M.Sc. Data Science and Computational Modelling

Curriculum and Syllabus

School of Digital Sciences

Kerala University of Digital Sciences, Innovation and Technology (KUDSIT)

Technopark Phase IV, Mangalapuram, Thiruvananthapuram, India

-2026-

School of Digital Sciences

The School of Digital Sciences positions itself across the broad areas of computational science, data analytics, and scalable data systems in various science and technology domains. The SoDS curriculum aims to instill the concept of AI applications within STEM education. It focuses on educating students in four specific disciplines—science, technology, engineering, and mathematics—through an interdisciplinary and applied approach. The school was established as a part of the Kerala University of Digital Sciences, Innovation, and Technology (KUDSIT), also known as Digital University Kerala (DUK), in 2020 at the Technopark Phase IV Campus in Trivandrum. This document is prepared for the faculty and staff members of SoDS to provide the necessary guidance in the school's academic activities.

Vision and Mission

The vision of the school is to ensure the self-sustainability of our nation. The school aims to:

- Cater to the demand for trained human resources in the areas of STEM
- Foster advanced research, development, and innovation in frontier areas of Digital Sciences
- Encourage and motivate the student community to take up the future challenges of the growing IT industry
- Promote an ecosystem for social innovation and entrepreneurship

Objectives

Industry Revolution 4.0 mainly depends on artificial intelligence, and most of the developments in AI depend on the knowledge and information we gather from the data that the entire universe creates every second. As we live in the emerging data-driven world, decision support systems based on the insights derived from data are receiving much acceptance in every branch of science/technology, or even the arts. We can consider data analytics a trans-disciplinary subject that brings data, technology, information, statistical/mathematical analysis, and domain knowledge under a single umbrella. The success of the current era can be defined as the amount of useful data the organization is creating or gathering and gaining fruitful insights using computational methods by applying mathematical/statistical frameworks.

Despite the adoption of Industry 4.0 by several organizations, India still faces a shortage of human resources to meet the demands of industry, academia, and R&D. The parent organization of DUK, the Indian Institute of Information Technology and Management Kerala (IIITMK), has made significant progress in this direction. We offered programmes in cutting-edge technologies in data analytics, machine learning, and deep learning. To keep the momentum of our state and our country marching towards becoming the industry leader in Information Technology and to take a global leadership position for the world in the Industry 4.0 revolution, we need to create trained human resources in this area. The focus of the programmes offered by the School of Digital Sciences is to develop quality human resources so that they can lead the digital transformation of our country.

Academics

Our MSc programmes are designed to cater mainly to the industry needs of Data Analysts, Data Engineers, and Data Scientists at various levels in different domains. The suitable skill sets for the industry are:

- In-depth Knowledge of Data Analytics and Machine Learning
- Decent Knowledge of Statistics and Mathematics
- Good skills in Natural Language Processing and Information Retrieval
- Deep knowledge of Python Programming and Database management systems
- Basic knowledge of Computer Science
- Spatial Applications of Data Analytics/Machine Learning
- Computational methods to complement data analytics in real-life problem solving

Course Categorization

- 400 Level courses: Advanced courses, which would include lecture courses with practicum, seminar-based courses, term papers, research methodology, advanced laboratory experiments/software training, research projects, hands-on training, internship/apprenticeship projects at the undergraduate level, or First-year Postgraduate theoretical and practical courses.
- 500 Level courses- It provides an opportunity for original study or investigation in the major or field of specialization, on an individual and more autonomous basis at the postgraduate level. All 500-level courses should have a course project with a mandatory report submission and evaluation.

Programme Educational Objectives (PEO)

PEO1: Create globally competent data analytics/machine learning experts with leadership qualities and team spirit.

PEO2: Impart communication skills and professional ethics to students.

PEO3: Develop skills in computational problem-solving and R&D

PEO4: Engage in lifelong learning to keep pace with the emerging technology areas.

Programme-learning Outcomes (PO)

PO1: Develop strong fundamental knowledge in the area of study

PO2: Identify, formulate, and analyze problems to reach validated conclusions.

PO3: Design techniques to solve real-life problems to meet the specified needs.

PO4: Develop communication skills to address different levels of the audience.

PO5: Practice ethical standards in professional conduct and research.

PO6: Acquire professional skills such as collaborative skills, the ability to write grants, entrepreneurial skills, and writing articles for scholarly journals.

Pass Criteria

As stipulated in the University Examination Manual.

Examinations

Each course level would have a different type of examination, as stipulated in the University Examination Manual.

Credit Distribution of the M.Sc. programmes Offered by the School

Core Courses (50 credits)			**Elective Courses (30 credits)**		**Additional courses**
Programme Core (Mandatory)	University Core (Mandatory)	Capstone Project/ Thesis (Mandatory)	Program elective (Mandatory)	Open elective (Mandatory)	Additional credits (Optional- beyond the mandatory coursework and project)
25 credits	5 credits	20 credits	18 credits	12 credits	10 credits

Capstone Project/Thesis (Course Code: M5224451, 500 level)

A student is required to do a project during Semester 4 independently under the guidance of any University faculty member or as an internship project in an industry or any reputed academic/research institute. If a student opts for an internship project in an industry or any reputed academic/research institute, they must have an internal guide from the University. The project/internship aims to allow the student to participate and work in a major research/development activity. Typically, the industry internship helps the student to learn about work culture, business processes, technologies, marketing strategies, etc. At the end of the semester, the student must submit a report on the project/internship and give an oral presentation of the project/internship carried out by him/her. The project report and the oral presentation will be evaluated by an internal committee comprising the school's faculty members, including the project guide, and an external committee constituted by the university. The project/internship carries 20 credits.

Curriculum

Semester-wise Credit Distribution for M.Sc. in Data Science and Computational Modelling (DSCM)

Semester I

Course Category	**Credits**
University core (DACE)	5
Programme core	12
Programme elective	3
Total Credits	**20**

Semester II

Course Category	**Credits**
Programme core	9
Programme elective	5 (*2 credits for mini project/industry readiness)
Open elective	6

Total Credits	**20**

Semester III

Course Category	**Credits**
Program core	4
Programme elective	10 (*4 credits for mini project/industry readiness)
Open elective	6
Total Credits	**20**

Semester IV

Course Category	**Credits**
Capstone Project/Thesis	20
Total Credits	**20**

*Individual/Group mini projects are allowed as programme electives/open electives (500 level)

Bridge Courses for All M.Sc. Programmes

Course Code	**Type**	**Title of the Course**	**Level**	**Credit Split Lecture-Lab-Seminar-Project**	**Credits**

M2220 051	NC	Linear Algebra and Probability	200	1-2-0-0	P/F
M2220 052	NC	Computational Thinking for Problem Solving	200	1-2-0-0	P/F
		Total Credits			0

*NC: Non-credit Course

Core Courses

Course Code	Title of the Course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220151	Principles and Practices in Computer Science (Sem I)	4	400	2-1-1-0
M4220153	Data Analytics and Visualization (Sem I)	4	400	2-1-0-1
M4220154	Scientific Computing and Computational Techniques (Sem I)	4	400	3-1-0-0
M5220251	Predictive Analytics (Sem II)	3	500	1-1-0-1
M4220253	Numerical Methods (Sem II)	3	400	1-1-0-1
M5220252	Deep Learning and MLOps (Sem II)	3	500	1-1-0-1
M5220351	Generative AI (Sem III)	4	500	1-1-1-1

Courses Offered as Electives

Students can opt for electives from the following list in the first/second, or third semester based on the recommendations of the mentor/course coordinator. The school will decide the list of electives to be offered each semester based on requirements from students and the availability of faculty.

List of Elective Courses (Programme Electives and Open Electives) Offered by the School of Digital Sciences

Course Code	Title of the Course	Credits	For Programmes	Level	Credit Split Lecture- Lab- Seminar- Project	The semester in which the course is offered

M4221151	Python Programming for Data Analytics	3	All programmes	400	2-1-0-0	S1
M4221152	Applied Differential Equations	3	DSCM	400	1-1-1-0	S1
M4221153	Time Series Analysis and SEM Modeling	3	CSDA/DSCM	400	1-1-0-1	S1
M4220152	Database Architecture and Analytics	4	DSCM/BioAI/GIS/FinTech	400	3-1-0-0	S1
M4220252	Web Engineering	3	DSCM/ BioAI/ GIS	400	2-1-0-0	S2
M4221251	Computational Neuroscience	3	DSCM/BioAI	400	2-1-0-0	S2
M4221252	Ethics in Data	3	All programmes	400	1-0-2-0	S2
M4221253	Data Structures and Algorithms	3	All programmes	400	2-1-0-0	S2
M4221254	Computational Chemistry for Bio-Systems	3	DSCM/BioAI	400	1-1-0-1	S2
M4221256	Microwave Remote Sensing	3	GIS	400	1-1-0-1	S2
M4221257	Natural Language Processing and Information Retrieval	3	All programmes	400	1-1-0-1	S2
M4221258	Portfolio Management	3	FinTech	400	1-1-0-1	S2
M4221259	Risk Management	3	FinTech	400	1-1-0-1	S2
M4221260	Financial Technology Services and Management	3	FinTech	400	2-0-1-0	S2
M5221251	Advanced Topics in the Semantic Web and Social Network	3	All programmes	500	1-1-0-1	S2/S3

	Analysis					
M5221252	Advanced Geospatial Programming	3	GIS	500	1-1-0-1	S2/S3
M5221253	Spatial Data Analytics	3	CSDA/GIS	500	1-1-0-1	S2/S3
M5221254	Web and Mobile GIS	3	GIS	500	1-1-0-1	S2/S3
M5221255	Computer-Aided Drug Design	3	BioAI	500	1-1-0-1	S2/S3
M5221256	Data Security	3	All programmes	500	1-1-0-1	S2/S3
M5221257	Parallel and GPU Computing	3	CSDA/DSCM	500	1-1-0-1	S2/S3
M5221258	Computational Linear Algebra	3	CSDA/DSCM	500	1-1-0-1	S2/S3
M5221351	Anomaly Detection and Fraud Analytics	3	All programmes	500	1-1-0-1	S2/S3
M5221353	Healthcare Analytics	3	BioAI	500	1-1-0-1	S2/S3
M5221354	Advanced Programming	3	All programmes	500	1-1-0-1	S2/S3
M5221355	Thermal and Hyperspectral Remote Sensing	3	GIS	500	1-0-1-1	S2/S3
M5221356	Topographic Data Analysis Techniques and Applications	3	GIS	500	1-1-0-1	S2/S3
M5221357	Spatial Bigdata Analytics	3	GIS	500	1-1-0-1	S2/S3
M5221358	Geospatial Applications in Agriculture	3	GIS	500	1-1-0-1	S2/S3

M5221359	Geospatial Applications for Environment and Climate Change	3	GIS	500	2-0-0-1	S2/S3
M5221360	Geospatial Applications for Hydrological Modeling	3	GIS	500	1-1-0-1	S2/S3
M5221361	Geospatial Applications in Urban and Regional Planning	3	GIS	500	2-0-0-1	S2/S3
M5221362	AI Applications in Agriculture	3	BioAI	500	1-1-0-1	S2/S3
M5221363	Computational Finance	3	DSCM/FinTech	500	1-1-0-1	S2/S3
M5221364	Data Engineering	3	All programmes	500	1-1-0-1	S2/S3
M5221365	Big Data Technologies and Cloud Computing	3	All programmes	500	1-1-0-1	S2/S3
M5221366	Machine Learning with Graphs	3	All programmes	500	1-0-1-1	S2/S3
M5221367	Computational Nonlinear Dynamics	3	DSCM	500	0-0-0-3	S2/S3
M5221368	Stochastic Processes and Models	3	CSDA/DSCM/ FinTech	500	1-1-0-1	S2/S3
M5221369	Optimization Techniques	3	All programmes	500	1-1-0-1	S2/S3
M5221370	AI for Molecular Sciences	3	BioAI	500	1-1-0-1	S2/S3
M5221371	Machine Learning and Deep Learning for SAR Applications	3	GIS	500	0-1-0-2	S2/S3
M5221372	Reinforcement Learning	3	FinTech	500	2-1-0-0	S2/S3

M5221373	Algorithmic Trading	3	FinTech	500	1-1-0-1	S2/S3

*Student may opt for any course offered by other schools/same school as open electives.

Syllabus

University Core (DACE)-500 level-5 Credits

Digital Access for Community Empowerment (M5220013)

DACE shall be a 5-credit course offered to students in the first semester. It is split into 2 + 3 credits: lecture and practical/field session. The program comprises 30 hours of instruction, during which students are introduced to social research concepts, including problem identification. Students earn three credits by completing 90 hours of outbound/experiential learning. The students are expected to design ways to use digital technologies to solve problems they identify. It is expected that students conduct field studies in cohorts of 4 or 5 and present their findings in a short dissertation before the start of the end-of-semester summative exam.

Bridge Courses

Linear Algebra and Probability

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M2220051	Linear Algebra and Probability	Nil	200	1-2-0-0

Module	Content
1	Introduction to Probability Theory - sample space - events - Algebra of sets- Notion and Axioms of probability-Equally likely events - Conditional probability independent events. Bayes' theorem.

2	Axiomatic definition of Probability - Probability spaces- Random variables- PMF and PDF - Discrete and Continuous distributions. Joint, probability mass function, Marginal distribution function, Joint density function. Popular distributions-binomial, Bernoulli, Poisson, exponential, Gaussian.
3	Fundamental concepts in statistics- Measures of location and variability- Population, sample, parameters. Sampling and Testing of Hypothesis: Introduction to testing of hypothesis - Tests of significance for large samples – t, F and Chi-square tests; ANOVA - one-way and two-way classifications.
4	Vector Spaces: Vector spaces - Sub spaces - Linear independence - Basis – Dimension. Linear Transformations: Positive definite matrices - Matrix norm and condition number - - Linear transformation - Relation between matrices and linear transformations - Kernel and range of a linear transformation - Trace and Transpose, Determinants, Symmetric and Skew Symmetric Matrices. Concept of Eigen values and Eigen vectors.

Text Books:

1. H.P. Hsu, *Theory and Problems of Probability, Random Variables, and Random Processes*, McGraw-Hill, 2014.
2. S. M. Ross, *Introduction to Probability Models,* 11th ed., Academic Press, 2014.
3. S. Lipschutz, *Schaum's Outline of Theory and Problems of Linear Algebra*, New York: McGraw-Hill, 1968.
4. G. Strang, *Linear Algebra and its Applications*, 4th ed. India: Cengage Learning, 2005.
5. C. D. Meyer, *Matrix Analysis and Applied Linear Algebra*, Siam, 2000.
6. P. J. Olver and C. Shakiban, *Applied Linear Algebra*, Prentice Hall, 2006.
7. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, International Edition, Wiley, 1988.
8. R. V. Hogg, J. W. McKean, and Allen T. Craig, *Introduction to Mathematical Statistics*, 7th ed. Asia: Pearson Education, 2014.

References:

1. W. Feller, *An Introduction to Probability Theory and its Applications*, John Wiley and Sons, 2008.
2. D. S. Bernstein, *Matrix Mathematics: Theory, Facts, and Formulas with Application to Linear Systems Theory*, Princeton University Press, 2005.

Computational Thinking for Problem Solving

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project

M2220052	Computational Thinking for Problem Solving	Nil	200	1-2-0-0

Module	Content
1	Introduction to Computational Thinking. Breaking Down Complex Problems. Finding Similarities and Trends. Simplifying and Representing Information – Algorithm Designing Step-by-Step Procedures. Applying the Pillars of Computational Thinking in Real life.
2	Finding the Largest Value, Linear Search, Algorithmic Complexity. Binary Search, Brute Force Algorithms, Greedy Algorithms.

Text Books:

1. R. G. Dromey, How to Solve it by Computer, PHI, 2008
2. David Riley & Kenny Hunt, Computational Thinking for the Modern Solver, Chapman & Hall/CRC, 2014.

Online Tools:

1. Flowgorithm, Raptor, or Blockly for visual logic building.

Core Courses

Principles and Practices in Computer Science

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220151	Principles and Practices in Computer Science	4	400	2-1-1-0

Course Outcomes	
CO1	Analyze and differentiate computer-system components and their interrelations.
CO2	Evaluate operating-system functionalities in process, memory, file, and user management.
CO3	Compare network protocols, devices, and addressing schemes across layers.
CO4	Apply client–server and cloud-computing concepts and appraise emerging paradigms' societal impacts.

Mapping of Course Outcomes with Programme Outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	1	2	1	2
CO2	2	1	1	2	1	2
CO3	2	1	1	2	1	2
CO4	2	1	1	2	1	2
Module	**Contents**					
I	Computer Systems & Architecture: Theory: CPU design (ALU, registers, control unit); memory hierarchy (cache, RAM, virtual memory); binary representation and data storage; file-system basics and I/O devices Lab: Simulate ALU operations and memory access using CPUlator or MARS; convert values between binary, hexadecimal and decimal; map register contents to memory addresses Seminar: Case study on milestones in computer architecture; discussion on virtual-memory trade-offs					
2	Operating Systems Theory: OS roles and types; processes, threads and scheduling algorithms; memory management techniques; file-system structure and access methods; CLI vs GUI and core system utilities Lab: Implement and compare FCFS vs Round-Robin scheduling in a simulator; perform file operations in a VM (mount, permissions); write simple shell scripts for file tasks Seminar: Debate on process vs thread models; analysis of common OS security vulnerabilities					
3	Computer Networks Theory: OSI and TCP/IP models; core protocols (HTTP, FTP, SMTP); IPv4 vs IPv6 and subnetting; basic network security (firewalls, encryption, DoS) Lab: Capture and analyze packets with Wireshark; develop a Python UDP “ping” to measure round-trip time; configure basic firewall rules on a VM Seminar: Case study of a real-world DDoS attack; discussion on challenges in IPv4–IPv6 migration					

4	Client–Server & Cloud Basics & Emerging Trends Theory: Client–server interaction (HTTP, sockets); cloud fundamentals (NIST model, IaaS/PaaS/SaaS, virtualization); emerging paradigms (edge computing, IoT architectures, quantum computing overview) Lab: Build and test a Python HTTP server–client; launch and manage a VirtualBox VM and AWS Free Tier EC2 instance. Seminar: Compare REST vs RPC architectures; lightning talks on selected emerging-tech applications.

References

1. “Modern Operating Systems”mby Andrew S. Tanenbaum and Herbert Bos
2. “Operating System Concepts” by Abraham Silberschatz, Peter B. Galvin, and Greg Gagne
3. “Structured Computer Organization” by Andrew S. Tanenbaum
4. “Computer Networking: A Top-Down Approach” by James F. Kurose and Keith W. Ross
5. “Cloud Computing: Concepts, Technology and Architecture” by Thomas Erl, Ricardo Puttini, and Zaigham Mahmood

Data Analytics and Visualization

Course code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220153	Data Analytics and Visualization	4	400	2-1-0-1

Course Outcomes	
CO1	Analyze the core principles of data science and assess its applications across various domains.
CO2	Effectively engineer features from raw data and apply various data reduction techniques to streamline data.
CO3	Design and implement effective visualizations using appropriate tools and techniques to uncover patterns and communicate insights.
CO4	Evaluate the architecture and functionality of data warehouses and OLAP systems, and apply them for multidimensional analytical tasks.

