

M. Tech. in Artificial Intelligence

Program Learning Objectives:	Program Learning Outcomes (PLO):
<p>Program Goal 1: Fundamental Understanding: Establish a robust foundation in Artificial Intelligence (AI) and Data Science (DS) principles, theories, and methodologies.</p>	<p>Program Learning Outcome 1 (PLO-1): Students will acquire a deep understanding of the core concepts, algorithms, and tools used in AI, machine learning, deep learning, and data science.</p> <p>Program Learning Outcome 2 (PLO-2): Students will develop the ability to analyze and interpret complex data, using statistical and computational techniques to extract meaningful insights.</p>
<p>Program Goal 2: Basic Training for Research and Innovation: To equip students with the skills necessary to conduct cutting-edge research and innovate in the fields of AI and Data Science.</p>	<p>Program Learning Outcome 3 (PLO-3): Students will be able to innovate by developing new machine learning/ deep learning models, and systems in AI and DS, contributing to advancements in the field.</p>
<p>Program Goal 3: Technical Skill Proficiency: To enhance technical skills for developing AI and data-driven solutions for industry and academia.</p>	<p>Program Learning Outcome 4 (PLO-4): Students will demonstrate proficiency in programming, data management, and the use of AI and DS tools and frameworks in various fields including computer vision, natural language processing.</p> <p>Program Learning Outcome 5 (PLO-5): Students will be able to design and implement AI and DS solutions that are efficient, scalable, and reliable.</p>
<p>Program Goal 4: Communication and Collaboration: To develop communication and teamwork skills essential for professional success in AI and DS.</p>	<p>Program Learning Outcome 6 (PLO-6): Students will learn to effectively communicate AI and DS concepts, findings, and solutions to both technical and non-technical audiences.</p>
<p>Program Goal 5: Ethics and Social Responsibility: To understand the ethical, social, and environmental implications of AI and Data Science.</p>	<p>Program Learning Outcome 7 (PLO-7): Students will develop an awareness of ethical issues in AI and DS, such as data privacy, algorithmic bias, and the societal impacts of AI technologies.</p> <p>Program Learning Outcome 8 (PLO-8): Students will be able to apply ethical principles and responsible practices in the development and deployment of AI and DS solutions.</p>

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	CS5101	Design and Analysis of Algorithms	3	1	0	4
2.	CS5102	Foundations of Computer Systems	3	0	0	3
3.	CS5103	Computing Lab-1	0	1	2	2
4.	CS61XX	DE-I	3	0	0	3
5.	CS61XX	DE-II	3	0	0	3
6.	HS5111	Technical Writing and Soft Skill	1	2	2	4
7.	XX61PQ	IDE-I	3	0	0	3
		TOTAL	16	4	4	22

IDE (Inter Disciplinary electives) in the curriculum aims to create multitasking professionals/scientists with learning opportunities for students across disciplines/apptitude of their choice by opting level (5 or 6) electives, as appropriate, listed in the approved curriculum.

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	CS5201	Advanced Artificial Intelligence	3	0	0	3
2.	CS5203	Natural Language Processing	3	0	0	3
3.	CS5205	Advanced Artificial Intelligence Lab	0	1	2	2
4.	CS62XX	DE-III	3	0	0	3
5.	CS62XX	DE-IV	3	0	0	3
6.	CS62XX	DE-V	3	0	0	3
7.	RM6201	Research Methodology	3	1	0	4
8.	IK6201	IKS	3	0	0	3
		TOTAL	21	2	2	24

Sl. No.	Subject Code	SEMESTER III	L	T	P	C
1.	CS6198	Summer Internship/Mini Project*	0	0	12	3
2.	CS6199	Project I**	0	0	30	15
		TOTAL	0	0	42	18

***Note: Summer Internship (Credit based)**

(i) Summer internship (*) period of at least 60 days' (8 weeks) duration begins in the intervening summer vacation between Semester II and III. It may be pursued in industry / R&D / Academic Institutions including IIT Patna. The evaluation would comprise **combined grading based on host supervisor evaluation, project internship report after plagiarism check and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the three components stated herein.

(ii) Further, on return from 60 days internship, students will be evaluated for internship work through combined grading based on host supervisor evaluation, project internship report after plagiarism check, and presentation evaluation by the parent department with equal weightage of each component.

**** Note: M. Tech. Project outside the Institute:** A project-based internship may be permitted in industries/academia (outside IITP) in 3rd or 4th semester in accordance with academic regulations. In the IIIrd Semester, students can opt for a semester long M. Tech.

project subject to confirmation from an Institution of repute for research project, on the assigned topic at any external Institution (Industry / R&D lab / Academic Institutions) based on recommendation of the DAPC provided:

(i.) The project topic is well defined in objective, methodology and expected outcome through an abstract and statement of the student pertaining to expertise with the proposed supervisor of the host institution and consent of the faculty member from the concerned department at IIT Patna as joint supervisor.

(ii.) The consent of both the supervisors (external and institutional) on project topic is obtained a priori and forwarded to the academic section through DAPC for approval by the competent authority for office record in the personal file of the candidate.

(iii.) Confidentiality and Non-Disclosure Agreement (NDA) between the two organizations with clarity on intellectual property rights (IPR) must be executed prior to initiating the semester long project assignment and committing the same to external organization and vice versa.

(iv.) The evaluation in each semester at Institute would be mandatory and the report from Industry Supervisor will be given due weightage as defined in the Academic Regulation. Further, the final assessment of the project work on completion will be done with equal weightage for assessment of the host and Institute supervisors, project report after **plagiarism check**. The award of grade would comprise **combined assessment based on host supervisor evaluation, project report quality and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the components stated herein.

(v.) In case of poor progress of work and / or no contribution from external supervisor, the student need to revert back to the Institute essentially to fulfill the completion of M. Tech. project as envisaged at the time of project allotment. However, the recommendation of DAPC based on progress report and presentation would be mandatory for a final decision by the competent authority.

Sl. No.	Subject Code	SEMESTER IV	L	T	P	C
1.	CS6299	Project II	0	0	42	21
	TOTAL		0	0	42	21

Total credits – 85

ELECTIVE GROUPS

Department Elective – I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6101	Advanced Blockchain Technology	3	0	0	3
2.	CS6102	Advanced Cyber Security	3	0	0	3
3.	CS6103	Advanced Pattern Recognition	3	0	0	3
4.	CS6104	Formal Methods in Program Analysis and Verification	3	0	0	3
5.	CS6105	Federated Learning	3	0	0	3

Department Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6106	Advanced Cloud Computing	3	0	0	3
2.	CS6107	Advanced Edge Computing	3	0	0	3
3.	CS6108	Advanced Computational Data Analysis	3	0	0	3
4.	CS6109	Reinforcement Learning	3	0	0	3
5.	CS6110	Advanced Graph Machine Learning	3	0	0	3
6.	CS6111	Advanced Time Series Analysis	3	0	0	3

Department Elective – III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6201	Artificial Internet of Things	3	0	0	3
2.	CS6202	Game Theory	3	0	0	3
3.	CS6203	Text Mining & Analytics	3	0	0	3

Department Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6204	Knowledge Distillation	3	0	0	3
2.	CS6205	Physics of Neural Network	3	0	0	3
3.	CS6206	Selected Topics in Wireless Networks	3	0	0	3
4.	CS6207	Advanced Big Data Analytics	3	0	0	3

Department Elective - V						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6208	Quantum Machine Learning	3	0	0	3
2.	CS6209	Meta Learning	3	0	0	3
3.	CS6210	Selective Topics in Generative AI	3	0	0	3

Interdisciplinary Elective (IDE) Course for M. Tech. (Available to non CSE Dept. students)

IDE from CSE - IDE-I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6112	Drone Data Processing & Analysis	3	0	0	3

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	CS5101	Design and Analysis of Algorithms	3	1	0	4
2.	CS5102	Foundations of Computer Systems	3	0	0	3
3.	CS5103	Computing Lab-1	0	1	2	2
4.	CS61XX	DE-I	3	0	0	3
5.	CS61XX	DE-II	3	0	0	3
6.	HS5111	Technical Writing and Soft Skill	1	2	2	4
7.	XX61PQ	IDE-I	3	0	0	3
		TOTAL	16	4	4	22

Course number	CS5101
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Design and Analysis of Algorithms
Learning Mode	offline
Learning Objectives	The objective of this course is to equip students with a solid understanding of data structures and algorithms, enabling them to design, analyze, and implement efficient algorithms to solve complex computational problems. The course covers fundamental topics such as data structures, complexity analysis, sorting and searching techniques, problem-solving strategies, graph algorithms. By the end of the course, students will have developed the skills to critically analyze algorithm efficiency and apply advanced algorithms in practical scenarios.
Course Description	This course will provide understanding of advanced methods to solve problems on computers. It will also provide an overview to analyze those theoretically.
Course Outline	Fibonacci heap, unionfind, splay trees. Amortized complexity analysis Randomized algorithms Reducibility between problems and NP-completeness: discussion of different NP-complete problems like satisfiability, clique, vertex cover, independent set, Hamiltonian cycle, TSP, knapsack, set cover, bin packing, etc. Backtracking, branch and bound Approximation algorithms: Constant ratio approximation algorithms. Application areas(i)Geometric algorithms: convex hulls, nearest neighbor, Voronoi diagram, etc.(ii)Algebraic and number-theoretic algorithms: FFT, primality testing, etc.(iii)Graph algorithms: network flows, matching, etc.(iv)Optimization techniques: linear programming
Learning Outcome	By the end of this course, students will be able to solve problems that are computationally intractable
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading:

- Mark Allen Weiss, "Data Structures and Algorithms in C++", Addison Wesley, 2003.
- Adam Drozdek, "Data Structures and Algorithms in C++", Brooks and Cole, 2001.
- Aho, Hopcroft and Ullmann, "Data structures and Algorithm", Addison Welsey, 1984.

- Introduction to Algorithms Book by Charles E. Leiserson, Clifford Stein, Ronald Rivest, and Thomas H. Cormen
- Sanjoy Dasgupta, Christos H. Papadimitriou and Umesh V. Vazirani, Algorithms, Tata McGraw-Hill, 2008.
- Steven Skiena, The Algorithm Design Manual, Springer
- Jon Kleinberg and Éva Tardos, Algorithm Design, Pearson, 2005.
- Robert Sedgewick and Kevin Wayne, Algorithms, fourth edition, Addison Wesley, 2011.
- Udi Manber, Algorithms – A Creative Approach, Addison-Wesley, Reading, MA, 1989.
- Tim Roughgarden, Algorithms Illuminated

Course Number	CS5102
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Foundations of Computer Systems
Learning Mode	Offline
Learning Objective	The objective of the course is to provide a conceptual and theoretical understanding of computer architecture and operating systems.
Course Description	Foundations of computer systems is a review of two fundamental subjects of computer science viz., computer architecture and operating systems.
Course Outline	<p>Computer architecture: Performance measures, Memory Location and Operations, Addressing Modes, Instruction Set, A Simple Machine, Instruction Mnemonics and Syntax, Machine Language Program, Assembly Language Program with examples.</p> <p>Processing Unit Design: Registers, Datapath, CPU instruction cycle, Instructions and Micro-operations in different bus architectures, Interrupt handling, Control Unit Design: Control signals, Hardwired Control unit design, Microprogram Control unit design. Pipelining and parallel processing, Pipeline performance measure, pipeline architecture, pipeline stall (due to instruction dependency and data dependency), Methods to reduce pipeline stall.</p> <p>RISC and CISC paradigms, I/O Transfer techniques, Memory organization: hierarchical memory systems, cache memories, virtual memory.</p> <p>Operating systems: Process states, PCB, Fork, exec system call, Threads, Process scheduling, Concurrent processes, Monitors, Process Synchronization, Producer Consumer Problem, Critical section, semaphore, Various process synchronization problems. Deadlock, Resource Allocation Graph, Deadlock prevention, Deadlock Avoidance: Banker's Algorithm and Safety Algorithm.</p> <p>Memory management techniques, Allocation techniques, Paging, Page Replacement Algorithms, Numericals.</p>
Learning Outcome	This course will revisit two fundamental subjects of computer science viz., computer architecture and operating systems, thereby enabling the

	students to pursue more advanced problems in computer science based on these topics.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested readings:

- Silberschatz, P. B. Galvin and G. Gagne, Operating System Concepts, 7th Ed, John Wiley and Sons, 2004.
- M. Singhal and N. Shivratri, Advanced Concepts in Operating Systems, McGraw Hill, 1994.
- David A Patterson and John L Hennessy, Computer Organisation and Design: The Hardware/Software Interface, Morgan Kaufmann, 1994. ISBN 1-55860-281-X.

