M.TECH. COMPUTER SCIENCE AND ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE

M.Tech in Computer Science and Engineering (CSE) programme has been designed for students with sufficient background in computer science and engineering to develop into adept professionals. M.Tech in CSE is a graduate degree that builds skill and knowledge in advanced and current topics of computer science. The degree is suitable for students with a bachelor's degree in a computing related field as well as students who want to demonstrate computer science expertise in addition to a degree in another field. The curriculum has been designed to prepare students for highly prolific careers in industry. Some of the job profiles include: Application analyst, Data Scientist, Data analyst, Database administrator, Information systems manager, IT consultant, Multimedia analyst.

It is a reality that that computer technology has revolutionized the modern world. Technologies that we now use for granted - Internet, mobile phones, medical technology, would not be possible without the major developments made in the field of computing. This M.Tech programme gives a specialized focus on areas of technology, aiming to develop skills and career prospects. The master's degree program offers an integrated course of study covering the theory, implementation and design of information, computing, communication and embedded systems. This programme has specialized courses in the streams of Data Science, Computer Vision, IoT and High Performance Computing with significant focus on research. As a part of the programme during the period of study, students have the opportunity to intern at leading companies and R&D labs for a period of 6 months to one year. There are opportunities for the students to take up a semester or one year study at International Universities like Virje University, Netherlands, UC Davis, UNM for an exchange programme or to pursue a dual degree programme.

Graduates of this programme are well represented in Oracle, IBM, HP, Cerner, Intuit, and other major MNCs as well as in research in premier academic institutions in India and abroad. The graduates are competent to take up R&D positions in Industry, academia and research laboratories.

Programme Objectives:

- Hone the skill of computer science professionals in areas of research and innovation
- Develop experts with high professional competence in recent and futuristic technologies
- Create man power with technical competency in computer science to design and develop solutions for the societal problems

CURRICULUM

First Semester

Course Code	Type	Course	L T P	Cr
18CS601	FC	Foundations of Computer Science(Fractal) Data Structures (2 credits) Algorithms(2 credits)	3 0 1	4
18MA611	FC	Mathematics for Computer Science (Fractal) Linear Algebra (2 Credits) Probability and Statistics (2 credits)	3 0 1	4
	SC	Soft Core - I	3 0 1	4
	SC	Soft Core - II	3 0 1	4
	SC	Soft Core - III	3 0 1	4
18HU601	HU	Amrita Values Program*		P/F
18HU602	HU	Career Competency I*		P/F
Total Credits				**20**

*Non-credit course

Second Semester

Course Code	Type	Course	L T P	Cr
	SC	Soft Core - IV	3 0 1	4
	SC	Soft Core - V	3 0 1	4
	Elective	Elective - I	3 0 0	3
	Elective	Elective - II	3 0 0	3
	Elective	Elective - III	3 0 0	3
18RM600	SC	Research Methodology	2 0 0	2
18HU603	HU	Career Competency II	0 0 2	1
Total Credits				**20**

Third Semester

Course Code	Type	Course	L T P	Cr
	Elective	Elective - IV	3 0 0	3
	Elective	Elective - V	3 0 0	3
18CS798		Dissertation		8
Total Credits				**14**

Fourth Semester

Course Code	Type	Course	L T P	Cr
18CS799		Dissertation		12
Total Credits				**12**

Total Credits 66

Soft Core

Students have to select any five soft core subjects from the list given below:

Course Code	Course	L T P	Cr
18CS621	Foundation of Data Science	3 0 1	4
18CS622	Digital Signal and Image Processing	3 0 1	4
18CS623	Cloud and IoT (2 + 2)	3 0 1	4
18CS624	Machine Learning	3 0 1	4
18CS625	Modeling and Simulation	3 0 1	4
18CS626	Computational Methods for Optimization	3 0 1	4
18CS627	Parallel and Distributed Data Management	3 0 1	4
18CS628	Computational Intelligence	3 0 1	4
18CS629	Modern Computer Architecture	3 0 1	4
18CS630	Deep Learning	3 0 1	4
18CS631	Advanced Algorithms and Analysis	3 0 1	4

Subject Core

Course Code	Course	L T P	Cr
18RM600	Research Methodology	2 0 0	2

Elective (Machine Learning and Data Science Stream)

Course Code	Course	L T P	Cr
18CS701	Machine Learning for Big Data	3 0 0	3
18CS702	Applications of Machine Learning	3 0 0	3
18CS703	Statistical Learning Theory	3 0 0	3
18CS704	Natural Language Processing	3 0 0	3
18CS705	Information Retrieval	3 0 0	3
18CS706	Data Mining and Business Intelligence	3 0 0	3
18CS707	Semantic Web	3 0 0	3
18CS708	Data Visualization	3 0 0	3
18CS709	Computational Statistics and Inference Theory	3 0 0	3
18CS710	Networks and Spectral Graph Theory	3 0 0	3

Elective (Computer Vision Stream)

Course Code	Course	L T P	Cr
18CS711	Video Analytics	3 0 0	3
18CS712	Medical Signal Processing	3 0 0	3
18CS713	Content Based Image and Video Retrieval	3 0 0	3
18CS714	Pattern Recognition	3 0 0	3
18CS715	3D Modeling for Visualization	3 0 0	3
18CS716	Computer Vision	3 0 0	3
18CS717	Visual Sensor Networks	3 0 0	3
18CS718	Image Analysis	3 0 0	3

Elective (Networks and IoT Stream)

Course Code	Course	L T P	Cr
18CS721	Sensor Networks and IoT	3 0 0	3
18CS722	Predictive Analytics for Internet of Things	3 0 0	3
18CS723	Wireless Sensor Networks	3 0 0	3
18CS724	Wireless and Mobile Networks	3 0 0	3
18CS725	Pervasive Computing	3 0 0	3
18CS726	IoT Protocols and Architecture	3 0 0	3

Elective (High Performance Computing Stream)

Course Code	Course	L T P	Cr
18CS731	Parallel and Distributed Computing	3 0 0	3
18CS732	GPU Architecture and Programming	3 0 0	3
18CS733	Reconfigurable Computing	3 0 0	3
18CS734	Data Intensive Computing	3 0 0	3
18CS735	Fault Tolerant Systems	3 0 0	3
18CS736	Computer Solutions of Linear Algebraic Systems	3 0 0	3

Elective (Live-in-Labs)

18CS737	Live-in-Labs		3

Students can do Live-in-Labs course in lieu of an elective from II Semester or III Semester.

18CS601 FOUNDATIONS OF COMPUTER SCIENCE 3-0-1-4

Data Structures (Fractal: 2 Credits)

Asymptotic notation. Introduction to Algorithm Analysis Methodologies
Review of Data Structures: Linear Data Structures – Linked Lists: - Singly LL, Doubly LL, Circular LL. Implementation–Applications. Stacks:-Implementation using Arrays and Linked Lists –Applications in Recursion. Queues -Implementation and Applications. Binary Trees - Basic tree traversals - Binary tree -Priority queues -Binary search tree. AVL trees.

Graphs -Data Structures for Graphs, Types of Graphs: Directed Graphs, Weighted Graphs, etc.. Basic definitions and properties of Graphs, Graph Traversal –Breadth First Search and their applications, Spanning trees, Shortest Paths.
Hashtables – Collision using Chaining – Linear Probing – Quadratic Probing – Double Hashing.

TEXT BOOKS/ REFERENCES:

1. Michael T Goodrich and Roberto Tamassia and Michael H Goldwsasser, "Data Structures and Algorithms in Python++", John Wiley publication, 2013.
2. Goodrich, Michael T., and Roberto Tamassia. Data structures and algorithms in Java. John Wiley & Sons, 2008.
3. Tremblay J P and Sorenson P G, "An Introduction to Data Structures with Applications",Second Edition, Tata McGraw-Hill, 2002

Course Outcomes:

	Course Outcome	**Bloom's Taxonomy Level**
CO 1	Understand the concept and functionalities of Data Structures	L2
CO 2	Identify and apply appropriate data structures to solve problems and improve their efficiency	L3
CO 3	Analyze the complexity of data structures and associated methods	L4
CO 4	Analyze the impact of various implementation and design choices on the data structure performance	L5

ALGORITHMS (Fractal: 2 Credits)

Review of sets and relations, and matrices. Logic. Series, counting principles. Basic sorting and searching algorithms.

Algorithm Analysis: Recurrence Relations and their solutions. Recursion tree method, substitution method and Master theorem. Introduction to Amortized Analysis. Introduction to Divide and Conquer technique. Mergesort, Quicksort and binary search.

Introduction to Greedy Algorithms - Fractional Knapsack – Scheduling Algorithms. Introduction to: DP Algorithms – Matrix Chain – Subsequence Problems – 0-1 Knapsack.

TEXT BOOKS/ REFERENCES:

1. Thomas H Cormen, Charles E Leiserson, Ronald L Rivest and Clifford Stein, "Introduction to Algorithms", Third Edition, Prentice Hall of India Private Limited, 2009.
2. Michael T Goodrich and Roberto Tamassia, "Algorithm Design Foundations - Analysis and Internet Examples", John Wiley and Sons, 2007.
3. Dasgupta S, Papadimitriou C and Vazirani U, "Algorithms", Tata McGraw-Hill, 2009.

Course Outcomes

	Course Outcome	**Bloom's Taxonomy Level**
CO 1	Understand the correctness and analyze complexity of algorithms	L4
CO 2	Understand various algorithmic design techniques and solve classical problems	L3
CO 3	Solve real world problems by identifying and applying appropriate design techniques	L5

18MA611 MATHEMATICS FOR COMPUTER SCIENCE 3-0-1-4

Linear Algebra for Computer Science (Fractal: 2 Credits)

Vector – Vector operations – Advanced Vector operations – Slicing and Dicing – Linear transformations and Matrices – Principle of Mathematical Induction – Special Matrices – Vector Spaces – Span, Linear Independence, and Bases - Orthogonal Vectors and Spaces – Linear Least Squares –Eigenvalues, Eigenvectors, and Diagonalization – Applications in Computer Science.

TEXT BOOKS/ REFERENCES:

1. Ernest Davis, "Linear Algebra and Probability for Computer Science Applications",CRC Press, 2012.
2. Gilbert Strang, "Introduction to Linear Algebra", Fourth Edition, Wellelsley- Cambridge Press, 2009.
3. Howard Anton and Chris Rorrers,"Elementary Linear Algebra", Tenth Edition, 2010 John Wiley & Sons, Inc.

Probability and Statistics for Computer Science (Fractal: 2 Credits)

Introduction to Statistics and Probability – Probability and Conditioning – Conditional Probability – Baye's rule – Random variables – Expectation and Variance – Covariance – Discrete and Continuous Distributions – Central Limit Theorem – Statistics and Parameter estimation – Confidence intervals and Hypothesis testing.

