Indian Institute of Technology Jodhpur

Course Booklet

for

# M.Tech. (AI)

and

# Dual degree M.Tech. (AI) + PhD

Programs

offered by the

**Department of Computer Science and Engineering**

**July 2019**

**M.Tech in Artificial Intelligence (AI)**

**Introduction:**

Artificial Intelligence (AI) is a branch of computer science that aims to create machines to act with higher levels of intelligence and emulate the human capabilities of sense, comprehend and act. The core problems of artificial intelligence include programming computers for certain traits such as Knowledge, Reasoning, Problem-solving, Perception, Learning and Planning. AI technology development and applications are evolving rapidly with major implications for economies and societies. As the demand for such applications increases, there is also an increasing need for building the future workforce for AI. For developing the AI ecosystem, this program will be executed in synergy with other M.Tech programs running in IIT Jodhpur, such as Sensors & IoT, Cyber-Physical Systems, and Advanced Manufacturing and Design.

**Objectives:**

This M.Tech in AI programme will offer students with deep knowledge of both fundamental AI technologies, as well as application-oriented AI. A student completing this program will be capable to undertake careers in industry as well as academia. He/She will have the option to explore a variety of domains including Manufacturing, Fintech, Healthcare, Agriculture/Food Processing, Education, Retail/Customer Engagement, Human and Robot interaction/intelligent automation, Smart City , Aid for Differently Abled/Accessibility Technology.

**Expected Graduate Attributes:**

After completing this programme, a student will be able to develop an ability to:

1. Comprehend fundamental concepts and hands-on knowledge of the state-of-the-art AI methodologies.
2. Design and Build real-world AI systems for complex planning, decision making and learning, solving application-specific problems, and to reason about them.
3. Conceive, Design and Develop Intelligent multi-modal multi-sensory Man-Machine interfaces.
4. Design, Develop and Deploy machine learning based applications using structured and unstructured data (e.g., speech, text, images/videos).
5. Understand and Assess reliability, dependability and trust-worthiness of AI-based systems.
6. Design and develop AI applications for resource constrained environments.
7. Adhere to evolving ethics and privacy laws across various domains and territories.
8. Plan and manage technical projects.

**Learning Outcome:**

1. Understand the fundamentals of Artificial Intelligence, Machine Learning, Inference Engines, Speech, Vision, Natural Language Understanding, Robotics, and Human Computer Interaction.
2. Unify the knowledge of human cognition, AI, Machine Learning and data engineering for designing systems.
3. Demonstrate hands-on knowledge of state-of-the-art AI tools for real-world problem-solving.
4. Ability to develop real-time and robust AI-based systems with specific software, hardware and data requirements.
5. Build solutions to explore fully immersive computer-generated worlds (in VR), and overlay computer graphics onto our view of our immediate environment (AR) along with smart, cognitive functionality.
6. Demonstrate advanced skills to comprehend and communicate effectively.
7. Carry out projects using intelligent cognitive solutions provided by AI algorithms to get more insights in stakeholder management, risk modeling, intelligent resource scheduling and managing project constraints with intelligent use of data models.

Course Structure for

# M.Tech. (AI) Program and Dual degree M.Tech. (AI) + PhD

| Cat | Code | Course Title | L-T-P | Cr |
|---|---|---|---|---|
| **I Semester** | | | | |
| C | MAL7xx0 | Statistics I<br>Matrix Computation<br>Optimization | 1-0-0<br>1-0-0<br>1-0-0 | 3 |
| C | CSL7xx0 | Artificial Intelligence I | 3-0-0 | 3 |
| C | CSL7xx0 | Machine Learning I | 3-0-0 | 3 |
| C | CSP7xx0 | Data Structures and Practices | 0-0-2 | 1 |
| PE | xxxxx | Program Elective 1 | 3-0-0 | 3 |
| PE | xxxxx | Program Elective 2 | 3-0-0 | 3 |
| | xxxxx | Technical Communication | 1-0-0 | 1 |
| | | | Total Credits: 17 | |

| Cat | Code | Course Title | L-T-P | Cr |
|---|---|---|---|---|
| **II Semester** | | | | |
| C | CSL8xx0 | Artificial Intelligence II | 3-0-0 | 3 |
| C | CSL8xx0 | Machine Learning II | 3-0-0 | 3 |
| C | CSL8xx0 | Real Time Autonomous Systems | 2-0-0 | 2 |
| PE | xxxxx | Program Elective 3 | 3-0-0 | 3 |
| OE | xxxxx | Open Elective 1 | 3-0-0 | 3 |
| NG | xxxxx | Ethics and Professional Life | 1-0-0 | 1 |
| | | | | |
| | | | Total Credits: 15 | |