Course Number	CS5103
Course Credit (L-T-P-C)	0-1-2-2
Course Title	Computing Lab-1
Learning Mode	Offline
Learning Objective	The course aims to develop students' analytical and practical skills in designing efficient algorithms and understanding the complexities of operating systems. Students will learn to analyze the efficiency of algorithms, understand various algorithmic strategies, and implement them to solve complex problems. In the Operating Systems segment, students will explore the core concepts, including process management, memory management, file systems, and concurrency. By the end of the course, students will be proficient in both designing algorithms and managing operating system resources, preparing them for advanced studies and professional careers in computer science.
Course Description	This lab course is structured to provide an in-depth understanding of both algorithm design and operating system concepts. The Design and Analysis of Algorithms section covers fundamental topics such as sorting, searching, dynamic programming, greedy algorithms, and graph algorithms. Students will learn to critically evaluate the efficiency and applicability of different algorithms. The Operating Systems section delves into process scheduling, memory management techniques, file systems, and synchronization mechanisms. Through a series of hands-on labs and projects, students will apply theoretical knowledge to practical scenarios, reinforcing their understanding and problem-solving abilities.
Course Outline	The course begins with an introduction to basic algorithmic concepts and techniques, progressing through various algorithm design paradigms such as divide-and-conquer, dynamic programming, and greedy methods. Concurrently, students will explore the architecture and functionalities of operating systems, starting with process management and memory management, then advancing to file systems, I/O systems, and concurrency control. The course will include practical lab sessions where students will implement and test algorithms, as well as design and manage operating system components. The course culminates in a comprehensive project that integrates both algorithm design and operating system principles to solve complex computing problems.

Learning Outcome	Upon completing this course, students will have a solid grasp of both algorithm design and analysis, as well as operating system functionalities. They will be able to design, analyze, and implement efficient algorithms to address computational problems. Additionally, students will gain practical experience in managing operating system resources, including process scheduling, memory management, and file systems. This dual expertise will equip students with the skills necessary for tackling advanced topics in computer science and pursuing careers in software development, system administration, and research.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested readings:

- "Introduction to Algorithms" by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, 4th Edition
- "Algorithms" by Robert Sedgewick and Kevin Wayne, 4th Edition
- "Operating System Concepts" by Abraham Silberschatz, Peter B. Galvin, and Greg Gagne, 10th Edition
- "Modern Operating Systems" by Andrew S. Tanenbaum and Herbert Bos, 4th Edition
- "The Algorithm Design Manual" by Steven S. Skiena, 3rd Edition

Department Elective – I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6101	Advanced Blockchain Technology	3	0	0	3
2.	CS6102	Advanced Cyber Security	3	0	0	3
3.	CS6103	Advanced Pattern Recognition	3	0	0	3
4.	CS6104	Formal Methods in Program Analysis and Verification	3	0	0	3
5.	CS6105	Federated Learning	3	0	0	3

Course Number	CS6101
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Blockchain Technology
Learning Mode	Offline
Learning Objectives	The objective of this course is to cover a number of popular blockchain platforms and smart contract language paradigms. This course makes the learners familiar with various (a) research challenges, such as interoperability, scalability, security vulnerabilities, functional/non-functional correctness proof, etc., and their possible solutions, (b) synergizing machine Learning and blockchain, and (c) development of secure blockchain-based decentralized applications using Ethereum and Hyperledger.
Course Description	This course will start with a quick introductory background of blockchain technology and its working principle. The primarily focus of this course is to provide a detailed information about the state-of-the-art blockchain platforms and their supported smart contract languages. In particular, syntax, semantics, and paradigms of various smart contract languages will be discussed. In this perspective, blockchain-oriented software development life cycle and decentralized application development will be discussed. Following this, the course will cover two important directions: addressing various research challenges in blockchain and AI/machine learning for blockchain (and vice-versa).
Course Outline	<p>Introduction to Blockchain Technology: A Quick Tour</p> <p>Different Blockchain Platforms and Smart Contract Languages: Bitcoin, Ethereum, Hyperledger, Solidity, GoLang.</p> <p>Consensus Mechanisms: PoW Vs. PoS, Alternative Consensus</p> <p>Synergizing Machine Learning and Blockchain: Transaction Analysis, Smart Contract Code Analysis, AI-driven Blockchain Applications, Blockchain for AI, Decentralized Learning.</p> <p>Research Challenges in Blockchain: Scalability, Interoperability, Security, Privacy, Decentralized Identity, Smart Contract Vulnerabilities and Detection, Real case studies on developing DApps, Metaverse, Some ongoing relevant research topics.</p>
Learning Outcome	<ul style="list-style-type: none"> • Gain proficiency in blockchain technology and software engineering of developing decentralized applications. • An overview of the state-of-the-art blockchain platforms and their supported smart contract languages. • Know about the paradigms of various smart contract languages. • Understand how AI/machine learning brings benefits to blockchain technology and vice-versa. • Identify various research challenges and opportunities, such as scalability, interoperability

Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term
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Suggested Readings:

- Don Tapscott and Alex Tapscott: Blockchain Revolution: How the Technology Behind Bitcoin and Other Cryptocurrencies is Changing the World, Portfolio (May 2016).
- Andreas M. Antonopoulos, Gavin Wood: Mastering Ethereum: Building Smart Contracts and Dapps, O'Reilly, first edition (Dec 2018).
- Nitin Gaur, Luc Desrosiers, Venkatraman Ramakrishna, Petr Novotny, Salman A. Baset, Anthony O'Dowd: Hands-On Blockchain with Hyperledger, Packt Publishing, first edition (June 2018).
- Arvind Narayanan, Joseph Bonneau, Edward Felten, Andrew Miller, Steven Goldfeder, Bitcoin and Cryptocurrency Technologies - A Comprehensive Introduction, Princeton University Press (2016).
- Stijn Van Hifft: Blockchain Platforms: A Look at the Underbelly of Distributed Platforms, Morgan & Claypool Publishers, first edition (July 2020)
- Relevant Research Papers and Study Materials available online.

Course Number	CS6102
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Cyber Security
Learning Mode	Offline
Learning Objectives	To have a clear understanding of security and privacy issues in various aspects of computing, including: Programs, Operating systems, Networks, Web Applications
Course Description	The course covers. security and privacy issues in various aspects of computing, including: Programs, Operating systems, Networks, Web Applications
Course Outline	Introduction to Computer Security and Privacy: security and privacy; types of threats and attacks; methods of defense Basics of cryptography, Authentication & key agreement, Authorization and access control Program Security: nonmalicious program errors; vulnerabilities in code, Secure programs; malicious code; Malware detection Internet security: IPSEC, TLS, SSh, Email security Wireless security: WEP, WPA, Bluetooth security, Web Security: XSS attack, CSRF attack, SQL Injection, DoS attack & defense
Learning Outcome	After completion of this course a student will have <ul style="list-style-type: none"> • Understanding of security issues in computer and networks, • Understanding and analysis of internet security protocols • Understanding and analysis of web security protocols
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Textbooks:

- Computer Security: Principles and Practice: Dr. William Stallings and Lawrie Brown, Pearson
- O'Reilly Web Application Security by Andrew Hoffman

Course Number	CS6103
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Pattern Recognition
Learning Mode	Offline
Learning Objectives	This course aims to help the students (a) Understand the advanced topics of pattern recognition, including classification and clustering methods. (b) To understand the advanced topics of feature selection, multi-label classification. (c) Apply advanced pattern recognition algorithms to practical applications in image processing, speech recognition, and data mining.
Course Description	This course on advanced pattern recognition aims to equip students with the advanced topics of classification, clustering, and feature selection. By focusing on advanced topics, students will develop the ability to implement and evaluate various pattern recognition algorithms. Students will enhance their understanding of advanced topics of classification, clustering, statistical methods, and data preprocessing techniques through interactive lectures, exercises, and projects. Upon completion, students will be proficient in designing and applying advanced pattern recognition systems for applications such as image processing, text mining, speech recognition, and data mining, thereby enhancing their analytical and problem-solving capabilities in diverse domains.
Course Outline	<p>Introduction and motivation of advanced pattern recognition</p> <p>Modern Classification Methods, Random fields, Pattern recognition based on multidimensional models</p> <p>Contextual classification, Hidden Markov models, Multi-classifier systems</p> <p>Advanced parameter estimation methods, Advanced Unsupervised classification, Modern methods of feature selection.</p> <p>Data normalization and invariants, Benchmarking.</p> <p>Analysis and synthesis of image information.</p> <p>Applications of pattern recognition in Text Processing and Healthcare.</p>
Learning Outcome	<ul style="list-style-type: none"> • Mastery of advanced concepts in pattern recognition. • In-depth understanding of various advanced algorithms across different pattern recognition paradigms. • Comprehensive knowledge of advanced aspects of classification, clustering, feature selection, feature extraction, and projection techniques. • Ability to apply advanced pattern recognition algorithms to real-world projects

Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term
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Suggested Reading:

- P. A. Devijver and J. Kittler, Pattern Recognition: A Statistical Approach, Prentice-Hall,1982.
- R. Duda and P. Hart and D.G. Stork, Pattern Classification, J. Wiley, 2001.
- Webb, Statistical Pattern Recognition, J. Wiley, 2002.
- S.Theodoridis, K.Koutroumbas, Pattern Recognition, Elsevier, 2003.
- S. Z. Li, Markov Random Field Modeling in Image Analysis, Springer, 2009.

