# INDIAN INSTITUTE OF TECHNOLOGY PATNA

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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 Artificial Intelligence & Data Science Engineering:**

| Sl. No. | Subject Code | Elective-I | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | EAI 6101 | Computational Data Analysis | 3 | 0 | 0 | 3 |
| 2 | EAI 6102 | Pattern Recognition | 3 | 0 | 0 | 3 |
| 3 | EAI 6103 | Advance Machine Learning | 3 | 0 | 0 | 3 |

| Sl. No. | Subject Code | Elective-II, III | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | EAI 6201 | Deep Learning | 3 | 0 | 0 | 3 |
| 2 | EAI 6202 | Physics of Neural Network | 3 | 0 | 0 | 3 |
| 3 | EAI 6203 | Predictive Analytics | 3 | 0 | 0 | 3 |
| 4 | EAI 6204 | Federated Learning | 3 | 0 | 0 | 3 |

| Sl. No. | Subject Code | Elective-IV, V | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | EAI 6301 | Artificial Internet of Things | 3 | 0 | 0 | 3 |
| 2 | EAI 6302 | Natural Language Processing | 3 | 0 | 0 | 3 |
| 3 | EAI 6303 | Blockchain Technologies: Platforms and Applications | 3 | 0 | 0 | 3 |
| 4 | EAI 6304 | Advanced Cloud Computing | 3 | 0 | 0 | 3 |

| Sl. No. | Subject Code | Elective-VI, VII | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | EAI 6401 | Reinforcement Learning | 3 | 0 | 0 | 3 |
| 2 | EAI 6402 | Meta Learning | 3 | 0 | 0 | 3 |
| 3 | EAI 6403 | Selective Topics in Generative AI | 3 | 0 | 0 | 3 |
| 4 | EAI 6404 | Text Mining and Analytics | 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<br>Sorting and searching: Quick sort, merge sort, heap sort; Sorting in linear time; Ordered statistics;<br>Problem solving strategies: recursion, dynamic programming, branch and bound, backtracking, greedy, divide conquer,<br>Graph algorithms: BFS, DFS, Shortest path, MST, Network flow;<br>NP-completeness<br>Advanced topics: string matching, FFT-DFT, basics of approximation and randomized algorithms.<br>Lab Component: Implementation of above topics |
| **Learning Outcome** | By the end of this course, students will be able to:<br>Use linked lists, stacks, queues, trees, balanced trees, and graphs.<br>Analyze algorithm complexity and solve recurrence relations.<br>Implement Quick sort, Merge sort, Heap sort, and linear time sorting methods.<br>Apply recursion, dynamic programming, branch and bound, backtracking, greedy, and divide-and-conquer methods.<br>Implement BFS, DFS, shortest path algorithms, MST, and network flow algorithms.<br>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.<br><br>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.<br><br>RISC and CISC paradigms, I/O Transfer techniques, Memory organization: hierarchical memory systems, cache memories, virtual memory.<br><br>**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.<br><br>Memory management techniques, Allocation techniques, Paging, Page Replacement Algorithms, Numericals.<br><br>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.<br><br>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.<br><br>Confidence Interval: Coverage Probability, Confidence level, Sample size determination.<br><br>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.<br>● To learn and apply uninformed and informed search strategies for problem-solving.<br>● To explore local search techniques and optimization methods beyond classical search.<br>● To implement adversarial search techniques and problem reduction strategies.<br>● 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<br>● Problem-solving by searching: Example problems, uninformed, informed search strategies<br>● Uninformed/ blind search techniques: Breadth-first search (BFS), Depth-first search (DFS), Uniform-cost search (UCS)<br>● Informed search: Heuristic function design and evaluation, A* search<br>● Beyond classical search: local search techniques and optimization, hill climbing, simulated annealing, beam search<br>● Adversarial search: Games, optimal decision in games, min-max, alpha-beta pruning, partially observable games<br>● Problem reduction techniques: And-OR (AO) and AO*<br>● 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<br>• Learning Techniques: meta-heuristic (genetic algorithm), Bayesian, decision tree, etc.<br>• Some advanced techniques of AI and its applications<br>• Lab component: Implementation of above architectures. |
| **Learning Outcome** | By the end of this course, students will be able to:<br>• Understand the foundational concepts and motivations behind Artificial Intelligence and intelligent agents.<br>• Apply uninformed and informed search strategies to solve example problems.<br>• Utilize local search techniques and optimization methods such as hill climbing, simulated annealing, and beam search.<br>• Implement adversarial search techniques including min-max, alpha-beta pruning, and strategies for partially observable games. Apply problem reduction techniques.<br>• Formulate and solve Constraint Satisfaction Problems (CSPs) using techniques like backtracking search, forward checking, and arc consistency.<br>• Represent knowledge using propositional and first-order logic, and perform inference and planning.<br>• Explore and apply various learning techniques such as genetic algorithms, Bayesian methods, and decision trees. |
| **Assessment Method** | Quiz / Assignment / ESE |

