EC(1268)-15.12.2023

Appendix-11
Resolution No. 39-1-8

DEPARTMENT OF COMPUTER SCIENCE
UNIVERSITY OF DELHI

Masters of Technology

2024 onwards

1. **M.Tech. Programme Details:**

Programme Objectives (POs):

Masters of Technology (M.Tech.) is a full-time, four-semester course that has a significant component of project-based learning. It aims to prepare the student to:

- carry out research and development work using information technologies.
- face the challenges of innovation and problem-solving in the highly competitive IT industry.
- become a model professional who would contribute to society by observing ethical behavior.

Programme-Specific Outcomes (PSOs):

The programme is designed to:

- develop an ability to use advanced computing techniques and tools.
- develop and evaluate models, techniques, and algorithms and adapt the existing ones for problem-solving.
- develop an understanding of the limits of computing.
- develop core competence to undertake research in core computer science as well as multidisciplinary domains.
- develop an ability to work effectively as a member as well as leader of a team.
- develop an understanding of professional ethics.

2. **Programme Structure:**

The M.Tech. programme is a two-year course divided into four semesters.

		Semester	***Semester***
Part – I	First Year	Semester I	Semester II
Part – II	Second Year	Semester III	Semester IV

Course Credit Scheme

Semester	**Core Courses**			**Elective Course**			**Open Elective Course**			**Total Credits**
	No. of Courses	Credits (L+T+P)	**Total Credits**	No. of Courses	Credits (L+T+P)	**Total Credits**	No. of Courses	Credits (L+T+P)	**Total Credits**	
I	6	15+0+7	**22**	0	0	**0**	0	0	**0**	**22**
II	4	12+0+4	**16**	0	0	**0**	2	6+0+2	**8**	**24**
III	4	5+0+10	**15**	2	6+0+2	**8**	0	0	**0**	**23**
IV	1	0+0+12	**12**	2	6+0+2	**8**	0	0	**0**	**20**
Total Credits for the Course			**65**			**16**			**8**	**89**

- English shall be the medium of instruction and examination.
- Examinations shall be conducted at the end of each semester as per the academic calendar notified by the University.
- The duration of examination of a four credit course will be three hours and the duration of examination of a two credit theory course will be two hours. The internal assessment marks shall be based on factors such as the following: participation in case studies/ discussion, seminars and group activities; class tests, quizzes and midterm tests; submission of written assignments, term courses and viva-voce, class attendance.
- The students will choose the elective courses out of the list of courses which are offered in a semester. An elective course offered by another department/ center/ institute may be taken subject to approval of the department.
- **Project:** Each student shall carry out a project in the third and fourth semesters: The projects will be carried out under the supervision of a teacher in the department. A student must submit an article based on the project work to a respectable venue. Depending on the requirement, a joint supervisor may also be appointed from the department or another institution (including IT industry). The project will be evaluated jointly by the internal supervisor(s) and an examiner to be appointed by the Department in consultation with the internal supervisor(s). The project evaluation will comprise a. mid-semester evaluation: 30% weightage (to be carried out by the internal supervisor(s)) b. end-semester evaluation (to be carried out jointly by the internal supervisor(s) and external examiner) (i) Dissertation: 30% weightage (ii) Viva-voce: 40% weightage.
- Examination for courses specified in the odd (even) semesters shall be conducted only in the respective odd (even) semesters.
- **Promotion Criteria:** To be eligible for promotion to second year a student must successfully complete at least 30 credits out of the courses prescribed for semester I and semester II, taken together.
- **Evaluation Criteria:** Evaluation in a theory course will be based on continuous evaluation (30% weightage) and the semester-end examination (70% weightage). The Assessment in the practical course MTCSC106: Software Tools will be based on continuous evaluation. The minimum marks for passing a course shall be 40%, or the minimum marks required for obtaining the ‘D’ grade as per the relative grading criterion (if applicable), whichever is lower.
- **Award of Degree:** In order to be eligible for the award of the Masters of Technology (M. Tech.) degree, a student must earn at least 85 credits.
- In each semester, a student may register for an additional course, approved by the University, in addition to the courses prescribed in the course structure.

Semester-wise Details of M.Tech. Course

Semester I					
	Number of core courses	6			
Course Code	**Course Title**	**Credits in each core course**			
		Lecture	Tutorial	Practical	**Total**
MTCSC101	Algorithm Design and Analysis	3	0	1	**4**
MTCSC102	Wireless Communications	3	0	1	**4**
MTCSC103	Data Mining	3	0	1	**4**
MTCSC104	Information Security and Standards	3	0	1	**4**
MTCSC105	Statistical Methods	3	0	1	**4**
MTCSC106	Software Tools	0	0	2	**2**
	Total credits in core course	22			
	Number of elective courses	0			
	Total credits in elective course	0			
	Number of open electives	0			
	Total credits in elective course	0			
	Total credits in Semester I	**22**			

Semester II					
	Number of core courses	4			
Course Code	**Course Title**	**Credits in each core course**			
		Lecture	Tutorial	Practical	**Total**
MTCSC201	Advanced Databases	3	0	1	**4**
MTCSC202	Machine Learning	3	0	1	**4**
MTCSC203	Network Security	3	0	1	**4**
MTCSC204	Image Processing and Computer Vision	3	0	1	**4**
	Total credits in core course	16			
	Number of elective courses	0			
	Credits in each elective	0			
	Elective course 1	0			
	Total credits in elective courses	0			
	Number of open electives	2			
	Credits in each open elective	Theory	Tutorial	Practical	**Total**
	Total credits in open elective 1	3	0	1	**4**
	Total credits in open elective 1	3	0	1	**4**
	Total credits in Semester II	24			

List of Open Elective Courses for Semester II		
Course Code	**Course Title**	**L-T-P**
MTCSO201	Parallel and Distributed Computing	3-0-1
MTCSO202	Automata Theory	3-0-1
MTCSO203	Cloud Networking	3-0-1
MTCSO204	Internet of Things	3-0-1
MTCSO205	Cybersecurity, Cyber Forensics & Cyber Laws	3-0-1
MTCSO206	Numerical Optimization	3-0-1
MTCSO207	Interpretable and Responsible AI	3-0-1

Semester III		
	Number of core courses	4
Course Code	**Course Title**	**L-T-P**
MTCSC301	Summer Internship	0-0-1
MTCSC302	Research Methodology	3-0-1
MTCSC303	Research and Publication Ethics	2-0-0
MTCSC304	Project work	0-0-8

Number of Elective Courses				2
Credits in each elective	Lecture	Tutorial	Practical	**Total**
Elective course 1	3	0	1	**4**
Elective course 2	3	0	1	**4**
Total credits in elective courses				**8**
Number of open electives				0
Total credits in open elective courses				**0**
Total credits in Semester III				**23**

List of Elective Courses for Semester III		
Course Code	**Course Title**	**L-T-P**
MTCSE301	Deep Learning	3-0-1
MTCSE302	Generative AI	3-0-1
MTCSE303	Cryptography	3-0-1
MTCSE304	Network Science	3-0-1
MTCSE305	Compiler Design	3-0-1
MTCSE306	Recommender Systems	3-0-1
MTCSE307	Combinatorial Optimization	3-0-1
MTCSE308	Natural Language Processing	3-0-1
MTCSE309	Graph Theory	3-0-1
MTCSE310	Wireless Sensor Networks	3-0-1
MTCSE311	Artificial Intelligence	3-0-1

Semester IV		
	Number of core courses	1
Course Code	**Course Title**	
MTCSC401	Project work	12

Number of Elective Courses	2			
Credits in each elective	Theory	Tutorial	Practical	**Total**
Elective course 1	3	0	1	**4**
Elective course 2	3	0	1	**4**
Total credits in elective courses				**8**
Number of open elective				**0**
Total credits in open elective courses				**0**
Total credits in Semester IV				**20**

List of Elective Courses for Semester IV		
Course Code	**Course Title**	**L-T-P**
MTCSE401	Blockchain and post-quantum Cryptography	3-0-1
MTCSE402	Soft Computing	3-0-1
MTCSE403	Neural Networks	3-0-1
MTCSE404	Secure Software Development	3-0-1
MTCSE405	Vehicular Communication Networks	3-0-1
MTCSE406	5G and B5G Technologies	3-0-1
MTCSE407	NP Completeness and Approximation Algorithms	3-0-1
MTCSE408	Bayesian Machine Learning	3-0-1

Total Credits = 22 +24 + 23 + 20 = 89

Eligibility and Mode of Admissions and Number of seats in the M.Tech. programme:

- **To be decided by the University in every academic year.**

Conversion of Marks into Grades:

Letter Grade	**Numerical Grade**	**Formula**	**Computation of grade cut off**
O (outstanding)	10	$m \geq \overline{X} + 2.5\sigma$	the value of $\overline{X} + 2.5\sigma$ to be taken into account for grade computation will be actual $\overline{X} + 2.5\sigma$ or 90% whichever is lower
A+ (Excellent)	9	$\overline{X} + 2.0\sigma \leq m < \overline{X} + 2.5\sigma$	the value of $\overline{X} + 2.0\sigma$ to be taken into account for grade computation will be actual $\overline{X} + 2.0\sigma$ or 80% whichever is lower
A (Very Good)	8	$\overline{X} + 1.5\sigma \leq m < \overline{X} + 2.0\sigma$	the value of $\overline{X} + 1.5\sigma$ to be taken into account for grade computation will be actual $\overline{X} + 1.5\sigma$ or 70% whichever is lower
B+ (Good)	7	$\overline{X} + 1.0\sigma \leq m < \overline{X} + 1.5\sigma$	the value of $\overline{X} + 1.0\sigma$ to be taken into account for grade computation will be actual $\overline{X} + 1.0\sigma$ or 60% whichever is lower
B (Above Average)	6	$\overline{X} \leq m < \overline{X} + 1.0\sigma$	the value of $\overline{X}$ to be taken into account for grade computation will be actual $\overline{X}$ or 50% whichever is lower
C (Average)	5	$\overline{X} - 0.5\sigma \leq m < \overline{X}$	the value of $\overline{X} - 0.5\sigma$ to be taken into account for grade computation will be actual $\overline{X} - 0.5\sigma$ or 45% whichever is lower
D (Pass)	4	$\overline{X} - 1.0\sigma \leq m < \overline{X} - 0.5\sigma$	the value of $\overline{X} - 1.0\sigma$ to be taken into account for grade computation will be actual $\overline{X} - 1.0\sigma$ or 40% whichever is lower
F (Fail)	0	$\overline{X} - 1.0\sigma > m$	

CGPA to Percentage Conversion:

The formula for calculating the final percentage of marks from Cumulative Grade Point Average (CGPA) will be as per the University rules.

Eligibility for Award of Degree and Division Criteria:

A student would be eligible for the award of M. Tech. Computer Science degree provided he/ she earns the required number of credits. Such a student shall be categorized (on the basis of the CGPA to Percentage Conversion as mentioned above) as follows:

- 60% or more marks: First Division
- 50% or more marks but less than 60% marks: Second Division
- Less than 50% marks: Third Division

Division of Degree into Classes

Post Graduate degree to be classified based on CGPA obtained into various classes as notified into Examination policy.

Attendance Requirement

No candidate shall be considered to have pursued a regular course of study unless he/she has attended 75% of the total number of classroom/ tutorial/ lab sessions conducted in each semester during his/her course of study. A student not complying with this requirement shall not be allowed to appear in the semester examinations. However, considering the merit of the case, the Head of the Department may condone the required percentage of attendance by not more than 10 percent during a semester.

Span Period

The span period will be four years from the date of registration in the programme.

Guidelines for the Award of Internal Assessment Marks for the M.Tech. Programme

The performance of the students will be evaluated based on a comprehensive system of continuous evaluation. For each course, there shall be a minor test, assignments/ laboratory work. There shall be a monitoring committee to be constituted at the beginning of each semester to monitor the internal assessment.

I. Details of the curriculum for M.Tech. Computer Science Programme

SEMESTER – I

MTCSC101: ALGORITHM DESIGN AND ANALYSIS [3-0-1]

Course Objectives: The course is designed to develop the student's ability to design efficient algorithms for solving problems at hand. They also learn to compare and contrast the problems those admit and those may not admit fast solutions.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: design and analyze algorithms using augmentation, randomization, parallelization and linear programming.

CO2: analyze the strengths and weaknesses of algorithm design techniques.

CO3: prove the correctness of algorithms and analyze time complexity

CO4: analyze algorithms in the probabilistic framework.

CO5: appreciate that certain problems are too hard to admit fast solutions and be able to prove their hardness.

CO6: analyze approximate algorithms.

Syllabus:

Unit-I Review: Review and correctness of greedy and divide and conquer algorithms, dynamic programming.

Unit-II Advanced Techniques: Augmentation: Maximum Flow and Min Cut Problems, Matching in bipartite graphs, Minimum weight matching. Linear Programming: Formulating an LPP, Feasible region and Convex Polyhedron, Simplex Algorithm, LP-rounding to obtain integral solutions, Primal-Dual Algorithm. Randomized algorithms: Introduction to Random numbers, randomized Qsort, randomized selection, randomly built BST, randomized min-cut. Parallel Algorithms: Shared Memory Model, Distributed Memory Model, Speedup. Searching, sorting, selection, matrix-vector multiplication, prefix-sum;

Unit-III Introduction to Complexity Classes: Classes P, NP - Verifiability, NP-Hard - Reducibility, NP-Complete - Intractability .

