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Continuing Education Programme
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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/Capstone Project	1	2	2	4
5		DE-1(Elective 1)	3	0	0	3
	TOTAL		**13**	**2**	**8**	**19**

**Capstone Project (Optional) online industry case study

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

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Electives for Executive M.Tech Computer Science & Engineering:

Sl. No.	Subject Code	Elective-I	L	T	P	C
1	ECS 6101	Advanced Cyber Security	3	0	0	3
2	ECS 6102	Computational Data Analysis	3	0	0	3
3	ECS 6103	Cyber Physical Systems	3	0	0	3

Sl. No.	Subject Code	Elective-II, III	L	T	P	C
1	ECS 6201	Predictive Analytics	3	0	0	3
2	ECS 6202	Advanced Edge Computing	3	0	0	3
3	ECS 6203	Deep Learning	3	0	0	3
4	ECS 6204	Data virtualization and dashboard	3	0	0	3

Sl. No.	Subject Code	Elective-IV, V	L	T	P	C
1	ECS 6301	Artificial Internet of Things	3	0	0	3
2	ECS 6302	Advanced Cloud Computing	3	0	0	3
3	ECS 6303	Pattern Recognition	3	0	0	3
4	ECS 6304	Natural Language Processing	3	0	0	3

Sl. No.	Subject Code	Elective- VI, VII	L	T	P	C
1	ECS 6401	Advanced Time Series Analysis	3	0	0	3
2	ECS 6402	Selected Topics in Wireless Networks	3	0	0	3
3	ECS 6403	High Performance Computing	3	0	0	3
4	ECS 6403	Reinforcement Learning	3	0	0	3

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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

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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.

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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.

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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.

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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)

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Course Number	**ECS 6101**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Advanced Cyber Security**
Learning Mode	Online
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 (i) Understanding of security issues in computer and networks, (ii) Understanding and analysis of internet security protocols (iii) Understanding and analysis of web security protocols
Assessment Method	Quiz / Assignment / ESE

TEXTBOOKS:

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

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Course Number	**ECS 6102**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Computational Data Analysis**
Learning Mode	Online
Learning Objectives	In this subject, the students will be trained with the knowledge of various computational techniques required for multi-dimensional data analysis such that they are able to apply these techniques in practice through programming, modeling etc.
Course Description	Modern day data is vast and diverse owing to their different acquisition systems and medium. This course aims to give an in-depth view to different data generation/acquisition mechanisms over diverse domains and the challenges incurred. It will discuss the role of computational data analysis techniques to understand and mathematically model data formation process. It will also teach them about the various data processing techniques required to manipulate and operate data to suit various objectives.
Course Outline	**Module1:** Understanding multi-dimensional data formation from physical acquisition devices with example cases in Remote Sensing, Geoscience, Medical sciences. Drawbacks and challenges in data acquisition, Necessity for computational modelling and analysis of data. **Module 2:** Mathematical models for data formation and analysis, Probability models, Linear inverse optimization models, L1-L2 Regularizers, Minimizers, Cascade Modelling, Multiscale Modelling, Machine Learning models. **Module 3:** Data Interpretation: Handling missing/corrupted data, Handling outliers, Imputation techniques, Interpolation techniques, Curve based approximation, non-convex optimization, sparse regularizers, Non-convex minimizers, Machine learning based. **Module 4:** Data compression: Necessity, Applications, Lossless compression techniques, Lossy compression techniques, JPEG compression, Machine learning based. **Module 5:** Statistical Models, Data preprocessing techniques in Machine learning, Signal processing techniques for multi dimensional data, Application in various domains.

Learning Outcome	After completion of course, students will be able to ● Understand data formation/generation process and the role of computational techniques in analyzing those data. ● Apply the Mathematical principles behind computational techniques for data analysis. ● Understand the utilities of statistical models and ML models in data analysis.
Assessment Method	Quiz / Assignment / ESE

Suggested Readings:

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

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Course Number	**ECS 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	1. Basic understanding of cyber physical systems 2. To develop the skills to realize embedded systems that are safe, reliable, and efficient in their use of resources., 3. 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.

