केरल केन्द्रीय विश्वविद्यालय

CENTRAL UNIVERSITY OF KERALA

Department of Computer Science

Ph.D (Computer Science)

FEBRUARY 2026

Programme Structure

	CENTRAL UNIVERSITY OF KERALA DEPARTMENT OF COMPUTER SCIENCE Ph.D COMPUTER SCIENCE – PROGRAMME STRUCTURE					
COURSE CODE	**COURSE TITLE**	**CONTACT HRS/WEEK**				**CREDITS**
		LEC	**LAB**	**TUT**	**LIT**	
SEMESTER I						
26CSCPH1DSC01	Research Methodology	2	0	0	0	2
26CSCPH1DSC02	Research and Publication Ethics (RPE)	2	0	0	0	2
26CSCPH1DSC03	*Course from Basket 1 (Courses related to specific area of research)	2	1	1	0	4
26CSCPH1DSC04	*Course from Basket 2 (Courses related to specific research proposal)	2	1	1	0	4

***Courses are assigned by the respective Research Advisory Committee (RAC) depending on the research area and research proposal**
LEC – Lecture, LAB – Lab Work, TUT – Tutorial, LIT – Literature Survey

Basket 1 : Courses related to specific area of research	
CSC8111	Pattern Recognition
CSC8112	Cyber Security
CSC8113	Machine Learning
CSC8114	Image Data Mining
CSC8115	Precision Agriculture
CSC8116	Immersive Technologies
CSC8117	Multimodal Learning and Modelling
Basket 2 : Courses related to specific research proposal	
CSC8121	Sign Language Recognition
CSC8122	Brain Analysis
CSC8123	Audio Visual Speech Recognition and Semantic Summarization
CSC8124	Machine learning approaches for cyber threat detection
CSC8125	DDOS Attacks and Defense Mechanisms
CSC8126	Data Mining Trends and Research Frontiers
CSC8127	Multimodal Signal Processing
CSC8128	Bioinformatics
CSC8129	Image Processing
CSC8130	Geospatial Data Analysis of Agro-Ecological Zones
CSC8131	Metaverse
CSC8132	Human Computer Interaction
CSC8133	Intelligent Web Mining
CSC8134	Cloud Computing Security

Programme Outcomes

The students will be able to attain the following after the completion of Ph.D. Computer Science

(i) Inculcate critical thinking to carry out scientific investigation objectively without being biased with preconceived notions.

(ii) Equip the student with skills to analyze problems, formulate a hypothesis, evaluate and validate results, and draw reasonable conclusions thereof.

(iii) Able to articulate the scientific advances and limitations of results described in the research literature.

(iv) Plan and conduct original research that addresses questions of significance in a particular subject area in Computer Science and related fields.

(v) Prepare students for pursuing postdoc research or careers in industry/academics

(vi) Imbibe effective scientific and/or technical research communication in both oral and writing.

(vii) Continue to acquire relevant knowledge and skills appropriate to professional activities and demonstrate highest standards of ethical issues.

(viii) Create awareness to become an enlightened citizen with commitment to deliver one's responsibilities within the scope of bestowed rights and privileges for supporting the society.

Programme Specific Outcomes

The Computer Science Department's Ph.D program must enable students to attain, by the time of getting awarded with Doctoral degree

(i) An ability to apply knowledge of computing and mathematics appropriately.

(ii) An ability to identify, formulate, and develop solutions to challenges and to analyse, design and develop cost effective solutions to the societal problems.

(iii) An ability to design, implement, and evaluate a computational system to meet desired needs within realistic constraints.

(iv) An understanding of professional, ethical, legal, security, and social issues and responsibilities.

(v) An ability to communicate and engage effectively with diverse stakeholders while designing computational applications.

(vi) An ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modeling and design in a way that demonstrates comprehension of the tradeoffs involved in design choices and to meet realistic constraints.

(vii) Identify, analyze, and synthesize scholarly literature relating to the field of research

SYLLABUS

RESEARCH METHODOLOGY

(Common for the Departments of Mathematics, Physics, Chemistry & Computer Science)

Credits: 2 **Contact Hours:** 30

Semester: I **Course Type:** Core Coursework

COURSE OBJECTIVES

This course aims to:

1. Develop a rigorous understanding of scientific research foundations.
2. Enable scholars to formulate research problems and design methodologies.
3. Provide statistical and computational tools for data analysis.
4. Train scholars in scientific writing and publication practices.
5. Introduce contemporary practices in data-driven and reproducible research.

COURSE OUTCOMES

After successful completion of this course, the scholar will be able to:

CO1 – Formulate and justify a research problem using scientific reasoning.
CO2 – Design theoretical, experimental, or computational research frameworks.
CO3 – Apply statistical tools for analyzing and interpreting research data.
CO4 – Prepare research proposals and publishable manuscripts using standard tools.
CO5 – Implement reproducible, data-driven, and technology-enabled research practices.
CO6 – Apply GLP principles across laboratory, theoretical, and digital research environments.

COURSE STRUCTURE

Unit I – Foundations of Scientific Research (7 Hours)

- Nature and philosophy of science
- Inductive and deductive reasoning
- Scientific method and logic of discovery
- Hypothesis formulation and testing
- Identification and framing of research problems
- Interdisciplinary research approaches
- Research objectives, scope and delimitations

Unit II – Research Design & Methodological Approaches (8 Hours)

- Types of research: theoretical, experimental, computational
- Research design and planning
- Mathematical modeling and algorithmic formulation
- Experimental design principles
- Data collection methods (primary and secondary)
- Literature review methodology
- Systematic review basics

- Research documentation and record keeping

Unit III – Statistical Methods & Data Analysis **(8 Hours)**

- Errors and uncertainty analysis
- Measures of central tendency and dispersion
- Probability distributions: Normal, t, Chi-square, F
- Hypothesis testing
- Regression and correlation analysis
- ANOVA and covariance
- Data visualization principles
- Introduction to statistical software (R / Python / MATLAB – demonstration level)

Unit IV – Good Laboratory Practice (GLP) in Experimental, Theoretical & Computational Research

(7 Hours)

Foundations of Good Laboratory Practice

- Concept and objectives of Good Laboratory Practice (GLP)
- Quality assurance in research environments
- Standard Operating Procedures (SOPs)
- Documentation standards and traceability
- Calibration, validation and verification of instruments and methods
- Risk assessment and mitigation strategies

GLP in Experimental Research (Physical & Chemical Sciences)

- Laboratory safety protocols and hazard identification
- Handling, storage and disposal of chemicals and materials
- Instrument maintenance and preventive servicing
- Sample collection, labelling, and chain-of-custody
- Reproducibility in experimental workflow
- Error minimization and uncertainty estimation
- Maintenance of laboratory notebooks and raw data records

(OR)

GLP in Theoretical and Mathematical Research

- Structured problem formulation and documentation
- Assumption clarity and logical consistency
- Verification of proofs and cross-validation of results
- Proper citation of theorems, definitions, and prior work
- Version tracking of manuscripts and derivations
- Transparent Presentaion of algorithms and models

(OR)

GLP in Computational and Data-Driven Research

- Code documentation and annotation standards

- Version control systems (Git basics)
- Reproducible computational workflows
- Data storage, backup, and archiving protocols
- Validation and benchmarking of computational models
- Managing large datasets and metadata
- Cybersecurity and responsible data access

TEACHING-LEARNING METHODS

- Lectures
- Demonstration sessions
- Hands-on workshops (software & LaTeX)
- Student seminars
- Proposal drafting exercises

ASSESSMENT SCHEME

Component	**Weightage**
Research Proposal Preparation	20%
Seminar Presentation	10%
Assignment/Software Exercise	10%
End Semester Examination	60%
Total	**100%**

RECOMMENDED BOOKS & RESOURCES

1. C. R. Kothari, Research Methodology Methods and Techniques, 2nd Revised Ed., 1990.
2. Robert V Smith, Graduate Research: A Guide for Students in the Sciences, University of Washington Press, 1998.
3. Paul D Leedy, Jeanne E Ormrod and Jeanne Ellis Ormrod, Practical Research: Planning and Design, Prentice Hall, 2004.
4. M. P. Marder, Research Methods for Science, Cambridge (2011)
5. Born, Max, Natural Philosophy of Cause and Chance, Dover, (1964).
6. Brody, Thomas A., The Philosophy Behind Physics, Springer Verlag, (1993).
7. Polya, George, How to Solve It, Princeton University Press, (1957).
8. Popper, Karl R., The Logic of Scientific Discovery, (1959).
9. Feynman, R.P., The character of physical law, Penguin, (1992).
10. Squires, G.L., Practical Physics, Cambridge University Press, (2001).
11. Day, RA and B. Gastel, How to Write and Publish a Scientific Paper, Cambridge University Press, (2010).

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CSC8002 – Research and Publication Ethics (RPE)

This is a skill development course focusing on philosophy of science & ethics, research integrity, publication ethics with hands-on-sessions to identify research misconduct and predatory publications. Indexing/citation databases, open access publications, research metrics (citations, h-index, impact factor, etc.) and plagiarism tools will be introduced in this course.