Unit IV Dealing with Intractability: Introduction to Approximation Algorithms.

Readings:

1. J. Kleinberg and E.Tardos, **Algorithm Design**, 1st Edition 2013., Pearson Education India.

2. T.H. Cormen, C.E. Leiserson, R.L. Rivest and C. Stein, **Introduction to Algorithms**, 3rd Edition, 2010, Prentice-Hall of India Learning Pvt. Ltd.

3. Vijay V. Vazirani, **Approximation Algorithms**, 2013, Springer.

4. Bernhard Korte and Jens Vygen, **Combinatorial Optimization: Theory and Algorithms (Algorithms and Combinatorics)**, 6th edition, 2018, Springer.

5. Rajeev Motwani and Prabhat Raghavan, **Randomized algorithms**, 2004, Cambridge University Press.

MTCSC102: WIRELESS COMMUNICATIONS [3-0-1]

Course Objectives: The course covers the basic principles and protocols of wireless protocols. The course also introduces the students to emerging technologies in wireless communications.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: discuss the advantages and disadvantages of various multi access techniques in wireless communication.
CO2: fine-tune the multiple access parameters to reduce call drops and enhance the quality of service.
CO3: Comprehend difference of the spectrum spreading frameworks in communication channels.
CO4: Generate different wireless communication scenarios using a simulator such as NS3G and GLOMOSIM.

Syllabus:

Unit-I: Wireless Propagation and Channel Models: Overview of wireless communication systems, evolution from wired to wireless communication, generations of cellular networks: 1G, 2G, 3G, 4G, 5G, 6G and beyond, types of wireless communication: cellular, satellite, ad-hoc networks; radio wave propagation: free space path loss, shadowing, and multipath fading; fading channel models: AWGN (additive white Gaussian noise), Rayleigh, Rician, and Nakagami-m.

Unit II: Modulation and Demodulation, and Multiple Access Techniques: Analog modulation techniques: AM, FM, digital modulation techniques: ASK, FSK, PSK, QAM, performance metrics: signal-to-noise ratio (SNR), bit error rate (BER), frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), space division multiple access (SDMA), wireless networking standards (e.g., IEEE 802.11 Wi-Fi, Bluetooth, LTE, 5G), MAC (medium access control) and PHY (Physical) layers in wireless networks,

Unit-III: Wireless Networking Protocols and Cellular Networks: Cell concept and frequency reuse, wireless LANs (Wi-Fi); wireless MANs (WiMAX); ad-hoc and sensor networks, cellular architecture: base stations, mobile switching centers, seamless handovers, mobile ad-hoc networks (MANETs) and their challenges, integration of wireless technologies with the internet, internet of things (IoT) and wireless sensor networks, machine-to-machine (M2M) communication, link budget analysis, antenna design and placement, system-level optimization and trade-offs.

Readings:

1. Theodore S. Rappaport, **Wireless Communications: Principles and Practice**, Pearson, 2014
2. Cory Beard and William Stallings, **Wireless Communication Networks and Systems**, Pearson, 2015

MTCSC103: DATA MINING [3-0-1]

Course Objectives: The course will enable students to analyze univariate, bivariate, and multivariate relationships in data using rule mining, classification, and clustering techniques. The course also introduces the sequence mining and graph mining techniques to the students.

Course Learning Outcomes:

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

CO1: discover patterns using different algorithms.
CO2: implement various clustering algorithms for effective data grouping, and evaluate clustering quality using appropriate validation method.
CO3: demonstrate competence in utilizing graph matrices, clustering as graph cuts, and applying Markov Clustering for spectral and graph-based clustering.
CO4: deploy Successfully employ Decision Trees and Optimal Linear Discriminant Analysis for accurate classification tasks.
CO5: Successfully generate and analyze graph patterns through the application of gSpan Algorithm.

Syllabus:

Unit-I Foundations: Numeric and categorical attributes: univariate, bivariate, and multivariate analysis, data normalization, and discretization of numeric attributes; Dimensionality reduction: principal components and kernel principal components, singular value decomposition,

Unit-II Itemset Mining: Frequent Itemsets and Association Rules, Itemset Mining Algorithms, Generating Association Rules, Maximal and Closed Frequent Itemsets (GenMax AND Charm algorithms, High utility itemset mining algorithms such as HUIminer, UP-Growth, HUI-Trie, BUC, FHM, HUP-Miner, HUSpan. Non-Derivable Itemsets; parallel rule mining; rule assessment: Rule and Pattern Assessment Measures, Significance Testing and Confidence Intervals.

Unit-III Clustering and Classification: Hierarchical Clustering: agglomerative and divisive clustering, divisive clustering; density-based Clustering: DBSCAN Algorithm, Kernel Density Estimation, DENCLUE, Spectral and Graph Clustering: graph cuts and spectral clustering, Markov Clustering; Clustering validation;

Unit-IV: Classification: Probabilistic Classification: Bayes Classifier, Naive Bayes Classifier, K nearest neighbors classifier; decision trees; linear discriminant analysis: optimal linear discriminant, kernel discriminant analysis; bagging, Boosting.

Unit-V Sequence and Graph Mining: Pattern mining: Multilevel, Multidimensional, constraint-based FIM, Frequent Sequences, Mining Frequent Sequences, Substring Mining via Suffixes, Graph Pattern Mining: Isomorphism and Support, gSpan Algorithm, Pattern Communities and community detection in networks: Hierarchical, Modularity-based, and label Propagation algorithms.

Readings:

1. J. M. Zaki, and W. Meira, Data **mining and Analysis: Fundamental Concepts and Algorithms.** Cambridge University Press, 2014.
2. P. Tan, M. Steinbach and V. Kumar, **Introduction to Data Mining**, Addison Wesley, 2016.
3. Charu C Agrawal, **Data Mining: The Textbook**, Springer, 2015.
4. Han, Jiawei, Micheline Kamber, and Data Mining. Concepts and techniques, Morgan Kaufmann.

MTCSC104: INFORMATION SECURITY AND STANDARDS **[3-0-1]**

Course Objectives: The course introduces the students to key security concerns and threats. It covers various strategies like cryptography, security protocols, and models for IT security. Further, it provides a comprehensive introduction to security standards and regulations. .

Course Learning Outcomes: On completing this course, the student will be able to:

CO1: Describe various information security issues.
CO2: Analyze the vulnerabilities in any computing system and hence be able to design a security solution.
CO3: Implement symmetric and asymmetric cryptographic methods.
CO4: Implementation of digital signatures.
CO5: Describe security mechanisms like intrusion detection, Intrusion prevention etc.

Syllabus:

Unit-I Overview of Security: Protection versus security; aspects of security– confidentiality, data integrity, availability, privacy; user authentication, access controls.

Unit-II Security Threats: Program threats, worms, viruses, Trojan horse, trap door, stack and buffer overflow; system threats- intruders; communication threats- tapping and piracy.

UNIT-III: Symmetric and Asymmetric Key Cryptography- Basic number theory, classical encryption techniques, block ciphers, Data Encryption Standard (DES), Triple DES, modes of DES, Advanced Encryption Standard, stream cipher and RC4. DH key exchange, RSA, ElGamal, elliptic curve cryptography, Message Authentication and Hash Function, Birthday problem, birthday attack, HMAC, CMAC. Digital Signatures- RSA Signature, ElGamal digital signature scheme, Elliptic Curve digital signature scheme, Key Management, Public Key Infrastructure (PKI).

UNIT-IV: Security Protocols, Firewalls and Intrusion Detection/Prevention Systems: SSH, SSL, IPSec, Kerberos, WEP, GSM, Firewalls, Intrusion Detection (IDS) and Intrusion Prevention Systems (IPS), Signature-based and anomaly-based detection, Honeypots and honeynets.

Unit-V Computer Security Models: BLP Model, BIBA Model, HRU Model.

Unit-VI: Standards and regulations: Orange Book Standard, ISO 27001 and ISO 27002, NIST Cyber Security Framework (CSF), FINRA (Financial Industry Regulatory Authority), PCI DSS (The Payment Card Industry Data Security Standard), , HIPAA (The Health Insurance Portability and Accountability Act), IEC 62443, GDPR (General Data Protection Regulation), Digital Personal Data Protection (DPDP) Act, 2023.

Readings:

1. Wade Trappe, Lawrence C. W., **Introduction to Cryptography with Coding Theory**, Pearson Publication, 2011
2. Behrouz Forouzan, **Cryptography and network security**. 3rd edition (2015), McGraw Hill Education.
3. Stallings, W. (2021). **Cryptography and Network Security: Principles and Practice** (8th Edition). Pearson.
4. Bernard Menezes, **Network Security and Cryptography**, Cengage Learning.

MTCSC105: STATISTICAL METHODS [3-0-1]

Course Objectives: To equip students with the skills necessary to apply statistical methods for various applications.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: apply descriptive statistical techniques to summarize and interpret data

CO2: apply inferential statistical methods, including hypothesis testing and confidence interval estimation.

CO3: perform and interpret simple and multiple linear regression analysis

CO4: apply principles of experimental design in the context of a problem

Syllabus:

Unit-1 Introduction: Descriptive statistics: measures of central tendency and variability, representation of data: stem and leaf diagram, histogram, boxplot, and ogive; bar diagram and its variations, Pie charts; probability distributions: discrete and continuous, joint and conditional probability; theory of attributes: coefficient of association and coefficient of colligation.

Unit-II: Statistical Inference: Parameter and statistic; sampling distributions, confidence intervals and margin of error, hypothesis testing; ANOVA, parametric tests: normal test, t-test, f-test; non-parametric tests: Chi-Square test for goodness of fit, Mann-Whitney U test, Kruskal-Wallis test.

Unit-III Regression and Classification: Correlation: measure and significance, simple linear regression, multiple linear regression, one-way classification, analysis of variance, two-way classification, analysis of covariance, curvilinear regression, factorial experiments, Spearman's rank correlation coefficient.

Readings:

1. Robert S. Witte and John S. Witte, **Statistics**, John Wiley & Sons Inc; 11th edition, 2021
2. Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani, **An Introduction to Statistical Learning**, Springer, 2023.
3. G. W. Snedecor, W. G. Cochran, **Statistical Methods**, Iowa State University Press, 1973
4. John A. Rice, **Mathematical Statistics and Data Analysis**, Cengage, 2013

MTCSC106: SOFTWARE TOOLS [0-0-2]

Course Objective:

To develop proficiency in the use of software tools required for project development.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: master the command line, use a powerful text editor,
CO2: use features of version control systems
CO3: debug and profile code
CO4: manage dependencies

Syllabus:
Shell Tools and Scripting, Editors (Vim), Data Wrangling, Command-line Environment, Version Control (Git), Debugging and Profiling, Metaprogramming: Working with Daemons, FUSE, Backups, APIs, Common command-line flags/patterns, Window managers, VPNs, Markdown, Booting + Live USBs, Docker, Vagrant, VMs, Cloud, OpenStack, Notebook programming

Readings:

1. Newham C. Learning the bash shell: **Unix shell programming**. " O'Reilly Media, Inc."; 2005 Mar 29.
2. Shotts W. **The Linux command line: a complete introduction**. No Starch Press; 2019 Mar 5.
3. https://git-scm.com/book/en/v2

SEMESTER – II

MTCSC201: ADVANCED DATABASES [3-0-1]

Course Objectives: Studying Advanced Database aims to deepen understanding beyond basic concepts, focusing on advanced topics such as transaction management, stored procedures, triggers, NoSQL databases, and advanced security measures. The objective is to equip students with the skills needed to design, implement, and optimize complex database systems, addressing challenges related to scalability, performance, and emerging database technologies. Additionally, students will gain proficiency in administering databases, ensuring security, implementing backup strategies, and employing advanced monitoring and tuning techniques for optimal database performance.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: Demonstrate proficiency in SQL programming with user-defined data types, collection types, procedures, functions, triggers, and handling large datasets.
CO2: Design and develop web applications with an understanding of web technologies, digital signatures, performance considerations, and XML integration in databases.
CO3: Build robust database applications by establishing connections, implementing CRUD operations,

ensuring data consistency through transactions, and managing concurrency issues.
CO4: Explore advanced concepts such as stored procedures, triggers, and NoSQL databases, understanding their applications and differences from relational databases.
CO5: Implement comprehensive database security measures, including user authentication, authorization, encryption, and execute effective administration practices such as backup strategies, recovery procedures, and performance tuning using appropriate tools.

Syllabus:

Unit I Introduction: Review of database design methods: ER modeling and normalization.
Unit II Database Programming: SQL user-defined data types, collection types; procedures and functions, exception handling, triggers, large objects, bulk loading of data.
Unit III Web Application Design and Development: Web technologies, web interfaces to databases, digital signatures and digital certificates, performance issues, XML in Databases.
Unit IV Building Database Applications: Establishing database connections in applications, Handling connection strings and security, CRUD Operations: Creating, reading, updating, and deleting data, Implementing CRUD operations in applications, Transactions and Concurrency, ensuring data consistency with transactions, Managing concurrency issues
Unit V Advanced Database Concepts: Stored Procedures and Triggers, Writing and implementing stored procedures, Using triggers for automated actions, NoSQL Database, Use cases and differences from relational databases.
Unit VI Database Security and Administration: Database Security, User authentication and authorization, Encryption, and data protection, Implementing backup strategies, Recovery procedures in case of failures, Monitoring and Performance Tuning Tools for monitoring database performance, Techniques for performance tuning.