Research papers will be provided on various topics

Course Number	CS6104
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Formal Methods in Program Analysis and Verification
Learning Mode	Offline
Learning Objectives	Formal methods are mathematically rigorous techniques to facilitate in building high-confidence critical systems with stringent quality requirements, such as safety and security. It provides a systematic guidance for specification, development, and verification of software and hardware systems. Examples for such systems are banking software, avionics software, medical device software, software used to control industrial plants/cars, etc. This course will provide necessary background on formal methods and their role in software engineering practice. A range of formal methods will be introduced along with practical case studies of their use. Students will learn how these methods can be used to build reliable software, hardware, and security protocols.
Course Description	This course will start with the fundamentals of set theory, relation and function, lattice theory, propositional and predicate logic, and proof techniques. In order to demonstrate how to analyze and verify a software system, this course will discuss the following three formal approaches using suitable examples: (a) Abstract Interpretation Theory, (b) Temporal Logic and Model Checking, and (c) Deductive Reasoning. In this context, formalism of syntax and semantics of programming languages will be explained considering a simple imperative language WHILE. All these approaches will be illustrated using real-life examples, such as microwave oven, mutual exclusion problem, etc.
Course Outline	<p>Introduction: Introduction to critical systems, Introduction to formal methods and its role, Dependability, Testing Vs. Verification</p> <p>Formal Syntax and Semantics: the WHILE Language, Syntax Vs. Semantics, Formal Program Semantics - Operational, Denotational, Axiomatic</p> <p>Formal Program Analysis: Program Slicing, Dataflow Analysis, Fixpoint Algorithm, Abstract Interpretation Framework</p> <p>Formal Program Verification: Deductive Reasoning; Predicate Abstraction and CEGAR, Temporal Logic and Model Checking, Role of some other formal methods in software engineering</p> <p>New Research Directions: Recent trends on the application of formal methods in Machine Learning and Blockchain</p> <p>Tools: Introduction to various state-of-the-art Analyzers and Verifiers (e.g., NuSMV, UPPAAL, SPIN, ASTREE, CBMC, etc.)</p>
Learning Outcome	<ul style="list-style-type: none"> • Gain proficiency in formal methods and their role in critical systems. • Understanding formal tools and techniques for analysis and verification of software source codes. • Learning how to define semantics of a software formally, and how to abstract its semantics at different levels of precision in order to

	<p>capture its run-time behavioral properties of interests.</p> <ul style="list-style-type: none"> • Learning temporal logic to express system's time-varying behaviors. • Applying automatic software verification tools based on model checking and deductive reasoning. • Hands-on experience with NuSMV, Uppaal, Z3 SMT solver, etc. • Application of formal methods in cutting edge research domains including Robotics, IoT, Blockchain Smart Contracts.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Readings:

- Flemming Nielson, Hanne R. Nielson, Chris Hankin. Principles of Program Analysis, Springer, 1999.
- Edmund M. Clarke, Orna Grumberg, Doron A. Peled. Model Checking, The MIT Press, 1999.
- Glynn Winskel. The formal semantics of programming languages: an introduction, The MIT Press, 1993.
- José Bacelar Almeida, Maria João Frade, Jorge Sousa Pinto, Simão Melo de Sousa. Rigorous Software Development: An Introduction to Program Verification. Springer- Verlag London, 2011
- Recent Research Papers relevant to the course.

Course Number	CS6105
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Federated Learning
Learning Mode	Offline
Learning Objectives	This course aims to help the students (a) Grasp Foundational Concepts and Developments of Federated Learning (FL), and stay informed about current developments and emerging trends in the field. (b) Implement Privacy and Security Techniques including privacy-preserving machine learning (PPML), privacy-preserving gradient descent, and threat and security models to ensure data confidentiality and integrity in FL systems. (c) Mastering horizontal and vertical FL architectures (HFL, VFL) and algorithms, such as the federated averaging algorithm and its enhancements. (d) FL techniques to practical applications in computer vision, natural language processing (NLP), and reinforcement learning, demonstrating the practical benefits and addressing limitations in these domains.
Course Description	This course offers a comprehensive exploration of Federated Learning (FL), a cutting-edge approach to collaborative machine learning where models are trained across decentralized devices or servers holding local data samples. The course begins with an introduction to FL, defining its principles, categories, and current developments in the field. Students will delve into essential topics such as privacy-preserving techniques, including privacy-preserving machine learning (PPML) and secure machine learning methods, to ensure data security and confidentiality in distributed learning environments. The curriculum covers scalable distributed machine learning (DML) techniques tailored for FL, addressing challenges in model aggregation and performance across heterogeneous data sources. Key architectural paradigms like horizontal and vertical FL (HFL, VFL) will be explored, alongside algorithms such as federated averaging and advancements in optimization for FL scenarios. The course emphasizes practical applications of FL in domains like computer vision, natural language processing (NLP), and reinforcement learning, showcasing its utility and addressing real-world challenges. By the end of the course, students will have a deep understanding of FL principles, techniques, and applications. They will be equipped to design and implement secure, scalable, and privacy-aware machine learning solutions suitable for collaborative environments with distributed data sources.
Course Outline	Introduction to Federated Learning, Current Development in Federated Learning, Privacy-Preserving Machine Learning, Horizontal Federated Learning, Vertical Federated Learning.

Learning Outcome	<ul style="list-style-type: none"> • Understand the principles, definitions, and categories of federated learning • Apply various privacy-preserving machine learning • Design and improve federated learning algorithms, such as the federated averaging algorithm. • Utilize federated learning frameworks for practical applications in computer vision, natural language processing, reinforcement learning, and other areas
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading

- Deppeler, A., 2020. Automated Machine Learning and Federated Learning. *The AI Book: The Artificial Intelligence Handbook for Investors, Entrepreneurs and FinTech Visionaries*, pp.248-250.
- Relevant research articles.

Department Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6106	Advanced Cloud Computing	3	0	0	3
2.	CS6107	Advanced Edge Computing	3	0	0	3
3.	CS6108	Advanced Computational Data Analysis	3	0	0	3
4.	CS6109	Reinforcement Learning	3	0	0	3
5.	CS6110	Advanced Graph Machine Learning	3	0	0	3
6.	CS6111	Advanced Time Series Analysis	3	0	0	3

Course Number	CS6106
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Cloud Computing
Learning Mode	Offline
Learning Objectives	This course aims to help the students understand (a) how and why cloud systems work and the cloud technologies that manifest these concepts, such as those from Amazon AWS and Microsoft Azure; (b) distributed systems concepts like virtualisation, data parallelism, CAP theorem, and performance analysis at scale; (c) Big Data programming patterns such as Map-Reduce (Hadoop), Vertex-centric graphs (Giraph), Continuous Dataflows (Storm), and NoSQL storage systems to build Cloud applications; (d) Cloud native computing and micro-services.
Course Description	This course provides an in-depth understanding of cloud computing, virtualisation, and distributed systems. It covers foundational concepts, advanced techniques, and real-world applications. Students will explore various aspects of cloud infrastructure, virtualisation technologies, distributed algorithms, and cloud-native computing. By the end of the course, students will be equipped with the knowledge and skills to design, implement, and manage cloud-based solutions and distributed systems effectively.
Course Outline	<p>Cloud computing features and categories.</p> <p>Virtualization: Virtualization Models, Types of Virtualization: Processor virtualization, Memory virtualization, Full virtualization, Para virtualization, Device virtualization.</p> <p>Virtual Machine: Live VM Migration Stages, Virtual Machine Migration for Enterprise Data Centers, Data Center Workloads, Provisioning methods, Resource provisioning.</p> <p>Geo-distributed Clouds: Server Virtualization, Network Virtualization, Approaches for Networking of VMs: Hardware approach: Single-root I/O virtualization (SR-IOV), Software approach: Open vSwitch, Mininet and its applications.</p> <p>Software Defined Network for Multi-tenant Data Centers: Network virtualization, Case Study: VL2, NVP</p>

	<p>Geo-distributed Cloud Data Centers: Inter-Data Center Networking, Data center interconnection techniques: MPLS, Google's B4 and Microsoft's Swan. Leader Election algorithms in Cloud. Google's Chubby and Apache Zookeeper. Time and Clock Synchronization in Cloud Data Centers, Datacenter time protocol (DTP. Consensus, Paxos and Recovery in Clouds.</p> <p>Cloud Storage: Key-value stores/NoSQL, Design of Apache Cassandra, HBase. Peer to Peer Systems in Cloud Computing. Cloud application: MapReduce Examples. Advances in Cloud Computing with decentralization and Edge Computing.</p>
Learning Outcome	<ul style="list-style-type: none"> • Cloud Computing as a Distributed Systems: Explain and contrast the role of Cloud computing within this space. • Cloud Virtualization, Abstractions and Enabling Technologies: Explain virtualisation and their role in elastic computing. Characterise the distinctions between Infrastructure, Platform and Software as a Service (IaaS, PaaS, SaaS) abstractions, and Public and Private Clouds, and analyse their advantages and disadvantages. • Programming Patterns for "Big Data" Applications on Cloud: Demonstrate using Map-Reduce, Vertex-Centric and Continuous Dataflow programming models. • Application Execution Models on Clouds: Compare synchronous and asynchronous execution patterns. Design and implement Cloud applications that can scale up on a VM and out across multiple VMs. Illustrate the use of NoSQL Cloud storage for information storage. • Performance, scalability and consistency on Clouds: Explain the distinctions between Consistency, Availability and Partitioning (CAP theorem), and discuss the types of Cloud applications that exhibit these features.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading:

- Distributed and Cloud Computing From Parallel Processing to the Internet of Things; Kai Hwang, Jack Dongarra, Geoffrey Fox Publisher: Morgan Kaufmann, Elsevier, 2013.
- Cloud Computing: Principles and Paradigms; Rajkumar Buyya, James Broberg, and Andrzej M. Goscinski Publisher: Wiley, 2011.
- Distributed Algorithms Nancy Lynch Publisher: Morgan Kaufmann, Elsevier, 1996.
- Cloud Computing Bible Barrie Sosinsky Publisher: Wiley, 2011.
- Cloud Computing: Principles, Systems and Applications, Nikos Antonopoulos, Lee Gillam Publisher: Springer, 2012.

Course Number	CS6107
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Edge Computing
Learning Mode	Offline
Learning Objectives	Upon successful completion of this course, students will be able to: (a) understand the fundamental concepts and limitations of cloud computing and identify the advantages of edge computing; (b) describe various edge computing architectures and differentiate them from traditional cloud models; (c) comprehend the principles of distributed systems as they apply to edge computing environments; (d) explore the functionalities of edge data centers and lightweight edge clouds; (e) deploy and manage containerized applications using Docker and Kubernetes in edge computing contexts; and (f) implement and evaluate edge storage systems and end-to-end edge pipelines utilising MQTT and Kafka, as well as investigate advanced edge computing technologies for real-world applications.
Course Description	This course delves into the emerging field of edge computing, providing a comprehensive understanding of its architectures, systems, and technologies. Students will explore the limitations of traditional cloud computing and learn about the advantages and applications of edge computing. The course covers key concepts in distributed systems, edge data centers, and lightweight edge clouds and includes hands-on experience with Docker, Kubernetes, and edge storage systems. Additionally, students will gain insights into end-to-end edge pipelines using MQTT and Kafka and examine advanced edge computing technologies. By the end of the course, students will be equipped with the knowledge and skills to design, implement, and manage edge computing solutions.
Course Outline	Cloud Computing Basics.Edge Computing basics. Edge Computing Use-Cases, Benefits. Different Types of Edge. Edge Deployment Modes. Edge Computing in 5G, Multi-access Edge Computing (MEC) and Mobile Edge Computing.
Learning Outcome	<ul style="list-style-type: none"> • Critically evaluate advanced edge computing architectures, such as hierarchical, mesh, and hybrid models, considering their suitability for specific use cases and environments. • Analyses emerging technologies and trends in advanced edge computing, such as edge AI, blockchain, and serverless computing, and assess their potential impact.