*Maths Fractals: Linear Algebra, Probability and Random Processes, Optimization

| Cat | Code | Course Title | L-T-P | Cr |
|---|---|---|---|---|
| **III Semester** | | | | |
| P | CSDxx0 | Major Project – Part 1 | 0-0-10 | 5 |
| PE | xxxxx | Program Elective 4 | 3-0-0 | 3 |
| PE | xxxxx | Program Elective 5 | 3-0-0 | 3 |
| OE | xxxxx | Open Elective - 2 | 3-0-0 | 3 |
| NG | xxxxx | System Engineering and Project Management | 1-0-0 | 1 |
| | | | Total Credits: 15 | |

| Cat | Code | Course Title | L-T-P | Cr |
|---|---|---|---|---|
| **IV Semester** | | | | |
| P | CSDxx0 | Major Project – Part 2 | 0-0-22 | 11 |
| PE | xxxxx | Program Elective 6 | 3-0-0 | 3 |
| NG | xxxxx | Intellectual Property | 1-0-0 | 1 |
| | | | | |
| | | | | |
| | | | Total Credits: 15 | |

| Credit Distribution | | |
|---|---|---|
| 1 | Program Core | 18 credits |
| 2 | Program Electives | 18 credits |
| 3 | Open Electives | 6 credits |
| 4 | Project | 16 credits |
| 5 | Non-graded | 4 credits |
| | Total | 62 credits |

# Program Electives for M.Tech. (AI) and Dual Degree M.Tech. (AI)+Ph.D. Program

Courses offered by Department of Computer Science and Engineering

- Advanced Computer Graphics
- Algorithms for Big Data
- AI for Finance
- Bio-image computing
- Blockchain
- Computer Graphics
- Computer Vision
- Computational Optimization
- Computer Architecture
- Data Visualization
- Dependable AI
- Digital Image Analysis
- Edge and Fog Computing
- Embedded Systems
- GPU Programming
- Graph Theory and Applications
- Human Machine Interface
- Information Retrieval and Web Mining
- Introduction to Augmented Reality and Virtual Reality
- Machine Learning with Big Data
- Natural Language Processing
- Neuromorphic Computing and Design
- Ad hoc Wireless Networks
- Selected Topics in Artificial Intelligence - I
- Selected Topics in Artificial Intelligence - II
- Selected Topics in Artificial Intelligence - III
- Selected Topics in Computer Science - I
- Selected Topics in Computer Science - II
- Selected Topics in Computer Science - III
- Social Network Analysis
- Software and Data Engineering
- Security and its Applications
- Speech processing
- Stream Analytics
- Vehicular Ad-hoc Networks (VANETs)

Courses offered by Department of Electrical Engineering

- Adaptive Signal Processing
- Advanced Control System
- Advanced Digital Communication
- Advanced Signal Processing
- Analog and Interfacing Circuits

- Antenna Engineering
- Applied Optimization for Wireless Communication
- Backhaul Networks for Wireless Systems
- Coding Theory
- Compressive Sensing
- Computational Imaging
- Cyber Physical System Modelling Laboratory
- Data Compression
- Digital image and Video Processing Lab
- Digital Image Processing and Applications
- Digital Signal Processing
- Digital Video Processing
- Digital VLSI  Design
- Embedded System Design
- Embedded System Design Lab
- Flexible and Printed Electronics
- Free Space Optical Communications
- GNSS Signal Processing
- Image Sensor Design and Applications
- Introduction to Cyber-Physical Systems
- Machine Learning for Communication
- Mathematical Modelling and Simulation
- Microfluidics Technology
- Microsystems Fabrication Technology
- Millimeter Wave Technology
- Multi-rate Digital Signal Processing
- Nanosensors
- Network Information Theory
- Neuromorphic computing and design
- Optical Fiber Communications
- Optimal Filtering
- Physical Layer Security
- Principles of Data and System Security
- Real Time Communications
- Resource Constrained AI
- RF IC Design
- RF IC Design Lab
- Selected Topics in Communication I
- Selected Topics in Communication I
- Selected Topics in Communication II
- Selected Topics in Communication III
- Selected Topics in Sensors & IoT I
- Selected Topics in Sensors & IoT II
- Selected Topics in Sensors & IoT III
- Selected Topics in Signal Processing I
- Selected Topics in Signal Processing II