TEXT BOOKS/ REFERENCES:

1. David Forsyth, "Probability and Statistics for Computer Science", Springer international publishing, 2018

2. Ernest Davis, "Linear Algebra and Probability for Computer Science Applications",CRC Press, 2012.

3. Douglas C. Montgomery and George C. Runger, “Applied Statistics and Probability for Engineers”, Third Edition, John Wiley & Sons Inc., 2003.

4. Ronald E. Walpole, Raymond H Myres, Sharon.L.Myres and Kying Ye, “Probability and Statistics for Engineers and Scientists”, Seventh Edition, Pearson Education, 2002.

5. A. Papoulis and Unnikrishna Pillai, “Probability, Random Variables and Stochastic Processes”, Fourth Edition, McGraw Hill, 2002.

OUTCOMES:
Upon completion of the course, the student will be able to

	Course Outcome	**Bloom’s Taxonomy Level**
CO 1	Understand the key techniques and theory behind the type of random variable and distribution	L2
CO 2	Use effectively the various algorithms for applications involving probability and statistics in computing (data analytics)	L3
CO 3	Evaluate and Perform hypothesis testing and to conclude	L4,L5
CO 4	Design and build solutions for a real world problem by applying relevant distributions	L4,L5

18CS621 FOUNDATIONS OF DATA SCIENCE 3-0-1-4

Introduction: What is Data Science? Big Data and Data Science – Datafication - Current landscape of perspectives - Skill sets needed; Matrices - Matrices to represent relations between data, and necessary linear algebraic operations on matrices -Approximately representing matrices by decompositions (SVD and PCA); Statistics: Descriptive Statistics: distributions and probability - Statistical Inference: Populations and samples - Statistical modeling - probability distributions - fitting a model - Hypothesis Testing - Intro to R/ Python.

Data preprocessing: Data cleaning - data integration - Data Reduction Data Transformation and Data Discretization.Evaluation of classification methods – Confusion matrix, Students T-tests and ROC curves-Exploratory Data Analysis - Basic tools (plots, graphs and summary statistics) of EDA, Philosophy of EDA - The Data Science Process.

Basic Machine Learning Algorithms: Association Rule mining - Linear Regression- Logistic Regression - Classifiers - k-Nearest Neighbors (k-NN), k-means -Decision tree - Naive Bayes- Ensemble Methods - Random Forest. Feature Generation and Feature Selection - Feature Selection algorithms - Filters; Wrappers; Decision Trees; Random Forests.

Clustering: Choosing distance metrics - Different clustering approaches - hierarchical agglomerative clustering, k-means (Lloyd's algorithm), - DBSCAN - Relative merits of each method - clustering tendency and quality.

Data Visualization: Basic principles, ideas and tools for data visualization.

TEXT BOOKS / REFERENCES:

1. Cathy O'Neil and Rachel Schutt, " Doing Data Science, Straight Talk From The Frontline", O'Reilly, 2014.
2. Jiawei Han, Micheline Kamber and Jian Pei, " Data Mining: Concepts and Techniques", Third Edition. ISBN 0123814790, 2011.
3. Mohammed J. Zaki and Wagner Miera Jr, "Data Mining and Analysis: Fundamental Concepts and Algorithms", Cambridge University Press, 2014.
4. Matt Harrison, "Learning the Pandas Library: Python Tools for Data Munging, Analysis, and Visualization , O'Reilly, 2016.
5. Joel Grus, "Data Science from Scratch: First Principles with Python", O'Reilly Media, 2015.
6. Wes McKinney, "Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython", O'Reilly Media, 2012.

18CS622 DIGITAL SIGNAL AND IMAGE PROCESSING 3-0-1-4

Two-Dimensional Signals and Systems, Separable Signals, Periodic Signals, General Periodicity, 2-D Discrete-Space Systems, 2-D Convolution, Stability in 2-D Systems. Digital Image Fundamentals-Image acquisition, pixel representation, sampling quantization.

Image enhancement in spatial domain-linear and non linear operators, basic gray level transforms, Histogram, histogram processing- equalization, Matching & color histogram. Enhancement using arithmetic/logic operations, spatial filtering, smoothing spatial filtering, Sharpening spatial filtering. Discrete Fourier Series, Properties, Periodic Convolution, Shifting Property, DFT, Circular Convolution and Shift, Interpolating DFT- 1D and 2D Discrete Cosine Transform, Sub-bands and Discrete Wavelet Transform and relation to filter banks Smoothing frequency domain filtering, sharpening frequency domain Image Transforms --Morphological Image processing- restoration- Sparse representation in image processing. Color Image Processing:

Segmentation - Thresholding – Edge-Based Segmentation – Region Based Segmentation Mean Shift – Active Contour Models – Geometric Deformable Models – Fuzzy Connectivity – 3D Graph Based Image Segmentation – Graph Cut Segmentation - Optimal Surface segmentation- Shape Representation and Description: Hough Transform – Feature Detection and matching - Contour Based and Region Based Shape representation and Description – Feature descriptors- SIFT,SURF,GLOH-matching and tracking Motion Estimation Optical Flow Segmentation - Recognition(Applications as Case studies).

TEXT BOOKS/ REFERENCES:

1. Richard Szeliski, "Computer Vision: Algorithms and Applications", Springer, 2011.
2. Milan Sonka, Vaclav Hlavac and Roger Boyle, "Image Processing, Analysis and Machine Vision", Third Edition, Cengage Learning, 2007.

3. Rafael C. Gonzalez and Richard E. Woods, “Digital Image Processing”, Third Edition, Pearson Education, 2009.
4. John W. Woods, “Multidimensional Signal, Image, and Video Processing and Coding”, Second Edition, , Academic Press, Elsevier Inc. 2012.
5. William K. Pratt, “Digital Image Processing”, Fourth Edition, Wiley Interscience, 2007.

18CS623 CLOUD AND IOT 3-0-1-4

IoT (Fractal: 2 Credits)

Introduction to IoT – IoT definition – Characteristics – IoT Complete Architectural Stack – IoT enabling Technologies – IoT Challenges.

Sensors and Hardware for IoT – Hardware Platforms – Arduino, Raspberry Pi, Node MCU. A Case study with any one of the boards and data acquisition from sensors.

Protocols for IoT – Infrastructure protocol (IPV4/V6/RPL), Identification (URIs), Transport (Wifi, Lifi, BLE), Discovery, Data Protocols, Device Management Protocols. – A Case Study with MQTT/CoAP usage-IoT privacy, security and vulnerability solutions.

Case studies with architectural analysis:
IoT applications – Smart City – Smart Water – Smart Agriculture – Smart Energy – Smart Healthcare – Smart Transportation – Smart Retail – Smart waste management .

TEXT BOOKS/ REFERENCES:

1. "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by Pethuru Raj and Anupama C. Raman ,CRC Press.
2. Adrian McEwen, Designing the Internet of Things, Wiley,2013.

CLOUD (Fractal : 2 Credits)

Introduction to Cloud Computing - Service Model – Deployment Model- Virtualization Concepts – Cloud Platforms – Amazon AWS – Microsoft Azure – Google APIs.

IoT and the Cloud - Role of Cloud Computing in IoT - AWS Components - S3 – Lambda - AWS IoT Core -Connecting a web application to AWS IoT using MQTT- AWS IoT Examples.

Security Concerns, Risk Issues, and Legal Aspects of Cloud Computing- Cloud Data Security.

CLOUD and IoT

At the end of the course the students will be able to

	Course Outcome	Bloom's Taxonomy Level
CO 1	Understand the various concept of the IoT and their technologies.	L2
CO 2	Develop the IoT application using different hardware platforms	L4
CO 3	Implement the various IoT Protocols	L3
CO 4	Understand the basic principles of cloud computing	L2
CO 5	Develop and deploy the IoT application into cloud environment	L4

18CS624 MACHINE LEARNING 3-0-1-4

Introduction: Machine learning, Terminologies in machine learning, Types of machine learning: supervised, unsupervised, semi-supervised learning. Review of probability.

Discriminative Models : Least Square Regression, Gradient Descent Algorithm, Univariate and Multivariate Linear Regression, Prediction Model, probabilistic interpretation, Regularization, Logistic regression, multi class classification, Support Vector Machines- Large margin classifiers, Nonlinear SVM, kernel functions, SMO algorithm.

Computational Learning theory- Sample complexity, ε- exhausted version space, PAC Learning, agnostic learner, VC dimensions, Sample complexity - Mistake bounds.
Gaussian models: Multivariate Gaussian distributions, Maximum Likelihood Estimate, Inferring parameters, Linear and Quadratic Discriminant Analysis, Mixture models, EM algorithm for clustering and learning with latent variables.

Generative models: k-Nearest Neighbour Classification, Bayesian concept learning, Likelihood, Posterior predictive distribution, beta-binomial model, Naive Bayes classifiers, classifying documents using bag of words. Bayesian Statistics and Frequentist statistics. Directed graphical models (Bayes nets), Conditional independence, Inference.

Dimensionality Reduction, Combining weak learners- AdaBoost.

TEXT BOOKS/ REFERENCES:

1. E. Alpaydin, "Introduction to Machine Learning", PHI, 2005.
2. Tom Mitchell, "Machine Learning", McGraw Hill, 1997
3. Kevin P. Murphy, "Machine Learning, a probabilistic perspective", The MIT Press Cambridge, Massachusetts, 2012.
4. Alex Smola and SVN. Viswanathan, "Introduction to Machine Learning", Cambridge University Press, 2008.
5. http://robotics.stanford.edu/people/nilsson/mlbook.html

18CS625 MODELING AND SIMULATION 3-0-1-4

Introduction to Simulation: System and system environment, Component System, Type of systems, Types of models, Steps in simulation study, Advantages and disadvantages of Simulation. Types of Simulation: Discrete Event Simulation, Simulation of a single server queuing system, Simulation of an Inventory system, Continuous Simulation, Predator-prey system, Combined Discrete-Continuous Simulation, Monte Carlo Simulation. Statistical Models in Simulation: Useful statistical model, Discrete and Continuous Probability distributions, Poisson process and Empirical distribution. Random Numbers Generation: Properties of random numbers, Generation of pseudo random numbers, Techniques for generating random numbers, Tests for random numbers. Random Variate Generation: Inverse Transform technique, Convolution method, Acceptance Rejection Techniques. Input Modeling: Data Collection, Identifying the distribution of data, Parameter Estimation, Goodness of fit tests, Selection input model without data, Multivariate and Time series input models. Verification and Validation of Simulation Model: Model Building, Verification and Validation, Verification of Simulation models, Calibration and Validation of models. Output Analysis: Stochastic nature of output data, Measure of performance and their estimation, Output analysis of terminating simulators, Output Analysis of steady state simulation. Comparison and Evaluation of Alternate System Design: Comparison of two system design, Comparison of several system design, Confidence interval for the difference between expected responses of two systems.

TEXT BOOKS/ REFERENCES:

1. J. Banks, John S. Carson, Barry L. Nelson, 'Discrete-Event-System Simulation,' Prentice Hall of India Private Limited.
2. Averill. M. Law: Simulation Modeling and Analysis, Tata McGraw-Hill, Fourth Edition.

