DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

TRIGUNA SEN SCHOOL OF TECHNOLOGY

ASSAM UNIVERSITY: SILCHAR

PhD COURSE WORK STRUCTURE & SYLLABUS

PhD Course Work structure: Total credits 16

Course No	Course Code	Course Title	L	T	P	Credits
1	CW 701	Research and Publication Ethics	2	0	0	2
2	CW 702	Research Methodology	4	0	0	4
3	CW 703(A)	Data Structures and Algorithms	2	0	0	4
	CW 703(B)	Electives	2	0	0	
4	CW 704	Term Paper	0	0	12	6

Detailed Syllabus

CW 701: Research and Publication Ethics

THEORY

RPE 01: Philosophy and Ethics

- Introduction to philosophy: definition, nature and scope, concept, branches.
- Ethics: definition, moral philosophy, nature of moral judgements and reactions.

RPE 02: Scientific Conduct

- Ethics with respect to science and research.
- Intellectual honesty and research integrity.
- Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP).
- Redundant publications: duplicate and overlapping publications, salami slicing.
- Selective reporting and misrepresentation of data.

RPE 03: Publication Ethics

- Publication ethics: definition, introduction and importance.
- Best practices / standards setting initiatives and guidelines: COPE, WAME, etc.
- Conflicts of interest.
- Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, types.
- Violation of publication ethics, authorship and contributorship.
- Identification of publication misconduct, complaints and appeals.
- Predatory publishers and journals.

PRACTICE

RPE 04: Open Access Publishing

- Open access publications and initiatives.
- SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies.
- Software tool to identify predatory publications developed by SPPU.
- Journal finder / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

RPE 05: Publication Misconduct

A. Group Discussions

- Subject specific ethical issues, FFP, authorship.
- Conflicts of interest.
- Complaints and appeals: examples and fraud from India and abroad.

B. Software tools

Use of plagiarism software like Turnitin, Urkund and other open-source software tools.

RPE 06: DATABASES AND RESEARCH METRICS

A. Databases

- Indexing databases.
- Citation databases: Web of Science, Scopus, etc.

B. Research Metrics

- Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score.
- Metrics: h-index, g index, i10 index, altmetrics.

References

Bird, A. (2006). Philosophy of Science. Routledge.

MacIntyre, Alasdair (1967) A Short History of Ethics. London.

P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN:978-9387480865

National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition. National Academies Press.

Resnik, D. B. (2011). What is ethics in research & why is it important. National Institute of Environmental Health Sciences, 1–10.

Beall, J. (2012). Predatory publishers are corrupting open access. Nature, 489(7415), 179–179.

Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance (2019), ISBN:978-81-939482-1-7.

CW 702: Research Methodology

Unit 1: Introduction to Research Methodology

Objectives of research, Understanding research and its goals. Critical thinking. Techniques for generating research topics. Topic selection and justification.

Methods of acquiring knowledge: Traditional, empirical, national, interpretative, dialectical & scientific. Meaning of role of assumption, constructs, laws, theory, hypothesis, propositions, axioms and postulates. Types of research: Basic research, applied research, and action research. Method of research: theoretical, descriptive, experimental & analytical.

Unit 2: Research Problem and Reporting

Research Problem: selection of problem, process of designing a research proposal, steps to be followed in formulating a research proposal - theoretical and experimental processes, sources of research materials, review of literature - sources of information.

Preparation of Research Report/Thesis.

Unit 3: Quantitative Methods

Probability distribution: Normal, Binomial, Poisson, Exponential, Weibull and Geometric Distributions. Estimation, Hypothesis testing & application; Correlation & regression analysis. Parametric and non-parametric statistics. Confidence interval, Errors.

Quantitative Techniques: Levels of significance, Regression and Correlation coefficient. Statistical analysis and fitting of data; Chi-Square Test, Association of Attributes t-Test Anova, Standard deviation, Co-efficient of variations.

Open-source software for quantitative and statistical analysis.