Readings:

1. A. Silberschatz, H. Korth and S. Sudarshan, Database System Concepts (6th ed.), McGraw Hill, 2010.
2. Loney and Koch, Oracle 10g The Complete Reference, Tata McGraw Hill, 2006.
3. J. Morrison, M. Morrison and R. Conrad, Guide to Oracle 10g, Thomson Learning, 2005.
4. David Flanagan, JavaScript: The Definitive Guide, O'Reilly Media, 6th edition 2011.
5. Banker K, Garrett D, Bakkum P, Verch S., MongoDB in action: covers MongoDB version 3.0. Simon and Schuster; 2016.

MTCSC202 MACHINE LEARNING [3-0-1]

Course Objectives: The course aims to develop the core competence in developing, implementing, and evaluating machine learning algorithms for a given problem. The course covers supervised, unsupervised, and reinforcement learning approaches for solving real-world problems.

Course Learning Outcomes:

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

CO1: identify suitable machine learning approach for a given problem.

CO2: design and implement supervised, unsupervised and reinforcement learning algorithms for real-world applications.

CO3: fine-tune machine learning algorithms and evaluate models generated from data.

Syllabus:

Unit I Supervised Learning: Learning a Class from Examples, Vapnik-Chervonenkis (VC) Dimension, Probably Approximately Correct (PAC) Learning, Noise, Learning Multiple Classes, Regression, Model Selection and Generalization, Dimensions of a Supervised Machine Learning Algorithm; Bayesian Decision Theory: Losses and Risks, Discriminant Functions, Utility Theory, Value of Information, Bayesian Networks, Influence Diagrams; Voting, Error-Correcting Output Codes, Assessing and Comparing Classification Algorithms: Cross-Validation and Resampling Methods, *K*-Fold Cross-Validation, 5x2 Cross-Validation, Bootstrapping, Measuring Error, Interval Estimation, Hypothesis Testing, Assessing a Classification Algorithm's Performance, Binomial Test, Approximate Normal Test, Paired *t* Test.

Unit II Parametric Methods: Maximum Likelihood Estimation, Bernoulli Density, Multinomial Density, Gaussian (Normal) Density, Evaluating an Estimator: Bias and Variance, The Bayes' Estimator, Parametric Classification, Regression, Tuning Model Complexity: Bias/Variance Dilemma, Model Selection Procedures.

Unit III Multivariate Methods: Multivariate Data, Parameter Estimation, Estimation of Missing Values, Multivariate Normal Distribution, Multivariate Classification, Tuning Complexity Discrete Features, Multivariate Regression; Dimensionality Reduction: Subset Selection, Principal Components Analysis, Factor Analysis, Multidimensional Scaling, Linear Discriminant Analysis.

Unit IV Clustering: Mixture Densities, *k*-Means Clustering, Expectation-Maximization Algorithm, Mixtures of Latent Variable Models, Choosing the Number of Clusters

Unit V Nonparametric Methods: Nonparametric Density Estimation, Histogram Estimator, Kernel Estimator, *k*-Nearest Neighbor Estimator, Generalization to Multivariate Data, Nonparametric Classification, Condensed Nearest Neighbor, Nonparametric Regression: Smoothing Models, Running Mean Smoother, Kernel Smoother, Running Line Smoother, How to Choose the Smoothing Parameter

Unit VI Linear Discrimination: Generalizing the Linear Model, Geometry of the Linear Discriminant, Pairwise Separation, Parametric Discrimination Revisited, Gradient Descent, Logistic Discrimination, Discrimination by Regression.

Unit VII Support Vector Machines: Optimal Separating Hyperplane, The Non Separable Case: Soft Margin Hyperplane, Kernel Functions, Support Vector Machines for Regression

Unit VIII Multilayer Perceptrons: Introduction to neural networks, The Perceptron, Training a Perceptron, Learning Boolean Functions, Multilayer Perceptrons, MLP as a Universal Approximator, Backpropagation Algorithm, Nonlinear Regression, Multiple Hidden Layers

Unit IX Reinforcement Learning: Single State Case: *K*-Armed Bandit, Elements of Reinforcement Learning, Model-Based Learning, Temporal Difference Learning, Exploration Strategies, Deterministic

Rewards and Actions, Nondeterministic Rewards and Actions, Eligibility Traces, Generalization, Partially Observable States

Readings:

1. Alpaydin, Ethem, **Introduction to machine learning,** MIT press, 2014.
2. Christopher, M. Bishop, **Pattern Recognition And Machine Learning**, Springer-Verlag, 2016.
3. Shai Shalev-Shwartz, Shai Ben-David, **Understanding Machine Learning: From Theory to Algorithms,** Cambridge Press, 2014.
4. Michalski, Ryszard S., Jaime G. Carbonell, and Tom M. Mitchell, eds. **Machine learning: An artificial intelligence approach**, Springer Science & Business Media, 2013.

MTCSC203 NETWORK SECURITY [3-0-1]

Course Objectives:

This course provides a comprehensive understanding of various aspects of network security concepts in wireless, cloud, and IoT security. This course also brings knowledge and skills to analyze, design, and implement layer security measures in diverse wireless and mobile network environments.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: enumerate issues in network security.
CO2: identify vulnerabilities of intrusion and implement intrusion detection and prevention mechanisms.
CO3: describe and implement various network security protocols.

Syllabus:

Unit-I: Introduction- OSI security architecture, security attacks and security services, security mechanisms, key distribution and user authentication, remote user authentication principles, symmetric key distribution using symmetric encryption, Kerberos, key distribution using asymmetric encryption, certificates, public-key infrastructure, federated identity management.
Unit-II: Network Access Control and Cloud Security- Network Access Control, Extensible Authentication Protocol, IEEE 802.1X Port-Based Network Access Control, Cloud Computing, Cloud Security Risks and Countermeasures, Data Protection in the Cloud, Cloud Security as a Service, Addressing Cloud Computing Security Concerns.
Unit-III: Transport-Level Security- Web Security Considerations, Transport Layer Security, HTTPS, Secure Shell (SSH),
Unit-IV: Wireless Network Security- Wireless security, mobile device security, IEEE 802.11 wireless LAN, IEEE 802.11i wireless LAN security.
Unit-V: Electronic Mail Security-Internet mail architecture, e-mail formats, e-mail threats and comprehensive email security, S/MIME, pretty good privacy, DNSSEC, DNS-based authentication of named entities, sender policy framework, domain keys identified mail, domain-based message authentication, reporting, and conformance.

Unit-VI: IP-Security- IP security policy, encapsulating security payload, combining security associations, internet key exchange, cryptographic suites, malicious software, types of malicious software (malware), advanced persistent threat; propagation: Infected content, viruses, vulnerability exploit, worms, social engineering, spam e-mail, trojans, system corruption, attack, agent: zombie, bots, keyloggers, phishing, spyware, backdoors, rootkits, counter measures, distributed denial of service attacks.
Unit VII: Intrusion and Protection Mechanisms- Intrusion detection, password management, firewalls: need for firewalls, firewall characteristics and access policy, types of firewalls, firewall basing, firewall location and configurations.
Unit VIII: Security In Mobile and IoT- Threats to software defined networks (SDNs), network functional virtualization (NFV), security attack surfaces – ETSI perspective, cloud security: security as a service.

Readings:

1. Wade Trappe, Lawrence C. W., **Introduction to Cryptography with Coding Theory**, Pearson Publication.
2. Behrouz Forouzan, **Cryptography and network security**. Third edition, McGraw Hill Education, 2015.
3. William Stallings, **Cryptography and Network Security: Principles and Practice**, Eighth Edition, Pearson, 2021.
4. Bernard Menezes, **Network Security and Cryptography**, Cengage Learning., 2010.

MTCSC204 IMAGE PROCESSING AND COMPUTER VISION [3-0-1]

Course Objectives:
The primary objective of this course is to learn the various methods for Image Processing & Computer Vision and find the solution for the real time challenges.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: Identify and describe operation of different transforms with smoothing and sharpening filters.

CO2: Apply different models for color and de-noising to recover the original image.

CO3: Analyze the different compression and segmentation techniques.

CO4: Understand the geometric relationships between 2D images and the 3D world.

CO5: Introduce the major ideas, methods and techniques of computer vision.

CO6: Design and describe various methods used for motion, registration, alignment, detection, recognition and matching in images.

Syllabus:

Unit I Introduction: Applications of digital image processing, steps in digital image processing: image acquisition, image sampling and quantization, basic relationships between pixels; Image transforms: Two Dimensional Orthogonal and Unitary Transforms and their properties, Image representation by stochastic models, Image Decomposition; Image enhancement: Image enhancement in spatial and frequency domain, Design of Low pass, High pass, EDGE Enhancement, Filters in Frequency Domain and spatial domain; Image compression: Fundamentals, Basic compression methods.

Unit II Image restoration and reconstruction: A model of image degradation/restoration process, Noise models, restoration in presence of noise only-spatial filtering, Noise reduction by Frequency Domain, Estimating the degradation function, Inverse filtering, Minimum Mean Square Error (Wiener) Filtering, Constrained Least Squares Filtering, Geometric Mean Filter, Image Reconstruction from Projections

Unit III Color image processing: Fundamentals and models, Pseudo color image processing, Basics of full color image processing, Color transformations, Smoothing and sharpening, Image segmentation based on color; Morphological image processing: Dilation and Erosion, Opening and Closing, Some basic morphological algorithms, Gray scale morphology.

Unit IV Image segmentation: Point, Line and Edge Detection, Region based Segmentation

Unit V Image formation: Sources, Shadows and Shading, Geometric image features, Analytical image features; Early vision: One image- Linear filters, Edge detection, Filters and features, Texture; Early vision: Multiple images- Stereopsis, Projective structure from motion; Mid-level vision: Segmentation using clustering methods, Fitting- Hough transform, Fitting lines, Fitting curves, Tracking- Tracking as an abstract inference problem, Linear dynamic models, Non-linear dynamic models; High-level vision: Correspondence and pose consistency.

Unit VI 3D reconstruction: Shape from X, Active range finding, Surface representations, Point-based representations, Volumetric representations, Model-based reconstruction, Recovering texture maps

<u>Readings:</u>

1. Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, Pearson, Fourth Edition, 2018.
2. William. K. Pratt, Digital Image Processing, John Wiley & Sons, Fourth Edition, 2007.
3. Forsyth and Ponce, Computer Vision: A Modern Approach, Pearson Education India, Second Edition, 2015.
4. Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2011th Edition, 2010.

MTCSO201 PARALLEL AND DISTRIBUTED COMPUTING [3-0-1]

Course Objectives: This course teaches students how to use several processors or systems simultaneously. Students will learn to develop and implement efficient algorithms that divide large computations into smaller jobs, distribute them across several processors or machines, and coordinate their execution.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: describes architectures for parallel and distributed systems.
CO2: develop elementary parallel algorithms.

CO3: develop an application involving synchronization of communicating distributed processes.

Syllabus:

Unit-I Parallel and Distributed Computing- Trends in microprocessor architectures, memory system performance, dichotomy of parallel computing platforms, physical organization of parallel platforms, communication costs in parallel machines, SIMD versus MIMD architectures, global versus distributed memory, the PRAM shared-memory model, distributed-memory or graph models, basic algorithms for some simple architectures: linear array, binary tree, 2D mesh with shared variables., Characteristics and goals of distributed computing, architectural styles: centralized, decentralized, and hybrid architectures, layered, object-based and service oriented, resource-based, publish-subscribe architectures, middleware organization: wrappers, interceptors, and modifiable middleware, system architecture, example architectures: network file system and web.
Unit-II: Distributed Processes and Communication in Distributed Systems:- Threads in distributed systems, principle of virtualization, clients: network user interfaces and client-side software for distribution transparency; servers: design issues, object servers, server clusters; code migration; Layered protocols, remote procedure call: RPC operation, parameter passing; message oriented communication: transient messaging with sockets, message-oriented persistent communication; multicast communication: application-level tree-based multicasting, flooding-based multicasting, gossip-based data dissemination.
Unit III: Naming and Coordination and Security in Distributed Systems: Names, identifiers, and addresses, flat naming, Structured naming, and attribute-based naming; coordination: clock synchronization, logical clocks, mutual exclusion: centralized, distributed, token-ring, and decentralized algorithms; election algorithms, location systems, distributed event matching, gossip-based coordination.
Introduction to consistency models and protocols, fault tolerance, and security issues in distributed systems.

Readings:
1. Ananth Grama, Anshul Gupta, George Karypis, Vipin Kumar, Introduction to Parallel Computing, 2nd edition, 2003, Addison-Wesley.
2. B. Parhami, Introduction to Parallel Processing: Algorithms and Architectures, Plenum, 1999, Springer.
3. M. van Steen, A. S. Tanenbaum, Distributed Systems, CreateSpace Independent Publishing Platform, 2017.

