Course Name: Soft Computing
Course Code: DS-701
(Semester- VII)
Course Broad Category: Professional Elective (PE)

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1. Course Prerequisite: Strong Mathematical Background, Proficiency with Algorithms, Programming skill in JAVA, MATLAB, etc.

2. Course Learning Objectives:

i. To develop a foundational understanding of soft computing paradigms—including fuzzy logic, neural networks, and evolutionary algorithms—and appreciate their role in handling uncertainty, imprecision, and nonlinear problem spaces.

ii. To enable students to design and implement intelligent computational models that emulate human reasoning and adaptive decision-making for real-world engineering and data-driven applications.

iii. To cultivate the ability to analyze complex optimization and classification problems and select appropriate soft computing techniques such as genetic algorithms, swarm intelligence, and neuro-fuzzy systems for efficient problem-solving.

iv. To strengthen practical skills through hands-on experimentation, encouraging students to build, train, and evaluate soft computing systems using contemporary tools and frameworks, and to interpret the performance of these systems in real scenarios.

3. Teaching methodology and evaluation system for the course:

Teaching methodology – Lectures and Presentations, Interactive Discussions and Case Studies.

Evaluation System –

A. Mid-Term Exam (40 Marks)- Formative Assessment [Continuous Assessment 1 (CIA-1)]
B. Internal Assessment (40 Marks)- Formative Assessment [Continuous Assessment 2(CIA-2)]
C. End-Semester Exam (60 Marks)- Summative Assessment.

4. Course Content:

Course Name: Soft Computing
Course Code: DS-701

Hours per Week: 3L: 0T: 0P
Credits: 3

Module	Topics	45L
1.	**Foundations of soft computing:** Introduction and different definitions of Soft Computing, Differences between soft and hard computing, Components of Soft Computing: Fuzzy Logic, Neural Networks, Evolutionary Computing	10L
2.	**Fundamentals of Fuzzy Logic:** Crisp Sets, Fuzzy sets, Fuzzy membership functions, Basic operations on fuzzy sets, Fuzzy relations and Composition of fuzzy relations.	6L
3.	**Fuzzy Rules, Inference and Applications:** Fuzzy if-then rules: Mamdani-style (M-A) and Takagi-Sugeno-Kang (TSK) Rules, Fuzzification, Compositional rule of Inference/Approximate Reasoning, Defuzzification, Applications: Pattern Recognition, Fuzzy c-means Clustering and Control.	6L
4.	**Neural Networks – Models and Training:** Introduction to neural networks: Artificial Neuron and its model, Activation functions, Neural network architecture, learning algorithms/rules, Training and testing.	6L
5.	**Neural Networks – Advanced Architectures and Applications:** Perceptron model: single layer and multilayer perceptron (MLP), Error back propagation, Radial basis function network (RBFN), Self-organizing map network (SOMN), Recurrent neural network, Applications of artificial neural network (ANN).	6L
6.	**Evolutionary Computing:** ***Genetic Algorithm–I***: Evolutionary Computing, Basic concepts and working principle of simple GA (SGA), Genetic Operators: Selection, Crossover and Mutation, flow chart of SGA, Chromosome Encoding & Decoding, Population Initialization, Objective/fitness Function, variable length Chromosome, Applications: Travelling Salesman Problem (TSP). **Genetic Algorithm–II (Multi-objective Genetic Algorithm (MOGA))**: Conflicting objectives, Objective space and variable space, Domination, Pareto front, Pareto Set, Nondominated Sorting Genetic Algorithm II (NSGA-II): Non-dominated Sorting, Crowding distance operator, Applications. Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Local Search and Memetic algorithm.	11L

5. Text Book:

1. S. Rajsekharanand and V. Pai, *Neural Networks, Fuzzy Logic and Genetic Algorithm: Synthesis and Applications*, Prentice Hall of India.
2. K. H. Lee., *First Course on Fuzzy Theory and Applications*, SpringerVerlag.
3. G. J. Klir and T. A. Folger, *Fuzzy Sets, Uncertainty, and Information*, Prentice Hall of India.

Reference Books:

1. S. Haykin, *Neural Networks*, Prentice Hall of India.
2. T. J. Ross, *Fuzzy Logic with Engineering Applications*, Wiley India.
3. A. Konar, *Computational Intelligence*, Springer.
4. Y. H. Pao, *Adaptive Pattern Recognition and Neural Networks*, AddisonWesley.

