Department of Computer Science and Engineering

Artificial Intelligence and Machine Learning (AIML)

Honors

Title: Generative AI

Sem	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
III	HON-01	*<tbd>*	Introduction to Generative AI	3	-	-	1	**3**	30	20	50	--	--
IV	HON-02	*<tbd>*	Generative AI Models	3	-	2	1	**4**	30	20	50	50	50
V	HON-03	*<tbd>*	Generative AI Tools and Techniques	3	-	2	1	**4**	30	20	50	50	50
VI	HON-04	*<tbd>*	Generative AI Applications	3	-	2	1	**4**	30	20	50	50	50
VII	HON-05	*<tbd>*	Ethics of AI	3	-	-	1	**3**	30	20	50	--	--
			Total	**15**	**-**	**06**	**05**	**18**					

Artificial Intelligence and Machine Learning (AIML)

Interdisciplinary Minor

Title: AIML

Sem	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
III	IDP-01	*<tbd>*	Data Collection and Processing with Python	3	-	-	1	**3**	30	20	50	--	--
IV	IDP -02	*<tbd>*	Artificial Neural Network	3	-	2	1	**4**	30	20	50	50	50
V	IDP -03	*<tbd>*	Generative Adversarial Network	3	-	2	1	**4**	30	20	50	50	50
VI	IDP -04	*<tbd>*	MLOPS	3	-	2	1	**4**	30	20	50	50	50
VII	IDP -05	*<tbd>*	Explainable AI	3	-	-	1	**3**	30	20	50	--	--
			Total	**15**	**-**	**06**	**05**	**18**					

Detailed Syllabi

(HON-01) Introduction to Generative AI						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --50	ESE: --	50

Course Outcomes: Students will be able to:

1.To explain key concepts and models in Generative AI.

2. To explore Generative AI models like GANs, VAEs, and Transformers.

3. To create effective prompts for various AI tasks.

4. To develop basic applications using Generative AI tools.

5. To evaluate ethical and responsible AI practices.

Unit 1: Introduction to Generative AI	**[6 Hrs]**
Evolution of Artificial Intelligence and Generative AI, Difference between Traditional AI and Generative AI, Fundamentals of Machine Learning and Deep Learning, Neural Networks and Representation Learning, Types of Generative Models, Ethical Issues and Challenges in Generative AI.	
Unit 2: Natural Language Processing and Language Models	**[6 Hrs]**
Basics of Natural Language Processing (NLP), Text Preprocessing and Tokenization. Word Embeddings: One-Hot Encoding, Word2Vec, GloVe,Transformers and Attention Mechanism,Large Language Models (LLMs), Prompt Engineering and Text Generation.	
Unit 3: Generative Models and Architectures	**[6 Hrs]**
Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), Transformers, Attention Mechanism , Long Short-Term Memory Networks (LSTMs), Sequence-to-Sequence Models, Training and Fine-Tuning of Generative Models, Evaluation Metrics for Generative AI Models	
Unit 4: Prompt Engineering and LLM Techniques	**[6 Hrs]**
Introduction to Prompt, Structuring a Prompt, Correct and Incorrect Prompts, Building Blocks of Well-Constructed Prompts, Prompt Patterns, Prompt Tuning Techniques, Fine-tuning Prompts for Specific Tasks, Domain-specific Prompt Engineering. Prompt Engineering Approaches - Interview Pattern, Chain of Thought Pattern, Tree of Thought Pattern Techniques for skilfully crafting prompts - Task specification, Contextual guidance, Zero Shot Prompting, Few-shot prompting.	
Unit 5: Advanced Concepts in Generative AI	**[6 Hrs]**
Transfer Learning in Generative AI, Reinforcement Learning from Human Feedback (RLHF), Retrieval-Augmented Generation (RAG), AI Agents and Autonomous Systems, Hallucination and Model Reliability, Fine-Tuning and Parameter-Efficient Tuning Methods.	
Unit 5: Vector Search, Ethics, and Responsible Generative AI	**[6 Hrs]**
Vector Databases, High-dimensional Data Storage, Vector Embeddings, High-Dimensional Semantic Similarity, Multimodal Search, Knowledge Graph Search. Ethics and Risks in GenAI: Deepfakes, misinformation, copyright issues, Fairness, bias detection and mitigation, Model auditing and explainability. Responsible AI and Societal Impact: Privacy-preserving models, social/economic implications.	