MTCSO202 AUTOMATA THEORY [3-0-1]

Course Objectives: The course introduces the theoretical models of computation and their limitations. The students will develop skills to analyze automata and their computational power to recognize languages. The students will learn to apply the knowledge of Automata Theory, Grammar, and Turing machines to solving problems in language translation.

Course Learning Outcomes:

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

CO1: describe the mathematical models of machines and discuss their limitations.

CO2: prove equivalence of different computation models equivalent to Turing machine.

CO3: reason why the computers cannot solve some apparently simple tasks, for example hating problem..

CO4: design and implement a parser for context free grammar.

Syllabus:

Unit-I Introduction: Alphabets, strings, and languages.

Unit-II Finite Automata and Regular Languages: Deterministic and non-deterministic finite automata, regular expressions, regular languages and their relationship with finite automata, pumping lemma and closure properties of regular languages.

Unit-III Context-Free Grammars and Pushdown Automata: Context-free grammars (CFG), parse trees, ambiguities in grammars and languages, pushdown automaton (PDA) and the language accepted by PDA, deterministic PDA, Non- deterministic PDA, properties of context-free languages; normal forms, pumping lemma, closure properties, decision properties.

Unit-IV Turing Machines: Turing machine as a model of computation, programming with a Turing machine, variants of Turing machine and their equivalence

Unit-V Undecidability: Recursively enumerable and recursive languages, undecidable problems about Turing machines: halting problem, Post Correspondence Problem, and undecidability problems about CFGs.

Readings:

1. J. E. Hopcroft, R. Motwani, and J. D. Ullman, **Introduction to Automata Theory, languages, and computation**, 2016.
2. H.R. Lewis, C.H. Papadimitriou, C. Papadimitriou, **Elements of the Theory of Computation** (2nd ed.), Pearson Education, 2015
3. P. Linz, **Introduction to Automata Theory, Languages, and Computation**, Jones & Bartlett, 2016.

MTCSO203 CLOUD NETWORKING [3-0-1]

Course Objectives: This course aims to provide the importance of cloud networking services in terms of infrastructure, computing and storage facilities. The course renders of concept of visualization, migration, scalability, and elasticity for dynamic loading.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: Students will be able to compare major cloud computing service platforms such as public, private, hybrid, and community with traditional computing facilities.
CO2: to mitigate challenges of conventional computing facilities using SDN, NFV and DNs towards load balancing and elasticity of cloud network structures.
CO3: generate scenario of cloud computing services, protocols, and concepts through CloudSim software.

Syllabus:

Unit I Cloud Computing, Virtualization and Networking: Definition and characteristics of cloud computing, service models: IaaS, PaaS, SaaS, deployment models: public, private, hybrid, and community clouds; Virtualization: Basics of virtualization, Hypervisors and virtual machines, Containerization (e.g., Docker), Networking: data centers and their architecture, Servers, storage, and networking in the cloud Scalability and elasticity in cloud infrastructure, traditional networking vs. cloud networking, Software-Defined Networking (SDN), and Network Function Virtualization (NFV)

Unit II Cloud Storage, Security and Platform: Object storage and block storage, Cloud storage services (e.g., Amazon S3, Azure Blob Storage), Data management and durability in the cloud, Security challenges in cloud computing, Identity and access management, Data encryption and security best practices, Platforms: Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform (GCP), Comparison of major cloud providers, Cloud services and offerings, Overview of cloud networking protocols (e.g., TCP/IP, HTTP, HTTPS), load balancing and content delivery networks (CDNs), virtual private clouds (VPCs), and networking in public clouds

Unit III Cloud Migration and Deployment: Strategies for migrating applications to the cloud, Deployment models and considerations, monitoring and management tools for cloud infrastructure, examining real-world implementations of cloud networking, edge computing, serverless computing, Emerging technologies and their impact on cloud networking.

Readings:

1. Matthew Portnoy, Thomas Erl, Zaigham Mahmood, and Ricardo Puttini., Cloud Computing: Concepts, Technology & Architecture, Virtualization Essentials,
2. The Datacenter as a Computer: An Introduction to the Design of Warehouse-Scale Machines" by Urs Hölzle, Luiz André Barroso.
3. Software-Defined Networking: Anatomy of OpenFlow" by Abutaleb Takabi, Mehdi Kharrazi.
4. Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance" by Tim Mather, Subra Kumaraswamy, Shahed Latif.
5. Architecting the Cloud: Design Decisions for Cloud Computing Service Models" by Michael J. Kavis
6. Cloud Storage Security: A Practical Guide" by Aaron Rowe.
7. Migrating to the Cloud: A Step-by-Step Guide to Cloud Adoption and Data Migration" by Dinko Eror.

MTCSO204 INTERNET OF THINGS [3-0-1]

Course Objectives: The objective of this course is to introduce the concept of the Internet of Things (IoT) and how it works. The course will also cover the microcontroller and interfacing of IoT devices, the security policies and issues related to IoT devices, followed by some real-life applications of IoT.

Course Learning Outcomes:

On completion of this course, a student will be able to:

CO1: understand the significance of IoT in today's world

CO2: design, develop, and interface with microcontrollers, demonstrating a practical understanding of key concepts and methodologies of IoT
CO3: identify security issues related to IoT and propose effective mitigation strategies
CO4: demonstrate proficiency in designing a secure IoT systems

Syllabus:

Unit I Internet of Things: Introduction, characteristics, architecture, various sensors and sensing techniques. technological trends in IoT, impact of IoT on society, application scenarios, vision, scalability, current solutions, and issues; microcontroller and interfacing techniques**:** IoT and its architecture layers, IoT smart devices, typical embedded computing systems, ARM architecture and programming method, embedded system development: a case study, interfacing techniques.

Unit II IoT Protocols & Security: networking and basic networking hardware: networking protocols, interaction between software and hardware in an IoT device. IoT components and technologies to secure systems and devices. various security issues related to the IoT and security architectures, hardware security threats and security vulnerabilities, physical hardware protection.

Unit III Location Tracking: device localization and tracking; different types of localization techniques: time-of-arrival based, time-difference-of-arrival based, angle-of-arrival (AOA) based, received signal strength based, Radio-Frequency IDentification (RFID) based, and fingerprinting based, Monte-Carlo tracking, Kalman filter-based tracking, Cramer-Rao lower bound (CRLB) for device location estimator, device diversity/heterogeneity issue in IoT networks

Readings:

1. Davies, John, and Carolina Fortuna (edited), The Internet of Things: From Data to Insight. John Wiley & Sons, 2020
2. Pethuru Raj, and Anupama C. Raman, The Internet of Things: Enabling Technologies, Platforms, and Use Cases, CRC Press, 2017
3. Amir Vahid Dastjerdi, and Rajkumar Buyya, Internet of Things: Principles and Paradigms, Elsevier Science, 2016
4. Arshdeep Bahga, and Vijay Madisetti, Internet of Things: A Hands-on Approach, Universities Press, 2014

MTCSO205 CYBERSECURITY, CYBER FORENSICS AND CYBER LAWS [3-0-1]

Course Objectives: The course introduces the student to various aspects of cybersecurity. It equips the students for evaluating security scenarios, The course also includes legal aspects of cybersecurity and cyber forensics, and related legal frameworks.

Course learning Outcomes: On completion of this course, a student will be able to:

CO1: State the need and scope for cyber laws.

CO2: Enumerate various cyber-attacks, describe their sources, and mechanisms of prevention.

CO3: Carryout threat assessment, penetration testing, and vulnerability analysis

CO4: Carry out malware analysis using simulations.

Syllabus:

Unit-I Introduction: Cyberspace, Cyber Crimes, cyber criminals, Cyber security, Cyber Security Threats, Cyber laws and legislation, Law Enforcement Roles and Responses.

UNIT-II Network Attacks: Network Threat Vectors, MITM, OWAPS, ARP Spoofing, IP and MAC Spoofing, DNS Attacks, SYN Flooding attacks, UDP ping-pong and Fraggle attacks, TCP port scanning and reflection attacks, DoS, DDOS. Network Penetration Testing Threat assessment, Penetration testing tools, Penetration testing, Vulnerability Analysis, Threat matrices, Firewall and IDS/IPS, Wireless networks, Wireless Fidelity (Wi-Fi), Wireless network security protocols, Nmap, Network fingerprinting, BackTrack, Metasploit.

UNIT-III Introduction Malware Analysis: Static Analysis, Code Review, Dynamic Analysis, Behavioral analysis of malicious executable, Sandbox Technologies, Reverse-engineering malware, Defeat anti-reverse engineering technique, automated analysis, intercepting network connections, Network flow analysis, Malicious Code Analysis, Network analysis, Anti-disassembling techniques, Identifying assembly logic structures with a disassembler. Malware Handling: Malicious Documents and Memory Forensics - Reverse engineering of malicious executable using memory forensic techniques, analyze malicious Microsoft Office (Word, Excel, PowerPoint) and Adobe PDF documents, analyzing memory to assess malware characteristics and reconstruct infection artifacts. Using memory forensics to analyze rootkit infections, Legal & Ethical Issues - Reinforce understanding and the application of discipline specific legal and ethical issues, Reverse Engineering Malware (REM) Methodology.

UNIT IV Regulation and Jurisdiction for global Cyber security: Copyright source of risks – Pirates- Internet Infringement - Fair Use – postings - criminal liability - First Amendments - Data Losing. Copyright: Source of risks: Trademarks, Defamation - Privacy-Common Law Privacy - Constitutional law - Federal Statutes – Anonymity - Technology expanding privacy rights. GDPR (General Data Protection Regulation), Digital Personal Data Protection (DPDP) Act, 2023.

Readings:

1. Behrouz Forouzan, **Cryptography and network security**. Third Edition, McGraw Hill Education, 2015.
2. Peter W. Singer and Allan Friedman **Cybersecurity and Cyberwar**, Oxford University Press, 2014.
3. Robert Radvanovsky, Jacob Brodsky, **Handbook of SCADA/Control Systems Security**, CRC Press, 2013.
4. Ed Skoudis , Lenny Zeltser, **Malware: Fighting Malicious Code**, Prentice Hall Series in Computer Networking and Distributed, 2003.
5. Michael Sikorski, Andrew Honig, **Practical Malware Analysis: The Hands-On Guide to Dissecting Malicious Software** 2012, No Starch Press, San Francisco.

MTCSO206 NUMERICAL OPTIMIZATION [3-0-1]

Course Objectives: The course aims to provide students with the experience of mathematically formulating a large variety of optimization/decision problems emerging out of various fields like data science, machine learning, business, and finance. The course focuses on learning techniques to optimize problems in order to obtain the best possible solution.

Course Learning Outcomes:

At the end of the course, students will be able to:
CO1: Mathematically formulate the optimization problems using the required number of independent variables.
CO2: define constraint functions on a problem.
CO3: examine the feasibility and optimality of a solution.
CO4: apply conjugate gradient method to solve the problem.

Syllabus:

Unit I Introduction: Mathematical Formulation using example, Continuous versus Discrete Optimization, Constrained and Unconstrained Optimization, Global and Local Optimization, Stochastic and Deterministic Optimization, Convexity, Optimization Algorithms

Unit II Fundamentals of Unconstrained Optimization: Concept of a Solution: Recognizing a Local Minimum, Nonsmooth Problems. Overview of Algorithms- Two Strategies: Line Search and Trust Region, Search Directions for Line Search Methods, Models for Trust-Region Methods, Scaling. Line Search - Convergence of Line Search Methods, Rate of Convergence - Convergence Rate of Steepest Descent, Newton's Method, Quasi-Newton Methods. Trust Region - The Cauchy Point algorithm, Global Convergence - Reduction Obtained by the Cauchy Point, Convergence to Stationary Points.

Unit III Conjugate Gradient Methods: Basic Properties of the Conjugate Gradient Method, A Practical Form of the Conjugate Gradient Method, Rate of Convergence.

Unit IV Calculating Derivatives: Finite-Difference Derivative Approximations, Approximating the Gradient, approximating a Sparse Jacobian, Approximating the Hessian, Approximating a Sparse Hessian

Unit V Theory of Constrained Optimization: Local and Global Solutions, Smoothness, Examples - A Single Equality Constraint, A Single Inequality Constraint, Two Inequality Constraints, Tangent Cone and Constraint Qualifications, First-Order Optimality Condition, Second-Order Conditions - Second-Order Conditions and Projected Hessians. Linear and Non-linear Constrained Optimization. Augmented Lagrangian Methods.

Readings:

1. J. Nocedal and S.J. Wright, Numerical Optimization, 2nd edition, Springer Series in Operations Research, 2006.

2. A, Mehra, S Chandra, Jayadeva, Numerical Optimization with Applications, Narosa Publishing House, New Delhi, 2009.
3. R. W. Hamming, Numerical Methods for Scientists and Engineers, 2nd edition, Dover Publications, 1986.
4. Q. Kong, T. Siauw, A. Bayen, Python Programming and Numerical Methods: A Guide for Engineers and Scientists, 1st edition, 2020.