Unit 4: Computer Applications

Concept of algorithms, Flow Charts, Data flow diagrams

Matlab programming: Basics of MATLAB programming, Array operations in MATLAB, Loops and execution control, Working with files: Scripts and Functions, Plotting and program output

Suggested Reading:

1. Ranjit Kumar, Research Methodology: A Step-by-Step Guide for Beginners, 3rd Edition, SAGE Publication (2010).

2. C.R. Kothari, Research Methodology- Methods and Techniques, New Age International, 2nd Edition, New Delhi (2013).

3. Y.K. Singh and R.B. Bajpai, Research Methodology-Techniques and Trends, APH Publishing, 2nd Edn., New Delhi (2007).

4. Dan Gookin, MS Word (2003) for Dummies, John Wiley & Sons, (2003).

5. Dong Lowe, MS Power point (2003) for Dummies, John Wiley & Sons, (2003).

6. Wallace Wang, MS Office (2003) for Dummies, John Wiley & Sons, (2003).

7. Walpole R.A., Myers R.H., Myers S.L. and Ye, King, Probability & Statistics for Engineers and Scientists, 9th Edition, Pearson Prentice Hall, Pearson Education, Inc. (2011).

8. Anderson B.H., Dursaton, and Poole M., Thesis and assignment writing, John Wiley & Sons, Inc. (1979).

9. Bijorn Gustavii, How to write and illustrate scientific papers, Cambridge University Press; 3rd edition (2017).

10. Bordens K.S. and Abbott, B.B.: Research Design and Methods: A Process Approach, McGraw-Hill Education; 10th edition (2017).

CW 703(A): Data Structures and Algorithms

Complexity of Algorithms, Sorting techniques, Searching techniques, Hashing concepts, Search Trees – Binary search trees, AVL trees, Red-Black Trees, B & B+ Trees, KD tree, Splay Trees, Heaps and related algorithms.

Graph Search Algorithms – Generic Search, Breadth-First Search, Dijkstra's Shortest-Weighted-Path, Depth-First Search, Minimum Spanning Trees, Kruskal and Prim's algorithms. Single-Source Shortest Paths: The Bellman-Ford algorithm, Single source shortest paths in DAG's, Dijkstra's algorithm.

CW 703(B): Electives

List of Elective Courses:

1. Cryptography & Network Security.
2. Wireless and Mobile Technology.
3. Information Retrieval.
4. Soft Computing.
5. Image Processing.
6. Natural Language Processing.
7. Data Science.
8. Formal Methods for System Verifications.
9. GIS and Remote Sensing.
10. Machine Learning.
11. Introduction to Quantum Computing.

CSE 01: Cryptography and Network Security

Unit – I

Introduction to Cryptography, Security Attacks and Services, Mathematical Background, Number Theory, Substitutions and Permutations, Modular Arithmetic, Classical Cryptosystems, Cryptanalysis of Classical Cryptosystems.

Unit – II

Symmetric Encryption Algorithms: Theory of Block Cipher Design, Feistel Cipher Network Structures, DES and Triple DES, Modes of Operation, Modern Symmetric Encryption Algorithms, Cryptanalysis of Symmetric Key Ciphers.

Unit – III

Public Key Cryptography: Testing for Primality, Factoring Large Numbers, RSA, Diffie-Hellman, ElGamal, Key Exchange Algorithms, Public-Key Cryptography Standards.

Unit – IV

Hashes and Message Digests, Cryptanalysis of Asymmetric Key Ciphers, Modern Trends in Asymmetric Key Cryptography.

Digital Signature Standard (DSS and DSA), ECDSA, Security Handshake Pitfalls, Elliptic Curve Cryptosystems. Authentication of Systems: Kerberos V5, X.509 Authentication Service. OCSP

Unit – V

Secret Sharing Schemes, Network Protocols, Pretty Good Privacy (PGP), Transport Layer Security (TLS1.3), Secure email, Zero trust security architecture, Intruders and Viruses, Intrusion Detection Systems: Host Based and Network Based IDS, Honey pots. Firewalls, IPSec, Web Security, Access Control, security in e-commerce

Suggested Readings:

1. William Stallings, Cryptography and Network Security, Principles and Practice, 8th Edition, Pearson Education, 2023.

2. Schneier, Bruce, John Wiley & Sons, "Applied cryptography: protocols, algorithms, and source code in C" (20th Anniversary Ed.), 2015.

CSE 02: Wireless & Mobile Technology

Unit – I
Fundamentals of Wireless Communication Technology, Evolution of mobile systems: GSM, CDMA, 3G, 4G; Handoff, Location management.

Unit – II
Wireless MAC, Mobile Network Layer: Mobile IP; Mobile Transport Layer: Traditional TCP, Indirect TCP, Snooping TCP, Mobile TCP.

Unit – III
Mobile Ad-hoc Networks (MANET): Layered architecture of MANET, Ad hoc network routing protocols, MAC layer issues of MANET, Routing In MANET: DSR, AODV, DSDV, OLSR, Transport layer issues, Security issues in MANET; Vehicular Ad-hoc Networks.