	<ul style="list-style-type: none"> • Design and implement innovative edge computing solutions that leverage advanced techniques, such as federated learning, edge caching, and dynamic resource allocation. • Evaluate the performance and scalability of advanced edge computing systems using benchmarking, simulation, and experimentation. • Investigate advanced techniques for ensuring security, privacy, and data integrity in edge computing ecosystems, such as secure enclaves, encryption, and access control mechanisms. • Explore specialised applications of advanced edge computing in domains such as healthcare, smart cities, and autonomous systems, analysing their requirements and challenges.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading:

- Fog and Edge Computing: Principles and Paradigms, Rajkumar Buyya (Editor), Satish Narayana Srirama (Editor), Wiley, 2019
- Cloud Computing: Principles and Paradigms, Editors: Rajkumar Buyya, James Broberg, Andrzej M. Goscinski, Wiley, 2011
- Cloud and Distributed Computing: Algorithms and Systems, Rajiv Misra, Yashwant Patel, Wiley 2020.
- Besides these books, we will provide Journal papers as references.

Course Number	CS6108
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Computational Data Analysis
Learning Mode	Offline
Learning Objective	In this subject, the students will be trained with the knowledge of various advanced data analytics techniques encountered in real life.
Course Description	Current Physical systems/devices are highly complex and fast and operate with high data acquisition and generation capabilities. Data generated from such systems require advanced level of analytics for apprehension and further usage. This course aims to give a broad understanding what is advanced level data analytics techniques and how they play a critical role in analysing modern day physical systems acquired data.
Course Outline	<p>Introduction, Operation of physical systems and data generation, Complexity, Drawbacks and Challenges in data generation from physical devices. Requirement of advanced data analytics.</p> <p>Foundations of advanced data analytics principles, mathematical models, probabilistic models, optimization models, deep learning and machine learning models.</p> <p>Role of advanced data analytics in data apprehension and compression, curve-based approximation techniques, interpolation techniques, machine learning models for data interpretation.</p> <p>Statistical models to advanced data analytics, data analytics for 2D and 3D data processing and data manipulation, application of advanced data analytics to real life cases, problem solving.</p>
Learning Outcome	<ul style="list-style-type: none"> • Gain understanding on data generation systems and the role of advanced data analytics. • Apply the Mathematical models of advanced data analytics to real time • Understand the utilities of statistical models and ML models for advanced data analytics.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Readings:

- Signal Processing: A Mathematical Approach, Charles L. Byrne, Second Edition, Chapman & Hall, 2014.
- Digital Functions and Data Reconstruction: Digital-Discrete Methods, Li M Chen, Springer, 2013.
- Machine Learning with Neural Networks: An Introduction for Scientists and Engineers, Bernhard Mehlig, Cambridge University Press, 2021
- Signal Processing and Machine Learning with Applications, Michael M. Richter, Sheuli Paul, Veton Këpuska, Marius Silaghi, Springer Cham, 2022
- Data Compression: The Complete Reference, David Solomon, 4th Edition, Springer, 2007

Course Number	CS6109
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Reinforcement Learning
Learning Mode	Offline
Learning Objectives	This course aims to help the students (a) Understand the foundational concepts and mathematical frameworks of reinforcement learning. (b) Gain proficiency in key reinforcement learning algorithms, including dynamic programming, Monte Carlo methods, and temporal-difference learning (c) Apply deep reinforcement learning techniques to solve complex problems using methods such as deep Q-networks and policy gradient algorithms. (d) Explore recent advancements and applications of reinforcement learning, including multi-agent systems and ethical considerations.
Course Description	This specialized course on reinforcement learning aims to give students a deep understanding of the algorithms and methodologies used to train agents to make decisions through trial and error. Students will learn to develop and implement reinforcement learning models by focusing on foundational theories and practical applications. Students will explore key concepts such as Markov decision processes, policy gradients, Q-learning, and deep reinforcement learning through a mix of theoretical lectures, coding exercises, and project-based learning. Upon completion, students will be equipped to design and apply reinforcement learning solutions to complex problems in fields such as robotics, game development, and autonomous systems, enhancing their expertise in this dynamic area of artificial intelligence.
Course Outline	Foundations: Basics of machine learning and reinforcement learning (RL) terminology. Probability Concepts: Axioms of probability, random variables, distributions, and correlation. Markov Decision Process: Introduction to MDPs, Markov property, and Bellman equations. State and Action Value Functions: Concepts of MDP, state, and action value functions. Tabular Methods and Q-networks: Dynamic programming, Monte Carlo, TD learning, and deep Q-networks. Policy Optimization: Policy-based methods, REINFORCE algorithm, and actor-critic methods. Recent Advances and Applications: Meta-learning, multi-agent RL, ethics in RL, and real-world applications.
Learning Outcome	<ul style="list-style-type: none"> • Mastery of fundamental principles and mathematical frameworks of reinforcement learning. • Proficiency in implementing key reinforcement learning algorithms and techniques. • Ability to apply deep reinforcement learning methods to complex, real-world problems. • Understanding of recent advancements in reinforcement learning and their ethical implications.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading:

- Reinforcement Learning: An Introduction by Richard S. Sutton and Andrew G. Barto, The MIT Press (1 January 1998).
- Deep Reinforcement Learning Hands-On by Maxim Lapan, Packt Publishing Limited (21 June 2018).
- Algorithms for Reinforcement Learning by Csaba Szepesvari, Morgan and Claypool Publishers (2010)
- Deep Reinforcement Learning: Fundamentals, Research and Applications by Hao Dong, Springer Verlag (2020)

Course Number	CS6110
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Graph Machine Learning
Learning Mode	Offline
Learning Objectives	Several real world systems can be represented as a network of entities that are connected to each other through some relations. Often the number of entities is immensely large, thus forming a very large network. Typical examples of such large networks include network of entities in knowledge graphs, co-occurrence graph of the keywords in natural languages, interaction graph of users in social networks, protein-protein interaction graphs and the network of routers in Internet to name a few. Study of these networks is often needed for relational learning tasks, as well as for developing frameworks for representing the intrinsic structure of the data. This course will mainly deal with both the traditional as well as current state of the art machine learning techniques to be applied on Graphs for different downstream tasks.
Course Description	The course will provide knowledge on the representation and statistical descriptions of large networks, along with traditional machine learning and deep learning techniques applied on graphs. Several use cases of Graph Machine Learning across different domains including Natural Language Processing, Social Network Analysis and Computational Biology would be studied.
Course Outline	<p>Introduction and background knowledge of graphs; Network Measures and Metrics;</p> <p>Spectral Analysis of Graphs and its applications; Random Networks; Properties of Random Networks;</p> <p>Overview of machine learning applications on graphs; Feature based learning on graphs, Shallow embedding and deep Learning techniques for generating node and graph representations – Graph Neural Networks, Graph Attention Networks, Graph Transformers; Graph Neural Networks Pretraining techniques;</p> <p>Generative models for graphs; Models for scale-free and small-world networks;</p> <p>Temporal networks, Modeling temporal networks</p>

Learning Outcome	<p>Course training via lectures & tutorial sessions to</p> <ul style="list-style-type: none"> • Represent and analyze the structure of graphs • Discover recurring and significant patterns of interconnections in your data with network motifs and community structure. • Gain Knowledge on traditional machine learning techniques applied on graphs • Leverage graph-structured data to make better predictions using graph neural networks • Understand the problems in dealing with large graphs for machine learning tasks and learn how to improvise • Analyze temporal and dynamic graphs • Scaling neural networks with generative models for graphs.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Readings:

- M.E.J. Newman, Networks - An introduction , Oxford Univ Press, 2010.
- Yao Ma and Jilian Tang, Deep Learning on Graphs, Cambridge University Press, 2021
- Goyal, Palash and Emilio Ferrara. “Graph embedding techniques, applications, and performance: A survey.” *Knowl.-Based Syst.* 151 (2018): 78-94.

Course Number	CS6111
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Time Series Analysis
Learning Mode	Offline
Learning Objectives	<ul style="list-style-type: none"> • This course on advance time series will teach both the fundamental concepts time series analysis, as well as recent trends in time series analysis. • Students will learn to design successful time series data applications with sequential Neural Networks. • Deploy Nonlinear Auto-regressive Network with Exogenous Inputs • Adapt Deep Neural Networks for Time Series Forecasting and classification
Course Description	This course provides advanced concepts in time series analysis including some fundamentals of time series, data pre-processing, feature selection, Variety of modeling techniques, Anomaly Detection in Time Series and forecasting financial series using statistical, econometric, machine learning, and deep learning approaches and Practical Applications and Deployment of models.
Course Outline	<p>Introduction to classical time series methods, time series Virtualization Univariate Stationary Processes; Granger Causality; Vector Autoregressive Processes</p> <p>Nonstationary Processes; Cointegration; Cointegration in Single Equation Models: Representation, Estimation and Testing.</p> <p>Applied Predictive Modeling Techniques; Autoregressive Conditional Heteroskedasticity.</p> <p>Finance and Algorithmic trading: Machine Learning and Deep Learning in Stock Price</p> <p>Prediction Machine Learning, Deep Learned Time series Analysis, Risk and Portfolio Management</p> <p>Practical Applications and Deployment of models; applications of convolutional neural network (CNN) and long-and-short-term memory (LSTM) network architectures; designing predictive models for financial time series data</p> <p>Stock Price Prediction using Deep Learning and Natural Language Processing</p>

Learning Outcome	<p>At the end of the course, students will have achieved the following learning objectives.</p> <ul style="list-style-type: none"> • problems relating to obtaining, cleaning, simulating, and storing time series data. • Variety of modeling techniques that can be used for recent time series analysis • techniques of financial time series analysis and forecasting financial series using statistical, econometric, machine learning, and deep learning approaches. • Apply more recently developed methods, such as machine learning and neural network, to time series data, highlighting the challenges of data processing and data layout when time series data is used for fitting models
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Textbooks:

- Kirchgässner, Gebhard, Jürgen Wolters, and Uwe Hassler. *Introduction to modern time series analysis*. Springer Science & Business Media, 2012.
- Lazzeri, F. (2020). *Machine learning for time series forecasting with Python*. John Wiley & Sons.
- Jaydip, Sen, and Mehtab Sidra. *Machine Learning in the Analysis and Forecasting of Financial Time Series*. 2022.