18CS626 COMPUTATIONAL METHODS FOR OPTIMIZATION 3-0-1-4

Effective modeling in integer programming-Modeling with integer variables: correct formulations, Optimality, relaxation, bounds, search: branch–and–bound, Choices in modeling: strong formulations, extended formulations, Preprocessing of formulations. Relaxation and decomposition methods for large–scale problems-Describing polyhedra with extreme points and extreme rays, Connections between integer programming and polyhedral, Lagrangian relaxation, Subgradient optimization-Applications: traveling salesman problem, facility location problems, generalized assignment problem, Dantzig–Wolfe decomposition, column generation, Applications: generalized assignment and multicommodity flow problems, Benders decomposition, Applications: facility location, network design problems. Cutting plane methods for unstructured problems-Integer and mixed–integer rounding, Gomory cuts, disjunctive cuts. Cutting plane methods for structured problems-Affine independence, dimension and faces of polyhedral Strong valid inequalities, facets, Valid inequalities for set packing and 0–1 knapsack problems and their separation, Sequential lifting, Sequence independent lifting, Applications: airline crew scheduling, production lot–sizing, facility location problems, network design.

TEXT BOOKS/ REFERENCES:

1. G.L. Nemhauser and L.A. Wolsey, Integer and Combinatorial Optimization, Wiley, 1999.

18CS627 PARALLEL AND DISTRIBUTED DATA MANAGEMENT 3-0-1-4

Introduction: Parallel and Distributed architectures, models, complexity measures, Communication aspects, A Taxonomy of Distributed Systems - Models of computation: shared memory and message passing systems, synchronous and asynchronous systems, Global state and snapshot algorithms.

Distributed and Parallel databases : Centralized versus Distributed Systems, Parallel versus Distributed Systems, Distributed Database architectures-Shared disk, Shared nothing, Distributed Database Design – Fragmentation and Allocation, Optimization.

Query Processing and Optimization – Parallel/Distributed Sorting, Parallel/Distributed Join, Parallel/Distributed Aggregates, Network Partitions, Replication, Publish/Subscribe systems-Case study on Apache Kafka Distributed Publish/Subscribe messaging
Hadoop and Map Reduce – Data storage and analysis, Design and concepts of HDFS, YARN, MapReduce workflows and Features, Setting up a Hadoop cluster

TEXT BOOKS/ REFERENCES:

1. M. Tamer Ozsu, Patrick Valduriez, Principles of Distributed Database Systems 3rd ed. 2011 Edition, Springer
2. Silberschatz, Korth, Sudarshan, “Database system concepts”, 5th edition
3. Dimitri P. Bertsekas and John N. Tsitsiklis, “Parallel and distributed computation : Numerical methods”,
4. Andrew S. Tannenbaum and Maarten van Steen “Distributed Systems: Principles and Paradigms”, Second Edition, Prentice Hall, October 2006.
5. Ajay D. Kshemkalyani and Mukesh Singhal, “Distributed Computing: Principles, Algorithms, and Systems”, Cambridge University Press, 2011.
6. Vijay K Garg, “Elements of Distributed Computing”, Wiley-IEEE Press, , May 2002
7. Parallel database systems: The future of high performance database systems
8. Tom White, Hadoop-The definitive Guide, 4th edition, O’Reilly

Evaluation Pattern:

*Periodical 1 – 15
*Periodical 2 – 15
*Lab - 20
*Project - 10
*End Semester – 40

At the end of the course the students will be able to

	Course Outcome	**Bloom’s Taxonomy Level**
CO1	Describe clearly various distributed and parallel architectures, distributed and parallel databases, the concepts of Map Reduce in Hadoop architecture.	Knowledge
CO2	Implement distributed and parallel algorithms for	Application

	query processing in databases	
CO3	Set up a distributed system, execute algorithms in distributed environment and compare with its centralized version	Analyze
CO4	Set up Hadoop distributed system, develop a map reduce version of a serial algorithm and evaluate the performance	Synthesis

18CS628 COMPUTATIONAL INTELLIGENCE 3-0-1-4

Computational intelligence (CI): Adaptation, Self-organization and Evolution, Biological and artificial neuron, Neural Networks Basic Concepts,- Single Layer perceptron-Multilayer perceptron- Supervised and unsupervised learning- Back propagation networks-Kohnen's self-organizing networks-Hopfield networks- Implementations.
Fuzzy systems: Basic Concepts, Fuzzy sets- properties- membership functions- fuzzy operations, Applications, Implementation, Hybrid systems
Evolutionary computing: -Introduction to Genetic Algorithms. The GA computation process-natural evolution-parent selection-crossover-mutation-properties - classification – Advances in the theory GA. Genetic Programming, Particle Swarm optimization, Ant Colony optimization, artificial immune Systems.
CI application: case studies may include image processing, digital systems, control, forecasting and time-series predictions.

TEXT BOOKS/ REFERENCES:

1. R.C. Eberhart, "Computational Intelligence: Concept to Implementations", Morgan Kaufmann Publishers, 2007.
2. Laurence Fausett, "Fundamentals of Neural Networks",Prentice Hall,1994
3. Timothy J Rose, "Fuzzy Logic with Engineering Applications", Third Edition, Wiley, 1995.
4. A Konar, "Computational Intelligence: Principles, Techniques and Applications", Springer -Verlag, 2005.

18CS629 MODERN COMPUTER ARCHITECTURE 3-0-1-4

Introduction-Fundamentals of computer design, evaluating performance -Pipelining-Instruction set design principles. Caches and memory hierarchy design-Review of memory hierarchy-Advanced memory hierarchy design concepts. Instruction level parallelism and its exploitation-Limits on instruction level parallelism. Multiprocessors and Thread-level parallelism-Models of parallel computation, network topologies, consistency models. Simultaneous Multi-Threading (SMT), Chip Multi-Processors (CMP), General Purpose Graphics Processing Units (GPGPU). VLSI Scaling issues, data speculation, dynamic compilation, communication architectures, near data processing, and other advanced topics.

TEXT BOOKS/ REFERENCES:

1. Computer Architecture: A Quantitative Approach, 5th Edition, 2011, By John L. Hennessy & David A. Patterson, Morgan Kaufmann, ISBN: 978-0-12-383872-8
2. Computer Organization and Design, the Hardware/Software Interface, David A Patterson & John L. Hennessy, Morgan Kaufmann, 5th Edition.)

18CS630 DEEP LEARNING 3-0-1- 4

Neural Networks basics - Binary Classification, Logistic Regression, Gradient Descent, Derivatives, Computation graph, Vectorization, Vectorizing logistic regression – Shallow neural networks: Activation functions, non-linear activation functions, Backpropagation, Data classification with a hidden layer – Deep Neural Networks: Deep L-layer neural network, Forward and Backward propagation, Deep representations, Parameters vs Hyperparameters, Building a Deep Neural Network (Application) - Supervised Learning with Neural Networks – Practical aspects of Deep Learning: Train/Dev / Test sets, Bias/variance, Overfitting and regularization, Linear models and optimization, Vanishing/exploding gradients, Gradient checking – Logistic Regression, Convolution Neural Networks, RNN and Backpropagation – Convolutions and Pooling – Optimization algorithms: Mini-batch gradient descent, exponentially weighted averages, RMSprop, Learning rate decay, problem of local optima, Batch norm – Parameter tuning process.

Neural Network Architectures – Recurrent Neural Networks, Adversarial NN, Spectral CNN, Self-Organizing Maps, Restricted Boltzmann Machines, Long Short-Term Memory Networks (LSTM) and Deep Reinforcement Learning – TensorFlow, Keras or MatConvNet for implementation.

TEXT BOOKS/ REFERENCES:

1. Deep Learning, Ian Goodfellow, Yoshua Bengio and Aeron Courville, MIT Press,First Edition, 2016.
2. Deep Learning, A practitioner's approach, Adam Gibson and Josh Patterson, O'Reilly, First Edition, 2017.
3. **Hands-On Learning with Scikit-Learn and Tensorflow,** Aurelien Geron, O'Reilly, First Edition, 2017.
4. **Deep Learning with Python, Francois Chollet, Manning Publications Co, First Edition, 2018.**
5. **Python Machine Learning by Example,** Yuxi (Hayden) Liu, First Edition, 2017.
6. A Practical Guide to Training Restricted Boltzmann Machines, Geoffrey Hinton, 2010, https://www.cs.toronto.edu/~hinton/absps/guideTR.pdf

	Course Outcome	**Bloom's Taxonomy Level**
CO 1	Apply deep neural networks from building to training models	L3
CO 2	Understand and use dropout regularization, Batch normalization and gradient checking in deep neural nets	L2
CO 3	Apply mini-batch, gradient descent, Momentum, RMSprop and Adam optimization algorithms with convergence	L3

CO 4	Understand train/dev/test datasets and test bias/variance	L2
CO 5	Analyse neural networks using tools - Tensorflow/Keras/MatConvNet	L4
CO 6	Analyse detection and recognition tasks using convolution/adversarial neural networks	L4

18CS631 ADVANCED ALGORITHMS AND ANALYSIS 3-0-1-4

Algorithm Analysis: Asymptotic Notation-Standard - Recurrences - Solution to Recurrences Divide and Conquer - Sorting, Matrix Multiplication and Binary Search. Dynamic Programming-Longest common substring/subsequence - Matrix Chain Multiplication - 0-1 Knapsack problem - Coin Change problem. Greedy algorithms: Fractional knapsack, job scheduling, matroids. Graph Algorithms - Graph Traversal, Single- Source Shortest Paths, All pairs Shortest Paths, Depth First Search, Breadth First Search and their applications, Minimum Spanning Trees. Network Flow and Matching: Flow Algorithms - Maximum Flow – Cuts - Maximum Bipartite Matching - Graph partitioning via multi-commodity flow**,**Karger'r Min Cut Algorithm. Amortized Analysis - Aggregate Method - Accounting Method - Potential Method. String Matching Algorithms: KMP, Aho- Korasik algorithm, Z-algorithm. NP Completeness: Overview - Class P - Class NP - NP Hardness - NP Completeness - Cook Levine Theorem - Important NP Complete Problems - Reduction of standard NP Complete Problems (SAT, 3SAT, Clique, Vertex Cover, Set Cover, Hamiltonian Cycle). Approximation Algorithms: Approximation algorithms for known NP hard problems - Inapproximability - Analysis of Approximation Algorithms

TEXT BOOKS/ REFERENCES:

1. Michael T Goodric and Roberto Tamassia, “Algorithm Design: Foundations, Analysis and Internet Examples”, John Wiley and Sons, 2002.
2. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein, “Introduction to Algorithms”, Third Edition, The MIT Press, 2009.
3. SanjoyDasgupta, Christos Papadimitriou and UmeshVazirani, “Algorithms”, Tata McGraw-Hill, 2009.
4. RK Ahuja, TL Magnanti and JB Orlin, “Network flows: Theory, Algorithms, and Applications”, Prentice Hall Englewood Cliffs, NJ 1993.
5. Rajeev Motwani and PrabhakarRaghavan, “Randomized Algorithms”, Cambridge University Press, 1995.