Textbooks:

[1]	“Generative AI for everyone: Understanding the essentials and applications of this breakthrough technology". Altaf Rehmani .
[2]	"Introduction to Generative AI” , Numa Dhamani, Kindle Edition, 2024.

[3]	Jozefowicz, R., Zaremba, W., Sutskever, I. (2023). An Introduction to Generative Models with Applications. Cambridge University Press.
Reference Books:	
[1]	Choi, H., Kim, J. (2023). Generative AI: A Practical Guide to Applications and Ethics. Springer
[2]	Natural Language Processing with Transformers by Lewis Tunstall, Leandro von Werra, and Thomas Wolf.

(HON-02) Generative AI Models						
Course Code	<tbd>		**Examination Scheme**			
Teaching Scheme	3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
Credits	3		**Laboratory**	CIE: --	ESE: --	--
Course Outcomes: Students will be able to:						
1.Understand fundamentals of Generative AI and deep learning. 2.Explain Autoencoders and Variational Autoencoders (VAEs). 3.Analyze Generative Adversarial Networks (GANs). 4.Apply transformer-based and Large Language Models (LLMs). 5.Understand diffusion and multimodal generative models. 6.Evaluate advanced techniques such as RAG, RLHF, and PEFT						
Unit 1: Fundamentals of Generative AI Models						**[6 Hrs]**
Introduction to Generative Models, Probabilistic Modeling Concepts, Latent Space Representation, Deep Learning Foundations for Generative AI, Training and Optimization Techniques, Evaluation Metrics for Generative Models.						
Unit 2: Autoencoders and Variational Autoencoders (VAE)						**[6 Hrs]**
Basic Autoencoder Architecture, Encoder–Decoder Mechanism, Latent Variable Models, Variational Autoencoders (VAE), Conditional VAE, Applications and Limitations of VAEs.						
Unit 3: Generative Adversarial Networks (GANs)						**[6 Hrs]**
GAN Architecture and Working, Generator and Discriminator Networks, Training Challenges in GANs, DCGAN, CycleGAN, and Conditional GAN, Image Synthesis using GANs, GAN Evaluation Techniques.						
Unit 4: Transformer-Based Generative Models						**[6 Hrs]**
Attention Mechanism, Transformer Architecture, GPT Models and Text Generation, BERT vs GPT, Large Language Models (LLMs), Fine-Tuning and Prompt Engineering.						
Unit 5: Diffusion and Multimodal Models						**[6 Hrs]**
Diffusion Model Fundamentals, Denoising Diffusion Process, Text-to-Image Generation Models, Multimodal Learning, Image, Audio, and Video Generation, Deepfake Generation and Detection.						
Unit 6: Advanced Generative AI Techniques						**[6 Hrs]**
Retrieval-Augmented Generation (RAG), Reinforcement Learning from Human Feedback (RLHF), AI Agents and Autonomous Systems, Parameter-Efficient Fine-Tuning (PEFT), Model Compression and Quantization, Federated Learning for Generative AI Models.						

Textbooks:	
[1]	Generative AI for Everyone: Understanding the Essentials and Applications of This Breakthrough Technology". Altaf Rehmani.
[2]	"Deep Learning" by Ian Goodfellow, Yoshua Bengio, and Aaron Courville.
[3]	Choi, H., Kim, J. (2023). Generative AI: A Practical Guide to Applications and Ethics. Springer.
Reference Books:	
[1]	"Generative Adversarial Networks Cookbook: Over 100 recipes to build generative models using Python, TensorFlow, and Keras" by Josh Kalin.
[2]	Ramesh, A., Pavlov, M., Goh, G., et al. (2022). DALL·E: Creating images from text. OpenAI. Retrieved from https://openai.com/research/dall-e
Note:	
List of Experiments:	
[1]	Implement a basic probabilistic generative model (e.g., Gaussian Mixture Models). OR Build a simple text generator using Markov Chains.
[2]	Implement a Generative Adversarial Network (GAN) architecture using TensorFlow 2. Train the GAN model on a dataset such as MNIST or CIFAR-10 for image generation tasks.
[3]	Explore advanced techniques such as Wasserstein GANs, Progressive GANs, or StyleGANs for image generation. Implement and compare these techniques for generating high-quality images.
[4]	Implement all Prompt Engineering approaches- Interview Approach, COT, TOT. Compare and contrast all and analyse their applications. Implement Zero shot and Few shot prompting and compare their results.
[5]	Develop applications for image and video generation using trained Generative AI models. Use the models to generate art, create deep fakes, or synthesize video content.
[6]	Create a text-to-image generation pipeline using a pre-trained model like DALL-E
[7]	Text generation: Fine-tune a pre-trained language model (e.g., GPT, BERT) using transfer learning techniques. Fine-tune the model on a domain-specific dataset and evaluate its performance for text generation tasks.