Mapping of course outcomes with program outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6

CO1	3	3	2	1	1	1
CO2	3	3	3	1	1	2
CO3	2	2	3	3	1	2
CO4	3	3	3	2	1	2

Module	**Content**
1	Data science concepts in practice: Data science and its applications, building models, data science project life cycle. Data quality and data preparation: data exploration, data types. Data cleaning: problems with data and data cleaning methods. Data integration, redundancy and correlation analysis. Data Transformation and discretization: converting data types, normalizing and scaling numerical features, encoding categorical variables, creating derived features and aggregating data.
2	Feature Engineering: selecting relevant features for analysis, creating new features that capture valuable information from the existing data, understanding domain knowledge to engineer meaningful features. Data reduction: different types of reduction methods, wavelet transform, PCA, attribute subset selection, parametric data reduction, sampling techniques in data reduction, data cube aggregation. Data validation and sanity checks: verifying the integrity and accuracy of data using validation rules and logic checks. Cross-validating data against external sources or known benchmarks. Ethics in data. Data security. Sampling, data distributions, Monte Carlo and MCMC simulations for data curation.
3	Data visualization: theory of data visualization. Univariate visualizations: different types of data visualizations, color theory, choosing the right data visualizations. Visual hierarchy, Associability and inclusivity, Interactive data visualizations. Multivariate visualizations: scatterplot, bubble chart, visualizing high dimensional data, exploratory data Analytics. Data storytelling.
4	Data Warehousing and Online Analytical Process: Data modeling, data extraction, transformation, and loading (ETL). Data warehouse design, data warehouse administration, and data warehouse applications.

Text Books:

1. Prakash, Kolla Bhanu, ed. *Data Science Handbook: A Practical Approach*. John Wiley and Sons, 2022.
2. CareerFoundry. *What is Data Analytics? A Complete Guide for Beginners.* CareerFoundry, 2023.
3. Taniar, David, and Wenny Rahayu. *Data warehousing and analytics: fueling the data engine*. Springer Nature, 2022.

References:

1. McKinney, Wes. *Python for data analysis: Data wrangling with Pandas, NumPy, and IPython.* " O'Reilly Media, Inc.", 2012.

Scientific Computing and Computational Techniques

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220154	Scientific Computing and Computational Techniques	4	400	3-1-0-0

Course Outcomes	
CO1	Introduction to scientific computing, Error in computing, Scientific models
CO2	Solutions of equations with one variable, Systems of equations
CO3	Eigenvalue problems
CO4	Curve fitting and approximations

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	0	0	0
CO2	3	2	2	0	0	0
CO3	3	2	2	2	2	2

CO4	3	2	2	2	2	2

Module	Content
1	Introduction to scientific computing, its applications. Number System and Errors Representation on integers and floating-point numbers, Errors in computation, loss of significance. Scientific models for computation, developing insights, Computational complexity
2	Solutions of Equations in one variable: Bisection Method, Newton Raphson Method, Secant method, Brent's method, Error Analysis, Accelerating Convergence, Polynomial Evaluation – Horner's rule, Zeros of polynomials and Muller's Method, Systems of Linear Equations: Gaussian Elimination, Triangular decomposition, LU decomposition, Cholesky decomposition, Pivoting strategies, Error analysis and Operations count, Ill-conditioning and condition number of system, Jacobi, Gauss-Seidel, Conjugate Gradient
3	Evaluation of determinants, Eigenvalue Computations: Diagonalization of the system of ODE, Power Method, Given's and Householder's methods for Tridiagonalization, Lanczos Method, QR Factorization
4	Curve fitting and Approximation: Lagrange's interpolation, Newton interpolation, Polynomial wiggle problem, Polynomial extrapolation, Spline interpolation, Least Square Method – line and other curves, Orthogonal Polynomials, Tchebyshev interpolation, Fourier approximation, and Fast Fourier Transforms (FFT) algorithm.

References:

1. Numerical Methods in Engineering with Python, Jaan Kiusalaas, Cambridge University Press, 2010.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical methods for scientific and Engineering computation, New Age International Publishers, 2007, 5th edition.
3. R.L. Burden, J. D. Faires, Numerical Analysis, Richard Stratton, 2011, 9th edition.
4. S.D. Conte and Carl de Boor, 'Elementary Numerical Analysis; An Algorithmic Approach'. International series in Pune and Applied Mathematics, McGraw Hill Book Co., 1980.
5. S. S. Sastry, Introductory methods of Numerical Analysis, 2012, PHI Publishers, 5th edition

Predictive Analytics

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5220251	Predictive Analytics	3	500	1-1-0-1

Course Outcomes	
CO1	Develop advanced analytical skills by applying complex predictive models.
CO2	Critically evaluate and select appropriate predictive analytics models.
CO3	Design and implement comprehensive machine learning workflows.
CO4	Develop reinforcement learning applications.

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	3	1
CO2	3	3	3	2	3	1
CO3	3	3	3	2	3	2
CO4	3	2	3	1	3	1

Module	Content
1	Types of analytics and their applications in industry. Advanced Predictive Analytics techniques and their Mathematical approach. Case study of supervised, unsupervised, semi-supervised, and reinforcement learning. Model Evaluation and Selection: Metrics (accuracy, precision, recall, F1-score, confusion matrix) and Techniques (cross-validation, ROC curves, AUC, model interpretability).

2	Supervised Machine Learning Hands-On Projects: Apply complex supervised machine learning models (e.g., Linear Regression, Logistic Regression, Ensemble Methods, and Support Vector Machines (SVM)) to solve real-world problems in diverse fields such as finance, healthcare, and e-commerce. Select appropriate model based on rigorous performance metrics and interpretability, understanding trade-offs in model complexity, accuracy, and generalizability.
3	Applications of Unsupervised Learning: Clustering, Hierarchical clustering, k-means clustering, Birch clustering, Measuring cluster goodness, Association rules, Affinity and Market Basket analysis. Clustering customer segments in an e-commerce dataset.
4	Advanced Techniques in Reinforcement Learning: Markov decision processes, Q-learning, Policy gradients. Applications of reinforcement learning in finance, recommendation systems, and real-time decision-making.

Text Books :

1. Alpaydin, Ethem. Introduction to machine learning. MIT press, 2020.
2. Géron, Aurélien. Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow. " O'Reilly Media, Inc.", 2022.
3. Bishop, Christopher M. Pattern recognition and machine learning by Christopher M. Bishop. Springer Science+ Business Media, LLC, 2006.
4. Molnar, Christoph. Interpretable machine learning. Lulu. com, 2020

Numerical Methods

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220253	Numerical Methods	3	400	1-1-0-1

Course Outcomes	
CO1	Apply advanced numerical techniques to compute derivatives and integrals of functions, critically analyzing their accuracy and establishing rigorous error bounds.
CO2	Formulate and implement numerical schemes to solve ordinary and partial differential equations, comparing and validating different approaches for efficiency and stability.

CO3	Design and evaluate numerical methods for solving complex partial differential equations, including real-world applications involving physical and engineering systems.
CO4	Integrate numerical techniques for linear and nonlinear regression and optimization, utilizing machine learning approaches to solve high-dimensional problems effectively.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	0	0	0
CO2	3	3	3	0	0	2
CO3	3	3	3	2	0	2
CO4	3	2	3	0	2	2

Module	**Content**
1	Numerical differentiation, forward finite difference, backward finite difference, central difference methods, Numerical Integration,Trapezoidal rule, Simpson's rule, Composite numerical integration, Gaussian quadrature
2	Classification of ODEs (Linear, Non-linear, Exact), Geometric meaning of $y' = f(x, y)$, Direction Fields, Numerical methods for solving ODEs, Euler's Method, Runge-Kutta methods, Multistep methods (e.g., Adams-Bashforth, Adams-Moulton), Implicit methods (e.g., backward Euler, implicit trapezoidal), Boundary Value Problems, Shooting method, Finite difference methods, Solving application oriented problems
3	Numerical Solutions to PDE, Finite difference methods, Laplace equation, Heat equation, Finite element methods, Finite volume methods, Spectral methods
4	Regression, linear regression, multiple regression, Numerical optimization, optimization of single and multivariable functions, gradient descent methods, Artificial Neural Network, Perceptron, Feed Forward Neural Network

References:

1. Numerical Methods in Engineering with Python, Jaan Kiusalaas, Cambridge University Press, 2010. 2. M.K. Jain, S.R.K. Iyengar and R.K. Jain,

2. Numerical methods for scientific and Engineering computation, New Age International Publishers, 2007, 5th edition,

3. R.L. Burden, J. D. Faires, Numerical Analysis, Richard Stratton, 2011, 9th edition.

4. S.D. Conte and Carl de Boor, 'Elementary Numerical Analysis; An Algorithmic Approach'. International series in Pune and Applied Mathematics, McGraw Hill Book Co., 1980.

5. S. S. Sastry, Introductory methods of Numerical Analysis, 2012, PHI Publishers, 5th edition

6. Willaim Boyce and Richard DiPrima, Elementary Differential Equations and Boundary Value Problems, 11th Edition, Wiley-India

7. Erwin Kreyszig, Advanced Engineering Mathematics, 10th Edition, Wiley-India.

Deep Learning and MLOps

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5220252	Deep learning and MLOps	3	500	1-1-0-1

Course Outcomes	
CO1	Advanced Neural Network Design: Apply deep learning principles to design complex neural networks for specialized applications, emphasizing both feedforward and recurrent architectures.
CO2	Evaluation of Architectures: Critically evaluate and optimize different architectures for tasks in computer vision, NLP, generative modeling, and reinforcement learning.
CO3	MLOps Frameworks: Implement MLOps frameworks to manage large-scale deep learning model deployments, with a focus on reproducibility, scalability, and governance.
CO4	Research and Innovation: Conduct independent research projects in deep learning applications, resulting in original work that contributes to the field.

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	1	1	2
CO2	2	3	3	1	1	2
CO3	2	3	3	1	1	3
CO4	2	3	3	1	1	3

Module	**Content**
1	Advanced Deep Learning Fundamentals: Topics: Introduction to perceptron; Multilayer Perceptrons (MLPs); Activation funtions: ReLU, Leaky ReLU, Tanh, Sigmoid; Forward and backward propagation; Loss functions for classification and regression; Universal approximation theorem; Deep feedforward networks and hidden layer design Lab Activities: Implement and train MLPs using TensorFlow or PyTorch; Experiment with ac-tivation functions and loss variations
2	Optimization and Regularization in Deep Learning Gradient descent, stochastic gradient descent (SGD); Advanced opti-mizers: Adam, RMSProp, learning rate schedules; Batch normalization and layer normalization; Regularization: L2 weight decay, dropout, ear-ly stopping, model averaging; Overfitting and the bias-variance trade-off Lab Activities: Train deep models with and without regularization; Visualize learning curves under different optimizers
3	Convolutional and Recurrent Neural Networks CNNs: filters, feature maps, padding, pooling; CNN architectures: Le-Net, AlexNet, VGG, ResNet; Image classification and object detection basics; RNNs: sequence modeling, vanishing gradients; LSTM and GRU architectures Lab Activities: • Implement CNNs for image classification (e.g., CIFAR-10) • Build RNN/LSTM for time series or text data
4	Practical Deep Learning & MLOps

	Training pipelines: data preprocessing, model training, evaluation; Deployment fundamentals: ONNX, TensorFlow Lite Introduction to DLOps: Simple model tracking (e.g., MLflow); Lightweight versioning and reproducibility Lab Activities: Build and deploy a complete deep learning application; Track experi-ments and model performance

Assessment:

- Course Project (40%): Evaluation includes a written report, code submission, and oral presentation.
- Examinations (40%): Final assessments on theoretical and practical knowledge.
- Seminars/Research Review (10%): In-depth discussions and presentations on recent research papers.
- Lab Work (10%): Demonstrate hands-on proficiency in implementing deep learning architectures and DLOps practices.

References:

1. Deep Learning with Python by François Chollet
2. Python Deep Learning by Ivan Vasilev, Daniel Slater, and Gianmario Spacagna
3. Practical MLOps: Operationalizing Machine Learning Models" by Noah Gift and Alfredo Deza

Generative AI

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5220351	Generative AI	4	500	1-1-1-1

Course Outcomes	
CO1	Introduction to generative AI
CO2	Text, Video and Image generation
CO3	Prompt engineering

CO4	Transformer architecture

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	2	1	1	2
CO2	2	2	2	2	1	2
CO3	3	2	2	2	1	2
CO4	2	1	1	2	1	2

Module	**Content**
1	Topics: Beyond GANs & VAEs: landscape of generative modelling, Denoising Diffu-sion Probabilistic Models (DDPMs), Score-based generative modelling, Au-toregressive models and masked modelling (PixelCNN, BERT), Foundation models and self-supervised pretraining Lab Component: • Model comparison on Hugging Face using pretrained GAN, VAE, Dif-fusion models • Fine-tune and deploy a GPT-based summarization or question answer-ing system
2	Pretraining and Finetuning Process in Generative AI models (GPT) – Instruction and Parameter Efficient Fine Tuning (PEFT) – Reinforcement Learning from Human Feedback (RLHF) – Generative AI Model – Evaluation Metrics – Inception Score (IS), Frechet Inception Distance (FID), Perplexity, Human Evaluation. Lab Components: LLM implementation
3	Introduction to Prompt Engineering - Understanding the concept and significance of prompt engineering - Strategies for designing effective prompts - Techniques for controlling model behavior and output quality - Best practices for prompt engineering in generative AI Lab components: Analytics & QA with tables
4	Generative models for tabular data (CTGAN, TabDDPM, TVAE), Time-series data generation (TimeGAN), Evaluating synthetic data: fidelity, utility, privacy, Synthetic data pipelines for imbalanced classification,

	Lab Components: Time Series Data Generation

References:

1. Joseph Babcock, Raghav Bali, Generative AI with Python and TensorFlow 2: Create images, text, and music with VAEs, GANs, LSTMs, Transformer models, Packt publishing, ISBN 13: 978-1800200883, 2021.
2. Divit Gupta, Anushree Srivastava, The Potential of Generative AI: Transforming technology, business and art through innovative AI applications, BPB Publications, ISBN-13: 978-9355516725,2024.
3. Generative Adversarial Networks by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, 2017.
4. Generative AI: A Modern Approach by David Barber. Cambridge University press, 2022

Courses offered as electives (Programme electives and open electives)

Python Programming for Data Analytics

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221151	Python Programming for Data Analytics	3	400	2-1-0-0

Course Outcomes	
CO1	Apply data representation techniques including numeral systems, bit patterns, and data encoding to analyze and convert between various forms of digital data in computational systems.
CO2	Analyze computational problems and design structured solutions using flowcharts, algorithms, and modular programming techniques in Python.
CO3	Develop robust Python programs utilizing control structures, functions, collections, and object-oriented programming principles to solve real-world problems.
CO4	Evaluate and implement data handling techniques including file operations, error handling, and use of external libraries (NumPy, Pandas, Matplotlib) for data analysis and visualization.

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	0	0	0
CO2	3	3	3	0	0	1
CO3	3	3	3	0	0	1
CO4	3	3	3	0	0	1s

Module	Content
1	Basics: Information and Data, Analog and Digital systems, Bits, Bytes and Bit patterns, Numeral Systems, Data Encoding. Computational problem solving: Problem analysis, Program design, Program implementation, Program testing. Algorithms and flowcharts, Overview of programming languages. Python: Introduction, Installing and running Python programs, Jupyter notebook.
2	Data and expressions: Comment statements, Literals, Variables and identifiers, Keywords, Operators, Expressions and Data Types, Operator precedence and associativity, Type conversion. Environment variables, Formatting numbers, the format method. Control structures: Boolean expressions, One and multi-way selection, Iterative control, Nested loops, Indentation, break and continue statements.
3	Functions: Defining and calling functions, Scope and lifetime, Local functions, Returning single and multiple values, Parameter passing, Namespaces, Keyword and default arguments, Optional parameters, Variable number of arguments, Closures, Lambda functions, Function redefinition. Object-oriented programming basics: Objects, abstraction, encapsulation, classes, the __init__() method.

4	String formatting and processing. Collections: Range function, Lists, Tuple, Sets and Dictionaries - Creating, Accessing, Basic operations and Methods, Sorting and Copying, Passing collections to a function, Mapping functions in a dictionary. Modules: Modules, Packages, Standard Library modules, Installing packages via pip, Introduction to NumPY, Pandas, Virtual environments. Iterators: Sequences, iterables, iterator protocol. Generators: Generator functions and expressions. Files: Types of files, Opening, Closing, Reading and Writing files. Error Handling: Catching and handling exceptions, multiple exceptions, user-defined exceptions, Context managers, Standard logging module. Graphics: Turtle Module, Drawing with colors, Drawing basic shapes using iterations, Creating bar charts, Introduction to Matplotlib.

Reference books and articles

[1] Charles Dierbach, "Introduction to Computer Science Using Python: A Computational Problem-Solving Focus", Wiley.
[2] Ashok Namdev Kamthane, Amit Ashok Kamthane, "Programming and Problem Solving with Python", McGraw Hill Education.
[3] Jake Vander Plas, "Python Data Science Handbook – Essential Tools for Working with Data", O'Reilly Media, Inc.
[4] Zhang.Y. , "An Introduction to Python and Computer Programming", Springer Publications.
[5] Wes McKinney, Python for Data Analysis: Data Wrangling with Pandas, NumPy, and Ipython" O'Reilly Media.
[6] Haslwanter, T., "An Introduction to Statistics with Python", Springer.

Applied Differential Equations

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221152	Applied Differential Equations	3	400	1-1-1-0

Course Outcomes

CO1	Analyze the stability and geometric properties of linear and non-linear ODEs/PDEs, and implement classical numerical integrators (RK4, Finite Difference) while critically evaluating their stability
CO2	Formulate differential equations as differentiable computational graphs and implement continuous-depth neural networks (Neural ODEs) using the Adjoint Sensitivity Method for efficient time-series modeling.
CO3	Develop and train Physics-Informed Neural Networks (PINNs) to solve forward, ill-posed, and inverse scientific problems by embedding governing physical laws, initial conditions, and boundary conditions directly into the network's loss function.
CO4	Evaluate and apply advanced operator learning frameworks—specifically DeepONets and Fourier Neural Operators (FNOs)—to learn infinite-dimensional functional mappings and achieve zero-shot super-resolution for complex systems like the Navier-Stokes equations.

