National Institute of Technology Delhi

Proposed Curriculum

M. Tech. Programme
Computer Science and Engineering
# Course Structure of M.Tech Computer Science and Engineering (Analytics)

## SEMESTER – I

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Course No.</th>
<th>Course Name</th>
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## SEMESTER-III

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### I. Core Courses

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Syllabus for Mandatory Courses

Mathematics for Computer Science

CSL 501

Credits 3 (L-T-P): 3-0-0

Probability
The concept of probability, The axioms of probability, Some important theorems on Probability, Conditional Probability, Theorems on conditional probability, Independent Event's, Bayes'Theorem.

Random Variables and Probability Distributions
Random variables, discrete probability distributions, Distribution functions for Discrete random variables, Continuous probability distribution, Distributions for Continuous random variables, joint distributions, Independent random variables.

Mathematical Expectation
Definition, Functions of random variables, some theorems on Expectation, The variance and Standard Deviation, Moments, Moment Generating Functions, Covariance, Correlation Coefficient.

Special Probability Distributions
The Binomial Distribution, The Normal Distribution, The Poisson Distribution, Relations between different distributions, Central limit theorem, Uniform distribution, Chi-square Distribution, Exponential distribution.

Sampling Theory
Population and Sample, Sampling with and without replacement, the sample mean, Sampling distribution of means, proportions, differences and sums, the sample variance, the sample distribution of variances.

Tests of Hypotheses and Significance
Statistical Decisions, Statistical hypotheses, Null Hypotheses, Tests of hypotheses and significance, Type I and Type II errors, level of significance, Tests involving the Normal distribution, One- Tailed and Two-tailed tests, Special tests of significance for large and small samples.

Markov Process

Text books:

References:
Algorithms for Analytics

CSL 551

Credits 3 (L-T-P): 3-0-0

Introduction: Performance of algorithms, Design techniques, Graph Algorithms.


Competitive Analysis and Online Algorithm: MTF list problem, Buy vs. rent problem, Secretary Problem, Paging algorithm.

Probabilistic analysis of Randomized algorithm: Linearity of Expectation, Markova’s inequality, Threshold phenomena in graph analysis.


Parallel algorithm and External Memory algorithm: Pointer Jumping and Parallel Prefix. Tree Contraction.

Text Books:

References:
Syllabus for Core Courses

Quantitative Techniques

**CSL 511**

**Credits 3 (L-T-P):3-0-0**

**A overview to quantitative Techniques**
An analytical scientific approach to Problem solving, quantitative analysis, Operational research models & modeling process for Managerial Decision Making.

**Collection and analysis of Data**

**Decision making and quantitative techniques**

**Linear programming formulation and solution**

**Multi-criteria Decision making tools**

**Advance quantitative methods and application**

**Text Books:**
- Barry Render, Ralph MStair Jr, Michael E Hanna, 2005, Quantitative analysis for management, Pearson Education.

Optimization Techniques

**CSL 512**

**Credits 3 (L-T-P):3-0-0**

**Preliminaries:** Proofs,Vector Spaces and Matrices, Linear Transformations, Eigenvalues and Eigenvectors, Orthogonal Projections, Quadratic Forms, Matrix Norms, Concepts from Geometry,Elements of Calculus

**Unconstrained Optimization:** Basics of Set-Constrained and Unconstrained Optimization, One-Dimensional Search Methods,Golden Section Search, Fibonacci Search, Newton’s Method, Secant Method, Solving $Ax = b$

**Advance Data Mining and Databases**

**CSL 513**  
Credits 3 (L-T-P):3-0-0

**Introduction**

**Machine learning concepts and approaches**
Supervised Learning Framework, concepts & hypothesis, Training & Learning, Boolean functions and formulae, Monomials, Disjunctive Normal Form & Conjunctive Normal Form, A learning algorithm for monomials.