(IPD-01) Data Collection and Processing with Python	
<tbd>	**Examination Scheme**

3-0-0-1		**Theory**	TA: 20	MSE: 30	ESE: 50
3		**Laboratory**	CIE: --	ESE: --	

Course outcomes

1. Demonstrate proficiency in Python's core data types and built-in structures for storing and organizing raw data.
2. Write reusable functions and modules to automate repetitive data handling tasks.
3. Extract data from relational databases and flat files, and apply responsible data-collection practices.
4. Design and implement reusable data-transformation pipelines that automate preprocessing steps end-to-end.

Course content

Python Foundations for Data Processing:	**[5 Hrs]**

Python data types & structures, Lists, tuples, dicts, sets, Comprehensions, File I/O basics,Exception handling, Functions & modules.

Data Collection Techniques:	**[7 Hrs]**

CSV / Excel ingestion, Database connectivity (SQLite),Web scraping, REST APIs & JSON parsing, Rate limiting & ethics.

Data Wrangling with Pandas:	**[8 Hrs]**

Introduction to Pandas, Installing and importing Pandas, Features and applications of Pandas, Data type conversion, Indexing & slicing, Series & DataFrame, Handling missing values,Merging, joining, concatenating, GroupBy & aggregation.

Numerical Processing with Numpy:	**[6 Hrs]**

Basic of NumPy, Installing and importing NumPy, Creating NumPy arrays(1D),(2D), ndarray creation & attributes, Array indexing & slicing, Statistical functions, Linear algebra basics, Vectorised operations.

Data Cleaning & Transformation:	**[8 Hrs]**

Normalisation & standardisation, Encoding categorical variables, Datetime parsing, Feature creation & binning, Outlier detection & treatment.

Data Visualisation and Exploratory Data Analysis:	**[6 Hrs]**

Matplotlib fundamentals, Seaborn statistical plots, Correlation & heatmaps, EDA workflow & reporting, Plotly interactive charts.

Self-study	**[12Hrs]**

Lambda functions & closures, Multi-index DataFrames, HTTP caching strategies, Structured arrays & record arrays, Jupyter notebook best practices, Automated EDA.

Textbooks:	
[1]	Wes McKinney, “Python for Data Analysis”,3rd edition,O'Reilly Media,ISBN-13: 978-1098104030
[2]	Jacqueline Kazil and Katharine Jarmul “Data Wrangling with Python” 2nd edition,O'Reilly Media,978-1491948811
[3]	Jake VanderPlas, “Python Data Science Handbook",1st edition,O'Reilly Media,ISBN-13:978-1491912058. .
Reference Books:	
[1]	Ryan Mitchell, “Web Scraping with Python”, 3rd edition,O'Reilly Media,ISBN-13: 978-1098145354
[2]	1. Stefanie Molin, “Hands-On Data Analysis with Pandas”, 3rd edition,Packt Publishing,ISBN-13: 978-1836206071

Web references
1. https://nptel.ac.in/courses/106107220 2. https://nptel.ac.in/courses/106106212

(IPD-02) Artificial Neural Network					
<tbd>		**Examination Scheme**			
3-0-2-1		**Theory**	TA: 20	MSE: 30	ESE: 50
3		**Laboratory**	CIE: --50	ESE: --	50

Course Outcomes: Students will be able to:
1. Understand the fundamentals and architectures of artificial neural networks. 2. Apply perceptron-based learning algorithms and neural network learning algorithms for training and optimizing multilayer networks. 3. Analyze probabilistic and energy-based neural network models for pattern recognition and classification tasks. 4. Develop self-organizing and associative memory neural networks for clustering and pattern association applications. 5. Design and evaluate deep neural network models using regularization and optimization

techniques.