- Selected Topics in Signal Processing III
- Sensors and IoT Lab
- Sensors and Measurement
- Smart Grid
- Speech and Audio Signal Processing
- Statistical Decision Theory
- Systems-on-Chips Design
- VLSI Design Lab
- Wavelets
- Wireless Communication
- Wireless Networks

Courses offered by Department of Mechanical Engineering

- Robotics

Courses offered by Department of Bioscience and Bioengineering

- Bioinformatics
- Computational Biology

Courses offered by Department of Mathematics

- Financial Engineering
- Computational finance
- Computational Game Theory
- Advanced topics in computational PDE
- Dynamical Systems
- Stochastic Processes
- Representation of Finite Groups

Courses offered by Department of Physics

- Quantum Computing
- Quantum Information Processing
- Quantum Cryptography and Coding

Courses offered by IDRP Digital Humanities

- Digital Humanities

| Title | **Data structures and practices** | Number | CSP7XX0 |
|---|---|---|---|
| Department | Computer Science and Engineering | L-T-P [C] | 0–0–2 [1] |
| Offered for | M.Tech. | Type | Compulsory |
| Prerequisite | Computer Programming | | |

**Objectives**

The Instructor will:

1. Explain various data structures and provide details to implement and use them in different algorithms

**Learning Outcomes**

The students are expected to have the ability to:

1. Write, debug and rectify the programs using different data structures
2. Expertise in transforming coding skills into algorithm design and implementation

**Contents**

**Laboratory Experiments**

Exercises based on

*Abstract Data Types:* Arrays, link-list/list, hash tables, dictionaries, structures, *stack, queues* (4 labs)

*Data Structures:* Heap, Sets, Sparse matrix, Binary Search Tree, B-Tree/ B+ Tree, Graph (4 labs)

*Algorithm implementation:* Quick or Merge sort, Breadth or Depth first search or Dijkstra's Shortest Path First algorithm, Dynamic programing (6 labs)

**Textbook**

1. Weiss, M. A. (2007), Data Structures and Algorithm Analysis in C++, Addison-Wesley.
2. Lipschutz, S. (2017), Data Structures with C, McGraw Hill Education.
3. Cormen, T. H., Leiserson, C. E., Rivest, R. L. and Stein, C., (2009), Introduction to Algorithms, MIT Press.

**Online Course Material**

1. Department of Computer Science and Engineering, IIT Delhi, http://www.nptelvideos.in/2012/11/data-structures-and-algorithms.html

| Title | **Artificial Intelligence I** | Number | CSL7XX0 |
|---|---|---|---|
| Department | Computer Science and Engineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | M.Tech. 1st Year, Ph.D. 1st Year | Type | Compulsory |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Cover various paradigms that come under the broad umbrella of AI.

**Learning Outcomes**

The students are expected to have the ability to:

1. Develop an understanding of where and how AI can be used.

**Contents**

*Introduction* (1 lecture)
*Propositional logic* (8 lectures)
*Search:* Uninformed strategies (BFS, DFS, Dijkstra), Informed strategies (A* search, heuristic functions, hill-climbing), Adversarial search (Minimax algorithm, Alpha-beta pruning) (10 lectures)
*Predicate logic:* Knowledge representation, Resolution (6 lectures)
*Rule-based systems:* Natural language parsing, Context free grammar (3 lectures)
*Constraint satisfaction problems* (4 lectures)
*Planning:* State space search, Planning Graphs, Partial order planning (4 lectures)
*Uncertain Reasoning:* Probabilistic reasoning, Bayesian Networks, Dempster-Shafer theory, Fuzzy logic (6 lectures)

**Textbook**

1. Russel,S., and Norvig,P., (2015), *Artificial Intelligence: A Modern Approach*, 3rd Edition, Prentice Hall

**Reference Books**

1. Research literature

**Self Learning Material**

1. Department of Computer Science, University of California, Berkeley, http://www.youtube.com/playlist?list=PLD52D2B739E4D1C5F
2. NPTEL: Artificial Intelligence, https://nptel.ac.in/courses/106105077/

| Title | **Artificial Intelligence II** | Number | CSL8XX0 |
|---|---|---|---|
| Department | Computer Science and Engineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | M.Tech. 1st Year, Ph.D. 1st Year | Type | Compulsory |
| Prerequisite | Artificial Intelligence-1 | | |

**Objectives**

The Instructor will:

1. Cover modern paradigms of AI that go beyond traditional learning.

**Learning Outcomes**

The students are expected to have the ability to:

1. Develop an understanding of modern concepts in AI and where they can be used.
2. Design, implement and apply novel AI techniques based on emerging real-world requirements.