Unit – IV
Wireless Sensor Networks (WSN): Introduction, MAC layer protocols for WSN, Routing Protocols for WSN, Transport Control protocols and Middlewares, Operating Systems for WSN;

Unit -V
Architecture and Design issues of Wireless Mesh Networks (WMNs), MAC layer issues, Routing issues in WMN, Security issues in WMN.

Suggested Readings:
1. "Mobile Communications", J. Schiller, Addison-Wesley.
2. "Fundamentals of Mobile and Pervasive Computing", Frank Adelstein, S.K.S. Gupta, Golden G. Richard and Loren Schwiebert, McGraw-Hill Professional.
3. "Ad-hoc and Sensor Networks: Theory and Applications", C.D.M. Cordeiro & D.P. Agarwal, World Scientific Publishing Company.
4. "Ad Hoc Wireless Networks: Architectures and Protocols", C. Siva Ram Murthy and B.S. Manoj, Pearson

CSE 03: Information Retrieval

Unit – I

Introduction: Goals and history of IR. The impact of the web on IR. Basic IR Models: Boolean and vector-space retrieval models; ranked retrieval; text-similarity metrics; TF-IDF (term frequency/inverse document frequency) weighting; cosine similarity.

Unit – II

Basic Tokenizing, Indexing, and Implementation of Vector-Space Retrieval: Simple tokenizing, stop-word removal, and stemming; inverted indices; efficient processing with sparse vectors; Java implementation. Experimental Evaluation of IR: Performance metrics: recall, precision, and F-measure; Evaluations on benchmark text collections.

Unit – III

Query Operations and Languages: Relevance feedback; Query expansion; Query languages. Text Representation: Word statistics; Zipf's law; Porter stemmer; morphology; index term selection; using thesauri. Metadata and markup languages (SGML, HTML, XML). Text Categorization: Categorization algorithms: Rocchio, nearest neighbor, and naive Bayes. Applications to information filtering and organization.

Unit – IV

Web Search: Search engines; Spidering; Metacrawlers; directed Spidering; link analysis (e.g. hubs and authorities, Google PageRank); shopping agents. Language-Model Based Retrieval: Using naïve Bayes text classification for ad hoc retrieval. Improved smoothing for document retrieval.

Unit – V

Text Clustering: Clustering algorithms: agglomerative clustering; k-means; expectation maximization (EM). Applications to web search and information organization. Information Extraction and Integration: Extracting data from text; semantic web; collecting and integrating specialized information on the web.

Text Books:

1. Introduction to Information Retrieval – Manning, Prabhakar, Schütze, Cambridge University Press (2008).

2. Modern Information Retrieval – Ricardo Baeza-Yate, Berthier Ribeiro-Neto, Pearson Education Asia (2005).

Reference Books:

1. Introduction to Modern Information Retrieval (2nd Edition), G.G. Chowdhury, Neal-Schuman Publishers (2003).

2. Information Retrieval: Algorithms, and Heuristics, David A. Grossman, Ophir Frieder, Academic Press (2000).

3. Text Information Retrieval Systems, Charles T. Meadow, Bert R. Boyce, Donald H. Kraft, Academic Press (2000).

CSE 04: Soft Computing

Unit – I: Introduction and Artificial Neural Networks

Evolution of computing: hard computing vs. soft computing, constituents of soft computing. Overview of the biological neuron and the mathematical model of an artificial neuron. ANN architectures – single-layer, multilayer, feedforward and recurrent networks.

Learning rules and paradigms: Hebbian learning, the perceptron learning rule, the delta rule, supervised, unsupervised, and reinforcement learning paradigms. Multilayer Perceptron and the Backpropagation algorithm. Hopfield networks and associative memory. Radial Basis Function networks. Applications of ANNs.

Unit – II: Fuzzy Sets and Fuzzy Logic

Classical sets vs. fuzzy sets, membership functions and their construction. Operations on fuzzy sets – complement, intersection, union, and other aggregation operations. Fuzzy relations. Fuzzy arithmetic: fuzzy numbers, linguistic variables, arithmetic operations on intervals and fuzzy numbers.

Fuzzy rules and fuzzy reasoning, fuzzy inference systems (Mamdani and Sugeno models). Applications of fuzzy logic in control and decision-making.