6. **COURSE OUTCOMES (COs)**

On completion of the course students will be able to

Course Outcomes	Details	Action Verb	Knowledge Level
DS-701.CO1	Explain foundations of Soft Computing and differentiate from hard computing.	Explain, Distinguish	Level 1 – Remember Level 2 – Understand
DS-701.CO2	Apply fuzzy sets, membership functions, and relations.	Apply, Model	Level 3 – Apply , Level 4 – Analyze
DS-701.CO3	Construct and evaluate fuzzy rule-based systems and applications.	Construct, Evaluate	Level 4 – Analyze, Level 5 – Evaluate
DS-701.CO4	Develop neural models and implement training–testing processes.	Develop, Implement	Level 3 – Apply , Level 4 – Analyze
DS-701.CO5	Design and assess advanced neural architectures.	Design, Assess	Level 5 – Evaluate Level 6 – Create
DS-701.CO6	Formulate and apply evolutionary/swarm methods for optimization.	Formulate, Apply	Level 3 – Apply Level 6 – Create

7. Mapping of course outcomes to module / course content

Module	CO1	CO2	CO3	CO4	CO5	CO6
1	5	1	1	1	1	1
2	1	5	3	1	1	1
3	1	3	5	1	1	1
4	1	1	1	5	3	1
5	1	1	1	3	5	1
6	1	1	1	1	1	5

Scale interpretation:

1 = Very Low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very High/Direct

8. Mapping of the Course outcomes to Program Outcomes (PO)

Mapping of COs with POs and PSOs (Course Articulation Matrix):

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	3	2	--	1	--	--	--	--	--	1	--	1
CO2	2	2	2	2	--	--	--	--	--	1	--	1
CO3	3	3	3	2	1	--	--	--	--	1	--	2
CO4	2	3	3	3	2	--	--	--	--	2	--	1
CO5	3	2	2	3	2	--	--	--	--	2	--	--
CO6	2	2	3	3	3	--	--	--	--	2	1	--

9. Mapping to Program Specific Outcome (PSO)

	PSO1	PSO2	PSO3	PSO4
CO1	2	1	1	1
CO2	2	2	2	1
CO3	3	3	3	1
CO4	3	3	3	1
CO5	3	3	3	2

Reference: NIT Durgapur

*** End of Syllabus ***

Course Name: Computer Vision
Course Code: DS-704
(Semester- VII)
Course Broad Category: Professional Elective (PE)

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1. Course Prerequisite: Linear algebra, Calculus, Probability statistics, Programming Skills, Fundamentals of Image Processing**.**

2. Course Learning Objectives:

This course aims to provide an understanding of the fundamental principles of computer vision from a computational perspective, with emphasis on how visual information is acquired, represented, and interpreted by machines, and on the conceptual and practical implications of these principles for intelligent perception and decision-making system.
Upon successful completion of the course, students will be able to:

- Understand the fundamentals of digital image formation, transformations, and low-level image processing techniques.
- Apply depth estimation, multi-camera geometry, and 3D reconstruction techniques in computer vision systems
- Extract and analyze features such as edges, corners, lines, and descriptors for designing vision algorithms.
- Implement image segmentation and pattern analysis techniques for object detection and classification.
- Analyze and apply motion estimation, optical flow, and dynamic scene analysis in real-world applications
- Design and develop end-to-end computer vision systems incorporating shape-from-X, photometric methods, and real-time processing.

3. Teaching methodology and evaluation system for the course:

Teaching methodology -

Lectures and Presentations, Interactive Discussions and Case Studies.

Evaluation System –

A. Mid-Term Exam (20 Marks)- Summative Assessment (CIA-1)
B. Internal Assessment (20 Marks)- Formative Continuous Assessment [Continuous Assessment 1(CIA-2)]
C. End-Semester Exam (60 Marks)- Summative Assessment.

4. Course Content:

Course Name: **Computer Vision**
Course Code: DS-704

Hours per Week: 3L: 0T: 0P
Credits: 3

Module	Topics	
1.	Digital Image Formation and low-level processing: Overview and State-of-the-art, Fundamentals of Image Formation, Transformation: Orthogonal, Euclidean, Affine, Projective, etc; Fourier Transform, Convolution and Filtering, Image Enhancement, Restoration, Histogram Processing.	6L
2.	Depth estimation and Multi-camera views: Perspective, Binocular Stereopsis: Camera and Epipolar Geometry; Homography, Rectification, DLT, RANSAC, 3-D reconstruction framework; Auto-calibration. Apparel	6L
3.	Feature Extraction: Edges - Canny, LOG, DOG; Line detectors (Hough Transform), Corners - Harris and Hessian Affine, Orientation Histogram, SIFT, SURF, HOG, GLOH, Scale-Space Analysis- Image Pyramids and Gaussian derivative filters, Gabor Filters and DWT.	8L
4.	Image Segmentation: Region Growing, Edge Based approaches to segmentation, Graph-Cut, Mean-Shift, MRFs, Texture Segmentation; Object detection.	6L
5.	Pattern Analysis: Clustering: K-Means, K-Medoids, Mixture of Gaussians, Classification: Discriminant Function, Supervised, Un-supervised, Semi-supervised; Classifiers: Bayes, KNN, ANN models; Dimensionality Reduction: PCA, LDA, ICA; Non-parametric methods.	8L
6.	Motion Analysis: Background Subtraction and Modeling, Optical Flow, KLT, SpatioTemporal Analysis, Dynamic Stereo; Motion parameter estimation.	5L
7.	Shape from X: Light at Surfaces; Phong Model; Reflectance Map; Albedo estimation; Photometric Stereo; Use of Surface Smoothness Constraint; Shape from Texture, color, motion and edges.	6L
		45L