Course Objective:

The objective of the course is to provide awareness about the publication ethics, publication misconducts, research integrity, indexing, research metrics and plagiarism.

By completing this course, students will obtain the following course/learning outcomes:

1. Knowledge to be gained:
   - (i) Philosophy and ethics of research
   - (ii) Scientific Conduct
   - (iii) Publication ethics and misconduct
   - (iv) Databases and research metrics
2. Skill to be gained:
   - (v) Skills to identify research misconduct and predatory publications
3. Competency to be gained:
   - (vi) To do effectual research by properly following research ethics

Prerequisites: Nil

Grading:

Group Discussion	: 12%
Paper reviewing and analysis	: 15%
Assignment/Quiz/presentation	: 8%
Class Test	: 5%
Final Exam	: 60%

Unit 1: PHILOSOPHY AND ETHICS (3 hrs.)

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

Unit 2: SCIENTIFIC CONDUCT (5 hrs.)

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

Unit 3: PUBLICATION ETHICS (7 hrs.)

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

Unit 3: OPEN ACCESS PUBLISHING (4 hrs.)

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

Unit 5: PUBLICATION MISCONDUCT (4 hrs.)

A. Group Discussions (2 hrs.).
   Subject specific ethical issues, FFP, authorship. Conflicts of interest. Complaints and appeals: examples and fraud from India and abroad.
B. Software tools (2 hrs.).
   Use of plagiarism software like Turnitin, Urkund and other open source software tools.

Unit 6: DATABASES AND RESEARCH METRICS (7 hrs.)

A. Databases (4 hrs.).
Indexing databases. Citation databases: Web of Science, Scopus, etc.

B. Research Metrics (3 hrs.).
Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score. Metrics: h-index, g index, i10 index, altmetrics

References

1. *Bird, A. (2006). Philosophy of Science. Routledge*
2. *MacIntyre, Alasdair (1967) A Short History of Ethics. London*
3. *P. Chaddah, (2018) Ethics in Competitive Research: Do not get scoped; do not get plagiarized, ISBN: 978-9387480865*
4. *National Academy of Science, National Academy of Engineering and Institute of Medicine. (2009). On Being a Scientist: A guide to Responsible Conduct in Research: Third Edition, National Academies Press.*
5. *Resnik, D. B. (2011). What is ethics in research & why is it important. National Institute of Environmental Health Sciences, 1-10. Retrieved from https://www.niehs.gov/research/resources/bioethics/whatis/index.cfm*
6. *Beall, J. (2012). Predatory publishers are corrupting open access. Nature, 489(7415), 179-179. https://doi.org/10.1038/489179a*
7. *Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance (2019), ISBN: 978-81-939482-1-7. http://www.insaindia.res.in/pdf/Ethics_Book.pdf*

CSC8111 – Pattern Recognition

This is a practical/lab oriented course focusing on pattern recognition.

Course Objective:

To train the students and make them understand the latest trends in pattern recognition

By completing this course, students will obtain the following course/learning outcomes:

1. Knowledge to be gained:
   (i) Understanding the features and properties of patterns
   (ii) Representation of patterns
2. Skill to be gained:
   (iii) Skills to solve problems using pattern recognition algorithms
3. Competency to be gained:
   (iv) Ability to carry out independent research in pattern recognition

Prerequisites: Nil

Grading:

Lab	: 20%
Assignment/Quiz/presentation	: 10%
Class Test 1	: 5%
Class Test 2	: 5%
Final Exam	: 60%

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	40 Marks
Lab	1	End Semester Assessment	60 Marks
Tutorial	1	Credits	4

Module 1

Pattern Recognition Systems –Definitions, data representation, representations of patterns and classes. Types of pattern recognition systems. Applications of pattern recognition systems. Bayesian decision making and Bayes Classifier for continuous and discrete features.

Module 2

Min-max and Neymann-Pearson classifiers, Discriminant functions, decision surfaces. Maximum likelihood estimation and Bayesian parameter estimation. Overview of Nonparametric density estimation –Histogram based approach, classification using Parzen window.

Module 3
K-nearest neighbour estimation and classification. Classification of clustering algorithms –hierarchical clustering –agglomerative clustering. Partitional clustering –Forgy's algorithm. K-means clustering.

Module 4
Introduction to feature selection –filter method –sequential forward and backward selection algorithms. Wrappers method and embedded methods. Feature extraction methods –principal component analysis, fisher linear discriminant analysis, ICA.

References:

1. *Duda R.O., Hart P.E., Stork D.G., Pattern Classification, John Wiley and Sons, 2nd Edition, 2001*
2. *Bishop C.M., Pattern Recognition and Machine Learning, Springer, 2nd Edition, 2006*
3. *Theodoridis S., Pikrakis A., Koutroumbas K., Cavouras D., Introduction to Pattern Recognition: A Matlab approach, Academic Press, 2010*

CSC8112 – Cyber Security

This is a practical/lab oriented course focusing on cyber security.

Course Objective:
To train the students and make them understand the latest trends in cyber security.

By completing this course, students will obtain the following course/learning outcomes:
1. Knowledge to be gained:
   (i) Understanding the possible threats in cyber world
2. Skill to be gained:
   (ii) Skills to avoid possible cyber threats and detect new type of threats.
3. Competency to be gained:
   (iii) Ability to carry out independent research in Cyber Security

Prerequisites: Nil

Grading:

Lab	: 20%
Assignment/Quiz/presentation	: 10%
Class Test 1	: 5%
Class Test 2	: 5%
Final Exam	: 60%

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	40 Marks
Lab	1	End Semester Assessment	60 Marks
Tutorial	1	Credits	4

Unit I
Introduction to Cyber Security, Cyber Security Goals & policies, Domain of Cyber Security Policy, Elements, Cyber Security Evolution, Implementing Hardware Based Security, Software Based Firewalls, Security Standards, assessing threat levels, forming an Incident Response Team, difference between cyber forensics and cyber security

Unit II
Classifications of Cybercrime, E-Mail Spoofing, Spamming, Cyber defamation, Industrial Spying/Industrial Espionage, Hacking, Software Piracy, Password Sniffing, Credit Card Frauds, Cyberstalking, Botnets, Phishing, Pharming, Password Cracking, Keyloggers and Spywares, Virus and Worms, Trojan Horses and Backdoors, DoS and DDoS Attacks, Malware, Ransomware, Types of Identity Theft, Techniques of ID Theft, Cyber terrorism

Unit III
Significance of Buffer Overflow Vulnerability, Why Programs/Applications are vulnerable. Reasons for Buffer Overflow Attacks. Methods of trapping buffer overflows. Active and passive sniffing, Sniffing countermeasures. ARP poisoning and countermeasures. Man in the middle attacks, Spoofing attacks. SQL Injection, Attacking SQL Servers, Brute Forcing and Application Configuration Files, Input validation attacks. Preventive Measures.

Unit IV

Network defense tools, Secure protocols, Firewalls, VPNs, Tor, I2P, Intrusion Detection and filters, Host-Based IDS vs Network-Based IDS, Dealing with unwanted traffic, Malicious Software & Security, Malicious Web, Internet Security Issues, Types of Internet Security Issues, Secure Coding, Electronic & Information Warfare.

Reference Books:

1. *William Stallings, Network Security Essentials: Applications and Standards, Prentice Hall, 4th edition, 2010.*
2. *David Salomon, Foundations of Computer Security, Springer, 2006.*
3. *Walter Turner, Cyber Security for You, Kindle Edition, Secure Web Apps, 2016*
4. *Michael T. Goodrich and Roberto Tamassia, Introduction to Computer Security, Addison Wesley, 2011.*
5. *Anderson, Ross. Security Engineering: A Guide to Building Dependable Distributed Systems. New York: John Wiley & Sons. 2001.*
6. *J. P. Anderson, "Computer Security Threat Monitoring and Surveillance," Technical Report, James P. Anderson Company, Fort Washington, 1980.*

CSC8113 – Machine Learning

This is a participatory, experimental and problem solving course.

Course Objective:

The objective of the course is to provide theoretical and practical aspects of Machine Learning.

By completing this course, students will obtain the following **course outcomes**:

1. Knowledge gained:
   (i) Theoretical concepts for developing methods and algorithms in Machine Learning
2. Skill gained:
   (ii) Critical analyzing and logic skills in developing methods and algorithms in Machine Learning
3. Competency gained:
   (iii) Modelling and development of Machine Learning based applications.

Prerequisites: Basic knowledge of programming

Grading:

Lab	: 20%
Assignment/Quiz/presentation	: 10%
Class Test 1	: 5%
Class Test 2	: 5%
Final Exam	: 60%

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	40 Marks
Lab	1	End Semester Assessment	60 Marks
Tutorial	1	Credits	4

Module 1

Introduction to Machine Learning, Review on Probability, supervised and unsupervised learning, Classification, Regression and Clustering. Types of error calculations and evaluation measures, confusion table, cross validations-LOOCV, 5-fold and 10-fold, control groups.