**Data Preparation**
Data Cleaning, Data Integration & Transformation, Data Reduction.

**Mining Association Rules**
Associations, Maximal Frequent & Closed Frequent item sets, Covering Algorithms & Association Rules, Linear Models & Instance- Based Learning, Mining Association Rules from Transactional databases, and Mining Association Rules from Relational databases & Warehouses, Correlation analysis & Constraint-based Association Mining.

**Classification and Prediction**
Issues regarding Classification & Prediction, Classification by Decision Tree induction, Bayesian classification, Classification by Back Propagation, k-Nearest Neighbour Classifiers, Genetic algorithms, Rough Set & Fuzzy Set approaches.

**Cluster Analysis**
Types of data in Clustering Analysis, Categorization of Major Clustering methods, Hierarchical methods, Density-based methods, Grid-based methods, Model-based Clustering methods.

**Mining Complex Types of Data**
Multidimensional analysis & Descriptive mining of Complex data objects, Mining Spatial Databases, Mining Multimedia Databases, Mining Time-series & Sequence data, Mining Text databases, Mining World -Wide Web.

**Data Mining Applications and Trends in Data Mining**
Massive Datasets/Text mining, Agent-Based Mining.

**Variance Analysis and MLE**
F-test, Techniques of Analysis of Variance, Analysis of Variance in two-way Classification Model.

**Text Books:**

**References:**
• Larose D.T., Discovering knowledge in data: an introduction to data mining, Wiley-Interscience, 2005.

Big Data Analytics

CSL 514

Credits 3 (L-T-P):3-0-0

Fundamentals of Business Analytics-Business Intelligence (BI), Business Intelligence vs. Business Analytics, BI Framework, BI Roles & Responsibilities, BI DW Best Practices, Popular BI Tools, BI Applications, Enterprise Reporting Characteristics in OLAP World, Balanced Scorecard, Dashboards, Multidimensional Data Modelling (MDDM), SMART test, Measures, Metrics, KPIs, and Performance Management, Supply chain, Fact-based decision making and KPIs, Mapping metrics to business phases, Malcolm Baldrige Criteria for Performance Excellence Framework, Typical enterprise application architecture
Visualizing Relationship in Data, Probability, Estimation, Outliers and Normal Distribution, Inference, Regression, Exploratory Data Analysis (EDA), Big Data, Scaling Problems, HDFS, Design Patterns, Cluster
Data Statistics- Visualizing relationship in Data, Estimation, Outliers and Normal Distribution, Inference, Regression
Big Data Analytics-In Memory Analytics, In-Database Processing, Symmetric Multiprocessor System (SMP), Massively Parallel Processing, Shared Nothing Architecture, Parallel and Distributed Systems, CAP Theorem, NoSQL
Big Data Analytics Tool- Hadoop, MongoDB, Cassandra, MapReduce, Hive, Pig, JasperReport

Text Books:

• Fundamentals of Business Analytics by R.N. Prasad, Seema Acharya, Wiley.
• Big Data, Big Analytics: Emerging Business Intelligence and Analytic Trends for Today's Businesses by Michael Minelli, Michele Chambers, Ambiga Dhiraj

References:

• An Introduction to Data Science by Jeffery Stanton.
• Big Data and Analytics by Seema Acharya, Subhashini Chellapan

Simulation and Modeling

CSL 515

Credits 3 (L-T-P):3-0-0


Techniques of Simulation:
Monte Carlo Method, Types of System Simulations, Real Time Simulation, Stochastic Variables, Discrete Probability Functions.

General Principles:
Simulation Software:

Statistical Models in Simulation:
Useful Statistical Models, Discrete Distributions, Continuous Distributions, Poisson Process, Empirical Distributions

Queuing Models:

Random Number Generation:

Input Modeling:
Data Collection, Identifying the Distribution with Data, Parameter Estimation, Chi – Square Test, Selecting Input Models with Data Verification & Validation of simulation Modelling: Model Building, Verification & Validation, Verification of simulation Models, Calibration & Validation of Models.