Unit – III: Uncertainty and Advanced Fuzzy Concepts

Classical logic vs. multivalued logic, fuzzy propositions, fuzzy qualifiers, linguistic hedges. Uncertainty-based information: information and uncertainty, non-specificity of fuzzy and crisp sets, measures of fuzziness.

Fuzzy decision-making, an overview of fuzzy expert systems, and representative application domains (control systems, pattern recognition, medical diagnosis).

Unit – IV: Evolutionary and Swarm Intelligence

Genetic Algorithms (GAs): representation, selection strategies, crossover, mutation, schema theorem, and an overview of convergence behaviour. Evolution Strategies (ES), Evolutionary Programming (EP), and Genetic Programming (GP), with a comparison of these evolutionary computation paradigms.

Swarm Intelligence: Particle Swarm Optimization (PSO) – formulation, velocity and position update rules, parameter selection; Ant Colony Optimization (ACO) and its application to combinatorial optimization problems. Comparative discussion of evolutionary vs. swarm-based approaches.

Unit – V: Hybrid Systems and Recent Trends

Neuro-Fuzzy Systems: architecture of neuro-fuzzy networks, Adaptive Neuro-Fuzzy Inference Systems (ANFIS).

Other Metaheuristics: Simulated Annealing and Tabu Search as representative trajectory-based optimization methods, and their relationship to population-based approaches covered in Unit IV.

Hybrid soft computing approaches combining neural, fuzzy, and evolutionary/swarm components; representative application areas – pattern recognition, optimization, and control – and current research trends, including the relationship between classical soft computing techniques and modern deep learning and explainable AI methods.

Text Books:

1. J.-S.R. Jang, C.-T. Sun, E. Mizutani, Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, Pearson Education (2004).

2. S.N. Sivanandam and S.N. Deepa, Principles of Soft Computing, Wiley India Pvt. Limited (2011).

Reference Books:

1. S. Rajasekaran and G.A. Vijayalakshmi Pai, Neural Networks, Fuzzy Logic and Genetic Algorithm: Synthesis and Applications, Prentice-Hall of India Pvt. Limited (2006).

2. George J. Klir, Ute St. Clair, Bo Yuan, Fuzzy Set Theory: Foundations and Applications, Prentice Hall (1997).

3. J. Kennedy and R. Eberhart, Swarm Intelligence, Morgan Kaufmann Publishers (2001).

CSE 05: Image Processing

Unit – I: Digital Image Fundamentals

Background, digital image representation, fundamental steps in image processing, elements of digital image processing – acquisition, storage, processing, communication, display. Digital image formation: a simple image model, geometric model (translation, scaling, rotation), perspective projection, sampling and quantization (uniform and non-uniform).

Mathematical preliminaries: neighbours of a pixel, connectivity, relations, equivalence and transitive closure, distance measures, arithmetic and logic operations.

Unit – II: Image Transforms and Enhancement

Image transforms: Fourier transform and its properties, the two-dimensional Discrete Fourier Transform, Discrete Cosine and Sine Transforms, an overview of the Discrete Wavelet Transform for multi-resolution analysis.

Image enhancement: spatial and frequency domain methods, contrast enhancement (linear and non-linear stretching), histogram processing; smoothing (image averaging, mean filtering, low-pass filtering) and sharpening (high-pass, high-boost, derivative, and homomorphic filtering).

Unit – III: Restoration, Colour, and Morphological Processing

Image restoration: degradation model, discrete formulation, unconstrained and constrained algebraic restoration, constrained least-squares restoration, restoration by homomorphic filtering, geometric transformation (spatial transformation, grey-level interpolation).

Colour image processing: colour models (RGB, CMY/CMYK, HSI), colour transformations, pseudocolour and full-colour image processing, colour image smoothing and sharpening.

Morphological image processing: binary morphology – erosion, dilation, opening, and closing; the hit-or-miss transform; morphological algorithms – boundary extraction, region filling, thinning and skeletonisation; an overview of greyscale morphology.

Unit – IV: Segmentation and Representation

Image segmentation: point, line, and edge detection; combined detection; edge linking and boundary detection – local processing and global processing via the Hough Transform; thresholding – foundations, simple global thresholding, optimal thresholding; region-oriented segmentation – basic formulation, region growing by pixel aggregation, region splitting and merging; an overview of watershed segmentation.

Representation and description: chain codes, polygonal approximation, boundary descriptors (shape numbers, Fourier descriptors), regional descriptors (texture, moments), an introduction to relational descriptors.