Module 2

Eigen values and Eigen vectors, Dimensionality reduction method, PCA, LDA, ICA, rough set based methods. Linear Regression, Logistic Regression, Linear Classification.

Module 3

Review of Gradient Descent methods, Non-parametric Methods, K-NN, Decision Trees, Random Forest, Multi-class Classification, Probabilistic Classifiers, Naive Bayes classifiers, boosting.

Module 4

Neural Networks, Autoencoders- sparse, variational and graph autoencoders, Kernels, Ensemble Methods, SVM, DNN, CNN, GNN, GCN and GAN.

Text Books:

1. Tom M. Mitchell, “Machine Learning”, McGraw-Hill, 2010
2. Ethem Alpaydin, (2004) “Introduction to Machine Learning (Adaptive Computation and Machine Learning)”, The MIT Press

Reference:

1. Bishop, Christopher. Neural Networks for Pattern Recognition. New York, NY: Oxford University Press, 1995
2. T. Hastie, R. Tibshirani, J. H. Friedman, “The Elements of Statistical Learning”, Springer (2nd ed.), 2009
3. Ian Goodfellow, YoshuaBengio and Aeron Courville,” Deep Learning”, MIT Press, First Edition, 2016.
4. Kevin P. Murphy, “Machine Learning, a probabilistic perspective”, The MIT Press Cambridge,Massachusetts, 2012.
5. Darwiche Adnan, ”Modeling and reasoning with Bayesian networks”, Cambridge University Press, 2009.
6. Shalev-Shwartz,S., Ben-David,S., (2014), Understanding Machine Learning: From Theory to Algorithms, Cambridge University Press.
7. R. O. Duda, P. E. Hart, D. G. Stork (2000), Pattern Classification, Wiley-Blackwell, 2nd Edition.

CSC8114 – Image Data Mining

This is a participatory, experimental and problem solving course.

Course objective:
The objective of the course is to provide theoretical and practical aspects of design and development of image data mining systems for solving real world problems.
By completing this course, students will obtain the following course outcomes:

1. Knowledge gained:
   (i) State-of-art pre and post data processing techniques and algorithms for image data.
   (ii) Image representation and feature extraction, classification of images
2. Skill gained:
   (iii) Feature extraction from images
   (iv) Extract knowledge form image data using image classification techniques
   (v) Ability to analyse the real world image data mining problems
3. Competency gained:
   (vi) Development of data mining algorithms for complex real world problems.
   (vii) Ability to participate in data challenges and to do higher order research.

Prerequisites: Basic knowledge of programming

Grading:

Lab	: 20%
Assignment/Quiz/presentation	: 10%
Class Test 1	: 5%
Class Test 2	: 5%
Final Exam	: 60%

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	40 Marks
Lab	1	End Semester Assessment	60 Marks
Tutorial	1	Credits	4

Module 1
Fourier transformations: Introduction, Fourier series, DFT, 2D Fourier transform and its properties, techniques to compute FT. Windowed Fourier transform: short-term Fourier transform, Gabor filters, DWT, multirelational analysis, fast wavelet transform.

Module 2 - Image representation and feature extraction
Color feature extraction: Introduction, color space, image clustering and segmentation, color feature extraction. Texture feature extraction: spatial texture feature extraction methods, spectral texture feature extraction methods. Shape representation: perceptual shape descriptors, contour based shape methods, region based shape feature extraction.

Module 3 - Image classification and annotation
Bayesian classification, support vector machine: linear classifier, KNN Classification, SVM, fusion of SVM’s. Artificial Neural Network(ANN): Artificial neuron, non-linear neural network, activation and inhabitation, back propagation neural network, Convolutional Neural Network(CNN), implementation of CNN. Image annotation with decision tree: ID3, C4.5,

CART, DT for image classification.

Module 4 - - Image retrieval and presentation
Image indexing: Numerical indexing, inverted file indexing. Image ranking: Similarity measures, performance measures. Image presentation: Caption browsing, Category browsing, content browsing, query by example, query by keywords.
References:

1. *Dengsheng Zhang, Fundamentals of Image Data Mining Analysis, Features, Classification and Retrieval, Springer.*
2. *Jiawei Han, M. Kamber, Jian Pei, Data Mining: Concepts and Techniques, Morgan Kaufmann, 2nd Ed., 2005.*
3. *Arun K Pujari, Data Mining Techniques, Universities Press, 2nd Ed., 2010.*
4. *Rafael C. Gonzalez, Richard E. Woods, "Digital Image Processing", 3rd Ed., PHI, 2007.*
5. *Anil K. Jain, "Fundamentals of Digital Image Processing", Prentice Hall, US Ed., 1988.*

CSC8115 – Precision Agriculture

This is a practical/lab-oriented course focusing on Precision Agriculture (PA).
Course Objective:
To train the students and make them understand the methods of understanding the PA.
By completing this course, students will obtain the following course/learning outcomes:
1. Knowledge to be gained:
Understanding the features and parameters of PA
2. Skill to be gained:
Skills to find effectual features of PA.
3. Competency to be gained:
Ability to develop methods for effectual understanding of PA.
Prerequisites: Nil
Grading:

Lab	: 20%
Assignment/Quiz/presentation	: 10%
Class Test 1	: 5%
Class Test 2	: 5%
Final Exam	: 60%

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	40 Marks
Lab	1	End Semester Assessment	60 Marks
Tutorial	1	Credits	4

Module 1
Precision Agriculture: Introduction, Scope, Techniques. Understanding and Identifying Variability. Water Management (Irrigation, Drain Tile Systems, Supply), Crop Residue Management (CRM).
Module 2
Cost benefit analysis of Precision Agriculture: Maximizing Farm Profitability, Estimating Precision Farming Benefits, Yield monitoring and mapping, Grid Sampling vs Management Zone Sampling, Variable Rate Technology (VRT), Managing Long-Term Soil Fertility.
Module 3
Soil and Crop Sensing: Electrical Conductivity, Active Optical Sensors, Proximal Sensing, pH Mapping. Understanding Machine Vision.
Module 4
Smart Agriculture: Introduction to IoT - Sensors, Actuation, Sensor Networks, Communication Protocols, Machine-to-Machine(M2M) Communications. Cloud Computing and Sensor-Cloud in IoT.

References:

1. *Precision agriculture for grain production systems* - Brett Whelan and James Taylor -2013.
2. *The Nature and Properties of Soils* - Nyle C. Brady and Ray R Weil – 2016.
3. *Soil Genesis and Classification* - Boul SW, Hole ED, MacCraken RJ and Southard RJ - 2011.
4. *IoT and Analytics for Agriculture* - Prasant Kumar Pattnaik, Raghvendra Kumar, Souvik Pal, S. N. Panda – 1st ed. - 2020.
5. *The Internet of Things: Enabling Technologies, Platforms, and Use Cases* – Pethuru Raj and Anupama C. Raman - CRC Press - 2017.
6. *Internet of Things: A Hands-on Approach* - Arsheep Bahga, Vijay Madisetti - Universities Press - 2015.

7. *Precision Agriculture Basics* - D. Kent Shannon, David E. Clay, Newell R. Kitchen – 2020.
8. *The Precision Farming Guide for Agriculturist* - Kuhar J E - 2010.
9. *Soil-Specific Farming: Precision Agriculture* - Rattan Lal, B.A. Stewar 2015.

CSC8116 Immersive Technologies

This is a practical/lab oriented course focusing on immersive technologies

Course Objectives:

(i) To understand Augmented Reality, Virtual Reality, Mixed Reality and Extended Reality.
(ii) To identify the recent developments in Augmented and Virtual Reality
(iii) To build applications with Graphical User Interface using immersive .

By completing this course, students will obtain the following **course/learning outcomes**:

1. Knowledge to be gained:
   (i) Familiarize Virtual reality, Augmented reality, Mixed Reality and Extended Reality
   (ii) Familiarize the visual, aural and haptic rendering systems
2. Skill to be gained:
   Develop AR and VR applications with Graphical User Interface
3. Competency to be gained:
   Simulate real world applications using VRTK, MRTK and XR interaction toolkit

Prerequisites: Programming skill

Grading:

Lab	: 20%
Assignment/Quiz/presentation	: 10%
Class Test 1	: 5%
Class Test 2	: 5%
Final Exam	: 60%

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	40 Marks
Lab	1	End Semester Assessment	60 Marks
Tutorial	1	Credits	4

Syllabus

Module I
Introduction of Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR) and Extended Reality (xR), Comparison of AR, VR, MR and xR, Types of AR, Augmented Reality Interaction, Collaborative Augmented Reality, Heterogeneous user interfaces, Mobile Augmented Reality, WebAR, Augmented Reality Methods, Visualization Techniques for Augmented Reality, AR toolkits, Building AR applications with Graphical User Interface.

Module II
User input to the Virtual World, Virtual Reality devices and Manipulators, Types of Virtual Reality, Social interactions within the virtual world, Heterogeneous VR hardware, VR

Database, Creating Virtual Objects, Bringing real world to the virtual world, Rendering the virtual world, Representation of Virtual World, Geometry of Virtual Worlds, Visual, Aural and Haptic rendering systems.