	Course Outcome	**Bloom’s Taxonomy Level**
CO 1	Understand the correctness and analyze complexity of algorithms	L4
CO 2	Understand various algorithmic design techniques and solve classical problems	L3
CO 3	Solve real world problems by identifying and applying appropriate design techniques	L5
CO 4	Analyze and map a given real world problem to classical problems and find solutions	L5
CO 5	Analyze the impact of various implementation choices on the algorithm complexity and correctness	L4

18RM600 RESEARCH METHODOLOGY 2-0-0-2

Unit I:

Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Research, Research Questions, Research design, Approaches to Research, Quantitative vs. Qualitative Approach, Understanding Theory, Building and Validating Theoretical Models, Exploratory vs. Confirmatory Research, Experimental vs Theoretical Research, Importance of reasoning in research.

Unit II:

Problem Formulation, Understanding Modeling & Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures, Indexing and abstracting services, Citation indexes

Unit III:

Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement Systems Analysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, Field Experiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical Data Analysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results

Unit IV:

Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript. References, Citation and listing system of documents

Unit V:

Intellectual property rights (IPR) - patents-copyrights-Trademarks-Industrial design geographical indication. Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work, Ethics in science

TEXT BOOKS/ REFERENCES:

1. Bordens, K. S. and Abbott, B. B., “Research Design and Methods – A Process Approach”, 8th Edition, McGraw-Hill, 2011
2. C. R. Kothari, “Research Methodology – Methods and Techniques”, 2nd Edition, New Age International Publishers
3. Davis, M., Davis K., and Dunagan M., “Scientific Papers and Presentations”, 3rd Edition, Elsevier Inc.
4. Michael P. Marder,“ Research Methods for Science”, Cambridge University Press, 2011
5. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008
6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New Technological Age”. Aspen Law & Business; 6 edition July 2012

Elective Stream - (Machine Learning and Big Data)

18CS701 MACHINE LEARNING FOR BIG DATA 3-0-0-3

Concept of Machine Learning: Approaches to Modelling - Importance of Words in Documents - Hash Functions- Indexes - Secondary Storage -The Base of Natural Logarithms - Power Laws - MapReduce. Finding similar items: Shingling – LSH - Distance Measures. Mining Data Streams: Stream data model - Sampling data - Filtering streams. Link Analysis: Page Rank, Link Spam.

Frequent Item Sets: Market Basket Analysis, A-Priori Algorithm - PCY Algorithm,
Clustering: Hierarchical clustering, K-Means, Clustering in Non-Euclidean Spaces, BFR, CURE. Recommendation Systems: Utility matrix - Content based - Collaborative filtering - UV Decomposition. Mining Social Network Graphs: Social networks as graphs–Clustering – Partitioning - Simrank. Dimensionality Reduction: Eigen Value Decomposition- PCA - SVD.

Large Scale Machine Learning: Neural Networks - The Support Vector Machines model and use of Kernels to produce separable data and non-linear classification boundaries.
Overview - Deep learning; Tools for Data Ingestion; analytics and visualization.

TEXT BOOKS/ REFERENCES:

1. Anand Rajaraman, Jure Leskovec and J.D. Ullman, “Mining of Massive Data Sets”, ebook, Cambridge University Press, 2014.
2. Kevin P. Murphey, “Machine Learning, a Probabilistic Perspective”, The MIT Press Cambridge, Massachusetts, 2012,
3. Tom M. Mitchel, “Machine Learning”, McGraw Hill, 2013.

18CS702 APPLICATIONS OF MACHINE LEARNING 3-0-0-3

Review of machine learning Concepts, Design of ML system – Model selection, bias, variance, learning curves, and error analysis

Recommendation Systems – Model for Recommendation Systems, Utility Matrix, Content-Based Recommendations, Discovering Features of Documents, Collaborative Filtering.

Mining Social network graphs – Clustering of Social Network Graphs, Partitioning of Graphs, and Finding Overlapping Communities.

Advertising on the Web: Issues in Online Advertising, Online and offline algorithms, The matching Problem, The AdWords Problem, The Balance Algorithm, A Lower Bound on Competitive Ratio for Balance.

Application of dimensionality reduction in Image Processing – compression and Visualization.

Sparse models, State space models, Markov random Fields, Review of Inference for graphical models, Latent Linear and Variable models for discrete data, random algorithms in Computational Linear algebra.

TEXT BOOKS/ REFERENCES:

1. Anand Rajaraman, Jure Leskovec and J.D. Ullman, "Mining of Massive Data sets", e-book, Publisher, 2014.
2. Kevin P. Murphey, "Machine Learning, a Probabilistic Perspective", The MIT Press Cambridge, Massachusetts, 2012,
3. Selected papers.

Evaluation Pattern:

The evaluation will be as follows

- Periodical 1 – 10
- Periodical 2 – 10
- Lab - 20
- Project - 30
- End Semester – 30

At the end of the course the students will be able to

	Course Outcome	**Bloom's Taxonomy Level**
CO1	Describe few Machine Learning systems like recommendation systems, social graph mining, and targeted web advertising	Knowledge
CO2	Implement ML algorithms to solve real world problems	Application
CO3	Compare different solutions for a given problem in the context of performance	Analyze
CO4	Design a machine learning system by incorporating various components of ML and evaluate the performance	Synthesis

18CS703 STATISTICAL LEARNING THEORY 3-0-0-3

Overview of Supervised Learning, Basis Expansions and Regularization, Kernel smoothing, Model assessment and Selection, Model Inference, Additive Models, Trees & Related Methods, Boosting and Additive Trees, Support Vector Machines and Flexibilities, Prototype methods and Nearest Neighbors, Unsupervised Learning, Ensemble Learning, Undirected graphical Models, High dimensional Problems.

TEXT BOOKS/ REFERENCES:

1. Trevor Hastie, Robert Tibshirani and Jerome Friedman, "Elements of Statistical Learning" Second Edition, Springer, 2008.

At the end of the course the students will be able to

	Course Outcome	**Bloom's Taxonomy Level**
CO 1	Overview of Supervised Learning, Basis Expansions and Regularization	L2
CO 2	Unsupervised Learning, Ensemble Learning	L2

CO 3	Model assessment and Selection, Model Inference, Additive Models	L3
CO 4	Support Vector Machines and Flexibilities	L3
CO 5	Prototype methods and Nearest Neighbors, Undirected graphical Models, High dimensional problems	L4
CO 6	Implementation of Additive models, SVM and its variants.	L5

18CS704 NATURAL LANGUAGE PROCESSING 3-0-0-3

Introduction and Mathematical foundations: Elementary probability theory – Essential information theory. Linguistic essentials: Part of speech and morphology – Phrase structure. Corpus based work: Looking up text - Marked-up data. Statistical inference: Bins: Forming equivalence classes - Statistical Estimators – Combining Estimators. Word Sense Disambiguation: Supervised and Dictionary based Disambiguation. Markov Models: Hidden Markov Models – Implementation - Properties and Variants. Part of Speech Tagging: Hidden Markov Model Taggers - Transformation based Learning of Tags – Tagging accuracy and use of Taggers. Probabilistic Context free grammars and Probabilistic parsing. Statistical alignment and Machine translation: Text alignment – Word alignment – Statistical Machine Translation.

TEXT BOOKS/ REFERENCES:

1. Christopher D. Manning and HinrichSchutze, “Foundations of Statistical Natural Language Processing”, MIT Press, 1999.
2. Daniel and James H. Martin “Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition”, Second Edition, Prentice Hall of India, 2008.
3. James Allen, “Natural Language Processing with Python”, First Edition, O'Reilly Media, 2009.

18CS705 INFORMATION RETRIEVAL 3-0-0-3

Introduction to IR: Space Retrieval Models - Ranked Retrieval - Text Similarity Metrics - Tokenizing- stemming-Evaluations on benchmark text collections - Components of an information retrieval system. Indexing for IR: Inverted Indices - Postings lists - Optimizing indices with skip lists - Proximity and phrase queries - Positional indices - Dictionaries and tolerant retrieval - Dictionary data structures - Wild-card queries- n-gram indices - Spelling correction and synonyms - Edit distance - Index construction - Dynamic indexing - Distributed indexing - real-world issues. Relevance in IR: Parametric or fielded search - Document zones - Vector space retrieval model - tf.idf weighting - queries as vectors - Computing scores in a complete search system - Efficient scoring and ranking - Evaluation in information retrieval : User happiness- Creating test collections: kappa measure-interjudge agreement - Relevance feedback and query expansion: Query expansion - Automatic thesaurus generation - Sense-based retrieval -. Document Classification and Clustering: Introduction to text classification -Latent Semantic Indexing.

TEXT BOOKS/ REFERENCES:

1. C. Manning, P. Raghavan, and H. Schütze, "Introduction to Information Retrieval", Cambridge University Press, 2008.
2. R. Baeza-Yates and B. Ribeiro Neto,"Modern Information Retrieval: The Concepts and Technology behind Search", Second Edition, Addison Wesley, 2011.
3. David A. Grossman and Ophir Frieder "Information Retrieval: Algorithms and Heuristics", Second Edition, Springer 2004.

18CS706 DATA MINING AND BUSINESS INTELLIGENCE 3-0-0-3

Introduction: Evolution and importance of Data Mining-Types of Data and Patterns minedTechnologies-Applications-Major issues in Data Mining. Knowing about Data- Data Preprocessing: Cleaning– Integration–Reduction–Data transformation and Discretization. Data Warehousing: Basic Concepts-Data Warehouse Modeling- OLAP and OLTP systems - Data Cube and OLAP operations–Data Warehouse Design and Usage-Business Analysis Framework for Data Warehouse Design- OLAP to Multidimensional Data Mining. Mining Frequent Patterns: Basic Concept – Frequent Item Set Mining Methods – Mining Association Rules – Association to Correlation Analysis. Classification and Predication: Issues - Decision Tree Induction - Bayesian Classification – Rule Based Classification – kNearest mining Classification. Prediction –Accuracy and Error measures. Clustering: Overview of Clustering – Types of Data in Cluster Analysis – Major Clustering Methods. Introduction to BI -BI definitions and concepts- BI Frame work-Basics of Data integration Introduction to Business Metrics and KPI - Concept of dash board and balance score card. Tool for BI: Microsoft SQL server: Introduction to Data Analysis using SSAS tools Introduction to data Analysis using SSIS tools- Introduction to Reporting Services using SSRS tools- Data Mining Implementation Methods.

TEXT BOOKS/ REFERENCES:

1. Jiawei Han, Micheline Kamber and Jian Pei, "Data Mining Concepts and Techniques", Third Edition, Elsevier Publisher, 2006.
2. K.P.Soman, Shyam Diwakar and V.Ajay, "Insight into Data Mining Theory and Practice", PHI of India, 2006.
3. Loshin D, "Business Intelligence", First Edition, Elsevier Science, 2003.
4. Darren Herbold, Sivakumar Harinath, Matt Carroll, Sethu Meenakshisundaram, Robert Zare and Denny Guang-Yeu Lee, "Professional Microsoft SQL Server Analysis Services 2008 with MDX", Wrox, 2008.
5. Brian Knight and Erik Veerman, Grant Dickinson and Douglas Hinson, "Professional SQL Server 2008 Integration Services", Wiley Publishing, Inc, 2008.

18CS707 SEMANTIC WEB 3-0-0-3

Introduction to the Web Science and Semantic Web, Introduction to Ontologies, Ontology Languages for the Semantic Web – Resource Description Framework (RDF) – Lightweight ontologies: RDF Schema – Web Ontology Language (OWL) – A query language for RDF: SPARQL, Ontology Engineering Semantic web and Web 2.0 Applications of Semantic Web, Infrastructure Social Networks, Web 3.0 - Linked Data RDFa and the Open Graph Protocol schema.org and search enhancement Semantic

Knowledge Representation: Languages - Formalisms, Logics - Semantic Networks, Frame-Based KR, and Description Logics - Ontology Design and Management using the Protege editor Ontology Reasoning with Pellet, Ontology Querying with SPARQL - Ontology Programming with the Jena API - Emerging Semantic Web Ontology Languages using Protégé tool.

TEXT BOOKS/ REFERENCES:

1. Michael C. Daconta, Leo J. Obrst, and Kevin T. Smith, "The Semantic Web: A Guide to the Future of XML, Web Services, and Knowledge Management", Fourth Edition, Wiley Publishing, 2003.
2. John Davies, Rudi Studer, and Paul Warren John, "Semantic Web Technologies: Trends and Research in Ontology-based Systems", Wiley and Son's, 2006.
3. John Davies, Dieter Fensel and Frank Van Harmelen, "Towards the Semantic Web: Ontology-Driven Knowledge Management", John Wiley and Sons, 2003.

Evaluation Pattern:

*Periodical 1 – 15
*Periodical 2 – 15
*Continuous Evaluation – 30
*End Semester – 40

At the end of the course the students will be able to

	Course Outcome	**Bloom's Taxonomy Level**
CO 1	Understand the concept structure of the semantic web technology and how this technology revolutionizes the World Wide Web.	L2
CO 2	Understand the concepts of Web Science, semantics of knowledge and resource, ontology.	L2
CO 3	Describe logic semantics and inference with OWL.	L3
CO 4	Use ontology engineering approaches in semantic applications	L3
CO 5	Learn Web graph processing for various applications such as search engine, community detection	L4
CO 6	Program web applications and graph processing techniques using Python	L5

18CS708 DATA VISUALIZATION 3-0-0-3

Value of Visualization – What is Visualization and Why do it: External representation – Interactivity – Difficulty in Validation. Data Abstraction: Dataset types – Attribute types – Semantics. Task Abstraction – Analyze, Produce, Search, Query. Four levels of validation – Validation approaches – Validation examples. Marks and Channels

Rules of thumb – Arrange tables: Categorical regions – Spatial axis orientation – Spatial layout density. Arrange spatial data: Geometry – Scalar fields – Vector fields – Tensor fields. Arrange networks and trees: Connections, Matrix views – Containment. Map color: Color theory, Color maps and other channels.

Manipulate view: Change view over time – Select elements – Changing viewpoint – Reducing attributes. Facet into multiple views: Juxtapose and Coordinate views – Partition into views – Static and Dynamic layers – Reduce items and attributes: Filter – Aggregate. Focus and context: Elide – Superimpose - Distort – Case studies.

TEXT BOOKS/REFERENCES:

1. Tamara Munzner, Visualization Analysis and Design, A K Peters Visualization Series, CRC Press, 2014.
2. Scott Murray, Interactive Data Visualization for the Web, O'Reilly, 2013.
3. Alberto Cairo, The Functional Art: An Introduction to Information Graphics and Visualization, New Riders, 2012
4. Nathan Yau, Visualize This: The FlowingData Guide to Design, Visualization and Statistics, John Wiley & Sons, 2011.

At the end of the course the students will be able to

	Course Outcome	**Bloom's Taxonomy Level**
CO 1	Understand the key techniques and theory behind data visualization	L2
CO 2	Use effectively the various visualization structures (like tables, spatial data, tree and network etc.)	L3
CO 3	Evaluate information visualization systems and other forms of visual presentation for their effectiveness	L4,L5
CO 4	Design and build data visualization systems	L4,L5

18CS709 COMPUTATIONAL STATISTICS AND INFERENCE THEORY 3-0-0-3

Computational Statistics- Probability concepts, Sampling Concepts, Generating Random Variables, Exploratory Data Analysis, Monte Carlo Methods for Inferential Statistics, Data Partitioning, Probability Density Estimation, Statistical Pattern Recognition, Nonparametric Regression. Data Mining- data mining algorithms-Instance and Features, Types of Features (data), Concept Learning and Concept Description, Output of data mining Knowledge Representation; Decision Trees- Classification and Regression trees constructing.

Classification trees, Algorithm for Normal Attributes, Information Theory and Information. Entropy, Building tree, Highly-Branching Attributes, ID3 to c4.5, CHAID, CART, Regression Trees, Model Trees, Pruning. Preprocessing and Post processing in data mining – Steps in Preprocessing, Discretization, Manual Approach, Binning, Entropy- based Discretization, Gaussian Approximation, K-tile method, Chi Merge, Feature extraction, selection and construction, Feature extraction, Algorithms, Feature selection, Feature construction, Missing Data, Post processing. Association Rule Mining- The Apriori Algorithm. Multiple Regression

Analysis, Logistic Regression, k- Nearest Neighbor Classification, Constructing new attributes for algorithms of decision trees. Induction, Quick, Unbiased and Efficient Statistical tree.

TEXT BOOKS/ REFERENCES:

1. Wendy L. Martinez and Angel R, "Martinez Computational Statistics," Chapman & Hall/CRC, 2002.
2. Ian H. Witten, "Data Mining: Practical Machine Learning Tools and Techniques with Java Implementations", Morgan Kaufmann, 2000.
3. Jiawei Han and Micheline Kamber, "Data Mining: Concepts and Techniques," Morgan Kaufmann Publishers, 2001.
4. K. P. Soman, V. Ajay and Diwakar Shyam, "Insight into Data Mining: Theory and Practice", Prentice Hall India, 2005.

At the end of the course the students will be able to

	Course Outcome	**Bloom's Taxonomy Level**
CO 1	Concepts of probability and statistics	L2
CO 2	Data analysis, statistical pattern recognition and data mining concepts	L2
CO 3	Classification and regression trees	L3
CO 4	Multiple Regression Analysis, Logistic Regression, k- Nearest Neighbor Classification	L3
CO 5	Feature selection and extraction algorithms	L4
CO 6	Implementations of Logistic regression and Apriori algorithms	L5

18CS710 NETWORKS AND SPECTRAL GRAPH THEORY 3-0-0-3

Graphs and Networks- Review of basic graph theory, Mathematics of networks- Networks and their representation, Graph spectra, Graph Laplacian, The structure of complex networks, Clustering, Community structures, Social networks - the web graph, the internet graph, citation graphs.

Measures and metrics- Degree centrality, Eigenvector centrality, Katz centrality, PageRank, Hubs and authorities, Closeness centrality, Betweenness centrality, Transitivity, Reciprocity, Similarity, assortative mixing.

Networks models - Random graphs, Generalized random graphs, The small-world model, Exponential random graphs, The large-scale structure of networks- small world effect, Degree distributions, Power laws and scale-free networks; Structure of the Internet, Structure of the World Wide Web.

Fundamental network algorithms- Graph partitioning, Maximum flows and minimum cuts, Spectral graph partitioning, Community detection, Girvan and Newman Algorithm, Simple modularity maximization, Spectral modularity maximization, Fast methods based on the modularity.

Models of network formation-Preferential attachment, The model of Barabasi and Albert, Vertex copying models, Network optimization models; Epidemics on networks- Models of the spread of

disease, SI model, SIR model, SIS model, SIRS model; Network search-Web search, Searching distributed databases

TEXT BOOKS/ REFERENCES:

1. M.E.J. Newman, "Networks: An Introduction", Oxford University Press, 2010.
2. Dougles West, "Introduction to Graph Theory", Second Edition, PHI Learning Private Limited, 2011.
3. Guido Caldarelli, "Scale-Free Networks", Oxford University Press, 2007.
4. Alain Barrat, Marc Barthelemy and Alessandro Vespignani, "Dynamical processes on Complex networks", Cambridge University Press, 2008.
5. Reuven Cohen and Shlomo Havlin, "Complex Networks: Structure, Robustness and Function", Cambridge University Press, 2010.

Evaluation Pattern:

The evaluation will be as follows

- Periodical 1 – 10
- Periodical 2 – 10
- Lab -10
- Project - 20
- End Semester – 50

At the end of the course the students will be able to

	Course Outcome	**Bloom's Taxonomy Level**
CO1	Describe fundamental tools to study networks, mathematical models of network structure, computer algorithms for network data analysis and the theories of processes taking place on networks.	Knowledge
CO2	Experience working with complex network data sets and implement computer algorithms to solve network problems, use modern network tools to analyze data	Application
CO3	Compare different solutions of large network problems in terms of network performance measures, Compare structure of different types of networks	Analyze
CO4	Design algorithms to solve large real-world network problems, devise models of network structure to predict the behavior of networked systems.	Synthesis

Elective Stream - (Computer Vision)

18CS711 VIDEO ANALYTICS 3-0-0-3

Introduction: Video Analytics. Computer Vision: Challenges- Spatial Domain Processing – Frequency Domain Processing-Background Modeling-Shadow Detection-Eigen Faces - Object Detection -Local Features-Mean Shift: Clustering, Tracking - Object Tracking using Active Contours – Tracking & Video Analysis: Tracking and Motion Understanding – Kalman filters,

condensation, particle, Bayesian filters, hidden Markov models, change detection and model based tracking- Motion estimation and Compensation-Block Matching Method, Hierarchical Block Matching, Overlapped Block Motion and compensation,Pel-Recursive Motion Estimation, Mesh Based Method, Optical Flow Method - Motion Segmentation -Thresholding for Change Detection, Estimation of Model parameters - Optical Flow Segmentation-Modified Hough Transform Method- Segmentation for Layered Video Representation-Bayesian Segmentation -Simultaneous Estimation and Segmentation-Motion Field Model - Action Recognition - Low Level Image Processing for Action Recognition: Segmentation and Extraction, Local Binary Pattern, Structure from Motion - Action Representation Approaches: Classification of Various Dimension of Representation, View Invariant Methods, Gesture Recognition and Analysis, Action Segmentation. Case Study: Face Detection and Recognition, Natural Scene Videos, Crowd Analysis, Video Surveillance, Traffic Monitoring, Intelligent Transport System.

TEXT BOOKS/ REFERENCES:

1. Richard Szeliski, “Computer Vision: Algorithms and Applications”, Springer, 2011.
2. Yao Wang, JornOstermann and Ya-Qin Zhang, “Video Processing and Communications”, Prentice Hall, 2001.
3. A.MuratTekalp, “Digital Video Processing”, Pearson, 1995.
4. Thierry Bouwmans, FatihPorikli, Benjamin Höferlin and Antoine Vacavant ,“Background Modeling and Foreground Detection for Video Surveillance: Traditional and Recent Approaches, Implementations, Benchmarking and Evaluation", CRC Press, Taylor and Francis Group, 2014.
5. Md. Atiqur Rahman Ahad, "Computer Vision and Action Recognition-A Guide for Image Processing and Computer Vision Community for Action Understanding", Atlantis Press, 2011.

Evaluation Pattern

* Periodical 1 – 15
* Periodical 2 – 15
* Continuous Evaluation – 20
* End Semester – 50

At the end of the course the students will be able to

	Course Outcome	**Bloom’s Taxonomy Level**
CO 1	Understand the algorithms available for performing analysis on video data and address the challenges	L2
CO 2	Understand the approaches for identifying and tracking objects and person with motion based algorithms.	L2
CO3	Understand the algorithms available for searching and matching in video content	L2
CO 4	Analyze approaches for action representation and recognition	L4
CO 5	Identify, Analyze and apply algorithms for	L6

	developing solutions for real world problems	

18CS712 MEDICAL SIGNAL PROCESSING 3-0-0-3

Medical Imaging Modalities and the need for different modalities (MRI, CT, OCT for Retinal Images, PET, X-Ray, Ultra Sound, Microscopy, Flow Cytometry, Imaging Flow Cytometry, etc.
Pre-processing – Image Enhancement – Focus Analysis - Noise reduction (Additive and Speckle Noise) – Image Quality Measures - Domain Transformation: Fourier Domain and Wavelet Domain
Medical Image Segmentation – Threshold Based – Region Growing – Active Contours – Level Set – Graph Partitioning – Deep Learning based Segmentation on 2D or 3D volume of Data
Feature Extraction – Morphological Features – Textural Features – SIFT, SURF, MSER, HoG, Feature extraction for 1D Biomedical signals : LPC, MFCC – Deep Features
Image Registration and Fusion – Keypoints selection – Keypont Descriptors - Keypoint Matching - Geometric transformations
Classification and Clustering– Examples of image classification for diagnostic/assistive technologies – Traditional and Deep learning based classifiers
3D volume reconstruction – Reconstruction of cell structure from focus stack of images - CT and MRI volume reconstruction – Wavelet based Volume Rendering

TEXT BOOKS / REFERENCES:

1. Guide to Medical Image Analysis - Methods and Algorithms, Klaus D. Toennies , in Advances in Computer Vision and Pattern Recognition, 2nd Edition, Springer-Verlag London, DOI: 10.1007/978-1-4471-7320-5, ISBN 978-1-4471-7318-2
2. Geoff Dougherty, Medical Image Processing Techniques and application, Springer New York 2011

18CS713 CONTENT BASED IMAGE AND VIDEO RETRIEVAL 3-0-0-3

Architecture and Design: Introduction - Architecture of content-based image and video retrieval - Designing an image retrieval system - Designing a video retrieval system. Feature extraction and similarity measure: Color - Texture - Shape - Spatial relationships - MPEG 7 features. Video Indexing and understanding- Query Language for multimedia search- Relevance feedback- Semantic based retrieval – Trademark image retrieval- Standards relevant to Content based image retrieval- Query Specification - Metadata description. Content based video Retrieval: Feature extraction - Semantics understanding -Summarization - Indexing and retrieval of video, Case studies and applications.

TEXT BOOKS / REFERENCES:

1.Oge Marques and Borko Furht, “Content Based Image and Video Retrieval”, Multimedia Systems and Applications, Springer, 2002.
2**.** Lew, Michael S, “Principles of Visual Information Retrieval”, Advances in Pattern recognition, Springer, 2001.

3. Image Databases: Search and Retrieval of Digital Imagery , by Vittorio Castelli and

Lawrence D. Bergman, Wiley-Interscience, 2001

At the end of the course the students will be able to

	Course Outcome	**Bloom's Taxonomy Level**
CO 1	Understand the modules involved in designing CBIVR systems and their applications	L2
CO 2	Extract different visual features from images and videos	L4
CO 3	Understand query specification and evaluate the retrieval	L4
CO 4	Understand indexing and the semantics of visual data	L3
CO 5	Develop and evaluate visual retrieval algorithms	L6, L5

18CS714 PATTERN RECOGNITION 3-0-0 3

Introduction to Pattern Recognition,Tree Classifiers -Decision Trees: CART, C4.5, ID3., Random Forests. Bayesian Decision Theory. Linear Discriminants. Discriminative Classifiers: the Decision Boundary- Separability, Perceptrons, Support Vector Machines. Parametric Techniques- Maximum Likelihood Estimation, Bayesian Parameter Estimation, Sufficient Statistics. Non -Parametric Techniques-Kernel Density Estimators, Parzen Window, Nearest Neighbor Methods. Feature Selection- Data Preprocessing, ROC Curves, Class SeparabilityMeasures,Feature Subset Selection,Bayesian Information Criterion. The Curse of Dimensionality-Principal Component Analysis. Fisher Linear Discriminant, Singular Value Decomposition, Independent Component Analysis, Kernel PCA Locally Linear Embedding.Clustering-. Sequential Algorithms, Hierarchical Algorithms,Functional Optimization-Based Clustering,Graph Clustering, Learning Clustering, Clustering High Dimensional Data, Subspace Clustering,Cluster Validity Measures, Expectation Maximization, Mean Shift. Classifier Ensembles-Bagging, Boosting / AdaBoost. Graphical Models- Bayesian Networks, Sequential Models- State-Space Models, Hidden Markov Models, Context Dependent Classification. Dynamic Bayesian Networks.

TEXT BOOKS/ REFERENCES:

1. Duda, R.O., Hart, P.E., and Stork, D.G. "Pattern Classification". Second Edition, Wiley-Interscience. 2003.
2. Theodoridis, S. and K. Koutroumbas, "Pattern Recognition", Fourth Edition, San Diego, CA: Academic Press, 2009.
3. Christopher M. Bishop, "Pattern Recognition and Machine Learning", Springer, 2006.
4. Earl Gose, Richard Johnsonbaugh and Steve Jost, "Pattern Recognition and Image Analysis", Prentice Hall of India, 2002.

18CS715 3D MODELING FOR VISUALIZATION 3-0-0-3

Introduction to Graphics, Two-dimensional Geometric Transformations, Three-dimensional Concepts. Modeling: Three-Dimensional Object Representations: Raw 3D data, Surface Representation, Solid Representation, High-Level Representation. Reconstruction of 3D Meshes from Polygon Soup: Cell complex, Solidity Determination, Meshes reconstruction. Advanced Rendering Techniques:Photorealistic Rendering, Global Illumination, Participating Media Rendering, Ray tracing, Monte Carlo algorithm, Photon Mapping. Volume Rendering: Volume

graphics Overview, Marching cubes, Direct volume rendering. Surfaces and Meshes.Visualization: Meshes for Visualization, Volume Visualization and Medical Visualization.

TEXT BOOKS / REFERENCES:

1. Tomas Akenine Moller, Eric Haines and Naty Hoffman," Real-Time Rendering", Third Edition, A K Peters Ltd, 2008.
2. Matt Pharr and Greg Humphreys,"Physically Based Rendering: From Theory to Implementation", Second Edition, Morgan Kaufmann, 2010.
3. Lars Linsen, Hans Hagen and Bernd Hamann, "Visualization in Medicine and Life Sciences", Springer-Verlag Berlin Heidelberg, 2008.
4. Computer Graphics with OpenGL, Fourth Edition, Donald Hearn, M. Pauline Baker ans Warren Carithers, Pearson Education India, 2013.

18CS716 COMPUTER VISION 3-0-0-3

Image Formation Models - Monocular imaging system, Orthographic & Perspective Projection, Camera model and Camera calibration, Binocular imaging systems. Image Processing and Feature Extraction - Image representations (continuous and discrete), Edge detection. Motion Estimation, Regularization theory, Optical computation, Stereo Vision, Motion estimation, Structure from motion. Shape Representation and Segmentation, Deformable curves and surfaces, Snakes and active contours, Level set representations, Fourier and wavelet descriptors, Medial representations, Multiresolution analysis. Object recognition - Hough transforms and other simple object recognition methods, Shape correspondence and shape matching, Principal component analysis, Shape priors for recognition

TEXT BOOKS/ REFERENCES:

1. Computer Vision - A modern approach, by D. Forsyth and J. Ponce, Prentice Hall
2. Robot Vision, by B. K. P. Horn, McGraw-Hill.

18CS717 VISUAL SENSOR NETWORKS 3-0-0-3

Visual Sensor network technology-Sensor node-transmission technology-MAC protocol-routing protocol-transmission protocol-energy efficient algorithm -low level representation of data-collaborative information processing-Case studies- human tracking- object association-Information fusion-Smart camera-hardware technology-middleware-application

TEXT BOOKS/ REFERENCES:

1. Li-minnAug,KahPhooiSeng,"visual information processing in wireless sensor networks:Technology, Trends and applications ",IGI Global ,2011
2. KasemSohrab,DanielMinoli,TaiebZnati, "Wireless Sensor Networks:Technology, protocols and applications, Wiley Interscience publication 2007
3. IbrahimpatnamM.M.Elmary,S.Ramakrishna, Wireless Sensor From Theory to Application",CRC press book, 2016
4. Hamid Aghajan,AndreaCavallaro,"Multi camera networks: Principles and Application,Elsevier Publication, 2009.

18CS718 IMAGE ANALYSIS 3-0-0-3

Image Morphology: Binary and gray scale Morphological analysis - Dilation and Erosion -Skeletons and Object Marking – Granulometry – Morphological Segmentation. Feature extraction: Global image measurement, feature specific measurement, characterizing shapes, Hough Transform. Representation and Description: Region Identification – Contour Based and Region Based Shape Representation and Description – Shape Classes. Flexible shape extraction: active contours, Flexible shape models: active shape and active appearance. Texture representation and analysis: Statistical Texture Description – Syntactic Texture Description Methods – Hybrid Texture description Methods – Texture Recognition Method Applications. Image Understanding: Control Strategies –RANSAC – Point Distribution Models – Scene Labeling and Constraint Propagation. Image Data Compression: Predictive Compression Methods – Vector Quantization, DCT, Wavelet, JPEG.