Unit – V: Image Compression and Deep Learning for Image Processing

Image compression: coding, interpixel, and psychovisual redundancy; lossless compression (Huffman, run-length, arithmetic coding, LZW); lossy compression (transform coding, JPEG); an overview of wavelet-based and modern learned compression approaches.

Text Books:

1. Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, 4th Edition, Pearson (2018).

2. Bernd Jähne, Digital Image Processing, 7th Edition, Springer (2017).

3. Scott E. Umbaugh, Digital Image Processing and Analysis, 2nd Edition, CRC Press (2010).

Reference Books:

1. Anil K. Jain, Fundamentals of Digital Image Processing, Pearson (1988).

2. Milan Sonka, Vaclav Hlavac and Roger Boyle, Image Processing, Analysis, and Machine Vision, 4th Edition, Cengage Learning (2014).

3. Richard Szeliski, Computer Vision: Algorithms and Applications, 2nd Edition, Springer (2022).

CSE 06: Natural Language Processing

Unit – I

Introduction to NLP: Definition, issues and strategies, application domain, tools for NLP, Linguistic organisation of NLP, NLP vs PLP. Word Classes: Review of Regular Expressions, CFG and different parsing techniques. Morphology: Inflectional, derivational, parsing and parsing with FST, Combinational Rules. Phonology: Speech sounds, phonetic transcription, phoneme and phonological rules, optimality theory, machine learning of phonological rules, phonological aspects of prosody and speech synthesis. Pronunciation.

Unit – II

Spelling and N-grams: Spelling errors, detection and elimination using probabilistic models, pronunciation variation (lexical, allophonic, dialect), decision tree model, counting words in Corpora, simple N-grams, smoothing (Add One, Witten-Bell, Good-Turing), N-grams for spelling and pronunciation.

Unit – III

Syntax: POS Tagging: Tagsets, concept of HMM tagger, rule based and stochastic POST, algorithm for HMM tagging, transformation-based tagging. Sentence level construction & unification: Noun phrase, co-ordination, sub-categorization, concept of feature structure and unification.

Unit – IV

Semantics: Representing Meaning: Unambiguous representation, canonical form, expressiveness, meaning structure of language, basics of FOPC. Semantic Analysis: Syntax driven, attachment & integration, robustness. Lexical Semantics: Lexemes (homonymy, polysemy, synonymy, hyponymy), WordNet, internal structure of words, metaphor and metonymy and their computational approaches. Word Sense Disambiguation: Selectional restriction based, machine learning based and dictionary-based approaches.

Unit – V

Pragmatics: Discourse: Reference resolution and phenomena, syntactic and semantic constraints on Coreference, pronoun resolution algorithm, text coherence, discourse structure. Dialogues: Turns and utterances, grounding, dialogue acts and structures. Natural Language Generation: Introduction to language generation, architecture, discourse planning (text schemata, rhetorical relations).

Text Books:

1. Speech and Language Processing: An introduction to Language processing, Computational Linguistics, and Speech Recognition – D. Jurafsky & J. H. Martin (2nd Edition), Prentice Hall (2008).

2. Foundation of Statistical Natural Language Processing (Kindle edition) – Christopher D. Manning, Hinrich Schütze, The MIT Press (1999).

3. Machine Translation – Pushpak Bhattacharyya, Chapman and Hall/CRC publication (2015).

Reference Books:

1. Natural Language Understanding (2nd Edition) – James Allen, Pearson (1994).

2. Natural Language Processing: A Panininan Perspective (Eastern Economy Edition) – Bharathi, Vineet Chaitanya and Rajeev Sangal, Prentice Hall India.

3. Statistical Language Learning – Eugene Cherniak, MIT Press (1993).

CSE 07: Data Science

Unit – I

Introduction to core concepts and technologies: Introduction, Terminology, data science process, data science toolkit, Types of data, Example applications.

Unit – II

Data collection and management: Introduction, Sources of data, Data collection and APIs, Exploring and fixing data, Data storage and management, Using multiple data sources.

Unit – III

Data analysis: Introduction, Terminology and concepts, Introduction to statistics, Central tendencies and distributions, Variance, Distribution properties and arithmetic, Samples/CLT, Basic machine learning algorithms, Linear regression, SVM, Naive Bayes.

Unit – IV

Data visualization: Introduction, Types of data visualization, Data for visualization: Data types, Data encodings, Retinal variables, Mapping variables to encodings, Visual encodings.

Unit – V

Applications of Data Science, Technologies for visualization, Bokeh (Python).

