Post Graduate Programme Syllabus

School of Digital Sciences

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

Technopark Phase IV, Mangalapuram, Thiruvananthapuram, India

-2024-

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 technologydomains. 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 ofDigital 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-drivenworld, 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 considerdata 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, 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 problemsolving

Course Categorization

- 400 Level - Advanced courses, including 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 - 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 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

Programme Courses (45 credits)			**University Courses (15 credits)**		**Final Year Project (20 credits)**	**Additional Credits**
Programme Core (Mandatory)	Programme Elective (Mandatory)	Open Elective (Mandatory)	University Core Digital Access for Community Empowerment – DACE (Mandatory)	University Elective Holistic Development - HD (Mandatory)	Capstone Project/ Thesis (Mandatory)	Additional courses (optional) (Optional)
18 credits	15 credits	12 credits	6 credits	9 credits	20 credits	10 credits

Project/Internship (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, he 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 of M.Sc. Programmes offered by SoDS

The School of Digital Sciences offers the following programmes in the academic year 2024-25

- M.Sc. in Computer Science with Specialization in Data Analytics (CSDA)
- M.Sc. in Data Analytics and Computational Science (DACS)
- M.Sc. in Data Analytics and Geoinformatics (GIS)
- M.Sc. in Data Analytics and BioAI (BioAI)

Semester-wise split of the category of all programmes

Semester I

Title of the course	**Credits**
University core (DACE I)	3
Programme core	12
Programme elective	3
University elective (HD1)	2
Total Credits	**20**

Semester II

Title of the course	**Credits**
University core (DACE II)	3

Open elective	6
Programme core	6
Programme elective	3
University elective (HD2)	2
Total Credits	**20**

Semester III

Title of the course	**Credits**
Open elective	6
Programme elective	9
University elective (HD3)	5
Total Credits	**20**

Semester IV

Title of the course	**Credits**
Internship/Thesis	20
Total Credits	**20**

Core Courses for each of the programmes

<u>M.Sc. Computer Science with Specialization in Data Analytics</u>

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	3-0-1-0
M4220152	Database Systems (Sem I)	4	400	3-1-0-0
M4220153	Data Analytics and Visualization (Sem I)	4	400	2-1-0-1
M5220251	Predictive Analytics (Sem II)	3	500	1-1-0-1
M4220252	Web Technology (Sem II)	3	400	2-1-0-0

M.Sc. Data Analytics and Computational Science

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	3-0-1-0
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

M.Sc. Data Analytics and BioAI

Course Code	Title of the Course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220153	Data Analytics and Visualization (Sem I)	4	400	2-1-0-1
M4220155	Molecular Biology (Sem I)	4	400	3-0-1-0
M4220156	Bioinformatics (Sem I)	4	400	2-1-1-0

M5220251	Predictive Analytics (Sem II)	3	500	1-1-0-1
M4220254	NGS and Genome Data Analysis (Sem II)	3	400	1-1-0-1

M.Sc. Data Analytics and Geoinformatics

Course Code	Title of the Course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220153	Data Analytics and Visualization (Sem I)	4	400	2-1-0-1
M4220157	Geographic Information System (Sem I)	4	400	3-1-0-0
M4220158	Remote Sensing and Earth Observation (Sem I)	4	400	3-1-0-0
M5220251	Predictive Analytics (Sem II)	3	500	1-1-0-1
M4220255	Advanced Geospatial Analytics (Sem II)	3	400	1-1-0-1

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 decidethe list of electives to be offered each semester based on requirements from students and the availability of faculty.

List of Elective Courses 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 offered
M4221151	Python Programming for Data Analytics	3	All programmes	400	2-1-0-0	S1
M4221152	Differential Equations	3	DACS	400	1-1-1-0	S1

M4221153	Time series analysis and SEM Modeling	3	CSDA/DACS	400	1-1-0-1	S1
M4220252	Web Technology	3	DACS/ BioAI/GIS	400	2-1-0-0	S2
M4221251	Computational Neuroscience	3	DACS/BioAI	400	2-1-0-0	S2
M4221252	Ethics in Data	3	All programmes	400	1-0-2-0	S2
M4221253	Data Structuresand Algorithms	3	All programmes	400	2-1-0-0	S2
M4221254	Computational Chemistry	3	DACS/BioAI	400	1-1-0-1	S2
M4221255	Deep learningand MLOps	3	All programmes	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
M5221251	Advanced Topics in the Semantic Web and Social Network Analysis	3	All programmes	500	1-1-0-1	S2/S3
M5221252	Advanced Geospatial Programming	3	GIS	500	1-1-0-1	S2/S3
M5221253	Spatial DataAnalytics	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	Structural Biology and 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/DACS	500	1-1-0-1	S2/S3
M5221258	Numerical Linear Algebra	3	CSDA/DACS	500	1-1-1-0	S2/S3
M5221351	Anomaly Detection and Fraud Analytics	3	All programmes	500	1-1-0-1	S3
M5221352	Generative AI	3	All programmes	500	1-1-0-1	S3
M5221353	HealthcareAnalytics	3	BioAI	500	1-1-0-1	S3
M5221354	Advanced Programming	3	All programmes	500	1-1-0-1	S3
M5221355	Thermal andHyperspectral remote sensing	3	GIS	500	1-0-1-1	S3
M5221356	Topographic Data Analysis Techniques and Applications	3	GIS	500	1-1-0-1	S3
M5221357	Spatial Bigdata Analytics	3	GIS	500	1-1-0-1	S3
M5221358	Geospatial Applications in Agriculture	3	GIS	500	1-1-0-1	S3
M5221359	Geospatial Applications for Environment and Climate Change	3	GIS	500	2-0-0-1	S3
M5221360	Geospatial Applicationsfor HydrologicalModeling	3	GIS	500	1-1-0-1	S3
M5221361	Geospatial Applications in Urban andRegional Planning	3	GIS	500	2-0-0-1	S3
M5221362	AI applications in agriculture	3	BioAI	500	1-1-0-1	S3
M5221363	Computational Finance	3	DACS	500	1-1-0-1	S3

M5221364	Data Engineering	3	All programmes	500	1-1-0-1	S3
M5221365	Big Data Technologies and Cloud Computing	3	All programmes	500	1-1-0-1	S3
M5221366	Machine Learning with Graphs	3	All programmes	500	1-1-0-1	S3
M5221367	Computational Nonlinear Dynamics	3	DACS	500	1-1-0-1	S3
M5221368	Stochastic Processes and Models	3	CSDA/DACS	500	1-1-0-1	S3
M5221369	Optimization Techniques	3	All programmes	500	1-1-0-1	S3

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

Syllabus

University Core (DACE I and DACE II)-500 level

DIGITAL ACCESS FOR COMMUNITY EMPOWERMENT I

Course Code	Course Name	Credit	Year of Introduction
M5220013	Digital Access for Community Empowerment I	3	2024
Prerequisites: Nil			
DEL 1 Credit	Digital Experience Laboratory (DEL), where they get exposed to various digital technologies through a set of hands-on lab projects.		
DTI 1 credit	Design Thinking and Innovation (DTI), where students will be exposed to the idea of applying innovative thinking in digital sciences.		
PDSC 1 credit	Personal Development and Scientific Communication (PDSC)		

DIGITAL ACCESS FOR COMMUNITY EMPOWERMENT II

Course Code	Course Name	Credit	Year of Introduction
M5220014	Digital Access for Community Empowerment II	3	2024
Prerequisites: Successful completion of DACE - I			
Community Empowerment - 3 Credits	Community Empowerment is a 5 days outbound programme where students get exposed to problems faced by the society and explore ways to use digital technologies to find solutions. students are expected to conduct research and present their findings through a short dissertation at the end of the programme.		