**<u>Suggested Reading</u>**


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<br>QR Factorization and Least Squares, Eigenvalues, Power method, Reduction to Hessenberg or Tridiagonal form, Rayleigh quotient, inverse iteration, QR Algorithm without and with shifts,<br>Singular Value Decomposition and Its applications<br>Introduction to nonlinear programming, Convex Sets, Convex Functions and their properties.<br>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<br>Constrained optimization of functions of several variables, Lagrange Multiplier method, Karush-Kuhn-Tucker theory, Constraint Qualifications, Convex optimization<br>Merit functions for constrained minimization, logarithmic barrier function for inequality constraints, A basic barrier-function algorithm<br>Practice of algorithms using Software. |
| **Learning Outcome** | On successful completion of the course, students should be able to:<br>1. Understand different Matrix factorization method and employ them to solve linear equations and linear least square problems<br>2. To comprehend the basic computer arithmetic and the concepts of conditioning and stability of a numerical method.<br>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** | **EAI 6101** |
| **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.<br><br>**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.<br><br>**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.<br><br>**Module 4:** Data compression: Necessity, Applications, Lossless compression techniques, Lossy compression techniques, JPEG compression, Machine learning based.<br><br>**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<br><br>● 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.<br>• 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, $4^{th}$ Edition, Springer, 2007

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|---|---|
| **Course Number** | **EAI 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:<br>(a) Understand the advanced topics of pattern recognition, including classification and clustering methods.<br>(b) To understand the advanced topics of feature selection, multi-label classification.<br>(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<br>• Modern Classification Methods, Random fields, Pattern recognition based on multidimensional models<br>• Contextual classification, Hidden Markov models, Multi-classifier systems<br>• Advanced parameter estimation methods, Advanced Unsupervised classification, Modern methods of feature selection.<br>• Data normalization and invariants, Benchmarking.<br>• Analysis and synthesis of image information.<br>• Applications od pattern recognition in Text Processing and Healthcare. |
| **Learning Outcome** | • Mastery of advanced concepts in pattern recognition.<br>• In-depth understanding of various advanced algorithms across different pattern recognition paradigms.<br>• Comprehensive knowledge of advanced aspects of classification, clustering, feature selection, feature extraction, and projection techniques.<br>• Ability to apply advanced pattern recognition algorithms to real-world projects |

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| **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.

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|---|---|
| **Course Number** | **EAI 6103** |
| **Course Credit** | L-T-P-C: 3-0-0-3 |
| **Course Title** | **Advance Machine Learning** |
| **Learning Mode** | Online |
| **Learning Objectives** | This course aims to help the students to understand the advanced machine learning techniques and its application in various dimensions. |
| **Course Description** | This course will concentrate on some advanced topics of machine learning like graphical models, auto-encoders, GANs, time series forecasting, advanced unsupervised classification algorithms, neural architectures for sequence and graph-structured predictions. When appropriate, the techniques will be linked to applications in translation, conversation modeling, and information retrieval. |
| **Course Outline** | Mathematics of machine learning, Overview of supervised, unsupervised learning and Multi-task learning.<br><br>Undirected graphical models: Overview, representation of probability distribution and conditional independence statement, Factorization, CRFs, Applications to NLP.<br><br>Deep Networks for Sequence Prediction: Encoder-decoder models (case study translation), Attention models, LSTM, Memory Networks.<br><br>Deep Network for Generation: Sequence to Sequence Models, Variational Auto-encoders, Generative Adversarial Networks (GANs), Pointer Generator Networks, Transformer Networks, Learning Representations, Learning representations for text<br><br>Models for continuous variables: Time series forecasting, Modern clustering techniques, Recent topics for solving various problems of natural language processing, bioinformatics information retrieval. |
| **Learning Outcome** | ● Students can design and implement advanced machine learning models, such as deep learning, and transfer learning.<br>● Students can apply advanced techniques, such as attention mechanisms, generative adversarial networks (GANs), and transformers.<br>● Students can analyze and solve challenging machine learning problems, including those involving large datasets, high-dimensional spaces, and complex relationships. |
| **Assessment Method** | Quiz / Assignment / ESE |