TEXT BOOKS / REFERENCES:

1. Milan Sonka, Vaclav Hlavac and Roger Boyle, "Image Processing, Analysis and Machine Vision", Third Edition, Cengage Learning, 2007.
2. Tinku Acharya, Ajoy K Ray,"Image Processing- Principles and Applications", Wiley, 2005.
3. John C. Russ, "The Image Processing Handbook", Sixth Edition, CRC Press, 2007.
4. Mark S. Nixon, Alberto S. Aguado, "Feature Extraction and Image Processing", Second Edition, Academic Press, 2008.

Electives (Networks and IoT)

18CS721 SENSOR NETWORKS AND IOT 3-0-0-3

Introduction and Applications: smart transportation, smart cities, smart living, smart energy, smart health, and smart learning. Examples of research areas include for instance: Self-Adaptive Systems, Cyber Physical Systems, Systems of Systems, Software Architectures and Connectors, Software Interoperability, Big Data and Big Data Mining, Privacy and Security
IoT Reference Architecture-Introduction, Functional View, Information View, Deployment and Operational View, Other Relevant architectural views. Real-World Design Constraints-Introduction, Technical Design constraints, hardware, Data representation and visualization, Interaction and remote control.

IOT Physical Devices & Endpoints: What is an IOT Device, Exemplary Device Board, Linux on Raspberry , Interface and Programming & IOT Device. Hardware Platforms and Energy Consumption, Operating Systems, Time Synchronization, Positioning and Localization, Medium Access Control, Topology and Coverage Control, Routing: Transport Protocols, Network Security, Middleware, Databases

Industrial Automation-Service-oriented architecture-based device integration, SOCRADES: realizing the enterprise integrated Web of Things, IMC-AESOP: from the Web of Things to the Cloud of Things, Commercial Building Automation-Introduction,

Case study: phase one-commercial building automation today, Case study: phase two-commercial building automation in the future. Recent trends in sensor network and IOT architecture, Automation in Industrial aspect of IOT.

TEXT BOOKS / REFERENCES:

1.Mandler, B., Barja, J., MitreCampista, M.E., Cagáová, D., Chaouchi, H., Zeadally, S., Badra, M., Giordano, S., Fazio, M., Somov, A., Vieriu, R.-L., Internet of Things. IoT Infrastructures, Springer International Publication

2.Internet of Things: A Hands-On Approach Paperback – 2015, by ArsheepBahga (Author), Vijay Madisetti (Author)

3.IoT Fundamentals: Networking Technologies, Protocols and Use Cases for the Internet of Things by Pearson Paperback – 16 Aug 2017 ,by Hanes David (Author), Salgueiro Gonzalo (Author), Grossetete Patrick (Author), Barton Rob (Author)

18CS722 PREDICTIVE ANALYTICS FOR INTERNET OF THINGS 3-0-0-3

IoT Analytics- Definition, Challenges, Devices, Connectivity protocols, data messaging protocols- MQTT, HTTP, CoAP, Data Distribution Services (DDS), IoT Data Analytics – Elastics Analytics Concepts, Scaling.

Cloud Analytics and Security, AWS / Azure /ThingWorx. Design of data processing for analytics, application of big data technology to storage, Exploring and visualizing data, solution for industry specific analysis problem.

Unit 3:
Visualization and Dashboard – Designing visual analysis for IoT data- creating dashboard – creating and visualizing alerts – basics of geo-spatial analytics- vector based methods-raster based methods- storage of geo-spatial data-processing of geo spatial data- Anomaly detection-forecasting. case study: pollution reporting problem.

TEXT BOOKS / REFERENCES:

1.Analytics for Internet of Things – Andrew Minteer – Packt Publications Mumbai 2017
2.Big–Data Analytics for Cloud, IoT and Cognitive Computing Hardcover –by Kai Hwang (Author), Min Chen (Author)

18CS723 WIRELESS SENSOR NETWORKS 3-0-0-3

Introduction to wireless sensor Networks - Advantages of ad-hoc/sensor networks, Unique constraints and challenges-. Applications Platforms for WSN: Sensor node hardware: mica2, micaZ, telosB, cricket, Imote2, tmote, btnode . Sensor node software (Operating System): tiny0S, MANTIS, Contiki, and Ret0S. Programming tools: C, nesC .Single-Node Architecture. WSN coverage and placement: Coverage problems in WSN – Type of coverage – OGDC coverage Algorithm- Placement Problem. Topology management in wireless sensor Networks-: Different classification of topology management Algorithms- topology discovery-sleep cycle management. Medium access control in wireless networks. Routing in sensor networks: Data centric- position based routing- data aggregation- Clustered based routing Algorithms .Congestion and flow

control: Source of congestion- congestion control scenarios- Protocols for congestion and flow control in sensor networks: ESRT-CODA-PSFQ-RCRT-RMST-Fusion. Hard ware design of sensor Networks : Characteristics – Design challenges- Design of Architecture- Functional components- Energy supply- operating system. Application: Underwater sensor networks. Real life deployment of WSN-: Development of sensor based networking for improved management of irrigated crops - **usage of sensors on medical devices (like accelerometer and gyroscope) and study of their performance**. Research Paper Discussion and Presentation

TEXT BOOKS/REFERENCES:

1. Holger Karl and Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks", John Wiley & Sons, 2005.
2. Zhao and L. Guibas, "Wireless Sensor Networks", Morgan Kaufmann, San Francisco, 2004.
3. C. S. Raghavendra, K.M.Shivalingam and T.Znati, "Wireless Sensor Networks", Springer, New York, 2004
4. Anna Hac, "Wireless Sensor Network Designs", John Wiley & Sons, 2004.
5. Kazem Sohraby, Daniel Minoli and Taieb Znati, "Wireless Sensor Networks: Technology, Protocols, and Applications", Wiley Inter Science, 2007.

	Course Outcome	Bloom's Taxonomy Level
CO1	Understand the basis of Sensors with its applications	L2
CO2	To learn the architecture and placement strategies of Sensors	L2
CO3	To analyze routing and congestion algorithms	L3
CO4	To design, develop , and carry out performance analysis of sensors on specific applications	L4
CO5	To explore and implement solutions to real world problems using sensor devices, enumerating its principles of working	L5

18CS724 WIRELESS AND MOBILE NETWORKS 3-0-0-3

Wireless Network Generation – Comparison of wireless systems - Multiplexing – Modulation. Medium Access Control: motivation for a specialized MAC (Hidden and exposed terminals - Near and far terminals) - SDMA - FDMA, TDMA - CDMA -OFDMA- Comparison of multiple access techniques- Random Multiple access- Erlang capacity . GSM: Mobile services - System architecture -Radio interface - Localization and calling, Handover. Routing Protocol – Distance vector routing-Link state routing – AODV- Routing metrics – Controlled flooding protocols – opportunistic protocol. Mobile IP (Goals - assumptions - entities and terminology - IP packet delivery - Agent advertisement and discovery – registration - tunneling and encapsulation - optimizations) . Dynamic Host Configuration Protocol (DHCP) - Mobile Transport Layer: Traditional TCP - Indirect TCP - Snooping TCP - Mobile TCP - Fast retransmit/fast -recovery, Transmission /time-out freezing - Selective retransmission- Transaction oriented TCP. TCP over Adhoc Networks. Energy management in Adhoc wireless networks- Need for Energy management- Classification of Energy management schemes –battery management schemes – Transmission power management schemes – system management schemes. Case study: Network formulation games.

TEXT BOOKS/REFERENCES:

1. SivaRam Murthy.C, Manoj B.S, "Adhoc wireless Networks: Architecture and Protocols", Prentice Hall, 2005
2. Jochen Schiller,"Mobile Communications", Second Edition, Pearson Education 2012.
3. William Stallings, "Wireless Communication and Networks", 2nd edition, Prentice Hall, 2005.
4. Kaveh Pahlavan, Prashant Krishnamurthy, "Principles of wireless Networks: A unified Approach", Prentice Hall, 2001.

	Course Outcome	Bloom's taxonomy level
CO1	To Understand the concept of wireless and mobile systems	L2
CO2	To learn the system architecture	L2
CO3	To analyze on routing Protocol	L3
CO4	To understand the features of Mobile IP , DHCP and modified TCP	L2
CO5	To perform study on system, energy and power Management systems	L3
CO6	To perform case study of applications pertaining to mobile and wireless systems	L3

18CS725 PERVASIVE COMPUTING 3-0-0-3

Pervasive Computing Concepts: Perspectives of Pervasive Computing, Challenges, Technology; The Structure and Elements of Pervasive Computing Systems: Infrastructure and Devices, Middleware for Pervasive Computing Systems, Pervasive Computing Environments

Context Collection, User Tracking, and Context Reasoning; Resource Management in Pervasive Computing: Efficient Resource Allocation in Pervasive Environments, Transparent Task Migration, Implementation and Illustrations.

HCI interface in Pervasive Enviornments: HCI Service and Interaction Migration, Context-Driven HCI Service Selection, Scenario Study: Video Calls at a Smart Office, A Web Service–Based HCI Migration Framework .

Pervasive Mobile Transactions: Mobile Transaction Framework, Context-Aware Pervasive Transaction Model, Dynamic Transaction Management, Formal Transaction Verification, Evaluations

Case Studies: iCampus Prototype, IPSpace: An IPv6-Enabled Intelligent Space

TEXT BOOKS/REFERENCES:

1. Minyi Guo, Jingyu Zhou, Feilong Tang, Yao Shen ,"Pervasive Computing: Concepts, Technologies and Applications",CRC Press, 2016.
2. Obaidat, Mohammad S., Mieso Denko, and Isaac Woungang, eds. *Pervasive computing and networking*. John Wiley & Sons, 2011.

3. Laurence T. Yang, Handbook On Mobile And Ubiquitous Computing Status And Perspective, 2012, CRC Press.

Outcomes:

	Course Outcome	**Bloom's Taxonomy Level**
CO1	Understand the fundamental theoretical concepts in pervasive computing.	L2
CO2	Understand the aspects of context awareness	L2
CO3	Study the methods for efficient resource allocation and task migration	L3
CO4	Learn and Analyze the HCI Service Selection and HCI migration framework	L4
CO3	Design and implement pervasive application systems	L5

18CS726 IOT PROTOCOLS AND ARCHITECTURE 3-0-0 3

Introduction to IOT, Applications of IOT, Use cases of IOT

The IoT Architectural Reference Model as Enabler, IoT in Practice: Examples: IoT in Logistics and Health, IoT Reference Model: Domain, information, functional and communication models;

IoT Reference Architecture: Architecture, Functional, information, deployment and operation views; SOA based Architecture, API-based Architecture, OPENIoT Architecture for IoT/Cloud Convergence

Application Protocols for IoT: UPnP, CoAP, MQTT, XMPP. SCADA, WebSocket; IP-based protocols: 6LoWPAN, RPL; Authentication Protocols; IEEE 802.15.4

Case study: Cloud-Based Smart-Facilities Management, Healthcare, Environment Monitoring System

TEXT BOOKS/REFERENCES:

1. Bassi, Alessandro, et al, "Enabling things to talk", Springer-Verlag Berlin An, 2016.
2. David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Robert Barton, Jerome Henry, "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things", CISCO Press, 2017
3. Hersent, Olivier, David Boswarthick, and Omar Elloumi. The internet of things: Key applications and protocols. John Wiley & Sons, 2011.
4. Buyya, Rajkumar, and Amir Vahid Dastjerdi, eds. Internet of Things: Principles and paradigms. Elsevier, 2016.