University Electives

Holistic Developmet- HD1, HD2, and HD3 (500 level)

Course Code	Course Name	Credit	Year of Introduction
M5220010, M5220011, M5220012	Holistic Development	9	2024
Prerequisites: Nil			
HD1 2 credits HD2 2 credits HD3 5 credits	Holistic development comprises of 3 modules; HD1, HD2, and HD3 in 1st semester, 2nd semester, and 3rd semester, respectively. Holistic Development will involve workshops/activities, bridge courses, research with proof of publication/conference presentation/prototypes/filed IP, completion of MOOCs with internal evaluation at 500 level and industry/research internships with an internal evaluation at 500 level or any other 500 level activity as permitted by the academic committee. The list of activities permitted for HD1, HD2, and HD3 will be decided at the University level based on the proposals received from the schools/faculty members and as approved by the Academic committee and will be communicated through the Academic office. The credits required for HD-1, HD-2, and HD-3 may be acquired through multiple activities from the list of permitted activities.		

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	3-0-1-0

Course Outcomes	
CO1	Analyze and differentiate computer system components and identify the relationships between hardware and software within a computing environment.
CO2	Evaluate and categorize operating system functionalities and understand how these systems manage processes, memory, files, and user interactions
CO3	Demonstrate the ability to categorize and compare network protocols and devices and address schemes, forming connections between different layers of network architecture
CO4	Design and appraise the implementation of computer science concepts in real-world scenarios while recognizing and assessing their applications' ethical and societal implications

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 and Architecture - Introduction to Computer Systems, Evolution of computing systems and key milestones, Essential components: CPU, RAM, and storage devices, Binary Representation and Data Storage, Basic CPU architecture - ALU, Registers, Control unit, Memory hierarchy: Registers, Cache, RAM, Virtual memory, File Systems, Output devices, Parallel Computing Architectures - SIMD, MIMD, GPU, and TPU
2	Operating Systems - Definition and functions, Types of OS, Processes and threads, Memory Management, Memory allocation techniques, File Systems, and Storage Management- File system structure and organization, File operations, Disk scheduling and storage optimization, User Interface - CLI and GUI, System

	Utilities - Text editors, file browsers, terminal commands, User management, and security considerations
3	Computer Networks - Definition and importance, Types of networks, Network Protocols - OSI model, TCP/IP, HTTP, FTP, SMTP, etc., Data encapsulation and packet structure, Networking Devices: routers, switches, hubs, gateways, etc., Topologies: star, bus, ring, mesh, hybrid, Network Addressing, and Subnetting - IP addressing: IPv4 vs. IPv6, Subnetting, DHCP, NAT/PAT, Network Security - Network security threats: malware, phishing, DoS, etc., Firewalls, VPNs, and secure communication protocols.
4	Client-Server Architecture: Understanding client-server interaction, Practical examples: web servers, email servers, game servers, Cloud Computing Fundamentals: Cloud deployment models: IaaS, PaaS, SaaS, Virtualization and cloud service providers, Emerging Trends in Computer Science: Quantum computing, Edge computing, and distributed systems, Ethical and Social Implications of Computing: Privacy concerns and data security, Algorithmic bias and digital divide, Internet of Things (IoT) - Applications and Challenges.

References

1. "Structured Computer Organization" by Andrew S. Tanenbaum
2. "Operating System Concepts" by Abraham Silberschatz, Peter B. Galvin, and Greg Gagne
3. "Modern Operating Systems" by Andrew S. Tanenbaum and Herbert Bos
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

Database Systems

Course Code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220152	Database Systems	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.

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	Understand the fundamentals of data science and its applications.
CO2	Effectively engineer features from raw data and apply various data reduction techniques to streamline data.
CO3	Use a diverse range of data visualization techniques to explore and communicate insights effectively.
CO4	Understand the design, implementation, and management of data warehouses

	and OLAP systems.

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

Module	**Content**
1	Introduction to data science: 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	Introduction to 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

CourseCode	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	0	0	0
CO4	3	2	2	0	0	0

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

Molecular Biology

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

M4220155	Molecular Biology	4	400	3-0-1-0

Course Outcomes	
CO1	Understanding nucleic acids and their functions
CO2	Exploring protein structure and function
CO3	Molecular processes and flow of genetic information
CO4	Importance of enzymes and their functions

Mapping of course outcomes with programme outcomes

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

Module	Content
1	Importance of molecular biology, introduction to the central dogma of life. Nucleic acids: Nucleic acid as the genetic material, structure and functions of nucleic acids, nucleosides and nucleotides, purines and pyrimidines, biologically important nucleotides, Watson and Crick model of DNA, structure and types of RNA.
2	Amino acids: Amino acids are the building blocks of proteins, structure of standard amino acids, classification of amino acids, essential amino acids, zwitterions, physical and chemical properties. Proteins: Classification of proteins based on composition and solubility, nutritive value, conformation and function, structural organization of proteins- primary, secondary, tertiary and quaternary structures, forces stabilizing protein structure and shape, structure of peptide bond, denaturation of proteins, Ramachandran Plot.
3	Central dogma of molecular biology DNA replication: semi-conservative model, different enzymes and their functions in replication, types of DNA damage and repair mechanisms.