## <u>Textbook:</u>


- Kevin P. Murphy. Machine Learning: A Probabilistic Perspective. MIT Press 2012.
- Ian Goodfellow, Yoshua Bengio and Aaron Courville. Deep Learning. MIT Press 2016.

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|---|---|
| **Course Number** | **EAI 6201** |
| **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<br>● Feature engineering: Basics of machine learning (linear regression, classification)<br>● Neural network: Deep feed forward network, cost function, activation functions, overfitting, underfitting, Universal approximation theorem<br>● Gradient based learning: DG, SGD, Backpropagation<br>● Regularization: L2, L1, L\infinity, drop-out, early stopping, data augmentation, etc.<br>● Optimization: Multivariable taylor series, momentum, adaptive learning rate, ADAM, Nesternov, AdaGrad, etc.<br>● CNN: CNN and its application in computer vision<br>● RNN: RNN, LSTM, GRU and their applications in NLP<br>● Advanced topics: Autoencoder, Transformer, Deep reinforcement learning |
| **Learning Outcome** | ● Basic understanding of deep learning and neural networks.<br>● Problem modeling skill<br>● Usage of different open source tools / libraries.<br>● 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.

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|---|---|
| **Course Number** | **EAI 6202** |
| **Course Credit** | L-T-P-C: 3-0-0-3 |
| **Course Title** | **Physics of Neural Network** |
| **Learning Mode** | Online |
| **Learning Objectives** | This course aims to help the students (a) Comprehend the basic models and structures of neural networks, including the structure and function of the central nervous system, associative memory, and information storage and recall principles. (b) Gain detailed knowledge of various neuron types, such as stochastic and cybernetic neurons, and different network architectures, including layered and perceptron networks.(c) Learn to apply neural network models to practical applications such as time series prediction, game playing (e.g., Backgammon), and protein structure prediction, as well as exploring their use in biomedicine and economics.(d) Delve into advanced topics like pattern recognition, unsupervised learning, evolutionary algorithms, combinatorial optimization, VLSI, specialized networks (e.g., Hopfield networks, Kohonen maps), and advanced learning techniques like back-propagation and solving optimization problems. |
| **Course Description** | This course offers a comprehensive exploration of neural networks, encompassing their fundamental models, the structure of the central nervous system, and a brief historical overview. Students will delve into the core principles of associative memory, information storage and recall, and learning mechanisms such as Hebb's rule. The curriculum covers a variety of neuron types, including stochastic and cybernetic neurons, and introduces layered and perceptron network architectures. Throughout the course, students will investigate practical applications of neural networks, ranging from time series prediction to strategic game playing (e.g., Backgammon) and protein structure prediction. The course also highlights the role of neural networks in biomedicine and economics, showcasing their versatility and impact. Advanced topics are thoroughly explored, including pattern recognition, unsupervised learning, and evolutionary algorithms. Students will engage with combinatorial optimization, VLSI design, and specialized network models such as Hopfield networks and Kohonen maps. The course emphasizes the significance of back-propagation, learning functions, and optimization problem-solving techniques. By the end of the course, students will have a deep understanding of neural networks' theoretical foundations and practical applications, equipping them with the skills to leverage these powerful tools in various scientific and industrial domains. |
| **Course Outline** | Models of Neural Networks, A Brief History of Neural Network Models, Prediction of the Secondary Structure of Proteins, Associative Memory for Time Sequences. |