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	3	3	3	3	3
CO3	2	2	2	2	2	2
CO4	1	1	1	1	1	1

Module	**Content**
1	Geometric meaning of y′=f(x,y), Direction Fields, and phase portraits. Linear vs. Non-linear, separable, and Exact equations, 2D systems, eigenvalues, critical points, node/saddle/focus classification, and Lyapunov stability. IVP Solvers: Euler's method, Runge-Kutta (RK4), Multistep methods.
2	Classification of PDEs into Elliptic (Poisson/Laplace), Parabolic (Heat/Diffusion), and Hyperbolic (Wave/Transport) equations. Forward, backward, and central differencing schemes. Elliptic PDEs: Boundary conditions (Dirichlet, Neumann) and block matrix formulations for 2D Poisson problems. Explicit and implicit schemes for Parabolic PDEs. Von Neumann stability analysis and the Courant-Friedrichs-Lewy (CFL) condition

	for Hyperbolic equations.
3	Differential equations as computational graphs; Introduction to differentiable programming. Neural Ordinary Differential Equations: Interpreting Residual Networks (ResNets) as Euler discretizations. Continuous-depth neural networks. Training Continuous Systems: The Adjoint Sensitivity Method for memory-efficient backpropagation through ODE solvers. Time-series modeling using Neural ODEs.
4	Physics-Informed Neural Networks (PINNs)**:** Embedding PDE residuals, initial conditions, and boundary conditions directly into the neural network loss function. Solving Ill-Posed Problems**,** inverse problems. Introduction to Operator Learning: Moving beyond function approximation (learning x→y) to learning operators (learning functional mappings u(x)→v(x)). DeepONets and Neural Operators: Architecture of Deep Operator Networks. Introduction to Fourier Neural Operators (FNO) for solving parametric families of PDEs (e.g., Navier-Stokes) with zero-shot super-resolution.
Textbooks LeVeque, R. J. , Finite Difference Methods for Ordinary and Partial Differential Equations: Steady-State and Time-Dependent Problems. SIAM. C. Kumar, B. Kaur, G. Manchanda, A Textbook on Differential Equations and Applications, Sultan Chand and Sons, 2023 Boyce, W. E., DiPrima, R. C., & Meade, D. B. (2021). Elementary Differential Equations and Boundary Value Problems. John Wiley & Sons. Brunton, S. L., & Kutz, J. N. (2022). Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control (2nd Ed.). Cambridge University Press.	

Time Series Analysis and SEM Modeling

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221153	Time series analysis and SEM Modeling	3	400	1-1-0-1

Course Outcomes	
CO1	Introduction to time series
CO2	ARIMA model discussion
CO3	State-space model
CO4	Structural Equation Models

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	2	2	1
CO2	2	3	1	2	1	1
CO3	2	2	1	1	1	1
CO4	3	3	2	2	2	1

Module	**Content**
1	Characteristics of Time Series, The Nature of Time Series Data, Time Series Statistical Models, Measures of Dependence: Autocorrelation and Cross-Correlation, Stationary Time Series, Estimation of Correlation
2	ARIMA Models, Introduction, Auto regressive Moving Average Models, Auto correlation and Partial Autocorrelation Functions , Forecasting , Estimation , Building ARIMA Models, Multiplicative Seasonal ARIMA Models
3	State-Space Model, Introduction, Filtering, Smoothing, and Forecasting, Maximum Likelihood Estimation, Structural Models: Signal Extraction and Forecasting, ARMAX Models in State-Space Form
4	Structural equation models: The basics, Latent versus observed variables, Exogenous versus endogenous latent variables, The factor analytic model, The general structural equation model, The formulation of covariance and mean structures

References:

1. Robert H. Shumway, David S. Stoffer, Time Series Analysis and Its Applications With R Examples, Springer, 2014
2. Subba Rao, Calyampudi Radhakrishna Rao, Time Series Analysis: Methods and Applications, Elsevier, 2012

Database Architecture and Analytics

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220152	Database Architecture and Analytics	4	400	3-1-0-0

Course Outcomes	
CO1	Summarize the basic concepts and applications of Database Management System.
CO2	Design Entity – Relationship diagram and convert into the corresponding logical schema.
CO3	Write SQL queries based on the given requirements and get practical knowledge on data modeling, data manipulation and data retrieval
CO4	Summarize the architecture and features of distributed databases and get the knowledge on distributed databases and understanding on handling unstructured data

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	1	1	1	1
CO2	2	2	3	1	1	2
CO3	2	3	2	1	1	1
CO4	2	3	2	1	1	2

Module	Content
1	Introduction to Database Management Systems: Data, Information, Database, File Server Model, Client Server Model, Components of DBMS, DBMS Features, Transaction and ACID properties, Data Abstraction and data independence.
2	Data Modeling: Logical and Physical Data Models, E-R Modeling A detailed study, Record Based Models, Relational Model - overview, Relational Concepts, Tables, Keys, Constraints, Data Integrity and Constraints, Integrity Rules, Database

	Objects, Schema and Non-schema, Database Normalization, Codds Rules, Functional dependency.
3	Introduction to SQL: Introduction to SQL, SQL Features, SQL Operators, SQL Datatypes, SQL Parsing, Types of SQL Commands, Advanced Study of Structured Query Language, Querying Data from the database, Queries, Correlated Sub-queries, Joins, Hierarchical Queries, Bind Variables, Cursors, Views, Functions, Stored Procedures and Triggers.
4	Distributed Databases: Architectures for parallel databases, Parallel query evaluation; Parallelizing individual operations, Distributed database concepts, Data fragmentation, Replication, and allocation techniques for distributed database design; Query processing in distributed databases; Concurrency Control and Recovery in distributed databases. NoSQL- The Emergence and relevance of NoSQL, Types of NoSQL Databases, MongoDB, Cassandra, HBASE, Neo4j use and deployment, Application, Challenges NoSQL approach, Key-Value store and Document Data Models, Column-Family Store and graph database.

Text Books:

1. Database Management System, MonelliAyyavaraiah, ArepalliGopi, Horizon Books,2017
2. SQL and NoSQL Databases: Models, Languages, Consistency Options and Architectures for Big Data Management, Andreas Meier, Michael Kaufmann, Springer, 2019
3. Abraham Silberschatz; Henry F Korth, Database System Concepts, McGraw Hill Publication, 2002
4. Hellerstein, Joseph, and Michael Stonebraker. Readings in Database Systems (The Red Book). 4th ed. MIT Press, 2005.
5. Raghu, and Johannes Gehrke. Database Management Systems. 3rd ed. McGraw- Hill, 2002.

References:

1. Stefano Ceri; Giuseppe Pelagatti, Distributed Databases: Principles andSystems, Universities Press, 2000.
2. Jan L Harrington, Object Oriented Database Design Clearly Explained,Harcourt, 2000.
3. Elmasri,Ramez; Navathe, Shamkant B, Fundamentals ofDatabase Systems, Pearson, 2000.

Web Engineering

CourseCode	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project

M4220252	Web Engineering	3	400	2-1-0-0

Course Outcomes	
CO1	Summarize transmission protocols and web server architecture
CO2	Utilize CSS to display HTML elements in Webpage
CO3	Develop web pages using java script
CO4	Summarize various design patterns used in software development

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	3	3	1	3
CO2	2	1	3	2	1	2
CO3	2	1	3	3	1	2
CO4	1	1	2	3	2	3

Module	**Content**
1	Design, HTML5 Elements, Attributes and elements, Type of Style sheets: Internal Style sheet, Inline Style sheet, External Style Sheet, CSS3 Elements and features, CSS frameworks, Content delivery network, Selectors, XML Schema, Presenting XML Using XML Processors: DOM and SAX
2	Introduction to Java Script, Object in JavaScript, Dynamic HTML with Java Script, JavaScript Object Notation, Data types, Arrays, Decisions and Loops, Functions and scope, JavaScript libraries, JavaScript Frameworks, ECMAScript, TypeScript, Single page applications (SPA), Basics of React Web Framework. Introduction to MERN framework.

3	Creational Design Patterns, Factory Pattern, Abstract Factory Pattern, Prototype pattern, Singleton Pattern, Builder Pattern, Dependency Injection pattern, The Web Services based on technologies such as SOAP, REST, WSDL, Django Framework: Architecture, MTV Architecture Pattern in Django Structure.
4	Data Access with Django and Python, CRUD Operations with DJango, Models, Templates, Controllers, Sample Django MTV Web Application, REST API with Django - Advanced, Cache and Sessions with Django, Data Visualization Techniques for small and large data, Fundamentals of web application architecture (1Tier, 2-Tier, 3-Tier, N Tier and MVC) and components, User interface app components, Structural components, Microservices, Monolithic vs. Microservices.

References :

1. Jeffrey C. Jackson, Web Technologies - A Computer Science Perspective, Pearson Education - 2009.
2. Joseph B. Mille, Internet Technologies and Information Services, ABC-CLIO - 2014.
3. William S Vincent, Django for Professionals: Production websites with Python andDjango Paperback, Import - 2019.

Computational Neuroscience

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221251	Computational Neuroscience	3	400	2-1-0-0

Course Outcomes	
CO1	Analyze the biological and electrical behaviour of neurons.
CO2	Evaluate the applicability of advanced computational techniques to create models of biological neurons.
CO3	Evaluate the applicability of Kirchoffs's laws, cable theory and numerical methods in neuroscience.
CO4	Evaluate mathematical problems related to neuroscience.

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	0	0	0
CO2	2	1	3	0	0	0
CO3	2	3	2	0	0	0
CO4	1	2	3	0	0	0

Module	**Content**
1	Basic neuroscience: The nervous system, central and peripheral nervous system, organization of the brain, brain anatomy and function, neurons, dendrites and axons, electrical and chemical synapses, synaptic and action potentials. Nernst Potential, GHK equation, Electrochemical Driving Force (EDF), Ohm's law, Electrical Equivalent Circuit of a neuronal membrane.
2	The Hodgkin-Huxley theory of action potentials: Voltage Clamp Experiments, activation and non-inactivation parameters (n, m, h), estimation of n, m, h., action potential generation and propagation, HHsim - simulation experiments.
3	Introduction to computational neuroscience: Modelling and understanding, the modelling perspective, formulating a conceptual model, Numerical methods for neural modelling. Compartmental modelling, Kirchoff's current and voltage laws, The cable theory. Time constant and space constant.
4	The NEURON simulation environment: Introduction, representing neurons with a digital computer, model implementation, signal sources and monitors, running simulation experiments, analysing results. Simple single cell and network models. Simple exercises using the NEURON module in Python.

References:

1. Malmivuo, J., and Plonsey, R. Bioelectromagnetism: principles and applications of bioelectric and biomagnetic fields. Oxford University Press, USA.
2. Kandel, E.R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S. A., Hudspeth, A. J. Principles of Neural Science, McGraw Hill.
3. Neuroscience. Edited by Dale Purves, George J. Augustine, David Fitzpatrick, William C. Hall, Anthony-Samuel LaMantia, and Leonard E. White. Sinauer Associates Inc.
4. Gazzaniga, M., Ivry, R. B., andMangun, G. R. Cognitive neuroscience: the biology of the mind. Cambridge: MIT press.

Ethics in Data

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221252	Ethics in Data	3	400	1-0-2-0

Course Outcomes	
CO1	Understand the historical evolution and ethical considerations of data-driven decision-making.
CO2	Apply ethical principles to assess and mitigate bias in data collection and analysis.
CO3	Analyze the societal implications of data-driven technologies and their ethical consequences.
CO4	Evaluate and design ethical data policies and practices for responsible data usage.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	2	1
CO2	3	3	3	2	2	1
CO3	3	3	3	2	2	1
CO4	3	2	3	2	2	1

Module	Content
1	Introduction to Data Ethics - Data ethics: Definition and scope, Overview of computer components and their roles, Historical context, Evolution of data ethics, Ethical considerations in data-driven decision-making: utilitarianism, deontological ethics, etc., Case studies on ethical challenges in data usage: Cambridge Analytica scandal, Target's pregnancy prediction, etc.
2	Ethical Considerations in Data Collection and Analysis - Privacy rights and data protection regulations: General Data Protection Regulation - (GDPR), California Consumer Privacy Act (CCPA), Digital Personal Data Protection Bill (DPDPB - India),

	Ethical data collection: Role of informed consent, Bias and fairness in data analysis: algorithmic bias, fairness-aware machine learning, Transparency and accountability in algorithmic decision-making: Explainable AI, Algorithm auditing, Real-world examples of ethical dilemmas in data collection and analysis: facial recognition technology, predictive policing, etc.
3	Social and Cultural Impacts of Data Use - Data-driven discrimination and social inequality, Algorithmic bias and its impact on marginalized communities, Ethical considerations in AI and machine learning applications, Digital surveillance and its effects on civil liberties, The role of data ethics in shaping public policy - data protection regulations, ethical AI guidelines by governments.
4	Building Ethical Data Practices - Ethical frameworks for data use and decision-making, Establishing data governance and responsible AI practices - Data Ethics Committees, AI Ethics Guidelines, Privacy Impact Assessments - PIAs, data anonymization techniques, Ethical considerations for data sharing and collaboration, Case studies of organizations leading in ethical data practices - Microsoft's AI Ethics principles, Google's Responsible AI practices

References:

1. "Ethics of Big Data" by Kord Davis and Doug Patterson
2. "Data and Goliath: The Hidden Battles to Collect Your Data and Control Your World"
3. "Ethics for Robots: How to Design Ethical Robots and AI" by Matthias Scheutz
4. "Responsible AI: A Global Policy Framework" by IFG Advisory Board and Paula Goldman

Data Structures and Algorithms

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221253	Data Structures and Algorithms	3	400	2-1-0-0

Course Outcomes	
CO1	Develop algorithms for searching and sorting problems.
CO2	Formulate/Apply the solution using the concepts of Stack, Queue, Linked List, Recursion and Tree

CO3	Evaluate algorithms to assess their performance based on time and space complexity.
CO4	Implement programs and some application using different Data Structures
CO5	Utilize the acquired skills of algorithms and data structures for creating better quality applications

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	0	0	0
CO2	3	3	3	0	0	1
CO3	3	2	2	0	0	0
CO4	3	3	3	0	0	1
CO5	3	3	3	0	0	1

Module	**Content**
1	Introduction to ADT and Algorithms: Data types, Data structures, Abstract data types, Algorithms, Algorithm analysis, Best case, worst case and average case complexities, Big-O notation, Analysis of Python List and Dictionary operations. Introduction to complexity classes.
2	Stacks: Introduction to stack, the stack abstract data type, basic operations, implementing a stack in Python, algorithm analysis of Python implementations of stack, computational problems relating to stack, expression representation using prefix and postfix notations, Evaluation of expression using stack. Queues: Introduction to queues, the queue ADT, basic operations, Python implementation, computational problems related to queue. Linked List: The unordered list ADT, linked list, linked list operations, doubly linked list, Python implementation, applications.
3	Recursion: The laws of recursion, format of a recursive function, applications of recursion such as Fibonacci series, Towers of Hanoi. Searching: Sequential and binary search, hashing. Sorting: Selection, bubble, insertion, quick, merge, heap sorts.
4	Trees: Vocabulary, Definitions, Tree operations, Implementation of tree, Binary trees, Balanced binary tree, Complete binary tree, binary search tree, balanced

	binary search tree, tree traversals. Heap: Introduction to binary heap, max heap, min heap, representation.

References:

1. Miller, B., & Ranum, D. Problem solving with algorithms and data structures, Franklin, Beedle and Associates.
2. Cormen, T. H., Leiserson, C. E., Rivest, R. L., & Stein, C.. Introduction to algorithms. MIT press.
3. Langsam, Y., Augenstein, M. J., & Tenenbaum, A. M. Data Structures using C and C++. Prentice Hall Press.
4. Drozdek, A. Data structures and algorithms in Java. Brooks/Cole.
5. Kleinberg, J., & Tardos, E. Algorithm design. Pearson Education India.
6. Dasgupta, S., Papadimitriou, C., & Vazirani, U. Algorithms. McGraw Hill.

Computational Chemistry for Bio-Systems

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221254	Computational Chemistry for Bio-Systems	3	400	1-1-0-1

Course Outcomes	
CO1	Apply advanced quantum chemical methods, including QM/MM approaches, to model and analyze biomolecular systems.
CO2	Develop and simulate computational models of bio-materials using molecular dynamics to investigate their properties and interactions.
CO3	Simulate and interpret spectroscopic data of biological systems using computational techniques, correlating results with experimental findings.
CO4	Utilize machine learning and data science tools to build predictive models and analyze large computational datasets in bio-systems ethically.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	2	2	1
CO2	3	3	3	2	2	1
CO3	3	3	3	2	2	1
CO4	3	3	3	2	3	2

Module	Content
1	Quantum Chemistry of Biomolecules: Advanced quantum chemical methods (DFT, post-Hartree-Fock) for biomolecules, QM/MM (Quantum Mechanics/Molecular Mechanics) methods for large biological systems, basis set selection, introduction to enzymatic active sites and simplified reaction mechanisms, overview of bio-catalysis with emphasis on conceptual understanding. Lab: Software Focus- ORCA, Psi4, NWChem for quantum simulations; NWChem for QM/MM methods.
2	Computational Modeling of Bio-materials: Simulation of bio-inspired materials, design and analysis of peptides, proteins, and nucleic acids, modeling bio-interfaces and biomimetic materials, self-assembly and molecular recognition, emphasis on computational modeling, with optional collaboration with experimental methods for enhanced understanding. Lab: Software Focus- GROMACS and NAMD for molecular dynamics simulations.
3	Computational Spectroscopy of Biological Systems: Simulation of spectroscopic properties (IR, Raman, NMR, EPR). Time-dependent DFT for electronic excitations in bio-chromophores. Interpretation of experimental data. Structure-function relationships in biomolecules. Lab: Software Focus- ORCA for spectroscopic simulations.
4	Data-Driven Computational Chemistry in Bio-Systems: Machine learning for predicting molecular properties, reaction outcomes, and biological activities. Data mining techniques for analyzing chemical libraries, protein sequences, and genomic data. Statistical modeling and regression techniques for quantitative structure-property relationships (QSPR). Integration of cheminformatics for drug discovery and material design. Lab: Python programming using scikit-learn, TensorFlow, and DeepChem. Developing ML models for property predictions and molecular design. Analyzing and visualizing data from high-throughput screening and simulations. Applying QSPR techniques to predict properties of new compounds.

Hands-On Project	Objective: Address a complex computational chemistry problem related to biological systems. Activities: Applying advanced computational methods to study a biomolecule or bio-material. Analyzing results to gain insights into structure, properties, or reactivity. Preparing a comprehensive report and presentation demonstrating methodologies, findings, and their significance.

Textbooks & References:

1. Jensen, F. (2017). Introduction to computational chemistry (3rd ed.). Wiley. ISBN 9781118825990
2. Cramer, C. J. (2004). Essentials of computational chemistry: Theories and models (2nd ed.). Wiley. ISBN 9780470091821
3. Schlick, T. (2010). Molecular modeling and simulation: An interdisciplinary guide (2nd ed.). Springer. ISBN 9781441963505
4. Young, D. C. (2001). Computational chemistry: A practical guide for applying techniques to real-world problems. Wiley-Interscience. ISBN 9780471333685
5. Leach, A. R. (2001). Molecular modelling: Principles and applications (2nd ed.). Prentice Hall. ISBN 9780582382107
6. Tutorials and user manuals for ORCA, Psi4, GROMACS, and NAMD.