Forecasting:
Forecasting technique/method based upon key criteria such as: Forecast time horizon Amount and relevance of historical data Data patterns (seasonality, trends), Accuracy requirements and purpose of the forecast, Assessment of the potential for forecasting – can the variable be forecasted? Understand the organizational and decision making context of forecasting Understand the basic principles for each of the following and be able to apply each using appropriate software:

Extrapolation and growth models (e.g., the Bass model) Time series models such as smoothing (Holt-Winters, multiplicative and additive), ARIMA, Causal models (e.g., ordinary regression, econometric models)

Text Books:
• System simulation and modelling by V P Singh.

References:
• A.M. Law and W.D. Kelton, Simulation Modeling and Techniques, Macgraw Hill.
• Network modeling and simulation a practical perspective, by Mohsen Guizani, Ammar Rayes, Bilal Khan, Ala Al-Fuqaha, Wiley publication.

Data Warehouse

CSL 516            Credits (L-T-P): 3-0-0

Data Warehousing Basics
An overview of data warehousing and OLAP technology and decision support, Data Warehouse Constructs and Components, Data cube: a relational aggregation operator generalizing group-by, cross-tabs and subtotals, Dimensional Modeling, Data Cleaning, Data Integration, Record Linkage, The Merge/Purge Problem for Large Databases.
Multidimensional Data Models

Multidimensional data modeling, Dimensional Modeling, Granularity in Data Warehouse, Dimensions, Characteristics, and hierarchies, Star schema, Snowflake schema, and Multi-star schema, Technical Architecture, ETL Design, ETL Development, Physical Data Model, Logical Data Model.

Query Processing

SQL Server Query Processor Overview, Star Queries, Merge Join and Hash Join, Bitmap Indexes and Compression, Improved Query Performance, Bitmap indexes, projection indexes, and bit-sliced indexes, Performance Measurements of Compressed Bitmap Indices

Quality Factors

Quality factors of data warehouse and its evaluation, supporting data mining tasks, partitioning the data, Data warehouse CRM applications, Data warehouses in practice.

Text Books:


References:


Game Theory & Business Intelligence

CSL 517 Credits 3 (L-T-P): 3-0-0


Mixed Strategy Equilibrium: Introduction, Mixed strategy Nash equilibrium, The formation of players’ beliefs, finding all mixed strategy Nash equilibria, games in which each player has a continuum of actions;


Repeated Games: The Prisoner’s Dilemma, General Result

Incentives and Pricing in Communications Networks: Large Networks, Pricing and Resource Allocation, Alternative Pricing and Incentive Approaches;

Incentives in Peer-to-Peer Systems: The p2p File sharing games, Reputation, Barter based system, Currency, Hidden action in p2p systems;

Text Books:

References:

Syllabus for Electives

Natural Language Processing

CSL 521

Introduction- Human languages, models, ambiguity, processing paradigms; Phases in natural language processing, applications. Text representation in computers.
Linguistics resources- Introduction to corpus, elements in balanced corpus, TreeBank, PropBank, WordNet, VerbNet etc.
Regular expressions, Finite State Automata, word recognition, lexicon. Morphology, acquisition models, Finite State Transducer.
N-grams, smoothing, entropy, HMM, Maximum Entropy.
Part of Speech tagging- Stochastic POS tagging, HMM, Transformation based tagging (TBL), Handling of unknown words, named entities, multi word expressions.
Parsing- Statistical Parsing, Probabilistic parsing.
Semantics- Meaning representation, semantic analysis, lexical semantics, WordNet
Word Sense Disambiguation- Selectional restriction, machine learning approaches, dictionary based approaches.
Text Classification
Sentiment Analysis
Applications of NLP- Spell-checking, Summarization Information
Retrieval- Vector space model, term weighting, homonymy, polysemy, synonymy, improving user queries.

Machine Translation
Overview

Text Book:

References:

Machine Learning
Supervised Learning

Unsupervised Learning
Grouping unlabeled items using k-means clustering, Association analysis with the Apriori algorithm, Efficiently finding frequent itemsets with FP-growth.