MTCSO207 INTERPRETABLE AND RESPONSIBLE AI [3-0-1]

Course Objectives: The course introduces the students to the need and methods for interpretability of machine learning algorithms and the related societal concerns. The students will develop skills to apply different explanation techniques for various real-world applications.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: distinguish between local and global explanations.

CO2: choose a type of explanation method for a given situation.

CO3: provide mathematical reasoning behind different explanation methods.

CO4: to conduct what-if-analysis of a machine learning model by generating counterfactuals.

CO5: use programming tools for generating explanations of machine learning models.

Unit-I Introduction to Interpretability: Motivation of interpretability; taxonomy of interpretability methods; scope of interpretability- local explanation vs global explanation; properties of explanation methods and individual explanations; model agnosticity: model-specific vs model-agnostic; dataset type- image, textual, speech, tabular, and graph-based; type of explanations.

Unit-II Inherently Explainable Models: Linear regression, logistic regression, Generalized Linear Models (GLM), Generalized Additive Models (GAM), decision tree, rule-based classifier, naive Bayes classifier, k-nearest neighbors.

Unit-III Model-Agnostic Post-hoc Methods: Global model-agnostic methods: Partial Dependence Plot (PDP), Accumulated Local Effect Plot (ALE), feature interaction, functional decomposition, permutation feature importance; local model-agnostic methods: SHAP (SHapley Additive exPlanations), LIME (Local Interpretable Model-Agnostic Explanations), Counter-Factual Explanations.

Unit-IV Model-Specific Post-hoc Methods: Gradient, gradient*input, smooth-gradient, guided backpropagation, Layerwise Relevance Propagation (LRP), Layerwise Relevance Propagation-Epsilon (LRP-ε), deep Taylor, integrated gradient, DeepLIFT (Deep Learning Important FeaTures), deconvolution, Class Activation Mapping (CAM), Gradient-weighted Class Activation Mapping (Grad-CAM), Guided Gradient-weighted Class Activation Mapping (Guided Grad-CAM).

Unit-V Limitations of Explainable Methods: Faithfulness/fidelity, fragility, stability, usefulness in practice

Unit-VI Future of Machine Learning and Explainability: Open issues: Modelling uncertainty, generating stable explanations, issue of over-trust on model's explanations by domain experts and end-users, data leakage exposing sensitive information from the dataset, usefulness of the explanations in the real-world.

Readings:

1. Molnar, Christoph. **Interpretable machine learning. A Guide for Making Black Box Models Explainable**, 2019, Lulu.com, https://christophm.github.io/interpretable-ml-book/.
2. Rothman, Denis, **Hands-On Explainable AI (XAI) with Python: Interpret, visualize, explain, and integrate reliable AI for fair, secure, and trustworthy AI apps**, Packt Publishing Ltd, 2020

SEMESTER – III

MTCSC302 RESEARCH METHODOLOGY [3-0-1]

Course Objectives: The main objective of this course is to introduce the basic concepts of research methodologies and the scope of research. This course addresses the issues of selecting research problems and discusses the techniques and tools to be employed in completing a research project. This will also enable the students to prepare reports/dissertation writing and framing research proposals.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: able to demonstrate the ability to choose appropriate qualitative and quantitative methods concern to research problems.

CO2: to develop skills in data collection and data analysis procedures towards statistical characterization subject to appropriate parameter estimation frameworks and confidence intervals.

CO3: choose the appropriate research design and develop appropriate research hypothesis for a research project.

Syllabus:

Unit 1 The Literature Review: Importance of the literature review, planning a literature search, locating relevant literature, Reliability of a source, Note making, Writing a survey and identifying the problem. Planning and writing a research proposal: Research projects, Finding a research problem, and Analysis of research ideas. Planning a proposal: Some general considerations, Proposal outline, Presentation and evaluation of proposals, Students' outline of research work, Major funding agencies.

Unit 2 Collection and Analysis Of Data: Design of experiments principles for the purpose of testing research hypotheses and evaluating the results of those experiments, Analysis of data, Inferential Statistics, Some common statistical tests, Monitoring research, Records to be maintained by researchers, hypothesis testing and inferences. Tables and illustrations: Making of a table, Arrangement of data in tables, Illustrations, Graphs and visualization.

Unit 3 Information Sources: Tools for identifying literature, Types of publications, Indexing and abstracting services, online library, Search engines, Citation indexes, Citation analysis, online searching methods, initiatives for knowledge management. References: How to cite and list correctly, importance of citation of source materials,, Citation and listing system of documents, Common documentation styles, Citation of sources in the text, Examples of writing references, Electronic and online Sources, Some worked out examples for the prominent styles, Reference management software, Selecting a journal, conference.

Unit 4 Scientific Writing: Use of paragraphs and sentence checking. Abbreviations: Care with numerals, SI unit rules and style conventions. Titles, Verbs, Tenses, active or passive voice, articles, Prepositions, Relative pronouns, Transitional words and phrases, Economy in words, Singular and plural words, commonly confused words, Choosing correct words and phrases, Punctuation. Preparation of thesis and research papers: Structure of a thesis/research article/ review article, including title, introduction, literature review, methods and materials, and referencing. Editing and proofreading, use of abbreviations.

Readings:

1. Wayne C. Booth, The Craft of Research, Fourth Edition, University of Chicago Press, 2016
2. Catherine Dawson, Introduction to Research Methods, Fifth Edition, Robinson, 2019
3. C. R. Kothari, Research Methodology: Methods and Techniques, New Age International, 2004
4. R. Kumar, Research Methodology: A Step by Step Guide for Beginners, Fourth Edition, Pearson Education, 2023.
5. Relevant study material from ACM, IEEE, Elsevier, Springer

MTCSC303 RESEARCH AND PUBLICATION ETHICS [2-0-0]

Course Objectives: This course aims to build a broad understanding of philosophy and ethics, including the nature of moral judgments, ethical conduct in scientific research, and publication. Students will also familiarize themselves with databases, research metrics, and the nuances of open-access publication.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: discuss the nature and scope of philosophy and ethics. .
CO2: consciously observe scientific conduct, including intellectual honesty and research integrity.
CO3: follow best practices and standards set by organizations like COPE and WAME, addressing conflicts of interest and authorship issues.
CO4: use research metrics like h-index, SJR-score, i10-index. and altmetrics.
CO5: avoid predatory publishing.
CO6: use software tools for plagiarism-checking tools.

Syllabus:

Unit I: Philosophy and Ethics- Introduction to Philosophy, Origin of Philosophy, Characteristics of Philosophy, Common sense and Philosophy, Relationship between Philosophy & Science

Unit-II: Scientific Conduct- Integrity and Ethics, Ethics with Respect to Science & Research, Intellectual Honesty & Research Integrity: Scientific Misconducts & Redundant Publications, Selective Reporting and Misrepresentation of data

Unit-III Publication Ethics - Publication Ethics, Best Practices/Standards Setting, Initiatives & Guidelines: COPE, WAME, Conflict of Interest; Publication Misconduct, Violation of Publication Ethics, Authorship and Contributor ship; Identification of Publication Misconduct, Complacent & Appeals, Predatory Publishers & Journals.

Unit IV: Open Access Publishing: Concept of OER, Concept of open license, Open access publishing, Open access content management.

Unit-V: Publication Misconduct: Publication Misconduct, Ethical issues in various Disciplines, Fabrication, Falsification and Plagiarism (FFP), Authorship: Definition and types, Conflict of Interest, Complaints and Appeals, Software Tools

Unit-VI: Database and Research Metrics: Indexing Databases, Citation Databases: Web of Science, Scopus, Google Scholar, Metrics: h-index, g-index, i10 index, almetrics, Understanding Citation Metrics for Quality Research: Impact & Visualization Analysis, Exploring the Citation Network, Rules & Tools

Readings:

1. Jaworski W. **Philosophy of mind: A comprehensive introduction.** John Wiley & Sons; 2011 May 6.
2. Rachels J, Rachels S. **The Elements of Moral Philosophy** Seventh Edition, McGraw Hill; 2012
3. Design C. **On Being a Scientist** Responsible conduct in research.
4. American Psychological Association. **Publication manual of the American psychological association**. American Psychological Association; 2010.
5. Sugimoto CR, Larivière V. **Measuring research: What everyone needs to know**. Oxford University Press; 2018.

MTCSE301 DEEP LEARNING [3-0-1]

Course Objectives: The student learns various state-of-the-art deep learning algorithms and their applications to solve real-world problems. The student develops skills to design neural network architectures and training procedures using various deep learning platforms and software libraries.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: design and fine-tune convolutional neural networks for classification tasks.
CO2: design sequence networks for language translation tasks.
CO3: apply autoencoders for data compression tasks.
CO4: analyze the performance of deep networks.

Syllabus:

Unit-II Convolutional Neural Networks: Historical context and motivation for deep learning; review of optimizing logistic classifier using gradient descent, stochastic gradient descent, momentum, and adaptive subgradient method, and feedforward neural networks, Convolution neural networks: stacking, striding and pooling, applications like image, and text classification.

Unit-II Sequence Modeling: Recurrent Nets: Unfolding computational graphs, recurrent neural networks (RNNs), bidirectional RNNs, encoder-decoder sequence to sequence architectures, deep recurrent networks.

Unit-III Autoencoders: Undercomplete autoencoders, regularized autoencoders, sparse autoencoders, denoising autoencoders, representational power, layer, size, and depth of autoencoders, stochastic encoders and decoders.

Unit-IV Structuring Machine Learning Projects: Orthogonalization, evaluation metrics, train/dev/test distributions, size of the dev and test sets, cleaning up incorrectly labelled data, bias and variance with mismatched data distributions, transfer learning, multi-task learning.

Readings:

1. Ian Goodfellow, **Deep Learning**, MIT Press, 2016.
2. Jeff Heaton, **Deep Learning and Neural Networks**, Heaton Research Inc, 2015.
3. Mindy L Hall, Deep Learning, VDM Verlag, 2011.
4. Li Deng (Author), Dong Yu, **Deep Learning: Methods and Applications (Foundations and Trends in Signal Processing)**, Now Publishers Inc, 2009.

MTCSE302 GENERATIVE AI [3-0-1]

Course Objectives: The study of Generative AI aims to empower learners with the skills to create AI models capable of generating new content autonomously. By understanding and implementing various generative models, students will gain the expertise to apply these technologies across diverse applications in areas such as image generation and text creation, while giving due importance to ethical considerations.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: Implement GAN variants such as DCGAN, WGAN, and CGAN.
CO2: Use Variational Autoencoders (VAEs) for image generation, data reconstruction.

CO3: Apply Generative AI techniques to text generation, image-to-image translation.
CO4: Evaluate different generative models.
CO5: Address ethical concerns in Generative AI, including mitigating biases in models, promoting responsible AI practices.

Syllabus:

Unit I Generative AI Models: GANs (Generative Adversarial Networks), VAEs (Variational Autoencoders), and other approaches, GAN Architecture: Generator and discriminator components, VAE Architecture: Encoder and decoder structures. Training Generative Models: Loss functions, optimization techniques, and model evaluation; GAN Variants: DCGAN, WGAN, CGAN, etc., Conditional GANs: Applications and implementation, GANs for image generation: StyleGAN and beyond, applications of VAEs: Image generation, data reconstruction, and more.

Unit II Applications of Generative AI: Text Generation: Language models and applications. Image-to-Image Translation: Pix2Pix and CycleGAN, Deepfake Technology: Ethics, challenges, and applications; Bias in Generative Models: Addressing and mitigating biases, Responsible AI: Ethical considerations and guidelines, Case Studies: Real-world examples of ethical challenges in Generative AI.

Unit III Advanced Topics in Generative AI: Adversarial Training: Defense mechanisms against adversarial attacks, Transfer Learning with Generative Models, Research Trends: Recent developments and emerging areas in Generative AI.

Readings:

1. D. Foster; **Generative Deep Learning. Teaching Machines to Paint, Write, Compose and Play** (2019). Beijing-Boston-Farnham-Sebastopol-Tokyo, OREILLY. 2019:330.
2. R. Valle, **Hands-On Generative Adversarial Networks with Keras: Your guide to implementing next-generation generative adversarial networks,** Packt Publishing Ltd; 2019

MTCSE303 CRYPTOGRAPHY [3-0-1]

Course Objectives: The course focuses on Mathematical aspects of symmetric and asymmetric key cryptography, and cryptanalysis. The students implement various cryptographic algorithms and analyze them for their strengths. The course also provides insights into the working of Authentication Mechanisms and Key Management.

Course Learning Outcomes: On completing this course, the student will be able to:

CO1: Describe strengths and weaknesses of various symmetric and asymmetric key algorithms.
CO2: Workout underlying Mathematics of cryptographic algorithms.
CO3: Implement symmetric and asymmetric key algorithms.
CO4: Carryout cryptanalysis of cryptographic algorithms.

Syllabus:

UNIT-I Introduction: Security Goals, Cryptographic attacks, Services and Mechanism, Techniques for Security Goals Implementation – Mathematics of Cryptography – Modular Arithmetic, Congruence and Matrices, Pseudo-random number generation.