Module III
Immersive virtual reality applications, Visual Perception - Perception of Depth, Perception of Motion, Perception of Color, Combining Sources of Information, Ray Tracing and Shading Models, Correcting Optical Distortions, Techniques used in Virtual Reality, Steps used for Virtual Reality development in Unity, Simple programs for VR applications with Graphical User Interface and controlling the objects in Virtual Environment, Creating immersive audio experiences, Storing and transmitting VR data over the network.

Module IV
Mixed reality: current trends, challenges and prospects, Computer Vision for Mixed Reality, Extended Reality and its applications, Simultaneous localization and mapping (SLAM), Variants of SLAM : dense tracking and mapping (DTAM), parallel tracking and mapping (PTAM) and semi-direct monocular visual odometry (SVO). Microsoft HoloLens, Simple programs in Mixed Reality.

Module V
Software Development Toolkit: VRTK (The virtual reality toolkit), Oculus Interaction SDK, Animation and interaction in the immersive environment, Developing simple User interface menu with images, canvas, sprites and buttons, VR trigger, VRIK, MRTK (Microsoft's official MR toolkit) , XR Interaction toolkit (Unity's XR Tool Kit).

References

1. Coiffet, P., Burdea, G. C., (2003), "Virtual Reality Technology," Wiley-IEEE Press.
2. Schmalstieg, D., Höllerer, T., (2016), "Augmented Reality: Principles & Practice," Pearson.
3. Norman, K., Kirakowski, J., (2018), " Wiley Handbook of Human Computer Interaction," Wiley-Blackwell.
4. LaViola Jr., J. J., Kruijff, E., McMahan, R. P., Bowman, D. A., Poupyrev, I., (2017), "3D User Interfaces: Theory and Practice," Pearson.
5. Fowler, A., (2019), "Beginning iOS AR Game Development: Developing Augmented Reality Apps with Unity and C#," Apress.
6. Hassanien, A. E., Gupta, D., Khanna, A., Slowik, A., (2022), "Virtual and Augmented Reality for Automobile Industry: Innovation Vision and Applications," Springer.
7. Jonathan Linowes , Unity Virtual Reality Projects, Packt *Publishing, 2015.*
8. Jason Jerald, The VR Book: Human-Centred Design for Virtual Reality, Association for Computing Machinery and Morgan and Claypool, 2015.

CSC8117 - Multimodal Learning and Modelling

This is a theoretical, practical and skill development course.
Course Objective:
This course aims to provide students with a strong foundation in classical and deep learning

techniques, along with exposure to the rapidly evolving field of multimodal learning and modelling.

By Completing this course, the students will obtain the following course outcomes:
Knowledge gained:

- Core concepts of classical machine learning and deep learning with the understanding of multimodal learning and modeling.

Skill gained:

- Building machine learning and deep learning models, and multimodal systems with real-world datasets.

Competency gained:

- Integration of multimodal data for complex problem-solving using advanced machine learning and deep learning architectures.

Grading:

Lab	: 20%
Assignment/Quiz/presentation	: 10%
Class Test 1	: 5%
Class Test 2	: 5%
Final Exam	: 60%

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module I
Introduction to machine learning: probability and statistics for machine learning, classical machine learning algorithms: regression, classification, clustering, dimensionality reduction. Neural networks: optimization techniques, backpropagation, activation functions, feedforward neural networks (FNN).

Module II
Convolutional Neural Networks (CNNs), transfer Learning and fine tuning. Bias-variance trade-off, regularization, early stopping, cross-validation, performance metrics, handling imbalanced data. Auto encoders, variational auto encoders (VAEs).

Module III
Recurrent Neural Networks (RNNs): LSTM, GRU. Embeddings: Word2Vec, FastText, GloVe, encoder-decoder models. Transformers: attention mechanism, BERT, LLMS, GPT. Generative AI, GANs. Explainable AI.

Module IV
Multimodal modelling: overview of modalities - text, vision, audio, other sensor data, feature representations, challenges, fusion strategies in multimodal learning: early, late, and hybrid, graph neural networks (GNNs) for multimodal data, multitask and few-shot learning, multi-stream networks, cross-modal transformers, BERT variants, vision-language models, contrastive learning, alignment and co-learning strategies.

Text Books:

1. Zhou, Zhi-Hua. Machine learning. Springer nature, 2021.
2. Bishop, Christopher M., and Hugh Bishop. Deep learning: Foundations and concepts. Springer Nature, 2023.
3. Duda, Richard O., and Peter E. Hart. Pattern classification. John Wiley & Sons, 2006.

CSC8121 – Sign Language Recognition

This is a practical/lab oriented course focusing on sign language recognition.

Course Objective:

To train the students and make them understand the methods of recognizing sign languages.

By completing this course, students will obtain the following course/learning outcomes:

1. Knowledge to be gained:
   (i) Understanding the possible deviations/variations in sign languages
2. Skill to be gained:
   (ii) Skills to find effectual features of sign languages.
   (iii) Skills to write algorithms for sign language recognition
3. Competency to be gained:
   (iv) Ability to develop methods for effectual sign language recognition.

Prerequisites: Nil

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module 1

Distance measures. Image enhancement in spatial and frequency domains. Morphological operations.

Module 2

Image Segmentation: Detection of discontinuities:-point detection-line detection-edge detection. Hough transforms. Thresholding:-simple, global and optimal. Region-based segmentation: -Region growing, region splitting/merging. Colourimage segmentation.

Module 3

Image features. Background/foreground estimation. Object detection/classification. Object tracking. Image/Video analysis and understanding.

Module 4

Literature review on (i) object/image features, (ii) segmentation, (iii) object detection, (iv) object tracking, (v) sign language recognition methods, (vi) sign language recognition features, and (vii) sign language recognition databases.

Reference:

1. *Rafael C. Gonzalez, Digital Image Processing, Pearson Education, 3 edition (2013), ISBN-10: 9332518467, ISBN-13: 978-9332518469*
2. *Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2011, ISBN 1868-0941, ISBN 978-1-84882-934-3*

CSC8122 – Brain Analysis

This is a practical/lab oriented course focusing on the analysis of Brain.

Course Objective:

To train the students and make them understand the methods of understanding the brain.

By completing this course, students will obtain the following course/learning outcomes:

1. Knowledge to be gained:

(i) Understanding the possible ways for analysing the brain

2. Skill to be gained:
   (ii) Skills to find effectual features for brain analysis.
   (iii) Skills to write algorithms for brain analysis
3. Competency to be gained:
   (iv) Ability to develop methods for effectual understanding of brain images/signals.

Prerequisites: Nil

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module 1
Distance measures. Image/signal enhancement in spatial and frequency domains. Morphological operations. Signal/image pre-processing.

Module 2
Image Segmentation: Detection of discontinuities: -point detection -line detection -edge detection. Hough transforms. Thresholding: -simple, global and optimal. Region-based segmentation: -Region growing, region splitting/merging. Colour image segmentation.

Module 3
Image/signal features. Image/Signal Registration. Image/signal classification. Modalities like EEG, MRI, CT, etc.

Module 4
Literature review on (i) signal/image features, (ii) image/signal pre-processing, (iii) image/signal –registration, (iv) image/signal –normalization, (v) statistical analysis of brain using EEG/MRI.

Reference:

1. *Rafael C. Gonzalez, Digital Image Processing, Pearson Education, 3 edition (2013), ISBN-10: 9332518467, ISBN-13: 978-9332518469*
2. *Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2011, ISBN 1868-0941, ISBN 978-1-84882-934-3*

CSC8123 – Audio Visual Speech Recognition and Semantic Summarization

This is a practical/lab oriented course focusing on the audio visual speech.

Course Objective:
To train the students and make them understand the methods of understanding the audio visual speech.

By completing this course, students will obtain the following course/learning outcomes:

1. Knowledge to be gained:
   (i) Understanding the possible ways for analysing the audio visual speech.
2. Skill to be gained:
   (ii) Skills to find effectual features for audio visual speech.
   (iii) Skills to write algorithms for the analysis of audio visual speech.
3. Competency to be gained:
   (iv) Ability to develop methods for effectual understanding of audio visual speech.

Prerequisites: Nil

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module 1
Basic elements of a Digital Signal Processing Systems, Classification of Signals, The Concept of Frequency in Continuous -Time and Discrete –Time Signals, The Speech Signal: Speech Production Mechanism, perception-Acoustic Phonetic Characterization and classification -The Speech Production Process-Representing speech in Time Frequency Domains-Speech Sounds and Features. Speech Analysis: The Bank of Filters Front End Processor-Linear Predictive Coding for Speech Recognition-Vector Quantization.

Module 2
Audio detection-Time delay estimation, Beamforming, Visual tracking algorithms:-Template matching and Mean-shift algorithms, Multimodal integration -likelihood combination, Tracker output combination, Partitioned sampling.