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| **Learning Outcome** | 1. Understand the basic concept of PINN<br>2. Apply the concept of Partial Differential in PINN<br>3. Analysis of Optimization techniques for PINNs.<br>4. Demonstrate the practical utility of PINNs in handling complex, real-time applications that require efficient and accurate simulations. |
| **Assessment Method** | Quiz / Assignment / ESE |

**TEXTBOOKS:**

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

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| **Course Number** | **EAI 6203** |
| **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.<br>● Gain proficiency in building predictive models using data-driven techniques.<br>● Learn to apply predictive analytics for solving business problems and decision-making.<br>● Explore tools and software used for predictive analytics, such as Python and R.<br>● 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**<br>• Definition and importance of predictive analytics.<br>• The role of data in predictive analytics: types of data (structured vs. unstructured).<br>• Introduction to the predictive modeling process.<br>• Understanding the difference between descriptive, predictive, and prescriptive analytics.<br>• Applications of predictive analytics in business: customer churn, credit scoring, fraud detection, etc.<br><br>**Module 2: Data Preparation for Predictive Modeling**<br>• Data collection, cleaning, and preprocessing.<br>• Handling missing data, outliers, and imbalanced datasets.<br>• Feature engineering: creating meaningful features from raw data.<br>• Data partitioning: training, testing, and validation datasets.<br>• Data transformation techniques: normalization and standardization.<br><br>**Module 3: Predictive Modeling Techniques**<br>• **Regression Analysis:**<br>o Linear regression, multiple regression, and polynomial regression.<br>o Assumptions of regression models and diagnostics.<br>• **Classification Techniques:**<br>o Logistic regression, decision trees, and random forests.<br>o Support Vector Machines (SVM) and k-Nearest Neighbors (k-NN).<br>o Gradient boosting and ensemble methods (XGBoost, AdaBoost).<br>• **Time Series Forecasting:**<br>o ARIMA, exponential smoothing, and seasonal decomposition. |