UNIT-II Symmetric and Asymmetric Ciphers: Traditional Symmetric Key Ciphers: Mathematics of Symmetric Key Cryptography: Algebraic Structures -- Modern Symmetric Key Ciphers: DES, IDEA, AES, RC5, Modes of operation of Modern Symmetric Key Ciphers; Mathematics of Asymmetric Key Cryptography: Primes, Primality Testing, Factorization, Chinese Remainder Theorem, Quadratic Congruence - Asymmetric Key Cryptography – RSA, ElGamal Cryptosystem, Elliptic Curve Cryptosystem, Public Key Infrastructure and Digital Certificates.

UNIT-III Integrity and Authentication: Message Integrity and Message Authentication: Random Oracle Model, Message Authentication – Cryptographic Hash Functions – MD5, SHA-512 - Digital Signature – Process, Services, Attacks on Digital Signature, Digital Signature Schemes – RSA, Linear and Differential Cryptanalysis attacks on RSA, El Gamal, Elliptic Curve – Variations and Applications; Entity Authentication: Password based Authentication, Challenge Response Protocols, Zero Knowledge Protocols, Biometrics – Key Management – Symmetric key Distribution, Kerberos, Symmetric Key Agreement, Public Key Distribution, Hijacking.

Readings:

1. Wade Trappe, Lawrence C. W., Introduction to Cryptography with Coding Theory, Pearson Publication.
2. Behrouz Forouzan, Cryptography and network security. 3rd edition (2015), McGraw Hill Education.
3. Stallings, W. (2021). Cryptography and Network Security: Principles and Practice (8th Edition). Pearson.
4. Bernard Menezes, Network Security and Cryptography, Cengage Learning.

MTCSE304 NETWORK SCIENCE [3-0-1]

Course Objectives: The course aims to acquaint the students with the graph theory concepts relevant for network science. The students learn the dynamics of and on networks in the context of applications from disciplines like biology, sociology, and economics.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: describe a network's structural features and their impact on network functions.

CO2: identify community structures in networks.

CO3: solve real-world problems modelled as complex networks.

Syllabus:

Unit-I Introduction: Introduction to complex systems and networks, modeling of complex systems, review of graph theory; Network properties: Local and global properties like clustering coefficient, eccentricity; centrality measures for directed and undirected networks.

Unit-II Graph models: Random graph model, Small world network model, Barabasi-Albert (preferential attachment) network model.

Unit-III Community structure in networks: Communities and community detection in networks, Hierarchical algorithms for community detection, Modularity-based community detection algorithms, Label Propagation algorithm.

Readings:

1. Mohammed J. Zaki, Wagner Meira Jr.; **Data Mining and Analysis: Fundamental Concepts and Algorithms**, Cambridge University Press, 2014.
2. Albert Barabasi, **Network Science**, Cambridge University Press, 2016.
3. David Easley and Jon Kleinberg, **Networks, Crowds, and Markets: Reasoning About a Highly Connected World**, Cambridge University Press, 2010.

MTCSE305 COMPILER DESIGN [3-0-1]

Course Objectives: The course aims to develop the ability to design, develop, and test a functional compiler/ interpreter for a subset of a popular programming language.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: describe how different phases of a compiler work.

CO2: implement top-down and bottom-up parsing algorithms.

CO3: use tools like Lex and Yacc to implement syntax-directed translation.

Syllabus:

Unit I Lexical and Syntactic Analysis: Review of regular languages, design of a lexical analyzer generator, context-free grammars, syntactic analysis: top-down parsing: recursive descent and predictive parsing, LL(k) parsing; bottom-up parsing: LR parsing, handling ambiguous in bottom-up parsers.

Unit II Syntax directed translation: Top-down and bottom-up approaches, data types, mixed mode expression; subscripted variables, sequencing statement, subroutines and functions: parameters calling, subroutines with side effects.

Unit III Code generation, machine-dependent and machine-independent optimization techniques.

Readings:

1. Alfred V. Aho, Ravi Sethi, D. Jeffrey Ullman, Monica S. Lam, **Compilers, principles, techniques, and tools**, Pearson Education India, 2nd edition, 2013.
2. Dick Grune, Kees van Reeuwijk, Henri E .Bal, Ceriel J.H. Jacobs, K Langendoen, **Modern Compiler Design,** Springer, 2012.

MTCSE306 RECOMMENDER SYSTEMS [3-0-1]

Course Objectives: The primary objective of this course is to major ideas of recommendations by automating a variety of choice-making strategies to provide the real-time application-based recommendation system.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: Learn the basic concepts for recommender systems and filtering algorithms to apply on recommendations.
CO2: To explore various types of recommender systems for building recommender systems.
CO3: Evaluate recommender systems on the basis of metrics such as accuracy, rank accuracy, etc.

Syllabus:

Unit I Introduction: Overview of Information Retrieval, Retrieval Models, Search and Filtering Techniques: Relevance Feedback, User Profiles, Recommender system functions, Matrix operations, covariance matrices, Understanding ratings, Applications of recommendation systems, Issues with recommender system. Content-based filtering: High level architecture of content-based systems, Advantages and drawbacks of content-based filtering, Item profiles, discovering features of documents, Pre-processing and feature extraction, obtaining item features from tags, Methods for learning user profiles, Similarity based retrieval, Classification algorithms.

Unit II Collaborative filtering: User-based recommendation, Item-based recommendation, Model based approaches, Matrix factorization, Attacks on collaborative recommender systems. Recommender systems: Recommender systems in personalized web search, Knowledge-based recommender system, social tagging recommender systems, Trust-centric recommendations, Group recommender systems, Constraint based recommenders, Case based recommenders.

Unit III Hybrid approaches: Opportunities for hybridization, Monolithic hybridization design: Feature combination, Feature augmentation, Parallelized hybridization design: Weighted, Switching, Mixed, Pipelined hybridization design: Cascade, Meta-level, Limitations of hybridization strategies. Evaluating recommender system: Introduction, General properties of evaluation research, Evaluation designs: Accuracy, Coverage, Confidence, Novelty, Diversity, Scalability, Serendipity, Evaluation on historical datasets, Offline evaluations.

Readings:

1. Charu C Aggarwal, Recommender Systems: The Textbook, Springer, First Edition, 2016.

2. Francesco Ricci, Lior Rokach, and Bracha Shapira, Recommender Systems Handbook, Springer, 2011th Edition, Kindle Edition.
3. Rounak Banik, Hands-On Recommendation Systems with Python, Packt Publishing, First Edition, 2018.
4. Kim Falk, Practical Recommender Systems, Manning Publications, First Edition, 2019.
5. Deepak Agarwal and Bee-Chung Chen, Statistical Methods for Recommender Systems, Cambridge University Press, First Edition, 2016.

MTCSE 307: COMBINATORIAL OPTIMIZATION [3-0-1]

Course Objectives: This course aims to introduce the mathematical tools for solving and analyzing combinatorial optimization problems. The course develops skills for the formulation of problems in different computing and data science domains as combinatorial optimization problems.

Course Learning Outcomes:

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

CO1: differentiate between the computational complexities of LP and IP.

CO2: develop knowledge and skills in linear and integer programming (LP;IP) and their applications.

CO3: apply polyhedral analysis to develop algorithms.

CO4: use the concept of duality to design exact and approximate algorithms.

Syllabus:

Unit-I Introduction: Optimization problems, neighborhoods, local and global optima, convex sets and functions, simplex method, degeneracy; duality and dual simplex algorithm, computational considerations for the simplex and dual simplex algorithms-Dantzig-Wolfe algorithms.

Unit-II Integer Linear Programming: Cutting plane algorithms, branch and bound technique and approximation algorithms for traveling salesman problem.

Unit-III Graph Algorithms: Primal-Dual algorithm and its application to shortest path (Dijkstra's algorithm, Floyd-Warshall algorithms), max-flow problem (Ford and Fulkerson labeling algorithms), matching problems (bipartite matching algorithm, non-bipartite matching algorithms, bipartite weighted matching-hungarian method for the assignment problem, non-bipartite weighted matching problem), efficient spanning tree algorithms.

Unit-IV Matroids: Independence Systems and Matroids, Duality, Matroid Intersection.

Readings:

1. Bernhard Korte and Jens Vygen, **Combinatorial Optimization: Theory and Algorithms (Algorithms and Combinatorics)**, 6th edition, 2018, Springer.
2. Matousek and Gartner, **Understanding and Using Linear Programming**, 2007, Springer.
3. C.H. Papadimitriou and K.Steiglitz, **Combinatorial Optimization: Algorithms and complexity**, 1998, Dover Publications.

4. Mokhtar S.Bazaraa, John J. Jarvis and Hanif D. Sherali, **Linear Programming and Network Flows**, 4th Edition, 2010, Wiley-Blackwell.
5. H.A. Taha, **Operations Research An Introduction**, 8th edition, 2014, Pearson Education India.

MTCSE 308: NATURAL LANGUAGE PROCESSING [3-0-1]

Course Objectives: The course provides a rigorous introduction to the essential components of a Natural Language Processing (NLP) system. The students will learn various statistical, machine learning, and deep learning techniques in NLP and apply them to solve machine translation and conversation problems.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: Understand and describe the evaluation of NLP systems.

CO2: Understand deep learning techniques in NLP and apply them to solve machine translation and conversation problems.

CO3: Learn about major NLP issues and identify possible future areas of NLP research.

Syllabus:

UNIT I Introduction: Natural Language Processing (NLP), History of NLP, Neural Networks for NLP, Applications - Sentiment Analysis, Spam Detection, Resume Mining, Conversation Modeling, Chat-bots, dialog agents, Question Processing

UNIT II Language Modeling and Part of Speech Tagging: Unigram Language Model, Bigram, Trigram, N-gram, Advanced smoothing for language modeling, Empirical Comparison of Smoothing Techniques, Applications of Language Modeling, Natural Language Generation, Parts of Speech Tagging, Morphology, Named Entity Recognition

UNIT III Words and Word Forms: Bag of words, skip-gram, Continuous Bag-Of-Words, embedding representations for words Lexical Semantics, Word Sense Disambiguation, Knowledge Based and Supervised Word Sense Disambiguation

UNIT IV Text Analysis, Summarization and Extraction: Sentiment Mining, Text Classification, Text Summarization, Information Extraction, Named Entity Recognition, Relation Extraction, Question Answering in Multilingual Setting; NLP in Information Retrieval, Cross-Lingual IR

UNIT V Machine Translation: Need of MT, Problems of Machine Translation, MT Approaches, Direct Machine Translations, Rule-Based Machine Translation, Knowledge Based MT System, Statistical Machine Translation (SMT), Parameter learning in SMT (IBM models) using EM), Encoder-decoder architecture, Neural Machine Translation

Readings:

1. Speech and Language Processing. Dan Jurafsky and James H. Martin. Pearson (2009).
2. Introduction to Natural Language Processing. Jacob Eisenstein. The MIT Press (2019).
3. Neural Network Methods for Natural Language Processing. Yoav Goldberg. Morgan and Claypool Publisher (2017).
4. Deep Learning for Natural Language Processing: Develop Deep Learning Models for Natural Language in Python. Jason Brownlee. Machine Learning Mastery (2019).

5. Natural Language Processing with Python: Analyzing Text with the Natural Language Toolkit. Steven Bird, Ewan Klein and Edward Loper. O'Reilly (2009).

<u>MTCSE 309: GRAPH THEORY</u> [3-0-1]

<u>Course Objectives</u>: This course will thoroughly introduce the basic concepts of graphs theory, graph properties and formulations of typical graph problems. The student will learn to model real-life problems such as graph coloring and connectivity as graph problems.

<u>Course Learning Outcomes:</u>
On completing this course, the student will be able to:

CO1: model problems using different types of basic graphs like trees, bipartite graphs and planar graphs.
CO2: understand and identify special graphs like Euler graphs and Hamiltonian graphs.
CO3: have increased ability to understand various forms of connectedness in a graph
CO4: appreciate different graph-coloring problems and their solutions.
CO5: to model simple problems from real life as graph-coloring problems.

<u>Syllabus:</u>

Unit-I Fundamental Concepts: Definitions, examples of problems in graph theory, adjacency and incidence matrices, isomorphisms, paths, walks, cycles, components, cut-edges, cut-vertices, bipartite graphs, eulerian graphs, vertex degrees, reconstruction conjecture, extremal problems, degree sequences, directed graphs, de Bruijn cycles, Orientations and tournaments.

Unit-II Trees: Trees and forests, characterizations of trees, spanning trees, radius and diameter, enumeration of trees, Cayley's formula, Prüfer code, counting spanning trees, deletion-contraction, the matrix tree theorem, graceful labeling, minimum spanning trees (Kruskal's algorithm), shortest paths (Dijkstra's algorithm).

Unit-III Matching and Covers: Matchings, maximal and maximum matchings, M-augmenting paths, Hall's theorem and consequences, Min-max theorems, maximum matchings and vertex covers, independent sets and edge covers,Connectivity, vertex cuts, Edge-connectivity.

Unit-IV Connectivity and Paths: Blocks, k-connected graphs, Menger's theorem, line graphs, network flow problems, flows and source/sink cuts, Ford-Fulkerson algorithm, Max-flow min-cut theorem.

Unit-V Graph Coloring: Vertex colorings, bounds on chromatic numbers, Chromatic numbers of graphs constructed from smaller graphs, chromatic polynomials, properties of the chromatic polynomial, the deletion-contraction recurrence.