	Course Outcome	**Bloom's Taxonomy Level**
CO1	Comprehend the essentials of IoT and its applications	L2
CO2	Understand the concepts of IoT Architecture Reference model and IoT reference architecture	L2

CO3	Analyze various IoT Application layer Protocols	L4
CO4	Apply IP based protocols and Authentication Protocols for IoT	L3
CO5	Design IoT-based systems for real-world problems	L5

Elective Stream - (High Performance Computing)

18CS731 PARALLEL AND DISTRIBUTED COMPUTING 3-0-0-3

Introduction-Asynchronous/synchronous computation/communication, concurrency control, fault tolerance, GPU architecture and programming, heterogeneity, interconnection topologies, load balancing, memory consistency model, memory hierarchies, Message passing interface (MPI), MIMD/SIMD examples.
Multithreaded programming, parallel algorithms & architectures, parallel I/O, performance analysis and tuning, power, programming models (data parallel, task parallel, process-centric, shared/distributed memory), scalability and performance studies, scheduling, storage systems, synchronization, and tools.

TEXT BOOKS/ REFERENCES:

1. Kai Hwang, Jack Dongarra & Geoffrey C. Fox, "Distributed and Cloud Computing: Clusters, Grids, Clouds, and the Future Internet (DCC)", 2012.
2. Andrew S. Tanenbaum & Maarten van Steen, "Distributed Systems: Principles and Paradigms", Prentice Hall, 2017.

At the end of the course the students will be able to

	Course Outcome	**Bloom's Taxonomy Level**
CO 1	Understand the requirements for programming parallel systems and how they can be used to facilitate the programming of concurrent systems.	L2
CO 2	To learn and apply knowledge of parallel and distributed computing techniques and methodologies.	L3
CO 3	To learn the architecture and parallel programming in graphics processing units (GPUs).	L2
CO 4	Understand the memory hierarchy and cost-performance tradeoffs.	L2 L5
CO 5	To gain experience in the design, development, and performance analysis of parallel and distributed applications.	L4, L6, L5

18CS732 GPU ARCHITECTURE AND PROGRAMMING 3-0-0-3

(Prerequisite – Modern Computer Architecture)

Introduction to Parallel Programming - Introduction to OpenCL - OpenCL Device Architectures - Basic OpenCL – examples - Understanding OpenCL - Concurrency and Execution Model - Dissecting a CPU/GPU - OpenCL Implementation – OpenCL.

Case study: Convolution, Video Processing, Histogram and Mixed Particle Simulation - OpenCL Extensions - OpenCL Profiling and Debugging – WebCL, Applications of GPU Architecture like Gaming, Computer Vision, etc.

TEXT BOOKS/REFERENCES:

1. Benedict R Gaster, Lee Howes, David, R. Kaeli, Perhaad Mistry and Dana Schaa, "Heterogeneous Computing with OpenCL", Elsevier, 2013.
2. Aaftab Munshi, Benedict Gaster, Timothy G. Mattson, James Fung & Dan Ginsburg, "OpenCL Programming Guide", Addison-Wesley Professional, 2011.
3. RyojiTsuchiyama, Takashi Nakamura, TakuroIizuka & Akihiro Asahara, "The OpenCL Programming Book", Fixstars Corporation, 2010.
4. Matthew Scarpio, "OpenCL in Action: How to Accelerate Graphics and Computations", Manning Publications, 2011.

At the end of the course the students will be able to:

	Course Outcome	Bloom's Taxonomy Level
CO 1	Understand GPU computing architecture	L2
CO 2	Code with GPU programming environments	L5
CO 3	Design and develop programs that make efficient use of the GPU processing power	L5
CO 4	Develop solutions to solve computationally intensive problems in various fields	L6

18CS733 RECONFIGURABLE COMPUTING 3-0-0-3

(Prerequisite – Modern Computer Architecture)

General overview of computing models, Basic RC concepts, Performance, power, size, and other metrics, RC devices and architecture – fine grained and coarse grained, integration into traditional systems, FPGA computing platforms, Design tools and languages: HDLs, Synthesis, PAR, HLL and HLS, RC application development, domains and case studies, Special topics in RC: Middleware, Fault tolerance, Partial reconfiguration, device characterization.

TEXT BOOKS/REFERENCES:

1. Scott Hauck and Andre DeHon, "Reconfigurable Computing: The Theory and Practice of FPGA-Based Computation", Morgan Kaufmann (Elsevier), 2008.
2. M. Gokhale and P. Graham, "Reconfigurable Computing: Accelerating Computation with Field-Programmable Gate Arrays", Springer, 2005.
3. C. Maxfield, "The Design Warrior's Guide to FPGAs", Newnes, 2004.

At the end of the course the students will be able to

	Course Outcome	Bloom's Taxonomy Level
CO 1	Understand the Concept of Reconfigurable Computing and FPGA Architectures.	L1
CO 2	Understand and explore the various FPGA computing platforms in terms of design tools.	L2

CO 3	Explore and apply the basic building blocks of FPGA designing in terms of Programming (HDLs).	L3
CO 4	Analyze the Coarse-grained and Fine Grain configurability for performance enhancement using multi-FPGA systems.	L4
CO 5	Design, Analyze and apply reconfigurable computing in various applications for optimization.	L5
CO 6	To be able to create new designs and analyze advanced techniques such as Fault tolerance and Partial Reconfiguration	L6

18CS734 DATA INTENSIVE COMPUTING 3-0-0-3

(Prerequisite – Cloud and IOT)

Data Intensive computing Paradigms-types, need and use - Supercomputing, Grid Computing, Cloud Computing, Many-core Computing. Parallel Programming Systems-MapReduce-Hadoop, Workflows-Swift, MPI-MPICH, OpenMP, Multi-Threading-PThreads. Job Management Systems- Batch scheduling, Light-weight Task Scheduling. Storage Systems-File Systems-EXT3, Shared File Systems -NFS, Distributed File Systems-HDFS, FusionFS, Parallel File Systems-GPFS, PVFS, Lustre, Distributed NoSQL Key/Value Stores-Casandra, MongoDB, ZHT, Relational Databases-MySQL.
Data-Intensive Computing with GPUs and databases, many-core computing era and new challenges, Case studies on open research questions in data-intensive computing.

TEXT BOOKS/REFERENCES:
Readings will be from published research online material.

At the end of the course the students will be able to

	Course Outcome	**Bloom's Taxonomy Level**
CO1	Explain the architecture and properties of the computer systems needed to process and store large volumes of data	L2
CO2	Describe the different computational models for processing large data sets for data at rest (batch processing)	L2
CO3	Identify data parallelism to be exploited in large-scale data processing problems	L2
CO4	Compare and contrast advantages and disadvantages of the modern data-centric paradigm over the compute-centric one	L4
CO5	Design experimental studies to assess the performance of data-intensive systems	L6
CO6	Implement high-performance solutions to a real-world problem and sufficiently provide rationalizations to the design decisions and case studies	L3

18CS735 FAULT TOLERANT SYSTEMS 3-0-0-3

Hardware fault tolerance, software fault tolerance, information redundancy, check pointing, fault tolerant networks, reconfiguration-based fault tolerance, and simulation techniques. Dependability concepts: Dependable system, techniques for achieving dependability, dependability measure, fault, error, failure, and classification of faults and failures.
Fault Tolerance Strategies: Fault detection, masking, containment, location, reconfiguration, and recovery. Fault Tolerant Design Techniques: Hardware redundancy, software redundancy, time redundancy and information redundancy. Dependable communication: Dependable channels, survivable networks, fault-tolerant routing. Fault recovery, Stable storage and RAID architectures, and Data replication and resiliency. Case studies of fault tolerant multiprocessor and distributed systems.

TEXT BOOKS/REFERENCES:

1. Israel Koren and C. Mani. Krishna, "Fault Tolerant Systems", Elsevier.2007.
2. P. Jalote, "Fault Tolerance in Distributed Systems", Prentice-Hall Inc. 1994.
3. D. K. Pradhan, "Fault-Tolerant Computing, Theory and Techniques", Prentice-Hall, 1998.

Upon successful completion of this course, the student will be able to:

	Course Outcome	Bloom's Taxonomy Level
CO1	Enumerate the need and necessity to consider fault-tolerant design in digital systems	L3
CO2	Explain vividly, the various techniques for fault modelling and tests generation	L4
CO3	Determine the various forms of redundancy for enhancing reliability of digital systems	L5
CO4	Evaluate reliability of systems with permanent and temporary faults	L5
CO5	Carry out assessment of the relationship between software testing, residual defects and security vulnerabilities	L6
CO6	Understand cost-dependability trade-offs and the limits of computer system dependability	L2

18CS736 COMPUTER SOLUTIONS OF LINEAR ALGEBRAIC SYSTEMS 3-0-0-3

Matrix Multiplication Problems: Structure and Efficiency, Block Matrix and Algorithms, Fast Matrix vector products. Matrix Analysis: Vector Spaces, Norms, Matrix norms, Orthogonality, Singular value Decomposition, Sensitivity of Square systems, Finite precision matrix computation. Linear Systems: Triangular Systems, LU Factorization, Parallel LU, Diagonal Dominance and Symmetry, Positive Definite Systems, Banded Systems. Orthogonalizations and Least squares: Householder and Givens Transformation, QR Factorization.
Parallel Matrix Computation: Basic concepts, Cost of Communication, Challenge of Load Balancing, Tradeoffs, Shared Memory Systems, Parallel Matrix Multiplication. Eigen value Computation: Power Iteration, Jacobi Method.

TEXT BOOKS/REFERENCES:

1. Golub and Loan, “Matrix Computations”, John Hopkins University Press, Fourth Edition.
2. Carl. D. Meyer, “Matrix Analysis and Applied Linear Algebra”, SIAM., 2000.

At the end of the course the students will be able to

	Course Outcome	**Bloom’s Taxonomy Level**
CO 1	Analyze the efficiency of matrix multiplication in terms of data access, storage and flops	L4
CO 2	Understand and implement the iterative methods for eigen value computation	L2
CO 3	Compute/Evaluate the efficiency of matrix factorizations in finding solutions to linear systems, matrix transformations: LU factorization, Positive definiteness, QR factorization	L5
CO 4	Analyze the sensitivity of square systems, finite precision computations	L4
CO 5	Understand the basic concepts in parallel matrix computation	L2
CO 6	Apply the concepts of parallel programming and implement parallel matrix computations	L3