<table>
<tr><td></td><td>
<ul><li style="list-style-type:circle">Trends, seasonality, and forecasting future values.</li></ul>
Module 4: Machine Learning in Predictive Analytics
<ul>
<li>Introduction to supervised learning: classification and regression.</li>
<li>Key machine learning algorithms for predictive analytics:
<ul><li>Decision Trees, Random Forests, and Gradient Boosting Machines.</li>
<li>Support Vector Machines (SVM) and Neural Networks.</li></ul></li>
<li>Model selection and hyperparameter tuning using cross-validation.</li>
<li>Introduction to unsupervised learning for pattern recognition (clustering, association).</li>
</ul>
Module 5: Model Evaluation and Optimization
<ul>
<li>Performance metrics for regression: R-squared, Mean Absolute Error (MAE), Mean Squared Error (MSE).</li>
<li>Performance metrics for classification: Confusion Matrix, Precision, Recall, F1-Score, AUC-ROC curve.</li>
<li>Overfitting and underfitting: strategies to prevent overfitting (regularization, cross-validation).</li>
<li>Model tuning and optimization techniques: Grid Search, Random Search, and Hyperparameter Tuning.</li>
<li>Interpreting the results and communicating insights effectively.</li>
</ul>
Module 6: Advanced Topics in Predictive Analytics
<ul>
<li>Introduction to deep learning techniques in predictive analytics.</li>
<li>Using predictive analytics for real-time data and streaming analytics.</li>
<li>Ethical considerations in predictive analytics: fairness, transparency, and accountability.</li>
<li>Case studies and industry applications of predictive analytics: healthcare, finance, marketing, etc.</li>
<li>Practical implementation using Python or R with libraries like scikit-learn, TensorFlow, and statsmodels.</li>
</ul>
</td></tr>
<tr><td>Learning Outcome</td><td>
<ul>
<li>Comprehensive understanding of big data frameworks like Hadoop and Spark.</li>
<li>Ability to design and implement scalable data pipelines for batch and real-time processing.</li>
<li>Proficiency in managing and optimizing distributed data storage and processing systems.</li>
<li>Practical skills in working with various components of the Hadoop ecosystem and Spark framework.</li>
<li>Knowledge of best practices for big data security, performance tuning, and scalability.</li>
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</td></tr>
<tr><td>Assessment Method</td><td>Quiz / Assignment / End Semester Exam (ESE)</td></tr>
<tr><td colspan="2">TEXTBOOKS:</td></tr>
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| **Course Number** | **EAI 6204** |
| **Course Credit** | L-T-P-C: 3-0-0-3 |
| **Course Title** | **Federated Learning** |
| **Learning Mode** | Online |
| **Learning Objectives** | This course aims to help the students (a) Grasp Foundational Concepts and Developments of Federated Learning (FL), and stay informed about current developments and emerging trends in the field. (b) Implement Privacy and Security Techniques including privacy-preserving machine learning (PPML), privacy-preserving gradient descent, and threat and security models to ensure data confidentiality and integrity in FL systems. (c) Mastering horizontal and vertical FL architectures (HFL, VFL) and algorithms, such as the federated averaging algorithm and its enhancements. (d) FL techniques to practical applications in computer vision, natural language processing (NLP), and reinforcement learning, demonstrating the practical benefits and addressing limitations in these domains. |
| **Course Description** | This course offers a comprehensive exploration of Federated Learning (FL), a cutting-edge approach to collaborative machine learning where models are trained across decentralized devices or servers holding local data samples. The course begins with an introduction to FL, defining its principles, categories, and current developments in the field. Students will delve into essential topics such as privacy-preserving techniques, including privacy-preserving machine learning (PPML) and secure machine learning methods, to ensure data security and confidentiality in distributed learning environments. The curriculum covers scalable distributed machine learning (DML) techniques tailored for FL, addressing challenges in model aggregation and performance across heterogeneous data sources. Key architectural paradigms like horizontal and vertical FL (HFL, VFL) will be explored, alongside algorithms such as federated averaging and advancements in optimization for FL scenarios. The course emphasizes practical applications of FL in domains like computer vision, natural language processing (NLP), and reinforcement learning, showcasing its utility and addressing real-world challenges.By the end of the course, students will have a deep understanding of FL principles, techniques, and applications. They will be equipped to design and implement secure, scalable, and privacy-aware machine learning solutions suitable for collaborative environments with distributed data sources. |
| **Course Outline** | Introduction to Federated Learning, Current Development in Federated Learning, Privacy-Preserving Machine Learning, Horizontal Federated Learning, Vertical Federated Learning. |
| **earning Outcome** | ● Understand the principles, definitions, and categories of federated learning<br>● Apply various privacy-preserving machine learning<br>● Design and improve federated learning algorithms, such as the federated averaging algorithm. |

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| | • Utilize federated learning frameworks for practical applications in computer vision, natural language processing, reinforcement learning, and other areas. |
| **Assessment Method** | Quiz / Assignment / ESE |

**Suggested Reading**


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

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|---|---|
| **Course Number** | **EAI 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.<br>• Learn various AI techniques and their applications in IoT, including machine learning, deep learning, and data analytics.<br>• Develop skills in designing and implementing IoT systems, integrating sensors, and managing data flow.<br>• Understand the processes for collecting, storing, processing, and analyzing IoT data using AI techniques.<br>• Identify and mitigate security risks and privacy concerns in AIoT systems.<br>• Analyze various real-world applications of AIoT in industries such as healthcare, smart cities, agriculture, and manufacturing.<br>• 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<br>• Fundamentals of IoT, IoT Architecture and Protocols, Layers of IoT architecture, Communication protocols and standards, IoT Devices and Sensors<br>• Fundamentals of Artificial Intelligence, Machine Learning and Deep Learning, Overview of AI tools and frameworks<br>• AIoT System Architecture, Components and Designing AIoT, Edge Computing in AIoT, Edge vs. cloud computing, AI Models for IoT<br>• Data Management in AIoT, Data Processing and Analysis, Handling large-scale IoT data, Big data technologies and platforms<br>• AIoT Applications and Use Cases: Smart Homes and Buildings, Healthcare and Wearables, Industrial IoT (IIoT), Smart Cities and Transportation<br>• 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. |

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| | • Students should grasp the foundational concepts of AI and IoT, including machine learning algorithms, data analytics, sensor technologies, and network protocols.<br>• 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.<br>• Proficiency in developing AI-driven IoT applications, including sensor data processing, predictive analytics, anomaly detection, and automation.<br>• Awareness of security challenges and solutions in AIoT systems, including data privacy, authentication, encryption, and intrusion detection.<br>• 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.