**Contents**

**CSL8XX1: Artificial Intelligence: Probabilistic Reasoning and Knowledge Representation 1-0-0[1]**

*Probabilistic Reasoning over time:* Hidden Markov Models, Kalman Filters, Dynamic Bayesian Networks (7 lectures)
*Knowledge Representation:* Ontological engineering, Semantic Networks, Description Logics (7 lectures)

**CSL8XX1: Artificial Intelligence: Making Decisions 1-0-0[1]**

*Making decisions:* Utility theory, utility functions, decision networks, sequential decision problems, Partially Observable MDPs, Game Theory (14 lectures)

**CSL8XX1: Artificial Intelligence: Reinforcement Learning 1-0-0[1]**

*Reinforcement Learning:* Passive RL, Active RL, Generalization in RL, Policy Search, Deep Reinforcement Learning (14 lectures)

**Textbook**

1.Russel,S., and Norvig,P., (2015), *Artificial Intelligence: A Modern Approach*, 3rd Edition, Prentice Hall

**Reference Books**

1. Yang, Q. (1997), *Intelligent Planning: A decomposition and abstraction based approach,* Springer Verlag, Berlin Heidelberg.

| Title | **Machine Learning I** | Number | CSL7XX0 |
|---|---|---|---|
| Department | Computer Science and Engineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | M.Tech. 1st Year, Ph.D. 1st Year | Type | Compulsory |
| Prerequisite | None | | |

**Objectives**

The Instructor will:

1. Provide motivation and understanding of the need and importance of Machine Learning in today's world
2. Provide details about various algorithms in Machine Learning

**Learning Outcomes**

The students are expected to have the ability to:

1. Develop a sense of Machine Learning in the modern context, and independently work on problems relating to Machine Learning
2. Design and program efficient algorithms related to Machine Learning, train models, conduct experiments, and deliver ML-based applications

**Contents**

**CSL7XX1: Machine Learning I: Supervised Learning 1-0-0[1]**

*Introduction:* Motivation, Different types of learning, Linear regression, Logistic regression (2 lectures)
*Gradient Descent:* Introduction, Stochastic Gradient Descent, Subgradients, Stochastic Gradient Descent for risk minimization (2 lectures)
*Support Vector Machines:* Hard SVM, Soft SVM, Optimality conditions, Duality, Kernel trick, Implementing Soft SVM with Kernels (4 lectures)
*Decision Trees:* Decision Tree algorithms, Random forests (2 lectures)
*Neural Networks:* Feedforward neural networks, Expressive power of neural networks, SGD and Backpropagation (3 lectures)
*Model selection and validation:* Validation for model selection, k-fold cross-validation, Training-Validation-Testing split, Regularized loss minimization (1 lectures)

**CSL7XX2: Machine Learning I: Unsupervised Learning and Generative Models 1-0-0[1]**

*Nearest Neighbour:* k-nearest neighbour, Curse of dimensionality (1 lecture)
*Clustering:* Linkage-based clustering algorithms, k-means algorithm, Spectral clustering (3 lectures)
*Dimensionality reduction:* Principal Component Analysis, Random projections, Compressed sensing (2 lectures)
*Generative Models:* Maximum likelihood estimator, Naive Bayes, Linear Discriminant Analysis, Latent variables and Expectation-maximization algorithm, Bayesian learning (5 lectures)
*Feature Selection and Generation:* Feature selection, Feature transformations, Feature learning (3 lectures)

**CSL7XX3: Machine Learning I: Computational Learning Theory and Deep Neural Networks 1-0-0[1]**

*Statistical Learning Framework:* PAC learning, Agnostic PAC learning, Bias-complexity tradeoff, No free lunch theorem, VC dimension, Structural risk minimization, Adaboost (7 lectures)
*Foundations of Deep Learning:* DNN, CNN, RNN, Autoencoders (7 lectures)

**Textbook**

1. Shalev-Shwartz,S., Ben-David,S., (2014), *Understanding Machine Learning: From Theory to Algorithms*, Cambridge University Press

**Reference Books**

1. Mitchell Tom (1997). *Machine Learning,* Tata McGraw-Hill

**Self Learning Material**

1. Department of Computer Science, Stanford University, https://see.stanford.edu/Course/CS229

| Title | **Machine Learning II** | Number | CSL8XX0 |
|---|---|---|---|
| Department | Computer Science and Engineering | L-T-P [C] | 3–0–0 [3] |
| Offered for | M.Tech. 1st Year, Ph.D. 1st Year | Type | Compulsory |
| Prerequisite | Machine Learning-1 | | |

**Objectives**

The Instructor will:

1. Provide technical details about various recent algorithms and software platforms related to Machine Learning with specific focus on Deep Learning.

