SRI SATHYA SAI INSTITUTE OF HIGHER LEARNING

(Deemed to be University)

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

(Effective from the batch 2020-21 onwards)

Prasanthi Nilayam – 515 134

Anantapur District, Andhra Pradesh, Ph.: 08555 287239; Fax: 286919

Website: www.sssihl.edu.in ; Email: registrar@sssihl.edu.in

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, Chemistry, Bioscience, 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 programme 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 from 2020-21 batch and 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**	4	IE2	T	100
MDSC -102	Inferential Statistics	**4**	4	IE2	T	100
MDSC -103	Optimization Techniques	**4**	4	IE2	T	100
MDSC -104	Computer Organization and Architecture	**4**	4	IE2	T	100
MDSC -105	Design and Analysis of Algorithms	**4**	4	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	**30** Hours			**650** Marks
Semester II						
MDSC-201	Stochastic Processes	**4**	4	IE2	T	100
MDSC-202	Regression Methods	**4**	4	IE2	T	100
MDSC-203	Multivariate Statistical Analysis	**4**	4	IE2	T	100
MDSC-204	Distributed Systems	**4**	4	IE2	T	100
MDSC-205	Software Engineering	**4**	4	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	**30** 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**

Paper Code	Title of the Paper	Credits	Hours	Modes of Evaluation	Types of Papers	Maximum Marks
Semester IV						
MDSC -401	Elective - I	4	4**	IE2	T	100**
MDSC-402	Elective - II	4	4**	IE2	T	100**
MDSC-403	Elective - III	4	4**	IE2	T	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	**32** hours**			**600** marks**

	GRAND TOTAL	**92** credits	**117**** 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 4^{th} semester.
c. An E2 type evaluation of the project report at the end of 4^{th} semester will be for 100 marks.

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

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'.

List of Electives:

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

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

TEXT BOOKS

Gilbert Strang, *Linear Algebra and Its Applications*, 4th Edition, Thomson Brooks/Cole, 2005

REFERENCES

1. Allaire, Grégoire, Kaber, Sidi Mahmoud, *Numerical Linear Algebra*, Springer (2008)

2. James W. Demmel, *Applied Numerical Linear Algebra*, SIAM (1997)

3. Lloyd Trefethen and David Bau III, *Numerical Linear Algebra*, SIAM, 1997.

[Lectures 1-29, 32-35 covered in chapter 1-6 of the Text Book]

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[MDSC-102] – Inferential Statistics 4 Credits

	Course Objective: Inferential statistics are concerned with making inferences based on relations found in the sample, to relations in the population. For each individual statistical test we will consider 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 & Estimatpion	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**			

TEXT BOOKS

Key Text(s):

1. Paul G. Hoel, Sidney C. Port, Charles J. Stone, *Introduction to Probability Theory*,

Houghton Mifflin Company, BOSTON, Year: 2003.
Chapter: 7

2. Paul G. Hoel, Sidney C. Port, Charles J. Stone, *Introduction to Statistical Theory*, 1971
Chapters: 1, 2.1 - 2.7, 3.1 - 3.5, 4.1 - 4.7, 5

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[MDSC-103] – Optimization Techniques 4 Credits

Course Objective: 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 1. do a mathematical translation of the verbal formulation of an optimization problem; 2. discover, study and solve optimization problems; 3. 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	Classical Optimization theory	Unconstrained problems: The Newton-Raphson Method, Constrained problems	4
7	Nonlinear Programming Algorithms	Unconstrained algorithms: Direct search, Gradient methods; Constrained algorithms: separable, quadratic and chance constrained programmes	4
Key Text(s): Hamdy A.Taha, *Operations Research- An Introduction*, 9th Edition, Pearson Education - 2017.			
Chapters: 2 to 4, 7, 9, 13.1-13.3, 20, 21.1-21.2.3.			

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

Course Objective:

To study and understand the basics 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 computer's 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):

Patterson, David A. and Hennessy, John L, *Computer Organization and Design: The Hardware/Software Interface*, MIPS - Fourth Edition, Elsewhere Publications, 1994

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. John P. Hayes, *Computer Architecture and Organization* – McGraw Hill Edition, 1978.

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[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		
	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.		
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, 1998.			

Reference Texts:

1. AHO, Hopcraft, Ullman, *"The Design Analysis of Computer Algorithms"*, 1974.
2. Thomas H. Cormen, Charles E. Leiserson, R.L. Rivest, *Algorithms*, Prentice Hall of India Publications, New-Delhi, 1990.
3. Sara Baase and Allen Van Gelder, *Computer Algorithms: Introduction to Design and Analysis*, Pearson education (Singapore) Pte. Ltd, New Delhi, 1999.
4. Alfred V. Aho, John E. Hopcroft, Jeffrey D. Ullman, *The Design and Analysis of Computer Algorithms*, Pearson Education (Singapore) Pte. Ltd New Delhi, 1974

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Semester –II

[MDSC-201] -Stochastic Processes 4 Credits

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 analyze and solve a diverse range of problems arising in production and inventory control, resource planning, service systems, computer networks and many others.