Microwave Remote Sensing

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221256	Microwave remote sensing	3	400	1-1-0-1

Course Outcomes	
CO1	Understand Advanced Properties and Characteristics of Microwaves
CO2	Analyze and Interpret Synthetic Aperture Radar (SAR) Data
CO3	Apply SAR Interferometry (InSAR) for Geospatial and Environmental Monitoring
CO4	Implement SAR-Based Techniques for Environmental Applications

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	2	1	2	1
CO2	2	3	3	1	1	1
CO3	3	2	1	2	1	2
CO4	2	3	3	2	3	1

Module	Content
1	**Advanced Properties and Characteristics of Microwaves** ● Properties of Microwaves ● Types of Microwave Sensors: Active & Passive ● Radar Cross section and Image Interpretation ● Radar characteristics for Image Analysis ● Signal Polarization, Wavelength, and Penetration Depth ● Radar Brightness and its Applications.
2	**Synthetic Aperture Radar (SAR) and Image Correction Techniques** ● Fundamentals of Radar Principle and Side-Looking Radar Systems ● Range and Azimuth Resolution ● Synthetic Aperture Radar (SAR) Imaging ● Geometric Properties of SAR ● Radiometric Properties of SAR
3	**SAR Interferometry and Time Series Analysis Techniques** ● Principles of SAR Interferometry (InSAR) ● InSAR for Topographic Mapping and DEM Generation ● Differential SAR Interferometry for Deformation Monitoring ● InSAR Time Series Analysis Techniques for Tracking Surface Deformation ● Applications in Tracking Landslide Events and Urban Subsidence Monitoring
4	**Advanced Applications of SAR in Environmental Monitoring** ● SAR Inundation and Surface Water Mapping Techniques ● SAR for Agriculture Monitoring and Crop Health Assessment ● Forest Monitoring and Biomass Estimation Using SAR
Course Project: Each student will complete a project that leverages SAR and InSAR techniques for environmental monitoring. Students may choose one of the following topics:	

• Flood Mapping and Surface Water Monitoring: Utilizing threshold-based techniques and SAR data for accurate flood extent mapping. • Forest and Agriculture Monitoring: Analyzing Forest degradation or agricultural patterns over time using SAR data, with a focus on biomass estimation. • Landslide Monitoring: Tracking landslide or subsidence events over time with InSAR time series data to assess stability and movement.
References: 1. Lillesand, T., Kiefer, R. W., &Chipman, J. (2015). Remote sensing and image interpretation. John Wiley & Sons. 2. Iain H. Woodhouse (2006), Introduction to Microwave Remote Sensing, CRC Press.Chein I Chang, "Hyperspectral Imaging: Techniques for Spectral Detection and Classification", Kluwer Academic/Plenum Publishers, New York, N.Y., 2003. (ISBN: 0-306-47483-2). 3. Ulaby, F.T., Moore, K.R. and Fung, Microwave remote sensing vol-1, vol-2 and volAddison - Wesley Publishing Company, London,1986. 4. Floyd.M. Handerson and Anthony, J.Lewis "Principles and applications of Imaging RADAR", Manual of Remote sensing, Third edition, vol.2, ASPRS, Jhumurley and sons, Inc, 1998. 5. Philippe Lacomme,JeanclandeMarchais,Jean-Philippe Hardarge and Eric Normant, Air and spaceborne radar systems - An introduction, Elsevier publications 2001. 6. Roger J Sullivan, Knovel, Radar foundations for Imaging and Advanced Concepts, SciTech Pub, 2004. 7. Ian Faulconbridge, Radar Fundamentals, Published by Argos Press, 2002. 8. Eugene A.Sharkov,Passive Microwave Remote Sensing of the Earth: Physical Foundations, Published by Springer, 2003.

Natural Language Processing and Information Retrieval

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221257	Natural Language Processing and Information Retrieval	3	400	1-1-0-1

Course Outcomes	
CO1	Implement core NLP techniques: tokenization, POS-tagging, NER, dependency parsing

CO2	Apply statistical methods and embeddings: TF-IDF, Word2Vec/GloVe, BERT representations
CO3	Build IR models and evaluate them with precision@K, recall@K, MAP, nDCG, MRR
CO4	Develop and optimize end-to-end IR systems: indexing, ranking, query expansion, relevance feedback

Mapping of Course Outcomes with Programme Outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	1	1	1
CO2	3	3	3	1	1	1
CO3	3	3	3	1	1	3
CO4	3	3	3	1	2	3

Module	**Contents**
1	Text Ingestion & Core NLP Tasks Lecture Topics: Designing a production-style text-processing pipeline; Tokenization methods and normalization (lowercasing, stemming vs. lemmatization); Named-Entity Recognition and dependency parsing. Lab Exercises: : Ingest and clean a real-world text corpus (CSV/JSON) in Python. Build a spaCy pipeline for tokenization → POS → NER → dependency parse; Visualize dependency trees and extract entity spans. Project Milestone 1: Define your target corpus and implement the preprocessing component of your retrieval system.
2	Feature Engineering, Embeddings & Classification Lecture Topics: Bag-of-Words and TF-IDF vectorizers; Static embeddings (Word2Vec, GloVe) vs. contextual embeddings (BERT); Introduction to text classification (e.g., sentiment, intent). Lab Exercises: Compare CountVectorizer vs. TfidfVectorizer representations on sample documents; Load pretrained Word2Vec/GloVe models; compute nearest-neighbor queries; Fine-tune a small BERT model for text classification using Hugging Face's transformers. Project Milestone 2: Integrate your chosen feature extractor and embedding

	model into the system's pipeline.
3	IR System Construction & Evaluation Lecture Topics: Inverted-index architecture and BM25 ranking; Neural-IR overview: dense retrieval and re-ranking; Evaluation metrics: precision@K, recall@K, MAP, nDCG, MRR; Topic modeling (LDA) for corpus exploration. Lab Exercises: Deploy Elasticsearch via Docker; index your preprocessed corpus; Execute BM25 queries through the REST API and compute MAP/nDCG in Python; Perform LDA topic modeling to tag documents with dominant topicpreprocessing through API—accompanied by an optimization report detailing experiments. Project Milestone 3: Implement BM25 retrieval, evaluate baseline performance, and enrich the index with topic labels.
4	Fundamentals of transformer architectures: Attention mechanisms, BERT, and GPT, comparison of masked language models vs. autoregressive language models, fine-tuning transformer models (e.g., DistilBERT) for classification tasks, introduction to Generative AI in NLP and its key applications, text generation using GPT-based models (e.g., OpenAI GPT, GPT-Neo),Introduction to LangChain and agent-based LLM architectures, document-based question answering using vector databases (FAISS, Chroma), building QA bots using LangChain over custom documents.

References

1. Speech and Language Processing by Daniel Jurafsky and James H. Martin
2. Natural Languag Processing with PyTorch by Delip Rao and Brian McMahan
3. Introduction to Information Retrieval by Christopher D. Manning, Prabhakar Raghavan, and Hinrich Schütze
4. Research papers on recent advancements in neural IR and transformer-based models.

Portfolio Management

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221258	Portfolio Management	3	400	1-1-0-1

Course Outcomes	
CO1	Explain fundamental concepts of investment, risk, and return, and distinguish between speculation, gambling, and investment.
CO2	Apply modern portfolio theory and optimization techniques to construct efficient portfolios across asset classes.
CO3	Evaluate and compare portfolio performance using risk-adjusted measures and multifactor models.
CO4	Integrate advanced econometric, optimization, and machine-learning approaches in portfolio selection and rebalancing strategies.

Mapping of course outcomes with program outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	1	1
CO2	3	3	3	1	1	1
CO3	3	3	3	1	1	2
CO4	3	2	3	2	1	2

Module	Content
1	Meaning and objectives of investment, characteristics of different asset classes, comparison of investment, speculation, and gambling. Concepts of risk and return, estimation of security and portfolio risk, diversification benefits, and the impact of combining assets. Overview of fundamental and technical analysis including economic, industry, and company analysis, Dow theory, and chart-based techniques for market assessment.
2	Modern Portfolio Theory and Markowitz risk–return optimization, concept of efficient frontier, minimum-variance portfolios, and diversification. Single-index and multi-index models; Sharpe's optimization solution; Capital Market Line and Security Market Line. Risk-free lending and borrowing, Capital Asset Pricing Model (CAPM), and Arbitrage Pricing Theory (APT). Extensions to multi-factor models and estimation of beta for portfolio construction.
3	Black–Litterman model, probabilistic and scenario-based optimization, and Bayesian portfolio updates. Arbitrage portfolios and risk-parity concepts, Kelly criterion, and portfolio rebalancing techniques. Integration of quantitative optimization with advanced tools such as genetic algorithms and information-theoretic methods. Application of state-space and econometric models in portfolio

	allocation and factor timing.
4	Performance measurement using Sharpe, Treynor, and Jensen ratios; risk-adjusted return analysis and benchmark evaluation. Market timing and attribution analysis, evaluation criteria, and assessment procedures. Concepts of market efficiency and behavioral factors in portfolio management. Introduction to data-driven and AI-based portfolio optimization using neural networks and reinforcement learning for dynamic allocation and strategy evaluation.

Text Books:

1. Reilly, F. K. & Brown, K. C. *Investment Analysis and Portfolio Management.* South-Western College, 2011.
2. Elton, E. J. & Gruber, M. J. *Modern Portfolio Theory and Investment Analysis.* Wiley, 2014.
3. Prasanna Chandra. *Investment Analysis and Portfolio Management.* Tata McGraw-Hill, 2008.
4. Fabozzi, F. J. *Investment Management.* Prentice Hall, 1999.
5. Litterman, B. *Modern Investment Management: An Equilibrium Approach.* Wiley, 2003.

Risk Management

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221259	Risk Management	3	400	1-1-0-1

Course Outcomes	
CO1	Identify and classify various types of financial and non-financial risks affecting institutions and markets.
CO2	Apply quantitative techniques such as Value at Risk (VaR), stress testing, and scenario analysis for market risk measurement.
CO3	Evaluate and implement hedging and credit risk management strategies using derivatives and risk models.
CO4	Integrate modern approaches including Bayesian, machine learning, and extreme value methods for systemic and enterprise risk modeling.

Mapping of course outcomes with program outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	2	1

CO2	3	3	3	1	1	1
CO3	3	3	3	1	2	2
CO4	3	2	3	2	2	2

Module	**Content**
1	Nature and sources of financial risk—market, credit, liquidity, operational, and systemic risks. Risk identification and classification in financial institutions. Market risk measurement using Value at Risk (VaR): concepts, parameters, and elements of VaR systems. Overview of risk metrics such as expected shortfall and downside deviation. Stress testing and scenario analysis for portfolio risk assessment.
2	Overview of VaR estimation methods including delta-normal, historical simulation, and Monte Carlo approaches. Evaluation of full-valuation and local-valuation methods with practical examples of VaR applications. Extensions to volatility-based models such as GARCH and stochastic volatility modeling. Introduction to Extreme Value Theory (EVT) for modeling tail risk and rare events. Use of backtesting and validation procedures for model adequacy.
3	Hedging of linear and non-linear risks using derivatives. Optimal hedging and hedge ratios, duration and beta hedging, delta and dynamic hedging techniques. Credit risk concepts—exposure, default probability, and loss given default. Credit derivatives including credit default swaps and collateralized debt obligations. Measurement of credit VaR and introduction to credit risk models such as CreditMetrics and KMV. Basel accords and regulatory risk capital requirements.
4	Operational and enterprise risk management frameworks—identification, quantification, and control of operational risk. Risk-adjusted performance measurement using RAROC and economic capital allocation. Integration of market, credit, and operational risk for firm-wide risk assessment. Bayesian methods and network modeling of systemic risk. Machine learning and scenario-based approaches for risk forecasting and early warning systems.

Text Books:

1. Crouhy, M., Galai, D., & Mark, R. *The Essentials of Risk Management*. McGraw-Hill Education, 2014.
2. Jorion, P. *Value at Risk: The New Benchmark for Managing Financial Risk*. Wiley, 2007.
3. Iverson, D. *Strategic Risk Management: A Practical Guide to Portfolio Risk Management*. Wiley, 2013.
4. Chapman, R. J. *Simple Tools and Techniques for Enterprise Risk Management.* Wiley, 2006.
5. McNeil, A. J., Frey, R., & Embrechts, P. *Quantitative Risk Management: Concepts, Techniques and Tools*. Princeton University Press, 2015.

Financial Technology Services and Management

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221260	Financial Technology Services and Management	3	400	2-0-1-0

Course Outcomes	
CO1	Explain the evolution and structure of global banking and financial ecosystems, and distinguish between traditional and digital financial services.
CO2	Analyze digital transformation in finance through technologies such as digital payments, lending, insurance, blockchain, and cryptocurrencies.
CO3	Assess the role of RegTech, data strategy, and cybersecurity in ensuring compliance, risk management, and digital trust in financial systems.
CO4	Evaluate the use of artificial intelligence, big data, and digital business models in creating innovative and sustainable FinTech solutions.

Mapping of course outcomes with program outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	1	1	1
CO2	3	3	3	2	2	1
CO3	3	3	3	2	2	2
CO4	3	3	3	3	2	2

Module	Content
1	Introduction to banking, financial services, and FinTech – transformation of the global finance ecosystem – banks, FinTech companies, and digital startups – comparison of traditional banking and FinTech models – advantages and challenges in the financial landscape – key drivers of FinTech: technology, regulations, and digital innovation – FinTech typology and emerging sectors – collaboration between financial institutions and startups – trends driving FinTech adoption – opportunities and challenges in emerging economies.
2	Digital payments ecosystem – payment systems: SFMS, RTGS, NEFT, NDS, and mobile money platforms – regulation of digital and mobile payments – digital lending and digital insurance models – cryptocurrencies: meaning, regulation, and legal implications – blockchain technology: structure, consensus mechanisms, and smart contracts – applications of blockchain in banking, payments, and financial settlement – benefits and risks of distributed ledger technology in financial systems.
3	History of financial innovation and digitization – financial inclusion through digital finance – data-driven decision-making in finance – digital business models and new financial products – crowdfunding: rewards, charity, and equity models – peer-to-peer (P2P) and marketplace lending – initial coin offerings (ICOs) and tokenized finance – FinTech ecosystem development and emerging sectors – integration of big data and AI in alternative finance – technology types transforming the financial and banking industries.
4	Evolution and ecosystem of RegTech – compliance automation, regulatory sandboxes, and smart regulation – AI-based fraud detection and compliance analytics – data strategy in finance: governance, analytics, and data-driven models – GDPR, privacy, and data protection – digital identity management: from KYC to KYD – cybersecurity in finance: frameworks, threats, and mitigation strategies – AI governance and ethical AI systems – challenges of data regulation and algorithmic transparency – the future of secure and intelligent financial ecosystems.

Text Books:

1. Rubini, Agustin. FinTech in a Flash: Financial Technology Made Easy. Zaccheus, 3rd Edition, 2018.
2. J Chishti, Susanne, and Barberis, Janos. *The FinTech Book: The Financial Technology Handbook for Investors, Entrepreneurs and Visionaries*. John Wiley & Sons, 2016.
3. Nicoletti, Bernardo. *The Future of FinTech: Integrating Finance and Technology in Financial Services.* Palgrave Macmillan, 2018.

4. Lynn, Theo., Mooney, John G., Rosati, Pierangelo., and Cummins, Mark. *Disrupting Finance: FinTech and Strategy in the 21st Century*. Palgrave Macmillan, 2018.
5. Rafay, Abdul. *FinTech as a Disruptive Technology for Financial Institutions.* IGI Global, 2019.

Advanced Topics in the Semantic Web and Social Network Analysis

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221251	Advanced Topics in the Semantic Web and Social Network Analysis	3	500	1-1-0-1

Course Outcomes	
CO1	Explain the fundamental concepts of the Semantic Web and its evolution in applications; analyze social network principles and evaluate Social Network Analysis (SNA) for global and personal network insights.
CO2	Apply ontology-based knowledge representation techniques and Semantic Web languages to model social network data; develop ontological models and employ reasoning techniques for meaningful insights.
CO3	Design and implement advanced ontological models for network-based data representation; integrate Semantic Web technologies with social networks to develop applications and evaluate their scalability and integration challenges.
CO4	Identify and analyze community structures in social networks using archived web data; apply community detection algorithms, utilize tools for dynamic community characterization, and synthesize multi-relational data to understand community dynamics.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	2	1	1	2
CO2	2	2	2	2	1	2
CO3	3	2	2	2	1	2
CO4	2	1	1	2	2	3

Module	Content
1	Foundations of the Semantic Web and Social Networks • Overview of the Semantic Web and its relevance in modern data analysis. • Importance and technological adoption of the Semantic Web. • Introduction to Social Network Analysis: Key concepts, historical development, and global network structures. • Macro-structure of social networks, with a focus on analysing personal networks.
2	Ontology and Knowledge Representation for Social Data • Role of ontology in the Semantic Web; understanding ontology-based knowledge representation. • Semantic Web languages (RDF, OWL) and their applications in social network data modelling. • Ontological representation of social individuals and relationships. • Aggregation and reasoning over social network data for advanced knowledge inference.
3	Advanced Social-Semantic Applications and Modelling Techniques • Network-based data representation and ontological modeling for social individuals and relationships. • Techniques for aggregating and reasoning with social network data. • Building social-semantic applications: Integrating semantic web technology with social network features. • Developing semantic web applications with emphasis on scalability, data integration, and user engagement.
4	Community Detection and Dynamics in Social Networks • Community evolution and detection in archived web data. • Definitions, methods, and evaluation of community structures in social networks. • Techniques for mining community data and applications of community mining algorithms. • Tools for community detection, focusing on multi-relational and decentralized social networks. • Multi-relational dynamics and decentralized frameworks in modern online social network infrastructures.

References:

1. Social Network Analysis for Startups, Maksim Tsvetovat, Alexander Kouznetsov, O'Reilly Media, 2011.
2. Understanding Social Networks: Theories, Concepts, and Findings, Charles Kadushin, Oxford University Press, 2011.
3. Social Networks and the Semantic Web. Peter Mika, Springer Science and Business Media, 2007
4. Social Network Analysis: A Handbook by John P. Scott, 2000, Sage Publications Ltd

Advanced Geospatial Programming

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221252	Advanced Geospatial Programming	3	500	1-1-0-1

Course Outcomes	
CO1	Demonstrate proficiency in core Python geospatial libraries for effective data visualization and analysis.
CO2	Execute advanced raster and vector data processing using tools like GDAL and Rasterio.
CO3	Utilize Google Earth Engine (GEE) with Python to conduct large-scale geospatial and environmental analyses.
CO4	Develop custom plugins in QGIS, manage spatial databases with PostGIS, and integrate real-time spatial data.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	1	0	1
CO2	3	3	3	1	1	2
CO3	3	3	3	1	2	2
CO4	3	3	3	2	1	3

Module	Content
1	**Geospatial Libraries in Python** ● Geospatial libraries (e.g., Geopandas, Fiona, Shapely) ● Geospatial data visualization techniques Interactive geospatial data visualization with Plotly and Folium
2	**Raster and Vector Data Processing** ● Raster and vector data analysis workflows ● Raster data operations and analysis with Python (using modules such as Rasterio and GDAL) ● Satellite data processing and analysis techniques Vector data structures and operations, analysis using Python libraries (e.g., Pyproj, Geopandas)
3	**Google Earth Engine and Python for Geospatial Programming** ● Introduction to Google Earth Engine (GEE) and its Python API ● Accessing and processing large-scale satellite and geospatial datasets in GEE ● Developing workflows in GEE for environmental and geospatial applications Applications of GEE in land use/land cover analysis, climate studies, and resource management
4	**Advanced QGIS Python Programming and Spatial Databases** ● Python programming in QGIS and plugin development ● Spatial database management using PostgreSQL/PostGIS ● Integrating Python with PostGIS for advanced spatial data management Interfacing with real-time data: Retrieving and handling data from REST APIs

Course Project:

Each student will complete a project that applies advanced geospatial programming to a specific problem. Projects may include:

- Satellite and Remote Sensing Data Analysis: Developing Python scripts to analyze satellite data (e.g., land use classification, environmental monitoring).
- QGIS Plugin Development: Creating a custom plugin in QGIS for specialized spatial analysis or data visualization tasks.
- Automate Geoprocessing in GEE: Using satellite data develop workflows for geoprocessing
- Spatial Database Integration: Designing a Python-based solution that integrates PostGIS and QGIS for efficient spatial data management and retrieval.