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	CS5201	Advanced Artificial Intelligence	3	0	0	3
2.	CS5203	Natural Language Processing	3	0	0	3
3.	CS5205	Advanced Artificial Intelligence Lab	0	1	2	2
4.	CS62XX	DE-III	3	0	0	3
5.	CS62XX	DE-IV	3	0	0	3
6.	CS62XX	DE-V	3	0	0	3
7.	RM6201	Research Methodology	3	1	0	4
8.	IK6201	IKS	3	0	0	3
	TOTAL		21	2	2	24

Course Number	CS5201
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Artificial Intelligence
Learning Mode	Offline
Learning Objectives	<ul style="list-style-type: none"> • To understand the principles of Artificial Intelligence and the nature of intelligent agents. • To learn various problem-solving techniques, including informed search and exploration. • To gain proficiency in handling constraint satisfaction problems and adversarial search. • To develop a solid foundation in knowledge representation, first-order logic, and propositional logic. • To learn to plan and act effectively in real-world AI applications. • To grasp the concepts of uncertain knowledge and probabilistic reasoning. • To make informed decisions using simple and complex decision-making models. • To acquire skills in learning from observations and applying statistical learning methods. • To explore advanced AI techniques and their practical applications.
Course Description	<p>This course offers an in-depth exploration of advanced concepts in Artificial Intelligence (AI). Students will delve into the theoretical underpinnings and practical applications of AI, examining intelligent agents, the nature of environments, and advanced problem-solving techniques. The curriculum covers informed search and exploration, constraint satisfaction problems, adversarial search, and knowledge representation. Students will also explore reasoning with first-order and propositional logic, planning and acting in real-world scenarios, and handling uncertainty through probabilistic reasoning. The course concludes with statistical learning methods and advanced AI techniques, providing a comprehensive understanding of AI's capabilities and applications.</p>
Course Outline	<p>Introduction and motivation Artificial Intelligence, intelligent agents, nature of environments,</p> <p>Problem-solving by searching, informed search and exploration, constraint satisfaction problem, adversarial search,</p> <p>Knowledge and reasoning, first order logic, inference and propositional logic, knowledge representation,</p> <p>Planning and acting in real world of AI agent</p> <p>Uncertain knowledge and reasoning, uncertainty, probabilistic reasoning, making simple and complex decisions</p> <p>Learning from observations and knowledge, statistical learning methods,</p>

	Some advanced techniques of AI and its applications
Learning Outcome	<p>Upon completing this course, students will be able to:</p> <ul style="list-style-type: none"> • Analyze and implement intelligent agents in various environments. • Apply informed search techniques to solve complex problems. • Formulate and solve constraint satisfaction problems and engage in adversarial search strategies. • Represent and reason with knowledge using first-order and propositional logic. • Develop and execute plans in real-world AI scenarios. • Manage uncertainty and employ probabilistic reasoning to make sound decisions. • Utilize statistical learning methods to derive insights from data. • Implement advanced AI techniques in real-world applications. • Demonstrate a comprehensive understanding of advanced AI concepts and their implications.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading:

- Russell, S. J., & Norvig, P. (2016). Artificial intelligence: A modern approach. Pearson.
- Poole, D. L., & Mackworth, A. K. (2010). Artificial Intelligence: foundations of computational agents. Cambridge University Press.
- Hastie, T., Tibshirani, R., Friedman, J. H., & Friedman, J. H. (2009). The elements of statistical learning: data mining, inference, and prediction (Vol. 2, pp. 1-758). New York: Springer.

Course Number	CS5203
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Natural Language Processing
Learning Mode	Offline
Learning Objectives	The objectives of this course are to provide students with a comprehensive understanding of natural language processing (NLP) techniques and their applications. Students will learn the fundamentals of text processing, word vector representations, and advanced language models. The course aims to equip students with the skills to implement and evaluate various NLP tasks, such as part-of-speech tagging, named entity recognition, opinion mining, and machine translation. Additionally, students will explore advanced topics like language generation, summarization, and machine learning-based language processing methods. By the end of the course, students will be prepared to apply NLP techniques to real-world problems and contribute to the development of intelligent language-based systems.
Course Description	This course offers an in-depth exploration of natural language processing (NLP), covering both foundational and advanced topics. Students will begin with an introduction to the scope and applications of NLP, followed by essential text processing techniques. The course will delve into word vector representations, including word2vec and GloVe, and explore advanced methods for language models. Key NLP tasks such as part-of-speech tagging, named entity recognition, opinion mining, sentence classification, machine translation, question answering, language generation, and summarization will be covered. Emphasis will be placed on both rule-based and machine learning-based approaches to language processing. The course is designed to provide practical experience and theoretical knowledge, preparing students for advanced study or professional work in the field of NLP.
Course Outline	<ul style="list-style-type: none"> • Introduction and scope of the course, • Text Processing • Simple Word Vector representations: word2vec, GloVe, • Word Representations in Vector Space, Advanced word vector representations for language models, • PoS tagging and named entity recognition, • Language modeling, Opinion Mining, • Sentence classification, Machine Translation, Question Answering, • Language Generation and Summarization, • Machine learning-based language processing

Learning Outcome	By the end of this course, students will be able to: <ul style="list-style-type: none"> • Explain the fundamental concepts and scope of natural language processing. • Describe basic and advanced text processing techniques. • Discuss word vector representations like word2vec and GloVe to NLP tasks. • Interpret part-of-speech tagging and named entity recognition with proficiency. • Explain language models and perform opinion mining. • Execute sentence classification, machine translation, and question answering tasks. • Generate and summarize language using advanced techniques. • Execute machine learning methods for various NLP applications. • Analyze and evaluate the performance of different NLP models and techniques.
Assessment Method	Internal = 20%; Mid-semester = 30%; End semester = 50%

Suggested Reading

- Daniel Jurafsky and James H. Martin, "Speech and Language Processing," 3rd Edition, Prentice Hall, 2020.
- Christopher D. Manning, Hinrich Schütze, "Foundations of Statistical Natural Language Processing," 1st Edition, MIT Press, 1999.
- Jacob Eisenstein, "Introduction to Natural Language Processing," 1st Edition, MIT Press, 2019.
- Yoav Goldberg, "Neural Network Methods for Natural Language Processing," 1st Edition, Morgan & Claypool Publishers, 2017.
- Steven Bird, Ewan Klein, and Edward Loper, "Natural Language Processing with Python," 1st Edition, O'Reilly Media, 2009.

Course Number	CS5205
Course Credit (L-T-P-C)	0-1-2-2
Course Title	Advanced Artificial Intelligence Lab
Learning Mode	Offline
Learning Objectives	<ul style="list-style-type: none"> • To implement the techniques and algorithms learnt in Advance Artificial Intelligence theory • To analyze advanced AI techniques and their practical applications.
Course Description	This course offers an in-depth exploration and practical implementation of advanced concepts in Artificial Intelligence.
Course Outline	Practical implementation of algorithms and techniques learnt in Advance Artificial Intelligence theory
Learning Outcome	<p>Upon completing this course, students will be able to:</p> <ul style="list-style-type: none"> • Analyze and practically implement the advanced concepts in Artificial Intelligence. • Demonstrate a comprehensive understanding of advanced AI concepts and their implications in real world.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Department Elective – III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6201	Artificial Internet of Things	3	0	0	3
2.	CS6202	Game Theory	3	0	0	3
3.	CS6203	Text Mining & Analytics	3	0	0	3

Course Number	CS6201
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Artificial Internet of Things
Learning Mode	Offline
Learning Objectives	<ul style="list-style-type: none"> • Gain a comprehensive understanding of the convergence of Artificial Intelligence (AI) and Internet of Things (IoT), including basic concepts, architectures, and applications. • Learn various AI techniques and their applications in IoT, including machine learning, deep learning, and data analytics. • Develop skills in designing and implementing IoT systems, integrating sensors, and managing data flow. • Understand the processes for collecting, storing, processing, and analyzing IoT data using AI techniques. • Identify and mitigate security risks and privacy concerns in AIoT systems. • Analyze various real-world applications of AIoT in industries such as healthcare, smart cities, agriculture, and manufacturing. • Understand the regulatory and ethical considerations related to AIoT technologies and their deployment.
Course Description	<p>This course provides an in-depth exploration of the convergence of Artificial Intelligence (AI) and the Internet of Things (IoT), known as AIoT. It covers the fundamental principles and technologies of both AI and IoT, demonstrating how they can be integrated to create intelligent, autonomous systems. Students will learn about IoT architecture, AI algorithms, machine learning, data analytics, and the implementation of AI-driven IoT solutions. Through hands-on projects and real-world case studies, students will gain practical experience in developing smart applications for various domains such as smart cities, healthcare, industrial automation, and smart homes.</p>
Course Outline	<p>Introduction to AIoT, Intersection of AI and IoT, Benefits and challenges of AIoT</p> <p>Fundamentals of IoT, IoT Architecture and Protocols, Layers of IoT architecture, Communication protocols and standards, IoT Devices and Sensors</p> <p>Fundamentals of Artificial Intelligence, Machine Learning and Deep Learning, Overview of AI tools and frameworks</p>

	<p>AIoT System Architecture, Components and Designing AIoT, Edge Computing in AIoT, Edge vs. cloud computing, AI Models for IoT</p> <p>Data Management in AIoT, Data Processing and Analysis, Handling large-scale IoT data, Big data technologies and platforms</p> <p>AIoT Applications and Use Cases: Smart Homes and Buildings, Healthcare and Wearables, Industrial IoT (IIoT), Smart Cities and Transportation</p> <p>AIoT Platforms and Tools: AI Development Tools, Case Studies of AIoT Solutions, AIoT Project Development, Future Trends and Innovations in AIoT</p>
<p>Learning Outcome</p>	<p>At the end of course, students will learn:</p> <ul style="list-style-type: none"> • Students should grasp the foundational concepts of AI and IoT, including machine learning algorithms, data analytics, sensor technologies, and network protocols. • Ability to integrate AI algorithms with IoT devices and platforms to create intelligent systems capable of data collection, analysis, and decision-making in real-time. • Proficiency in developing AI-driven IoT applications, including sensor data processing, predictive analytics, anomaly detection, and automation. • Awareness of security challenges and solutions in AIoT systems, including data privacy, authentication, encryption, and intrusion detection. • Knowledge of optimization techniques for AIoT systems to enhance performance, scalability, and energy efficiency.
<p>Assessment Method</p>	<p>Internal(Quiz/Assignment/Project), Mid-Term, End-Term</p>

Suggested Reading:

- Olivier Hersent, David Boswarthick, and Omar Elloumi, The Internet of Things: Key Applications and Protocols, Wiley
- Maciej Kranz, Building the Internet of Things: Implement New Business Models, Disrupt Competitors, Transform Your Industry, Wiley
- John Paul Mueller and Luca Massaron, Machine Learning for the Internet of Things: Practical Guide, Packt

Course Number	CS6202
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Game Theory
Learning Mode	Offline
Learning Objectives	<ul style="list-style-type: none"> • Learn the principles of decision theory and its relevance to game theory. • Understand and analyze extensive form games, including game trees and backward induction. • Identify and compute pure and mixed strategy Nash equilibria. • Analyze matrix games, specifically two-player zero-sum games. • Understand Bayesian games and apply Bayesian equilibrium concepts to games with incomplete information. • Analyze and compute subgame perfect equilibria in dynamic games. • Explore coalitional games, including the core and the Shapley value. • Explore auction theory and its various models and applications. • Utilize game theory concepts in practical applications such as IoT, wireless networks, and cloud computing.
Course Description	<p>This course aims to establish a solid foundation in both game theory and mechanism design, enabling participants to apply these principles rigorously to solve problems. By the end of the course, students will be equipped to model real-world scenarios using game theory, analyze these scenarios with game-theoretic concepts, and design effective and robust solutions, including mechanisms, algorithms, and protocols suitable for rational and intelligent agents.</p>
Course Outline	<p>Non-cooperative Game Theory: Decision theory, Extensive Form Games, Strategic Form Games, Dominant Strategy Equilibria, Pure Strategy Nash Equilibrium, Mixed Strategy Nash Equilibrium, Computation of Nash Equilibrium, Complexity of Computing Nash Equilibrium, Matrix Games (Two Player Zero-sum Games), Bayesian Games, Subgame Perfect Equilibrium.</p> <p>Cooperative Game: Correlated Strategies and Correlated Equilibrium, Two Person Bargaining Problem, Coalitional Games, Core, Shapley Value.</p> <p>Mechanism Design: Introduction to Mechanism Design, Social Choice Functions and their properties, Incentive Compatibility, Auction theory and its variants.</p>

	Applications: IoT, Wireless Networks, Cloud Computing
Learning Outcome	<p>By the end of this course, students will be able to:</p> <ul style="list-style-type: none"> • Describe the principles of decision theory and its importance in game theory. • Formulate and solve strategic form games, identifying dominant strategy equilibria and Nash equilibria. • Analyze and solve matrix games, particularly two-player zero-sum games. • Formulate Bayesian games and determine Bayesian equilibria for games with incomplete information. • Compute subgame perfect equilibria for dynamic games using appropriate techniques. • Apply the concepts of correlated strategies and correlated equilibria in cooperative settings. • Analyze and solve two-person bargaining problems. • Analyze social choice functions and their properties, focusing on incentive compatibility. • Utilize game theory concepts to address practical problems in IoT, wireless networks, and cloud computing.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Textbook:

- M. Osborne, An Introduction to Game Theory, Oxford University Press.
- Y. Narahari. Game Theory and Mechanism Design. IISc Press and the World Scientific.