Reinforcement learning:
Markov decision process (MDP), Bellman equations, Value iteration and policy iteration, Linear quadratic regulation (LQR), Linear Quadratic Gaussian (LQG), Q-learning, Value function approximation, Policy search, POMDPs.

Forecasting and Learning Theory
Predicting numeric values: regression, Tree-based regression. Bias/variance tradeoff, Union and Chernoff/Hoeffding bounds, Vapnik-Chervonenkis (VC) dimension, Worst case (online) learning, Practical advice on how to use learning algorithms.

Additional Tools
Dimensionality reduction: Feature Extraction - Principal component analysis to simplify data, Simplifying data with the singular value decomposition, Feature Selection – Ranking methods, subset selection – forward and backward. Big data and MapReduce

Text Books/Reference Books:
- Tom Mitchel, Machine Learning, McGraw Hill.

Neural networks

CSL 523

Pre-requisites: Artificial Intelligence
Overview of Crisp Sets and Fuzzy Sets:
Associative memory: Matrix associative memory, Auto associative memories, hetero associative memories, Bi-directional associative memory, applications of associative memories.
Fuzzy Systems and Neuro fuzzy systems: Relevance of Integration between fuzzy sets and neural network, Fuzzy neural network, Neuro fuzzy systems, Fuzzy associative memories.
Application of Fuzzy sets and Neural networks: Application in pattern recognition, Image processing and computer vision, Application in control: Fuzzy controllers, neuro controllers and fuzzy neuro controllers, applications in expert systems and decision making systems, application in real world computing.
Text Book/References:
- S. Haykin, Neural Networks: A Comprehensive Foundation, Prentice Hall.
- Limin Fu, Neural Networks in computer intelligence, McGraw hill Intl.
- T Ross, Fuzzy logic with Engineering applications.
- G Klir, B Yuan, Fuzzy sets and fuzzy logic: Theory and application.

Soft Computing

CSL 524 Credits (L-T-P): 3-0-0

UNIT I: Crisp set and Fuzzy set, Basic concepts of fuzzy sets, membership functions. Basic operations on fuzzy sets, Properties of fuzzy sets, Fuzzy relations.
UNIT II: Propositional logic and Predicate logic, fuzzy If – Then rules, fuzzy mapping rules and fuzzy implication functions, Applications.

Text Books:

References:
- J. Yen and R. Langari. Fuzzy Logic, Intelligence, Control and Information, Pearson Education

Digital Image & Pattern Recognition

CSL 525 Credits (L-T-P): 3-0-0

Introduction
Digital image representation, Fundamental steps in image processing, Components of Digital Image processing systems, Elements of visual perception, Image Formation model, Sampling and quantization, Relationship between pixels, imaging geometry.

Image Enhancement

Image Segmentation
Detection of discontinuities, Edge linking and boundary detection, Thresholding, Region based segmentation, Use of motion in segmentation: Spatial techniques, Frequency domain techniques.

Wavelets and Multiresolution Processing
Image pyramids, Subband coding, Haar transform, Series expansion, Scaling functions, Wavelet functions, Discrete wavelet transforms in one dimensions, Fast wavelet transform, Wavelet transforms in two dimensions
Spatial Operations and Transformations
Spatially dependent transform template and convolution, Window operations, 2-Dimensional geometric transformations.

Color Image Processing
Color Models, Color Transforms, Image Segmentation Based on color.

Image Compression
Coding redundancy, Inter-pixel redundancy, fidelity criteria, Image compression models, Error-free compression, Variable length coding, Bit-plane coding, Loss-less predicative coding, Lossy compression, Image compression standards, Real-Time image transmission, JPEG and MPEG.

Pattern Recognition
Patterns and Pattern classes, Classification and description, Structure of a pattern recognition system, feature extraction, Classifiers, Decision regions and boundaries, discriminant functions, Supervised and Unsupervised learning, PR-Approaches: statistics, syntactic and neural networks.

Text Books:

References:
- Robert Scholkoff, Pattern Recognition-Statistical, Structural and Neural Approach, John Willey & Sons.

