

2. A. Taunenbaum, "Distributed Systems: Principles and Paradigms"
3. G. Coulouris, J. Dollimore, and T. Kindberg, "Distributed Systems: Concepts and Design", Pearson Education

[MDSC-205] – Software Engineering 4 Credits

	Course Objective: The main objective of the course is to introduce to the students about the product that is to be engineered and the processes that provides a framework for the engineering methodologies and practices. 1. To provide the knowledge of software engineering discipline. 2. To apply analysis, design and testing principles to software project development.3. To demonstrate and evaluate real time projects with respect to software engineering principles.		
	Course Outcome: Students will be able to ● Understand and demonstrate basic knowledge in software engineering. ● Identify requirements, analyze and prepare models. ● Plan, schedule and track the progress of the projects ● Design & develop the software projects. ● Identify risks, manage the change to assure quality in software projects. ● Apply testing principles on software project and understand the maintenance concepts.		
Unit	**Unit Title**	**Description**	**No. of Periods**
I	Software Engineering Basics	Software life cycle processes, Requirement Engineering , Project Management, Software metrics, testing and maintenance	8
II	Software Architecture	Definitions and foundations in Software architecture, Separation of concerns. Design patterns, Object-Oriented design practices, Refactoring	8
III	UML Modelling	Introduction, Use case modelling, Scenarios, Activity diagrams, Class analysis and object diagrams, Interaction diagrams, State diagrams, Component and deployment, Use Case modelling, Role of Use Cases, Example: use case modelling, Class Diagram, Relationships in class, diagrams, Generalisation in class diagrams, Class Diagram Analysis – Attributes, Class Diagram: Operations, Sequence Diagram, State	12

		Diagram, State Transition Diagram: Example, Component Diagram ,Deployment Diagram	
IV	Agile Software Development	Values, principles, stakeholders, Agile Principles: Twelve Practices of Agile process, Communication, Planning, Agile Product Management: Estimation, Quality, Risk, Metrics and Measurements, Agile Requirements: User Stories, Backlog Management, Agile Architecture: Feature-Driven Development, Agile Risk Management: Risk and Quality Assurance, Agile Testing: Test-Driven Development, User Acceptance Test	12
V	Case Studies	Agile concepts: Scrum, Extreme Programming , Lean , and Kanban , Introduction to Devops for agile software development (Continuous delivery)	12

Key Text :

1.Roger.S.Pressman, "Software Engineering - A Practitioner's approach", 7th Edition, MGH higher Education

Reference Text:

1.An Integrated Approach To Software Engineering by PankajJalote, 3rd Edition, Narosa Publishing House, New Delhi, 2005

2. Software Architecture in Practice, Len Bass, Paul Clements, Rick Kazman.

3.Documenting Software Architectures: Views and Beyond Paul Clements, Felix Bachmann, Len Bass, David Garlen, James Ivers, Reed Little, Robert Nord, Judith Stafford

4.B3 - Gamma, Helm, Johnson, Vlissides - Design Patterns: Elements of Reusable Object-Oriented Software

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Semester –III

[MDSC-301] - Machine Learning [Theory: 3 credits; LAB: 1 credit]

	Course Objective: 1. To introduce students to the basic concepts and techniques of Machine Learning. 2. To become familiar with regression methods, classification methods, clustering methods. 3. To become familiar with Dimensionality reduction Techniques	
	Course Outcome: Students will be able to ● Gain knowledge about basic concepts of Machine Learning ● Identify machine learning techniques suitable for a given problem ● Solve the problems using various machine learning techniques ● Apply Dimensionality reduction techniques. ● Design application using machine learning techniques (As a part of Lab).	
Unit	**Description**	**No. of Periods**
1	Machine Learning: Introduction, Types of machine learning, supervised learning-Basics, Over fitting the training data.	3
2	Nearest Neighbor Methods, Validation: Nearest neighbor prediction, K-nearest neighbor methods, Weighted neighbor methods, the curse of dimensionality, Computational considerations, Connection to density estimation. Bayesian Classifiers, Naive Bayes classifier, Classifiers and Error Rates	7
3	Linear regression: Optimization, Increasing the number of features, Over fitting and method Selection, linear classification: Characterizing a linear classifier, Training a linear classifier, Logistic regression	8
4	Support vector machines (SVMs), Linear SVM, Lagrangian optimization and duality, The soft margin SVM, The kernel Trick, VC dimension	6
5	Decision Trees: Predictor form, Training Decision trees, Decision tree classifiers, Learning Decision trees, Decision stumps.	6
6	Ensemble Methods: Stacking, Bagging and Boosting	6

7		4
	Clustering: K-means, Agglomerative, **Gaussian Mixtures and EM**	

Key Text :

1. A Course in Machine Learning by Hal Daumé III
Chapters: 1, 3, 7, 9, 10, 11, 13, 15.
2. Rogers and Girolami, A First Course in Machine Learning

Reference Books:

1. Hastie, Tibshirani, and Friedman, The Elements of Statistical Learning
2. Barber, Bayesian Reasoning and Machine Learning
3. Mitchell, Machine Learning

Chrisopher Bishap, Pattern Recognition and Machine Learning, Springer,2006
References: https://see.stanford.edu/Course/CS229

[MDSC-301 (P)] - Machine Learning Practical: 1 credit

Algorithms/Exercises from different units in the syllabus will be implemented in Lab. This will be evaluated internally.

[MDSC-302] – Big Data Analytics [Theory: 3 credits; LAB: 1 credit]

	Course Objective: ● To provide an overview of an exciting growing field of big data analytics. ● To introduce the tools required to manage and analyze big data like Hadoop, NoSql MapReduce. ● To teach the fundamental techniques and principles in achieving big data analytics with scalability and streaming capability. ● To enable students to have skills that will help them to solve complex real-world problems in for decision support.		
	Course Outcome: Students will be able to ● Understand the key issues in big data management and its associated applications in intelligent business and scientific computing. ● Acquire fundamental enabling techniques and scalable algorithms like Hadoop, Map Reduce and NO SQL in big data analytics. ● Interpret business models and scientific computing paradigms, and apply software tools for big data analytics. ● Achieve adequate perspectives of big data analytics in various applications like recommender systems, social media applications etc.		
S. No	**UNIT**	**Topics**	**No. of Periods**
1	Introduction to Big Data	Big Data - Why and Where?, Characteristics of Big Data and Dimensions of Scalability, Getting value out of Big Data, Foundations for Big Data Systems and Programming	4
2	Similarity Algorithms	Near-Neighbor search, Shingling, Similarity preserving summary, Locality sensitive functions, Distance measures, Locality sensitive hashing and its applications to different distance measures, Applications of Locality sensitive hashing	10

3	Streaming Data	Stream Data model, Sampling data in a stream, Filtering streams, Counting distinct elements in a stream, Application of stream algorithms in counting.	12
4	Link Analysis	Page Rank, Computation of Page Rank, Topic sensitive page rank, Link spam.	6
5	Frequent Item sets	Market-Basket model, A-priori algorithm, Larger datasets in main memory, Limited pass algorithms, Counting frequent sets in a stream	8
Text Book		Mining Massive Datasets by Anand Rajaraman Stanford University Press – 2014 – Chapters 1 - 5	

[MDSC302 (P)] – Big Data Analytics **Practical - 1 Credit - This will be evaluated internally.**

List of Assignments:

1. MapReduce Implementation
2. Bloom Filter Implementation
3. Jaccard Similarity implementation:
4. Page Rank algorithm implementation
5. Min Hash Implementation
6. Clustering Algorithm – K means

[MDSC-303] – Data Visualization [Theory: 2 credit; LAB: 2 credits]

	Course Objective: ● Design effective data visualizations in order to provide new insights into a research question or communicate information to the viewer. ● Find and select appropriate data that can be used in order to create a visualization that answers a particular research question. ● Understand how Cultures of Practice influence the way data may be collected, described, or formatted in order to align their own data management practices with those of their discipline		
	Course Outcome: Students will be able to ● Properly document and organize data and visualizations in order to prepare them for reuse. ● Handle data and data visualizations in a manner that demonstrates an understanding of ethical considerations surrounding data (including data storage, citation, and protection).		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
	Effective Communication of Quantitative Information	Purpose, Scope, Communication Style, Quantitative relationships, Differing roles of tables and graphs	6
	Visual Perception and Graphical Communication	Mechanics of Sight, Applying visual attributes to design, Gestalts principle, Fundamental variations of tables, Fundamental variations of graphs	10
	General Design principles for Communication	Organizing, Highlighting, Integration, Table design, General graph design, Component level graph design, Multi-Variable display	10
Key Text - Show me the numbers: Designing tables and graphs to enlighten by Stephen Few, 2nd Edition **Chapters** - 1 to 11			
Reference Text - The Visual display of quantitative information by Edward R. Tufte, 2nd Edition			

[MDSC-303 (P)] – Data Visualization Practical 2 Credit

This will be evaluated internally.

Unit I - Fundamentals: Introduction to Matplotlib, importing libraries in python, Basic Scatter plot, Creating Axes, Line plot

Unit II - Customization: Title & Axis labels, Equations in text, Formatting Axis ticks, Customizing Tick Labels, Adding Legend, Annotations, Plot Styles

Unit III - Types of Visualizations: Histograms, Bar Graphs, Box and Whisker Plots, Pit charts, 2D histograms, Images, Colour maps, 3D Line and Scatter plots, Adding animation.