References:

1. Python Geospatial Analysis Cookbook, Michael Diener

2. Mastering Geospatial Analysis with Python, Paul Crickard, Eric van Rees, Silas Toms

3. QGIS Python Programming Cookbook, Joel Lawhead

Spatial Data Analytics

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221253	Spatial Data Analytics	3	500	1-1-0-1

Course Outcomes	
CO1	Demonstrate the ability to analyze geographic distributions, point patterns, and spatial autocorrelation using methods like nearest neighbor, kernel density, and clustering.
CO2	Apply geostatistical techniques, including semi-variogram analysis and kriging, for effective spatial data interpolation and prediction.
CO3	Utilize machine learning approaches for spatial classification, regression, and object-based image analysis (OBIA).
CO4	Conduct advanced multidimensional spatial data analysis with 3D/4D visualization and dimensionality reduction for environmental and urban applications.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	1	2	1
CO2	3	2	2	1	1	1
CO3	3	2	2	2	1	2
CO4	3	3	3	1	2	1

Module	Content

1	**Geographic Distributions and Point Pattern Analysis** ● Analyzing Geographic Distributions, Point Pattern Analysis ● Spatial Processes, Complete Spatial Randomness ● First- and Second-Order Effects in Spatial Data ● Nearest Neighbor Analysis, Ripley's K Function, L Function Transformation ● Kernel Density Estimation
2	**Spatial Autocorrelation and Clustering** ● Global and Local Spatial Autocorrelation ● Optimized Hot Spot Analysis ● Cluster Analysis: Hierarchical Clustering, k-Means, Density-Based Clustering ● Spatial Regression Techniques
3	**Advanced Geostatistical and Machine Learning Methods** ● Semi-variogram Analysis, Isotropic and Anisotropic Models ● Kriging Techniques: Ordinary, Simple, Indicator, and Cokriging ● Machine Learning in Spatial Data: Classification and Regression, OBIA ● Predictive Modeling in Spatial Analysis
4	**Multidimensional Spatial Data Analysis** ● Methods for visualizing complex spatial datasets in 3D and 4D (space-time) contexts ● Principal Component Analysis (PCA), and other methods for reducing complexity while preserving spatial relationships ● Urban change detection, environmental monitoring, precision agriculture, and ecosystem modeling

Course Project:

Each student will complete a project applying spatial data analysis techniques to a selected geospatial problem. Topics may include:

- Spatial Regression or Machine Learning: Implement spatial regression or machine learning algorithms to address a defined geospatial issue.
- Geostatistical Analytics: Conduct a geostatistical analysis, such as Kriging, on environmental or urban datasets to assess spatial patterns.
- Predictive Modeling: Develop a predictive model using spatial data for applications like land cover classification or urban planning.

References:

1. Data Engineering with Python" by Paul Crickard, Packt Publishing, 2020
2. "Data Engineering with Apache Spark, Delta Lake, and Lakehouse" by Manoj Kukreja, Danil Zburivsky, Packt Publishing, 2021
3. "Designing Data-Intensive Applications: The Big Ideas Behind Reliable, Scalable, and Maintainable Systems" by Martin Kleppmann, 2017
4. "Fundamentals of Data Engineering" by Joe Reis, Matt Housley, O'Reilly Media, Inc., 2022

Web and Mobile GIS

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221254	Web and Mobile GIS	3	500	1-1-0-1

Course Outcomes	
CO1	Analyze complex Web GIS and Mobile GIS architectures, including client-server models and OGC standards
CO2	Critically evaluate geospatial data interoperability and assess their impact on seamless data sharing and integration across GIS platforms.
CO3	Design and develop advanced, interactive web mapping applications
CO4	Implement and optimize mobile GIS workflows and integration with web-based GIS systems

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	3	1
CO2	3	2	3	2	1	2
CO3	3	3	2	3	2	1
CO4	2	2	1	3	3	2

Module	Content
1	**Advanced Web GIS and Enterprise GIS Architecture** ● Client-Server Computing: Advanced Architecture and Deployment ● File Transfer Models and Protocols for GIS Data ● Open Geospatial Consortium (OGC) Standards: WMS, WFS, WCS, WPS ● Interoperable vs. Non-Interoperable Systems and Data Exchange Standards (e.g., GML, GeoJSON)
2	**GeoServer and Leaflet for Web GIS**

	● Advanced Configuration and Installation of GeoServer ● Handling and Publishing Vector and Raster Data with GeoServer ● Geoprocessing Operations and Scripting in GeoServer ● Advanced Styling Techniques and Thematic Mapping for Web Maps ● Developing Interactive Web Maps with Leaflet: Customization, Plugins, and User Interaction
3	**GoeNode for Web GIS** ● Configuration and deployment of GeoNode for Web GIS infrastructure ● Manage and Publish Geospatial Data with GeoNode. ● Implement Geospatial Standards for Data Interoperability in GeoNode ● Create and Customize GeoNode for Collaborative Data Sharing and Visualization. ● Integrate GeoNode with Mobile GIS and Field Data Collection Systems
4	**Mobile GIS and Field Data Collection** ● Architecture and Application in Field Data Collection ● Mobile GIS Tools: Survey123, QField, and Locus Map ● Integration of Mobile GIS with Web GIS Systems ● Data Synchronization and Real-Time Data Collection for Field Applications ● Case Studies: Applications in Environmental Monitoring, Urban Planning, and Disaster Management

Course Project:

Students will undertake a project or thesis focusing on an advanced topic in Web or Mobile GIS.

Potential topics include:

- Development of an interactive mobile GIS solution for field data collection.
- Implementation of a Web GIS platform for real-time environmental monitoring.
- Case study on data synchronization and integration between Web GIS and Mobile GIS.

References:

1. Fu, P., & Wang, J. (2011). Web GIS: Principles and Applications. Esri Press.
2. Chasco, R. G. (2008). Enterprise GIS: Spatial Data Infrastructure Design and Implementation.
3. Moore, J., & Aiken, S. (2018). GeoServer Beginner's Guide: A Practical Guide to Building Geospatial Web Services with GeoServer.
4. Kiesling, S. (2016). Mastering Leaflet: A Hands-on Guide to Building Interactive Web Maps with Leaflet.js.
5. Gómez, S., & Hernández, E. (2015). GeoNode Beginner's Guide: A Practical Guide to Build and Deploy GeoNode for Collaborative Geospatial Data Sharing.
6. Giraud, F. (2016). GeoNode Essentials: Build a Collaborative Geospatial Data Infrastructure with GeoNode.
7. Zhou, X., & Zhang, L. (2015). Mobile GIS: A Handbook for Developers. CRC Press.
8. Brovelli, M. A., Zamboni, G., & Minghini, M. (2017). Mobile Mapping and GIS: Field Data Collection and Management.

Computer-Aided Drug Design

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221255	Computer-Aided Drug Design	3	500	1-1-0-1

Course Outcomes	
CO1	Demonstrate an in-depth understanding of the fundamentals of drug discovery.
CO2	Apply cheminformatics and data analysis methods effectively in drug research.
CO3	Utilize computational chemistry to predict molecular structures and explore drug-target interactions.
CO4	Conduct an independent research project using machine learning and computational tools to identify and evaluate potential drug candidates.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	1	1	1
CO2	3	3	2	1	2	2
CO3	3	3	2	1	2	2
CO4	3	3	3	2	3	3

Module	Content
1	Stages in the drug discovery process and associated challenges, classification of drugs and drug targets, enzyme kinetics, pharmacokinetics (ADME/T), pharmacodynamics, and drug-receptor interactions. *Research Focus:* Literature review on drug classification and advancements in ADME/T properties.
2	Computational Methods in Drug Design: structure-based, ligand-based, and de novo drug design, molecular docking, molecular dynamics, pharmacophore mapping, Quantitative Structure–Activity Relationship (QSAR), Quantitative

	Structure–Property Relationship (QSPR), fragment-based drug design, lead optimization, retrosynthetic approaches. *Research Focus:* Project using pharmacophore modeling or molecular docking/dynamics simulations.
3	Role of cheminformatics in drug discovery, molecular descriptors and fingerprints, machine learning approaches in drug design, ADME/T databases, chemical, biochemical, pharmaceutical databases, data mining, and visualization. *Research Focus:* Database creation and data mining using cheminformatics databases (e.g., SMILES, PDB).
4	Computational chemistry in drug design: Classical mechanics vs quantum mechanics, potential energy surfaces: stationary and saddle points, energy minimization, basis sets, Slater type orbitals (STO) and Gaussian type orbitals (GTO), ab initio methods, semi-empirical approaches, and Density Functional theory (DFT). *Research Focus:* Computational analysis of a bioactive molecule using DFT.

Assessment Components:

Research Project (40%): Conduct an individual research project or case study focusing on innovative drug discovery or design methodologies. Deliverables include a report and presentation.

Lab Work (20%): Practical exercises in molecular modeling, docking, and cheminformatics.

Seminar (10%): Each student will present a selected paper or topic in a seminar format, discussing recent advancements in drug design.

Written Exam (30%): Comprehensive exam covering theoretical concepts and practical applications.

Textbooks & References:

1. Rudrapal, M., & Egbuna, C. (Eds.). (2022). Computer aided drug design (CADD): From ligand-based methods to structure-based approaches (1st ed.). Elsevier. ISBN 9780323906081
2. Voit, E. (2017). A first course in systems biology (2nd ed.). Garland Science. ISBN 9780815344674
3. Heifetz, A. (Ed.). (2022). Artificial intelligence in drug design (1st ed.). Springer US: Humana. ISBN 9781071617892
4. Gasteiger, J., & Engel, T. (2003). Chemoinformatics: A textbook. Wiley-VCH. ISBN 9783527306817
5. Wermuth, C. G., Aldous, D., Raboisson, P., & Rognan, D. (Eds.). (2015). The practice of medicinal chemistry (4th ed.). Academic Press. ISBN 9780124172050

Data Security

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221256	Data Security	3	500	1-1-0-1

Course Outcomes	
CO1	Analyze and apply advanced threat modeling and cryptographic techniques
CO2	Design and implement comprehensive data storage, transmission, and lifecycle management strategies
CO3	Evaluate and apply secure software engineering principles and resilient network defenses
CO4	Handle data breaches, assess compliance frameworks, and adapt to new data security technologies.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	2	3	1
CO2	3	3	2	2	3	2
CO3	2	2	3	2	3	2
CO4	3	3	2	2	3	2

Module	Content
1	Data Security Frameworks and Sensitive Data - Types of sensitive data: personal, financial, healthcare, intellectual property, etc., Advanced classifications of sensitive data (e.g., genomic, biometric), standards for handling and protecting data types (e.g., NIST, ISO standards). Threat Modeling and Risk Analysis: In-depth examination of modern threats, including zero-day vulnerabilities, Advanced Persistent Threats (APTs), and social engineering tactics. Cryptographic Principles and Applications: cryptography and its role in data security, Symmetric vs.

	asymmetric encryption, Hash functions, digital signatures, and encryption algorithms, Access Control Mechanisms: Role-based access control (RBAC) and its implementation, Mandatory and discretionary access control, Multi-factor authentication (MFA) and its significance.
2	Secure Data Handling and Storage - Secure Data Storage: Encryption of data at rest: full disk encryption, database encryption, Data masking and tokenization techniques, Secure storage solutions: cloud storage security, on-premises storage best practices, Secure Data Transmission: Transport Layer Security (TLS) and Secure Sockets Layer (SSL), VPNs (Virtual Private Networks) for secure remote access, Secure file transfer protocols: SFTP, SCP, HTTPS, Data Lifecycle and Retention Management: Developing organization-wide retention and disposal policies, automated secure deletion protocols, data retention in high-compliance sectors, and modern challenges of digital footprints. Creation and management of robust disaster recovery frameworks, real-world applications, and testing in cloud-native and hybrid environments.
3	Network Defense and Cyber-Resilience - Zero-trust architecture, network segmentation, and advanced IDS/IPS with machine learning for threat detection. Secure Software Engineering Practices: Integration of security within SDLC (e.g., DevSecOps), application of formal security models, code review automation, and secure API development. Advanced Web and Mobile Security: In-depth approaches to counteract web and mobile vulnerabilities (e.g., RCE, server-side request forgery), security frameworks for mobile/IoT, and secure handling of distributed systems. Emerging Technologies in Network Security: Practical applications of AI/ML in threat detection, blockchain for decentralized security, and quantum computing impacts on network defenses.
4	Strategic Incident Response and Crisis Management: Advanced incident response planning, forensic tools, and stakeholder communication for high-impact data breaches, with focus on recovery metrics and continuous improvement. Data Breach Response and Forensics: Advanced breach containment strategies, digital forensics in varied sectors, and managing legal considerations in evidence handling. Compliance and Governance in Global Data Security: Exploration of complex compliance environments (e.g., GDPR, HIPAA, CCPA in cross-border data flows), security audit practices, and continuous compliance monitoring systems. Innovations and Future Trends in Data Security: AI-driven security automation, blockchain for identity management, quantum-safe algorithms, and adaptive security strategies for emerging threats in cyber-physical systems.

References:

1. "Data and Goliath: The Hidden Battles to Collect Your Data and Control Your World" by Bruce Schneier
2. "Cryptography and Network Security: Principles and Practice" by William Stallings.
3. "Web Application Security: A Beginner's Guide" by Bryan Sullivan and Vincent Liu.
4. "The Practice of Network Security Monitoring: Understanding Incident Detection and Response" by Richard Bejtlich.

Parallel and GPU Computing

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221257	Parallel and GPU Computing	3	500	1-1-0-1

Course Outcomes	
CO1	Comprehensive Understanding of High-Performance Computing (HPC) Foundations.
CO2	Proficiency in Parallel Programming Models and Techniques.
CO3	Mastery of GPU Computing and Acceleration.
CO4	Expertise in Programme Execution Analysis and Concurrent Programming.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	0	1	0	0
CO2	3	2	1	1	0	0
CO3	3	2	1	1	0	0
CO4	3	3	0	0	0	2

Module	Content
1	HPC Introduction, Architecture of a supercomputer and the performance comparisons. Flynn’s taxonomy, vector and pipelining, Single instruction, Multiple

	data array, Multiprocessors: Shared – Memory processors, Massively parallel processors, Heterogeneous computer Structures. Importance of HPC Benchmark, Resource management in HPC, Amdahl's law, Processor Core Architecture, Memory hierarchy
2	OpenMP programming model: Thread parallelism, Thread variables, Synchronization, Reduction, Message-Passing Interface (MPI) MPI standards, Communicators, Point-to Point messages, Synchronization collectives, Parallel Algorithms: Fork-Join, Divide-Conquer, Manager-Worker, Embarrassingly parallel Importance of Checkpointing in HPC
3	GPU Architecture, CPU / GPU comparisons, CUDA Standard, Kernels and host-device communication, shared and constant memory, CUDA OpenCL / OpenACC, Kernels Launch parameters, GPU coding restrictions
4	Programme Execution Time: Flow of time, process scheduling, measuring time by interval counting operation, reading the processor timers, accuracy of processor timers, programme execution time with cycle counter. Concurrent programming with processes, Concurrent programme with Threads

References:

1. Sterling, Thomas, Maciej Brodowicz, and Matthew Anderson. High performance computing: modern systems and practices. Morgan Kaufmann, 2017.
2. Michael J Quinn. Parallel programming in C with MPI and OpenMP. Tata McGraw Hill, 2003.
3. Kai Hwang, Naresh Jotwani. Advanced Computer Architecture: Parallelism, Scalability, Programmemability, 2nd edition. Mcgraw-Hill Education, 2008.
4. Brian Tuomanen. Hands-On GPU Programming with Python and CUDA: Explore high-performance parallel computing with CUDE. Packt Publishing, 2018.

Computational Linear Algebra

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221258	Computational Linear Algebra	3	500	1-1-0-1

Course Outcomes	
CO1	Analyze matrix theory concepts such as rank, vector spaces, matrix norms, and condition numbers, and evaluate their impact on numerical stability and algorithm accuracy.

CO2	Design and implement efficient algorithms using LU factorization, sparse matrix methods, and block matrix multiplication for large-scale linear systems.
CO3	Apply L1/L2 regularization techniques and regression models (including polynomial features and compressed sensing) to solve noisy and ill-posed problems.
CO4	Compare full vs reduced matrix factorizations and evaluate algorithmic performance with respect to memory, speed, and parallel computation strategies.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	0	0	0
CO2	2	3	2	3	2	0
CO3	2	3	3	2	3	1
CO4	2	2	3	3	2	1

Module	**Content**
1	Overview of basics of matrix theory, rank of matrix, vector space, linear dependence, matrix norms, condition number and stability of numerical algorithms Machine epsilon, catastrophic cancellation, and the limits of computer accuracy, Singular Value Decomposition (SVD) and Non-negative Matrix Factorization (NMF), Modeling on large text datasets using Truncated SVD and Randomized SVD.
2	The mathematical difference between the L1 Norm and L2 Norm, and why the L1 penalty induces sparse solutions. Robust Principal Component Analysis (PCA): Separating sparse noise from low-rank matrices.
3	Block Matrix Multiplication, Sparse matrices, CT Scans and Compressed Sensing, L1 and L2 regression, Polynomial Features, Reconstructing CT Scans and medical images using L1 robust regression.
4	Regression and Noise: Solving the Normal Equations. Handling non-linear data with Polynomial Features. Regularization techniques to prevent overfitting. Timing Comparison, PageRank and Markov Chains: How search engines rank billions of nodes using sparse graphs. Conditioning and Stability, Full vs Reduced Factorizations, symbolic regression Under the Hood of Eigen Solvers: Schur Factorization and the QR Algorithm (how libraries like SciPy actually compute eigenvalues).