Reference Book:

- M. Maschler, E. Solan, and S. Zamir, Game Theory. Cambridge University Press
- D. Niyato, & W. Saad. Game theory in wireless and communication networks. Cambridge University Press.

Course Number	CS6203
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Text Mining and Analytics
Learning Mode	Offline
Learning Objectives	<ul style="list-style-type: none"> • To understand the fundamental principles and scope of text mining and analytics. • To acquire skills in data collection, cleaning, and integration for text data. • To learn text preprocessing techniques including tokenization, stemming, stopword removal, and normalization. • To construct knowledge graphs by linking entities and extracting relationships. • To identify and mine frequent patterns and apply advanced pattern mining techniques. • To extract features from text data and apply clustering and classification methods. • To implement practical applications such as sentiment analysis and text summarization. • To utilize advanced techniques for enhanced text data analysis and mining.
Course Description	<p>This course provides a comprehensive understanding of the principles and techniques of text mining and analytics. Students will learn about data collection, cleaning, integration, and preprocessing methods essential for handling text data. The course covers knowledge graph construction, pattern mining, feature extraction, and advanced text clustering and classification techniques. Practical applications such as sentiment analysis and text summarization are also explored. By the end of the course, students will be prepared to tackle real-world challenges in data mining and text analytics.</p>
Course Outline	<p>Text mining and analytics introduction: Overview, motivation, scope,</p> <p>Data Collection and Pre-processing: Techniques for collecting data from various sources,</p> <p>Text data cleaning and integration, descriptive analytics</p> <p>Text preprocessing: tokenization, stemming, stopword removal, and normalization</p> <p>Knowledge graph construction: Basics of graphs, entity linking, relationship extraction</p>

	<p>Concepts of frequent patterns, closed patterns, max-patterns, and association rules, mining frequent patterns: apriori algorithm, pattern-growth approach.</p> <p>Advanced: mining sequential patterns</p> <p>Feature extraction, Bag-of-Words, TF-IDF, word embeddings Clustering and classifying text data, Expectation-maximization (EM) algorithm for text data, Latent Dirichlet Allocation (LDA) for topic modeling, and some advanced techniques</p> <p>Some applications: sentiment analysis, text summarization, etc. Some advanced topics and project</p>
Learning Outcome	<ul style="list-style-type: none"> • By the end of this course, students will be able to: • Understand the core principles and scope of text mining and analytics. • Collect, clean, and integrate text data from various sources. • Apply text preprocessing techniques such as tokenization, stemming, and normalization. • Construct and utilize knowledge graphs for entity linking and relationship extraction. • Identify and mine various patterns in text data, including frequent, closed, and sequential patterns. • Extract features from text data using methods like Bag-of-Words, TF-IDF, and word embeddings. • Perform text clustering and classification using algorithms such as EM and LDA. • Implement practical text analytics applications such as sentiment analysis and text summarization. • Utilize advanced techniques for enhanced text data analysis and mining.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading

- Srivastava, A. N., & Sahami, M. (Eds.). (2009). Text mining: Classification, clustering, and applications. CRC press.
- Chakraborty, G., Pagolu, M., & Garla, S. (2014). Text mining and analysis: practical methods, examples, and case studies using SAS. SAS Institute.
- Sarkar, D. (2016). Text analytics with python (Vol. 2). New York, NY, USA:: Apress.
- Witten, I. H., Frank, E., Hall, M. A., Pal, C. J., & Data, M. (2005, June). Practical machine learning tools and techniques. In Data mining (Vol. 2, No. 4, pp. 403-413). Amsterdam, The Netherlands: Elsevier.

Department Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6204	Knowledge Distillation	3	0	0	3
2.	CS6205	Physics of Neural Network	3	0	0	3
3.	CS6206	Selected Topics in Wireless Networks	3	0	0	3
4.	CS6207	Advanced Big Data Analytics	3	0	0	3

Course Number	CS6204
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Knowledge Distillation
Learning Mode	Offline
Learning Objectives	This course aims to help the students (a) understand and apply knowledge distillation techniques; (b) master deep neural network compression methods; (c) deploy ML/DNN models on edge devices like Raspberry Pi and others; (d) analyze and optimize model performance in resource-constrained environments; (e) identify the research opportunity in the domain of knowledge distillation and DNN compression on resource-constrained devices.
Course Description	This course delves into advanced techniques for enabling machine learning on resource-constrained devices. Beginning with an introduction to on-device training, students will explore the principles and methods of knowledge distillation and deep neural network (DNN) compression. The course covers practical strategies for implementing machine learning and deep neural networks on devices with limited computational resources. Additionally, students will learn to combine knowledge distillation and compression techniques to optimise performance, making sophisticated machine-learning models viable on edge devices.
Course Outline	<ul style="list-style-type: none"> • Introduction to on-device training: Overview of resource-constrained edge devices and their significance, possibilities of enabling machine learning (ML) and deep neural networks (DNN) models on resource-constrained devices, applications and use cases of ML/DNN on edge devices. • Knowledge Distillation: Concept and principles of knowledge distillation, Teacher-student model framework, Applications and benefits of knowledge distillation. Advanced techniques in knowledge distillation, Implementation of knowledge distillation in various frameworks, and Practical exercises on distilling models. • Deep Neural Network Compression: Overview of DNN compression techniques, Quantization and its impact on model performance, Pruning methods for model size reduction. Low-rank factorization, Weight sharing and clustering, Hands-on implementation of compression techniques. • ML/DNN on resource-constrained devices: Introduction to edge devices: Raspberry Pi, NVIDIA Jetson, etc, Setting up an AI development environment on Raspberry Pi, Case study: Running a pre-trained model on Raspberry Pi. TensorFlow Lite, ONNX, etc, Practical exercises with TensorFlow Lite on Raspberry Pi.

	<ul style="list-style-type: none"> Combining Knowledge Distillation and Compression: Integrating knowledge distillation and compression for optimal performance, Strategies for balancing accuracy and efficiency, Real-world examples and case studies.
Learning Outcome	<ul style="list-style-type: none"> Explain and implement knowledge distillation techniques. Apply DNN compression methods such as quantisation and pruning. Set up and optimise ML/DNN models on Raspberry Pi using TensorFlow Lite and ONNX. Evaluate and enhance ML/DNN model performance on edge devices. Create real-time applications, including object detection and predictive maintenance. Plan, develop and present comprehensive projects that may lead to publication.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading:

- Deep Learning for Edge AI” by John Doe
- Knowledge Distillation: Principles, Methods and Applications” by Jane Smith
- Official documentation and tutorials for TensorFlow Lite, ONNX, and edge devices
- “Knowledge Distillation: A Survey” Jianping Gou, Baosheng Yu, Stephen John Maybank, Dacheng Tao
- K. Nan, S. Liu, J. Du and H. Liu, "Deep model compression for mobile platforms: A survey," in Tsinghua Science and Technology, vol. 24, no. 6, pp. 677-693, Dec. 2019, doi: 10.26599/TST.2018.9010103.
- Mishra et al.. "A survey on deep neural network compression: Challenges, overview, and solutions."

Course Number	CS6205
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Physics of Neural Network
Learning Mode	Offline
Learning Objectives	This course aims to help the students (a) Comprehend the basic models and structures of neural networks, including the structure and function of the central nervous system, associative memory, and information storage and recall principles. (b) Gain detailed knowledge of various neuron types, such as stochastic and cybernetic neurons, and different network architectures, including layered and perceptron networks.(c) Learn to apply neural network models to practical applications such as time series prediction, game playing (e.g., Backgammon), and protein structure prediction, as well as exploring their use in biomedicine and economics.(d) Delve into advanced topics like pattern recognition, unsupervised learning, evolutionary algorithms, combinatorial optimization, VLSI, specialized networks (e.g., Hopfield networks, Kohonen maps), and advanced learning techniques like back-propagation and solving optimization problems.
Course Description	This course offers a comprehensive exploration of neural networks, encompassing their fundamental models, the structure of the central nervous system, and a brief historical overview. Students will delve into the core principles of associative memory, information storage and recall, and learning mechanisms such as Hebb's rule. The curriculum covers a variety of neuron types, including stochastic and cybernetic neurons, and introduces layered and perceptron network architectures. Throughout the course, students will investigate practical applications of neural networks, ranging from time series prediction to strategic game playing (e.g., Backgammon) and protein structure prediction. The course also highlights the role of neural networks in biomedicine and economics, showcasing their versatility and impact. Advanced topics are thoroughly explored, including pattern recognition, unsupervised learning, and evolutionary algorithms. Students will engage with combinatorial optimization, VLSI design, and specialized network models such as Hopfield networks and Kohonen maps. The course emphasizes the significance of back-propagation, learning functions, and optimization problem-solving techniques. By the end of the course, students will have a deep understanding of neural networks' theoretical foundations and practical applications, equipping them with the skills to leverage these powerful tools in various scientific and industrial domains.

Course Outline	Models of Neural Networks, A Brief History of Neural Network Models, Prediction of the Secondary Structure of Proteins, Associative Memory for Time Sequences
Learning Outcome	<ul style="list-style-type: none"> • Understand the basic concept of PINN • Apply the concept of Partial Differential in PINN • Analysis of Optimization techniques for PINNs. • Demonstrate the practical utility of PINNs in handling complex, real-time applications that require efficient and accurate simulations.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading:

- Müller, B., Reinhardt, J. and Strickland, M.T., 2012. *Neural networks: an introduction*.
- Peretto, P., 1992. An introduction to the modeling of neural networks (Vol. 2).
- Relevant research articles.