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

Unit	Topic	No. of Periods
1	Markov Chains : classification of states, transition functions, existence and uniqueness of stationary distribution, expected time between successive visits to a state - positive recurrent states,	14
2	Convergence to the stationary distribution, Birth and death chains, Branching and queuing chains.	12
3	Markov Processes: Continuous time discrete state Markov processes, Poisson processes, birth and death processes	12
4	Gaussian processes, The Wiener process; continuity of the mean, covariance and sample functions.	14

Key text:

Paul G. Hoel, Sidney C. Port and Charles J. Stone, *Introduction to Stochastic Processes,* Houghton Mifflin Company, BOSTON, 1972. Chapters: 1-4.

Reference books:

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.

[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	No. of Periods
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, Multi Collinearity, 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:
Douglas C. Montgomery, Elizabeth A. Peck and G. Geoffrey Vining, *Introduction to Linear Regression Analysis*, 5th Edition, Wiley, 2012.
Chapters: 1 - 5, 13.

References:
Norman Draper and Harry Smith, *Applied Regression Analysis*, 3rd Edition, ISBN:9780471170822, Wiley series in Probability and Statistics - Online, 1998.

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[MDSC-203] Multivariate Statistical 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 1. Select appropriate methods of multivariate data analysis, given multivariate data; 2. Write python program to carry out multivariate data analyses; Interpret the output of such analysis.		
Unit	**Chapters**	**Hrs**
0	Bivariate: normal distributions, conditional and marginal distributions	2
1	Matrix algebra, random vectors, random sampling and Maximization Lemma	8
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; Assessing normality, detecting outliers and Transformation to near normality	12
3	Tests of hypothesis about the mean and several means vector of multivariate normal distribution, Hotelling's T^2- statistics, its distribution and applications; Wishart distribution and its properties and MANOVA	14
4	Introduction to principle components, Graphing the Principal Components; canonical correlation and canonical variables; Large sample inference for canonical correlation	8
5	Cluster analysis: Similarity measures, Hierarchical and Nonhierarchical clustering methods; classification of populations.	8
Key text: Richard Johnson and Dean Wichern, *Applied Multivariate Statistical Analysis (AMSA)*, (6th edition). Pearson Publications, 2007. Chapters: 2, 3, 4, 5.1-5.5, 6.1-6.6, 8.1-8.4, 10.1-10.4, 10.6, 12.1-12.4		
Reference books: 1. Anderson, T. W., *An Introduction to Multivariate Statistical Analysis*, Wiley, 2003. 2. Kshirsagar, A. M., *Multivariate Analysis*, Marcel Dekker, 1978.		

[MDSC-204] – Distributed Systems 4 Credits

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. To provide master skills to measure the performance of parallel and distributed algorithms

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.

Unit	Description	No. of Periods
I	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	10
II	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	10
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
	Key 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"*, ISBN-10 : 0132392275, Publisher: Pearson, 2006 3. G. Coulouris, J. Dollimore, and T. Kindberg, *"Distributed Systems: Concepts and Design"*, Pearson Education, 5th Edition, 2012	

[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 provide 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.			
Unit No.	**Unit Title**	**Topics**	**No. of Periods**
1	Software Engineering Basics	Software process Models, Requirement Engineering, Software Project Management, Product metrics, Project Metrics, Estimation of Software projects , Software testing.	8
2	Software Architecture	Definitions and foundations in Software architecture, Architectural tactics and patterns, designing an architecture.	8
3	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, Generalization in class diagrams, Class Diagram Analysis – Attributes, Class Diagram: Operations, Sequence Diagram, State Diagram, State Transition Diagram: Example, Component Diagram, Deployment Diagram.	12

4	Agile Software Development	Basics of agile Process, understanding agile roles, Agile Planning, Creating User Stories Estimating, Tracking Velocity, Burndown Reports, Test-Driven Development, Continuous Integration and Deployment, Iteration Review, Improving at the Iteration Retrospective.	12
5	Agile Approaches	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, 2015
   Chapters:(1.2-1.5),2.3,5.1-5.7,17.3-17.7,18.3,18.6,23.2,25.1-25.4,26.1-26.7.
2. Len Bass, Paul Clements, Rick Kazeman, *"Software Architecture in Practice"*, 3rd Edition, Pearson, 2013
   Chapters:1.1-1.3,2.1-2.13,13.1,13.2,17.1-17.3
3. Rajib Mall, *"Fundamentals of Software Engineering"*, PHI, 3rd Edition, 2007. Chapters: 7
4. Scott W Ambler. Matthew Holitza, *"Agile for Dummies"*, IBM, 2012, Chapters:1,2,3,4

Reference Texts:

1. Pankaj Jalote, *An Integrated Approach to Software Engineering*, 3rd Edition, Narosa Publishing House, New Delhi, 2005
2. Len Bass, Paul Clements, Rick Kazman, *Software Architecture in Practice*, 1997
3. Felix Bachmann, Len Bass, David Garlen, James Ivers, Reed Little, Robert Nord, Judith Stafford, *Documenting Software Architectures: Views and Beyond Paul Clements*, 2nd edition, 2010.
4. Helm, Johnson, Vlissides, *B3 - Gamma - Design Patterns: Elements of Reusable Object-Oriented Software*, 1994

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

Text books

1. Hal Daumé III, *A Course in Machine Learning*, e-Edition, 2020

Chapters: 1, 3, 7, 9, 10, 11, 13, 15.
2. Rogers and Girolami, *A First Course in Machine Learning*, September 2015, by Chapman and Hall/CRC. Chapters: 5.1—5.3, 6.1—6.3.

Reference Books:

1. Hastie, Tibshirani, and Friedman, *The Elements of Statistical Learning*, Springer, 2017
2. Barber, *Bayesian Reasoning and Machine Learning*, Publisher: Cambridge University Press; Online publication date: June 2012; Print publication year: 2012; Online ISBN: 9780511804779; DOI.
3. Mitchell, *Machine Learning*, McGraw Hill series, 1986
4. Chrisopher Bishap, *Pattern Recognition and Machine Learning*, Springer, 2006

References: https://see.stanford.edu/Course/CS229

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[MDSC-301 (P)] - Practicals: Machine Learning 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 and growing field of big data analytics.
- To introduce algorithms needed to handle big data.
- 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 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 & Where?, Characteristics of Big Data, Distributed File Systems, MapReduce, Algorithms using MapReduce	3
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	8
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	8
4	Link Analysis	Page Rank, Computation of Page Rank, Topic sensitive page rank, Link spam	4

5	Frequent Item sets	Market-Basket model, A-priori algorithm, Larger datasets in main memory, Limited pass algorithms	8
6	Social Network Graphs	Clustering, Discovery of Communities, Partitioning, Finding overlapping communities, Simrank, Counting Triangles, Neighborhood properties	8
		Total	39 hours
Key Text: Anand Rajaraman, *"Mining Massive Datasets"*, Stanford University Press – 2014 Chapters: 2.1 - 2.3, 3.1 - 3.7, 4.1 - 4.6, 5.1 - 5.4, 6.1 - 6.4, 10			

[MDSC-302 (P)] – Practicals: Big Data Analytics - 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

[MDSC-303] – Data Visualization [Theory: 2 credits; 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
1	Effective Communication of Quantitative Information	Purpose, Scope, Communication Style, Quantitative relationships, Differing roles of tables and graphs	6
2	Visual Perception and Graphical Communication	Mechanics of Sight, Applying visual attributes to design, Gestalts principle, Fundamental variations of tables, Fundamental variations of graphs	10
3	General Design principles for Communication	Organizing, Highlighting, Integration, Table design, General graph design, Component level graph design, Multi-Variable display	10

Key Text - Stephen Few, *Show me the numbers: Designing tables and graphs to enlighten*, 2nd Edition, Publisher: Analytics Press, 2012

Chapters - 1 to 11

Reference Text - Edward R. Tufte, *The Visual display of quantitative information*, 2nd Edition, ISBN-13 : 978-1930824133, Publisher : Graphics Press (1 May 2001)

[MDSC-303 (P)] – Practicals: Data Visualization 2 Credits

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.

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[MDSC 304 – Hadoop Programming] [Theory: 2 Credits; Lab: 2 Credits]

Course Objective:

- Learn the core techniques and concepts of Big Data and Hadoop ecosystem.
- Write code using MapReduce framework
- Understanding the HDFS architecture
- Write code using the Apache Spark framework

Course Outcome: Student will be able to

- Think in MapReduce paradigm
- Analyze data using Hadoop MapReduce / Apache Spark algorithms
- Design Hadoop / Spark clusters

Unit No.	Unit Title	Unit Contents	No. of Periods
1	Hadoop Overview	Big Data Technologies, Challenges in Big Data Management, Hadoop Architecture, Phases in MapReduce, MapReduce example programs, HDFS Design, HDFS command line interface	6
2	Spark Programming Concepts	Architecture, Unified Stack, RDD, RDD Operations	6
3	Spark SQL	DataFrames, DataSets, SQL in Spark	7
4	Spark Streaming	Concepts, DStream, Structured Streaming	7

Key Text(s):

1. Tom White, *"Hadoop: The Definitive Guide"*, 4th Edition, O'Reilly, 2009.
Chapters: 2 (2.1 - 2.3 till Combiner Functions), 3 (3.1 - 3.3 till Command Line Interface)

2. Hien Luu, *"Beginning Apache Spark 2,"* Apress, 2018.
Chapters: 1, 3, 4, 6

MDSC-304 (P) – Practicals: Hadoop Programming 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 credits]
2) **MDSC – MMS**: Multimedia Systems [4 credits]
3) **MDSC – MIS**: Management Information System [4 credits]
4) **MDSC – MP**: Microprocessor [3 credits] and
   MDSC – MP (P): Practicals: Microprocessor Lab [1 credit]
5) **MDSC – IR**: Information Retrieval [4 credits]
6) **MDSC – EC:** Embedded Computing [4 credits]
7) **MDSC – SC:** Soft Computing [4 credits]
8) **MDSC – CD:** Compiler Design [4 credits]
9) **MDSC – FL:** Formal Languages [4 credits]
10) **MDSC – NS:** Network Security [4 credits]
11) **MDSC – CC:** Cloud Computing [4 credits]
12) **MDSC – GT:** Game Theory [4 credits]
13) **MDSC – PR:** Pattern Recognition [4 credits]
14) **MDSC – CG:** Cryptography [3 credits] and
    MDSC – CG (P): Practicals: Cryptography Lab [1 credit]
15) **MDSC – PP**: Parallel Processing [3 credits] and
    MDSC – PP (P): Practicals: Parallel Processing Lab [1 credit]
16) **MDSC –NLP**: Natural Language Processing [3 credits] and
    MDSC – NLP (P): Practicals: Natural Language Processing Lab [1 credit]
17) **MDSC –IoT:** Internet of Things [3 credits] and
    MDSC – IoT (P): Practicals: Internet of Things Lab [1credit]
18) **MDSC – DL**: Deep Learning [4 credits]
19) **MDSC- IM:** Image Processing [3 credits] and
    MDSC- IM (P): Practicals: Image Processing Lab [1 credit]
20) **MDSC – CV:** Computer Vision [3 credits] and
    MDSC – CV (P): Practicals: Computer Vision Lab [1 credit]
21) **MDSC – RO:** Robotics [4 credits]
22) **MDSC – ARM:** Advanced Regression Methods [4 credits]
23) **MDSC – ACA:** Advanced Computer Architecture [4 credits]
24) **MDSC – TDA:** Topological Data Analysis [4 credits]
25) **MDSC – LSP:** Linux System Programming [4 credits]
26) **MDSC – CGR:** Computer Graphics [4 credits]

Electives

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: Gary Chartrand, Ping Zhang, *Introduction to Graph Theory (reprint)*, Tata McGraw Hill, 2006 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. Toy Vaughan, *Multi Media - Making It Work*, Osborne McGraw Hill,1993

2. Bohdan O. Synpronicz, *Multi Media Networking*, McGraw Hill, 1995

3. Walter Worth John, *A Multimedia Technology and Applications*, 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

- analyze, evaluate, and make recommendations regarding business technology and decisions.
- not only identify problems but also generate solutions and make recommendations based on a logical and thorough analysis of the alternatives.
- evaluate techniques and processes to think differently and to solve and resolve problems by using technology, making informed decisions.
- strengthen and enhance their skills in effective communication through written and oral analyses of cases.
- 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 Foundations of Database Management, Managing Data Resources.	12
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. James O'Brien, *Management Information System*, 11th edition, TMH, 2019.

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

References:

1. Effy Oz, *Management Information System*, Thomson Learning, 5th edition, 2007.
2. W.S. Jawadekar, *Management Information System*, 7th edition, TMH, 2008
3. Steven Alter, *Information Systems the foundation of E-Business*, 4th Edition, Person education, 2002.
4. Turban, McLean, Wetherbe, *Information Technology for management*, 4th edition, Wiley, 2007
5. Mahadeo Jaiswal & Monika Mittal, *Management Information Systems*, Jaswal Oxford Press, 2004
6. Laudon and Loudon, *Management Information Systems*, 10th edition, Pearson Educations, 2007

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 interrupts
- 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: Ramesh S. Gaonkar, Microprocessor Architecture, *Programming and Applications with 8085/8080A* – Wiley Eastern Limited, 5th edition, 2002

Reference Books:

1. B.RAM, *Fundamentals of Microprocessors and Microcomputers* – Dhanpat Rai Pub., 3rd edition, 2008

2. Barry R. Brey, *The Intel Microprocessors 8086/8080, 186/286, 386, 486, Pentium and Pentium Pro Processor Architecture, Programming and Interfacing* – PHI – 3rd edition, 2009

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

CODE: MDSC-MP(P): Practicals: Microprocessor Lab **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.