References:

1. Numerical Linear Algebra, Lloyd N. Trefethen and David Bau, III
2. Numerical Linear Algebra, Grégoire Allaire , Sidi Mahmoud Kaber
3. Numerical Linear Algebra: An Introduction, Cambridge university Press, Holger Wendlend

Anomaly Detection and Fraud Analytics

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221351	Anomaly detection and Fraud Analytics	3	500	1-1-0-1

Course Outcomes	
CO1	Foundations of Anomaly Detection
CO2	Anomaly Detection Algorithms and Techniques
CO3	Fraud Detection and Analytics
CO4	Machine Learning for Fraud Detection

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	1	2
CO2	2	2	2	2	1	2
CO3	3	2	2	2	1	2
CO4	2	1	1	2	1	2
CO5	3	3	2	1	1	2

Module	Content
1	Introduction to anomalies, Data pre-processing for anomaly detection, Types of anomalies, Benefits and limitations of anomaly detection. Anomaly detection algorithms

	Statistical methods: Z-score; Interquartile range (IQR), Mean absolute deviation (MAD)Tukey's fences, Robust covariance estimation
2	Machine learning methods: Isolation forest, Local outlier factor (LOF), One-class support vector machine (OCSVM), Gaussian mixture model, One-class Support Vector Machines (OCSVM), Autoencoders; Time Series Anomaly Detection: Moving averages, Exponential Smoothing.Seasonal decomposition and trend analysis. Techniques like ARIMA, LSTM for time series anomalies. Dealing with concept drift and evolving anomalies. Anomaly detection in high-dimensional data. Handling noisy data and false positives/negatives.
3	Introduction to fraud analytics; Types of fraud; Benefits and limitations of fraud analytics. Exploratory Data Analysis for Fraud Detection; Profiling data to identify patterns, trends, and anomalies. Unsupervised Anomaly Detection for Fraud: Using clustering techniques (K-Means, DBSCAN) to identify unusual patterns.Local Outlier Factor (LOF) and other proximity-based methods..
4	Model-Based Fraud Detection: Applying logistic regression and decision trees for fraud prediction. Ensemble methods (Random Forest, Gradient Boosting) for improved accuracy. Network Analysis for Fraud Detection, Building and analyzing graphs to identify unusual connections. Centrality measures and community detection. Time Series Analysis for Fraud Detection

References:

1. Anomaly Detection Principles and Algorithms, By Kishan G. Mehrotra, Chilukuri K. Mohan, HuaMing Huang · 2017
2. Practical Machine Learning: A New Look at Anomaly Detection books.google.co.in › books Ted Dunning, Ellen Friedman · 2014
3.Anomaly Detection: Techniques and Applications, Saira Banu · 2021

Healthcare Analytics

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221353	Healthcare Analytics	3	500	1-1-0-1

Course Outcomes

CO1	Analyze and integrate heterogeneous healthcare data (EHR, registries, sensor streams) with privacy and compliance constraints.
CO2	Design and implement reproducible ETL pipelines and basic MLOps workflows for healthcare datasets.
CO3	Develop, validate, and calibrate predictive models and Clinical Decision Support tools using advanced statistical and machine-learning methods.
CO4	Apply multimodal ML analytics to medical images, physiological signals, and clinical text, and present findings via interactive dashboards.

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	1	3
CO2	2	2	1	3	3	2
CO3	1	2	3	3	2	1
CO4	3	2	2	1	2	2

Module	**Content**
1	**Theory:** Overview of healthcare data sources and formats; Privacy and security frameworks (HIPAA/GDPR), de-identification techniques; Data preprocessing and cleaning (missing-value imputation, normalization, outlier detection); Exploratory data analysis and visualization using Python (pandas, matplotlib, seaborn) **Lab:** Use pandas to ingest a sample EHR (FHIR) dataset; implement de-identification and basic cleaning; conduct EDA with matplotlib/seaborn to generate summary statistics and charts highlighting data quality issues
2	**Healthcare Information Systems & EHR Analytics** **Theory:** EHR structure and challenges; FHIR queries and data models; SQL basics for querying clinical databases; Healthcare coding standards (ICD-10, CPT); Sensor and wearable time-series data (ECG/PPG) and filtering techniques; Indian case studies in remote patient monitoring and early warning scores (e.g., NEWS2) **Lab:** Query a de-identified EHR dataset (CSV/SQLite) using SQL (via pandas) to extract patient cohorts and compute aggregate statistics; load a sample ECG time-series, apply noise filters in NumPy, detect R-peaks, compute heart-rate variability, and visualize the cleaned signal

3	**Predictive Analytics & Clinical Decision Support** **Theory:** Supervised ML workflows for healthcare (scikit-learn): logistic regression, decision trees, random forests, XGBoost; Feature engineering and selection for high-dimensional EHR data; Model evaluation metrics (confusion matrix, ROC-AUC, precision/recall) and handling class imbalance; Survival analysis overview (Kaplan–Meier, Cox models); Model interpretability (SHAP, LIME) and bias/fairness considerations; Designing a simple CDS prototype using Streamlit; Ethical and regulatory considerations in healthcare AI **Lab:** Train and evaluate a classification model (e.g., logistic regression) on a healthcare dataset using scikit-learn; apply SHAP to interpret model outputs and plot feature importance; prototype a Streamlit-based CDS app that takes patient inputs and displays a risk score plus explanation
4	**Advanced Analytics – NLP & Image Processing** **Theory:** Clinical NLP tasks: tokenization, named-entity recognition (spaCy/scispaCy), mapping to UMLS; Text summarization and information extraction from discharge summaries; Basic medical image processing (grayscale conversion, filtering, edge detection) using scikit-image/OpenCV; Applying pre-trained CNNs (e.g., ResNet) for X-ray image classification on CPU; Evaluating image models (accuracy, sensitivity, specificity); Multimodal fusion concepts: combining EHR, text, and image outputs; Dashboard design principles for presenting multimodal insights **Lab:** Build an NLP pipeline in spaCy to extract medical entities (diseases, medications) from sample clinical notes; load a small set of de-identified X-ray images, apply a pre-trained CNN for classification (e.g., pneumonia vs. normal), and report performance metrics; develop an interactive Streamlit dashboard showcasing EDA plots, NLP outputs, and image classification results for stakeholder review
Project	Develop a practical analytics solution for an healthcare problem (e.g., readmission prediction, clinic operations, or clinical text insights).

References:

1. Strome, T. L., *Healthcare Analytics for Quality and Performance Improvement*, Wiley, 2013.
2. Berner, E. S. (Ed.), *Clinical Decision Support Systems: Theory and Practice*, Springer, 2007.
3. Kelleher, B. D., Mac Namee, B. & D'Arcy, A., *Machine Learning and Healthcare Analytics*, MIT Press, 2020.
4. Dhawan, A. P. & Suri, J. S., *Medical Image Analysis*, IEEE Press/Wiley, 2011.

5. Bansal, A., Raman, K. & Agarwal, S., *Natural Language Processing for Health and Life Sciences*, Packt Publishing, 2021.

Advanced Programming

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221354	Advanced Programming	3	500	1-1-0-1

Course Outcomes	
CO1	Advanced OOP features
CO2	Lambda expressions, Error Handling, Multi threading
CO3	Web API's
CO4	Python coding standards and quality checking

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	2	1	2	1
CO2	2	3	2	1	1	1
CO3	2	2	1	2	1	2
CO4	2	3	2	1	2	1

Module	Content
1	Advanced OOP features of Python, Inheritance, Multiple Inheritance, Polymorphism, Object Introspection, Dunder Methods, Method Resolution Order, Practice with Objects, and Extending Lists.
2	Lambda Expressions, List Comprehensions, Set and Dictionary Comprehension, Decorators, Multiple Decorators, Magic Methods, Collections, Higher Order Functions, Error Handling in Python, Generators, Practice with decorators, and Error Handling, Multi-threading.

3	Web APIs, Integration of Web APIs in modules, Request and Response, Status Codes, Custom Headers, Authentication of an API, API Keys, Practices on Visualization of data from a Web API to a web application module, Web Scrapping.
4	Python coding standards and best practices for code quality, Development Cycle, Flask Restful APIs, API Module development with MongoDB, Unit testing, Practices on writing Unit Tests with unit testing frameworks, and introduction to automation testing with Selenium and Python.

References:

1. Steven F Lott, Mastering Object-Oriented Python, second edition, Packt publishing, 2019.
2. Charles Dierbach, "Introduction to Computer Science Using Python: A Computational Problem- Solving Focus", Wiley, 2017.
3. Ashok Namdev Kamthane, Amit Ashok Kamthane, "Programming and Problem Solving with Python", McGraw Hill Education, 2018.

Thermal and Hyperspectral Remote Sensing

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221355	Thermal and Hyperspectral remote sensing	3	500	1-0-1-1

Course Outcomes	
CO1	Explain various concepts of thermal and hyperspectral remote sensing
CO2	Understand Thermal and hyperspectral data products
CO3	Gain knowledge in thermal and hyperspectral image analysis
CO4	Understand various application domains of thermal and hyperspectral data product

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	1	0	0
CO2	3	2	2	0	0	1
CO3	3	3	2	1	1	2
CO4	3	3	3	2	1	2

Module	Content
1	**Fundamentals of Thermal Remote Sensing** • Thermal Radiation Principles and Processes • Thermal Properties of Surfaces and Terrain Elements • Characteristics of Thermal Infrared (IR) Images • Factors Affecting Thermal Image Acquisition and Quality • Interaction of Thermal Radiation with Surface Features • Thermal Sensors and Their Characteristics • MUST (Medium Scale Surface Temperature) Missions
2	**Fundamentals of Hyperspectral Remote Sensing** • Spectroscopy and Hyperspectral Data Representation • The Spectral Data Cube: Structure and Interpretation • Airborne and Spaceborne Hyperspectral Sensors • Hughes Phenomenon and its Implications • Multivariate Analysis for Dimensionality Reduction • Hyperspectral Image Compression Techniques • Spectral Libraries for Material Identification
3	**Thermal Image Analysis** • Types and Formats of Thermal Remote Sensing Data Products • Interpretation of Thermal Images: Day vs Night Imaging • Land Surface Temperature (LST) Retrieval Techniques **Hyperspectral Image Analysis** • Calibration and Normalization of Hyperspectral Images • Spectral Signature Analysis and Matching with Spectral Libraries • Spectral Mapping Techniques: Spectral Angle Mapper (SAM), Spectral Correlation Mapper (SCM), Spectral Feature Fitting (SFF), Linear Spectral Unmixing (LSU)
4	**Applications of Thermal and Hyperspectral Remote Sensing** • Applications of Thermal Remote Sensing: Crop Health Monitoring, Pollution and Urban Heat Island Monitoring, Oil Spill Detection, and Land Surface Temperature (LST) Monitoring • Applications of Hyperspectral Remote Sensing: Agriculture (Crop Type & Stress Detection), Soil Mapping and Analysis, Forestry (Species Classification and Health Monitoring), and Environmental Monitoring and Resource Management

Course Project
Each student will complete a project utilizing thermal or hyperspectral remote sensing techniques for real-world applications. Topics may include: • Urban Heat Mapping using thermal satellite data • Hyperspectral Crop Stress Detection • Pollution Monitoring in Coastal Waters • Hyperspectral Classification for Soil or Forest Types • LST Variability Mapping for Climate Studies

References:

1. Dale A Quattarochi and Jeffrey C Luvall, "Thermal Remote Sensing in Land surface Processes" e- book, 2005 Taylor andFancis, ISBN 0 203 50217 5.
2. John A. Richards and XiupingJia, "Remote sensing digital Image Analysis – an introduction" fifth edition, Springer Verlag., 2012 ISBN 978 3 642 30061 5.
3. Chein I Chang, "Hyperspectral Imaging: Techniques for Spectral Detection and Page | 84 Classification", Kluwer Academic/Plenum Publishers, New York, N.Y., 2003. (ISBN: 0-306-47483-2).
4. Marcus Borengasser and William C., Hungate and Russel Watkins Hyper spectral Remote sensing: principles and application" CRC, 2008, ISBN 13: 9781566706544.
5. Chein I Chang, "Hyperspectral Data Exploitation: Theory and Applications, Wiley Inter Science, 2006 (ISBN: 9780470124628).
6. Liguo Wang and Chunhui Zhao., Hyperspectral Image Processing, Springer, 2016.
7. Michael T, Eismann., Hyperspectral Remote Sensing, SPIE press, USA, 2012.

Topographic Data Analysis Techniques and Applications

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221356	Topographic Data Analysis Techniques and Applications	3	500	1-1-0-1

Course Outcomes	
CO1	Understand the concepts of Elevation data products.
CO2	Able to perform Topographic Analysis from DEM
CO3	Volumetric and Bathymetric Analysis from DEM
CO4	Understand the applications of DEM in real-world problems

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	1	0	0
CO2	3	3	2	1	1	1
CO3	3	3	3	1	1	1
CO4	3	3	3	2	1	1

Module	Content
1	**Digital Elevation Models: Principles and Data Sources** • Fundamentals of Digital Elevation Models (DEM) and Digital Surface Models (DSM) • Terrain Visualization Techniques • Methods of Representing DEMs: Image-based Methods and Point Models • Data Sources for DEMs: Satellite-based Elevation Data (e.g., SRTM, ASTER), UAV/Drone-based DSM Extraction, and LiDAR-derived Elevation Models
2	**Topographic and Terrain Analysis Techniques** • Contour Generation and Interpretation • Slope and Aspect Analysis • Hillshade Modeling for Terrain Visualization • Viewshed and Line-of-Sight Analysis
3	**Volumetric and Bathymetric Analysis Techniques** • Volumetric Computation Methods • Cut and Fill Analysis for Terrain Modification Studies • Bathymetric Analysis and Estimation Techniques • Reservoir Volume Calculation and Monitoring
4	**Geospatial Applications of Digital Elevation Models (DEMs)** • Water Resource Management: Hydrological Modelling and Watershed Delineation • Disaster Risk Management: Flood Modeling and Hazard Zonation, and Landslide Susceptibility Mapping • Infrastructure Planning and Development: Route Alignment, and Site Suitability Analysis using DEMs
Course Project	

Each student will complete a project applying DEM-based analysis for real-world environmental or infrastructure challenges. Students may choose from topics such as: • Flood Hazard Mapping: Using DEMs to model inundation areas and drainage paths. • Landslide Risk Assessment: Terrain analysis using slope, aspect, and landform features. • Infrastructure Corridor Planning: Optimal path analysis using DEM for roads or pipelines. • Reservoir Capacity Estimation: 3D modeling of reservoirs using elevation and bathymetric data.
References: 1. Christopher Zhu, Chris Golc, Zhi Lin Li, Digital Terrain Modelling - Principles and Methodology, 2004, CRC Press, ISBN - 9780415324625. 2. John p Wilson, John C Gallant, Terrain Analysis, Principles and Applications, 2000, ISBN - 978-0- 471-32188-0

Spatial Bigdata Analytics

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221357	Spatial Bigdata Analytics	3	500	1-1-0-1

Course Outcomes	
CO1	Analyze the characteristics, challenges, and applications of spatial big data frameworks.
CO2	Design efficient workflows for spatial data cleaning, wrangling, partitioning, and storage.
CO3	Apply machine learning algorithms in the context of spatial big data for real-world problem-solving.
CO4	Evaluate the societal, environmental, and economic impacts of spatial big data through case studies.

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	3	1
CO2	3	2	3	2	1	2
CO3	3	3	2	3	2	1
CO4	2	2	1	3	3	2

Module	**Content**
1	Introduction to big data computing for geospatial applications: Spatially referenced big data, Map-reduce based problems in geospatial big data, societal applications and challenges, Apache Spark vs Apache Sedona
2	Spatial big data, Data cleaning in spatial big data Challenges in using the big data in spatial technologies, Databases supporting spatial data – Postgres-based spatial data storage, Real-time query engine, workflow Data partitioning and storage.
3	Spatial data wrangling with Apache Sedona values in spatial big data, visualizations, Decision support systems using spatial big data: Data intelligence, Machine learning with spatial big data. Common algorithms such as association rule of mining, clustering and classification rule etc in geospatial context
4	Case studies with spatial big data in 1. Societal applications 2. Environment and economics 3. Agriculture 4. Distaster Management

Course Project:

Students will undertake a project or thesis focusing on an advanced topic in Spatial Bigdata Analytics. Potential topics include:

- Create a big data architecture that incorporates social media inputs, GPS data, and real-time traffic sensor feeds to identify patterns of congestion and enable dynamic route optimization.
- Construct a spatial data lake that receives citizen-reported geodata and satellite data for combined analysis and display.

- Develop a hybrid edge-cloud system that analyzes sensor data and high-resolution UAV pictures to quickly identify changes in disaster-affected areas.

References:

1. Chaowei, Yang et al; Introduction to GIS Programming and Fundamentals with Python and ArcGIS : CRC Press.
2. Aurelia Moser, Jon Bruner, Bill Day; Geospatial Data and Analysis; O'Reilly Media, Inc.
3. Zhe Jiang, Shashi Shekhar Spatial Big Data Science: Classification Techniques for Earth Observation Imagery Hardcover
4. Hassan A Karimi,: Big Data Technologies in Geoinformatics
5. Sandya Ryza, Uri Laserson, Sean Owen, Josh Wills: Advanced Analytics with Spark: Patterns for Learning from Data at scale
6. Ramcharan Kakarla, Sundar Krishnan, Sridhar Alla: Applied Data Science Using PySpark, Apress
7. Scott Bateman, Janahan Gnanachandran, Jeff Demuth: Geospatial Data Analytics on AWS, Packt

Geospatial Applications in Agriculture

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221358	Geospatial Applications in Agriculture	3	500	1-1-0-1

Course Outcomes	
CO1	Evaluate and integrate concepts of agricultural science with geospatial technology to develop a systems-level understanding.
CO2	Critically analyze GIS and Remote Sensing (RS) methodologies for agricultural applications
CO3	Design and develop geospatial models to solve real-world agricultural problems.
CO4	Apply remote sensing and GIS techniques for crop health assessment and effectively communicate results to diverse audiences.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	3	1
CO2	3	2	1	3	1	3
CO3	3	3	2	3	2	1
CO4	2	2	1	2	1	2

Module	**Content**
1	Introduction to Crop Types, Cropping Patterns, and Cropping Seasons; Agricultural practices of major crops including various stages of crop cultivation. Crop yield monitoring and condition assessment techniques. Identification and monitoring of important insects and pest infections affecting major crops. Overview of Precision Agriculture concepts and technologies.
2	Applications of GIS and Remote Sensing in Agriculture: Various techniques overview. Spectral characteristics and structure of leaves. Vegetation indices including NDVI, SAVI, PCA, TVI; vegetation classification and mapping. Estimation of Leaf Area Index and biomass. Remote sensing-based detection of pests and diseases.
3	Spectral behaviour of crops and vegetation across VIS, NIR, MIR, TIR, and Microwave regions. Microwave backscattering from crop canopy for crop identification and inventory. Crop acreage estimation techniques. Reflectance properties of stressed crops and detection of stressed plants. Land Use and Land Cover (LULC) analysis using remote sensing data.
4	Digital Soil Mapping fundamentals. Application of Machine Learning and Deep Learning for soil nutrient prediction, crop disease classification, and crop yield prediction models. Development of geospatial decision support systems using AI.

Course Project:

- Students will undertake a project or thesis focusing on an advanced topic in Applications in Agriculture. Potential topics include:
- Spatial analysis of pest and disease outbreaks in a specific crop using historical data and remote sensing.
- Biomass and Leaf Area Index (LAI) estimation for a selected crop using remote sensing data.
- Machine learning-based prediction of soil nutrient levels and spatial variability mapping.