Unit-VI Planar Graphs: Planar graphs, Euler's formula, Kuratowski's theorem, five- and four-color theorems.

<u>Readings:</u>

1. Douglas B West, **Introduction to Graph Theory**, II Edition, 2017, Pearson.
2. Gary Chartrand and Ping Zhang, **Introduction to Graph Theory**, 2017, Tata McGraw Hill.
3. Jonathan L. Gross and Jay Yellen, **Graph Theory and Its Applications**, 2nd Edition, 2005, Chapman Hall (CRC).

MTCSE310 WIRELESS SENSOR NETWORKS [3-0-1]

Course Objectives:
The course covers architecture of wireless sensor networks and placement strategies of sensors. It equips the student with the skills to design, develop, and conduct performance analysis for sensor networks tailored to specific applications.

Course Learning Outcomes:

On completing this course, the student will be able to:
C01: describe the architecture of wireless sensor networks and placement strategies of sensors.
C02: design, develop, and carry out performance analysis of sensors for specific applications.
C03: apply the design principles of WSN architectures for simulating various environment situations.
C04: propose, implement, and evaluate new protocols for solving wireless sensor network design issues.

Syllabus:
Unit-I Introduction: wireless sensor networks, sensor network architecture, WSN applications (healthcare, agriculture, military operation), issues in design of sensor networks; deterministic and random sensor deployment, network topology, coverage and connectivity.

Unit II MAC Protocols: issues in designing MAC protocols for ad hoc wireless networks, design goals, MAC protocol classification, location discovery, IEEE 802.15.4 standard and ZigBee

Unit III Routing Protocols and Performance Evaluation: routing challenges and design issues in routing protocols, routing Strategies, flooding and gossiping, data centric routing, energy aware routing, location-based routing (GF, GAF, GEAR, GPSR), real-time routing protocols – TEEN, APTEEN, SPEED, RAP; performance evaluation of wireless sensor networks: key performance metrics, simulation tools: MATLAB, NS-3, Creating and Analyzing WSN Simulations

Readings:

1. Jun Zheng and Abbas Jamalipour, Wireless Sensor Networks: A Networking Perspective, Wiley, 2014
2. Hossam Mahmoud Ahmad Fahmy, Concepts, Applications, Experimentation and Analysis of Wireless Sensor Networks, Springer, 2020
3. Carlos D M Cordeiro and D P Agrawal, Ad Hoc and Sensor networks: Theory and Applications, World Scientific, 2011
4. Kazem, Sohraby, Daniel Minoli, Taieb Zanti, Wireless Sensor Network: Technology, Protocols and Application, John Wiley and Sons, 2010

MTCSE311: ARTIFICIAL INTELLIGENCE [3-0-1]

Course Objectives: The course aims to introduce the student to intelligent systems and agents, formalization of knowledge, reasoning with and without uncertainty at a basic level. The student develops skills to apply the concepts, methods, and theories of search, heuristics, games, knowledge representation, and planning in different applications.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: describe various approaches to Artificial Intelligence.
CO2: design intelligent agents.
CO3: distinguish between Utility-based agents and Goal-based agents.
CO4: describe and apply concepts, methods, and theories of search, heuristics, games, knowledge representation, and planning.
CO5: acquire basic knowledge of Natural language processing.
CO6: understand the limitations of Artificial Intelligence techniques.

Syllabus:

Unit-I Introduction: Introduction to Artificial Intelligence, various definitions of AI, AI Applications and Techniques, Turing Test and Reasoning - forward & backward chaining.

Unit-II Intelligent Agents: Introduction to Intelligent Agents, Rational Agent, their structure, , reflex, model-based, goal-based, and utility-based agents, behavior and environment in which a particular agent operates.

Unit-III Problem Solving and Search Techniques: Problem Characteristics, Production Systems, Control Strategies, Breadth First Search, Depth First Search, iterative deepening, uniform cost search, Hill climbing and its Variations, simulated annealing, genetic algorithm search. Heuristics Search Techniques: Best First Search, A* algorithm, AO* algorithm, Minmax & game trees, refining minmax, Alpha – Beta pruning, Constraint Satisfaction Problem, Means-End Analysis.

Unit-IV Knowledge Representation: Introduction to First Order Predicate Calculus, Resolution Principle, Unification, Semantic Nets, Conceptual Dependencies, semantic networks, Frames system, Production Rules, Conceptual Graphs, Ontologies.

Unit-V Planning: Basic representation for planning, symbolic-centralized vs reactive-distributed, partial order planning algorithm.

Unit-VI Reasoning with Uncertain Knowledge: Different types of uncertainty - degree of belief and degree of truth, various probability constructs - prior probability, conditional probability, probability axioms, probability distributions, and joint probability distributions, Bayes' rule, other approaches to modelling uncertainty such as Dempster-Shafer theory and fuzzy sets/logic.

Unit-VII Understanding Natural Languages: Components and steps of communication, contrast between formal and natural languages in the context of grammar, parsing, and semantics, Parsing Techniques, Context-Free and Transformational Grammars.

Readings:

1. S. Russell and P. Norvig, **Artificial Intelligence: A Modern Approach, 3 rd edition**, Pearson Education, 2015.
2. Elaine Rich and Kelvin Knight, Artificial Intelligence, 3rd edition, Tata McGraw Hill , 2017.
3. DAN.W. Patterson, **Introduction to A.I. and Expert Systems** – PHI, 2007.
4. Michael Wooldridge, **An Introduction to MultiAgent Systems**, 2nd edition, John Wiley & Sons, 2009.

5. Fabio Luigi Bellifemine, Giovanni Caire, Dominic Greenwood, **Developing Multi-Agent Systems with JADE**, Wiley Series in Agent Technology, John Wiley & Sons, 2007.
6. W.F. Clocksin and C.S. Mellish, **Programming in PROLOG**, , 5th edition, Springer, 2003.
7. Saroj Kaushik, **Logic and Prolog Programming**, New Age International Publisher, 2012.
8. Ivan Bratko, **Prolog Programming for Artificial Intelligence**, Addison-Wesley, Pearson Education, 4th edition, 2011.

SEMESTER – IV

MTCSE401 BLOCKCHAIN AND POST-QUANTUM CRYPTOGRAPHY [3-0-1]

Course Objectives: The course focuses on the impact of quantum computing on traditional cryptographic approaches and the need to develop new approaches that do not succumb to the challenges of quantum computing. IN this context, blockchain approach is discussed in detail.

Course Learning Outcomes: On completing this course, the student will be able to:

CO1: describe the use and importance of post-quantum security.

CO2: describe the importance of Blockchain for security solutions.

CO3: distinguish between classical, modern and Post-quantum cryptography

Syllabus:

UNIT-I Symmetric and Asymmetric Key Cryptography: Basic Number Theory, Classical Encryption Techniques, Block Ciphers, Data Encryption Standard (DES), Triple DES, Modes of DES, Advanced Encryption Standard, Stream Cipher and RC4. DH key exchange, RSA, ElGamal, Linear and Differential Cryptanalysis attacks on RSA, Elliptic Curve Cryptography, Message Authentication and Hash Function, Birthday problem, birthday attack, HMAC, CMAC. Digital Signatures**-** RSA Signature, ElGamal digital signature scheme, Elliptic Curve digital signature scheme, Key Management.

UNIT-II Post-Quantum Security: Quantum Basics of Quantum Computing, Single and multi-qubit quantum gates, No cloning theorem. Quantum circuits. Quantum Algorithms: Deutsch-Jozsa, Simons, Bernstein-Vazirani, Grover's, Shor's, Quantum attack resistant Digital Signatures.

UNIT-III Blockchain: Introduction to Blockchain, Types of blockchain (public, private and semi-private blockchain), Blocks, Block Headers, Merkel Trees, applications of blockchain.

Readings:

1. Wade Trappe, Lawrence C. W., Introduction to Cryptography with Coding Theory, Pearson Publication.
2. Behrouz Forouzan, Cryptography and network security. 3rd edition (2015), McGraw Hill Education.
3. Stallings, W. (2021). Cryptography and Network Security: Principles and Practice (8th Edition). Pearson.
4. Bernard Menezes, Network Security and Cryptography, Cengage Learning.

MTCSE402 SOFT COMPUTING [3-0-1]

Course Objectives:

This course provides insights of soft computing frameworks applicable to bring its precision solutions for wide range of complex scientific applications.

Course Leaning Outcomes:

CO1: applying soft computing techniques towards various real-time case studies.

CO2: idea to design hybrid soft techniques over conventional computing methods.

CO3: Identify and select suitable Soft Computing methods to solve scientific complex problems where standard computing procedures are in intractable forms.

Syllabus:

UNIT-I Soft Computing: Introduction of Soft Computing, Soft Computing vs. Hard Computing, Various Types of Soft Computing Techniques, Applications of Soft Computing, Predicate Calculus, Rules of Interference, Overview of neural networks, estimating regularization parameter Kohnen's self-organizing networks, Hopfield network, applications of neural networks.

UNIT-II Fuzzy Logic Computing: Introduction of fuzzy sets and fuzzy reasoning, Basic functions on fuzzy sets, relations, rule based models and linguistic variables, fuzzy controls, Fuzzy decision making, , inferencing, defuzzification, fuzzy clustering, fuzzy rule based classifier, applications of fuzzy logics.

UNIT-III Evolutionary Algorithms: Introduction to evolutionary algorithms, Basic principles of Evolutionary Algorithms, Evolutionary strategies, Genetic Algorithm, Fitness Computations, Cross Over, Mutation, Evolutionary Programming, Classifier Systems, Genetic Programming Parse Trees, Variants of GA, Applications, Ant Colony Optimization, Particle Swarm Optimization, Artificial Bee Colony Optimization, concept of multi-objective optimization problems (MOOPs), Multi-Objective Evolutionary Algorithm (MOEA), Non-Pareto approaches to solve MOOPs, Pareto-based approaches to solve MOOPs, Some applications with MOEAs.

Readings:

1. Simon S. Haykin, Neural Networks, Prentice Hall, 2nd edition.
2. B. Yegnanrayana, “Artificial Neural Networks” , PHI.
3. Jacek M. Zurada, Introduction to Artificial Neural Systems, Jaico Publishing House,1994
4. Zimmermann, “Fuzzy Set Theory and its Application”, 3rd Edition.
5. Jang J.S.R., Sun C.T. and Mizutani E, "Neuro-Fuzzy and Soft computing", Prentice Hall, 1998.
6. Timothy J. Ross, "Fuzzy Logic with Engineering Applications", McGraw Hill, 1997.
7. D.E. Goldberg, "Genetic Algorithms: Search, Optimization and Machine Learning", Addison Wesley, N.Y, 1989.

MTCSE403 NEURAL NETWORKS [3-0-1]

Course Objectives: The course covers state-of-the-art techniques in neural network design, optimization, and specialized architectures. Students will gain hands-on experience through practical assignments and projects, enabling them to apply advanced neural network models to real-world problems.

Course Learning Outcomes:

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

CO1: implement and analyze kernel methods, radial-basis function networks, and kernel regression.

CO2: implement and evaluate regularization networks and self-organizing maps.

CO3: develop information-theoretic models for the machine learning tasks.

Syllabus:

Unit I Kernel Methods and Radial-Basis Function Networks: Cover's Theorem on the Separability of Pattern, The Interpolation Problem, Radial-Basis-Function Networks, Recursive Least-Squares Estimation of the Weight Vector, Hybrid Learning Procedure for RBF Networks, Interpretations of the Gaussian Hidden Units, Kernel Regression and Its Relation to RBF Networks

Unit II Regularization Theory: Hadamard's Conditions for Well-Posedness, Tikhonov's Regularization Theory, Regularization Networks, Generalized Radial-Basis-Function Networks, The Regularized Least-Squares Estimator, Estimation of the Regularization Parameter, Manifold Regularization, Differentiable Manifolds, Generalized Regularization Theory, Laplacian Regularized Least-Squares Algorithm

Unit III Self-Organizing Maps: Two Basic Feature-Mapping Models, Self-Organizing Map, Properties of the Feature Map, Contextual Maps, Hierarchical Vector Quantization, Kernel Self-Organizing Map, Relationship Between Kernel SOM and Kullback–Leibler Divergence.

Unit IV Information-Theoretic Learning Models: Entropy, Maximum-Entropy Principle, Mutual Information, Copulas, Mutual Information as an Objective Function to be Optimized, Maximum Mutual Information Principle, Infomax and Redundancy Reduction, Spatially Coherent Features, Spatially Incoherent Features, Independent-Components Analysis, Sparse Coding of Natural Images and Comparison with ICA Coding, Natural-Gradient Learning for Independent-Components Analysis, Maximum-Likelihood Estimation for Independent-Components Analysis, Maximum-Entropy Learning for Blind Source Separation, Maximization of Negentropy for Independent-Components Analysis, Coherent Independent-Components Analysis, Rate Distortion Theory and Information Bottleneck, Optimal Manifold Representation of Data.