5. Text Books:

1. **Computer Vision: Algorithms and Applications**
   Authors: Richard Szeliski
   Publisher: Springer-Verlag London Limited 2011

2. **Computer Vision: A Modern Approach**
   Authors: D. A. Forsyth, J. Ponce
   Publisher: Pearson Education, 2003

3. **Introduction to Statistical Pattern Recognition**
   Authors: K. Fukunaga
   Publisher: Academic Press, Morgan Kaufmann, 1990.

4. **Digital Image Processing**
   Authors: R.C. Gonzalez and R.E. Woods
   Publisher: Addison- Wesley, 1992

5. **Multiple View Geometry in Computer Vision**
   Authors: Richard Hartley and Andrew Zisserman
   Publisher: Cambridge University Press, March 2004

6. COURSE OUTCOMES (COs)

On completion of the course students will be able to

Course Outcomes	Details	Action Verb	Knowledge Level
DS-704.CO1	Understanding basic architecture and principles of computer vision systems.	Understand	Level 2-Understand, Level 3-Apply
DS-704.CO2	Implementation of computer vision algorithms including depth estimation, multi-camera view and motion analysis components	Implement	Level 3-Apply, Level 4 -Analyze
DS-704.CO3	Apply basic image processing and feature extraction techniques in order to design computer vision algorithms.	Apply	Level 3-Apply Level 4-Analyze,
DS-704.CO4	Analysis of pattern analysis and image segmentation techniques used for computer vision systems.	Analyze	Level 4-Analyze, Level 5-Evaluate
DS-704.CO5	Design and development of real time computer vision systems	Design	Level 2-Understand Level 3-Apply, Level 4-Analyze

7. Mapping of course outcomes to module / course content

Course Outcome (CO)	Mapped Course Content / Module Topics
CO1	Image Formation, Transformations, Fourier Transform, Filtering Overall CV pipeline overview
CO2	Depth Estimation, Stereo Vision, Epipolar Geometry, 3D Reconstruction Motion Analysis (Optical Flow, KLT, Dynamic Stereo)
CO3	Low-level Image Processing Feature Extraction (Edges, Corners, SIFT, SURF, HOG, Gabor, DWT)
CO4	Image Segmentation Pattern Analysis, Clustering, Classification, Dimensionality Reduction
CO5	Object Detection, Motion Analysis, Shape-from-X, Real-time CV applications

8. Mapping of the Course outcomes to Program Outcomes (PO) (1 = Low, 2 = Moderate, 3 = High)

Mapping of COs with POs and PSOs (Course Articulation Matrix):

CO / PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	3	2	2	1	2	-	-	-	1	1	-	1
CO2	2	3	3	2	3	-	-	-	2	1	2	1
CO3	3	2	3	2	3	-	-	-	1	1	1	1
CO4	2	3	2	3	2	-	-	-	1	1	1	1
CO5	2	3	3	2	3	-	-	-	2	2	3	1

9. Mapping to Program Specific Outcome (PSO)

CO / PSO	PSO1	PSO2	PSO3	PSO4
CO1	**2**	**1**	**2**	**-**
CO2	**2**	**1**	**3**	**-**
CO3	**2**	**1**	**3**	**-**
CO4	**3**	**1**	**3**	**-**
CO5	**2**	**1**	**3**	**2**

Reference: NIT Durgapur

***** End of Syllabus******

Course Name: Pattern Recognition
Course Code: DS-714
(Semester– VII)
Course Broad Category: Program Core (PC)

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1. Course Prerequisite:

- Basic knowledge of Introductory ML, and Python.
- Basic knowledge of linear algebra, probability & statistics, data structures.