Course Number	CS6206
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Selected Topics in Wireless Networks
Learning Mode	Offline
Learning Objectives	In this subject, the students will be trained with the knowledge of 802.11 wireless networks, including protocol knowledge and the associated security vulnerabilities.
Course Description	In the consumer, industrial, and military sectors, 802.11-based wireless access networks have been widely used due to their convenience. This application, however, is reliant on the unstated assumptions of availability and anonymity. The management and media access protocols of 802.11 may be particularly vulnerable to malicious denial-of-service (DoS) and various security attacks. This course analyzes these 802.11-specific attacks, including their applicability, effectiveness, and proposed low-cost implementation improvements to mitigate the underlying vulnerabilities.
Course Outline	<p>Introduction to Wireless Networks: Basic principles, types of wireless networks (Wi-Fi, Bluetooth, cellular), and network topologies.</p> <p>Wireless Communication Fundamentals: Radio frequency, signal propagation, modulation techniques, and interference management.</p> <p>Network Protocols and Standards: IEEE 802.11 (Wi-Fi), IEEE 802.15 (Bluetooth), and cellular standards (2G, 3G, 4G, 5G).</p> <p>Network Design and Architecture: System design, frequency reuse, and resource allocation.</p> <p>Mobility and Handoff: Techniques for managing mobility, handoff processes, and roaming.</p> <p>Security in Wireless Networks: Security protocols, encryption, and threat mitigation.</p> <p>Emerging Technologies: Overview of 6G, IoT, in-network caching</p>
Learning Outcome	<p>On successful completion of the course, students should be able to:</p> <ul style="list-style-type: none"> • Understand the fundamentals of 802.11 wireless networks • Describe the WLAN services-association, disassociation, re-association, distribution, integration, authentication, de authentication and data delivery services • Comprehend the vulnerabilities associated with 802.11 protocol.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Text Books and References:

- "Wireless Communications: Principles and Practice" by Theodore S. Rappaport (2nd Edition)

- "802.11 Wireless Networks: The Definitive Guide" by Matthew S. Gast (2nd Edition)
- "Wireless Communications & Networks" by William Stallings (2nd Edition)
- "Wireless Communications: Principles and Practice" by Andreas F. Molisch (2nd Edition)
- "Fundamentals of Wireless Communication" by David Tse and Pramod Viswanath (1st Edition)
- "Next Generation Wireless LANs: 802.11n and 802.11ac" by Eldad Perahia and Robert Stacey (2nd Edition)
- "Wireless Networking: Understanding Internetworking Challenges" by Anurag Kumar, D. Manjunath, and Joy Kuri (1st Edition)
- "Wireless Communications: Principles and Practice" by Kaveh Pahlavan and Prashant Krishnamurthy (1st Edition)

Course Number	CS6207
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Big Data Analytics
Learning Mode	Offline
Learning Objectives	The primary objective of this course is to equip students with advanced knowledge and skills in big data analytics. By the end of the course, students will be able to understand and apply advanced data analysis techniques, develop and implement big data solutions, and leverage big data technologies for strategic decision-making. Additionally, students will gain proficiency in using big data tools and platforms, enhance their ability to handle and analyze large datasets, and develop critical thinking skills for solving complex data-driven problems.
Course Description	This course provides an in-depth exploration of advanced big data analytics, focusing on the theoretical foundations, practical techniques, and cutting-edge technologies in the field. Students will learn about various aspects of big data, including data acquisition, storage, processing, and analysis. The course covers advanced topics such as machine learning algorithms for big data, real-time data processing, and big data visualization. Emphasis will be placed on the use of big data tools and platforms such as Hadoop, Spark, and NoSQL databases. Through hands-on projects and case studies, students will develop the skills needed to design and implement big data solutions for a variety of applications.
Course Outline	<p>Introduction to Big Data Analytics: Definition and characteristics (Volume, Velocity, Variety, Veracity, and Value), Importance and challenges of Big Data. Big Data Ecosystem: Components and architecture, Key players and technologies in Big Data (e.g., Hadoop, Spark). Big Data vs. Traditional Data: Differences in processing and analysis, Applications of Big Data Analytics- Industry-specific applications and Case studies</p> <p>Data Acquisition and Storage: Structured, semi-structured, and unstructured data and Data generation and collection methods. Distributed file systems (e.g., HDFS), NoSQL databases (e.g., MongoDB, Cassandra), and Cloud storage options, ETL (Extract, Transform, Load) processes, Data pipelines and workflow automation, Insuring data integrity and accuracy, Data privacy and security considerations</p>

	<p>Data Processing Frameworks: Hadoop MapReduce architecture and workflow, Advantages and limitations, Apache Storm, Apache Flink, and Kafka Streams, Real-time data processing and its significance, Apache Spark architecture and RDDs (Resilient Distributed Datasets), Spark SQL, Spark Streaming, and MLlib</p> <p>Machine Learning for Big Data: Introduction to Machine Learning, Machine Learning Algorithms, Machine Learning Tools and Libraries, Training and evaluating models on large datasets, Scalability and performance optimization</p> <p>Real-Time Data Processing: Importance and applications of real-time analytics, Apache Kafka, Apache Flink, and Apache Storm, Designing and implementing real-time data workflows, Industry examples and best practices</p> <p>Big Data Visualization: Making data comprehensible and actionable, Visualization Tools and Techniques, Building user-friendly and interactive data dashboards, Intersection of data science and big data analytics, Integrating AI techniques with big data analytics, Processing and analyzing IoT-generated data, Distributed computing at the edge of networks, and Industry-Specific Case Studies- Healthcare, finance, retail, and other industries.</p>
<p>Learning Outcome</p>	<ul style="list-style-type: none"> • Understand the key concepts and significance of big data analytics. • Acquire, store, and manage large datasets using appropriate big data technologies. • Apply advanced data processing techniques using Hadoop and Spark. • Implement machine learning algorithms for big data applications. • Perform real-time data processing and analysis. • Utilize big data visualization tools to interpret and present data insights. • Develop and implement comprehensive big data solutions for various industry applications. • Critically evaluate and solve complex data-driven problems using advanced analytics techniques.
<p>Assessment Method</p>	<p>Internal(Quiz/Assignment/Project), Mid-Term, End-Term</p>

Suggested Reading:

- Marz, N., & Warren, J. (2015). Big Data: Principles and Best Practices of Scalable Real-Time Data Systems (1st ed.). Manning Publications.
- White, T. (2015). Hadoop: The Definitive Guide (4th ed.). O'Reilly Media.
- Karau, H., & Warren, R. (2017). High Performance Spark: Best Practices for Scaling and Optimizing Apache Spark (1st ed.). O'Reilly Media.
- Gulla, U., Gupta, S., & Kumar, V. (2020). Practical Big Data Analytics: Hands-on Techniques to Implement Enterprise Analytics and Machine Learning Using Hadoop, Spark, NoSQL and R (2nd ed.). Packt Publishing.

- Zikopoulos, P. C., Eaton, C., & deRoos, D. (2012). Understanding Big Data: Analytics for Enterprise Class Hadoop and Streaming Data (1st ed.). McGraw-Hill Education.

Department Elective - V						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6208	Quantum Machine Learning	3	0	0	3
2.	CS6209	Meta Learning	3	0	0	3
3.	CS6210	Selective Topics in Generative AI	3	0	0	3

Course Number	CS6208
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Quantum Machine Learning
Learning Mode	Offline
Learning Objectives	This course aims to help the students (a) proficiency in implementing and applying classical machine learning algorithms, including classification, regression, gradient descent, and neural networks. (b) grasp the foundational principles of quantum computing, quantum states, qubits, and basic quantum operations.(c) advanced quantum algorithms and their applications in machine learning and computational tasks. (d) gain practical experience in implementing quantum algorithms and simulating quantum processes.
Course Description	This course offers a comprehensive exploration of machine learning (ML) and quantum computing (QC) principles, preparing students to navigate the intersection of classical and quantum computational paradigms. Students will master classical ML techniques including classification, regression, neural networks, and optimization methods like gradient descent. In the quantum computing segment, foundational concepts such as quantum states, qubits, and basic quantum operations (e.g., Hadamard gates) will be covered, alongside encoding classical data on quantum systems and implementing basic quantum algorithms. Advanced topics include variational quantum algorithms, quantum support vector machines, the HHL algorithm for linear systems, and quantum neural networks. Through lectures, practical exercises using quantum programming frameworks, and real-world applications, students will develop a dual proficiency in classical ML and quantum computing, equipping them for roles in research, development, or applications across industries leveraging emerging quantum technologies.
Course Outline	Overview of Machine Learning, Quantum Circuit, Variational quantum algorithm, Quantum Neural Network

Learning Outcome	<ul style="list-style-type: none"> • Understanding of Machine Learning and Quantum Computing Fundamentals. • Apply the concept of feature vectors, encode data in Quantum computing. • Analysis of Variational quantum algorithms to solve complex problems. • Implementation and analysis of advanced quantum machine learning algorithms.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Textbooks:

- Nielsen, M.A. and Chuang, I.L., 2010. *Quantum computation and quantum information*.
- Schuld, M. and Petruccione, F., 2021. *Machine learning with quantum computers* (Vol. 676). Berlin.
- Relevant research articles.

Reference books:

- Kasirajan, V., 2021. *Fundamentals of quantum computing*.
- Quantum Machine Learning,
Link: <http://sites.iiserpune.ac.in/~santh/course/QML/qml.html>

Course Number	CS6209
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Meta Learning
Learning Mode	Offline
Learning Objectives	<p>This course aims to help the students (a) Gain a solid understanding of the foundational principles of meta-learning, including model evaluation, basic machine learning concepts, and their limitations. (b) Delve into advanced techniques such as deep learning, transfer learning, and multitask learning, and understand how these methodologies enhance meta-learning capabilities. (c) Develop proficiency in key meta-learning strategies, including model-based, metric-based, and optimization-based approaches, and familiarize yourself with advanced architectures like memory-augmented networks and conditional sequential neural networks (CSNNs). (d) Apply meta-learning techniques to practical applications in various domains, such as computer vision, natural language processing (NLP), reinforcement learning, healthcare, recommendation systems, and climate science, demonstrating the ability to solve complex real-world problems.</p>
Course Description	<p>This comprehensive course provides an in-depth overview of meta-learning, guiding students from foundational principles to advanced techniques. The curriculum begins with the basics of model evaluation, machine learning concepts, and their inherent limitations. Students will then explore advanced topics such as deep learning, transfer learning, and multitask learning, gaining a robust understanding of how these methodologies enhance the capabilities of meta-learning systems. Key meta-learning strategies are thoroughly examined, including model-based, metric-based, and optimization-based approaches. The course features advanced architectures like memory-augmented networks and conditional sequential neural networks (CSNNs), showcasing their roles in improving learning efficiency and effectiveness. Practical applications of meta-learning are highlighted across various fields, including computer vision, natural language processing (NLP), reinforcement learning, healthcare, recommendation systems, and climate science. These examples demonstrate the versatility and power of meta-learning in addressing complex, real-world problems. By the end of the course, students will be equipped with a robust understanding of meta-learning principles and techniques, enabling them to leverage these advanced methodologies to solve intricate problems across diverse domains.</p>

Course Outline	Meta-Learning Basics and Background, Evaluation of Meta learning, Model-Based Meta-Learning Approaches, Metric-Based Meta-Learning Approaches, Optimization-Based Meta-Learning Approaches
Learning Outcome	<ul style="list-style-type: none"> • Understand and articulate the foundational principles of meta-learning • Apply probabilistic modeling and Bayesian inference to quantify uncertainty and improve model robustness in decision-making processes. • Analysis of Optimization-Based Meta-Learning Approaches. • Explore and address new challenges in emerging applications
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading:

- Zou, L., 2022. *Meta-learning: Theory, algorithms and applications*.
- Brazdil, P., Van Rijn, J.N., Soares, C. and Vanschoren, J., 2022. *Metalearning: applications to automated machine learning and data mining* (p. 346).
- Relevant research articles.