	Transcription: 3 stages-initiation, elongation and termination, sense and antisense strands, promoter, post-transcriptional modifications, introns and exons, splicing, reverse transcription. Translation: 3 stages-initiation, elongation and termination, ribosome-E, P, A sites, codons and anti-codons, stop codons, gene and genetic code. Mutations: Point mutations-transitions and transversions; silent, missense, nonsense mutations; Frame shift mutations.
4	Enzymes: Nomenclature, classification and characteristics of enzymes, holoenzyme, apoenzyme, cofactors, coenzyme, prosthetic groups, enzyme catalysis- activation energy and transition state, enzyme activity and specificity, factors affecting enzyme activity, active site, Enzyme kinetics-concept of ES complex, Michaelis-Menten Equation. Enzyme inhibition: reversible – competitive, non-competitive and un-competitive inhibitions, irreversible inhibition.
References:	

Fundamentals of Biochemistry-Life at the Molecular Level, Donald Voet, Judit G Voet, Charlotte W Pratt, Wiley, ISBN 978-1-118-91840-1.
Biochemistry, U Satyanarayana, U Chakrapani, Elsevier, ISBN 978-81-312-3601-7.

Bioinformatics

CourseCode	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220156	Bioinformatics	4	400	2-1-1-0

Course Outcomes	
CO1	Foundations of bioinformatics
CO2	Bioinformatics databases
CO3	Basics of genomic sequencing and analysis
CO4	Sequence alignment methods

Mapping of course outcomes with programme outcomes

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

Module	**Content**
1	Introduction to Bioinformatics, cell as the basic unit of life- gene, genome, genetic code, Omics-genomics, proteomics, pharmacogenomics, phenomics, metabolomics, transcriptomics, interactomics, epigenomics; applications of bioinformatics. Human Genome Project: an overview of the project, goals and major scientific strategies of HGP, expected scientific and medical benefits of the project.
2	Bioinformatics databases: Categories of databases- sequence databases, structure databases, genome databases, proteomic databases, chemical databases, enzyme databases, expression databases, pathway databases, disease databases, primary databases and secondary databases. Nucleotide sequence databases-GenBank, EMBL, DDBJ, Protein databases-UniProt, Swiss-Prot, Genome Databases- NCBI, EBI; Protein-Protein interaction databases-STRING, Structure databases- Protein Data bank (PDB), Nucleic Acid Data Bank (NDB), Molecular modelling Data Bank (MMDB), PubChem, ChEMBL, ZINC, Gene expression databases- GEO, SRA.
3	Genomics: Genome Mapping, DNA Sequencing methods, basic concepts of similarity searching and sequence alignments, genomic data and data organization, DNA sequence analysis, identity and homology, local and global alignment, Smith Waterman and Needleman-Wunsch algorithms, scoring matrices- PAM and BLOSUM matrices, gap penalty.
4	Pairwise sequence alignments, Multiple sequence alignments, BLAST (Basic Local Alignment Search Tool), Nucleotide BLAST, Protein BLAST, PSI-BLAST, PHI-BLAST, word/k-tuple method, analysis of BLAST results, E Value, sensitivity and specificity of BLAST, FASTA sequence similarity search, ClustalW

References:

Bioinformatics-Databases, tools and algorithms, Orpita Bosu, Simminder Kaur Thukral,OXFORD Higher Education, ISBN0-19-567683-1.

Bioinformatics for Beginners-Genes, genomes, molecular evolution, databases and analytical tools, Supratim Choudhuri, Elsevier, ISBN: 9780124104716.

Geographic Information System (GIS)

CourseCode	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220157	Geographic Information System (GIS)	4	400	3-1-0-0

Course Outcomes	
CO1	Understanding the relevance of spatial cognition/information and spatial processes
CO2	Have a basic understanding of the nature of spatial data
CO3	Introducing spatial data editing and data management techniques
CO4	Integrating and applying the concepts of various spatial modelling techniques

Mapping of course outcomes with programme outcomes

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

Module	Content

1	Introduction to GIS: nature and scope of GIS, components of GIS, proprietary and open-source software, spatial data sources, spatial data types and formats. Applications of GIS.
2	Modelling real world: Geodesy - shape and size of the earth, ellipsoid, geoid, datum, projections, coordinate reference systems. Spatial data models - vector and raster data models, Spatial and attribute data modelling, projections and transformation.
3	Data creation and management: Input, editing and management of spatial data, encoding methods, conventional data storage methods, concepts of databases - Geo-database, RDBMS,comparison of various storage methods. Spatial and tabular query
4	Introduction to geoprocessing: Overlay analysis, proximity analysis, neighborhood analysis. Terrain analysis, spatial interpolation, surface analysis. Spatial data visualization.
References: Kang-Tsung Chang, Introduction to Geographic Information Systems 9th edition,ISBN10:1259929647, 2019 Burrough P A, McDonnell Principles of Geographical Information Systems 3rd edition: Oxford University Press, 2016.	

Remote Sensing and Earth Observation

CourseCode	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220158	Remote Sensing and Earth Observation	4	400	3-1-0-0

Course Outcomes	
CO1	Understand Various techniques and types of Remote sensing for earth observation
CO2	Gain knowledge of various Remote sensing techniques
CO3	Apply knowledge acquired in real-world contexts

CO4	Discuss the modern relevance of UAV Remote sensing

Mapping of course outcomes with programme outcomes

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

Module	**Content**
1	Introduction to Remote Sensing – Remote sensing process – Physics of Remote Sensing: Electro Magnetic Radiation, EMR Theory – Energy sources and Radiation principles – Energy interaction in the atmosphere: Scattering, Absorption – Atmospheric windows – Energy interaction with earth surface features: Spectral reflectance of earth surface feature types – Spectral reflectance patterns for different regions of EMR - Spectral response patterns – Atmospheric and Geometric influence on spectral response patterns
2	Earth observation systems – Platforms – Orbits – Sensors – Concept of Resolution: Spatial, Spectral, Radiometric and Temporal – Multispectral Scanning – Characteristic of Earth Observation satellites: IRS, Landsat, Sentinel – Elements of Visual Image Interpretation – Visual Data interpretation keys
3	Types of Remote Sensing System: Based on Energy sources and Range of EMS – Characteristics of Optical, Thermal and Microwave and Hyperspectral Remote Sensing
4	Introduction to UAV: UAV Remote Sensing – Payload and Onboard Sensors - Mission Planning – UAV Image Processing - Orthophoto, DSM/ DEM and 3D Point Cloud Generation - UAV Applications; Introduction to GEE: Platform – Code editor – Datasets and case studies

Text Books:

1. Lillesand, T., Kiefer, R. W., and Chipman, J. (2015). Remote sensing and image interpretation. John Wiley and Sons.
2. Campbell, J. B., and Wynne, R. H. (2011). Introduction to remote sensing. Guilford Press.
3. Thenkabail, P. S. (2016). Remote Sensing Handbook; Volume 1: Remotely Sensed Data Characterization, Classification, and Accuracies. Taylor and Francis. Girard, C. (2018). Processing of remote sensing data. Routledge.