Module 3
Representing Meaning: Meaning Structure of Language, Predicate-Argument Structure, First Order Predicate Calculus. Semantic Analysis: Syntax-Driven Semantic Analysis, Attachments for a Fragment of English, Lexical Semantics: Relations among Lexemes and Their Senses, WordNet: A Database of Lexical Relations, The internal Structure of Words.

Module 4
Literature review on (i) Speech and audio processing (ii) Audio visual speech processing (iii) Language processing (iv) Semantic analysis and (v) Multimodal speech processing.

References:

1. *Fundamentals of Speech Recognition- Lawrence Rabiner, Biing-Hwang Juang, Prentice Hall. 1993*
2. *Digital processing of speech signals- L.R. Rabiner and R.W Schafer, Prentice Hall, 1978*
3. *Speech and Language Processing- Daniel Jurafsky and James H. Martin, Prentice Hall, 2000*
4. *Audio –Visual Person Tracking A Practical Approach – Fotios Talantzis, A.Pnevmatikakis and A.G. Constatinides, Imperial College Press, 2012*

CSC8124 – Machine Learning Approaches for Cyber Threat Detection

This is a practical/lab oriented course focusing on the cyber threat detection.

Course Objective:
To train the students and make them understand the methods of detecting cyber threats.

By completing this course, students will obtain the following course/learning outcomes:
1. Knowledge to be gained:
   (i) Understanding the possible ways for analysing the cyber threat.
2. Skill to be gained:
   (ii) Skills to find effectual features of cyber threat.
   (iii) Skills to write algorithms for the analysis of cyber threat.
3. Competency to be gained:
   (iv) Ability to develop methods for effectual detection of cyber threat.

Prerequisites: Nil

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module I
Review of Cybersecurity Solutions, Reactive Security Solutions, Misuse/Signature Detection, Anomaly Detection, Hybrid Detection, Scan Detection, Profiling Modules, Understanding the Fundamental Problems of Machine-Learning Methods in Cybersecurity, Incremental Learning in Cyberinfrastructures, Feature Selection/Extraction for Data with Evolving Characteristics, Privacy-Preserving Data Mining

Module II
Supervised Learning for Misuse/Signature Detection: Machine Learning in Misuse/Signature Detection, Machine-Learning Applications in Misuse Detection, Rule-Based Signature Analysis; Machine Learning for Anomaly

Detection: Machine Learning in Anomaly Detection Systems, Machine-Learning Applications in Anomaly Detection, Rule-Based Anomaly Detection, Unsupervised Anomaly Detection.

Module III

Machine Learning in Hybrid Intrusion Detection Systems, Machine-Learning Applications in Hybrid Intrusion Detection, Anomaly–Misuse Sequence Detection System, Association Rules in Audit Data Analysis and Mining, Misuse–Anomaly Sequence Detection System; Emerging Challenges in Cybersecurity: Emerging Cyber Threats, Network Monitoring, Profiling, and Privacy Preservation, Emerging Challenges in Intrusion Detection.

Module IV

Literature review on (i) Malware Detection and Classification (ii) Botnet Detection (iii) Drive-By Download Attacks (iv) Network Intrusion Detection (v) File Type Identification (vi) Network Traffic Identification (vii) SPAM Identification (viii) Insider Threat Detection

Reference Books:

1. *Ankit Fadia, Manu Zacharia, Network intrusion alert: an ethical hacking guide to intrusion detection, Thomson Course Technology PTR, 2007.*
2. *Roberto Di Pietro, Luigi V. Mancini, Intrusion Detection System, Springer ,2008.*
3. *Sumeet Dua, Xian Du, Data Mining and Machine Learning in Cybersecurity Data Mining and Machine Learning in Cybersecurity, CRC Press, 2011, ISBN -13: 978-1-4398-3943-0 (Ebook).*
4. *Padmavathi Ganapathi, Shanmugapriya, Handbook of Research on Machine and Deep Learning Applications for Cyber Security, IGI Global, 2019, ISBN13: 9781522596110.*
5. *Sinan Ozdemir, Soma Halder, Hands-On Machine Learning for Cybersecurity, Packt Publishing, 2018.*
6. *Daniel S. Berman, Anna L. Buczak, Jeffrey S. Chavis and Cherita L. Corbett, A Survey of Deep Learning Methods for Cyber Security, Information, MDPI, 2019.*

CSC8125 – DDoS Attacks and Defense Mechanisms

This is a practical/lab oriented course focusing on the DDoS attacks, Cyber Security and Intrusion Detection Systems.

Course Objective:

To train the students and make them understand the defense mechanisms for DDoS attacks.

By completing this course, students will obtain the following course/learning outcomes:

1. Knowledge to be gained:
   (i) Understanding the possible ways for analysing the DDoS attacks.
2. Skill to be gained:
   (ii) Skills to find effectual features of DDoS attacks.
   (iii) Skills to write algorithms for the analysis of DDoS attacks.
3. Competency to be gained:
   (iv) Ability to develop methods for effectually defending DDoS attacks.

Prerequisites: Nil

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module I

DDoS Attacks: Overview, Criminals, Thrill Seekers and Status Seekers, Hacktivist, Common Types of DDoS Attacks, Volumetric Floods, Network Protocol–Level Attacks, Amplification and Reflection, Application-Level Attacks, Multivector Attacks, Botnets and IoT Devices.

Module II

DDoS Detection, types of DDoS Detection, DDoS Mitigation and Countermeasures, DDoS Mitigation Topology, Mitigation Tools & Devices, Evaluating Cloud-Based Mitigation Vendors, Cloud-Based DDoS Mitigation Methods, DDoS Event Reporting, Hybrid Model.

Module III

DDoS Focused Threat Intelligence, IP Blocklists, Community Supported Efforts, IP Geolocation Providers, Purpose-Built Node Lists, Honeypots, DDoS-as-a-Service, DDoS Detection Mechanism in the Cloud, DDoS

Mitigation Mechanism in the Cloud.

Module IV

Literature review on (i) DDoS attacks and detection in Software Defined Networks (ii) DDoS attacks and detection in Cloud Computing (iii) Mitigating DDoS attacks in SDN (iv) Mitigating DDoS attacks in Cloud Computing

Text Books/References:

1. *Distributed Denial of Service (DDoS), by Rich Groves, Eric Chou, Publisher: O'Reilly Media, Inc., Release Date: April 2018, ISBN: 9781492026181*
2. *DDoS Attacks: Evolution, Detection, Prevention, Reaction, and Tolerance, Dhruba Kumar Bhattacharyya, Jugal Kumar Kalita, Publisher: Chapman and Hall/CRC; 1 edition, 2016, ISBN-10: 1498729649*
3. *An Introduction to DDoS Attacks and Defense Mechanisms: An Analyst's Handbook, by B. B. Gupta, Publisher: LAP LAMBERT Academic Publishing, 2011, ISBN-10: 3846595691, ISBN-13: 978-3846595695*
4. *Detection and Defeating Distributed Denial of Service (DDoS) Attacks, Seyed Mohammad Reza Khalifeh Soltanian, Iraj Sadegh Amiri, CreateSpace Independent Publishing Platform, 2014, ISBN-10: 1500568872, ISBN-13: 978-1500568870*
5. *DDoS Attacks: Evolution, Detection, Prevention, Reaction, and Tolerance, Dhruba Kumar Bhattacharyya, Jugal Kumar Kalita, Chapman & Hall/CRC ©2016, ISBN:1498729649, 9781498729642*
6. *S. Dong, K. Abbas, and R. Jain, A Survey on Distributed Denial of Service (DDoS) Attacks in SDN and Cloud Computing Environments, published in IEEE Access, Volume 7, pp. 80813-80828, 201*

CSC8126 – Data Mining Trends and Research Frontiers

This is a practical/lab oriented course focusing on the data mining trends and related technologies. The course objective of the course is to provide theoretical and practical aspects of complex data mining and design for decision support systems.

By completing this course, students will obtain the following course/learning outcomes:

1. Knowledge to be gained: State-of-art pre/and post data processing techniques/algorithms for complex data.
2. Skill to be gained:
   (i) Extract knowledge using advanced data mining techniques form complex data
   (ii) Adapt to new data mining tools
   (iii) Ability to analyse the real world complex data mining problems
3. Competency to be gained:
   (i) Development of data mining algorithms for complex real world problems.
   (ii) Ability to participate in data challenges and to do higher order research.

Prerequisites: Nil

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module I

Mining Stream, Time Series, Sequence Data: Mining Data Streams: Methodologies for Stream Data Processing and Stream Data Systems, Stream OLAP and Stream Data Cubes, Frequent-Pattern Mining in Data Streams, Classification of Dynamic Data Streams, Clustering Evolving Data Streams. Mining Time Series Data: Trend analysis, Similarity Search in Time-Series Analysis. Mining Sequences: Sequential Pattern mining, Scalable methods, Periodicity Analysis for Time-Related Sequence Data, Mining Sequence Patterns in Biological Data, Alignment of Biological Sequences.