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CODE: MDSC-IR: INFORMATION RETRIEVAL 4 Credits			
Course Objectives: ● The main objective of this course is to present the basic concepts in information retrieval and more advanced 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			

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

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. Sriram Iyer and Pankaj Gupta, *Embedded Real-time Systems Programming*, Tata McGraw Hill, 2004 (Tenth reprint)

2. Raj Kamal, *Embedded Systems*, Hill Pub. Co. Ltd, 11th print 2007. [Chaps 15, Appendix G]

3. David E. Simon, *An Embedded Software Primer*, Pearson Education, 2007. [Chps 510]

4. *Programming for Embedded Systems*, Dream Software Team, WILEY dreamtech India Ltd. 2005.

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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

- analyze and appreciate the applications which can use fuzzy logic.
- design inference systems.
- understand the difference between learning and programming and explore practical applications of Neural Networks (NN).
- appreciate the importance of optimizations and its use in computer engineering fields and other domains.
- 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'sself 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 - Fuzzy controls - Evolutionary computation	10
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	10

		Neural Networks – Simple Applications –Soft Computing Based Distributed Intelligent Systems – Elements of Chaos Theory	

Key Text:

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

REFERENCE BOOKS:

1. George J. Klir and Bo Yuan, *Fuzzy Sets and Fuzzy Logic*, Prentice Hall, USA, 1995.
2. Timothy J. Ross, *Fuzzy Logic with Engineering Applications*, McGraw Hill, 1997.
3. A.Di. Nola, Lakshmi C Jain, Mauro Madravo, *Soft Computing: A fusion of foundations, methodologies and applications*, Springer – Verlag Berlin Heidelberg, 2004.
4. Laurene Fausett, *Fundamentals of Neural Networks*, Prentice Hall, 1994.
5. D. E. Goldberg, *Genetic Algorithms: Search, Optimization and Machine Learning*, 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 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 environment - Fully dynamic environment - Parameter passing mechanisms	7
8	UNITVIII	Code Generation - Intermediate code and data structures - Basic techniques - Code generation for data structure references	8

		- Code generation for control statements and logical expressions - Code generation for functions and procedure calls, Code Optimization	
Key Text: Kenneth C. Louden, *Compiler Construction: Principles and Practice*, 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	UNITIII	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	UNITV	Hierarchy of formal languages and automata: Recursive languages and Recursively enumerable languages, Unrestricted grammars, Context sensitive grammars and languages, Chomsky hierarchy	10
6	UNITVI	Turing machines: Standard Turing machine, Combining Turing machine for complicated tasks, Turing thesis, Variations in Turing machine, Linear Bound automata.	10

Key Text:

P.Linz, *Introduction To Formal Languages and Automata*, Narosa Pub. 1997.

REFERENCES

1. A. Salomaa, *Formal Languages*, Academic Pub., 1973.
2. Gyorgy E Revesz, *Introduction to Formal Languages*, 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: William Stallings, *Cryptography and Network Security: Principles and Practice*, 5th edition, Pearson Education Inc., 2011.
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. Richard R. Brooks, *Introduction to Computer and Network Security: Navigating Shades of Gray*, 1st Edition, 2013. 2. Charlie Kaufman, Radia Perlman and Mike Speciner, *Network Security: Private Communication in a public world*, 2nd Edition, 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:

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

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

REFERENCE BOOKS

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

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

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

4. Ronald L. Krutz, Russell Dean Vines, *Cloud Security: A Comprehensive Guide to Secure Cloud Computing,* 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	8
6	Extensive Games with	Extensive Games With Perfect Information, Sub game Perfect Equilibrium, two Extensions of the Definition of	8

	Perfect Information	Game, and The Interpretation of a Strategy, Two Notable Finite Horizon Games, and Iterated Elimination of Weakly Dominated Strategies.	
7	Bargaining Games	Bargaining and Game Theory, A Bargaining Game of Alternating Offers, Sub game Perfect Equilibrium, Variations and Extensions	8
Key Text: Martin J Osborne and Ariel Rubinstein, *A Course in Game Theory*, The MIT Press, Cambridge Massachusetts, London, 1994 Chapters: 1 to 7			
REFERENCE BOOKS N.N. Vorobev, *Game Theory*, 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, Support Vector Machines for Separable Classes, SVM for Non-Separable Classes, SVM for Multiclass Case, ϑ-SVM	8
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	10

		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	
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: Sergios Theodoridis and Knostantinos Koutroumbas, *Pattern Recognition*, 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. J. Katz and Y. Lindell, *Introduction to Modern Cryptography*, 2nd 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:

1. S. Goldwasser and M. Bellare, *Lecture Notes on Cryptography*, July 2008. Available online: https://cseweb.ucsd.edu/~mihir/papers/gb.pdf.
2. C. Paar and J. Pelzl, *Understanding Cryptography*, Springer, 2010.

DSC-CG (P): Practicals: Cryptography 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-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: Michale J Quinn, *Parallel Programming in C with MPI and OpenMP*, Tata McGraw Hill 2004			
Reference Book: AnanthaGrama, Anshul Gupta, George Karypis, Vipin Kumar, *Introduction to Parallel Computing*, Pearson education LPE, 2nd Edition, 2004.			