Recent trends in various data collection and analysis techniques, various visualization techniques, application development methods used in data science.

Text Books:

1. Cathy O'Neil and Rachel Schutt. Doing Data Science, Straight Talk from The Frontline. O'Reilly. 2014.

2. Jure Leskovek, Anand Rajaraman and Jeffrey Ullman. Mining of Massive Datasets. v2.1, Cambridge University Press. 2014.

Reference Books:

1. Kevin P. Murphy. Machine Learning: A Probabilistic Perspective. 2013.

2. Foster Provost and Tom Fawcett. Data Science for Business: What You Need to Know about Data Mining and Data-analytic Thinking. 2013.

3. Trevor Hastie, Robert Tibshirani and Jerome Friedman. Elements of Statistical Learning, 2nd Edition. 2009.

CSE 08: Formal Methods for System Verifications

Unit – I

Introduction to the formal methods and modeling systems. Introduction: The need for formal methods, Motivation for formal verification, Hardware and software verification, simple verification examples. Model Checking and Theorem Proving, Spectrum of logic with examples.

Unit – II

Logical formalism. Propositional logic: Declarative sentences, Natural deduction, Propositional logic as a formal language, Syntax and Semantics of propositional logic. Predicate logic: Syntax, Semantics and examples, First order logic – Axioms, decidability of first order logic, higher order logic, normal forms – NNF, CNF, DNF, conversion of normal forms, Tsetin transformation.

Unit – III

SAT Solving: Introduction, conflict clause, Backtrack, analyze clause, introduction to SAT solver, different techniques for SAT solving like implication graph, Backtrack, CDCL, DPLL algorithm, decision heuristics, DIMACS format, preprocessing of SAT formula, case study on SAT based modeling. BDD, ROBDD, reduction rules, variable ordering in BDD, Formal property verification (FPV), introduction to Model Checking, different properties of FPV.

Unit – IV

CTL model checking – Syntax and semantics, encoding examples. LTL model checking – Syntax and semantics, encoding examples. CTL and LTL model checking algorithms, correctness of model checking algorithm.

Unit – V

Model checking and Automata Theory. Introduction: Automata on finite and infinite words, Model checking using automata, Checking emptiness, Translating LTL into automata, On-the-Fly model checking.

Text Books:

1. Logic in Computer Science: Modelling and Reasoning about Systems, 2nd Edition, M. Huth and M. Ryan, Cambridge University Press (2011).

2. Model Checking, E. M. Clarke, O. Grumberg and D. Peled, MIT Press (1999).

3. Principles of Model Checking, Christel Baier and Joost-Pieter Katoen, MIT Press (2008).

4. Decision Procedures - An Algorithmic Point of View, Daniel Kroening and Ofer Strichman, Springer (2008).

Reference Books:

1. Higher Order Logic and Hardware Verification, T. F. Melham, Cambridge University Press (1993).

2. Algorithm Design, 1st Edition, Jon Kleinberg and Eva Tardos, Pearson Education Limited (2014).

3. The Temporal Logic of Reactive and Concurrent System Specification, Z. Manna and A. Pnueli, Springer-Verlag (1992).

CSE 09: GIS and Remote Sensing

Unit – I: Introduction to Geographic Information Systems

Definition and components of a GIS – hardware, software, data, people, and procedures. Spatial data models: raster vs. vector representations, and their relative advantages. Geodesy fundamentals: shape of the earth, datums, and ellipsoids. Map projections and coordinate reference systems – geographic vs. projected coordinates, commonly used projections (UTM, Mercator, Lambert Conformal Conic). Concepts of scale, resolution, and generalisation.

Unit – II: Spatial Data Acquisition, Management, and Standards

Sources of spatial data: ground surveying, GPS/GNSS positioning, digitisation of maps, and remote sensing. Spatial database design and geodatabase concepts; topology and its role in vector data integrity. Spatial data quality: sources of error, accuracy and precision, uncertainty propagation. Metadata standards, spatial data infrastructure (SDI), and Open Geospatial Consortium (OGC) standards – WMS, WFS, WCS, and GML.

Unit – III: Spatial Analysis

Vector-based analysis: buffering, overlay operations (union, intersect, clip), and network analysis (shortest path, service area). Raster-based analysis: map algebra, reclassification, and raster overlay. Terrain analysis using Digital Elevation Models (DEMs) – slope, aspect, hillshade, viewshed, and watershed/drainage delineation.