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| **Course Number** | **EAI 6302** |
| **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.<br>• Apply pre-processing techniques to clean and prepare text data for analysis, such as tokenization, lemmatization, stemming, and stop-word removal.<br>• 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).<br>• 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.<br>• 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.<br>• Apply text pre-processing techniques to prepare data for analysis, including tokenization, stemming, and lemmatization.<br>• Utilize various feature extraction and representation methods such as bag-of-words, TF-IDF, and word embeddings.<br>• Develop and evaluate both traditional machine learning models and advanced deep learning models for a range of NLP tasks.<br>• 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.<br>• Demonstrate a solid understanding of key concepts in NLP, including tokenization, stemming, lemmatization, and part-of-speech tagging.<br>• Apply techniques for text pre-processing and cleaning, including removing stop words, normalizing text, and handling noisy data. |

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| | • Implement and evaluate methods for feature extraction and representation, such as bag-of-words, TF-IDF, and word embeddings (e.g., Word2Vec, GloVe).<br>• 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).<br>• 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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| **Course Number** | **EAI 6303** |
| **Course Credit** | L-T-P-C: 3-0-0-3 |
| **Course Title** | **Blockchain Technologies: Platforms and Applications** |
| **Learning Mode** | Online |
| **Learning Objectives** | ● Articulate blockchain platforms that show promise in solving complex business problems<br>● Examine the life cycle of a chain code and its components<br>● Implement various blockchain-based enterprise applications |
| **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 BLOCKCHAIN TECHNOLOGIES**<br>● Introduction to Blockchain Technologies<br>● Overview of Blockchain Platforms: Ethereum, Hyperledger Project, IBM Blockchain, Multichain, Hydrachain, Ripple, R3 Corda, BigChainDB, IPFS<br><br>**Module 2 - ETHEREUM SMART CONTRACTS**<br>● Introduction to Smart Contracts<br>● Solidity Programming Language<br>● Contract Creation and Deployment<br>● Web3js and RPC Protocols<br>● Miners, Transactions, and Blocks in Ethereum<br>● Front-End Development with React and Web3<br><br>**Module 3 - HYPERLEDGER FABRIC**<br>● Introduction to Hyperledger Fabric<br>● Fabric Model<br>● Identity Management in Fabric: Membership Service Provider (MSP)<br>● Policies in Fabric<br>● Ledgers in Fabric: World State and Transaction Log<br>● Chaincode in Fabric: Writing and Deploying Smart Contracts<br>● Endorsement Peers and Endorsement Policies in Fabric<br><br>**Module 4 - ADVANCED TOPICS IN BLOCKCHAIN TECHNOLOGIES**<br>● Ordering Nodes in Hyperledger Fabric: Solo Ordering Service, Kafka<br>● Committing Peers and Anchor Peers in Hyperledger Fabric<br>● Private Data Sharing in Hyperledger Fabric: Sharing Private Data, Private Data Sharing Patterns<br>● Key-level Transaction Access Control and Endorsement in Hyperledger Fabric<br>● Setting up a Production Network on Hyperledger Fabric |

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| **Learning Outcome** | • Comprehensive understanding of big data frameworks like Hadoop and Spark.<br>• Ability to design and implement scalable data pipelines for batch and real-time processing.<br>• Proficiency in managing and optimizing distributed data storage and processing systems.<br>• Practical skills in working with various components of the Hadoop ecosystem and Spark framework.<br>• Knowledge of best practices for big data security, performance tuning, and scalability. |
| **Assessment Method** | Quiz / Assignment / End Semester Exam (ESE) |

**TEXTBOOKS:**


- Tom Serres, Bill Wagner and Bettina Warburg, Basics of Blockchain (1 ed.), missing, 2019. ISBN 9781089919441.
- a) Gaur and Nitin, Hands-On Blockchain with Hyperledger: Building decentralized applications with Hyperledger Fabric an (1 ed.), Packt Publishing Ltd, 2018. ISBN 978-17889945

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| **Course Number** | **EAI 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:<br>a) How and why cloud systems work and the cloud technologies that manifest these concepts, such as those from Amazon AWS and Microsoft Azure;<br>b) Distributed systems concepts like virtualization, data parallelism, CAP theorem, and performance analysis at scale;<br>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;<br>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.<br>• Network Virtualization and Geo-distributed Clouds.<br>• Leader Election in Cloud, Distributed Systems, and Industry Systems.<br>• Classical Distributed Algorithms and Industry Systems.<br>• Consensus, Paxos, and Recovery in Clouds.<br>• Cloud Storage: Key-value Stores/NoSQL Systems and their Use in Industry Systems.<br>• Cloud Applications: MapReduce, Spark, and Apache Kafka.<br>• 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.<br>• 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.<br>• Programming Patterns for "Big Data" Applications on Cloud: Demonstrate using Map-Reduce, Vertex-Centric and Continuous Dataflow programming models.<br>• Application Execution Models on Clouds: Compare synchronous and asynchronous execution patterns. Design and implement Cloud |

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| | applications that can scale up on a VM and out across multiple VMs. Illustrate the use of NoSQL Cloud storage for information storage.<br>• 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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|---|---|
| **Course Number** | **EAI 6401** |
| **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:<br>**(a)** Understand the foundational concepts and mathematical frameworks of reinforcement learning.<br>**(b)** Gain proficiency in key reinforcement learning algorithms, including dynamic programming, Monte Carlo methods, and temporal-difference learning.<br>**(c)** Apply deep reinforcement learning techniques to solve complex problems using methods such as deep Q-networks and policy gradient algorithms.<br>**(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.<br>• **Probability Concepts**: Axioms of probability, random variables, distributions, and correlation.<br>• **Markov Decision Process**: Introduction to MDPs, Markov property, and Bellman equations.<br>• **State and Action Value Functions**: Concepts of MDP, state, and action value functions.<br>• **Tabular Methods and Q-networks**: Dynamic programming, Monte Carlo, TD learning, and deep Q-networks.<br>• **Policy Optimization**: Policy-based methods, REINFORCE algorithm, and actor-critic methods.<br>• **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. |

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| | 2. Proficiency in implementing key reinforcement learning algorithms and techniques.<br>3. Ability to apply deep reinforcement learning methods to complex, real-world problems.<br>4. Understanding of recent advancements in reinforcement learning and their ethical implications. |
| **Assessment Method** | Quiz / Assignment / 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)

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| **Course Number** | **EAI 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 |

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| **Learning Outcome** | 1. Understand and articulate the foundational principles of meta-learning<br>2. Apply probabilistic modeling and Bayesian inference to quantify uncertainty and improve model robustness in decision-making processes.<br>3. Analysis of Optimization-Based Meta-Learning Approaches.<br>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).

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| **Course Number** | **EAI 6403** |
| **Course Credit** | L-T-P-C: 3-0-0-3 |
| **Course Title** | **Selective Topics in Generative AI** |
| **Learning Mode** | Online |
| **Learning Objectives** | ● To gain a comprehensive understanding of advanced AI architectures, particularly in the context of Generative AI.<br>● To develop proficiency in implementing and evaluating a variety of Generative AI techniques and models.<br>● To understand the principles and applications of Generative Pre-trained Transformers and other application-specific architectures.<br>● To explore and address ethical considerations and biases in Generative AI, emphasizing the importance of explainability.<br>● To engage with advanced topics and apply knowledge through hands-on projects. |
| **Course Description** | This course provides an in-depth exploration of Generative AI (GenAI), focusing on advanced AI architectures such as Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), and Generative Pre-trained Transformers (GPT). Students will learn about hybrid and emerging models, application-specific architectures, and the ethical considerations and biases in Generative AI. The course includes hands-on projects to design, implement, and evaluate sophisticated generative AI models, emphasizing innovation and practical problem-solving skills. |
| **Course Outline** | Introduction to advanced AI, overview of advanced AI architectures and Generative AI (GenAI)<br>Generative Adversarial Network (GAN): various GAN architectures, DCGAN<br>Advanced Variational AutoEncoder (VAE): hierarchical VAEs, Semi-supervised VAE<br>Hybrid and emerging models: Energy-based models, diffusion models, autoregressive and flow-based models, attention mechanism in generative models<br>Generative Pre-trained Transformers (GPT): architectural details and variations.<br>Advanced application-specific architecture: Models for Image-to-Text generation, Text-to-Image generation, Prompt engineering, Multimodality<br>Ethical consideration and bias in Generative AI, Explainability<br>Some advanced topics and project |
| **Learning Outcome** | By the end of the course, students will be able to:<br>● Master various Generative AI architectures, including GANs, VAEs, and emerging models. |