Module II

Graph Mining, Social Network Analysis, and Multirelational Data Mining- Graph Mining-Methods for Mining Frequent Subgraphs, Mining Variant and Constrained Substructure Patterns, Applications, Social Networks, Characteristics of Social Networks, Link Mining- Tasks and Challenges, Mining on Social Networks. Multi-relational Data Mining: ILP Approach to Multirelational Classification, Tuple ID Propagation, Multirelational Classification Using Tuple ID Propagation, Multirelational Clustering with User Guidance.

Module III

Mining Spatial, Multimedia, Text, and Web Data:. Spatial Data Mining: Spatial Data Cube Construction and Spatial OLAP, Mining Spatial Association and Co-Location Patterns, Spatial clustering, Classification and trend analysis. Multimedia Data Mining: Similarity Search in Multimedia Data, Multidimensional Analysis of

Multimedia Data, Classification and Prediction Analysis of Multimedia Data, Mining Associations in Multimedia Data, Audio and Video Data Mining. Text Mining: - Text Data Analysis and Information Retrieval, Dimensionality Reduction for Text, Text Mining Approaches. Mining the Web Wide Web: Mining the Web Page Layout Structure, Mining the Web's Link Structures to Identify Authoritative Web Pages. Mining Multimedia Data on the Web, Automatic Classification of Web Documents, Web Usage Mining.

Module IV

Applications and Trends in Data Mining: Data Mining Applications, Data Mining for Financial Data Analysis, Data Mining for the Retail Industry, Data Mining for the Telecommunication Industry, Data Mining for Biological Data Analysis, Data Mining in Other Scientific Applications, Data Mining for Intrusion Detection, Data Mining System Products and Research Prototypes, How to Choose a Data Mining System, Examples of Commercial Data Mining Systems, Additional Themes on Data Mining, Theoretical Foundations of Data Mining, Statistical Data Mining, Visual and Audio Data Mining, Data Mining and Collaborative Filtering, Social Impacts of Data Mining, Data Mining, Privacy, and Data Security, Trends in Data Mining.

Module V

Literature review on data mining, its applications, latest trends and algorithms

Reference:

1. *Jiawei Han, M.Kamber, Jian Pei, Data Mining: Concepts and Techniques, Morgan Kaufmann, 2nd Ed., 2005.*
2. *Arun K Pujari, Data Mining Techniques, Univerities Press, 2nd Ed., 2010.*
3. *Da Ruan, Guoqing Chen, Etienne E. Kerre, Geert Wets, Intelligent Data Mining: Techniques and Applications (Studies in Computational Intelligence), Springer, 1st Ed., 2010.*
4. *MasoudMohammadian, Intelligent Agents for Data Mining and Information Retrieval, Idea Group Publishing, 2004.*

CSC8127 – Multimodal Signal Processing

This is a practical/lab oriented course focusing on the data mining trends and related technologies.

Course Objective:
The objective of the course is to equip the students with strong basics in signal processing.

By completing this course, students will obtain the following course/learning outcomes:

1. Knowledge to be gained:
   (i) Develop methods for signal transformation
2. Skill to be gained:
   (ii) Practical Skills in representation of digital signal processing concepts using AI related toolbox/packages.
3. Competency to be gained:
   (iii) Computational modelling of digital signal processing in any real world problems

Prerequisites: Nil

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module 1

Basic elements of a Digital Signal Processing Systems, Classification of Signals, Sampling, reconstruction. Time Domain Representation of Signals and Systems- Discrete Time Signals, Operations on sequences, Discrete time Systems, Linear Time Invariant Discrete Time Systems, Frequency Analysis of Signals- Frequency Analysis of Continuous/Discrete Time Signals, Frequency/Time Domain Signal Properties

Module II

The Speech Signal: Speech Production Mechanism, perception- Acoustic Phonetic Characterization and classification - The Speech Production Process- Representing speech in Time Frequency Domains- Speech Sounds and Features. Speech Analysis: The Bank of Filters Front End Processor- Linear Predictive Coding for Speech Recognition-Vector Quantization.

Module III

Digital Image Fundamentals: - Image representation and modelling - sampling and quantization, Relationships between pixels, Image Enhancement in the spatial domain: - point operations, spatial operations. Color models and conversions, Enhancement in frequency domain, Morphological Image Processing, Image Segmentation

Module IV
Introduction to video processing: Principles of color video processing, Composite versus component video, sampling of video signals, 2D/3D motion estimation: Spectral analysis of video signal: Fourier, CT and Wavelet analysis, Audio visual integration: audio-visual speech processing, audio-Visual emotion/gesture recognition
Module V
Literature review on multimodel signal processing, its applications, latest trends, features and algorithms

Text Books/References:

1. *J.G. Proakis, D.G. Manolakis, Digital Signal Processing – Principles, Algorithms and Appl., Pearson, 2013.*
2. *Lawerence Rabiner, B.-H. Juang & B Yegnanarayana, "Fundamental od Speech Recognition", Person, 2009*
3. *Anil K. Jain, "Fundamentals of Digital Image Processing", Prentice Hall, US Ed., 1988.*
4. *William K. Pratt, "Digital Image Processing: PIKS Scientific Inside", Wiley Interscience, 4th Ed., 2007.*
5. *G. Bailly, P. Perrier & V.-B. Eric, "Audio Visual Speech Processing", Cambridge University Press, 2012.*
6. *Peter E Hart, Richard O Duda & David G Stork, "Pattern Classification", John Wiley and Sons, 2005.*

CSC8128 – Bioinformatics

This is a participatory, experimental and problem solving course.

Course Objective:
The objective of the course is to provide theoretical and practical aspects of bioinformatics.
By completing this course, students will obtain the following **course outcomes**:
1. Knowledge gained:
   (i) Theoretical concepts for developing methods and algorithms for bioinformatics
2. Skill gained:
   (ii) Critical analyzing and logic skills in developing methods and algorithms for bioinformatics
3. Competency gained:
   (iii) Modelling and development of bioinformatics based applications.

Prerequisites: Basic knowledge of programming

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module 1
Introduction to Bioinformatics and Computational biology, Biological databases and its types, Applications of Bioinformatics. The central dogma of molecular biology. Information retrieval from biological databases: Sequence homology, protein alignments, multiple sequence alignment, alignment tools.
Module 2
DNA and RNA structure – Nucleic Acid structure and function, Genetic Code.
General introduction to Gene expression in prokaryotes and eukaryotes- Prokaryotic Genomes – Gene structure. RNA classification –coding and non-coding RNA- mRNA, tRNA, miRNA, circRNA, sRNA, piRNA and RNAi.
Module 3
Sequence alignment – local/global, pairwise sequence alignment, scoring methods.
Needleman algorithm, global and local alignments. Multiple sequence alignment. Scoring matrices: basic concept of a scoring matrix, Matrices for nucleic acid and proteins sequences. Differences between distance & similarity matrix.
Module 4
Protein and RNA structure Prediction: Protein Structures, Algorithm for protein folding, Structure prediction, microarrays.
Module 5
Literature review on Biomedical data classification.

Text Books:

1. *Neil C Jones and Pavel A Pevzner, An Introduction to Bioinformatics Algorithms, MIT press, 2004.*
2. *Bioinformatics: Sequence & Genome Analysis, by David W. Mount, Cold spring Harbor press, 2004.*
3. *Introduction to Bioinformatics, by T K Attwood & D J Parry-Smith Addison Wesley Longman, 1999*
4. *Fundamentals of bioinformatics and computational biology, by Gautam B. Singh, Springer, 2015*

References:

5. *Bioinformatics- A Beginner's Guide, Jean-Michel Claverie, Cerdric Notredame, WILEY Dreamtech India Pvt. Ltd, 2006*
6. *Bioinformatics- Basics, Algorithms and Applications, Ruchi Singh, Richa Sharma, University Press, 2010*
7. *Bioinformatics- Databases, Tools, and Algorithms, Orpita Bosu, S K Thukral, Oxford University Press, 2007*
8. *Fundamentals of Bioinformatics and Computational Biology - Methods and Exercises in MATLAB, Gautam B. Singh, Springer International Publishing Switzerland 2015.*

CSC8129 – Image Processing

This is an experimental and problem solving skill development course.

Course Objective:

The objective of the course is to provide theoretical and practical aspects of image processing and computational vision.

By completing this course, students will obtain the following course outcomes:

1. Knowledge gained:
   (i) Theoretical concepts for developing methods and algorithms for computational vision.
2. Skill gained:
   (ii) Critical analyzing and logic skills in developing methods and algorithms for computational vision.
3. Competency gained:
   (iii) Modelling and development of computational vision based applications.

Prerequisites: Basic knowledge of programming

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module 1

Digital Image Fundamentals**:** - Image representation and modelling - Image sampling and quantization, gray level resolution. Relationships between pixels, adjacency, connectivity, regions and boundaries, distance measures, image operations on pixel basis. Image Enhancement in the spatial domain: - point operations, spatial operations. Color models and conversions.

Module 2

Image Enhancement in frequency domain - Fourier Transform, DFT and its inverse, filtering in the frequency domain. Smoothing and sharpening filters in frequency domain, Homomorphic filters-Unsharp Masking, High-Boost Filtering, High-frequency Emphasis Filtering. Concepts of image restoration and degradation models.