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LARGE NETWORK ANALYSIS

CSL 526

Credits (L-T-P): 3-0-0

Pre-requisites: Probability and Statistics

Introduction

Basic Network Properties: nodes, edges, adjacency matrix, node degree, connected components, giant component, average shortest path, diameter.


Social Network Analysis tools: NetworkX, UCINET, Gephi, Pajek, Graphviz

Network centrality: Betweenness, closeness, eigenvector centrality.


Network community detection: Modularity optimization and Spectral Clustering, Community Detection Algorithms, Overlapping communities in networks.


Epidemic models over networks: SI, SIS, SIR, SIRS models.

Text Book:

References:
- Networks, Crowds, and Markets’ by Easley and Kleinberg

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257
• Introduction to social network methods by Hanneman, Robert A. and Mark Riddle.

Knowledge representation & reasoning

CLS 527

Credits (L-T-P): 3-0-0

Prerequisite: Discrete Structures


Review of logical foundations of knowledge representation including key properties of formal systems (such as soundness, completeness, expressiveness and tractability).

Principles of Logic Programming.

Representing and reasoning about time and actions and physical changes (e.g., interval calculus, event calculus). Representing space and physical situations (topology, orientation, physical objects). Automated inference techniques (e.g., refinements of resolution, relational composition, nonmonotonic reasoning).

Formalisms for representing other aspects of knowledge e.g., vagueness, uncertainty, belief, desire.


Text Book:


References:

• Daniel S. Weld, Readings in Qualitative Reasoning about Physical Systems, Morgan Kaufmann, 1990.

• Ernest Davis, Representations of Commonsense Knowledge, Morgan Kaufmann, 1990.

Social Media And online Marketing

CSL 528

Credits (L-T-P): 3-0-0

Introduction

Basic Definitions, The Strength of Weak Ties, Tie Strength and Network Structure in Large-Scale Data, Tie Strength, Social Media, and Passive Engagement, Closure, Structural Holes, and Social Capital.

Game Theory


Auctions and Matching Markets

Types of Auctions, When are Auction Appropriate? Relationships between Different Auction Formats, Second-Price Auctions, First-Price Auctions and Other Formats, Common Values and The

**Network Models of Markets with Intermediaries**

**Health Care & Financial Analytic Web Analysis**
Understand managerial issues related to web analytics: Leveraging benchmarks and goals for web analytics to create executive dashboards. Being cognizant of legal, ethical and privacy issues in the use of web trails.
Understand and employ different types of data used in web analytics, e.g., server logs, visitor's data, search engine data.
Understand and explain the issues related to click stream data quality and the implications for applications.
Understand key terms and terminology as well as different types of web-data based metrics that can be tracked, e.g., visitors, session, page views, hits, session summary, referrals, most popular search engine, search terms by engine, keyword searches, top entrance pages, top exit pages, bounce rate, length and depth of session.
Perform both internal site search analytics and search engine optimization (SEO).
Become familiar with the capabilities and limitations of currently available web analytics tools.

**Text Book:**

**INFORMATION STORAGE AND RETRIEVAL**

**CSL 529**

**Credits (L-T-P):3-0-0**

**Pre-requisites: None**
Introduction: concepts and terminology of information retrieval systems, Significance of information retrieval and storage, Information Retrieval Vs Information Extraction; Indexing: inverted files, encoding, Zipf's Law, compression, boolean queries; Fundamental IR models: Boolean, Vector Space, probabilistic, TFIDF, Okapi, language modeling, latent semantic indexing, query processing and refinement techniques;
Performance Evaluation: precision, recall, F-measure; Classification: Rocchio, Naive Bayes, k-nearest neighbors, support vector machine; Clustering: partitioning methods, k-means clustering, hierarchical; Introduction to advanced topics: search, relevance feedback, ranking, query expansion.

**Text Books:**
References:

Cloud Computing

CLS 530  Credits(L-T-P): 3-0-0


Text Books:
- Distributed and Cloud Computing ” By Kai Hawang, Geoffrey CFox, Jack J. Dongarra Pub. Elservier

References: