INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1	ECS 5101	Design and Analysis of Algorithms	3	0	2	4
2	ECS 5102	Foundations of Computer Systems	3	0	2	4
3	EMC 5103	Probability and Statistics	3	0	2	4
4	EHS 5104	Technical Writing and Soft Skill	1	2	2	4
5		DE-1(Elective 1)	3	0	0	3
	TOTAL		**13**	**2**	**8**	**19**

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1	ECS 5201	Artificial Intelligence	3	0	2	4
2	EMC 5202	Numerical Linear Algebra and Optimization Techniques	3	0	2	4
3		DE-2(Elective 2)	3	0	0	3
4		DE-3(Elective 3)	3	0	0	3
5		IKS	2	0	0	2
	TOTAL		**14**	**0**	**4**	**16**

Sl. No.		SEMESTER III	L	T	P	C
1		DE-4(Elective 4)	3	0	0	3
2		DE-5(Elective 5)	3	0	0	3
3		Project I	0	0	34	17
	TOTAL		**6**	**0**	**34**	**23**

Sl. No.		SEMESTER IV	L	T	P	C
		DE-6(Elective 6)	3	0	0	3
1		DE-7(Elective 7)	3	0	0	3
2		Project II	0	0	40	20
	TOTAL		**6**	**0**	**40**	**26**

Total credits = 84

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Electives for M.S in Artificial Intelligence & Cyber Security:

Sl. No.	Subject Code	Elective-I	L	T	P	C
1	ESD 6101	Advanced Blockchain Technology	3	0	0	3
2	ESD 6102	Pattern Recognition	3	0	0	3
3	ESD 6103	Cyber Physical Systems	3	0	0	3

Sl. No.	Subject Code	Elective-II, III	L	T	P	C
1	ESD 6201	Advanced Edge Computing	3	0	0	3
2	ESD 6202	Advanced Graph Machine Learning	3	0	0	3
3	ESD 6203	Game Theory	3	0	0	3
4	ESD 6204	Knowledge Distillation	3	0	0	3

Sl. No.	Subject Code	Elective-IV, V	L	T	P	C
1	ESD 6301	Advanced Time Series Analysis	3	0	0	3
2	ESD 6302	Quantum Cyber Security	3	0	0	3
3	ESD 6303	Generative Artificial Intelligence	3	0	0	3
4	ESD 6304	Advanced Cloud Computing	3	0	0	3

Sl. No.	Subject Code	Elective-VI, VII	L	T	P	C
1	ESD 6401	High Performance Computing	3	0	0	3
2	ESD 6402	Meta Learning	3	0	0	3
3	ESD 6403	Quantum Machine Learning	3	0	0	3
4	ESD 6404	Advanced Big Data Analytics	3	0	0	3

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course number	**ECS 5101**
Course Credit	L-T-P-C: 3-0-2-4
Course Title	**Design and Analysis of Algorithms**
Learning Mode	Online
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, and advanced topics like string matching, FFT-DFT, and approximation 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 basic understanding of methods to solve problems on computers. It will also provide an overview to analyze those theoretically.
Course Outline	Data structures: linked list, stack, queue, tree, balanced tree, graph; Complexity analysis: Big O, omega, theta notation, solving recurrence relation, master theorem Sorting and searching: Quick sort, merge sort, heap sort; Sorting in linear time; Ordered statistics; Problem solving strategies: recursion, dynamic programming, branch and bound, backtracking, greedy, divide conquer, Graph algorithms: BFS, DFS, Shortest path, MST, Network flow; NP-completeness Advanced topics: string matching, FFT-DFT, basics of approximation and randomized algorithms. Lab Component: Implementation of above topics
Learning Outcome	By the end of this course, students will be able to: Use linked lists, stacks, queues, trees, balanced trees, and graphs. Analyze algorithm complexity and solve recurrence relations. Implement Quick sort, Merge sort, Heap sort, and linear time sorting methods. Apply recursion, dynamic programming, branch and bound, backtracking, greedy, and divide-and-conquer methods. Implement BFS, DFS, shortest path algorithms, MST, and network flow algorithms. Comprehend NP-completeness and its significance.
Assessment Method	Quiz / Assignment / ESE

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

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

• **Course Number**	**ECS 5102**
Course Credit	L-T-P-C: 3-0-2-4
Course Title	**Foundations of Computer Systems**
Learning Mode	Online
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	**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. 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 dependancy and data dependancy), Methods to reduce pipeline stall. RISC and CISC paradigms, I/O Transfer techniques, Memory organization: hierarchical memory systems, cache memories, virtual memory. **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. Memory management techniques, Allocation techniques, Paging, Page Replacement Algorithms, Numericals. Lab Component: Implementation of above topics
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	Quiz / Assignment / ESE

Suggested readings:

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

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**EMC 5103**
Course Credit (L-T-P-C)	L-T-P-C: 3-0-2-4
Course Title	**Probability and Statistics**
Learning Mode	Online
Learning Objective	To understand the basic concepts in Probability Theory and Statistics through practical examples.
Course Description	The course is divided into two parts: In first part, basic concepts of probability theory are introduced. In the second part, different problems in classical statistics are discussed.
Course Outline	Conditional probability, Bayes' rule, Total probability law, Independence of events. Random variables (discrete and continuous), probability mass functions, probability density functions, Expectation, variance, moments, cumulative distribution functions, Function of random variables, Multiple random variables, joint and marginal, conditioning and independence, Markov and Chebyshev inequalities, Different notions of convergence. Weak law of large number, Central limit theorem. Estimation: Properties, Unbiased Estimator, Minimum Variance Unbiased Estimator, Rao-Cramer Inequality and its attainment, Maximum Likelihood Estimator and its invariance property, Efficiency, Mean Square Error. Confidence Interval: Coverage Probability, Confidence level, Sample size determination. Testing of Hypotheses: Null and Alternative Hypotheses, Test Statistic, Error Probabilities, Power Function, Level of Significance, Neyman-Pearson Lemma.
Learning Outcome	Students will become familiar with principal concepts probability theory and statistics. This helps them to handle, mathematically, various practical problems arising in uncertain situations.
Assessment Method	Quiz / Assignment / ESE

Text Books:

1. Ross, S.M.(2008) Introduction to Probability Models, Ninth edition, Academic Press.
2. Statistical Inference (2007), G. Casella and R.L. Berger, Duxbury Advanced Series.

Reference Book:

1. An Introduction to Probability and Statistics, V.K. Rohatgi and A.K.Md. Ehsanes Saleh, John Wiley, 2nd Ed, 2009.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ECS 5201**
Course Credit	L-T-P-C: 3-0-2-4
Course Title	**Artificial Intelligence**
Learning Mode	Online
Learning Objectives	● To understand the foundational concepts and motivations behinrtificial Intelligence and intelligent agents. ● To learn and apply uninformed and informed search strategies for problem-solving. ● To explore local search techniques and optimization methods beyond classical search. ● To implement adversarial search techniques and problem reduction strategies. ● To formulate and solve Constraint Satisfaction Problems (CSPs) using advanced techniques.
Course Description	This course aims to provide students with a comprehensive understanding of the fundamental principles and techniques of Artificial Intelligence (AI). It covers the basics of intelligent agents and their environments, various problem-solving methods through search strategies, and techniques beyond classical search. Students will learn about adversarial search, constraint satisfaction problems, knowledge representation, reasoning, planning, and various learning techniques. The course prepares students to design and implement AI solutions for complex real-world problems.
Course Outline	● Introduction and motivation Artificial Intelligence, intelligent agents, nature of environments ● Problem-solving by searching: Example problems, uninformed, informed search strategies ● Uninformed/ blind search techniques: Breadth-first search (BFS), Depth-first search (DFS), Uniform-cost search (UCS) ● Informed search: Heuristic function design and evaluation, A* search ● Beyond classical search: local search techniques and optimization, hill climbing, simulated annealing, beam search ● Adversarial search: Games, optimal decision in games, min-max, alpha-beta pruning, partially observable games ● Problem reduction techniques: And-OR (AO) and AO* ● Constraint Satisfaction Problem (CSP): definition and examples of CSPs, basic techniques: backtracking search, forward checking, arc consistency

	● Knowledge Representation, Reasoning, and Planning: Propositional logic, first-order logic, inference, planning ● Learning Techniques: meta-heuristic (genetic algorithm), Bayesian, decision tree, etc. ● Some advanced techniques of AI and its applications ● Lab component: Implementation of above architectures.
Learning Outcome	By the end of this course, students will be able to: ● Understand the foundational concepts and motivations behind Artificial Intelligence and intelligent agents. ● Apply uninformed and informed search strategies to solve example problems. ● Utilize local search techniques and optimization methods such as hill climbing, simulated annealing, and beam search. ● Implement adversarial search techniques including min-max, alpha-beta pruning, and strategies for partially observable games. Apply problem reduction techniques. ● Formulate and solve Constraint Satisfaction Problems (CSPs) using techniques like backtracking search, forward checking, and arc consistency. ● Represent knowledge using propositional and first-order logic, and perform inference and planning. ● Explore and apply various learning techniques such as genetic algorithms, Bayesian methods, and decision trees.
Assessment Method	Quiz / Assignment / ESE

Suggested Reading

1. Russell, S. J., & Norvig, P. (2016). Artificial intelligence: A modern approach. Pearson.
2. Poole, D. L., & Mackworth, A. K. (2010). Artificial Intelligence: foundations of computational agents. Cambridge University Press.
3. 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.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**EMC 5202**
Course Credit	L-T-P-C: 3-0-2-4
Course Title	**Numerical Linear Algebra and Optimization Techniques**
Learning Mode	Online
Learning Objectives	The objective of the course is to train students about the different numerical techniques to solve linear equations, linear least square problems and find eigen values of matrices as well as check the stability of numerical methods. Moreover, students would be able to perform modeling of convex programming problems and employ various classical and numerical optimization techniques and algorithms to solve these problems
Course Description	Numerical Linear Algebra and Optimization Techniques, as a basic subject for postgraduate students, provides the knowledge of various numerical techniques to solve linear equations as well as check the stability of numerical methods. Moreover, this course would help the students to models convex optimization problems and learn different algorithms to solve such problems with its applications in various problems arising in economics, science and engineering.
Course Content	Review of matrix Algebra, Norms and condition numbers of Matrix, Systems of Equations, Gaussian Elimination, LU, PLU and Cholesky Factorization, Iterative Solvers: Jacobi, Gauss Seidel, SOR and their convergence, Gram-Schmidt orthogonalization QR Factorization and Least Squares, Eigenvalues, Power method, Reduction to Hessenberg or Tridiagonal form, Rayleigh quotient, inverse iteration, QR Algorithm without and with shifts, Singular Value Decomposition and Its applications Introduction to nonlinear programming, Convex Sets, Convex Functions and their properties. Unconstrained optimization of functions of several variables: Classical techniques. Numerical methods for unconstrained optimization: One Dimensional Search Methods, Golden Section Search and Fibonacci search, Basic descent methods, Conjugate direction, Newton's and Quasi-Newton methods Constrained optimization of functions of several variables, Lagrange Multiplier method, Karush-Kuhn-Tucker theory, Constraint Qualifications, Convex optimization Merit functions for constrained minimization, logarithmic barrier function for inequality constraints, A basic barrier-function algorithm Practice of algorithms using Software.
Learning Outcome	On successful completion of the course, students should be able to: 1. Understand different Matrix factorization method and employ them to solve linear equations and linear least square problems 2. To comprehend the basic computer arithmetic and the concepts of conditioning and stability of a numerical method. 3. Understand the terminology and basic concepts of various kinds of convex optimization problems and solve different solution methods to solve convex Programing problem.
Assessment Method	Quiz / Assignment /ESE

Text Books:

1. Lloyd N. Trefethen, David Bau III: Numerical Linear Algebra, 1st Edition, SIAM, Philadelphia (1997)
2. Edwin K. P. Chong, Stanislaw H. Zak: An Introduction to Optimization, 4th Edition, Wiley India (2017)
3. Gilbert Strang: Lecture Notes for Linear Algebra, Wellesley Cambridge Press, SIAM (2021)

Reference Books:

1. Stephan Boyd and Lieven. Vandenberghe: Convex Optimization, Cambridge University Press (2004)

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6101**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Advanced Blockchain Technology**
Learning Mode	Online
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/nonfunctional 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 importantdirections: addressing various research challenges in blockchain and AI/machine learning for blockchain (and vice-versa).
Course Outline	Introduction to Blockchain Technology: A Quick Tour Different Blockchain Platforms and Smart Contract Languages: Bitcoin, Ethereum, Hyperledger, Solidity, GoLang. Consensus Mechanisms: PoW Vs. PoS, Alternative Consensus Synergizing Machine Learning and Blockchain: Transaction Analysis, Smart Contract Code Analysis, AI-driven Blockchain Applications, Blockchain for AI, Decentralized Learning. ResearchChallengesin Blockchain: Scalability, Interoperability, Security, Privacy, Decentralized Identity, Smart Contract Vulnerabilities and Detection, Real case studies on developing DApps, Metaverse, Some ongoing relevant research topics.
Learning Outcome	• 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	Quiz / Assignment / ESE

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 andDapps, 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 (June2018).
- Arvind Narayanan, Joseph Bonneau, Edward Felten, Andrew Miller, Steven Goldfeder, Bitcoin and Cryptocurrency Technologies - A Comprehensive Introduction, Princeton University Press (2016).
- Stijn Van Hijfte: 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.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6102**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Pattern Recognition**
Learning Mode	Online
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 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	• Introduction and motivation of advanced pattern recognition • Modern Classification Methods, Random fields, Pattern recognition based on multidimensional models • Contextual classification, Hidden Markov models, Multi-classifier systems • Advanced parameter estimation methods, Advanced Unsupervised classification, Modern methods of feature selection. • Data normalization and invariants, Benchmarking. • Analysis and synthesis of image information. • Applications od pattern recognition in Text Processing and Healthcare.
Learning Outcome	• 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	Quiz / Assignment / ESE

TEXTBOOKS:

1. "Pattern Recognition and Machine Learning" by Christopher M. Bishop, Springer, 2006.
2. "Pattern Classification" by Richard O. Duda, Peter E. Hart, and David G. Stork, Wiley, 2001.
3. "Machine Learning: A Probabilistic Perspective" by Kevin P. Murphy, MIT Press, 2012.
4. "Deep Learning" by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, 2016.

"Introduction to Statistical Pattern Recognition" by Keinosuke Fukunaga, Academic Press, 1990.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6103**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Cyber Physical Systems**
Learning Mode	Online
Learning Objectives	To learn how to model and design the joint dynamics of software, networks, and physical processes., To develop the skills to realize embedded systems that are safe, reliable, and efficient in their use of resources., To learn to think critically about technologies that are available for achieving such joint dynamics.
Course Description	This course will provide an overview of modeling, building, analyzing methods for cyber physical systems.
Course Outline	Models of computation: finite state machines, threads, ordinary differential equations, hybrid systems, actors, discrete-events, data flow Basic analysis, control, and systems simulation: Bisimulations, reachability analysis, controller synthesis, approximating continuous-time systems. Interfacing with the physical world: sensor/actuator modeling and calibration, concurrency in dealing with multiple real-time streams, handling numerical imprecision in software Mapping to embedded platforms: real-time operating systems, execution time analysis, scheduling, concurrency Distributed embedded systems: Protocol design, predictable networking, security
Learning Outcome	• Basic understanding of cyber physical systems • To develop the skills to realize embedded systems that are safe, reliable, and efficient in their use of resources., • To learn to think critically about technologies that are available for achieving such joint dynamics.
Assessment Method	Quiz / Assignment / ESE

Suggested Reading:

• Introduction to Embedded Systems - A Cyber-Physical Systems Approach, Second Edition, by E. A. Lee and S. A. Seshia, 2015
• Vahid, F. and T. Givargis (2010). Programming Embedded Systems - An Introduction to Time-Oriented Programming, UniWorld Publishing.
• Schaumont, P. R. (2010). A Practical Introduction to Hardware/Software Codesign, Springer.
• E. A. Lee and P. Varaiya, Structure and Interpretation of Signals and Systems, Addison-Wesley, 2003.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6201**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Advanced Edge Computing**
Learning Mode	Online
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 UseCases, Benefits. Different Types of Edge. Edge Deployment Modes. Edge Computing in 5G, Multi-access Edge Computing (MEC) and Mobile Edge Computing.
Learning Outcome	• 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. • 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	Quiz / Assignment / ESE

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.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6202**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Advanced Graph Machine Learning**
Learning Mode	Online
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	Introduction and background knowledge of graphs; Network Measures and Metrices; Spectral Analysis of Graphs and its applications; Random Networks; Properties of Random Networks; 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; Generative models for graphs; Models for scale-free and small-world networks; Temporal networks, Modeling temporal networks;
Learning Outcome	Course training via lectures & tutorial sessions to • 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	Quiz / Assignment / ESE

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.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6203**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Game Theory**
Learning Mode	Online
Learning Objectives	• 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	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.
Course Outline	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. Cooperative Game: Correlated Strategies and Correlated Equilibrium, Two Person Bargaining Problem, Coalitional Games, Core, Shapley Value. Mechanism Design: Introduction to Mechanism Design, Social Choice Functions and their properties, Incentive Compatibility, Auction theory and its variants. Applications: IoT, Wireless Networks, Cloud Computing
Learning Outcome	By the end of this course, students will be able to: • 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 zerosum 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	Quiz / Assignment / End Semester Exam (ESE)

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.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6204**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Knowledge Distillation**
Learning Mode	Online
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	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. 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	• 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	Quiz / Assignment / ESE

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."

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6301**
Course Credit	3-0-0-3
Course Title	**Advanced Time Series Analysis**
Learning Mode	Online
Learning Objectives	• 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	Introduction to classical time series methods, time series Virtualization Univariate Stationary Processes; Granger Causality; Vector Autoregressive Processes Nonstationary Processes; Cointegration; Cointegration in Single Equation Models: Representation,Estimation and Testing. Applied Predictive Modeling Techniques; Autoregressive Conditional Heteroskedasticity. Finance and Algorithmic trading: Machine Learning and Deep Learning in Stock Price Prediction Machine Learning, Deep Learned Time series Analysis, Risk and Portfolio Management 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 Stock Price Prediction using Deep Learning and Natural Language Processing
Learning Outcome	At the end of the course, students will have achieved the following learning objectives. • 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	Quiz / Assignment / ESE

Suggested Reading

- 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.
- Gharehbaghi, Arash. Deep Learning in Time Series Analysis. CRC Press, 2023.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6302**
Course Credit	3-0-0-3
Course Title	**Quantum Cyber Security**
Learning Mode	Online
Learning Objectives	To have a clear understanding of Quantum technology and that brings on the security and privacy of communication and computation
Course Description	The course covers various effects that developing quantum technologies will have on cyber security.
Course Outline	Quantum information concepts: qubits, mixed states, operations, distance measures, quantum circuits, quantum algorithms (factoring, discrete logarithms, search). Classical Cryptography, encryption, authentication and key distribution protocols, Security analysis, quantum cryptography, quantum-key-distribution protocols, Security and implementation aspects. classical protocols and their security under quantum attacks, general quantum attacks (superposition attacks)
Learning Outcome	After completion of this course a student will have • Understanding of the quantum technologies. • Demonstrate their understanding of the power of quantum algorithms and be able to use the basic mathematical formalism for quantum information and quantum cryptography • Test whether a classical cryptosystem is secure against a range of quantum attacks • Use security notions for quantum information, such as encryption and authentication, in quantum cryptographic protocols
Assessment Method	Quiz / Assignment / ESE
Suggested Readings: • Quantum Computation and Quantum Information by Nielsen and Chuang • Cryptography: Theory and Practice by D.R. Stinson	

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6303**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Generative AI**
Learning Mode	Online
Learning Objectives	• To provide a comprehensive understanding of advanced AI concepts with a focus on generative AI • To design and implement various generative models such as GANs, VAEs, and Diffusion Models. • To explore the architecture and applications of Generative Pre-trained Transformers (GPT). • To design application-specific architectures for prompt engineering and multimodal generative AI. • To analyze and address ethical considerations in the development and deployment of generative AI models. • · To conduct independent research and projects involving advanced generative AI techniques.
Course Description	This course provides an in-depth exploration of advanced artificial intelligence (AI) concepts, with a specific focus on generative AI (GenAI). Students will delve into advanced generative models, including Generative Adversarial Networks (GANs), Variational AutoEncoders (VAEs), Diffusion Models, and Generative Pre-trained Transformers (GPT). The course also covers the application of these models across various domains, the design of application-specific architectures for prompt engineering, and multimodal generative AI. Additionally, ethical considerations surrounding the use of generative AI will be discussed. By the end of the course, students will have the knowledge and skills to design, implement, and evaluate advanced generative AI models and understand their ethical implications
Course Outline	Introduction to Generative AI (GenAI): Overview of GenAI, historical context and scope. Generative Adversarial Networks (GAN) and Deep Convolutional GAN (DCGAN): Understanding the architecture of GANs, Training dynamics and loss functions in GANs, Implementation and applications of DCGANs, Challenges and solutions in training GANs. Advanced Variational AutoEncoders (VAE): Fundamentals of VAEs and their architectures, Latent space representation and sampling techniques, Advanced VAE variants and their improvements, Applications of VAEs in image and data generation. Basics of Diffusion Models and Attention Mechanisms in Generative Models: Introduction to diffusion models and their principles, Understanding the role of attention mechanisms in generative models, Implementation of attention-based generative models, Case studies and applications of diffusion models. Generative Pre-trained Transformers (GPT) Basics: Overview of transformer architecture, Understanding the training and functioning of GPT models, Applications of GPT models in text generation and NLP, Finetuning and optimizing GPT for specific tasks. Application-Specific Architecture for Prompt Engineering and Multimodality: Designing and optimizing prompt engineering techniques, exploring multimodal generative models, Integrating text, image, and audio in generative models, Case studies of application-specific generative architectures. Ethical Considerations in Generative AI: Understanding the ethical implications of Generative AI, Addressing bias, fairness, and accountability in generative models, Privacy concerns and data security in Generative AI.

Learning Outcome	By the end of this course, students will be able to: • Understand the foundational concepts and the latest advancements in artificial intelligence and generative AI. • Design and implement Generative Adversarial Networks (GANs) and their advanced variants, such as DCGAN. • Develop and apply advanced Variational AutoEncoders (VAEs) for generative tasks. • Grasp the basics of Diffusion Models and the role of attention mechanisms in enhancing generative models. • Understand the architecture and functioning of Generative Pre-trained Transformers (GPT) and their applications. • Create application-specific architectures for prompt engineering and explore the integration of multimodal generative AI techniques. • Analyze and address ethical considerations and challenges in the development and deployment of generative AI models. • Conduct independent research and projects involving advanced generative AI techniques, demonstrating a comprehensive understanding of both theoretical and practical aspects.
Assessment Method	Quiz / Assignment / End Semester Exam (ESE)

TEXTBOOKS:

- 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.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6304**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Advanced Cloud Computing**
Learning Mode	Online
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 virtualization, data parallelism, CAP theorem, and performance analysis at scale; c) Big Data programming patterns such as Map-Reduce (Hadoop), Vertex-centric graphs (Graph), 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, virtualization, and distributed systems. It covers foundational concepts, advanced techniques, and real-world applications. Students will explore various aspects of cloud infrastructure, virtualization 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	• Introduction to Clouds, Virtualization, and Virtual Machines. • Network Virtualization and Geo-distributed Clouds. • Leader Election in Cloud, Distributed Systems, and Industry Systems. • Classical Distributed Algorithms and Industry Systems. • Consensus, Paxos, and Recovery in Clouds. • Cloud Storage: Key-value Stores/NoSQL Systems and their Use in Industry Systems. • Cloud Applications: MapReduce, Spark, and Apache Kafka. • Cloud Native Computing and Micro-services.
Learning Outcome	• 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	Quiz / Assignment / ESE

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.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6401**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**High Performance Computing**
Learning Mode	Online
Learning Objectives	The course is designed to provide basic understanding of structure, and function of various building blocks of high performance Computing System. Students will be able to design various functional units and components and to identify the elements of modern GPUs and their impact on processor/GPU/TPU and parallel architecture design including memory
Course Description	Using a set of fundamental techniques and technologies, the high performance systems theme broadly explains how computing platforms work at various levels of abstraction, including both software and hardware. The course introduces HPS architecture with focus on parallel architectures
Course Outline	Computer types, Structure with basic computer components - instruction sets of some common CPUs/GPUs; Parallel Processing Concepts: a) Levels of parallelism (instruction, transaction, task, thread, memory, function) Models (SIMD, MIMD, SIMT, SPMD, Dataflow Models, Demanddriven Computation etc) c) Architectures: N-wide superscalar architectures, multi-core, multi-threaded Parallel Programming with CUDA: a) Processor Architecture, Interconnect, Communication, Memory Organization, and Programming Models in high performance computing architectures: Fundamental Design Issues in Parallel Computing: a) Synchronization b) Scheduling, c) Job Allocation d) Job Partitioning, e) Dependency Analysis,f) Mapping Parallel Algorithms onto Parallel Architectures g) Performance Analysis of Parallel Algorithms Power-Aware Computing and Communication: a) Power-aware Processing Techniques Advanced Topics:(a) Petascale Computing,(b) Optics in Parallel Computing,(c) Quantum Computers,(d) Recent developments in Nanotechnology and its impact on HPC
Learning Outcome	The student will be able to : • Appreciate understanding of the HPC blocks, key terminology, and current industry trends in high performance computer architecture. • Understand parallel programming and evaluate and compare the architectural features of the state of the art high performance commodity hardware platforms. • Understand the processor (CPU/GPU/TPU) subsystem. • Employ concepts of the HPS memory subsystem and hierarchy
Assessment Method	Quiz / Assignment / ESE

Text Books:

- "Highly Parallel Computing", by George S. Almasi and Alan Gottlieb
- "Advanced Computer Architecture: Parallelism, Scalability, Programmability", by Kai Hwang, McGraw Hill 1993
- "Parallel Computer Architecture: A hardware/Software Approach", by David Culler Jaswinder Pal Singh, Morgan Kaufmann, 1999.
- "Scalable Parallel Computing", by Kai Hwang, McGraw Hill 1998.
- "Principles and Practices on Interconnection Networks", by William James Dally and Brian Towles, Morgan Kauffman 2004.
- GPU Gems 3 --- by Hubert Nguyen (Chapter 29 to Chapter 41)
- Introduction to Parallel Computing, Ananth Grama, Anshul Gupta, George Karypis, and Vipin Kumar, 2nd edition, Addison-Welsey, © 2003.
- Petascale Computing: Algorithms and Applications, David A. Bader (Ed.), Chapman & Hall/CRC Computational Science Series, © 2007.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6402**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Meta Learning**
Learning Mode	Online
Learning Objectives	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.
Course Description	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.
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	1. Understand and articulate the foundational principles of meta-learning 2. Apply probabilistic modeling and Bayesian inference to quantify uncertainty and improve model robustness in decision-making processes. 3. Analysis of Optimization-Based Meta-Learning Approaches. 4. Explore and address new challenges in emerging applications
Assessment Method	Quiz / Assignment / ESE

TEXTBOOKS:

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

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6403**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Quantum Machine Learning**
Learning Mode	Online
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	By the end of the course, students will be able to: • 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. Explore advanced topics in Generative AI and apply acquired knowledge through hands-on projects, fostering innovation and practical problem-solving skills.
Assessment Method	Quiz / Assignment / ESE

Suggested Reading:

- 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.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: M.S in Computer Science & Data Analytics
Curriculum and Syllabus-2025

Course Number	**ESD 6404**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Advanced Big Data Analytics**
Learning Mode	Online
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	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 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 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 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 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 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.
Learning Outcome	• 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.
Assessment Method	• Quiz / Assignment / ESE

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.