[MDSC 304 – Hadoop Programming] [Theory: 2 credit; LAB: 2 credits]

	Course Objective: ● Learn the core techniques and concepts of Big Data and Hadoop ecosystem. ● Write codes using MapReduce framework and managing large data sets with HBase. ● Understanding the HDFS architecture
	Course Outcome: Student will be able to ● Write code to understand big data concepts. ● Write Mapreduce algorithms ● Design Hadoop clusters ● Installation of Hadoop master slave architecture

Unit No.	Unit Title	Unit Contents	No. of Periods
1	Hadoop	Traditional enterprise solutions; Google's solution; Hadoop Architecture; MapReduce	5
2	Hadoop and BigData	What is BIG data; BIG data benefits; BIG data technologies; challenges of BIG data Management	5
3	HDFS overview	Features of HDFS; HDFS Architecture;	6
4	Hadoop MapReduce	The MapReduce algorithm; Applications; Hadoop streaming	5
5	Multinode cluster	Installing and Configuring Hadoop; Master and Slave servers	5

Key Text:
Hadoop with Python by Zachary Radtka and Donald Miner – O'Reilly publications – 2015 ;
Online materials from: *hadoop.apache.org/*

MDSC-304 (P) –Hadoop Programming Practical: 2 credits

Algorithms/Exercises from different units in the syllabus will be implemented in Lab. This will be evaluated internally.

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List of Electives:

1. **MDSC – GRT**: Graph Theory [4 credit]
2. **MDSC – MMS**: Multimedia Systems [4 credit]
3. **MDSC – MIS**: Management Information System [4 credit]
4. **MDSC – MP (T)**: Microprocessor [3 credit] and **MDSC-MP (P)** Microprocessor Lab [1 credit]
5. **MDSC – IR**: Information Retrieval [4 credit]
6. **MDSC – EC**: Embedded Computing [4 credit]
7. **MDSC – SC**: Soft Computing [4 credit]
8. **MDSC – CD**: Compiler Design [4 credit]
9. **MDSC – FL**: Formal Languages [4 credit]
10. **MDSC – NS**: Network Security [4 credit]
11. **MDSC – CC**: Cloud Computing [4 credit]
12. **MDSC – GT**: Game Theory [4 credit]
13. **MDSC – PR**: Pattern Recognition [4 credit]
14. **MDSC – CG (T)**: Cryptography [3 credit] and **MDSC – CG (P):** Cryptography Lab [1 credit]
15. **MDSC – PP (T)**: Parallel Processing [3 credit] and **MDSC – PP (P):** Parallel Processing Lab [1 credit]
16. **MDSC –NLP**: Natural Language Processing [3 credit] and **MDSC – NLP (P)**: Lab [1 credit]
17. **MDSC –IoT (T):** Internet of Things [3 credit] and **MDSC – IoT (P):** Lab [1credit]
18. **MDSC – DL**: Deep Learning [4 credit]
19. **MDSC- IM (T)**: Image Processing [3 credit] and **MDSC- IM (P)**: Lab [1 credit]
20. **MDSC – CV (T):** Computer Vision [3 credit] and **MDSC – CV (P)**: Lab [1 credit]
21. **MDSC – RO**: Robotics [4 credit]
22. **MDSC – ARM** : Advanced Regression Methods [4 credit]

CODE: MDSC-GRT	Graph Theory	4 Credits	
	Course Objectives: This course is aimed to cover a variety of different problems in Graph Theory. In this course students will come across a number of theorems and proofs. Theorems will be stated and proved formally using various techniques. Various graphs algorithms will also be taught along with its analysis.		
	Course Outcome: Develop the skill set to ● Model and solve real-world problems using graphs and trees, both quantitatively and qualitatively. ● apply the basic concepts of mathematical logic ● describe and solve some real time problems using concepts of graph theory		
Unit	**Title**	**Contents**	**Hrs**
1	Introduction	Graphs and Graph model, Connected graphs, Multi graphs and Digraphs	6
2	Degree	Degree of a vertex, Regular graph, Degree sequence	6
3	Isomorphism of graphs	Definition of isomorphism, Isomorphism as a relation	6
4	Trees	Bridges, Trees, Minimal Spanning trees	6
5	Connectivity	Cut-vertices, Blocks, Connectivity	8
6	Traversability	Eulerian graph, Hamiltonian graph	6
7	Planarity	Planar graph, Embedding planar graphs on surface	6
8	Coloring	Color Problem, Vertex Coloring	8
Key Text: Introduction to Graph Theory (reprint) Gary Chartrand, Ping Zhang, Tata McGrawHill			
Chapters: 1 to 6, 9, 10.			

CODE: MDSC- MMS	MULTIMEDIA SYSTEMS	4 Credits
	Course Objective: ● The objective of this course is to provide students with a basic understanding of multimedia systems. ● This course focuses on topics in multimedia information representation and relevant signal processing aspects, multimedia networking and communications, and multimedia standards especially on the audio, image and video compression.	
	Course Outcome: Students will be able to ● Achieve a basic understanding of multimedia systems. ● With such background equipment, students would be able to evaluate more advanced or future multimedia systems. ● This course will also arouse students' interest in the course and further motivate them towards developing their career in the area of multimedia and internet applications.	
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	Unit-I	Introduction to Multimedia: media and data streams: Medium main properties of Multimedia systems-multimedia traditional data streams characteristics–Data streams Chrematistics for continuous media-information units-sound/audio: Basic concepts computer image processing.	12
2	Unit-II	Video and Animation Basic Concepts –Television computer based Animation-Data compression: Storage space coding requirements – Source, entropy and hybrid coding some basic compression techniques-JPEGH261-MPEG-DVI	12
3	Unit-III	Optical Storage Media: Basic Technology-Video Disks and other WORMs Compact Disk Read Only Memory-CDROM Extended Architecture-CDROM Technologies-BDisk-Multimedia Workstation	14
4	Unit IV	Software And Hardware Components -- 2D ,3D Graphics In Multimedia -- Design Of Authoring Tools-- Organizing A Multimedia Project -- Case Studies -- Multi Media Information Systems -- Video Conferencing --Virtual Reality	14

Key Text:

1. Multi Media - Making It Work, by Toy Vaughan, Osborne McGraw Hill,1993
2. Multi Media Networking, by Bohdan O. Synpronicz, McGraw Hill,1995
3. A Multimedia Technology and Applications, by Walter Worth John, Ellis Harwood Ltd, London, 1991.

CODE: MDSC-MIS	Management Information System		4 Credits
	Course Objective: ● Recognize contemporary MIS theory and how information systems support business strategy, business processes, and practical applications in an organization. ● Interrelate how various support systems can be used for business decisions and to sustain competitive advantage. ● Describe how the Internet and World Wide Web provide a global platform for e-business, business mobility and communications, collaboration, and cloud computing. ● Express the proven value of, and relationship between business data, data management, and business intelligence.		
	Course Outcome: Students will be able to ● The student should be able to analyze, evaluate, and make recommendations regarding business technology and decisions. ● Problem Solving: Students will be required to not only identify problems but also generate solutions and make recommendations based on a logical and thorough analysis of the alternatives. ● Critical Thinking: Students will be required to evaluate techniques and processes to think differently and to solve and resolve problems by using technology, making informed decisions. ● Communication: Through written and oral analyses of cases, students will further strengthen and enhance their skills in effective communication. All assignments and presentations will be prepared in professional language and format. • Team Work: Students will work collaboratively, demonstrating courtesy, using appropriate etiquette, in preparing and presenting presentations		
Unit No.	**Unit Title**	**Unit Contents**	**No. of periods**
1	**Foundation Concepts**	Foundations of Information Systems in Business : Information Systems in Business, The Components of Information Systems	10
2	**Information Technologies**	Using Information Technology for Strategic Advantage, Data Resource Management: Technical	12

		Foundations of Database Management, Managing Data Resources.	
3	**Business Applications**	E-Business Systems, Functional Business Systems, and Enterprise Business Systems: ERP, SCM, Supporting Decision Making: Decision Support in Business.	10
4	**Development Processes**	Developing Business/IT Strategies :Planning Fundamentals, Implementation Challenges Developing Business/IT Solutions: Developing Business Systems, Implementing Business Systems	10
5	**Management Challenges**	Security and Ethical, and Societal Challenges of IT ,Security Management of Information Technology	10

Key Texts:

1. Management Information System, James O'Brien, 11th edition, TMH

Chapters: 1,2,5,7,8,10,11,12,13

References:

1. Management Information System, Oz Thomson Learning 5th edition
2. Management Information System, W.S. Jawadekar, 3rd edition, TMH
3. Information Systems the foundation of E-Business, Steven Alter, 4th Edition Person education
4. Information Technology for management, Turban, McLean, Wetherbe, 4th edition, Wiley
5. Management Information Systems, Jaswal Oxford Press
6. Management Information Systems, Loudon and Loudon, 10th edition, Pearson Educations

CODE: MDSC-MP(T):MICROPROCESSOR: Theory 3 Credits : lab 1 Credit

Course Objective:

- To equip students with the fundamental knowledge and basic technical competence in the field of Microprocessors.
- To emphasize on instruction set and logic to build assembly language programs.
- To prepare students for higher processor architectures and Embedded systems

Course Outcome:

Students will be able to

- Describe architecture of x86 processors.
- Interpret the instructions of 8086 and write assembly and Mixed language programs.
- Explain the concept of interrupts4.Identify the specifications of peripheral chip

Unit No.	Unit Title	Unit Contents	No. of Periods
1	Overview of VLSI technology	Applications of Microprocessors & Embedded systems in daily life	3
2	8085 Microprocessor Architecture & Microcomputer System	Microprocessor Architecture and its Operations, Memory, Input/Output, 8085 MPU. Instruction Classification, Instruction Format. Overview of Instruction cycle, machine cycle, T-states, op-code fetch memory read and memory write; Interrupts;	9
3	Instruction Set of 8085 μP and Assembly Language Programming-I	Data Transfer (8 Bit, 16 Bit, from memory to μp & from μp to memory) Instructions, Arithmetic (8 & 16 Bit) Operations, Arithmetic Operation related to Memory, Logic Operations (Including Rotate & Compare), Branch Operations;	9
4	Assembly Language Programming-II	Counter and Time Delays, Stack, Subroutine, Conditional Call & Return Instructions; BCD to Binary conversions & arithmetic manipulations	9
5	Intel 8086 Microprocessor	Pin Description, Operating Mode, Registers, Interrupts, Addressing modes. Comparison with 8085 microprocessor. Overview of other Microprocessors from Intel, Zilog and Motorola;	9

Key Text:

Microprocessor Architecture, Programming and Applications with 8085/8080A – Ramesh S. Gaonkar, Wiley Eastern Limited. 5th edition

Reference Books:

1. Fundamentals of Microprocessors and Microcomputers – B.RAM, DhanpatRai Pub. 3rd edition
2. The Intel Microprocessors 8086/8080, 186/286, 386, 486, Pentium and Pentium Pro processor Architecture, Programming and Interfacing – Barry R. Brey, PHI – 3rd edition

3. Understanding of 8085/8086 microprocessor and peripheral ICs- S.K.Sen, New Age International Publishers, 2nd Edition 2010.

CODE: MDSC-MP (P): MICROPROCESSOR 1 Credit

The following programs will be simulated and tested on microprocessor hardware.

Program No.	Program Title
1	Transfer of a block of numbers
2	Addition of n 8-bit numbers
3	a) Multiplication by repeated addition b) Multiplication by shift and add method
4	Sorting to arrange in ascending order
5	Delay routine for a specified time
6	16-bit arithmetic (Register pair operations)
7	BCD to Binary and Binary to BCD Conversion
8	BCD Addition, BCD Subtraction, Multiplication
9	Programming with few interface kits like Traffic controller, Elevator, music synthesizer, LCD displays etc.

CODE: MDSC-IR: INFORMATION RETRIEVAL 4 Credits			
	Course Objective: ● The main objective of this course is to present the basic concepts in information retrieval and more advance techniques of multimodal based information systems. ● Word statistics, Vector space model (relevance feedback, query expansion, document normalization, document re-ranking), evaluation of retrieval, generalized VSM, latent semantic indexing, Web retrieval, data fusion, meta search, multimodal retrieval, applications.		
	Course Outcome: Student will be able to ● Understand the underlined problems related to IR and ● Acquired the necessary experience to design, and implement real applications using Information Retrieval systems.		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	INTRODUCTION	Boolean retrieval, The term vocabulary and postings lists, Dictionaries and tolerant retrieval	10
2	Indexing	Index construction, Index compression	12
3	Scoring	Scoring, term weighting & the vector space model, Computing scores in a complete search system	10
4	Evaluation and Query Expansion	Evaluation in information retrieval, Relevance feedback & query expansion	10
5	Classification	Text classification & Naive Bayes, Vector space classification	10
Key Text: Manning, Raghavan and Schutze, Introduction to Information Retrieval, 2009, Freely Downloadable (http://nlp.stanford.edu/IR-book/information-retrieval-book.html)			
Chapters: 1 to 9, 13, 14			

CODE: MDSC-EC: EMBEDDED COMPUTING

Course Objective:

- To have knowledge about the basic working of a microcontroller system and its programming in assembly language.
- To provide experience to integrate hardware and software for microcontroller applications systems.

Course Outcome: Students will be able to

- To acquire knowledge about microcontrollers embedded processors and their applications.
- Foster ability to understand the internal architecture and interfacing of different peripheral devices with Microcontrollers.
- Foster ability to write the programs for microcontroller.
- Foster ability to understand the role of embedded systems in industry.
- Foster ability to understand the design concept of embedded systems.

Unit No	Unit Contents	Topics	No. of Periods
1	An Overview of Embedded Computing	Introduction to embedded systems; Complex systems and microprocessors, embedded system design process, Design example: Model train controller, Instructions Sets: Preliminaries, ARM Processor	12
2	Embedded Hardware Fundamentals	Programming Input and output, Supervisor mode, exceptions and traps, coprocessors, memory system mechanism, CPU performance,	14
3	Embedded Software and Platforms	Basic computing platforms, CPU bus, memory device and systems, designing with computing platforms,	12
4	Program, Design and Analysis Exercises	components for embedded systems, models of programs, assembly, linking and loading, compilation techniques, program level performance analysis, optimization, programs validation and testing, system design techniques design methodologies requirement analysis,	14

Key Text:

1. Computers as Components: Principles of Embedded Computing System Design by Wayne Wolf, Morgan Kauffman Publishers, 2nd edition, 2008.

Chapters:
Chapter 1 (1.11.4), 2 (2.12.3), 3(3.13.6), 4 (4.14.5), 5(5.15.7, 5.95.10), 7(7.17.3),

REFERENCE BOOKS:

1. Embedded Realtime Systems Programming by SriramIyer and Pankaj Gupta, Tata McGraw Hill, 2004 (Tenth reprint)
2. Embedded Systems, Raj Kamal, Hill
Pub. Co. Ltd, 11th print 2007. [Chaps 15, Appendix G]
3. An Embedded Software Primer, David E. Simon, Pearson Education, 2007. [Chps 510]
4. Programming for Embedded Systems, Dream Software Team, WILEY dreamtech India Ltd. 2005.

CODE: MDSC-SC:SOFT COMPUTING			
	Course Objective: ● To conceptualize the working of human brain using ANN. ● To become familiar with neural networks that can learn from available examples and generalize to form appropriate rules for inference systems. ● To introduce the ideas of fuzzy sets, fuzzy logic and use of heuristics based on human experience. ● To provide the mathematical background for carrying out the optimization and familiarizing genetic algorithm for seeking global optimum in self-learning situation.		
	Course Outcome: Students will be able to ● Ability to analyze and appreciate the applications which can use fuzzy logic.2. Ability to design inference systems. ● Ability to understand the difference between learning and programming and explore practical applications of Neural Networks (NN). ● Ability to appreciate the importance of optimizations and its use in computer engineering fields and other domains. ● Students would understand the efficiency of a hybrid system and how Neural Network and fuzzy logic can be hybridized to form a Neuro-fuzzy network and its various applications.		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	INTRODUCTION	Foundations of Fuzzy Set Theory: Fuzzy Sets - Basic Definition and Terminology -Set-theoretic Operations - Member Function Formulation and Parameterization – Fuzzy Logic - Fuzzy Rules and Fuzzy Reasoning: Fuzzy If-Then Rules - Fuzzy Reasoning - Fuzzy Inference Systems – Fuzzy Models - Input Space Partitioning and Fuzzy Modeling. Optimization: Derivative-based Optimization - Descent Methods - Derivative-free Optimization - Simulated Annealing - Random Search.	12
2	ARTIFICIAL NEURAL NETWORKS	Basic concepts-Supervised learning - Perceptron - Multilayer Perceptron: Back Propagation Model - Unsupervised learning - Competitive learning - Kohonen's self-organizing networks - Hopfield network	10
3	NEURO - FUZZY MODELING	Introduction to Neuro - Fuzzy and Soft Computing - Adaptive networks based Fuzzy interface systems - Classification and Regression Trees - Data clustering algorithms - Rule based structure identification – Neuro -	10

		Fuzzy controls - Evolutionary computation	
4	GENETIC ALGORITHMS	Survival of the Fittest - Fitness Computations - Cross over - Mutation - Reproduction - Rank method - Rank space method	10
5	OTHER TOPICS	Combinations of Neural Networks and Genetic Algorithms – Genetic Algorithms and Fuzzy Logic – Neuro-Fuzzy Genetic Approach – Cellular Neural Networks: Fuzzy Cellular Neural Networks – Simple Applications –Soft Computing Based Distributed Intelligent Systems – Elements of Chaos Theory	10

Key Text:

1. Soft Computing and Its Applications, by R.A. Aliev and A.R.Aliev, World Scientific Publishers, 2001.
2. Neuro- Fuzzy and Soft Computing, by Jang J.S.R., Sun C.T. and Mizutani, E Prentice Hall 1998.
3. Neural Networks: Algorithms, Applications and Programming Techniques, by James A Freeman / David M Skapura, Pearson Education Asia1991.
4.Soft Computing, by Luigi Fortuna, Gianguido Rizzoto , Giuseppe Nunnari, Springer – 2001

REFERENCE BOOKS:

1. Fuzzy Sets and Fuzzy Logic, George J. Klir and Bo Yuan, Prentice Hall, USA , 1995.
2. Fuzzy Logic with Engineering Applications, by Timothy J. Ross, McGraw Hill, 1997.
3. Soft Computing: A fusion of foundations, methodologies and applications, A.Di.Nola, Lakshmi C Jain, Mauro Madravo, Springer – Verlag Berlin Heidelberg, 2004.
4. Fundamentals of Neural Networks, by LaureneFausett, Prentice Hall, 1994,.
5. Genetic Algorithms: Search, Optimization and Machine Learning, by D. E. Goldberg, Addison Wesley, N.Y, 1989.

CODE: MDSC-CD : COMPILER DESIGN

Course Objective:

- To understand the role and functioning of various system programs over application program.
- To understand basic concepts and designing of assembler, Macro processor and role of static and dynamic loaders and linkers.
- To understand the need to follow the syntax in writing an application program and to learn the how the analysis phase of compiler is designed to understand the programmer's requirements without ambiguity.
- To synthesize the analysis phase outcomes to produce the object code that is efficient in terms of space and execution time.

Course Outcome:

- Identify the relevance of different system programs.
- Describe the various data structures and passes of assembler design.
- Identify the need for different features and designing of macros.
- Distinguish different loaders and linkers and their contribution in developing efficient user applications.
- Construct different parsers for given context free grammars. Justify the need synthesis phase to produce object code optimized in terms of high execution speed and less memory usage

Unit No.	Unit Title	Unit Contents	No. of Periods
1	UNIT I	Introduction - Why compilers? - Programs related to compiler – Overview of compilation, Phases of Compilation, Lexical Analysis,The Translation Process - Major Data structures in a compiler - Boot trapping and porting	2
2	UNIT II	Scanning - The scanning process - Regular expressions - Finite automata - Regular expressions to DFA	5
3	UNIT III	Context free grammars and Parsing - The Parsing process - CFG - Parse trees and Abstract Syntax Trees - Ambiguity	4
4	UNITIV	Top-Down Parsing - Recursive descent parsing - LL(1) Parsing - First and Follow sets - Error recovery	7
5	UNITV	Bottom-Up Parsing - Overview - LR(0) parsing - SLR(1) parsing - LR(1) and LALR(1) parsing - Error recovery	7
6	UNITVI	Semantic analysis - Attribute Grammar - Algorithms for attribute computation - Symbol table - Data types and type checking	12
7	UNITVII	Runtime environments - Fully static environment- stack-based	7

		environment - Fully dynamic environment - Parameter passing mechanisms	
8	UNITVIII	Code Generation - Intermediate code and data structures - Basic techniques - Code generation for data structure references - Code generation for control statements and logical expressions - Code generation for functions and procedure calls, Code Optimization	8
Key Text: Compiler Construction: principles and Practice by Kenneth C. Louden, Cengage Learning Publishers, Indian Edition, 1997			
Chapters: 1.1-1.6, 2.1-2.4, 3.1 – 3.4, 4.1 – 4.3, 4.5, 5.1, 5.1 – 5.4, 5.7, 6.1-6.4, 7.1 – 7.5, 8.1 – 8.5			

CODE: MDSC-FL: FORMAL LANGUAGES 4 Credits

Course Objective:
Differentiate and manipulate formal descriptions of languages, automata and grammars with focus on regular and context-free languages, finite automata and regular expressions.

Course Outcome:

- Explain and manipulate the different concepts in automata theory and formal languages such as formal proofs, (non-)deterministic automata, regular expressions, regular languages, context-free grammars, context-free languages, Turing machines;
- Explain the power and the limitations of regular languages and context-free languages.

Unit No.	Unit Title	Unit Contents	No. of Periods
1	UNIT I	Deterministic Finite Automata, Non-deterministic automata, Equivalence of NFA and DFA, Reduction in number of states in Finite Automata	8
2	UNIT II	Regular Languages and Regular Grammars: Regular expressions, Connection between regular expressions and regular languages, Regular Grammars, Closure properties of Regular languages, Pumping lemma-Non regular languages.	8
3	UNIT III	Context free grammars, Parsing Ambiguity, Context free grammars and programming languages, Simplification of complex grammars and their normal forms (Chomsky and Greibach Normal form.	8
4	UNIT IV	Pushdown Automata: Nondeterministic pushdown automata, deterministic pushdown automata, Pushdown automata and context free languages, Context free grammars and pushdown automata.),Properties of context free languages, Pumping lemma for non-context free languages	8
5	UNIT V	Hierarchy of formal languages and automata: Recursive languages and Recursively enumerable languages, Unrestricted grammars, Context sensitive grammars and languages, Chomsky hierarchy	10
6	UNIT VI	Turing machines: Standard Turing machine, Combining Turing machine for complicated tasks, Turing thesis, Variations in Turing machine, Linear Bound automata.	10

KEY TEXTS:
Introduction To Formal Languages And Automata, by P.Linz, Narosa Pub. 1997.
Chapters:

REFERENCES

1. Formal Languages, by A. Salomaa, Academic Pub.1973.
2. Introduction To Formal Languages , by Gyorgy E Revesz, McGraw-Hill Book Co.,1985

CODE: MDSC-NS: NETWORK SECURITY 4 Credits			
	Course Objective: ● To explore the design issues and working principles of various authentication protocols, PKI standards and various secure communication standards including Kerberos, IPsec, and SSL/TLS and email. ● To develop the ability to use existing cryptographic utilities to build programs for secure communication..		
	Course Outcome: ● Apply the knowledge of cryptographic checksums and evaluate the performance of different message digest algorithms for verifying the integrity of varying message sizes. ● Apply different digital signature algorithms to achieve authentication and design secure applications ● Understand network security basics, analyze different attacks on networks and evaluate the performance of firewalls and security protocols like SSL, IPSec, and PGP. ● Analyze and apply system security concept to recognize malicious code.		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	Introduction	Computer Security Concepts, The OSI Security Architecture, Security Attacks, Security Services, Security Mechanisms, A Model for Network Security	4
2	Symmetric Encryption	Symmetric Encryption Principles, Symmetric Block Encryption Algorithms, Random and Pseudorandom Numbers, Stream Ciphers and RC4, Cipher Block Modes of Operation	10
3	Message Authentication and Hash Functions	Approaches to Message Authentication, Secure Hash Functions, Message Authentication Codes	4
4	Public Key Cryptography	Public-Key Cryptography Principles, Public-Key Cryptography Algorithms, Digital Signatures	6
5	Key Distribution and User Authentication	Kerberos, X.509 Certificates, Public-Key Infrastructure	6
6	Cloud Security	Cloud Security Risks and Countermeasures, Data Protection in the Cloud, Cloud Security as a Service	4
7	Transport-Level Security	Web Security Considerations, Secure Sockets Layer (SSL), Transport Layer Security (TLS), HTTPS, Secure Shell (SSH)	6
8	Electronic Mail Security	Pretty Good Privacy (PGP), S/MIME	6
9	IP Security	IP Security Overview, IP Security Policy, Encapsulating Security Payload, Combining Security Associations	6

Key Text: Cryptography and Network Security : Principles and Practice by William Stallings, 5th edition, Pearson Education Inc.
Chapters: 1.1-1.6, 2.1-2.5, 3.1-3.6, 5.1-5.6, 6.1-6.5, 9.1-9.4, 10.1-10.4, 11.1-11.6, 12.1-12.6, 13.1-13.4, 14.1-14.5, 15.1-15.3, 16.1-16.5, 18.1-18.3, 19.1-19.5
REFERENCE BOOKS: 1. Introduction to Computer and Network Security: Navigating Shades of Gray by Richard R. Brooks, 1st Edition, 2013. 2. Network Security: Private Communication in a public world, by Charlie Kaufman, Radia Perlman and Mike Speciner, IInd Edn, ISBN 0-13-046019-PrenticeHall PTR, 2002.

CODE: MDSC –CC: CLOUD COMPUTING 4 Credits			
	Course Objective: ● To learn how to use Cloud Services. ● To implement Virtualization ● To implement Task Scheduling algorithms. ● Apply Map-Reduce concept to applications. ● To build Private Cloud. Broadly educate to know the impact of engineering on legal and societal issues involved		
	Course Outcome: Students will be able to • Analyze the Cloud computing setup with it's vulnerabilities and applications using different architectures. • Design different workflows according to requirements and apply map reduce programming model. • Apply and design suitable Virtualization concept, Cloud Resource Management and design scheduling algorithms. • Create combinatorial auctions for cloud resources and design scheduling algorithms for computing clouds • Assess cloud Storage systems and Cloud security, the risks involved, its impact and develop cloud application • Broadly educate to know the impact of engineering on legal and societal issues involved in addressing the security issues of cloud computing.		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	Introduction; Principles of Parallel and Distributed Computing	Cloud computing at a glance; Historical Developments; building Cloud computing environment; computing platforms and Technologies Principles of Parallel and Distributed Computing: Eras of Computing; parallel Vs. distributed computing; elements of distributed computing; technologies of Distributed computing	7
2	Virtualization and Cloud Computing Architecture	Characteristics of virtualized environments; virtualization techniques; virtualization and cloud computing; pros and cons of virtualization; examples. Cloud Reference model; Types of clouds; cloud economics; open challenges	8

3	Aneka: Cloud application Platform	Overview; anatomy of the Aneka container; building Aneka clouds; cloud programming and management	7
4	Concurrent Computing and High-Throughput Computing and Map Reduce Programming	Introducing parallelism; programming with threads; multithreading with Aneka; applications; Task Computing; task based Application Model; Task based Programming; Data Intensive Computing; Technologies; Aneka Map Reduce Programming	10
5	Cloud Platforms in Industry and Cloud Applications	Amazon Web services; Google App Engine; Microsoft Azure; Cloud scientific Applications; Business and Consumer Applications	8
6	Advanced Topics in Cloud Computing and Cloud Security	Energy Efficiency Clouds; Market based management clouds; Federated Clouds; Third Party Cloud Services; Infrastructure Security: Network level security, Host level security, and Application level security; Data security and Storage	12

Key Text(s):

Mastering C*loud Computing,* Editors: Rajkumar Buyya, Christian Vecchiola, S. Thamarai Selvi*, MGH-*2013

Chapters: 1 ,2,3,4,5,6,7,8,9,10,11

REFERENCE BOOKS

Cloud Computing: Principles and Paradigms, Editors: RajkumarBuyya, James Broberg, Andrzej M. Goscinski*, Wile,* 2011

Cloud Computing Bible, Barrie Sosinsky*, Wiley-India,* 2010

Cloud Computing: Principles, Systems and Applications, Editors: Nikos Antonopoulos, Lee Gillam*, Springer,* 2012

Cloud Security: A Comprehensive Guide to Secure Cloud Computing, Ronald L. Krutz, Russell Dean Vines*, Wiley-India,* 2010

CODE: MDSC-GT:GAME THEORY 4 Credits			
	Course Objective: ● To introduce Game Theory. Game Theory is a mathematical framework which makes possible the analysis of the decision making process of interdependent subjects. ● It is aimed at explaining and predicting how individuals behave in a specific strategic situation, and therefore help improve decision making. ● A situation is strategic if the outcome of a decision problem depends on the choices of more than one person. Most decision problems in real life are strategic. ● The course will explain in depth the standard equilibrium concepts (such as Nash Equilibrium, Subgame-Perfect Nash Equilibrium, and others) in Game Theory.		
	Course Outcome: Student will be able to ● Identify strategic situations and represent them as games ● Solve simple games using various techniques ● Analyse economic situations using game theoretic techniques ● Recommend and prescribe which strategies to implement		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	Introduction	Games and Solutions, Game theory and the Theory of Competitive Equilibrium, Rational Behaviour, The Steady State and Deductive Interpretations, Bounded Rationality, Terminology and Notation.	7
2	Nash Equilibrium	Strategic Games, Nash Equilibrium, Existence of a Nash Equilibrium, Strictly Competitive Games, Bayseian Games: Strategic Games with Imperfect Information.	7
3	Mixed, Correlated, and Evolutionary Equilibrium	Mixed Strategy Nash Equilibrium, Interpretations of Mixed Strategy Nash Equilibrium, Correlated Equilibrium, Evolutionary Equilibrium.	7
4	Rationalizability, Iterated Elimination of Dominated Actions	Rationalizability, Iterated Elimination of Strictly Dominated Actions, Iterated Elimination of Weakly Dominated Actions	7
5	Knowledge and Equilibrium	A Model of Knowledge, Common Knowledge, Can People Agree to Disagree, Knowledge and Solution Concepts, The Electronic Mail Game	7

6	Extensive Games with Perfect Information	Extensive Games With Perfect Information, Sub game Perfect Equilibrium, two Extensions of the Definition of Game, and The Interpretation of a Strategy, Two Notable Finite Horizon Games, and Iterated Elimination of Weakly Dominated Strategies.	8
7	Bargaining Games	Bargaining and Game Theory, A Bargaining Game of Alternating Offers, Sub game Perfect Equilibrium, Variations and Extensions	8

KEY TEXTS:

A Course in Game Theory by, Martin J Osborne and Ariel Rubinstein, The MIT Press, Cambridge Massachusetts, London
Chapters: 1 to 7

REFERENCE BOOKS:

Game Theory by N.N. Vorobev, Springer Verlag Publications, 1977

CODE: MDSC-PR: Pattern Recognition 4 Credits			
	Course Objective: ● Introduce the concepts of feature extraction, Bayesian decision theory, nearest-neighbor rules, clustering, support vector machines, neural networks, classifier combination, and syntactic pattern recognition techniques such as stochastic context-free grammars. ● The course is part lecture and part seminar: students will present some course material to the class as well as complete and present a research paper. ● In addition, programming assignments will provide students with practical experience in constructing pattern recognition systems such as optical character recognizers (OCR).		
	Course Outcome: Student will be able to ● Explain and compare a variety of pattern classification, structural pattern recognition, and pattern classifier combination techniques. ● Summarize, analyze, and relate research in the pattern recognition area verbally and in writing. ● Apply performance evaluation methods for pattern recognition, and critique comparisons of techniques made in the research literature. ● Apply pattern recognition techniques to real-world problems such as document analysis and recognition. ● Implement simple pattern classifiers, classifier combinations, and structural pattern recognizers.		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	Introduction	Introduction, Features, Feature Vectors, Classifiers, Supervised, Unsupervised and Semi-Supervised Learning.	4
2	Classifiers based on Bayes Theory	Introduction, Bayes Decision Theory, Discriminant Functions, Bayes Classification for Normal Distributions, Estimation of Unknown Probability Distributions: ML Parameter Estimation, MAP Estimation, Bayesian Inference, Maximum Entropy Estimation, Mixture Models, Non-Parametric Estimation, the Naïve-Bayes Classifier, the Nearest Neighbor Rule, Bayesian Networks.	10
3	Linear Classifiers	Introduction, Linear Discriminant Functions and Decisions, Hyper-planes, The Perceptron algorithm, Least Square Methods, Mean Square Estimation Revisited, Logistic Discrimination,	8

		Support Vector Machines for Separable Classes, SVM for Non-Separable Classes, SVM for Multiclass Case, ϑ-SVM	
4	Nonlinear Classifiers	XOR Problem, Two Layer Perceptron, Three-Layer Perceptrons, Algorithms based on Exact Classification of Training Set, The Back-Propagation Algorithm, Variation of BP Theme, Choice of Cost Function, Choice of Network Size, Generalized Linear Classifiers, Capacity of d-dimensional space in linear Dichotomies, Polynomial Classifiers, Radial Basis Function Networks, Universal Approximators, Probabilistic Neural Networks, SVM-Nonlinear Case, Beyond SVM Paradigm, Decision Trees, Combining Classifiers, Boosting, Class Imbalance Problem	10
5	Clustering	Introduction, Proximity Measures, Number of Possible Clusterings, Categories of Clustering Algorithms, Sequential Clustering Algorithms, Agglomerative Algorithms, Divisive Algorithms, Hierarchical Algorithms for Large Datasets., Choice of the Best Number of Clusters, Hard Clustering Algorithms, Vector Quantization. Algorithms based on Graph Theory, Competitive Learning algorithms	10
6	**Bargaining Games**	Bargaining and Game Theory, A Bargaining Game of Alternating Offers, Sub game Perfect Equilibrium, Variations and Extensions	10
Key Text: Pattern Recognition by Sergios Theodoridis and Knostantinos Koutroumbas, Fourth Edition, Elsevier Publications, 2009, Chapters: 1, 2, 3, 4, 11, 12.1-12.3, 13, 14.5, 15.1-15.3.			

CODE: MDSC- CG (T) : Cryptography Theory 3 Credits :: Lab 1 Credit			
	Course Objective: ● To introduce classical encryption techniques and concepts of modular arithmetic and number theory. ● To explore the working principles and utilities of various cryptographic algorithms including secret key cryptography, hashes and message digests, and public key algorithms.		
	Course Outcome: Student will be able to ● Understand system security goals and concepts, classical encryption techniques and acquire fundamental knowledge on the concepts of modular arithmetic and number theory. ● Understand, compare and apply different encryption and decryption techniques to solve problems related to confidentiality and authentication.		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	Introduction to Classical Cryptography	Cryptography and modern cryptography, Setting of private key encryption, Historical ciphers and their Cryptanalysis, Principles of modern cryptography, Perfectly secret encryption, One-Time Pad, Limitations of Perfect Secrecy	6
2	Private-Key Encryption	Computational Security, Defining Computationally Secure Encryption, Constructing Secure Encryption Schemes, Stronger Security Notions, Constructing CPA-Secure Encryption Schemes, Modes of Operation, Chosen-Ciphertext Attacks	6
3	Message Authentication Codes and Hash Functions	Message Integrity, Message Authentication Codes – Definitions, Hash Functions – Definitions, Merkle–Damgard Transform, Birthday Attacks on Hash Functions	6
4	Number Theory and Key Exchange	Preliminaries and Basic Group Theory, Factoring and RSA, Cryptographic Assumptions in Cyclic Groups, Key Exchange and the Diffie–Hellman Protocol	7

5	Public-Key Encryption	Public-Key Encryption – An Overview and Definitions, Hybrid Encryption and KEM/DEM paradigm, RSA Encryption – Plain RSA, Padded RSA and PKCS #1 v1.5	8
6	Digital Signature Schemes	Digital Signatures – An Overview and Definitions, Hash-and-Sign Paradigm, RSA Signatures – Plain RSA, Schnorr Signature Scheme	6
Key Text: 1. Introduction to Modern Cryptography by J. Katz and Y. Lindell, Second edition, CRC Press, 2015, Chapters & Sections: 1.1-1.4, 2.1-2.3, 3.1-3.6, 3.7.1, 4.1-4.3, 5.1-5.2, 5.4.1-5.4.2, 8.1.1-8.1.4, 8.2.1, 8.2.3-8.2.4, 8.3.1-8.3.3, 10.3, 11.1-11.3, 11.5.1-11.5.2, 12.1-12.3, 12.4.1, 12.5.1, 12.8.			
References: S. Goldwasser and M. Bellare, Lecture Notes on Cryptography, July 2008. available online: https://cseweb.ucsd.edu/~mihir/papers/gb.pdf. C. Paar and J. Pelzl, Understanding Cryptography, Springer, 2010.			

MDSC-CG (P): Cryptography - Lab- 1 Credit

Algorithms/Exercises from different units in the syllabus will be implemented in Lab. This will be evaluated internally.

CODE: MDSC-PP (T):Parallel Processing Theory 3 Credits :: Lab 1 Credit

Course Objective:

Theoretical and practical survey of parallel processing, including a discussion of parallel architectures, parallel programming language, and parallel algorithms. Programming one or more parallel computers in a higher-level parallel language

Course Outcome:

Students will be able to

- Compute speedup, efficiency, and scaled speedup of parallel computations, given appropriate data.
- Apply Amdahl's Law to predict the maximum speedup achievable from a parallel version of a sequential program, given its execution profile.
- Analyze the iso-efficiency of a parallel algorithm.
- Explain the relative advantages and disadvantages of mesh, hypercube, and butterfly networks with respect to diameter, bisection width, and number of edges/node

Unit No.	Unit Title	Unit Contents	No. of Periods
1	introduction	Modern Parallel Computers - Types of Concurrency – Programming.	3
2	Parallel Architecture	Interconnection Network – Processor arrays – Multiprocessors – Multi Computers – Flynn's taxonomy	5
3	Parallel Algorithm Design	Foster's Design Methodology – Example Problems.	4
4	Algorithms for Illustrations	Sieve of Eratosthenes – Floyd's Algorithm.(To discuss all the concepts introduced so far).	4
5	Performance analysis	Speed up and Efficiency – Amdahl's Law – Gustafson's Barsis Law – Karp Flatt Metric – Isoefficiency Metric	4
6	Matrix Vector Multiplication	Monte Carlo Methods – Matrix Multiplication – Solving linear System - finite Difference Methods - sorting algorithm - combinatorial Search.	14
7	Shared Memory Programming	Open MP	5

Key Text:

Parallel Programming in C with MPI and OpenMP by Michale J Quinn, Tata McGraw Hill 2004

Reference Book: Introduction to Parallel Computing by AnanthaGrama, Anshul Gupta, George Karypis, Vipin Kumar, Pearson education LPE, Second edition, 2004.

MDSC- PP (P): PARALLEL PROCESSING (**1 Credit**),

This will be evaluated internally.

1. Message Passing programming Model – MPI – Point to Point & Collective Calls.
2. Document classification Problem
3. Matrix Vector & Matrix Matrix Multiplication
4. Parallel Quick Sort 5. Shared Memory Programming – Open MP

CODE: MDSC- NLP (T): NATURAL LANGUAGE PROCESSING –

(3 Credit- 39 Periods)

	Course Objective: To understand natural language processing and to learn how to apply basic algorithms in this field. To get acquainted with the algorithmic description of the main language levels: morphology, syntax, semantics, and pragmatics, as well as the resources of natural language data - corpora. To conceive basics of knowledge representation, inference, and relations to the artificial intelligence.
	Course Outcome: The students will get acquainted with natural language processing and learn how to apply basic algorithms in this field. They will understand the algorithmic description of the main language levels: morphology, syntax, semantics, and pragmatics, as well as the resources of natural language data - corpora. They will also grasp basics of knowledge representation, inference, and relations to the artificial intelligence.

Unit No.	Unit Title	Unit Contents	No. of Periods
1	UNIT -1	Introduction to Languages And Grammars - Transformational Grammars of Natural Language	13
2	UNIT -2	Two-Level Representation - Transition Networks - From Grammar To Acceptor	13
3	UNIT-3	Two Level Processing Systems RTN's And ATN's- Issues And Applications.	13
Key Text 1. Computer Processing Of Natural Language, by Gilbert K. Krulee, Prentice Hall 1991.			

MDSC-NLP (P): Lab: NATURAL LANUAGE PROCESSING - 1 Credit

Algorithms/Exercises from different units in the syllabus will be implemented in Lab. This will be evaluated internally.

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CODE: MDSC- IOT (T): Internet of Things Theory 3 Credits :: Lab 1 Credit			
	Course Objective: Students will be explored to the interconnection and integration of the physical world and the cyberspace. They are also able to design & develop IOT Devices.		
	Course Outcome: Students will be able to ● Understand the application areas of IOT ● Realize the revolution of Internet in Mobile Devices, Cloud & Sensor Networks ● Understand building blocks of Internet of Things and characteristics.		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	introduction	What is the Internet of Things? : History of IoT, About IoT, Overview and Motivations, Examples of Applications, Internet of Things Definitions and Frameworks : IoT Definitions, IoT Architecture, General Observations, ITU -T Views, Working Definition, IoT Frameworks, Basic Nodal Capabilities	4
2	FUNDAMENTAL IoT MECHANISMS AND KEY TECHNOLOGIES	Identification of IoT Objects and Services, Structural Aspects of the IoT, Environment Characteristics, Traffic Characteristics, Scalability, Interoperability, Security and Privacy, Open Architecture, Key IoT Technologies, Device Intelligence, Communication Capabilities, Mobility Support, Device Power, Sensor Technology, RFID Technology, Satellite Technology	4
3	RADIO FREQUENCY IDENTIFICATION TECHNOLOGY	RFID: Introduction, Principle of RFID, Components of an RFID system, Issues EPCGlobal Architecture Framework: EPCIS & ONS, Design issues, Technological challenges, Security challenges, IP for IoT, Web of Things. Wireless Sensor Networks: History and context, WSN Architecture, the node, Connecting nodes, Networking Nodes, Securing Communication WSN specific IoT applications, challenges: Security, QoS,	6

		Configuration, Various integration approaches, Data link layer protocols, routing protocols and infrastructure establishment.	
4	RESOURCE MANAGEMENT IN THE INTERNET OF THINGS	Clustering, Software Agents, Clustering Principles in an Internet of Things Architecture, Design Guidelines, and Software Agents for Object Representation, Data Synchronization. Identity portrayal, Identity management, various identity management models: Local, Network, Federated and global web identity, user -centric identity management, device centric identity management and hybrid -identity management, Identity and trust.	10
5	INTERNET OF THINGS PRIVACY, SECURITY AND GOVERNANCE	Vulnerabilities of IoT, Security requirements, Threat analysis, Use cases and misuse cases, IoT security tomography and layered attacker model, Identity establishment, Access control, Message integrity, Non-repudiation and availability, Security model for IoT.	6
6	BUSINESS MODELS FOR THE INTERNET OF THINGS	Business Models and Business Model Innovation, Value Creation in the Internet of Things , Business Model Scenarios for the Internet of Things. Internet of Things Application : Smart Metering Advanced Metering Infrastructure, e-Health Body Area Networks, City Automation, Automotive Applications, Home Automation, Smart Cards,	9

Key Text:

1. Daniel Minoli, "Building the Internet of Things with IPv6 and MIPv6: The Evolving World of M2M Communications", ISBN: 978 -1-18-47347-4, Willy Publications.
2. Bernd Scholz-Reiter, Florian ichahelles, Architecting the Internet of Things", ISBN 978-3-642-19156-5 e-ISBN 978-3-642-9157-2, Springer
3. Parikshit. ahalle&Poonam N. Railkar, "Identity Management for Internet of Things", River Publishers,

Reference Books

4. HakimaChaouchi, "The Internet of Things Connecting Objects to the Web" Willy Publications
5. Olivier Hersent, David Boswarthick, Omar Elloumi, The Internet of Things: Key Applications and Protocols, 2nd Edition, Willy Publications
6. Daniel Kellmereit, Daniel Obodovski, "The Silent Intelligence: The Internet of Things", Publisher: Lightning Source Inc; 1 edition.
7. Fang Zhaho, Leonidas Guibas, "Wireless Sensor Network: An information processing approach",Elsevier,

CODE: MDSC- IOT (P) – Internet of Things – 1 Credit

LAB Assignments: This will be evaluated internally.