Spatial interpolation techniques: Inverse Distance Weighting (IDW), spline, and an introduction to Kriging. Spatial statistics: spatial autocorrelation, Moran's I, hotspot analysis, and their role in identifying spatial patterns.

Unit – IV: Remote Sensing Fundamentals

The electromagnetic spectrum and energy interactions with the atmosphere and earth surface features. Passive vs. active sensing; imaging platforms – satellite, aerial, and UAV-based systems. Resolution characteristics of remote sensing data: spatial, spectral, radiometric, and temporal resolution, and the trade-offs between them.

Overview of major satellite systems and sensors – Landsat, Sentinel, MODIS, and Indian Remote Sensing (IRS) satellites. Image acquisition geometry, orbits, and swath characteristics; an introduction to LiDAR and SAR as active sensing modalities.

UNIT – V: Remote Sensing Image Analysis and GIS-RS Integration

Preprocessing of remote sensing imagery: radiometric correction, atmospheric correction, and geometric correction/georeferencing. Image enhancement techniques for visual interpretation.

Image classification: supervised classification (maximum likelihood, SVM, Random Forest) and unsupervised classification (k-means, ISODATA); accuracy assessment using confusion matrices and the Kappa coefficient. Change detection techniques for multi-temporal imagery.

Machine learning and deep learning for remote sensing: CNN-based land use/land cover classification, semantic segmentation of satellite imagery, and an overview of current research trends. Integration of GIS and remote sensing in application domains – urban planning, disaster management, precision agriculture, and environmental monitoring; an introduction to Web GIS and geospatial web services.

Text Books:

1. Kang-tsung Chang, Introduction to Geographic Information Systems, 10th Edition, McGraw-Hill (2019).

2. Thomas M. Lillesand, Ralph W. Kiefer and Jonathan W. Chipman, Remote Sensing and Image Interpretation, 7th Edition, Wiley (2015).

3. John R. Jensen, Introductory Digital Image Processing: A Remote Sensing Perspective, 4th Edition, Pearson (2015).

Reference Books:

1. Paul Bolstad, GIS Fundamentals: A First Text on Geographic Information Systems, 6th Edition, XanEdu (2019).

2. Michael N. DeMers, Fundamentals of Geographic Information Systems, 4th Edition, Wiley (2008).

3. Floyd F. Sabins and James M. Ellis, Remote Sensing: Principles, Interpretation, and Applications, 4th Edition, Waveland Press (2020).

4. Robert A. Schowengerdt, Remote Sensing: Models and Methods for Image Processing, 3rd Edition, Academic Press (2006).

5. Paul A. Longley, Michael F. Goodchild, David J. Maguire and David W. Rhind, Geographic Information Science and Systems, 4th Edition, Wiley (2015).

CSE 10: Machine Learning

Unit – I

Introduction to Machine Learning: Definitions, well-posed learning problems, types of learning – supervised, unsupervised, semi-supervised, and reinforcement learning. Hypothesis space, inductive bias, bias-variance trade-off, overfitting and underfitting, regularization. Training, validation, and test sets; cross-validation (k-fold, leave-one-out). Evaluation metrics: accuracy, precision, recall, F1-score, ROC curve and AUC, confusion matrix.

Linear Regression: Simple and multiple linear regression, cost function, gradient descent and its variants (batch, stochastic, mini-batch). Logistic Regression for classification, sigmoid function, maximum likelihood estimation, multi-class extensions (one-vs-rest, softmax regression).

Unit – II

Supervised Learning – Classification: Decision Trees (ID3, C4.5, CART), entropy, information gain, Gini index, pruning strategies. Naive Bayes classifiers and their variants. k-Nearest Neighbours.

Support Vector Machines: Maximum margin classifiers, hard and soft margin formulations, the kernel trick, common kernels (linear, polynomial, RBF), multi-class SVM strategies.

Ensemble Methods: Bagging, Random Forests, Boosting (AdaBoost, Gradient Boosting), introduction to XGBoost/LightGBM, comparison of ensemble strategies and their bias-variance behaviour.

Unit – III

Unsupervised Learning: Clustering – k-means, hierarchical (agglomerative and divisive) clustering, DBSCAN, Gaussian Mixture Models and the Expectation-Maximization algorithm. Cluster validity measures.

Dimensionality Reduction: Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), an overview of t-SNE and UMAP for visualization.

Association Rule Mining: Apriori and FP-Growth algorithms, support, confidence, and lift. Introduction to anomaly and outlier detection techniques.