References:

1. Christy Nirmala Mary, P. Kannan, Geospatial Technologies for Agriculture, 2020

2. Kaushik Bhagowati, GIS Assisted Farm Management Information System, 2012 3. V. M. Abdul Hakkim, GIS Integrated Site-Specific Drip Fertigation, 2013 4. Thenkabail, P. S., Remote Sensing of Global Croplands for Food Security, CRC Press 5. Li, J. & Heap, A. D. (2014). A Review of Spatial Interpolation Methods for Environmental Scientists, CSIRO

Geospatial Applications for Environment and Climate Change

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221359	Geospatial Applications for Environment and Climate change	3	500	2-0-0-1

Course Outcomes	
CO1	Understanding the basic aspects of Environmental GIS.
CO2	Able to apply GIS to a range of problems within the environmental sciences
CO3	Utilize Google Earth Engine (GEE) with Python to conduct large-scale geospatial and environmental analyses.
CO4	Understanding technical know-hows of real world environment challenges

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	1	1	1
CO2	3	3	3	1	2	2
CO3	3	3	2	1	3	2
CO4	2	3	3	2	2	3

Module	Content

1	Introducing GIS in environment management, Different aspects in environment, applied aspects of environmental GIS, Introduction to key sources of spatial data related to environment management- Using public domain environmental data.
2	Environmental assessment and monitoring with GIS, Studying Spatial and Temporal variability of environmental data for change detection analysis, Environmental spatial decision support system, Impact assessment – basic concepts, environmental impact assessment (EIA) methods.
3	Geospatial Technology for Climate studies, Floods and Water Resource Management, Droughts and Food Security, Land Cover, land Use Change and Ecosystems, Air Quality and Health
4	Climate Change and climate adaptation planning, impacts of sea level rise, Impact of rising temperature and Urban heat island, impact on public health. technical approaches to formulating mitigation and adaptation strategies

References:

1. Mitsova, Diana, and Ann-Margaret Esnard. Geospatial Applications for Climate Adaptation Planning. Routledge, 2019.
2. Sundaresan, Janardhanan, et al., editors. Geospatial Technologies and Climate Change. Springer International Publishing, 2014. DOI.org (Crossref), https://doi.org/10.1007/978-3-319-01689-4.
3. Geospatial Modelling for environmental Management; case studies from south asia edited by Shruthi Kanga, Suraj Kumar Singh, GowharMeraj, Majid Farooq

Geospatial Applications for Hydrological Modeling

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221360	Geospatial Applications for Hydrological Modeling	3	500	1-1-0-1

Course Outcomes	
CO1	Critically evaluate advanced GIS and remote sensing techniques and their applications in complex hydrological systems analysis.
CO2	Formulate and implement hydrological models using geospatial data to solve real-world water resource challenges.
CO3	Design and assess flood modeling frameworks incorporating multi-source geospatial

	datasets for effective flood risk prediction.
CO4	Develop comprehensive management and mitigation strategies for hydrological phenomena.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	3	1
CO2	3	2	3	2	1	2
CO3	3	3	2	3	2	1
CO4	2	2	1	3	3	2

Module	**Content**
1	In-depth study of hydrologic cycle, parameters, and complex interrelations in water systems. Critical evaluation of Remote Sensing (RS) and GIS applications in integrated water resources management. Exploration of advanced hydrological data sources including satellite and sensor networks
2	Watershed delineation and surface/groundwater inventory using advanced GIS tools. Development and critical assessment of flow and runoff models. Integration of multi-source data for hydrological simulations
3	Detailed analysis of global and regional water balance scenarios including blue, green, and grey water concepts. Modelling of complex water systems and dynamic assessment methods. Critical review of water balance models and their limitations
4	Development and validation of flood models using multi-temporal geospatial data. Flood hazard simulation and potential flood zone mapping incorporating uncertainty analysis. Advanced flood risk assessment methodologies and design of mitigation strategies with ethical and social considerations

Course Project:

Students will undertake a project or thesis focusing on an advanced topic in Hydrological Modelling. Potential topics include:

- Design of a mobile GIS application for community-based flood event reporting and field hydrological data collection.

- Development of an early warning system for flood-prone zones using GIS-based risk assessment and rainfall thresholds.
- Development of a GIS-based decision support tool for water budgeting in semi-arid river basins.

References:

1. John G Lyon, GIS for Water Resources and Watershed Management, 2014, ISBN: 9788184892932
2. Tim Davie, Fundamentals of Hydrology, 3rd edition, 2019, ISBN: 0415858704
3. A. M. Gurnell and D. R. Montgomery, Hydrological Applications of GIS (Advances in Hydrological Processes), 2000
4. R. Allen et al., Remote Sensing and GIS for Hydrological Modelling, 2022.

Geospatial Applications in Urban and Regional Planning

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221361	Geospatial Applications in Urban and Regional Planning	3	500	2-0-0-1

Course Outcomes	
CO1	Understanding the basics in the field of urban and regional planning
CO2	Get the idea regarding the different data, and its scale and technologies for urban and regional planning
CO3	Different modelling techniques used in urban and regional planning
CO4	Management and mitigation in urban development

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	1	1	1
CO2	3	3	2	1	1	2
CO3	2	3	3	1	1	2
CO4	2	3	3	2	2	2

Module	Content
1	GIS and Remote Sensing in Urban and regional Planning – Overview. Basics in Urban Planning, Region Planning, Regions Definition Characteristics, Need for regional planning, Levels of planning
2	Data requirement, Dataset and Innovative technologies for urban planning and regional planning, High resolution satellite for mapping, Cadastral databases in urban areas, Levels and scales of mapping, Detection, Interpretation, Delineation and Analysis of different settlements – rural, urban, slum, etc
3	Urban Growth modelling, Roof Top solar Protection assessment, 3D Modelling and Visualization of urban areas, Database design and analysis for urban and regional resource mapping
4	Site selection and suitability analysis for urban development. Urban sprawl and change detection studies, Urban hazards and risk management through GIS – Flood modelling using Hydrological tools in GIS

References:

1. Henk J Scholten, John C H Stillwill, Geographical Information Systems for Urban and Regional Planning, 2007, The Geojournal Library
2. Martin Van Maarseveen, Javier Martiniz, Johannes Flack, GIS in Sustainable Urban Planning and Management - A Global Perspective, 2019, CRC Press, ISBN : 9781138505551
3. Mohd Aktar Ali, Kabir Mohan Sethy, Muzafir Wani, Urban Environment and Spatial Science, Ane Books Pvt Ltd, First Edition (2021), ISBN : 9390658284

AI Applications in Agriculture

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221362	AI Applications in Agriculture	3	500	1-1-0-1

Course Outcomes	
CO1	Demonstrate a fundamental understanding of the principles and concepts of artificial intelligence as applied to agriculture, distinguishing between different AI techniques and their potential benefits.

CO2	Analyze and evaluate agricultural data using AI-driven techniques, leading to improved decision-making for precision farming practices.
CO3	Develop the ability to design and implement AI-based solutions for early detection, diagnosis, and management of crop diseases, thereby enhancing agricultural productivity and sustainability.
CO4	Assess emerging trends in AI applications within the agriculture sector and demonstrate an awareness of ethical, social, and environmental implications associated with integrating AI technologies.

Mapping of course outcomes with program outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	2	1
CO2	3	3	2	2	2	1
CO3	3	3	2	2	2	1
CO4	3	3	2	2	2	1

Module	**Content**
1	Foundations of AI in Agriculture - Introduction to AI in Agriculture: Narrow AI vs. General AI, supervised learning, unsupervised learning, AI-driven crop monitoring, agricultural automation, precision farming, Machine Learning Fundamentals: Regression, classification, clustering, reinforcement learning, Feature engineering, model evaluation, cross-validation, Transfer learning, image segmentation, object detection
2	Data Analytics and Precision Agriculture - Remote Sensing and IoT in Agriculture: Multispectral imaging, hyperspectral imaging, LiDAR, Wireless sensor networks, smart sensors, data fusion, Data Preprocessing, and Feature Selection: Outlier detection, data normalization, data imputation, Principal Component Analysis (PCA), Recursive Feature Elimination (RFE), Predictive Modeling for Crop Management: Decision trees, random forests, gradient boosting, Support Vector Machines (SVM), ensemble learning, hyperparameter tuning, Decision Support Systems in Precision Agriculture: Geographic Information Systems (GIS), spatial analysis
3	Crop Health and Disease Management - Image Analysis for Disease Detection: Leaf-level disease recognition, plant phenotyping, hyperspectral imaging, Instance

	segmentation, transfer learning with pre-trained models, fine-tuning, Sensor-based Disease Detection: Disease-related stress indicators, Wireless sensor networks for disease monitoring, data fusion techniques, AI-driven Pest Management: Pest species identification, insect behavior modeling, Genetic algorithms for optimizing pest control schedules, swarm intelligence, Sustainable Agriculture and AI: Precision application of agrochemicals, site-specific nutrient management, Predictive models for sustainable irrigation practices, water use efficiency
4	Future Trends and Ethical Considerations in AI Agriculture - Emerging Trends in AI Agriculture: Swarm robotics, drone technology, blockchain in agriculture, Ethical and Social Implications: Algorithmic bias, fairness in AI, explainable AI in Agriculture, Data privacy regulations, digital divide, farmer livelihoods, Environmental Sustainability and AI: Renewable energy integration and climate-resilient agriculture, AI and remote sensing to assess soil erosion and land degradation

References:

1. "Artificial Intelligence In Agriculture" by Singh Rajesh and Anita Gehlot, New India Publishing Agency, 2020
2. "Using R for Digital Soil Mapping", Malone, Minasny, and McBratney, Springer, ISBN: 978-3-319-44325-6.
3. "Agriscience Fundamentals and Applications" by L. DeVere Burton, 2009
4. "Agricultural Technology: Emerging Trends" by Caroline Walters, 2022
5. "Soil and Crop Sensing for Precision Crop Production" by Minzan Li, Chenghai Yang, Qin Zhang, Springer, 2022

Computational Finance

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221363	Computational Finance	3	500	1-1-0-1

Course Outcomes	
CO1	Understanding Financial Asset Dynamics and Models:
CO2	Master numerical techniques for pricing financial derivatives, particularly European options, using methods like the COS (Characteristic Function Expansion) method.

CO3	Analyze pay-off coefficients and conduct error analysis when using the COS method.
CO4	Introduce the fundamental concepts of portfolio management, including portfolio objectives, constraints, risk, and return.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	1	1	1	1
CO2	2	3	2	1	1	1
CO3	3	3	2	1	1	1
CO4	3	3	1	1	1	1

Module	**Content**
1	Introduction to Computational Finance, Financial asset dynamics; Proportional dividended model Martingales and asset prices; Black scholes option pricing equations; local volatality models
2	Numerical Methods for Pricing Financial Derivatives: Pricing europian options by the OS method Pay off coefficients, error analysis by COS methods, Numerical COS method results; Geometric Brownian Motion; Stochastic Volatility models; Introduction, CIR process of variance, Monte Carlo Simulation: Introduction, Simulation of CIR models
3	Financial Data Analysis; Statistical Modeling of Financial Data; Time series analysis of financual data Financial forecasting; Rsik management, Types of risks, measuring risks, Financial risk management

4	Portfolio Optimization: Introduction to portfolio management Portfolio objectives and constraints; Risk and return; Portfolio diversification; Asset allocation Security selection; Portfolio performance evaluation; Active and passive portfolio management Algorithmic trading; Machine learning for portfolio optimization

References:

1. Maheshwari, Anil. Financial Data Analytics: Theory and Application. 2nd ed. Pearson, 2023. Print
2. Benninga, Simon. Financial Modeling: Equilibrium, Capital Structure, and Asset Pricing. 3rd ed. Wiley, 2016

Data Engineering

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221364	Data Engineering	3	500	1-1-0-1

Course Outcomes	
CO1	Analyze and apply foundational concepts and principles of modern data engineering, including data modeling, ETL/ELT patterns, cloud-native architectures, data integration, and data quality management.
CO2	Select, utilize, and configure scalable data storage and processing technologies—such as SQL/NoSQL systems, data lakes/lakehouses, distributed computing platforms, and in-memory databases—to meet varied analytical and operational requirements.
CO3	Design, construct, and manage end-to-end data pipelines, incorporating tools for batch and real-time ingestion, orchestration, transformation, monitoring, and CI/CD, using platforms like Kafka, Airflow, dbt, and OpenLineage.
CO4	Analyze complex data engineering challenges and implement advanced techniques such as real-time analytics, data versioning, secure API delivery, and performance tuning, while also exploring modern paradigms like Data Mesh and Data-as-a-Product.

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	1	1
CO2	3	2	3	2	2	1
CO3	3	3	2	2	2	1
CO4	2	2	3	1	2	1

Module	**Content**
1	Exploration of the data engineering lifecycle, data modeling at conceptual, logical, and physical levels, modern ETL and ELT design patterns, cloudnative data architecture with platforms such as Snowflake and BigQuery, evolution of data warehousing systems, data integration strategies, principles of data quality and observability using tools like Great Expectations, and metadata management through OpenMetadata and DataHub. Lab: Design a normalized schema and convert it into a logical model, develop a basic ETL pipeline using Python or Apache NiFi, apply data validation using Great Expectations, and configure metadata discovery using OpenMetadata.
2	Advanced SQL operations and analytical queries, NoSQL systems including MongoDB, Cassandra, and Neo4j, modern data lake and lakehouse frameworks such as Delta Lake and Apache Iceberg, fundamentals of distributed computing through Hadoop and HDFS, highperformance data transformations using Apache Spark, batch and stream data processing models, and inmemory data platforms such as Apache Ignite. Lab: Execute complex analytical queries using SQL, perform data operations in MongoDB and Cassandra, ingest raw files into a lakehouse setup and query with Spark, build and visualize graph relationships using Neo4j.
3	Comprehensive understanding of data pipeline architecture, batch and realtime ingestion using Kafka, Flink, and cloudnative tools like AWS Kinesis and Google Pub/Sub, workflow automation with Apache Airflow, Prefect, and Dagster, data transformation and modeling using dbt, observability and lineage tracking through OpenLineage, implementation of robust monitoring, alerting, error recovery, and integration of CI/CD in data workflows.

	Lab: Develop and schedule data tasks using Airflow DAGs, create a streaming pipeline with Kafka, implement a dbt project for layered transformations, and configure data pipeline monitoring using Prefect or Airflow UI.
4	Exploration of realtime streaming platforms such as Kafka, Flink, and Redpanda, efficient data serialization using Parquet, Avro, and ORC, data version control and lineage using LakeFS and DataHub, microservicebased data delivery through REST and GraphQL APIs, security best practices including GDPR compliance and data encryption, strategies for integrating data lakes and warehouses, performance optimization techniques in distributed environments, and emerging concepts such as Data Mesh and DataasaProduct. Lab: Deploy realtime analytics workflows using Kafka and Flink, benchmark serialization formats for storage and query performance, implement versioning and lineage visualization with LakeFS and DataHub, develop secure data APIs, and apply tuning strategies for Spark and cloudbased systems.

References:

1. "Data Engineering with Python" by Paul Crickard, Packt Publishing, 2020
2. "Data Engineering with Apache Spark, Delta Lake, and Lakehouse" by Manoj Kukreja, Danil Zburivsky, Packt Publishing, 2021
3. "Designing Data-Intensive Applications: The Big Ideas Behind Reliable, Scalable, and Maintainable Systems" by Martin Kleppmann, 2017
4. "Fundamentals of Data Engineering" by Joe Reis, Matt Housley, O'Reilly Media, Inc., 2022

Big Data Technologies and Cloud Computing

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221365	Big Data Technologies and Cloud Computing	3	500	1-1-0-1

Course Outcomes	
CO1	Introducing Apache Spark
CO2	Text Mining in Big data

CO3	Link analysis and recommendation systems
CO4	Introduction to cloud computing

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	2	1
CO2	3	2	1	1	1	1
CO3	3	3	1	1	1	1
CO4	3	3	2	1	2	1

Module	**Content**
1	Topics: Overview of modern big data architecture: Lambda, Kappa, and Delta Architecture, Spark Core, Spark Context, RDD, DAG Execution Model, Lazy Evaluation and Caching Strategies, DataFrame and Spark SQL, Machine Learning with MLlib and PySpark: feature engineering, classification, clustering, Introduction to Spark Struc-tured Streaming, Lab Work: Setup and execute a Spark job on a cluster (local or cloud), Implement a classification task using PySpark MLlib, Create real-time analytics dashboards using Spark Structured Streaming
2	Topics: Advanced similarity detection techniques in bigdata: Shingling of documents, Min-hashing and signature matrix construction, Locality Sensitive Hashing (LSH), In-cremental computation over data streams, Real-time semantic matching and index-ing, Integration with vector databases for similarity search (e.g., FAISS, Pinecone) Lab Work: Implement LSH-based text similarity in PySpark, Analyze stream data using Spark Streaming and sliding windows
3	Topics: Graph-based algorithms: PageRank, computation and convergence issues, Topic-sensitive PageRank and Link Spam Detection, HITS algorithm and hub-authority dynamics, Mining frequent itemset: A-Priori, FP-Growth, Introduction to modern graph engines, Building Recommendation Systems: Collaborative filtering, content-based filtering, Real-time recommendation via batch + stream pipelines Lab Work: Compute PageRank using PySpark and GraphFrames, Build a collabo-rative filtering model using ALS on a sample user-product dataset

4	Topics: Cloud-native architecture for big data processing, Containers and orchestration: Docker, Kubernetes, Helm, Introduction to Serverless computing (e.g., AWS Lambda, Azure Functions), Cloud components and service models: IaaS, PaaS (e.g., GCP App Engine, AWS Elastic Beanstalk), and SaaS, Cloud benefits and limitations: scalability, elasticity, multi-tenancy, security, Cloud storage systems: S3, HDFS on cloud, GCS, Azure Blob, Data pipeline orchestration with Airflow or Prefect, Introduction to cloud-based MLOps and data versioning tools (e.g., DVC, MLflow) Lab Work: Deploy a Spark job on a cloud platform (Databricks, EMR, or GCP DataProc), Create a simple CI/CD pipeline for a PySpark job using GitHub Actions and Docker, Build a cloud-hosted REST API to serve a recommendation model

Text Books:

1. Data Analytics with Spark Using Python, By Jeffrey Aven, Addison Weley Data and Analytics series, 2018
2. Big Data Analytics with Spark, Mohammed Guller, APress, 2015

References:

1. Anand Rajaraman, Jeffrey D Ullman. Mining of Massive Datasets, Cambridge University Press 2010

Machine Learning with Graphs

Course code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221366	Machine Learning with Graphs	3	500	1-0-1-1

Course Outcomes	
CO1	Critically analyze the structural properties and theoretical foundations of graph-based systems, including their relevance to diverse real-world domains.
CO2	Design and implement advanced graph representation learning algorithms to generate expressive embeddings for structured and unstructured graph data.
CO3	Evaluate and apply state-of-the-art graph-based machine learning models for tasks such as clustering, link prediction, node/graph classification, and graph generation.
CO4	Develop and validate domain-specific graph analytics solutions to address complex real-world problems.