Unit V Stochastic Methods Rooted in Statistical Mechanics: Statistical Mechanics, Markov Chains, Metropolis Algorithm, Simulated Annealing, Gibbs Sampling, Boltzmann Machine, Logistic Belief Nets, Deep Belief Nets, Deterministic Annealing, Analogy of Deterministic Annealing with Expectation-Maximization Algorithm

Readings:

1. Simon O. Haykin, **Neural Networks and Learning Machines,** Pearson Education, 3rd Edition, 2016
2. C. M. Bishop, **Pattern Recognition and Machine Learning**, Springer, 2010.

MTCSE404 SECURE SOFTWARE DEVELOPMENT [3-0-1]

Course Objectives: This course teaches students how to build secure software. Students will study software security concepts, identify and resolve prevalent risks and weaknesses, and integrate secure coding techniques across the development life cycle. The course teaches online application security, network security, and secure software testing best practices and integrates security into DevSecOps and CI/CD. Empowering students to create secure and resilient software applications is the goal.

Course Learning Outcomes:

On completing this course, the student will be able to:

CO1: Understand core software security concepts, identify common threats, and implement secure coding practices, including robust error handling and logging.
CO2: Mitigate web application vulnerabilities, deploy Web Application Firewalls, ensure secure session management, and apply best practices for secure coding in web services (RESTful APIs).
CO3: Grasp network security basics, implement secure communication using protocols like HTTPS, defend against network-based attacks, and consider API security in software development.
CO4: Recognize the importance of testing for security, employ various security testing methods (e.g., penetration testing, code review), utilize automated security testing tools, and seamlessly integrate security into the development and testing processes.
CO5: Integrate security measures into the CI/CD pipeline, automate security checks for early detection, establish continuous monitoring practices, and apply DevSecOps principles to foster collaboration and enhance overall software security.

Syllabus:

Unit I Introduction to Secure Software Development: Overview of software security concepts, Importance of secure software development, Common security threats and vulnerabilities, Secure development life cycle (SDLC), Secure Coding Practices, Principles of secure coding, Input validation and output encoding, Authentication and authorization best practices, Error handling and logging securely
Unit II Web Application Security: Common web application vulnerabilities (e.g., SQL injection, Cross-Site Scripting), Web application firewalls, Session management and protection, Secure coding for web services (RESTful APIs)
Unit III Network Security for Software Developers: Basics of network security, Secure communication protocols (e.g., HTTPS), Mitigating network-based attacks, API security considerations; Secure Software Testing and Code Review, Importance of testing for security, Types of security testing (e.g., penetration testing, code review), Automated security testing tools, Integrating security into the development and testing processes
Unit IV DevSecOps and Continuous Integration/Continuous Deployment (CI/CD): Integrating security into the CI/CD pipeline, Automation of security checks, Continuous monitoring for security, DevSecOps best practices

Readings:

1. Seacord, Robert C. *Secure Coding in C and C++*. Addison-Wesley, 2013.

2. Stuttard, Dafydd, and Marcus Pinto. The web application hacker's handbook: Finding and exploiting security flaws. John Wiley & Sons, 2011.
3. Stallings, William. *Network security essentials: Applications and standards, 4/e*. Pearson Education India, 2003.
4. Barnett, Ryan C. *Web Application Defender's Cookbook: Battling Hackers and Protecting Users*. John Wiley & Sons, 2013.
5. Kim, Gene, Jez Humble, Patrick Debois, John Willis, and Nicole Forsgren. The DevOps handbook: How to create world-class agility, reliability, & security in technology organizations. IT Revolution, 2021.

MTCSE405: VEHICULAR COMMUNICATION NETWORKS [3-0-1]

Course Objectives: This course introduces the student to the challenges of the world of vehicular communication networks. It covers various architectures and protocols designed for such networks, and prepares the student to implement and evaluate them.

Course Learning Outcomes:
On completing this course, the student will be able to:

C01: describe the significance of vehicular networks in modern communication systems.
C02: develop new MAC layer protocols and routing protocols for efficient vehicular network operation.
C03: apply different vehicular mobility models, including flow models and behavioral models, to analyze and predict the movement patterns of vehicles.
C04: deal with the challenges and opportunities in vehicular networks, and apply problem-solving skills to address these issues.

Syllabus:

Unit-I Introduction: Vehicular networks and their architectures, vehicle-to-vehicle communication, vehicle-to-infrastructure communication, characteristics, applications, enabling technologies, technical challenges, standardization, and open research issues.
Unit -II Medium Access Control and Routing Protocols: requirement and challenges, IEEE standard IEEE 802.11p, QoS scheme in MAC, DSRC/WAVE for connected vehicles, ad-hoc routing, geographic routing, geocasting, infrastructure Support, DTN and peer-to-peer networks.
Unit III Vehicular Mobility Models and Performance Evaluation: introduction, types of mobility models, flow models, traffic models, behavioral models, trace and survey based models; performance evaluation: concept and strategies, simulation techniques, vehicular networks simulation tools, deployment scenarios, models and metrics.

Reading:
1. Moustafa, Hassnaa, and Yan Zhang, Vehicular Networks: Techniques, Standards, and Applications. CRC Press, 2019
2. Radovan Miucic(edited), Connected Vehicles: Intelligent Transportation Systems, Springer, 2018
3. Chen, Wai (edited), Vehicular Communications and Networks: Architectures, Protocols, Operation and Deployment. Elsevier, 2015

4. Hannes Hartenstein, and Kenneth P. Laberteaux (edited), VANET Vehicular Applications and Inter-Networking Technologies, Wiley, 2010

MTCSE406: 5G and B5G TECHNOLOGIES [3-0-1]

Course Objectives: This course provides a comprehensive understanding of 5G and B5G technologies and their practical applications in modern communication systems. It also renders the importance of the link budget analysis for effective communication corresponding numerous conventional protocols.

Course Learning Outcomes:

On completing this course, the student will be able to:
C01: differentiate between traditional RAN, vRAN, and open RAN their respective roles in 5G networks.
C02: able to describe the concept of network slicing, SDN, virtualization, and MEC.
C03: establish link budget analysis for effective communication system design.

UNIT-I Introduction to 5G: Evolution of wireless technologies (1G-5G), ITU, IMT 2020 vision and requirements, radio spectrum, mm-wave characteristics, 5G new radio, modulation, OFDM, frequency division duplex and time division duplex, cellular concept, MIMO, beamforming, 5G radio access network concepts: 5G's 3-network features (enhanced mobile broadband (eMBB), massive machine-type communications (m-MTC), ultra reliable low latency communications (URLLC)), 5G core architecture, 3GPP architectural options, standalone and non-standalone architectures. 5G air interface-scalable OFDM, 5G NR numerology, resource block, use of TDD, BWP, carrier aggregation.

UNIT-II 5G Core Architecture: Reference point architecture and service based architecture, HTTP REST interfaces, policy control and charging, interworking with EPC, roaming, network slicing, software defined networks (SDN), virtualization, containers, microservices, automation, mobile edge computing (MEC) , session management – PDU session concepts, PDU session types, user plane handling, mechanisms to provide efficient user plane connectivity, session authentication and authorization, mobility management-network discovery and selection, registration and mobility, reachability, RRC inactive, N2 management, AMF management, 5GC assistance for RAN optimizations, unified Access Control. QoS in 5G- PDU session and QoS flow, 5G QoS architecture, default QoS flow, GBR QoS flow, QoS types and parameters, 5QI characteristics.

UNIT-III Other topics in 5G: Open radio access network and 5G-concept of traditional RAN, vRAN, and open RAN, centralized RAN, cloud RAN, BBU hotel, CIPRI and eCIPRI. link budget analysis-losses/gains in link budget, sample/ generic link budget. 5G and non-terrestrial networks- non-terrestrial networks, satellite and their orbits, role of satellite for 5G services, satellite for backhaul of 5G cells, multi-connectivity architecture, satellite for mMTC/mIOT.

Readings

1. Stefan Rommer ,Peter Hedman , Magnus Olsson , Lars Frid, Shabnam Sultana , Catherine Mulligan, 5G Core Networks: Powering Digitization, Academic Press, 2020.

2. Erik Dahlman, Stefan Parkvall, Johan Skold, 5G/5G-Advanced: The New Generation Wireless Access Technology, Academic Press, 20203.

MTCSE407: NP COMPLETENESS AND APPROXIMATION ALGORITHMS [3-0-1]

Course Objective: The course is designed to familiarize the students with the concept of computationally hard problems that do not admit fast solutions. Students also learn to deal with the hardness and design suboptimal solutions for them.

Course Learning Outcomes: On completion of this course, the student will be able to:

CO1: appreciate that certain problems are too hard to admit fast solutions and be able to prove their hardness.
CO2: state the purpose of an approximation algorithm.
CO3: design approximation algorithms using different techniques.
CO4: analyze the approximation factor of an algorithm.

Syllabus:

Unit-I Introduction to Classes P, NP, NP-Hard, NP Complete: Verifiability and Reduction**.**

Unit-II Proving NP-Completeness from first principle: Satisfiability Problem (SAT), 3SAT.

Unit-III Graph Problems: Clique, Vertex Cover, Independent Set, Hamiltonian Cycle Problem, Travelling Salesman Problem, Graph Partitioning, Subgraph problem, Graph Isomorphism, Graph Coloring.

Unit-IV Sets and Partitions: Set partition, Set Cover, Subset Sum and Knapsack Problem.

Unit-V Techniques to design approximation algorithms: LP-rounding, Primal-Dual, Dual Fitting, Greedy, Local Search.

Readings:

1. J. Kleinberg and E.Tardos, **Algorithm Design**, 1st Edition 2013., Pearson Education India
2. T.H. Cormen, C.E. Leiserson, R.L. Rivest and C. Stein, **Introduction to Algorithms**, 4th Edition, 2022, Prentice-Hall of India Learning Pvt. Ltd.
3. Vijay V. Vazirani, **Approximation Algorithms**, 2013, Springer.
4. David P. Williamson and David B. Shmoys, **The Design of Approximation Algorithms**, 2011, Cambridge University Press.
5. Part of the course will be covered by research papers.

MTCSE408: BAYESIAN MACHINE LEARNING [3-0-1]

Course Objective: This course will take the Bayesian statistical modeling approach to machine learning. It would inculcate the ability to incorporate prior knowledge in a principled way, the ability to learn the model hyperparameters and the right model size/complexity automatically from data, and the property of embodying online learning in a natural way.

Course Learning Outcomes: On completion of this course, the student will be able to:
CO1: apply the Beta-Bernoulli Model, Bayesian Linear Regression, Bayesian Generative Classification, Bayesian naïve Bayes, and Bayesian Logistic Regression.
CO2: master the concepts of Bayesian Inference with Gaussian Distributions, Inference via Laplace Approximation, and the role of Exponential Family in probabilistic inference.
CO3: develop competence in using Sampling Methods, Variational Bayes, and other methods such as EP, SGLD, and ABC for Approximate Bayesian Inference.
CO4: gain proficiency in Gaussian Process for Nonparametric Function Approximation, Dirichlet Process for Nonparametric Bayesian Clustering, and understanding the properties and extensions of the Dirichlet Process and Beta Process.
CO5: apply Bayesian Topic Models such as Latent Dirichlet Allocation, delve into Bayesian Deep Learning with Deep Latent Gaussian Models, Variational Autoencoders, and explore other Deep Generative Models for various applications.

Syllabus:

Unit I Introduction: Simple Models: Beta-Bernoulli Model and Bayesian Linear Regression, Bayesian Inference with Gaussian Distributions, Bayesian Generative Classification, and Bayesian naïve Bayes, Bayesian Discriminative Classification (Bayesian Logistic Regression). Inference via Laplace Approximation, Exponential Family and Its Role in Probabilistic Inference, Generalized Linear Models and Their Applications, Bayesian Inference with (Point) Estimation of Hyperparameters, Bayesian Inference with Local Conjugacy

Unit II Approximate Bayesian Inference: Sampling Methods, Variational Bayes, Scalable Inference via Stochastic methods, Other Methods (EP, SGLD - MCMC using Gradients, ABC), Bayesian Nonparametrics: Gaussian Process for Nonparametric Function Approximation, Dirichlet Process for Nonparametric Bayesian Clustering, Bayesian, Dirichlet Process Properties, Extensions, Beta Process, Dirichlet Process, A informal description of DP with some demos, Bayesian Topic Models: Latent Dirichlet Allocation and Extensions, Bayesian Deep Learning: Deep Latent Gaussian Models and Variational Autoencoders, On Bayesian Deep Learning, Variational Autoencoder

Unit III Deep Generative Models: Bayesian Optimization, Bayesian State-Space Models and Kalman Filtering, Probabilistic Numerics and Bayesian Quadrature

Readings:

1. Christopher Bishop, Pattern Recognition and Machine Learning (PRML), Springer, 2007.
2. Kevin Murphy, Machine Learning: A Probabilistic Perspective (MLAPP), MIT Press, 2012
3. Carl Rasmussen and Chris Williams. Gaussian Processes for Machine Learning. The MIT Press, 2006.
4. David Mackay. Information Theory, Inference, and Learning Algorithms. Cambridge Univ. Press, 2003.
5. David Barber. Bayesian Reasoning and Machine Learning Cambridge Univ. Press, 2012.
6. Andrew Gelman, John B. Carlin, Hal S. Stern, David B. Dunson, Aki Vehtari, Donald B. Rubin. Bayesian Data Analysis, Chapman & Hall/CRC, 2013.