Internet of things: Overview, technology of the internet of things, enchanted objects, Design principles for connected devices, Privacy, Web thinking for connected devices Writing Code: building a program and deploying to a device, writing to Actuators, Blinking Led, Reading from Sensors, Light Switch, Voltage Reader, Device as HTTP Client, HTTP, Push Versus Pull. Pachube, Netduino, Sending HTTP Requests—the Simple Way, Sending HTTP Requests—the Efficient Way.

HTTP: Device as HTTP Server, Relaying Messages to and from the Netduino, Request Handlers, WebHtml, Handling Sensor Requests, Handling Actuator Requests
Going Parallel: Multithreading, Parallel Blinker, prototyping online components, using an API, from prototypes to reality, business models, ethics, privacy, disrupting control, crowdsourcing

CODE: MDSC- DL: Deep Learning 4 Credits			
	Course Objective: To learn the basics of neural networks, convolutional networks, recurrent networks; Understand the concepts such as dropout, batch normalization, types of hyper-parameter optimization, distributed and constrained computing variants. Applications in the area of audio processing and image captioning and vision.		
	Course Outcome: ● The fundamental principles, theory and approaches for learning with deep neural networks ● The main variants of deep learning (such convolutional and recurrent architectures), and their typical applications ● The key concepts, issues and practices when training and modeling with deep architectures; as well as have hands-on experience in using deep learning frameworks for this purpose ● How to implement basic versions of some of the core deep network algorithms (such as back propagation) ● How deep learning fits within the context of other ML approaches and what learning tasks it is considered to be suited and not well suited to perform.		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	Basics of Deep leaning- Deep learning architectures	Convolutional Neural Networks : Neurons in Human Vision-The Shortcomings of Feature Selection-Vanilla Deep Neural Networks Don't Scale-Filters and Feature Maps-Full Description of the Convolutional Layer-Max Pooling-Full Architectural Description of Convolution Networks-Closing the Loop on MNIST with Convolutional Networks-Image Preprocessing Pipelines Enable More Robust Models-Accelerating Training with Batch Normalization-Building a Convolutional Network for CIFAR-10-Visualizing Learning in Convolutional Networks Leveraging Convolutional Filters to Replicate Artistic Styles-Learning Convolutional Filters for Other Problem Domains-Training algorithms.	14
2	Memory Augmented Neural Networks	Neural Turing Machines-Attention-Based Memory Access-NTM Memory Addressing Mechanisms-Differentiable Neural Computers-Interference-Free Writing in DNCs-DNC Memory Reuse-Temporal Linking of DNC Writes-Understanding the	12

		DNC Read Head-The DNC Controller Network Visualizing the DNC in Action-Implementing the DNC in Tensor Flow-Teaching a DNC to Read and Comprehend.	
3	Deep Reinforcement Learning	Deep Reinforcement Learning Masters Atari Games What Is Reinforcement Learning?-Markov Decision Processes (MDP)-Explore Versus Exploit-Policy versus Value Learning-Pole-Cart with Policy Gradients-Q-Learning and DeepQ-Networks-Improving and Moving Beyond DQN.	12
4	Implementing Neural Networks in Tensor Flow	What Is Tensor Flow?-How Does Tensor Flow Compare to Alternatives?-Installing Tensor Flow-Creating and Manipulating Tensor Flow Variables-Tensor Flow Operations-Placeholder Tensors-Sessions in Tensor Flow-Navigating Variable Scopes and Sharing Variables-Managing Models over the CPU and GPU-Specifying the Logistic Regression Model in Tensor Flow-Logging and Training the Logistic Regression Model-Leveraging Tensor Board to isualizeComputationGraphsandLearning-BuildingaMultilayerModelforMNISTinTensorFlow. Applications: Deep learning for computer vision, Deep Learning Applications at the enterprise Scale, Deep Learning Models for Healthcare Applications.	14

Key Texts:

Nikhil Buduma, Nicholas Locascio, "Fundamentals of Deep Learning: Designing Next-Generation Machine Intelligence Algorithms", O'Reilly Media, 2017. 2. Ian Goodfellow, Yoshua Bengio, Aaron Courville, "Deep Learning (Adaptive Computation and Machine Learning series", MIT Press, 2017.

References:

Ian Goodfellow, YoshuaBengio, Aaron Courville. Deep Learning.

Duda, R.O., Hart, P.E., and Stork, D.G. Pattern Classification. Wiley-Interscience. 2nd Edition. 2001. ■ Theodoridis, S. and Koutroumbas, K. Pattern Recognition. Edition 4. Academic Press, 2008. ■ Russell, S. and Norvig, N. Articial Intelligence: A Modern Approach. Prentice Hall Series in Articial Intelligence. 2003. ■ Bishop, C. M. Neural Networks for Pattern Recognition. Oxford University Press. 1995. ■ Hastie, T., Tibshirani, R. and Friedman, J. The Elements of Statistical Learning. Springer. 2001. ■ Koller, D. and Friedman, N. Probabilistic Graphical Models. MIT Press. 2009.

CODE: MDSC-IP (T)	Image Processing Theory 3 Credits : Lab 1 Credit		
	Course Objective: ● This course is an introduction to the fundamental concepts and techniques in basic digital image processing and their applications to solve real life problems. ● The topics covered include Digital Image Fundamentals, Image Transforms, Image Enhancement, Restoration and Compression, Morphological Image Processing, Nonlinear Image Processing, and Image Analysis.		
	Course Outcome: Student will be able to ● Familiar with basic image processing techniques for solving real problems. ● Have sufficient expertise in both the theory of two-dimensional signal processing and its wide range of applications, for example, image restoration, image compression, and image analysis.		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	Introduction	Fundamental Steps in Digital Image Processing - Components of an Image Processing System	6
2	Image processing Fundamentals	Elements of visual perception – Light and electromagnetic spectrum – image sensing and acquisition - Image Sampling and Quantization- Basic Relationships between Pixels – An introduction to mathematical tools used in digital image processing	6
3	Intensity Transformations and Spatial Filtering	Some basic intensity transformation functions - Histogram Processing – Fundamentals of spatial filtering- Smoothing and sharpening spatial filters - combining spatial enhancement methods	6
4	Filtering in the frequency domain	Sampling and the Fourier transform of sampled functions – basics of filtering in the frequency domain – image smoothing and sharpening using frequency domain filters – selective filtering	6
5	Image Restoration and Reconstruction	Model for image degradation and restoration process – noise models – restoration in the presence of noise only spatial filtering – periodic noise reduction by frequency domain filtering – linear position invariant degradations – estimating the degradation function – inverse filtering	9
6	Image Segmentation	Point, line and edge detection – thresholding – region based segmentation	6
Key Text: Digital Image Processing –by Rafael. C. Gonzalez & Richard E. Woods. 3rd Edition, Pearson Education, 2002. [Chapters 1, 2, 3.1 to 3.7, 4.1 to 4.10, 5.1 to 5.7, 10.1 to 10.4] 2. Relevant research papers selected for the course by the instructor			
References: Image Processing – The Fundamentals by Maria Petrou and Costas Petrou, Second			

Edition, John Wiley and Sons, 2010

2. Fundamentals of Digital Image Processing, by Anil. K. Jain , Eastern Economy Edition, Prentice Hall of India 1997

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MDSC-IP (P) Image Processing – Lab - 1 credit

Algorithms/Exercises from different units in the syllabus will be implemented in Lab. This will be evaluated internally

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CODE: MDSC-CV (T) Computer Vision Theory 3 Credits : Lab 1 Credit			
	Course Objective: ● To introduce students the fundamentals of image formation; ● To develop an appreciation for various issues in the design of computer vision and object recognition systems; and to provide the student with programming experience from implementing computer vision and object recognition applications.		
	Course Outcome: Student will be able to ● Identify basic concepts, terminology, theories, models and methods in the field of computer vision ● Describe known principles of human visual system ● Describe basic methods of computer vision related to multi-scale representation, edge detection and detection of other primitives, stereo, motion and object recognition ● Suggest a design of a computer vision system for a specific problem		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	Review of pre-requisites -1	Motivation, Image Representation and Image Analysis Tasks, Image Representations, a Few Concepts - Image Digitization, Sampling, Quantization, Digital Image Properties, Metric and Topological Properties of Digital Images, Histograms, Entropy, Image Quality, Noise in Images, Color Images, Color Spaces, Cameras: An Overview	6
2	Review of pre-requisites-II	The Image, its Mathematical and Physical Background Overview / Linearity / The Dirac Distribution and Convolution / Linear Integral Transforms / Images as Linear Systems / Introduction to Linear Integral Transforms / 1D Fourier Transform / 2D Fourier Transform / Sampling and the Shannon Constraint / Discrete Cosine Transform / Wavelet Transform / Eigen-Analysis / Singular Value Decomposition / Principle Component Analysis / Other Orthogonal Image Transforms / Images as Stochastic Processes / Images as Radiometric Measurements / Image Capture and Geometric Optics / Lens Aberrations and Radial Distortion / Image Capture from a Radiometric Point of View / Surface Reflectance /	6