MDSC- PP (P): Practicals: 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

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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. Gilbert K. Krulee, *Computer Processing of Natural Language*, Prentice Hall 1991.			

MDSC-NLP (P): Practicals: Natural Language 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- IOT (T): Internet of Things Theory 3 Credits :: Lab 1 Credit			
Course Objective: Students explore the interconnection and integration of the physical world and the cyberspace design and 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. ● Design and develop IOT Devices.			
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 IDENTIFICATIO N 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, Configuration, Various integration approaches, Data link layer protocols, routing protocols and infrastructure establishment.	6
4	RESOURCE MANAGEMENT IN THE	Clustering, Software Agents, Clustering Principles in an Internet of Things Architecture, Design Guidelines, and Software Agents for Object Representation, Data Synchronization.	10

	INTERNET OF THINGS	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.	
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 Texts:

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, 2013
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, 2011
3. Parikshit. Ahalle & Poonam N. Railkar, *Identity Management for Internet of Things*, River Publishers, 2015

Reference Books:

4. Hakima Chaouchi, *The Internet of Things Connecting Objects to the Web* Willy Publications, 2010
5. Olivier Hersent, David Boswarthick, Omar Elloumi, *The Internet of Things: Key Applications and Protocols*, 2nd Edition, Wiley Publications, 2012
6. Daniel Kellmereit, Daniel Obodovski, *The Silent Intelligence: The Internet of Things*, Publisher: Lightning Source Inc; 1st edition, 2014.
7. Fang Zhaho, Leonidas Guibas, *Wireless Sensor Network: An information processing approach*, Elsevier, 2004

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CODE: MDSC- IOT (P) – Practicals: Internet of Things Lab – 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, Web Html, 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

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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;
- To understand applications in the area of audio processing and image captioning and vision.

Course Outcome: Students will be able to

- learn fundamental principles, theory and approaches for learning with deep neural networks
- know main variants of deep learning (such convolutional and recurrent architectures), and their typical applications.
- learn 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.
- implement basic versions of some of the core deep network algorithms (such as back propagation)
- learn 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	12

		Linking of DNC Writes-Understanding the 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 Reinforcemen t 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 TensorFlow	What Is Tensor Flow?-How Does TensorFlow Compare to Alternatives?-Installing TensorFlow-Creating and Manipulating TensorFlow Variables-TensorFlow Operations-Placeholder Tensors-Sessions in TensorFlow-Navigating Variable Scopes and Sharing Variables-Managing Models over the CPU and GPU-Specifying the Logistic Regression Model in TensorFlow-Logging and Training the Logistic Regression Model-Leveraging TensorBoard to isualizeComputationGraphsandLearning-BuildingaMultilayerModelforMNISTinTensorFlow. Applications: Deep learning for computer vision, Deep Learning Applications at the enterprise Scale, Deep Learning Models for Health care 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, Yoshua Bengio, Aaron Courville. *Deep Learning*, The MIT Press, 2016, 800 pp, ISBN: 0262035618

■ Duda, R.O., Hart, P.E., and Stork, D.G. *Pattern Classification*. Wiley-Interscience. 2nd Edition. 2001.

■ Theodoridis, S. and Koutroumbas, K. *Pattern Recognition*, 4th Edition, Academic Press, 2008.

■ Russell, S. and Norvig, N. *Artificial Intelligence: A Modern approach,* Prentice Hall Series in Artificial 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

- be 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:

Rafael. C. Gonzalez & Richard E. Woods, *Digital Image Processing* – 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:

1. Maria Petrou and Costas Petrou, *Image Processing – The Fundamentals*, Second Edition, John Wiley

and Sons, 2010. 2. Anil. K. Jain, *Fundamentals of Digital Image Processing*, Eastern Economy Edition, Prentice Hall of India 1997.

MDSC-IP (P): Practicals: Image Processing Lab - 1 credit

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

<table>
<tr><th colspan="4">CODE: MDSC-CV Computer Vision
Theory 3 Credits : Lab 1 Credit</th></tr>
<tr><th>Unit No.</th><th>Unit Title</th><th>Unit Contents</th><th>No. of Periods</th></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td colspan="4">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</td></tr>
<tr><td>1</td><td>Review of pre-requisites -1</td><td>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</td><td>6</td></tr>
<tr><td>2</td><td>Review of pre-requisites-II</td><td>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 /</td><td>6</td></tr>
<tr><td>3</td><td>Data Structures for Image Analysis</td><td>Levels of Image Data Representation / Traditional Image Data Structures / Matrices / Chains / Topological Data Structures / Relational Structures / Hierarchical Data</td><td>6</td></tr>
</table>

		Structures / Pyramids / Quadtrees / Other Pyramidal Structures	
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	5

		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	

Key Text:

1) Milan Sonka, Vaclav Hlavac, Roger Boyle, *Image Processing, Analysis, and Machine Vision*, 3rd Edition, Thomson Brooks/Cole Pub, 2000.