References:

1. Borengasser, M., Hungate, W. S., and Watkins, R. (2007). Hyperspectral remote sensing: principles and applications. CRC press.
2. Chang, C. I. (Ed.). (2007). Hyperspectral data exploitation: theory and applications. John Wiley and Sons.
3. 4Kuenzer, C., andDech, S. (2013). Thermal infrared remote sensing. Remote Sensing and Digital Image Processing. doi, 10(1007), 978-94.
4. Woodhouse, I. H. (2017). Introduction to microwave remote sensing. CRC press

Predictive Analytics

CourseCode	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	

Web Technology

CourseCode	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4220252	Web Technology	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.
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.

Numerical Methods

CourseCode	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 UniversityPress, 2010. 2. M.K. Jain, S.R.K. Iyengar and R.K. Jain,

2. Numerical methods for scientific and Engineering computation, New Age InternationalPublishers, 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 BoundaryValue Problems, 11th Edition, Wiley-India

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

NGS and Genome Data Analysis

CourseCode	**Title of the course**	**Credits**	**Level**	**Credit Split Lecture-Lab-Seminar-Project**
M4220254	NGS and Genome DataAnalysis	3	400	1-1-0-1

Course Outcomes	
CO1	Analyze and interpret high-throughput sequencing data
CO2	Apply Omics data analysis for genomic and epigenomic studies
CO3	Utilize bioinformatics tools for phylogenetic and variant analysis
CO4	Explore the role of omics in precision medicine

Mapping of course outcomes with programme outcomes

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

CO4	3	3	2	1	2	3

Module	Content
1	Sequencing technologies, NGS-different platforms and Illumina workflow, data formats-(BCL, fasta, fastq, SAM, BAM, BED, VCF, GFF), data analysis- quality check and preprocessing, FastQC output analysis, assembly and mapping, sequence assembly and algorithms, graph theory and de Bruijn graph, assembly quality.
2	Sequence Read Archive (SRA) and Gene Expression Omnibus (GEO) databases, Genome-wide association study (GWAS) and whole-genome sequencing (DNA-seq), genetic variant detection and CNV, variant calling, gene prediction and annotation, RNA-seq, differential gene expression analysis, gene ontology, Mass-spec protein sequencing.
3	Epigenomics, DNA methylation, bisulfite sequencing, TAB-seq, oxBS-seq, TF binding site-ChIP-seq, metabolomics: analysis workflow and its main analysis softwares-MetaboAnalyst, integrative analysis of omics data- concatenation based, transformation based and model-based integration, machine learning for predictive modelling and analysis of omics data.
4	Precision medicine- gene therapy and gene editing technology, CRISPR technology, importance of pharmacogenomics in precision medicine. Phylogenetic analysis: Basics of phylogeny, gene phylogeny versus species phylogeny, phylogenetic tree of life, phylogenetic tree construction methods: distance-based methods, character-based methods, phylogenetic analysis tools-PHYLIP, ClustalW.

References:

1. Bioinformatics-Databases, tools and algorithms, Orpita Bosu, Simminder Kaur Thukral, OXFORD Higher Education, ISBN0-19-567683-1
2. Next Generation Sequencing and Data Analysis 2021, Melanie Kappelmann-Fenzl, Springer, ISBN: 978-3-030-62489-7
3. Data Analysis and Visualization in Genomics and Proteomics, Francisco Azuaje, Joaquin Dopazo, Wiley, ISBN: 978-0-470-09439-6

Advanced Geospatial Analytics

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

M4220255	Advanced GeospatialAnalytics	3	400	1-1-0-1

Course Outcomes	
CO1	Understand the manipulation of vector and raster data for geospatial modeling and analysis
CO2	Gain the knowledge and concepts and developing the skills in network analysis
CO3	Understand the concepts of spatio-temporal data and its analysis
CO4	Gain the knowledge about geo-computation methods and modelling

Mapping of course outcomes with programme outcomes

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

Module	**Content**
1	Advanced manipulation of vector and raster data. Spatial joins, aggregations and advanced filtering techniques.
2	Network modelling and analysis, Types of networks, Network data set and model construction, Network Analysis operations – Optimal Route and Optimal Tours, Location and Service Area Problems, Algorithms related to Network Analysis, Applications in Network Analysis
3	Working with spatio-temporal data, spatio-temporal data types, managing temporal data, visualizing and analyzing spatio-temporal data, spatio-temporal data estimation techniques
4	Geo-computation methods and modelling, Geo- simulation, Geospatial Applications of generic algorithms, Artificial Neural Networks, Agent Based Modelling, Cellular Automat

Text Books:

1. Heywood L, Comelius S and S Carver, An Introduction to Geographical Information Systems, Dorling Kindersley (India) Pvt Ltd, 2006

2. Micheal j de Smith, Micheal F Goodchild, Paul A Longley, Geospatial Analysis 5th edition, Troubadour Publishing Ltd, 2015

References:

1. 1Tsung Chang Kang, Introduction to Geographic Information Systems, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2002
2. Mitchell A, The ESRI Guide to GIS Analysis Volume 1: Geographical Patterns and Relationships, Environmental System Research Institute, Inc., Red Lands, California, USA

Courses offered as electives

Python Programming for Data Analytics

CourseCode	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 encoding and computational problem solving skills
CO2	Practice algorithm implementation to solve computational problems involving control structures and built-in data structures.
CO3	Obtain modularization, basic object oriented programming and basic graphical programming skills
CO4	Develop file processing, and exception handling skills

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	0	0	0

CO4	3	2	2	0	0	0

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.
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. Iterators: Sequences, iterables, iterator protocol. Generators: Generator functions and expressions. Files: Types of files, Opening, Closing, Reading and Writing files. Exceptions: Catching and handling exceptions, multiple exceptions. Graphics: Turtle Module, Drawing with colors, Drawing basic shapes using iterations, Creating bar charts.

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.

Differential Equations

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

Course Outcomes	
CO1	Employ numerical techniques to compute derivatives and integrals of functions, evaluating their accuracy and error bounds
CO2	Understand the fundamental concepts and classifications of differential equations.
CO3	Apply various analytical and numerical methods to solve ordinary and partial differential equations.
CO4	Analyze and interpret solutions of differential equations in the context of real-world problems.