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| | ● Demonstrate proficiency in implementing and evaluating advanced Generative AI techniques, such as hierarchical VAEs and energy-based models.<br>● Understand the design principles and applications of Generative Pre-trained Transformers (GPT) and application-specific architectures.<br>● Analyze and address ethical considerations and biases in Generative AI, emphasizing the importance of explainability.<br>● 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:**

# INDIAN INSTITUTE OF TECHNOLOGY PATNA

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

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| **Course Number** | **EAI 6404** |
| **Course Credit** | L-T-P-C: 3-0-0-3 |
| **Course Title** | **Text Mining and Analytics** |
| **Learning Mode** | Online |
| **Learning Objectives** | ● To understand the fundamental principles and scope of text mining and analytics.<br>● To acquire skills in data collection, cleaning, and integration for text data.<br>● To learn text preprocessing techniques including tokenization, stemming, stopword removal, and normalization.<br>● To construct knowledge graphs by linking entities and extracting relationships.<br>● To identify and mine frequent patterns and apply advanced pattern mining techniques.<br>● To extract features from text data and apply clustering and classification methods.<br>● To implement practical applications such as sentiment analysis and text summarization.<br>● To utilize advanced techniques for enhanced text data analysis and mining. |
| **Course Description** | This course provides a comprehensive understanding of the principles and techniques of text mining and analytics. Students will learn about data collection, cleaning, integration, and preprocessing methods essential for handling text data. The course covers knowledge graph construction, pattern mining, feature extraction, and advanced text clustering and classification techniques. Practical applications such as sentiment analysis and text summarization are also explored. By the end of the course, students will be prepared to tackle real-world challenges in data mining and text analytics. |
| **Course Outline** | Text mining and analytics introduction: Overview, motivation, scope.<br>Data Collection and Pre-processing: Techniques for collecting data from various sources.<br>Text data cleaning and integration, descriptive analytics.<br>Text preprocessing: tokenization, stemming, stopword removal, and normalization.<br>Knowledge graph construction: Basics of graphs, entity linking, relationship extraction.<br>Concepts of frequent patterns, closed patterns, max-patterns, and association rules, mining frequent patterns: apriori algorithm, pattern-growth approach.<br>Advanced: mining sequential patterns.<br>Feature extraction, Bag-of-Words, TF-IDF, word embeddings Clustering and classifying text data, Expectation-maximization (EM) algorithm for text data, |

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| | Latent Dirichlet Allocation (LDA) for topic modeling, and some advanced techniques.<br>Some applications: sentiment analysis, text summarization, etc.<br>Some advanced topics and project. |
| **Learning Outcome** | ● By the end of this course, students will be able to:<br>● Understand the core principles and scope of text mining and analytics.<br>● Collect, clean, and integrate text data from various sources.<br>● Apply text preprocessing techniques such as tokenization, stemming, and normalization.<br>● Construct and utilize knowledge graphs for entity linking and relationship extraction.<br>● Identify and mine various patterns in text data, including frequent, closed, and sequential patterns.<br>● Extract features from text data using methods like Bag-of-Words, TF-IDF, and word embeddings.<br>● Perform text clustering and classification using algorithms such as EM and LDA.<br>● Implement practical text analytics applications such as sentiment analysis and text summarization.<br>● Utilize advanced techniques for enhanced text data analysis and mining. |
| **Assessment Method** | ● Quiz / Assignment / ESE |

**Suggested Reading**


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