References:

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

MDSC-CV (P) - Practicals: 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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<table>
<tr><th colspan="4">CODE: MDSC-RO Robotics 4 Credits</th></tr>
<tr><th>Unit No.</th><th>Unit Title</th><th>Unit Contents</th><th>No. of Periods</th></tr>
<tr><td colspan="4">Course Objective:
● To introduce the fundamental concepts in robotics.
● Provide an introductory understanding of robotics.</td></tr>
<tr><td colspan="4">Course Outcome: Students will be exposed to
• a broad range of topics in robotics with emphasis on basics of manipulators,
• coordinate transformation and kinematics,
• know trajectory planning,
• know control techniques,
• know sensors and devices,
• learn robot applications and economics analysis.</td></tr>
<tr><td>1</td><td>Introduction</td><td>Introduction -- brief history, types, classification and usage, Science and Technology of robots, Some useful websites, textbooks and research journals.</td><td>4</td></tr>
<tr><td>2</td><td>Elements of robots -- joints, links, actuators, and sensors</td><td>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.</td><td>4</td></tr>
<tr><td>3</td><td>Kinematics of serial robots</td><td>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.</td><td>6</td></tr>
<tr><td>4</td><td>Kinematics of parallel robots</td><td>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 parallel manipulators and mechanisms, Direct kinematics of Gough-Stewart platform.</td><td>8</td></tr>
</table>

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.	5

		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).	
Key Text: *Robotics: Fundamental Concepts and Analysis* Oxford University Press, Second reprint, May 2008.			

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CODE: MDSC – ARM Advanced Regression Methods **4 credits**			
Unit	**Topic**	**Details**	**Hours**
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 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;			
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: Douglas C. Montgomery, Elizabeth A. Peck and G. Geoffrey Vining, *Introduction to Linear Regression Analysis*, 5th Edition, Wiley, 2012 Chapters: 7, 12 - 15. **References:** Norman Draper and Harry Smith, *Applied Regression Analysis* - 3rd Edition, Wiley, 1998			

[MDSC- ACA] – Advanced Computer Architecture (4 Credits) (52 Periods).

Course Objective:

- To learn the advanced concepts related to computer architecture, like branch prediction, vector processing etc.
- To have a sharp focus on emerging computing platforms.
- To emphasize on cost-performance-energy trade-offs and good engineering design.

Course Outcome: Student will be able to

1. Understand the principles of Instruction Set Architecture.
2. Understand the concept of Instruction Level Parallelism, branch prediction algorithms, memory hierarchy.
3. Analyze different emerging multicore and multiprocessors systems.

Unit No.	Unit Title	Topics	No. of Periods
1	Instruction Set Architecture	Instruction Set Architectures, Microcode, Pipelining Review Cache Review	9
2	Instruction Level Parallelism	Instruction level parallelism – hardware and software techniques (e.g., dynamic scheduling, superscalar, static and dynamic branch prediction, VLIW, loop unrolling). Exceptions.	14
3	Memory Concepts	Branch Prediction, Memory hierarchy – advanced concepts in caches (e.g., prefetching, lockup-free caches, and multi-level caches), main memory, and virtual memory. Memory Protection.	17
4	Multicore and Multiprocessors	Vector Processors and GPUs Multiprocessors / multicore – overview of different models, cache coherence with shared-memory systems/multicore (snoopy and directory solutions), synchronization.	12

Key Text:

John L. Hennessy and David A. Patterson, *Computer Architecture: A Quantitative Approach* (5^{th} Edition), 2012, ISBN: 978-0123838728

Chapters: 1- 5; Appendix A, B-1 - B67, C.

Reference Texts:

1. D. M. Harris and S. L. Harris, Morgan Kaufmann, *Digital Design and Computer Architecture*, 2nd edition, 2012.
2. John P. Shen and Mikko H. Lipasti, *Modern Processor Design: Fundamentals of Superscalar Processors* (1st Edition), ISBN: 0070570647, Princeton University Library Own, 2004

[MDSC - TDA] – Topological Data Analysis [4 credits]

Course Objective:
To understand complex datasets, where complexity arises from not only the massiveness of the data, but also from the richness of the features. The objective of this subject is to enable the students to become familiar with the new methods in Topological Data Analysis (TDA), from theory, algorithm and application perspectives.

Course Outcome: Student will be able to

- infer high dimensional structure from low dimensional representations and convert data sets into topological objects.
- pursue new research directions in the field of TDA and integrate advanced TDA techniques with other areas of data science such as data mining, machine learning, computer graphics, and data visualization.