Mapping of course outcomes with programme outcomes

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

Module	Content
1	Some basic differential equation models and Classification of ODEs (Linear, Non-linear, Exact, Separable, Geometric meaning of $y' = f(x, y)$, Direction Fields, Numerical methods for solving ODEs, More accurate methods for Initial Value Problems. Theory and Error analysis for Initial Value Problems. Adaptive, multistep, and other numerical methods for IVPs
2	Systems of First Order Differential Equations. Notations and relations. Two-dimensional First Order Systems. Phase-plane analysis for First-Order systems. General First-Order systems and higher-order differential equations.
3	Homogeneous Linear ODEs, Modelling of Free Oscillations of a Mass-Spring System, Euler-Cauchy Equations, Non-homogeneous ODEs, Variation of Parameters, Modelling (Forced Oscillations, Electric Circuits) Modelling Engineering problems (Electric Network, Mixing problem in two tanks etc.) as systems of ODEs, Wronskian, Phase-Plane Method, Critical Points and Stability
4	Introduction to Partial Differential Equations. Some concepts of PDEs. Finite Difference Methods for Elliptic Equations. General boundary conditions for elliptic problems and block matrix formulations. Concepts of Hyperbolic PDEs. Finite difference methods for hyperbolic PDEs. Finite difference methods for Parabolic PDEs

Textbooks

1. C. Kumar, B. Kaur, G. Manchanda, A Textbook on Differential Equations and Applications, Sultan Chand and Sons, 2023
2. M.D. Raisinghania, Advanced Differential Equations, Sultan Chand and Sons, 1995
3. J. Sundnes, Solving Ordinary Differential Equations in Python, 2023

Time Series Analysis and SEM Modeling

CourseCode	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 meanstructures

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 andApplications, Elsevier, 2012

Computational Neuroscience

CourseCode	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 EquivalentCircuit 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, Thecable 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 andbiomagnetic fields. Oxford University Press, USA.
2. Kandel, E.R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S. A., Hudspeth, A. J. Principles ofNeural 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

CourseCode	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 effectson civil liberties, The role of data ethics in shaping public policy - data protectionregulations, 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 PaulaGoldman

Data Structures and Algorithms

CourseCode	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	Analyze an algorithm and find its efficiency
CO2	Evaluate the applicability of the concepts of Stack, Queue and Linked List in problem solving
CO3	Evaluate the applicability of recursion for problem solving
CO4	Practice algorithm design and implementation to evaluate searching and sorting

Mapping of course outcomes with programme outcomes

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

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. Bradley N. Miller, David L. Ranum Problem Solving with Algorithms and Data Structures Using Python,Franklin, Beedle and Associates.
2. T.H. Cormen, Introduction to algorithms, MIT Press.
3. A.D Aho, J. E. Hopcroft and J. D. Ullman, Data Structures and Algorithms, Pearson education Asia.
4. Y. Langsam, M. J. Augenstein and A. M. Tenenbaum, Data Structures using C, Pearson Education Asia.
5. Adam Drozdek, Data Structures and Algorithms in Java, Published by Brooks/Cole

Computational Chemistry

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

M4221254	Computational Chemistry	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 Theory: 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. Activities: Familiarise with basic tasks such as optimization, conformational search, modeling active sites, biocatalytic reaction mechanisms using QM and QM/MM calculations.
2	Computational Modeling of Bio-materials

	Theory: 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. Activities: Simulating molecular dynamics of peptides and proteins; modeling bio-interfaces; analyzing properties for bio-sensors and bio-compatible devices.
3	Computational Spectroscopy of Biological Systems Theory: 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. Activities: Simulating IR, Raman, NMR, EPR spectra; time-dependent DFT calculations; correlating computational results with experimental data.
4	Data-Driven Computational Chemistry in Bio-Systems Theory: 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. Automating data preprocessing and molecular modeling tasks. 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.

References:

1. Jensen, F. (2017). Introduction to Computational Chemistry (3rd ed.). Wiley. ISBN: 978-1118825990.
2. Cramer, C. J. (2004). Essentials of Computational Chemistry: Theories and Models (2nd ed.). Wiley. ISBN: 978-0470091821.

3. Schlick, T. (2010). Molecular Modeling and Simulation: An Interdisciplinary Guide (2nd ed.). Springer. ISBN: 978-1441963505.
4. Young, D. C. (2001). Computational Chemistry: A Practical Guide for Applying Techniques to Real-World Problems. Wiley-Interscience. ISBN: 978-0471333685.
5. Leach, A. R. (2001). Molecular Modelling: Principles and Applications (2nd ed.). Prentice Hall. ISBN: 978-0582382107.
6. Tutorials and user manuals for ORCA, Psi4, GROMACS, and NAMD.

Deep Learning and MLOps

CourseCode	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M4221255	Deep learning and MLOps	3	400	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: Neural network architectures (feedforward, convolutional, recurrent, and transformers), deep learning optimizers, and regularization techniques. Lab Component: Implement advanced networks and test with real-world datasets.
2	Deep Learning Architectures: Topics: CNNs, RNNs, GANs, autoencoders, and transformer architectures for specialized tasks in NLP and computer vision. Seminar/Project: Critical analysis of recent research papers in each architecture area, with student presentations.
3	Deep Learning Operations (DLOps): Topics: CI/CD in deep learning, model versioning, monitoring, automated ML (AutoML), and ethical considerations. Project Component: Implement a DLOps pipeline for a chosen application using tools like TensorFlow Extended (TFX) or MLflow.
4	Capstone Project: Students design and implement an end-to-end deep learning solution for a complex, real-world problem. This includes model selection, tuning, deployment, and evaluation, aiming for outcomes suitable for publication or conference presentation.

Assessment:

- Capstone 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

Microwave Remote Sensing

CourseCode	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 Monitor-ing
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: Use linguistic principles to perform essential NLP tasks like tokenization, POS tagging, and dependency parsing.
CO2	Apply Statistical NLP and Embeddings: Utilize machine learning techniques, including word embeddings, for effective text representation.
CO3	Construct Information Retrieval Models: Implement core IR models and evaluate them using precision, recall, and other metrics on benchmark datasets.
CO4	Develop Advanced IR Systems: Design and optimize custom retrieval systems with advanced algorithms, including query expansion and 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	Foundational Concepts in NLP and Linguistics: Topics: Introduction to basic linguistic principles including syntax, semantics, and phonology. Key NLP tasks including tokenization, stemming, part-of-speech (POS) tagging, named entity recognition (NER), and dependency parsing. Lab Component: Students will implement basic NLP preprocessing techniques on datasets using libraries such as NLTK and spaCy. Exercises will include building tokenization and tagging pipelines and performing dependency parsing on sample text.
2	Statistical and Machine Learning Approaches in NLP: Topics: Machine learning techniques for language processing including Bag of Words, Term Frequency-Inverse Document Frequency (TF-IDF), n-grams, language modeling, and vector space models. Exploration of word embedding techniques, such as Word2Vec, GloVe, and contextual embeddings. Lab Component: Experiment with embedding techniques to analyze their effectiveness in representing text data for downstream tasks. Students will test embeddings for sentiment analysis, document classification, and semantic similarity applications.
3	Information Retrieval Models: Topics: Core models in information retrieval, including probabilistic models (e.g., BM25), vector space models, semantic retrieval models, and neural IR models. Lab Component: Implement and evaluate retrieval models using precision, recall, F1-score, and Mean Average Precision (MAP) on benchmark datasets. Students will test these models on IR datasets to retrieve relevant documents and assess model effectiveness.
4	Advanced Information Retrieval Algorithms: Topics: In-depth exploration of retrieval algorithms, including inverted index optimization, relevance feedback, query expansion techniques, term weighting, and dimensionality reduction methods. Project Component: Develop a custom retrieval system incorporating term weighting, query expansion, and relevance feedback. This project should address a real-world IR problem, evaluating effectiveness through metrics and providing insights for improvements.