6. Evaluate advanced neural network models and their real-world applications.

Course content

Unit I: Introduction	**[6 Hrs]**

Introduction to Artificial Neural Networks: Introduction, Artificial Neural Networks, Historical Development of Neural Networks, Biological Neural Networks, Comparison Between them and the Computer, Comparison Between Artificial and Biological Neural Network, Basic Building Blocks of Artificial Neural Networks, Artificial Neural Network (ANN) terminologies. Biological Neuron – Artificial Neural Model - Types of activation functions – Architecture: Feed forward and Feedback - Convex Sets - Convex Hull and Linear Separability, Non-Linear Separable Problem - XOR Problem - Perceptions -Multilayer Networks.

Unit II: Training Neural Network	**[6 Hrs]**

Perceptron learning and NonSeparable sets, alpha-Least Mean Square Learning, MSE Error surface, Steepest Descent Search, Multilayered Network Architecture - Back propagation Learning Algorithm - Practical consideration of BP algorithm.

Unit III: Probabilistic and Energy-Based Neural Networks	**[6 Hrs]**

Probabilistic Neural Networks (PNN), Hopfield Networks, Boltzmann Machines, Restricted Boltzmann Machines (RBMs), Sigmoid Networks, Applications of Probabilistic and Energy-Based Neural Networks.

Unit IV: Self Organization Feature Map & Memory Neural Network	**[6 Hrs]**

Maximal Eigenvector Filtering, Extracting Principal Components - Generalized Learning Laws, Vector Quantization Self Organization Feature Maps - Application of SOM. Associative Memory Networks: Introduction, Algorithms for Pattern Association, Hetero Associative Memory Neural Networks, Auto Associative Memory Network, Bi-directional Associative Memory.

Unit V: Deep Neural Networks	**[6 Hrs]**

Introduction to Deep Learning, Deep Feedforward Networks, Weight Initialization Techniques, Regularization Methods: Dropout, Early Stopping, Batch Normalization, Optimization Algorithms: SGD, Momentum, RMSProp, Adam, Challenges in Deep Networks.

Unit VI: Specialized Neural Network Architectures	**[6 Hrs]**

Convolutional Neural Networks (CNN), Pooling and Feature Extraction, Recurrent Neural Networks (RNN)
Long Short-Term Memory (LSTM) Networks, Autoencoders, Transfer Learning Concepts.

Self-study	**[12 Hrs]**

Attention Mechanism, Transformer Architecture, Generative Neural Networks, Explainable AI in Neural Networks, Neural Network Deployment and Model Optimization. Case Studies and Real-World Applications in Computer Vision, NLP, Healthcare, and Finance.

Textbooks:	
[1]	Charu C. Aggarwal," Neural Networks and Deep Learning", Springer, 1st Edition,2018
[2]	Satish Kumar, "Neural Networks A Classroom Approach", McGraw Hill Education (India) Pvt. Ltd, 2010. .
[3]	Christopher M. Bishop," Pattern Recognition And Machine Learning", Springer,1st Edition, 2016.
Reference Books:	
[1]	J.M. Zurada, "Introduction to Artificial Neural Systems", Jaico Publications 1994.
[2]	B. Yegnanarayana, "Artificial Neural Networks", PHI, New Delhi 2004.

Web references

1.https://nptel.ac.in/courses/106106139

Laboratory assignments

1. Implement an Artificial Neuron model and analyze the behavior of different activation functions used in neural networks.
2. Develop a Perceptron model to solve linearly separable classification problems.
3. Demonstrate why a single-layer perceptron fails to solve the XOR problem and implement a multilayer neural network to overcome this limitation.
4. Implement the Least Mean Square (LMS) learning algorithm and Gradient Descent optimization technique for minimizing prediction errors.
5. Design and train a multilayer neural network using the Backpropagation algorithm for classification.
6. Implement a Probabilistic Neural Network (PNN) and evaluate its performance on a classification problem.
7. Implement a Hopfield Network to store and retrieve binary patterns.
8. Implement a Restricted Boltzmann Machine (RBM) for feature extraction from image data.
9. Perform dimensionality reduction using PCA and cluster data using a Self-Organizing Map (SOM).
10. Design a Deep Feedforward Neural Network and evaluate the impact of regularization techniques on model performance.
11. Develop an image classification system using Convolutional Neural Networks and Transfer Learning.

Mini project

Develop an Artificial Neural Network (ANN)-based model to analyze a given dataset and predict the target class or output variable based on the input features. The project should include data collection, preprocessing, exploratory data analysis, feature selection, ANN model design, training, testing, and performance evaluation. Students should investigate the impact of different network architectures, activation functions, and optimization techniques on model performance