Unit – IV

Neural Networks and Deep Learning Foundations: The perceptron and its limitations, multilayer perceptrons, activation functions (sigmoid, tanh, ReLU and variants), the backpropagation algorithm, loss functions.

Training Deep Networks: Weight initialization, optimizers (SGD with momentum, RMSProp, Adam), regularization techniques (L1/L2, dropout, batch normalization, early stopping).

Introduction to Convolutional Neural Networks (convolution, pooling, common architectures) and Recurrent Neural Networks (sequence modelling, vanishing gradients, LSTM/GRU overview), as a bridge to specialised deep learning study.

Unit – V

Model Selection and Practical ML: Hyperparameter tuning (grid search, random search, an introduction to Bayesian optimization), feature engineering and feature selection methods, handling imbalanced datasets.

Reinforcement Learning Basics: Markov Decision Processes, value functions, Q-learning, an introduction to policy-gradient methods.

Text Books:

1. Tom M. Mitchell, Machine Learning, McGraw-Hill (1997).

2. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer (2006).

3. Ethem Alpaydin, Introduction to Machine Learning, 4th Edition, MIT Press (2020).

Reference Books:

1. Trevor Hastie, Robert Tibshirani and Jerome Friedman, The Elements of Statistical Learning, 2nd Edition, Springer (2009).

2. Kevin P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press (2013).
3. Ian Goodfellow, Yoshua Bengio and Aaron Courville, Deep Learning, MIT Press (2016).
4. Sebastian Raschka and Vahid Mirjalili, Python Machine Learning, 3rd Edition, Packt Publishing (2019).

CSE 11: Introduction to Quantum Computing

Unit – I

Introduction to the Quantum Computing. Quantum Computing Basics: Classical vs. Quantum Computing, Conventional bits vs. Qubits, concept of superposition, entanglement, Quantum gates. Overview of Quantum computing applications.

Unit – II

Mathematics for Quantum Computing. Linear Algebra: Vectors, matrices, inner products, representation of quantum states, transformation, quantum states in the form of vectors, quantum gate operations in matrices, Eigenvalue and Eigenfunction and their properties. Probability Theory: Measurement outcomes, probability distribution and expected values, complex numbers, trigonometry and calculus, etc. Introduction to Quantum Mechanics: Postulates of Quantum mechanics: Behavior of matter and energy – atoms, subatomic particles like electrons and photons, matrix formulation of quantum theory, state of a quantum system, physical quantities or observables in quantum systems.

Unit – III

Quantum Measurement: Detailed concept of quantum measurement. Introduction to Quantum Computers: Different aspects of Classical and quantum computers, different components of quantum computers, brief discussion of different quantum gate operations. Quantum gates and Circuit: Brief discussion of various quantum gate operations and formulation of quantum circuits. Discussion of some examples of quantum circuits for computation.

Unit – IV

Programming using IBM Quantum Experience and Circuit Composer. Quantum Computing concept in Entanglement and Interference. Quantum Algorithms – Deutsch-Jozsa algorithm, Bernstein-Vazirani algorithm, Grover's search.

Unit – V

Fixing quantum errors with quantum tricks: Brief introduction to quantum error correction, NISQ-era quantum algorithms, Variational Quantum Algorithms, Quantum Generative Adversarial Networks (QGANs).

Text Books:

1. Quantum Computation and Quantum Information, M. A. Nielsen and I. Chuang, Cambridge University Press (2010).

2. Introduction to Quantum Mechanics, Griffiths D. J., 3rd Edition, Cambridge University Press (2024).

3. Principles of Quantum Mechanics, Shankar, R., 2nd Edition, Springer (2014).

4. Quantum error correction and Fault tolerant computing, Frank Gaitan, 1st Edition, CRC Press (2008).

Reference Books:

1. A. Bhattacharya, Introduction to Quantum Communication, Khanna Publishing House (2025).

2. Quantum Measurement and Control, Howard Wiseman and David Milburn, Cambridge University Press (2014).

3. A. Pathak, Elements of Quantum Computation and Quantum Communication, Boca Raton, CRC Press (2015).

4. Quantum Measurement, Vladimir Braginsky and Farid Ya Khalili, Cambridge University Press (1995).

5. Quantum Computing & Techniques, Rajiv Chopra, Khanna Publishing House (2025).

6. Introduction to Quantum Computing: From a lay person to a programmer in 30 steps, Hui Yung Wong, 1st Edition, Springer-Nature Switzerland AG (2022).

7. Quantum computing explained, David McMahon, Wiley (2008).