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.

Advanced Topics in the Semantic Web and Social Network Analysis

CourseCode	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	2-1-0-1

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

CourseCode	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.
CO5	Apply geospatial data acquisition, analysis, and visualization techniques in project development.

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	3	2	1	2	1	2
CO4	2	3	2	1	2	1
CO5	3	3	2	1	2	1

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/Thesis:

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

CourseCode	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/Thesis:

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

CourseCode	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	Design and deploy web GIS architectures
CO2	Apply standards for interoperable web GIS services
CO3	Configure and manage GIS servers and spatial databases for web-based mapping services
CO4	Integrate mobile GIS for field data collection and synchronization with Web GIS systems

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	2	1	1	2
CO2	2	2	2	1	1	1
CO3	3	3	1	1	1	2
CO4	2	1	1	2	1	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: ArcGIS Field Maps, 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/Thesis:

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.

Structural Biology and Drug Design

CourseCode	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221255	Structural Biology and Drug Design	3	500	1-1-0-1

Course Outcomes

CO1	Demonstrate 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 in drug discovery, 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 of drug discovery process and its challenges, drug targets and their classification, enzyme kinetics, classification of drugs, ADMET properties of drugs, drug-receptor interactions *Research Focus:* Literature review on drug classification and ADMET advancements.
2	Structure-based and ligand-based drug design, the concept of de novo design for lead identification, molecular docking, molecular dynamics, pharmacophore mapping, QSAR, and QSPR, pharmacokinetics (ADME/T), pharmacodynamics, fragment-based drug design, retrosynthetic approaches. *Research Focus:* Conduct a small research project using pharmacophore mapping or molecular docking/dynamics simulations.
3	Role of cheminformatics in pharmaceutical research, molecular descriptors, machine learning approaches in drug design, molecular descriptors, fingerprint generation, ADME/T databases, chemical, biochemical and pharmaceutical databases, data mining, and visualization methods**.** *Research Focus:* Database creation and data mining project using cheminformatics databases (e.g., SMILES, PDB).

4	Computational chemistry in drug design: Classical mechanics vs quantum mechanics, potential energy surface-stationary point and saddle point, energy minimization, basis functions, basis sets, Slater type orbitals (STO) and Gaussian type orbitals (GTO), ab initio and semi-empirical methods, Density Functional theory (DFT). *Research Focus:* Computational analysis on a molecule of interest, utilizing Density Functional Theory (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 assignments on molecular modeling, docking, and cheminformatics tools.

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

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

References:

1. *Computer Aided Drug Design (CADD): From Ligand-Based Methods to Structure-Based Approaches, Mithun Rudrapal, Chukwuebuka Egbuna, Elsevier, ISBN: 9780323906081*
2. *A First Course in Systems Biology, Voit E, Garland Science, ISBN: 0815344678*
3. *Artificial Intelligence in Drug Design, Alexander Heifetz, Springer, ISBN: 9781071617892*

Data Security

CourseCode	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

CourseCode	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 systemsand 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, 2ndedition. Mcgraw-Hill Education, 2008.
4. Brian Tuomanen. Hands-On GPU Programming with Python and CUDA: Explore high-performance parallelcomputing with CUDE. Packt Publishing, 2018.

Numerical Linear Algebra

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

Course Outcomes	
CO1	Analyze and perform matrix computations efficiently, ensuring acceptable speed, accuracy, and stability in numerical algorithms.
CO2	Apply advanced numerical methods for linear algebra and matrix decompositions, utilizing Python libraries for high-performance computing.
CO3	Develop and implement numerical linear algebra techniques for real-life applications, including image processing, PageRank algorithms, and data compression.
CO4	Explore and evaluate various matrix decomposition techniques and their applications in solving practical and theoretical problems.

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	0	0	0
CO4	3	2	2	0	0	1

Mod-ule	**Content**
1	Overview of basics of matrix theory, rank of matrix, vector space, linear dependence, matrix norms, condition number and stability of numerical algorithms
2	Matrix and Tensor Products, Matrix Decompositions, Accuracy, Memory use, Speed, Parallelization and Vectorization L1 Norm Induces Sparsity, LU factorization, Stability of LU, LU factorization with Pivoting
3	Block Matrix Multiplication, Sparse matrices, CT Scans and Compressed Sensing, L1 and L2 regression, Polynomial Features,
4	Regularization and Noise, Normal equations, Timing Comparison, Conditioning and Stability, Full vs Reduced Factorizations, symbolic regression

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

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

M5221351	Anomaly detection and FraudAnalytics	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: Movingaverages, 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 forfraud 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

Generative AI

CourseCode	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221352	Generative AI	3	500	1-1-0-1

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	Introduction to Generative AI – Definition and Scope - Evolution and History of Generative AI Models – Importance of Generative AI in various domains – Overview of Generative AI models and their applications – GAN, VAE, GPT, Transformers and Diffusion models. Understanding GPT (Generative Pre-Trained Transformer) – Introduction to GPT and its significance – Architecture and Working of GPT Models – Overview of GPT variants and their use cases – ChatGPT – A practical application of GPT – Introduction and Significance
2	Exploring Generative AI project Life cycle - 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. 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
3	Applications and Advancements in Generative AI – Challenges and Ethical considerations in Generative AI – Bias and Fairness in Generative AI – Ensuring responsible use and deployment of Generative AI models -Future Directions and Open Problems in Generative AI
4	Use cases of Generative AI - Overview of various domains and industries benefiting from Generative AI – Generative AI in Healthcare – Generative AI in Finance – Generative AI in E-commerce

	Hands on Generative AI with Diffusion Models – Building an Unconditional Image Generation models – Building an text guided image generation model – Building an Image to Image translational model – Music generation with diffusion models.