**Learning Outcomes**

The students are expected to have the ability to:

1. Design and program efficient algorithms related to recent machine learning techniques, train models, conduct experiments, and develop real-world ML-based applications and products

**Contents**

**CSL7XX1: Machine Learning II: Introduction to Deep Learning 1-0-0[1]**

*Model Search:* Optimization, Regularization, AutoML (4 lectures)
*Deep Networks:* Attention layers, Gated CNNs, Graph Neural Networks (8 lectures)
*Applications:* Neural language models (2 lectures)

**CSL7XX2: Machine Learning II: Representation Learning & Structured Models 1-0-0[1]**

*Representation Learning:* Unsupervised pre-training, transfer learning and domain adaptation, distributed representation, discovering underlying causes (7 lectures)
*Structured models:* learning about dependencies, inference and approximate inference, sampling and Monte Carlo Methods, Importance Sampling, Gibbs Sampling, Partition Function, MAP inference and Sparse Coding, Variational Inference (7 lectures)

**CSL7XX3: Machine Learning II: Deep Generative Models 1-0-0[1]**

*Deep Generative Models:* Deep Belief Networks, Variational Autoencoder, Generative Adversarial Network (GAN), Deep Convolutional GAN, Autoencoder GANs, iGAN, pix2pix, CycleGAN, Conditional GANs, StackGAN (14 lectures)

**Laboratory Experiments**

Overview of Deep Learning platforms such Tensorflow and PyTorch.

**Textbook**

1.Goodfellow,I., Bengio.,Y., and Courville,A., (2016), *Deep Learning*, The MIT Press

**Reference Books**

1. Charniak, E. (2019), *Introduction to deep learning,* The MIT Press.

**Self Learning Material**

1. https://www.deeplearningbook.org/

| Title | Real Time Autonomous Systems | Number | CSL8XX0 |
|---|---|---|---|
| Department | Computer Science and Engineering | L-T-P [C] | 2–0–0 [2] |
| Offered for | | Type | Compulsory |
| Prerequisite | **Machine Learning I, Artificial Intelligence I** | | |

**Objectives**

The Instructor will:

1. Provide an understanding about autonomous/ semi autonomous systems like autonomous cars and drones.

**Learning Outcomes**

The students are expected to have the ability to:

1. Understand and use the methodologies to design, model and implementation of autonomous systems for real time applications.

**Contents**

Introduction to Agents, Agent Architectures: Subsumption Architecture, Situated Automata, Hybrid Architecture (4)

Real time System Implementation (3)

Mobile agents – locomotion (wheeled, legged, aerial), sensors and mechanisms. (3)

Robot localisation & SLAM (4)

Planning and Navigation (6)

Case Study: Autonomous car – learning to drive; human centered autonomous vehicle. (8)

**Laboratory Experiments**

**Textbook**

1. Seigwart, R. and Nourbakhsh, I.R. *Introduction to Autonomous Mobile Robots*, 2nd edition, MIT Press 2011
2. Giorgio C. Buttazzo, *Hard Real-Time Computing Systems: Predictable Scheduling Algorithms and Applications*," Springer US, Year: 2011
3. Stuart J. Russell and Peter Norwig, *Artificial Intelligence: A Modern Approach*, 3rd edition, Pearson Press
4. Markus Maurer et al. eds. *Autonomous Driving*, Springer Link (open access)
5. Gerhard Weiss ed., *Multiagent System*, Second Edition, MIT Press, 2013

**Reference Books**

1. Tzafestas, S. G. (Ed.). (2012). *Advances in intelligent autonomous systems* (Vol. 18). Springer Science & Business Media.
2. Ge, S. S. (2006). *Autonomous mobile robots: sensing, control, decision making and applications*. CRC press.
3. Mhamed Itmi, Alain Cardon(2016), New Autonomous Systems, Wiley-ISTE.
4. De Gyurky, S. M., & Tarbell, M. A. (2013). *The Autonomous System: A Foundational Synthesis of the Sciences of the Mind*. John Wiley & Sons.