Course Number	CS6210
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Selective Topics in Generative AI
Learning Mode	Offline
Learning Objectives	<p>To gain a comprehensive understanding of advanced AI architectures, particularly in the context of Generative AI.</p> <p>To develop proficiency in implementing and evaluating a variety of Generative AI techniques and models.</p> <p>To understand the principles and applications of Generative Pre-trained Transformers and other application-specific architectures.</p> <p>To explore and address ethical considerations and biases in Generative AI, emphasizing the importance of explainability.</p> <p>To engage with advanced topics and apply knowledge through hands-on projects.</p>
Course Description	<p>This course provides an in-depth exploration of Generative AI (GenAI), focusing on advanced AI architectures such as Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), and Generative Pre-trained Transformers (GPT). Students will learn about hybrid and emerging models, application-specific architectures, and the ethical considerations and biases in Generative AI. The course includes hands-on projects to design, implement, and evaluate sophisticated generative AI models, emphasizing innovation and practical problem-solving skills.</p>
Course Outline	<p>Introduction to advanced AI, overview of advanced AI architectures and Generative AI (GenAI)</p> <p>Generative Adversarial Network (GAN): various GAN architectures, DCGAN</p> <p>Advanced Variational AutoEncoder (VAE): hierarchical VAEs, Semi-supervised VAE</p> <p>Hybrid and emerging models: Energy-based models, diffusion models, autoregressive and flow-based models, attention mechanism in generative models</p> <p>Generative Pre-trained Transformers (GPT): architectural details and variations</p> <p>Advanced application-specific architecture: Models for Image-to-Text generation, Text-to-Image generation, Prompt engineering, Multimodality</p>

	Ethical consideration and bias in Generative AI, Explainability Some advanced topics and project.
Learning Outcome	<ul style="list-style-type: none"> • Master various Generative AI architectures, including GANs, VAEs, and emerging models. • Demonstrate proficiency in implementing and evaluating advanced Generative AI techniques, such as hierarchical VAEs and energy-based models. • Understand the design principles and applications of Generative Pre-trained Transformers (GPT) and application-specific architectures. • Analyze and address ethical considerations and biases in Generative AI, emphasizing the importance of explainability. • Explore advanced topics in Generative AI and apply acquired knowledge through hands-on projects, fostering innovation and practical problem-solving skills.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading:

- Foster, D. (2022). Generative deep learning: : Teaching Machines to Paint, Write, Compose, and Play. " O'Reilly Media, Inc."
- Valle, R. (2019). Hands-On Generative Adversarial Networks with Keras: Your guide to implementing next-generation generative adversarial networks. Packt Publishing Ltd.

Research Papers and Articles from Journals such as JMLR, IEEE Transactions on Neural Networks and Learning Systems, etc., and Conference Proceedings from NeurIPS, ICML, and CVPR,etc.

Course Number	RM6201
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Research Methodology
Learning Mode	Lectures
Learning Objectives	The objective of the course is to train student about the modelling of scalar and multi-objective nonlinear programming problems and various classical and numerical optimization techniques and algorithms to solve these problems
Course Description	Advanced Optimization Techniques, as a subject for postgraduate and PhD students, provides the knowledge of various models of nonlinear optimization problems and different algorithms to solve such problems with its applications in various problems arising in economics, science and engineering.
Course Content	<p>Module I (6 lecture hours) – Research method fundamentals: Definition, characteristics and types, basic research terminology, an overview of research method concepts, research methods vs. method methodology, role of information and communication technology (ICT) in research, Nature and scope of research, information based decision making and source of knowledge. The research process; basic approaches and terminologies used in research. Defining research problem and hypotheses framing to prepare a research plan.</p> <p>Module II (5 lecture hours) - Research problem visualization and conceptualization: Significance of literature survey in identification of a research problem from reliable sources and critical review, identifying technical gaps and contemporary challenges from literature review and research databases, development of working hypothesis, defining and formulating the research problems, problem selection, necessity of defining the problem and conceiving the solution approach and methods.</p> <p>Module III (5 lecture hours) - Research design and data analysis: Research design – basic principles, need of research design and data classification – primary and secondary, features of good design, important concepts relating to research design, observation and facts, validation methods, observation and collection of data, methods of data collection, sampling methods, data processing and analysis, hypothesis testing, generalization, analysis, reliability, interpretation and presentation.</p> <p>Module IV (16 lecture hours) - Qualitative and quantitative analysis: Qualitative Research Plan and designs, Meaning and types of Sampling, Tools of qualitative data Collection; observation depth Interview, focus group discussion, Data editing, processing & categorization, qualitative data analysis, Fundamentals of statistical methods, parametric and nonparametric techniques, test of significance, variables, conjecture, hypothesis, measurement, types of data and scales, sample and sampling techniques, probability and distributions, hypothesis testing, level of significance and confidence interval, t-test, ANOVA, correlation, regression analysis, error analysis, research data analysis and evaluation using software tools (e.g.: MS Excel, SPSS, Statistical, R, etc.).</p> <p>Module V (10 lecture hours) – Principled research: Ethics in research and Ethical dilemma, affiliation and conflict of interest; Publishing and sharing research, Plagiarism and its fallout (case studies), Internet</p>

	research ethics, data protection and intellectual property rights (IPR) – patent survey, patentability, patent laws and IPR filing process.
Learning Outcome	<p>On successful completion of the course, students should be able to:</p> <ol style="list-style-type: none"> 1. Understand the terminology and basic concepts of various kinds of nonlinear optimization problems. 2. Develop the understanding about different solution methods to solve nonlinear Programming problems. 3. Apply and differentiate the need and importance of various algorithms to solve scalar and multi-objective optimization problems. 4. Employ programming languages like MATLAB/Python to solve nonlinear programming problems. 5. Model and solve several problems arising in science and engineering as a nonlinear optimization problem.
Assessment Method	Quiz /Assignment/ Project / MSE / ESE

Textbooks & Reference Books:

1. C. R. Kothari, Research methodology: Methods and Techniques, 3rd Edn., New age International 2014.
2. Mark N K. Saunders, Adrian Thornhill, Phkip Lewis, “Research Methods for Studies, 3/c Pearson Education, 2010.
3. K.N. Krishnaswamy, apa iyer, siva kumar, m. Mathirajan, “Management Research Methodology”, Pearson Education, 2010.
4. Ranjit Kumar; “Research Methodology: A Step by Step Guide for Beginners; 2/e; Pearson Education, 2010.
5. Suresh C. Sinha, Anil K. Dhiman, ess ess, 2006 “Research Methodology” Panner Selvam.R. “Research Methodology”, Prentice Hall of India, New Delhi, 2004.
6. C.G. Thomas, Research methodology and scientific writing, Ane books, Delhi, 2015.
7. H. J. Ader and G. J. Mellenbergh, Research Methodology in the Social, Behavioural and Life Sciences Designs, Models and Methods, 3rd Edn., Sage Publications, London, 2000.

Interdisciplinary Elective (IDE) Course for M. Tech. (Available to non CSE Dept. students)

IDE from CSE - IDE-I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CS6112	Drone Data Processing & Analysis	3	0	0	3

Course Number	CS6112
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Drone Data Processing & Analysis
Learning Mode	Offline
Learning Objectives	This course aims to help the students (a) understand the integration of various sensors and platforms, including optical, thermal, LiDAR, multispectral, and hyperspectral sensors; (b) identify and analyze the use of drones in civilian and remote sensing applications; (c) to learn the importance and techniques of sensor calibration and boresighting to ensure data accuracy and reliability; (d) comprehend the operational requirements for UAVs and develop a Concept of Operation (CONOP) including risk assessment for safe and effective drone missions; (e) gain proficiency in using advanced data processing software tools to generate high-quality digital products from drone data; and (f) to evaluate data quality using accuracy metrics and understand the latest mapping standards to ensure high-precision geospatial data.
Course Description	This course provides an in-depth exploration of advanced drone systems, focusing on integrating and applying various sensors, including optical, thermal, LiDAR, multispectral, and hyperspectral. Students will learn how to integrate these sensors with different drone platforms and apply them in various fields such as agriculture, construction, environmental monitoring, and urban planning. The course covers using drones in remote sensing for resource management, disaster response, and scientific research, emphasising the importance of sensor calibration, boresighting methods, and operational best practices. Additionally, students will gain hands-on experience with leading software tools for drone data processing and understand the latest standards for geospatial data accuracy. Regulatory compliance, safety, security, and privacy issues will also be addressed. Practical applications and industry case studies will be analysed to illustrate successful drone data processing projects.
Course Outline	<p>Importance of Calibration, Methods and best practices for boresighting to align sensors accurately, Key operational requirements and best practices, Developing and implementing a Concept of Operation (CONOP) for drone missions, Risk assessment</p> <p>Introduction to leading software tools for drone data processing (e.g., Pix4D, Agisoft Metashape, DroneDeploy), Steps from data acquisition to final product generation</p> <p>Understanding the latest standards for geospatial data accuracy, Techniques for identifying and correcting errors in drone data, Creating digital elevation models (DEMs) and digital terrain models (DTMs)</p> <p>Current Rules and Regulations in India, Compliance and Certification, Comparison with global regulatory standards, UAV Safety Issues, Security Concerns, Privacy Issues</p> <p>Practical Applications and Case Studies, Analysis of successful drone data processing projects in various industries</p>

Learning Outcome	<ul style="list-style-type: none"> • Evaluate and apply drone technology in diverse civilian and remote sensing scenarios, identifying the benefits and challenges of each application. • Execute proper calibration and boresighting techniques to ensure the accuracy and reliability of sensor data. • Create and implement an effective CONOP for drone missions, including risk assessment and mitigation strategies. • Efficiently use leading data processing software tools to process drone data and generate high-quality digital products. • Assess data quality using established accuracy metrics and apply the latest mapping standards to ensure high-precision geospatial data. • Navigate and comply with current drone regulations in India and understand international regulatory frameworks.
Assessment Method	Internal(Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading

- Barnhart, R., Michael, M., Marshall, D., and Shappee, E. ed. 2016. Introduction to Unmanned Aircraft Systems, 2nd edition. Boca Raton. CRC Press.
- Fahlstrom, P. and Gleason, T. 2012. Introduction to UAV Systems. 4th edition. United Kingdom. John Wiley & Sons Ltd.
- Wolf, P., DeWitt, B., and Wilkinson, B. 2014. Elements of Photogrammetry with Applications in GIS, 4th edition. McGraw-Hill
- Introduction to UAV Systems, Paul G. Fahlstrom and Thomas J. Gleason
- Drone Technology in Architecture, Engineering, and Construction, Daniel Tal and Jon Altschuld

- UAV or Drones for Remote Sensing Applications, edited by Felipe Gonzalez Toro and Antonios Tsourdos