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

Healthcare Analytics

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

Course Outcomes	
CO1	Introduction to healthcare analytics
CO2	Electronic healthcare records
CO3	Predictive techniques in healthcare
CO4	Image and signal analysis; NLP applications

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	Introduction to Healthcare Data Overview of healthcare data sources and formats; Privacy and security considerations inhealthcare data; Data preprocessing and cleaning techniques for healthcare data
2	Electronic Health Records (EHR) Introduction to Electronic Health Records (EHR) systems; EHR data structure, components, and challenges; Analyzing EHR data for patient insights; Sensor Data in Healthcare Types of sensor data in healthcare; Collection, storage, and processing of sensor dataCase studies: Analyzing sensor data for disease monitoring and prevention
3	Predictive Analytics: Predictive modeling for disease risk assessment; Early diseasedetection using ML techniques; Feature selection and model validation in healthcare prediction Clinical Decision Support Systems: Role of ML in clinical decision-making; Building clinical decision support systems using ML; Ethical considerations in deploying ML models in healthcare
4	Image and Signal Analysis in Healthcare: Medical image analysis using ML techniques Signal processing for healthcare applications; Case studies: Image analysis for diseasediagnosis and treatment Natural Language Processing (NLP) in Healthcare: NLP techniques for processing clinicaltext data Extracting information from medical texts and reports; Applications of NLP in healthcareresearch and practice

References:

1. Healthcare Analytics for Quality and Performance Improvement by Trevor L. Strome
2.Introduction to Machine Learning with Python: A Guide for Data Scientists by Andreas C. Müller and Sarah Guido
3.Clinical Decision Support Systems: Theory and Practice by Eta S. Berner
4.Machine Learning and Healthcare Analytics by Kelleher, Mac Namee, and D'Arcy5.Medical Image Analysis by Atam P. Dhawan and Jasjit S. Suri
6.Natural Language Processing for Health and Life Sciences by Aakash Bansal, Karthik Raman, and Sumit Agarwal

Advanced Programming

CourseCode	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 withPython", McGraw Hill Education, 2018.

Thermal and Hyperspectral Remote Sensing

CourseCode	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	Understand various application domains of thermal and hyperspectral data product
CO4	Gain knowledge in thermal and hyperspectral image analysis

Mapping of course outcomes with programme outcomes

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

Module	Content
1	Thermal radiation principles, thermal process and properties – Characteristics of thermal IRimages and factors affecting thermal images – Interaction of thermal radiation with terrain elements – Thermal sensors and their characteristics – MUST (Medium Scale Surface Temperature Missions) – radiometric calibration of thermal scanners
2	Thermal image and types of available data products – Interpretation of thermal images - dayand night images – LST retrieval methods – Application of thermal remote sensing data in crop health monitoring, pollution monitoring, oil spill detection, Atmospheric modelling, SeaSurface Temperature
3	Hyperspectral Remote Sensing – Imaging Spectroscopy – representation systems – Spectral cube – Airborne and spaceborne hyperspectral sensors – Hughes phenomenon – multivariate analysis for data reduction – Spectral library – Hyperspectral image compression – Feature selection and feature extraction techniques
4	Hyperspectral Image Analysis: Calibration and normalization of hyperspectral images –Observing signatures of various features and comparing with spectral libraries – Spectral mapping methods: Spectral Angle Mapper (SAM), Spectral Correlation mapper, Spectral Feature Filtering (SFF), Linear Spectral Unmixing (LSU) – Application of hyperspectral remote sensing: Agriculture, Soils, Forestry, Environmental and Resource Management

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 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

CourseCode	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	Understanding the concepts of Elevation data products.
CO2	Able to perform Topographic Analysis from DEM
CO3	Volumetric and Bathymetric Analysis from DEM
CO4	Understanding the applications of DEM in real world problems

Mapping of course outcomes with programme outcomes

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

Module	Content
1	Basics of Digital Elevation Model and Digital Surface Model; Terrain visualization. Methods of representing DEM; Image methods, Point models; Data sources and sampling methods for DEMs; Data registration and geo-coding;Global Elevation Data Sources, DSM from UAV/Drone data,LiDAR data.
2	Topographic Analysis : Contour. Slope, aspect, Hillshade, Viewshed Analysis, Line-of-Sight.
3	Volumetric Analysis and Computation, Cut-Fill Analysis, Bathymetric applications Analysis and estimation, Reservoir Volume Calculation.

4	Application of Digital Elevation Models in Water Resource Management, Disaster RiskManagement, Infrastructure planning

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

CourseCode	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	Understanding geospatial big data basics and core concepts
CO2	Geospatial big data technologies and tools
CO3	Understanding about advanced GIS and machine learning algorithms
CO4	Open-source geospatial big data analysis and applications

Mapping of course outcomes with programme outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	1	2	1
CO2	3	3	2	1	1	1
CO3	3	2	1	2	1	2
CO4	3	3	2	3	2	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, Hadoop GIS vs parallel SDBMS, Geospark
2	Spatial big data, Data cleaning in spatial big data Challenges in using the big data in spatial technologies, Databases supporting spatial data – Hive based spatial data storage, Real time query engine, workflow Data partitioning and storage.
3	Spatial data wrangling with geospark values in spatial big data, visualizations, GeosparkVis 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

References:

1. Chaowei, Yang et al; Introduction to GIS Programming and Fundamentals with Python andArcGIS : 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: Patternsfor Learning from Data at scale

Geospatial Applications in Agriculture

CourseCode	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	Understanding the concepts of Agricultural Science
CO2	Familiarization of GIS and RS concepts specific to the agricultural domain
CO3	Application of learned skills to familiarize and create models in agricultural domain
CO4	Different crop disease and pest identification techniques in GIS and RS

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: Crop Types, Cropping Patterns and cropping seasons; agricultural practices of major crops -various stages of crop cultivation. Crop yield monitoring, condition assessment,important insects and pest infection of major crops; Precision agriculture
2	Applications of GIS and remote sensing in agriculture - various techniques; spectral characteristics of leaf -structure of leaf; Vegetation indices – NDVI, SVI, PCA, TVI – Vegetation classification and mapping – Estimation of leaf area index, Biomass estimation. Detection of pest and diseases.
3	Spectral behavior of different crops and vegetation in VIS, NIR, MIR, TIR and Microwave regions. Microwave back scattering behavior of crop canopy – crops identification and crop inventory- crop acreage estimation – reflectance properties of stressed crops, detection of stressed plants. Land use and land cover analysis.
4	Digital Soil Mapping, ML/Deep Learning for soil nutrient, disease and crop yield prediction

References:

1. P.Christy Nirmala Mary, P.Kannan, Geospatial Technologies for Agriculture, ISBN: 9789390082766, 2020

2. Bhagowati Kaushik, GIS Assissted Farm Management Information System, ISBN: 9783844333695, 2012

3. V M Abdul Hakkim, GIS Integrated Site-Specific Drip Fertigation, ISBN: 9783659261480, 2013

Geospatial Applications for Environment and Climate change

CourseCode	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	Understanding the different impacts of climate change and its analysis using GISs
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	1	-	-	-
CO2	2	3	3	-	-	-
CO3	3	1	2	-	-	-
CO4	3	3	1	-	-	-