Mapping of course outcomes with programme outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	1	1
CO2	3	3	3	1	1	2
CO3	3	3	3	1	1	2
CO4	2	3	3	2	1	3

Module	**Content**
1	Foundations of Graph Theory and Network Analysis: spectral graph theory, structural properties of real-world networks, Dynamic and heterogeneous graphs; temporal and attributed graphs, Graph traversal, centrality measures, and optimization techniques (shortest path, min-cut, max-flow). Analysis of complex real-world graphs like citation networks, web graphs, financial transaction networks, social networks, recommendation systems, biological networks using Python.
2	Graph Representation and Learning Techniques: DeepWalk, Node2Vec, LINE, matrix factorization methods; Comparative analysis of representation techniques. Graph Neural Networks (GNNs): message passing, inductive vs transductive learning. GNN architectures: GCN, GraphSAGE, GAT, and their limitations, Expressive power of GNNs (Weisfeiler-Lehman Test).
3	Graph Machine Learning and Generation: node classification, link prediction, graph classification, graph generation. Graph autoencoders, GraphVAE, and GraphGAN. Training challenges: scalability, over-smoothing, and generalization in GNNs. Evaluation metrics for graph learning tasks.
4	Domain-Specific Applications and Research Trends: Social Network Analysis: community detection, anomaly detection, influence propagation. Recommender Systems: collaborative filtering and content-based models using graph data; knowledge graph-based recommendation. Bioscience Applications: protein-protein interaction networks, drug discovery, gene expression analysis. Current research trends and open challenges in graph machine learning.

Text Books:

1. Hamilton, William L. *Graph representation learning*. Morgan and Claypool Publishers, 2020.
2. Ma, Yao, and Jiliang Tang. *Deep learning on graphs*. Cambridge University Press, 2021.

References:

1. CS224W-Machine Learning with Graphs, Stanford, Winter, 2023

Computational Nonlinear Dynamics

Course code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221367	Computational Nonlinear Dynamics	3	500	0-0-0-3

Course Outcomes	
CO1	Understanding the principles of nonlinear dynamics
CO2	Examining maps and flows through both analytical and computational methods
CO3	Use a diverse range of nonlinear dynamics techniques to explore and communicate insights effectively for a given dynamical system
CO4	Understanding how to obtain nonlinear dynamics insights from real world datasets

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	0	0
CO2	3	3	3	2	2	2
CO3	3	3	3	3	2	2
CO4	3	2	3	1	2	2

Module	Content
1	Introduction to nonlinear dynamics, maps and difference equations, transients, attractors, parameters, bifurcations, fixed points, saddles and eigenvectors, stable and unstable manifolds, strange attractors, renormalization and function space

2	Return maps, constructing 1D, 2D bifurcation diagrams, Arnold tongues, insights from bifurcations, Feigenbaum constant and applications, Feigenbaum universality
3	Flows, state variables, state phase, nonintegrability, flow solvers, shadowing and chaos, van der Pol oscillator, averaging theory, Lyapunov exponents, unstable periodic orbits, fractals and chaos, machine learning techniques for chaos prediction
4	Time series analysis, observer problem, delay coordinate embedding, reconstruction of dynamics, estimation of embedding parameters, fractals, geometry of strange attractors, computing fractal dimensions, noise and filtering, Chaos based cryptography

Text Books:

1. S. Strogatz, Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering, Westview Press, 2014.
2. R. A. Holmgren, A First Course in Discrete Dynamical Systems, Springer, 1996
3. E. Ott, Chaos in Dynamical Systems, Cambridge, 2002.

References:

1. S. Lynch. *Dynamical Systems with Applications using Python.* "Springer", 2018.

Stochastic Processes and Models

Course code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221368	Stochastic Processes and Models	3	500	1-1-0-1

Course Outcomes	
CO1	Analyse the mathematical foundations of modern stochastic models, their associated problems, and state-of-the-art solutions.
CO2	Evaluate the design, development, and integration of stochastic models, algorithms, and systems.
CO3	Create and demonstrate a functional stochastic model through collaborative research projects and project report presentations.
CO4	Analyse real-world scenarios to identify opportunities for applying stochastic modelling techniques.

CO5	Create innovative stochastic models and algorithms by integrating advanced mathematical concepts and computational techniques.

Mapping of course outcomes with program outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	0	0	0
CO2	3	3	3	0	0	2
CO3	3	2	3	3	2	3
CO4	3	3	3	2	0	2
CO5	3	3	3	2	1	3

Module	Content
1	Concepts of multiple random variables. Bayesian belief networks (BBN): Representation, Independence and conditional independence, Partial independence and other structure. Exact inference in BBN: Variable elimination, Pearl's algorithm, Junction tree, Recursive decomposition, Using additional structure.
2	Approximate inference: Monte Carlo approximations, Loopy belief propagation, Variational methods. Learning of BBNs: learning parameters, learning structure, Bayesian averaging, EM (learning with hidden variables and missing values), structural EM.
3	Dynamic belief networks: Particle filtering. Markov random fields (Markov networks): Representation (potentials), Independence and conditional independence, Trees, Boltzman machines, Conditional Markov random fields.
4	Inference in Markov networks. Learning Markov networks: Iterative proportional fitting, Cluster variational methods, Other approximations. Relational graphical models.

Text Books

1. D. Koller and N. Friedman, Probabilistic Graphical Models: Principles and Techniques, MIT Press, 2009
2. D. Barber, Bayesian Reasoning and Machine Learning, Cambridge University Press, 2012.
3. D. J. C. Mackay, Information Theory, Inference, and Learning Algorithms, UK: Cambridge University Press, 2003
4. J. Pearl, Probabilistic Reasoning in Intelligent Systems, Morgan Kaufman, 1997.

Optimization Techniques

Course	Title of the course	Credits	Level	Credit Split

code				Lecture-Lab-Seminar-Project
M5221369	Optimization Techniques	3	500	1-1-0-1

Course Outcomes	
CO1	Evaluate optimization problems and critically assess state-of-the-art solutions in the context of optimization techniques.
CO2	Design and create optimization algorithms through the integration of classical and modern optimization methods.
CO3	Develop, test, solve optimization techniques within team research projects, and effectively present the findings.
CO4	Critically analyze and compare optimization methods to identify suitable techniques for specific real-world problems.
CO5	Evaluate and defend the selection of optimization techniques for problem solving and research applications.

Mapping of course outcomes with program outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	0	0	0
CO2	3	3	3	0	0	0
CO3	3	3	3	3	2	3
CO4	3	3	3	3	0	2
CO5	3	3	3	3	3	3

Module	Content
1	Optimization - sequences and limits, derivative matrix, level sets and gradients, Taylor series.
2	Unconstrained optimization - necessary and sufficient conditions for optima, convex sets, convex functions, optima of convex functions, steepest descent, Newton and quasi-Newton methods, conjugate direction methods.
3	Constrained optimization - linear and non-linear constraints, equality and inequality constraints, optimality conditions.
4	Constrained convex optimization, projected grstochasticadient methods, penalty methods.

Text Books
1. E. K. P. Chong and S. H. Zak, *An Introduction to Optimisation*, 2nd ed. India: Wiley, 2010. 2. D. G. Luenberger and Y. Ye, *Linear and Nonlinear Programming*, 3rd ed., Springer, 2010.
References
1. S. Sra, S. Nowozin, and S. J. Wright, *Optimization for Machine Learning*, MIT Press, 2012. 2. R. Battiti and M. Brunato, *The LION Way: Machine Learning Plus Intelligent Optimization*, Createspace Independent Publishing, 2014.

AI for Molecular Sciences

Course code	**Title of the course**	**Credits**	**Level**	**Credit Split** **Lecture-Lab-Seminar-Project**
M5221370	AI for Molecular Sciences	3	500	1-1-0-1

	Course Outcomes
CO1	Understand and explain core AI/ML concepts and molecular representations used in chemistry, biology, and materials science.
CO2	Apply ML/DL algorithms to predict molecular properties and design models for virtual screening and QSAR analysis.
CO3	Utilize AI tools for chemical reaction prediction, retrosynthesis, and reaction optimization.
CO4	Design AI-driven workflows for molecule discovery in drug and material sciences.

Mapping of course outcomes with program outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	2	0	0
CO2	3	3	3	1	1	0
CO3	3	3	3	1	2	1
CO4	3	3	3	2	2	2

Module	**Content**

1	AI/ML in molecular sciences: Overview of AI/ML in molecular sciences (chemistry, biology, materials science), supervised vs unsupervised learning: classification, regression, clustering; molecular representations: SMILES, InChI, molecular graphs, fingerprints (ECFP, MACCS); feature engineering: physicochemical descriptors, topological indices; deep learning architectures: CNNs, RNNs, GNNs; generative models: VAEs, GANs, transformer-based molecule generators (e.g., ChemBERTa, MolBERT). *Lab Focus: Build and evaluate molecular property prediction models using ML and GNNs.*
2	AI for molecular structure and property prediction: QSAR/QSPR modeling using ML/DL; prediction of molecular properties: solubility, logP, bioavailability, toxicity, ADME; AI-guided conformer generation and structure optimization; quantum chemistry surrogate models (e.g., Δ-learning for DFT property prediction); applications in the prediction of HOMO-LUMO gaps, dipole moments, and reactivity indices. *Lab Focus: Prediction of molecular electronic properties (e.g., HOMO-LUMO gaps) using AI, with model interpretability techniques (SHAP, LIME).*
3	AI for reaction optimization and mechanism prediction: Chemical reaction prediction: template-based and template-free models; ML-guided reaction condition optimization (eg, temperature, solvent, catalyst prediction); retrosynthetic analysis using AI tools (e.g., AiZynthFinder, IBM RXN); learning reaction mechanisms from data. *Lab Focus: Use ML/DL for forward and retrosynthesis prediction, incorporating uncertainty quantification methods (Bayesian NNs, MC-dropout).*
4	AI Applications in drug discovery and molecular technologies: AI for virtual screening and de novo drug design; AI for target identification, binding affinity prediction, and drug repurposing; biomarker discovery from omics datasets; AI for material discovery: designing of molecular probes, organic photovoltaics, and molecular sensors. *Research Focus: AI-driven design of molecules for biomedical or material science applications with emphasis on ethical data practices.*
Assessment Components: Research Project (40%): Conduct an individual research project or case study focusing on AI in molecular discovery. Deliverables include a report and presentation. Lab Work (20%): Practical exercises in molecular modeling.	

Seminar (10%): Each student will present a selected paper or topic in a seminar format, discussing recent advancements in molecular design using AI. Written Exam (30%): Comprehensive exam covering theoretical concepts and practical applications.
Textbooks & References: 1. Pyzer-Knapp, E. O., & Laino, T. (Eds.). (2020). Machine learning in chemistry: Data-driven algorithms, learning systems, and predictions (ACS Symposium Series). ACS Publications. ISBN 9780841235052 2. Cartwright, H. M. (Ed.). (2020). Machine learning in chemistry: The impact of artificial intelligence (Vol. 17, Theoretical and Computational Chemistry Series). Royal Society of Chemistry. ISBN 9781788017893 3. Heifetz, A. (Ed.). (2022). Artificial intelligence in drug design (1st ed.). Springer US: Humana. ISBN 9781071617861 4. Bai, Q., Xu, T., & Huang, J. (Eds.). (2025). Deep learning in drug design: Methods and applications (1st ed.). Academic Press. ISBN 9780443329081 5. Vamathevan, J., Clark, D., Czodrowski, P., Dunham, I., Ferran, E., Lee, G., Li, B., Madabhushi, A., Shah, P., Spitzer, M., & Zhao, S. (2019). Applications of machine learning in drug discovery and development. Nature Reviews Drug Discovery, 18(6), 463–477. https://doi.org/10.1038/s41573-019-0024-5 6. Lundberg, S., & Lee, S.-I. (2017). A unified approach to interpreting model predictions. In Advances in neural information processing systems (Vol. 30). Curran Associates, Inc. https://doi.org/10.48550/arXiv.1705.07874 7. Hermann, E., Hermann, G., & Tremblay, J. C. (2021). Ethical artificial intelligence in chemical research and development: A dual advantage for sustainability. Science and Engineering Ethics, 27(45). https://doi.org/10.1007/s11948-021-00325-6

Machine Learning and Deep Learning for SAR Applications

Course code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221371	Machine Learning and Deep Learning for SAR Applications	3	500	1-1-0-1

Course Outcomes	
CO1	Develop advanced understanding of SAR data characteristics and their relevance for machine learning

CO2	Analyze and preprocess SAR datasets and extract features for machine learning and deep learning
CO3	Apply machine learning and deep learning methods for SAR-based environmental and geohazard applications
CO4	Evaluate SAR analytics outputs for monitoring, prediction, and geospatial decision-making

Mapping of course outcomes with program outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	1	1	1
CO2	2	3	2	1	1	2
CO3	1	3	3	1	1	2
CO4	1	3	2	2	2	3

Module	**Content**
1	Advanced Concepts of SAR and Data-Driven Analysis • Backscatter mechanisms and image interpretation • Polarization and SAR signal properties • Limitations and challenges in SAR data analysis • Emergence of data-driven approaches in SAR
2	SAR Data Preprocessing and Feature Engineering for ML/DL • SAR image preprocessing techniques • Speckle filtering and radiometric calibration • Polarimetric and interferometric SAR features • Texture and spatial feature extraction • Dataset preparation for machine learning and deep learning models
3	Machine Learning and Deep Learning Methods for SAR Analysis • Supervised learning methods: Random Forest, SVM • Unsupervised learning for SAR backscatter pattern analysis • Deep learning for SAR: ○ CNN for classification and feature extraction ○ segmentation models (e.g., U-Net) ○ RNN/LSTM for SAR time-series
4	Advanced SAR Applications using Machine and Deep Learning • Geohazard mapping using SAR: flood, landslide, deformation • Environmental monitoring: agriculture, vegetation, biomass

	• Urban and infrastructure analysis using SAR • SAR time-series analysis with deep learning

References:

1. S. Salcedo-Sanz et al., "Machine learning information fusion in Earth observation: A comprehensive review of methods, applications and data sources," Information Fusion, vol. 63, pp. 256–272, Nov. 2020, doi: 10.1016/j.inffus.2020.07.004.
2. M. Arias, M. Á. Campo-Bescós, and J. Álvarez-Mozos, "Crop classification based on temporal signatures of Sentinel-1 observations over Navarre province, Spain," Remote Sens. (Basel)., vol. 12, no. 2, pp. 20–49, Jan. 2020, doi: 10.3390/rs12020278.
3. B. Teodosio, P. L. P. Wasantha, E. Yaghoubi, M. Guerrieri, S. Fragomeni, and R. C. van Staden, "Monitoring of geohazards using differential interferometric satellite aperture radar in Australia," Int. J. Remote Sens., vol. 43, no. 10, pp. 3769–3802, May 2022, doi: 10.1080/01431161.2022.2106457.
4. X. X. Zhu et al., "Deep Learning Meets SAR," Jun. 2020, Accessed: Feb. 17, 2026. [Online]. Available: https://arxiv.org/pdf/2006.10027
5. G. Camps-Valls, D. Tuia, X. X. Zhu, and M. Reichstein, "Deep learning for the earth sciences: A comprehensive approach to remote sensing, climate science and geosciences," Deep Learning for the Earth Sciences: A Comprehensive Approach to Remote Sensing, Climate Science and Geosciences, pp. 1–405, Aug. 2021, doi: 10.1002/9781119646181

Reinforcement Learning

Course code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221372	Reinforcement Learning	3	500	2-1-0-0

Course Outcomes	
CO1	Understand the foundations of modern reinforcement learning theory, problem, and state-of-the-art solutions.
CO2	Analyze and evaluate critically the building and integration of reinforcement learning algorithms and systems.
CO3	Design and demonstrate a working deep learning system through a team research project and project report presentation.

Mapping of course outcomes with program outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	1	2
CO2	3	3	3	2	1	2

CO3	2	1	1	2	3	3

Module	Content
1	Introduction to Reinforcement Learning, Markov Processes Markov Reward Processes (MRPs) Markov Decision Processes (MDPs), MDP Policies, Policy Evaluation, Policy Improvement, Policy Iteration, Value operators.
2	Model-free learning - Q-learning, SARSA, Scaling up: RL with function approximation, RL with function approximation.
3	Imitation learning in large spaces, Policy search, Exploration/Exploitation, Meta-Learning, Batch Reinforcement Learning, Bandit problems and online learning.
4	Solution methods: dynamic programming, Monte Carlo learning, Temporal difference learning, Eligibility traces, Value function approximation, Models and planning.

Text Books:

1. R. S. Sutton and A. G. Barto, *Reinforcement Learning: An Introduction*, MIT Press, 1998.
2. C. Szepesvari, *Algorithms for Reinforcement Learning*, Morgan and Claypool Publishers, 2010.

References:

6. K. P. Murphy, *Machine Learning: A Probabilistic Perspective*, MIT Press, 2012.
7. M. L. Puterman, *Markov Decision Processes: Discrete Stochastic Dynamic Programming*, 1st ed. USA: John Wiley and Sons, 1994.

Algorithmic Trading

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221373	Algorithmic Trading	3	500	1-1-0-1

Course Outcomes	
CO1	Understand the structure, objectives, and evolution of algorithmic trading systems and their regulatory framework.
CO2	Apply statistical and mathematical methods such as correlation, volatility, and mean reversion for quantitative strategy design.
CO3	Develop and evaluate algorithmic trading strategies including trend-following, statistical arbitrage, and market-making models.

CO4	Implement back-testing, performance analysis, and risk management using analytical and programming tools such as Excel, Python, and R.

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	1	1
CO2	3	3	3	2	2	1
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	2

Module	**Content**
1	Introduction to algorithmic trading and its evolution in global and Indian markets – building blocks of algorithmic systems – automation lifecycle and development stages – benefits and challenges of algorithmic trading – overview of market microstructure, order types, and execution – regulatory frameworks and taxation aspects in India – transaction costs, latency issues, and risk of automation – current industry trends, high-frequency trading practices, and ethical considerations.
2	Review of quantitative tools and time-series concepts used in trading algorithms – statistical measures: mean, variance, standard deviation, and correlation – spread and volume curve analysis – volatility estimation and modeling for trading decisions – mean reversion concepts applied to equities, ETFs, currencies, and futures – statistical testing of trading signals and price relationships – foundations of regression-based alpha generation and quantitative signal construction.
3	Design and implementation of major trading strategies: trend-following, pair trading, statistical arbitrage, and market-making – momentum and high-frequency trading strategies – dark pool and latency-sensitive trading – agency algorithms: VWAP, TWAP, inline, passive, and aggressive orders – proprietary algorithms: pairs, trend-following, high-frequency, and delta-neutral strategies – direct market access (DMA), smart order routing (SOR), and dark pool execution – analysis of market sentiment, stealth, layering, and spoofing behaviors in automated systems.
4	Principles of risk management in algorithmic environments – optimal leverage, stop-loss mechanisms, and portfolio insurance – measurement of risk indicators

	such as Value at Risk and drawdown – back-testing methodologies and Monte Carlo simulation – evaluation of strategy performance and robustness – hands-on applications using Excel, Python, and R for back-testing, regression-based alpha modeling, and simulation – design and testing of VWAP and pair-trading algorithms – integration of risk control in automated execution frameworks.

Text Books:

1. Chan, E. P. Algorithmic Trading: Winning Strategies and Their Rationale. Wiley, 2013.
2. Leshik, E. A., & Cralle, J. An Introduction to Algorithmic Trading. Wiley, 2011.
3. Chan, E. P. Quantitative Trading. Wiley, 2008.

References:

1. Johnson, B. C. Algorithmic Trading and DMA: An Introduction to Direct Access Trading Strategies. Myeloma Press, 2009.
2. Tsay, R. S. Analysis of Financial Time Series. Wiley, 2014.