Module 3

Morphological Image Processing: Logical operations on binary Images-Dilation-Erosion-Opening and Closing-Hit-or-Miss Transformation. Morphological Algorithms: - Boundary Extraction-Region Filling-Extraction of connected Components-Convex Hull-Thinning-Thickening-Skeletons-Pruning. Image Segmentation: - Detection of discontinuities: -point detection-line detection-edge detection. Hough Transform, Thresholding. Region-based segmentation, Region Growing/splitting/merging.

Module 4

Image Analysis: feature extraction, classification. Fundamentals of video processing: Motion estimation, tracking concepts, Kalman filter, Particle filter.

Module 5

Literature review on image processing and computer vision

Text book:

1. Rafael C. Gonzalez, Richard E. Woods, "*Digital Image Processing*", 3rd Ed., PHI, 2007.

References:

2. William K. Pratt, "*Digital Image Processing: PIKS Scientific Inside*", Wiley Interscience, 4th Ed., 2007.
3. David A. Forsyth, Jean Ponce, Computer Vision: A Modern Approach, Prentice Hall, US Ed., 2002.
4. Berthold K. P. Horn, Robot Vision, MIT Press, 1986.
5. Robert M. Haralick, Linda G. Shapiro, Computer and Robot Vision, Vol. I, Addison Wesley, 1991.
6. Robert M. Haralick, Linda G. Shapiro, Computer and Robot Vision, Vol. II, Prentice Hall, 2002.

7. Trucco, Alessandro Verri, Introductory Techniques for 3-D Computer Vision, Prentice Hall, 1998.

CSC8130 - Geospatial Data Analysis of Agro-Ecological Zones

This is a practical/lab-oriented course focusing on Geospatial Technologies.
Course Objective:

To train the students and make them understand the methods of Geospatial Data Analysis.

By completing this course, students will obtain the following course/learning outcomes:
1. Knowledge to be gained:

(i) Understanding the basics of Geospatial Technology and AEU.

(ii) Understanding the features and parameters of ecology, environment, and biodiversity.

2. Skill to be gained:

Skills to develop Geospatial Data Analysis in AEU.

3. Competency to be gained:

Ability to develop methods for effectual utilization of Geospatial Data Analysis.

Prerequisites: Nil
Grading:

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module 1
AEU: Agro-ecological zones/regions, sub-regions, units, and cells. Adaptation of crops to different agro-climatic conditions. Potential and constraints of soils in different regions. Agricultural Meteorology: Meaning and scope, components, role of meteorological parameters in environmental stress, relationship between weather, climate, and agriculture.
Module 2
Ecology: concepts of crop ecology (definition, division, and significance, characteristics), energy flow in ecosystems, adaptation of crops. Environment: environmental management, environmental factors affecting plant growth as abiotic interaction. Agrobiodiversity and its conservation.
Module 3
Geospatial Technology: Basic concepts. Geographical Information System: Principle, functions, components, methodology. Vector and raster data models. Remote Sensing: Basic concepts, components (Sensors and Platforms), Sensor resolutions, Active vs Passive remote sensing, Image Processing, Global Navigation Satellite System (GNSS), Role of GIS in Precision Agriculture.
Module 4
Data Analysis and Big Data Processing: Introduction, Big Data Technologies, and tools. Analysis using geospatial data processing platforms. Terrain analysis using maps and satellite imagery. Advanced GIS and Machine Learning algorithms. Open-source GIS, Geospatial data analysis of AEU.
Module 5
Literature review on geospatial data analysis and its applications.
References

1. *Introduction to GIS Programming and Fundamentals with Python and ArcGIS* - Chaowei Yang et al., CRC Press (2020).
2. *Concepts and Techniques of Geographic Information Systems* - Chor Pang Lo, Albert K.W. Yeung (2016).
3. *Geographic Information Systems and Science* - Paul A. Longley, et.al. (2015).
4. *An Introduction to Geographical Information Systems*, Pearson - Ian Heywood – 4rth Edition (2011).
5. *Principles of GIS, an introductory textbook* - Otto Huisman and Rolf A. de By (2009).
6. *GIS - Fundamentals, Applications, and Implementations* - Elangovan, K, Nipa (2020).
7. *Introduction to Geographic Information Systems* - Chang, Kang-Tsung., Tata McGraw Hill Pub. Co. Ltd (2017).
8. *A Python package for Agro-Ecological Zoning - User Guide for PyAEZ (v2.0.0)* – Food and Agriculture Organization of the United Nations - Rome and Bangkok 2023.
9. *Global Agro Ecological Zones v4 model documentation* - Food and Agriculture Organization of the United Nations & International Institute for Applied Systems Analysis.
10. *Agroecology The Ecology of Sustainable Food Systems* - Stephen R. Gliessman – 3rd Edition (2015).

CSC8131 Metaverse

This is a practical/lab oriented course focusing on Metaverse

Course Objectives:

(i) To introduce technological developments through demonstrations, case studies and applications with a futuristic vision
(ii) To understand multi-technology perspective in Metaverse and its challenges
(iii) To identify the recent developments and to focus on research initiatives in Metaverse

By completing this course, students will obtain the following **course/learning outcomes**:

1. Knowledge to be gained:
   (i) Familiarize multiple technologies used in Metaverse
   (ii) Understand the security threats and its countermeasures in metaverse
2. Skill to be gained:
   Skills to develop AR, VR, blockchain and IOT applications with Graphical User Interface
3. Competency to be gained:
   Analyse the applications and their performance in Metaverse

Prerequisites: Programming Skill

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Syllabus

Module I

Fundamentals of metaverse, phases of development of the metaverse, characteristics, components and architecture of metaverse, metaverse engine, recognition and rendering, content creation modes in metaverse, technologies of metaverse, multi-technology convergence perspective, communication and computing infrastructure, metaverse challenges

and limitation. Ubiquitous computing.

Module II

Security threats and corresponding security countermeasures in metaverse, threats and countermeasures to data management in metaverse, sybil attack and DDOS attack in metaverse, economy-related threats and countermeasures in metaverse, threats to digital forensics, digital governance in metaverse, endogenous security empowered metaverse, cloud-edge-end orchestrated secure metaverse.

Module III

Overview of Blockchain, Structure of Blockchain, Transactions, Distributed Consensus, Understanding Cryptocurrency, Bitcoin and Non-Fungible Token, Security aspects of Blockchain, Hash pointer and Merkle tree, Distributed Ledger Technology, Smart Contracts in Blockchain, Operation of Smart Contracts, Remix IDE, Solidity syntax and semantics, solidity data types, contract types, access classifiers, Smart Contract creation using solidity. Truffle frame work, Deployment Process, Creating projects using Truffle, DAPP architecture, DAPP development framework.

Module IV

Virtual worlds, Multimodal metaverse interactions, limitations of two dimensional learning environments, multimodal training with videotext representation learning, setting waypoints for audio-visual navigation, Immersive Virtual Reality-Based Interfaces for Character Animation, Virtual reality in education, VR/AR integration in education, Potential of 360-Degree Virtual Reality Videos and Real VR for Education.

Module V

User experience on mobile pedestrian navigation between digital map interface and location-based augmented reality, advanced visual SLAM and image segmentation techniques for augmented reality, Internet of Things (IoT) for Seamless Virtual Reality Space, Status of attention based on EEG, Quantification of cognitive ability based on EEG.

Text Books/References:

1. Park, Sang-Min, and Young-Gab Kim, "A metaverse: Taxonomy, components, applications, and open challenges", IEEE access, 2022.
2. Chen, Shu-Ching, "Multimedia research toward the metaverse", IEEE MultiMedia, 2022.
3. C. Hacki, “Navigating the Metaverse: A Guide to Limitless Possibilities in a Web 3.0 World”, 2022, Wiley.
4. Terry Winters, “The Metaverse: Prepare Now for the Next Big Thing”, 2021.
5. Terry, Quharrison and Scott Keeney, The metaverse handbook: Innovating for the internet's next tectonic shift, John Wiley & Sons, 2022.
6. Rostami, Sajjad, and Martin Maier, "The metaverse and beyond: implementing advanced multiverse realms with smart wearables", IEEE Access, 2022.
7. Sara Abdelghafar, Dalia Ezzat, Ashraf Darwish, Aboul Ella Hassanien, Metaverse for Brain Computer Interface: Towards New and Improved Applications, Springer, 2023.
8. Aboul Ella Hassanien, Ashraf Darwish, Mohamed Torky, “The Future of Metaverse in the Virtual Era and Physical World”, Springer, 2023.
9. Lacity, Mary C., and Steven C. Lupien. Blockchain Fundamentals for Web 3.0, University of Arkansas Press, 2022.

CSC8132 - Human-Computer Interaction

This is a theoretical, practical and skill development course.

Course Objective:
This course aims to equip students with a comprehensive understanding of Human-Computer Interaction (HCI) and the emerging domain of Multimodal HCI.