3	Data Structures for Image Analysis	Levels of Image Data Representation / Traditional Image Data Structures / Matrices / Chains / Topological Data Structures / Relational Structures / Hierarchical Data Structures / Pyramids / Quadtrees / Other Pyramidal Structures	6
4	Segmentation	Watershed Segmentation / Region Growing Post-Processing / Matching / Matching Criteria / Control Strategies of Matching / Evaluation Issues in Segmentation / Supervised Evaluation / Unsupervised Evaluation/Mean Shift Segmentation / Active Contour Models - Snakes / Traditional Snakes and Balloons / Extensions / Gradient Vector Flow Snakes / Geometric Deformable Models - Level Sets and Geodesic Active Contours / Towards 3D Graph-Based Image Segmentation / Simultaneous Detection of Border Pairs / Sub-optimal Surface Detection / Graph Cut Segmentation / Optimal Single and Multiple Surface Segmentation	6
5	Shape Representation and Description	Region Identification / Contour-Based Shape Representation and Description / Chain Codes / Simple Geometric Border Representation / Fourier Transforms of Boundaries / Boundary Description using Segment Sequences / B-Spline Representation / Other Contour-Based Shape Description Approaches / Shape Invariants / Region-Based Shape Representation and Description / Simple Scalar Region Descriptors / Moments / Convex Hull / Graph Representation Based on Region Skeleton / Region Decomposition / Region Neighborhood Graphs / Shape Classes	5
6	Object Recognition	Knowledge Representation / Statistical Pattern Recognition / Classification Principles / Classifier Setting / Classifier Learning / Support Vector Machines / Cluster Analysis / Neural Nets / Feed-Forward Networks / Unsupervised Learning / Hopefield Neural Nets / Syntactic Pattern Recognition / Grammars and Languages / Syntactic Analysis, Syntactic Classifier / Syntactic Classifier Learning, Grammar Inference / Recognition as Graph Matching / Isomorphism of Graphs and Sub-Graphs / Similarity of Graphs / Optimization Techniques in Recognition.	5

7	Image Understanding	Image Understanding Control Strategies / Parallel and Serial Processing Control / Hierarchical Control / Bottom-Up Control / Model-Based Control / Combined Control / Non-Hierarchical Control / RANSAC: Fitting via Random Sample Consensus / Point Distribution Models / Active Appearance Models / Pattern Recognition Methods in Image Understanding / Classification-Based Segmentation / Contextual Image Classification / Boosted Cascade of Classifiers for Rapid Object Detection / Scene Labeling and Constraint Propagation / Discrete Relaxation / Probabilistic Relaxation / Searching Interpretation Trees / Semantic Image Segmentation and Understanding / Semantic Region Growing	5

Key Text:

1. Image Processing, Analysis, and Machine Vision by Milan Sonka, Vaclav Hlavac, Roger Boyle. 3rd Ed, Thomson Brooks/Cole Pub.

References:

"Computer Vision: A Modern Approach" by David A. Forsyth and Jean Ponce, Prentice Hall of India, 2006Emanuele Trucco, Alessandro Verri, "Introductory Techniques for 3-D Computer Vision", Prentice Hall, 1998. 2) Robert M. Haralick and Linda G. Shapiro, "Computer and Robot Vision", AddisonWesley. 3) Mubarak Shah, "Fundamentals of Computer Vision", Free E-Book available at Authors site: http://vision.eecs.ucf.edu/faculty/shah.html

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MDSC-CV (P) - Computer Vision – Lab – 1 credit

Algorithms/Exercises from different units in the syllabus will be implemented in Lab. This will be evaluated internally

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CODE: MDSC-RO Robotics 4 Credits			
	Course Objective: ● To introduce the fundamental concepts in robotics. ● Provide an introductory understanding of robotics.		
	Course Outcome: Students will be exposed to a broad range of topics in robotics with emphasis on basics of manipulators, coordinate transformation and kinematics, trajectory planning, control techniques, sensors and devices, robot applications and economics analysis.		
Unit No.	**Unit Title**	**Unit Contents**	**No. of Periods**
1	Introduction	Introduction -- brief history, types, classification and usage, Science and Technology of robots, Some useful websites, textbooks and research journals.	4
2	Elements of robots -- joints, links, actuators, and sensors	Position and orientation of a rigid body, Homogeneous transformations, Representation of joints, link representation using D-H parameters, Examples of D-H parameters and link transforms, different kinds of actuators – stepper, DC servo and brushless motors, model of a DC servo motor, Types of transmissions, Purpose of sensors, internal and external sensors, common sensors – encoders, tachometers, strain gauge based force-torque sensors, proximity and distance measuring sensors, and vision.	4
3	Kinematics of serial robots	Introduction, Direct and inverse kinematics problems, Examples of kinematics of common serial manipulators, workspace of a serial robot, Inverse kinematics of constrained and redundant robots, Tractrix based approach for fixed and free robots and multi-body systems, simulations and experiments, Solution procedures using theory of elimination, Inverse kinematics solution for the general 6R serial manipulator.	6
4	Kinematics of parallel robots	Degrees-of-freedom of parallel mechanisms and manipulators, Active and passive joints, Constraint and loop-closure equations, Direct kinematics problem, Mobility of parallel manipulators, Closed-form and numerical solution, Inverse kinematics of	8

		parallel manipulators and mechanisms, Direct kinematics of Gough-Stewart platform.	
5	Velocity and statics of robot manipulators	Linear and angular velocity of links, Velocity propagation, Manipulator Jacobians for serial and parallel manipulators, Velocity ellipse and ellipsoids, Singularity analysis for serial and parallel manipulators, Loss and gain of degree of freedom, Statics of serial and parallel manipulators, Statics and force transformation matrix of a Gough-Stewart platform, Singularity analysis and statics.	6
6	Dynamics of serial and parallel robots	Mass and inertia of links, Lagrangian formulation for equations of motion for serial and parallel manipulators, Generation of symbolic equations of motion using a computer, Simulation (direct and inverse) of dynamic equations of motion, Examples of a planar 2R and four-bar mechanism, Recursive dynamics, Commercially available multi-body simulation software (ADAMS) and Computer algebra software Maple.	6
7	Motion planning and control	Joint and Cartesian space trajectory planning and generation, Classical control concepts using the example of control of a single link, Independent joint PID control, Control of a multi-link manipulator, Non-linear model based control schemes, Simulation and experimental case studies on serial and parallel manipulators, Control of constrained manipulators, Cartesian control, Force control and hybrid Position/ force control, Advanced topics in non-linear control of manipulators.	5
8	Modeling and control of flexible robots	Models of flexible links and joints, Kinematic modeling of multi-link flexible robots, Dynamics and control of flexible link manipulators, Numerical simulations results, Experiments with a planar two-link flexible manipulator	4

9	Modeling and analysis of wheeled mobile robots	Introduction and some well-known wheeled mobile robots (WMR), two and three-wheeled WMR on flat surfaces, Slip and its modeling, WMR on uneven terrain, Design of slip-free motion on uneven terrain, Kinematics, dynamics and static stability of a three-wheeled WMR's on uneven terrain, Simulations using Matlab and ADAMS.	4
10	Advanced topics in robotics	Introduction to chaos, Non-linear dynamics and chaos in robot equations, Simulations of planar 2 DOF manipulators, Analytical criterion for unforced motion. Gough-Stewart platform and its singularities, use of near singularity for fine motion for sensing, design of Gough-Stewart platform based sensors. Over-constrained mechanisms and deployable structures, Algorithm to obtain redundant links and joints, Kinematics and statics of deployable structures with pantographs or scissor-like elements (SLE's).	5
Key Text: Robotics: Fundamental Concepts and Analysis Oxford University Press, Second reprint, May 2008.			

	CODE: MDSC – ARM	**Advanced Regression Methods- 4 credits**	
	Course Objective: Regression methods is one of the most powerful methods in statistics for determining the relationships between variables and using these relationships to forecast future observations. The foundation of regression analysis is very helpful for any kind of modelling exercises. Regression models are used to predict and forecast future outcomes. Its popularity in finance is very high; it is also very popular in other disciplines like life and biological sciences, management and engineering.		
	Course Outcome: Develop the skill set to • develop a deeper understanding of the non-linear regression model and its limitations;		
Unit	**Topic**	**Details**	**Hours**
1	Non Linear Regression	Origin, Non Linear Least squares, Transformation to Linear Model, Parameter Estimation, Statistical Inference	10
2	Polynomial Regression	Models in one, two or more variables, Non parametric Regression, Orthogonal Polynomials	10
3	Generalized Linear Models	Logistic Regression, Poisson Regression, Generalized Linear Model	10
4	Regression Analysis of Time Series Data	Models, Detecting Auto Correlation, Durbin-Watson test, Estimating Parameters	10
5	Advanced Topics	Robust Regression, Effect of Measurement Errors, Inverse Estimation, Bootstrapping, Classification and Regression Trees, Neural Networks	12

Key Text:
Introduction to Linear Regression Analysis by Douglas C. Montgomery, Elizabeth A. Peck and G. Geoffrey Vining, 5th Edition, Wiley.
Chapters: 7, 12 - 15.

References:
Applied Regression Analysis - Norman Draper and Harry Smith, 3rd Edition

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