Unit	Title	Contents	No. of Periods
1	Introduction	Graphs, connected components, topological space, manifold, point clouds.	12
2	Homology	Simplicial Complexes, Convex Set Systems, Delaunay Complexes and Alpha Complexes, Homology Groups, Relative Homology	12
3	Persistent homology	Persistent Homology, Efficient Implementations, Extended Persistence.	12
4	Persistence topology of data	Barcodes, Example of Natural image, Persistence Landscapes: Norms, Convergence, Confidence Intervals, and Stability of Persistence Landscapes, Statistical Inference using Landscapes	16

Key Text(s):

1. Edelsbrunner, Herbert. *Computational topology: an introduction*, AMS, 2010. Chapters: I, III, IV, VII.
2. Robert Ghrist. *Barcodes: The persistent topology of data*, Bulletin of the American Mathematical Society (AMS), 2008, 45(1): 61–75.
3. Peter Bubenik, *Statistical Topological Data Analysis using Persistence Landscapes*, J. of Machine Learning Research 16 (2015), 77-102.

Reference(s): Frédéric Chazal and Bertrand Michel, *An introduction to Topological Data Analysis: fundamental and practical aspects for data scientists*, 2017.

1. G. Carlsson, Topology and Data, *Bulletin of the American Mathematical Society* Volume 46(2), 2009, 255 - 308.

[MDSC- LSP] – Linux System Programming (4 Credits) (52 Periods).

Course Objective:

- To learn the different set of system calls for the Linux Operating System
- To understand how the Linux OS manages files, processes and memory
- To implement inter-process communication using different mechanisms

Course Outcome: Student will be able to

Assimilate the internal abstractions of any Operating System

Utilize the insights gained from how these abstractions were implemented and apply them in other areas of work

Unit No.	Unit Title	Topics	No. of Periods
1	Introduction	System Calls, Library Functions, Standard C Library, Error handling	6
2	File Management	Overview, File Operations (open, read, write, lseek, close), Atomicity, File Descriptors - relation to open files and duplication, File I/O variations (pread, pwrite, readv, writev), File truncation	10
3	Process Management	Process concept, Process Memory Layout, Virtual Memory Management, Stack Frames, Command line arguments, Environment Variables, Process - Creation, Termination, Execution and Monitoring	12
4	Memory Management	Heap and Stack Memory allocation, Memory Mapping - Creation, Unmapping, File mapping, Synchronization, Anonymous Mapping	12
5	Inter-Process Communication	Signals, Pipes, FIFO, POSIX Semaphores - Named Semaphore and Semaphore Operations, POSIX Shared Memory - Creation, Usage & Removal	12

Key Text: Michael Kerrisk, *The Linux Programming Interface*, No Starch Press, 2010
Chapters: 3 (3.1 - 3.4), 4 (4.1 - 4.7), 5 (5.1 - 5.8), 6 (6.1 - 6.7), 7, 20, 24, 25, 26, 27, 44 (44.1 - 44.4, 44.6 - 44.8), 49 (49.1 - 49.5, 49.7), 53 (53.1 - 53.3), 54 (54.1 - 54.4)

Reference Texts:

Robert Love, *Linux System Programming*, 2nd Edition, O'Reilly, 2013

[MDSC- CGR] – Computer Graphics (4 Credits) (52 Periods)

Course Objective:

- To learn the concepts involved in creating Computer Graphics
- To appreciate the mathematics behind Computer Graphics

Course Outcome: Student will be able to

- Implement algorithms to create graphical images
- Understand the internals of a graphics system

Unit No.	Unit Title	Topics	No. of Periods
1	Math Review	Sets, Quadratic Equations, Trigonometry, Vectors, Curves & Surfaces, Linear Interpolation, Triangles, Matrices, Determinants, Eigenvalues, Matrix diagonalization	6
2	Introduction to Graphics	Applications, API's, Graphics Pipeline, Numerical issues, Raster devices, Pixels, RGB color, Alpha composting	4
3	Ray Tracing	Basic algorithm, Perspective, Computing viewing rays, Ray-Object intersection, Shading, Shadows, Ideal Specular Reflection, Transparency, Refraction, Instancing, Solid Geometry, Distribution ray tracing	10
4	Transformation	2D & 3D Linear transformations, Translation, Affine transformations, Inverses, Coordinate Transformations, Viewing Transformations, Projective Transformations, Perspective projection, Field-of-view	10
5	Graphics Pipeline	Rasterization, Operations before and after Rasterization, Simple Antialiasing, Culling primitives	6
6	Data Structures for Graphics	Triangle Meshes, Scene Graphs, Spatial Data Structures, BSP Trees, Tiling Multidimensional arrays	8
7	Curves	Curve Properties, Polynomial pieces, Cubics, Approximating curves	8

Key Text:

Steve Marschner & Peter Shirley, *Fundamentals of Computer Graphics*, 4th Edition, CRC Press, 2015

Chapters: 1 - 8, 12, 13, 15.
Reference Texts: Sumanta Guha, *Computer Graphics through OpenGL – From Theory to Experiments*, 2nd Edition, CRC Press, 2014

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