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Course Number	**ECS 6201**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Predictive Analytics**
Learning Mode	Online
Learning Objectives	● Understand the key concepts of predictive analytics, including statistical models and machine learning algorithms. ● Gain proficiency in building predictive models using data-driven techniques. ● Learn to apply predictive analytics for solving business problems and decision-making. ● Explore tools and software used for predictive analytics, such as Python and R. ● Understand how to evaluate and interpret the results of predictive models.
Course Description	This course introduces students to the principles and techniques of predictive analytics. It focuses on building predictive models using statistical and machine learning methods. Students will learn how to apply predictive analytics to a variety of business and industry problems, using real-world datasets. The course also covers key evaluation metrics, model tuning, and the ethical implications of predictive models. Practical applications will be implemented using tools such as Python or R.
Course Outline	**Module 1: Introduction to Predictive Analytics** • Definition and importance of predictive analytics. • The role of data in predictive analytics: types of data (structured vs. unstructured). • Introduction to the predictive modeling process. • Understanding the difference between descriptive, predictive, and prescriptive analytics. • Applications of predictive analytics in business: customer churn, credit scoring, fraud detection, etc. **Module 2: Data Preparation for Predictive Modeling** • Data collection, cleaning, and preprocessing. • Handling missing data, outliers, and imbalanced datasets. • Feature engineering: creating meaningful features from raw data. • Data partitioning: training, testing, and validation datasets. • Data transformation techniques: normalization and standardization. **Module 3: Predictive Modeling Techniques** • **Regression Analysis:** o Linear regression, multiple regression, and polynomial regression. o Assumptions of regression models and diagnostics. • **Classification Techniques:** o Logistic regression, decision trees, and random forests. o Support Vector Machines (SVM) and k-Nearest Neighbors (k-NN). o Gradient boosting and ensemble methods (XGBoost, AdaBoost). • **Time Series Forecasting:** o ARIMA, exponential smoothing, and seasonal decomposition.

	○ Trends, seasonality, and forecasting future values. **Module 4: Machine Learning in Predictive Analytics** • Introduction to supervised learning: classification and regression. • Key machine learning algorithms for predictive analytics: ○ Decision Trees, Random Forests, and Gradient Boosting Machines. ○ Support Vector Machines (SVM) and Neural Networks. • Model selection and hyperparameter tuning using cross-validation. • Introduction to unsupervised learning for pattern recognition (clustering, association). **Module 5: Model Evaluation and Optimization** • Performance metrics for regression: R-squared, Mean Absolute Error (MAE), Mean Squared Error (MSE). • Performance metrics for classification: Confusion Matrix, Precision, Recall, F1-Score, AUC-ROC curve. • Overfitting and underfitting: strategies to prevent overfitting (regularization, cross-validation). • Model tuning and optimization techniques: Grid Search, Random Search, and Hyperparameter Tuning. • Interpreting the results and communicating insights effectively. **Module 6: Advanced Topics in Predictive Analytics** • Introduction to deep learning techniques in predictive analytics. • Using predictive analytics for real-time data and streaming analytics. • Ethical considerations in predictive analytics: fairness, transparency, and accountability. • Case studies and industry applications of predictive analytics: healthcare, finance, marketing, etc. • Practical implementation using Python or R with libraries like scikit-learn, TensorFlow, and statsmodels.
Learning Outcome	• Comprehensive understanding of big data frameworks like Hadoop and Spark. • Ability to design and implement scalable data pipelines for batch and real-time processing. • Proficiency in managing and optimizing distributed data storage and processing systems. • Practical skills in working with various components of the Hadoop ecosystem and Spark framework. • Knowledge of best practices for big data security, performance tuning, and scalability.
Assessment Method	Quiz / Assignment / End Semester Exam (ESE)
TEXTBOOKS:	

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Course Number	**ECS 6202**
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 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	● Critically evaluate advanced edge computing architectures, such as hierarchical, mesh, and hybrid models, considering their suitability for specific use cases and environments. ● Analyse 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

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

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Course Number	**ECS 6203**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Deep Learning**
Learning Mode	Online
Learning Objectives	This course aims to provide an introductory overview of deep learning and its application varied domains. The course will provide basic understanding of neural networks, mathematical description of it and finally applications of it in multiple domains. A few open source tools will be demonstrated during the course to provide hands-on experience.
Course Description	This course provides an introduction to big data problems and linear algebra, covering essential machine learning techniques like linear regression and classification. It delves into neural networks, gradient-based learning, regularization methods, optimization strategies, and advanced topics such as CNNs, RNNs, and deep reinforcement learning.
Course Outline	● Introduction: Introduction to bigdata problem, overview of linear algebra ● Feature engineering: Basics of machine learning (linear regression, classification) ● Neural network: Deep feed forward network, cost function, activation functions, overfitting, underfitting, Universal approximation theorem ● Gradient based learning: DG, SGD, Backpropagation ● Regularization: L2, L1, L\infinity, drop-out, early stopping, data augmentation, etc. ● Optimization: Multivariable taylor series, momentum, adaptive learning rate, ADAM, Nesternov, AdaGrad, etc. ● CNN: CNN and its application in computer vision ● RNN: RNN, LSTM, GRU and their applications in NLP ● Advanced topics: Autoencoder, Transformer, Deep reinforcement learning
Learning Outcome	● Basic understanding of deep learning and neural networks. ● Problem modeling skill ● Usage of different open source tools / libraries. ● Analysis of large volume of data
Assessment Method	Quiz / Assignment / ESE

Textbooks:

- Ian Goodfellow, Yoshua Bengio and Aaron Courville, “Deep Learning”, Book in preparation for MIT Press, 2016.

Reference books:

- Jerome H. Friedman, Robert Tibshirani, and Trevor Hastie, “The elements of statistical learning”, Springer Series in Statistics, 2009.
- Charu C Aggarwal, “Neural Networks and Deep Learning”, Springer.

- Aston Zhang, Zachary C. Lipton, Mu Li, Alexander J. Smola, "Dive into Deep Learning"
- Iddo Drori, "The Science of Deep Learning", Cambridge University Press
- Simon O. Haykin, "Neural Networks and Learning Machines", Pearson Education India
- Richard S. Sutton, Andrew G. Barto, "Reinforcement Learning: An Introduction", MIT Press
- Christopher M. Bishop, Hugh Bishop, "Deep Learning: Foundations and Concepts", Springer, 2022.
- Simon J. D. Prince, "Understanding Deep Learning", MIT Press 2023.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: Executive M. Tech in Computer Science & Engineering
Curriculum and Syllabus-2024

Course Number	**ECS 6204**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Data Virtualization and Dashboards**
Learning Mode	Online
Learning Objectives	1. To introduce students to the concept of data virtualization and its applications in the field of big data and blockchain. 2. To provide students with hands-on experience using popular data virtualization tools to create a unified view of data from multiple sources and running queries on the views in optimized manner. 3. To teach students how to design effective dashboards that provide meaningful insights into complex data sets and allows intelligent analytics o data. 4. To explore advanced topics in data virtualization and dashboards, such as real-time data integration, self-service. analytics, and integration with big data platforms and blockchain.
Course Description	This course introduces data virtualization concepts and applications in big data and blockchain, offering hands-on experience with popular tools for unified data views and optimized querying. Students will learn to design effective dashboards for intelligent analytics and explore advanced topics, including real-time integration, self-service analytics, and integration with big data platforms and blockchain.
Course Outline	**Module 1: Introduction to Data Virtualization** ● Overview of data virtualization and its benefits, Data Silos, Data Partitioning, performance parameters of data virtualization. ● Understanding data integration and how it differs from data virtualization, Centralized vs Peer-2-peer Data Integration, ETL, Mediation and Federated Databases. ● Data Transformation, Master Data and Metadata Management in Data Virtualization. ● Use cases for data virtualization. ● Challenges and limitations of data virtualization. ● Introduction to popular data virtualization tools and their architectures.

	Module 2: Data Virtualization in Action ● Building a virtual data layer with a popular data virtualization tool such as Denodo and TIBCO, Redhat JBOSS. ● Connecting to various data sources (relational databases, big data systems, cloud applications, web applications, etc.). ● Creating views and queries using the selected data virtualization tool, query optimization and caching in data virtualization. ● Handling complex data transformations with the selected tool. ● Managing metadata and security in a virtual environment. **Module 3: Data Visualization and Dashboards** ● Introduction to data visualization and dashboard design. ● Key principles of effective data visualization. ● Overview of popular dashboard tools (e.g. Tableau, Power BI, QlikView), Creating reports in Tableau and PowerBI. ● Best practices for designing interactive dashboards. ● Connecting virtual data sources to dashboards. **Module 4: Advanced Topics in Data Virtualization and Dashboards** ● Using data virtualization to support self-service analytics, Experimenting self-service analytics in Denodo and PowerBI. ● Real-time data integration and processing with data virtualization. ● Integrating data virtualization with big data platforms and blockchain. ● Best practices for performance tuning and optimization in data virtualization. ● Future trends in data virtualization and dashboard design.

Learning Outcome	1. Students will be able to describe the benefits and challenges of data virtualization and how it differs from traditional data integration approaches. 2. Students will be able to create a virtual data layer using a popular data virtualization tool and connect to various data sources, including relational databases, big data systems, and cloud applications. 3. Students will be able to design effective dashboards using popular dashboard tools and connect virtual data sources to create interactive visualizations. 4. Students will be able to identify and apply advanced techniques in data virtualization and dashboard design, such as real-time data processing, self-service analytics, and integration with big data platforms and blockchain.
Assessment Method	Quiz / Assignment / ESE

Suggested Reading

1. Data Virtualization for Business Intelligence Systems: Revolutionizing Data Integration for Data Warehouses (Rick van der Lans).

2. Data Virtualization: Going Beyond Traditional Data Integration to Achieve Business Agility (Judith R. Davis, Robert Eve, and Ramesh Chakkoli).

3. Data Visualization: A Practical Introduction (Kieran Healy).

4. The Big Book of Dashboards: Visualizing Your Data Using Real-World Business Scenarios (Steve Wexler, Jeffrey Shaffer, and Andy Cotgreave).

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Continuing Education Programme
Program: Executive M. Tech in Computer Science & Engineering
Curriculum and Syllabus-2024

Course Number	**ECS 6301**
Course Credit	3-0-0-3
Course Title	**Artificial Internet of Things**
Learning Mode	Online
Learning Objectives	● 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	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.
Course Outline	● Introduction to AIoT, Intersection of AI and IoT, Benefits and challenges of AIoT ● Fundamentals of IoT, IoT Architecture and Protocols, Layers of IoT architecture, Communication protocols and standards, IoT Devices and Sensors ● Fundamentals of Artificial Intelligence, Machine Learning and Deep Learning, Overview of AI tools and frameworks ● AIoT System Architecture, Components and Designing AIoT, Edge Computing in AIoT, Edge vs. cloud computing, AI Models for IoT ● Data Management in AIoT, Data Processing and Analysis, Handling large-scale IoT data, Big data technologies and platforms ● AIoT Applications and Use Cases: Smart Homes and Buildings, Healthcare and Wearables, Industrial IoT (IIoT), Smart Cities and Transportation ● AIoT Platforms and Tools: AI Development Tools, Case Studies of AIoT Solutions, AIoT Project Development, Future Trends and Innovations in AIoT
Learning Outcome	At the end of course, students will have achieved the following learning objectives.

	● 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.
Assessment Method	Quiz / Assignment / ESE

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.

INDIAN INSTITUTE OF TECHNOLOGY PATNA

Continuing Education Programme
Program: Executive M. Tech in Computer Science & Engineering
Curriculum and Syllabus-2024

Course Number	**ECS 6302**
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.

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Continuing Education Programme
Program: Executive M. Tech in Computer Science & Engineering
Curriculum and Syllabus-2024

Course Number	**ECS 6303**
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.
5. "Introduction to Statistical Pattern Recognition" by Keinosuke Fukunaga, Academic Press, 1990.

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Continuing Education Programme
Program: Executive M. Tech in Computer Science & Engineering
Curriculum and Syllabus-2024

Course Number	**ECS 6304**
Course Credit	3-0-0-3
Course Title	**Natural Language Processing**
Learning Mode	Online
Learning Objectives	● Define and describe fundamental concepts in NLP, including syntax, semantics, and pragmatics, and their relevance to text analysis and language modelling. ● Apply pre-processing techniques to clean and prepare text data for analysis, such as tokenization, lemmatization, stemming, and stop-word removal. ● Utilize methods for feature extraction and representation from text data, including bag-of-words, TF-IDF, and various types of word embeddings (e.g., Word2Vec, GloVe). ● Construct and evaluate machine learning and deep learning models for various NLP tasks, such as classification, regression, and sequence labelling, using techniques like Naïve Bayes, SVM, RNNs, and Transformers. ● Design and implement solutions for practical NLP problems, including sentiment analysis, named entity recognition, text summarization, and machine translation.
Course Description	● Understand foundational concepts and challenges in NLP, including language modelling, parsing, and semantic analysis. ● Apply text pre-processing techniques to prepare data for analysis, including tokenization, stemming, and lemmatization. ● Utilize various feature extraction and representation methods such as bag-of-words, TF-IDF, and word embeddings. ● Develop and evaluate both traditional machine learning models and advanced deep learning models for a range of NLP tasks. ● Implement practical solutions for applications such as sentiment analysis, named entity recognition, and text summarization.
Course Outline	Introduction to NLP, Simple Word Vector representations: word2vec, GloVe: Distributed Representations of Words and Phrases and their Compositionality, Efficient Estimation of Word Representations in Vector Space, Advanced word vector representations: language models, GloVe: Global Vectors for Word Representation, PoS tagging and named entity recognition, Language modelling and other tasks, Opinion Mining Parsing, Sentence classification, Machine Translation, Dynamic Memory Networks, Question Answering, Natural Language Generation and Summarization, Contextual Word Representations: BERT
Learning Outcome	At the end of course, students will have achieved the following learning objectives. ● Demonstrate a solid understanding of key concepts in NLP, including tokenization, stemming, lemmatization, and part-of-speech tagging. ● Apply techniques for text pre-processing and cleaning, including removing stop words, normalizing text, and handling noisy data.

	● Implement and evaluate methods for feature extraction and representation, such as bag-of-words, TF-IDF, and word embeddings (e.g., Word2Vec, GloVe). ● Develop and train various NLP models, including traditional machine learning models (e.g., Naive Bayes, SVM) and deep learning models (e.g., RNNs, LSTMs, Transformers). ● Apply techniques for natural language understanding (e.g., named entity recognition, sentiment analysis) and natural language generation (e.g., text summarization, machine translation).
Assessment Method	Quiz / Assignment / ESE

Tectbook:

- Dan Jurafsky and James H. Martin.Speech and Language Processing (3rd ed. draft)
- Jacob Eisenstein.Natural Language Processing
- Yoav Goldberg.A Primer on Neural Network Models for Natural Language Processing
- Ian Goodfellow, YoshuaBengio, and Aaron Courville.Deep Learning
- Delip Rao and Brian McMahan.Natural Language Processing with PyTorch (requires Stanford login).
- Michael A. Nielsen.Neural Networks and Deep Learning
- Eugene Charniak. Introduction to Deep Learning

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Continuing Education Programme
Program: Executive M. Tech in Computer Science & Engineering
Curriculum and Syllabus-2024

Course Number	**ECS 6401**
Course Credit	L-T-P-C: 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 covers classical time series methods, univariate stationary processes, and vector autoregressive processes, along with machine learning and deep learning techniques for stock price prediction and risk management.
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

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

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Continuing Education Programme
Program: Executive M. Tech in Computer Science & Engineering
Curriculum and Syllabus-2024

Course Number	**ECS 6402**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Selected Topics in Wireless Networks**
Learning Mode	Online
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	• Introduction to Wireless Networks: Basic principles, types of wireless networks (Wi-Fi, Bluetooth, cellular), and network topologies. • Wireless Communication Fundamentals: Radio frequency, signal propagation, modulation techniques, and interference management. • Network Protocols and Standards: IEEE 802.11 (Wi-Fi), IEEE 802.15 (Bluetooth), and cellular standards (2G, 3G, 4G, 5G). • Network Design and Architecture: System design, frequency reuse, and resource allocation. • Mobility and Handoff: Techniques for managing mobility, handoff processes, and roaming. • Security in Wireless Networks: Security protocols, encryption, and threat mitigation. • Emerging Technologies: Overview of 6G, IoT, in-network caching
Learning Outcome	On successful completion of the course, students should be able to: 1. Understand the fundamentals of 802.11 wireless networks 2. Describe the WLAN services-association, disassociation, re-association, distribution, integration, authentication, de authentication and data delivery services 3. Comprehend the vulnerabilities associated with 802.11 protocol.
Assessment Method	Quiz / Assignment / ESE

Text Books and References:

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

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Continuing Education Programme
Program: Executive M. Tech in Computer Science & Engineering
Curriculum and Syllabus-2024

Course Number	**ECS 6403**
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, Demand-driven 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:

[1] "Highly Parallel Computing", by George S. Almasi and Alan Gottlieb

[2] "Advanced Computer Architecture: Parallelism, Scalability, Programmability", by Kai Hwang, McGraw Hill 1993

[2] "Parallel Computer Architecture: A hardware/Software Approach", by David Culler Jaswinder Pal Singh, Morgan Kaufmann, 1999.

[3] "Scalable Parallel Computing", by Kai Hwang, McGraw Hill 1998.

[4] "Principles and Practices on Interconnection Networks", by William James Dally and Brian

Towles, Morgan Kauffman 2004.

[5] GPU Gems 3 --- by Hubert Nguyen (Chapter 29 to Chapter 41)

[6] Introduction to Parallel Computing, Ananth Grama, Anshul Gupta, George Karypis, and Vipin Kumar, 2nd edition, Addison-Welsey, © 2003.

[7] Petascale Computing: Algorithms and Applications, David A. Bader (Ed.), Chapman & Hall/CRC Computational Science Series, © 2007.

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Continuing Education Programme
Program: Executive M. Tech in Computer Science & Engineering
Curriculum and Syllabus-2024

Course Number	**ECS 6404**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Reinforcement Learning**
Learning Mode	Online
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	1. Mastery of fundamental principles and mathematical frameworks of reinforcement learning. 2. Proficiency in implementing key reinforcement learning algorithms and techniques. 3. Ability to apply deep reinforcement learning methods to complex, real-world problems.

	4. Understanding of recent advancements in reinforcement learning and their ethical implications.
Assessment Method	Quiz / Assignment / End Semester Exam (ESE)

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)