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

CourseCode	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	Understanding the concepts of GIS and RS applications of hydrology
CO2	Applying learned concepts on hydrological modeling
CO3	Applying learned concepts on flood modeling
CO4	Management and mitigation of hydrological phenomena

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

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

Module	Content
1	Basic concepts of hydrology - aspects, parameters and sciences involved in hydrology, hydrologic cycle. Remote sensing and GIS applications in Water Resources Management; sources of hydrological data.
2	Hydrological mapping and modeling – surface water and groundwater inventory, watershed delineation and flow modeling, run-off estimation
3	Hydrological mapping and modeling – surface water and groundwater inventory, watershed delineation and flow modeling, run-off estimation.
4	Water balance - principles, components, water systems and types; global water balance scenario, blue and green water perspective. Assessment of water balance.
5	Flood management - potential flood zone mapping, flood risk assessment, flood hazard simulation; mitigation methods for flood management

References:

1. John G Lyon, GIS for Water Resources and Watershed management, ISBN-10 :9788184892932.
2. Tim Davie, Fundamentals of Hydrology 3rd edition,, ISBN-10 : 0415858704, 2019.
3. A. M. Gurnell and D. R. Montgomery, Hydrological Applications of GIS (Advances inHydrological Processes) 1st edition, 2000

Geospatial Applications in Urban and Regional Planning

CourseCode	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 modeling 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	3	2	1	1
CO3	3	1	2	1	1	1
CO4	3	3	1	1	1	1

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 usingHydrological tools in GIS

References:

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

AI applications in agriculture

CourseCode	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 integratingAI 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 PublishingAgency, 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

CourseCode	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 methodresults; 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 seriesanalysis of financual data Financial forecasting; Rsik management, Types of risks, measuring risks,Fiancial 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 passiveportfolio 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

CourseCode	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, explain, and apply foundational concepts and principles of data engineering.

CO2	Selecting, utilizing, and configuring appropriate data storage and processing technologies for different scenarios.
CO3	Design, construct, and manage data pipelines for efficient and reliable datamovement and transformation.
CO4	Analyze complex data engineering challenges, implement advanced techniques, and optimize data processes for different use cases.

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	Fundamentals of Data Engineering - Introduction to Data Engineering, Data Lifecycle and Data Flow, Data Modeling: Conceptual, Logical, Physical, ETL (Extract, Transform, Load) Processes, Data Warehousing Basics, Introduction to Big Data Technologies, Data Quality and Data Governance
2	Data Storage and Processing - Relational Databases and SQL, NoSQL Databases (Document, Columnar, Key-Value, Graph), Data Lake Architecture and Technologies, In-Memory Databases, Introduction to Distributed Computing, Batch Processing vs. Stream Processing.Introduction to Apache Hadoop and Spark
3	Building Data Pipelines - Data Pipeline Architecture, Workflow Orchestration, Data Ingestion Methods (Batch and Real-time), Data Transformation and Enrichment, DataPipeline Monitoring and Error Handling, Introduction to Data Orchestration Tools (Airflow, Luigi, Prefect), Best Practices for Pipeline Scalability and Performance
4	Advanced Topics in Data Engineering - Data Security and Privacy, Data Versioningand Lineage, Microservices Architecture for Data, Data Serialization Formats (Avro, Parquet, JSON), Real-time Data Processing and Streaming

	Platforms, Data Warehousing and Data Lake Integration, Performance Tuning and Optimization Strategies

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

CourseCode	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	Introduction to Apache Hadoop and Spark, Spark Cluster, Spark Core, High level architecture, Spark Context, RDD, Lazy Operation, Caching methods, Spark SQL, Machine Learning with pySpark, Mining of data streams
2	Finding similar text items: Shingling of Documents, Similarity preserving summaries of sets-Minhashing and signatures, Locality Sensitive Hashing of Documents, Distance measures, Locality sensitive functions
3	Link Analysis: Page Rank, Computation of PageRank, Google PageRank Algorithm, Topic Sensitive PageRank, Link Spam, HITS algorithm, Mining of Frequent item sets, Recommendation Systems
4	Cloud components, Essential characteristics, Rapid elasticity, Architectural influences. Benefits: scalability, simplicity, vendor, security, Limitations, Layers in cloud architecture, Software as a Service (SaaS), features of SaaS and benefits, Platform as a Service (PaaS)

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	1-1-0-1

Course Outcomes	
CO1	Understand the fundamental concepts of graphs, graph theory, and applications
CO2	Implement graph representation learning algorithms to generate meaningful embeddings of graph structures

CO3	Apply graph-based machine learning algorithms for tasks such as clustering, link prediction, classification, and generation
CO4	Develop solutions to address specific challenges and requirements in real-world scenarios

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

Module	**Content**
1	Overview of graph theory: basic concepts, terminology, and representations. Types of graphs: directed graphs, undirected graphs, weighted graphs, and their properties. Graph operations: node and edge attributes, graph traversal, and common graph algorithms. Introduction to applications of graphs: social networks, recommendation systems, and biological networks.
2	Node embeddings: random-walk embeddings, nodezvec, matrix factorization method. Graphs embedding. Graph Neural Networks (GNNs): GNN architecture, message-passing algorithms. Graph Convolutional Networks (GCNs): fundamentals of GCN architecture, message aggregation.
3	Graph-based machine learning algorithms: graph clustering, link prediction, node classification, graph classification, graph generation.
4	Social network analysis: identifying communities, detecting anomalies, and predicting influential nodes. Recommender systems: collaborative filtering and content-based recommendation using graph data. BioAI: protein-protein interaction networks, drug-target interaction prediction, and gene expression analysis. Graph-based anomaly detection: detecting unusual patterns and outliers in complex networks.

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	1-1-0-1

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	1	1	0
CO3	3	3	3	3	0	0
CO4	3	2	3	1	0	0

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
	Flows, state variables, state phase, nonintegrability, flow solvers, shadowing and chaos, van der Pol oscillator, averaging theory, Lyapunov exponents, unstable

3	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	Understand the mathematical foundations of the theory, problem, and state-of-the-art solutions of modern stochastic models.
CO2	Analyze and critically evaluate the building and integration of stochastic models, algorithms, and systems.
CO3	Design and demonstrate a stochastic model through team research projects and project report presentations.

Mapping of course outcomes with program outcomes

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

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	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.
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 code	Title of the course	Credits	Level	Credit Split Lecture-Lab-Seminar-Project
M5221369	Optimization Techniques	3	500	1-1-0-1

Course Outcomes	
CO1	Understand the optimization techniques problem and state-of-the-art solutions.

CO2	Analyze and evaluate critically the building and integration of optimization techniques.
CO3	Design and demonstrate optimization techniques through team research projects, project reports and presentations.

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

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 gradient 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.