By Completing this course, the students will obtain the following course outcomes:
Knowledge gained:

- Theoretical methods for Human-Computer Interaction (HCI), covering its evolution from command-line interfaces to natural interaction paradigms

Skill gained:

- Students will develop practical skills in designing and prototyping user interfaces, applying UX research methods, and implementing multimodal interaction techniques with a focus on usability, accessibility, and user experience.

Competency gained:

- Design, evaluate, and implement user-centric and inclusive interactive systems for diverse populations and usage contexts.

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module I
Importance of HCI, difference between HCI and interface design, evolution of HCI: from command-line to natural interaction, relation to ergonomics and human factors, adaptive user interfaces and accessibility in HCI, problems and challenges.

Module II
Interaction Models: Norman's Execution-Evaluation Cycle, GOMS Model, Fitts' Law and Hick's Law, User Centered and User Experience (UX) Design. Principles of good design - affordances, constraints, feedback. Prototyping and Usability Testing. UX Research Methods.

Module III
Unimodal vs Multimodal HCI, Multimodal Input Modalities: Speech, Gesture, Eye gaze, Brain Computer Interfaces, Tactile and other natural interfaces. Multimodal Output Modalities: Visual, Auditory, and Haptic Feedback. Context-Aware Computing in HCI, adaptive multimodal Systems.

Module IV
Literature review on multimodal human computer interaction.

Text Books:

1. Julie A. Jacko, Human computer interaction handbook: Fundamentals, evolving technologies, and emerging applications, 3rd ed., CRC Press (2012).
2. Alan Dix, Janet Finlay, Gregory D. Abowd, Beale, Human-Computer Interaction, 3rd ed., Pearson, 2004.
3. I. Scott MacKenzie., Human-Computer Interaction: An Empirical Research Perspective, Morgan Kaufmann Publishers in, 2013.

4. Sharp, H., Preece J., Rogers Y., Interaction Design - Beyond Human-Computer Interaction, 6th ed., Wiley, 2023.
5. Deborah A. Dahl, Multimodal Interaction with W3C Standards - Toward Natural User Interfaces to Everything, Springer, 2017.

CSC8133: Intelligent Web Mining

This is a practical/lab oriented problem solving skill development course.

Course Objectives:

(i) To introduce technological developments through demonstrations, case studies and applications with a futuristic vision
(ii) To understand the multimodal Mining and its challenges
(iii) To identify the recent developments and to focus on research initiatives in Web Mining and its intelligent processing

By completing this course, students will obtain the following course/learning outcomes:

1. Knowledge to be gained:
   (i) Familiarize technologies used in the intelligent processing of Multimodal data
   (ii) Understand the Web Data Mining Techniques, Tools and Algorithms
2. Skill to be gained:
   Skills to perform web mining for multimodal data and behaviour tracking
3. Competency to be gained:
   Development of models for web mining and federated learning in web applications.

Prerequisites: Programming Skill

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module 1

Introduction to Web Mining, Evolution of Web Mining, Graph Theory for Web Structure, Information Theory in Mining, Probabilistic Models, Ensemble Methods, Deep NLP Models, Multilingual Web Mining Challenges, Types of web mining, Web Data Mining Techniques, Tools and Algorithms.

Module 2

Semantic Web Mining, Ontology Learning and Mining, Knowledge Graph Construction, Linked Open Data (LOD) Mining, Multimodal Mining, Cross-media Retrieval Techniques, Dynamic Topic Models, Intelligent Image mining, Audio mining and Video Mining, Context-aware and Situation-aware Recommendations, Session-based and Sequential Recommendation Models, Federated Learning in Web Applications.

Module 3

Temporal Link Mining, Trust and Reputation Systems in Link Mining, Social Network Mining, Community Detection, Influence Maximization Models, Web Usage Mining, Sequential Pattern Mining, Deep Session Mining using RNNs, LSTMs, Multi-intent User Behavior Mining, Cognitive Models in Web Mining, Cross-device and Cross-platform Behavior Tracking.

Module 4

Graph Neural Networks (GNNs) for Web Structure, Transformers for Web-scale Data Mining,

Contrastive Learning and Self-supervised Models, Web Page Clustering Based on Website Structure, Differential Privacy Techniques, Blockchain-based Web Mining, Bias and Fairness in Web Mining Algorithms, Ethical AI in Web Mining, Regulation and Policy Issues.

Text Books/References:

1. Covington, P., Adams, J., & Sargin, E. (2016). *Deep Neural Networks for YouTube Recommendations*. Proceedings of the 10th ACM Conference on Recommender Systems - RecSys '16, 191–198. https://doi.org/10.1145/2959100.2959190
2. Devlin, J., Chang, M.-W., Lee, K., & Toutanova, K. (2019). *BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding*. ArXiv.org. https://doi.org/10.48550/arXiv.1810.04805
3. Hamilton, W. L. (2020). *Graph representation learning*. San Rafael] Morgan Et Claypool.
4. Hamilton, W., Ying, R., & Leskovec, J. (2017). *Inductive Representation Learning on Large Graphs*. https://doi.org/10.48550/arxiv.1706.02216
5. Hitzler P, Krotzsch M., Rudolph S. (2009). *Foundations of Semantic Web Technologies*. CRC Press.
6. Leskovec, J., Anand Rajaraman, & Jeffrey David Ullman. (2015). *Mining of massive datasets*. Cambridge University Press.
7. Tommaso Teofili, & Mattmann, C. (2019). *Deep learning for search*. Manning Publications.
8. Bhatia P (2019). *Data Mining and Data Warehousing.* Cambridge University Press.

CSC8134 - Cloud Computing Security

This is a theoretical, practical and skill development course.

Course Objectives:

- Understand cloud computing models, security risks, and best practices.
- Implement security controls for cloud infrastructure, data, and applications.
- Gain hands-on experience with cloud platforms (AWS, Azure) and security tools.
- Develop skills in risk assessment, incident response, and compliance auditing.
- Apply design patterns and monitoring techniques to secure cloud environments.

By Completing this course, the students will obtain the following course outcomes:
Knowledge gained:

- Articulate cloud security risks and mitigation strategies.

Skill gained:

- Configure secure cloud environments using AWS and Azure tools.
- Implement encryption, access control, and monitoring solutions.

Competency gained:

- Integration of multimodal data for complex problem-solving using advanced machine learning and deep learning architectures.
- Conduct cloud security audits and respond to incidents.
- Apply best practices and design patterns to secure cloud architectures.

Total Contact Hrs. Per Week	4	Assessment –Total	100 Marks
Lectures	2	Continuous Internal Assessment	Nil
Lab	1	End Semester Assessment	100 Marks
Tutorial	1	Credits	4

Module I

Fundamentals of Cloud Security Concepts:

Overview of cloud computing models (IaaS, PaaS, SaaS; Public, Private, Hybrid), Cloud security challenges: data breaches, misconfigurations, insider threats, Security services: Confidentiality, Integrity, Authentication, Non-repudiation, Access Control, Cryptography basics: Conventional and public-key cryptography, Hash functions, digital signatures, and authentication protocols.

Module II

Data Protection in the Cloud:

Data security lifecycle: retention, deletion, and archiving procedures, Encryption techniques: AES, RSA, and key management with PKI, Data protection strategies: Tokenization, data redaction, and obfuscation, Egress monitoring and data loss prevention (DLP), Cloud data audit: best practices for data security compliance.

Module III

Access Control and Identity Management:

Access control requirements for cloud infrastructure, User identification, authentication, and authorization, Role-based access control (RBAC) and attribute-based access control (ABAC), Multi-factor authentication (MFA) and single sign-on (SSO), Identity federation and integration with identity providers (e.g., Okta, Azure AD), OS hardening, verified boot, and intrusion detection/prevention.

Module IV

Cloud Security Design Patterns:

Introduction to cloud security design patterns, Patterns: Cloud bursting, geo-tagging, secure cloud interfaces, Secure cloud resource access control, Secure on-premise to cloud connectivity (e.g., VPN, Direct Connect), External cloud connection security (e.g., secure APIs, load balancers).

Module V

Monitoring, Auditing, and Incident Management:

Proactive monitoring: CloudWatch, Azure Monitor, and third-party tools, Incident response: detecting unauthorized access, malicious traffic, and privilege abuse, Auditing: log generation, tamper-proofing, and compliance reporting, Security Information and Event Management (SIEM) integration, Quality of Service (QoS) and secure management practices.

Textbooks:

1. Cloud Computing Security: Foundations and Challenges. Vacca, J. R. (Ed.), CRC Press. 2017
2. Cloud Security: A Comprehensive Guide to Secure Cloud Computing by Ronald L. Krutz and Russell Dean Vines, Wiley, 2010.

References:

1. NIST Special Publication 800-144: Guidelines on Security and Privacy in Public Cloud Computing by Jansen, W., & Grance, T. (2011).
2. Security Guidance for Critical Areas of Focus in Cloud Computing (v3.0) by Cloud Security Alliance (2011).
3. Apache Spark Streaming Programming Guide: spark.apache.org/docs/latest/streaming-programming-guide.html.