2. Course Learning Objectives:

i. Understand the fundamental principles, terminology, and structure of pattern recognition systems and their real-world applications.
ii. Explain statistical decision theory, discriminant functions, and parameter estimation methods for classification.
iii. Apply classical and modern classification algorithms such as k-NN, Naïve Bayes, Decision Trees, SVM, and ensembles.
iv. Analyse unsupervised learning models, clustering techniques, mixture densities, EM algorithm, and cluster validity measures.
v. Perform feature extraction and feature selection using dimensionality reduction and optimization-based selection techniques.
vi. Apply advanced pattern recognition techniques such as ANN, RBF networks, Fuzzy methods, and Hidden Markov Models to real-world temporal and non-temporal data.

3. Teaching methodology and evaluation system for the course:

Teaching methodology –Lectures and Presentations, Learning Management System (LMS), Interactive Discussions and Case Studies, Industry Lecture.

Evaluation System –

A. Mid-Term Exam (40 Marks) - Summative Assessment (CIA-1)

B. Internal Assessment (40 Marks)- Formative Continuous Assessment [Continuous Assessment 1 (CIA-2)]

C. End-Semester Exam (60 Marks)- Summative Assessment.

4. Course Content:

Course Name: Pattern Recognition

Course Code: DS-714

Hours per Week: 3L: 0T: 0P

Credits: 3

Module	**Topics**	**Lectures (45L)**
1	**Fundamentals of Pattern Recognition:** Introduction, Definitions: Patterns, Features, Classes, Classifiers, Types of Learning: Supervised, Unsupervised, Semi-supervised, Pattern Recognition System Design Principles, Feature Space, Pattern Space, Vector Spaces, Applications of Pattern Recognition, Training Set, Test Set, Validation, Standardization & Normalization, Basic Mathematical Foundations: Linear Algebra Review, Probability Theory & Random Variables, Estimation Techniques	6L
2	**Statistical Classification & Decision Theory:** Bayes Decision Theory: Minimum-error-rate Classification, Discrete and Continuous Features, Discriminant Functions & Decision Boundaries, Univariate & Multivariate Normal Density, Decision Surfaces, Contextual Classification, Parameter Estimation**:** Maximum Likelihood Estimation (MLE), Maximum a Posteriori (MAP), Bayesian Estimation (Gaussian Case), Compound Bayesian Decision Theory	8L
3	**Classification Algorithms:** Classical Classifiers: k-Nearest Neighbor (kNN)**,** Naïve Bayes Classifier**,** Logistic Regression**,** Decision Trees**,** Random Forest**,** Support Vector Machines (SVM): Linear, Polynomial, RBF Kernels**,** Prototype Selection Methods**,** Combination & Ensemble Methods of Classifiers (Boosting, Bagging)	9L

4	**Clustering and Unsupervised Learning:** Concepts: Clustering vs. Classification**,** Similarity Measures & Distance Functions**,** Clustering Criteria Functions**,** Partitioning Methods**:** k-Means Algorithm**,** Variants of k-Means**,** Hierarchical Clustering**,** Density-Based Clustering (DBSCAN)**,** Graph-Theoretic Clustering**,** Cluster Validity Measures**,** Mixture Densities & Identifiability**:** EM Algorithm for Gaussian Mixtures (GMM)	8L
5	**Feature Extraction & Selection:** Introduction to Feature Extraction, Types of Features (Statistical, Structural, Transform-based), Feature Selection: Branch and Bound Method, Sequential Forward/Backward Selection, (l,r) Algorithm, Structural Pattern Recognition: Syntactic Approaches, Pattern Grammars & Parsing, Dimensionality Reduction Fundamentals: PCA (overview), LDA (overview)	7L
6	**Advanced PR Techniques:** ANN for pattern association & classification**,** Competitive learning, SOM**,** RBF Networks**,** Fuzzy Pattern Recognition, FCM**,** Hidden Markov Models: Forward/Backward, Viterbi, Baum-Welch**,** Temporal pattern recognition applications	7L

5. References:

Textbooks:

1. Pattern Recognition and Machine Learning – Christopher M. Bishop
2. Pattern Classification – Richard O. Duda, Peter E. Hart & David G. Stork

Reference Books:

1. Pattern Recognition and Classification: An Introduction – Geoff Dougherty
2. Fundamentals of Pattern Recognition and Machine Learning – Braga-Neto, Springer International Publishing
3. Pattern Recognition and Neural Networks – B. D. Ripley

6. Course Outcomes (CO):

After going through this course, the students will be able to:

Course Outcomes	Details	Action Verb	Knowledge Level
DS-714.CO1	Understand fundamentals, concepts, and applications of pattern recognition	Define, Describe, Summarise	Level 1-Remember Level 2-Understand
DS-714.CO2	Apply statistical decision theory and discriminant functions for classification	Apply, Compute, Illustrate	Level 2-Understand Level 3-Apply
DS-714.CO3	Implement classification algorithms for real-world datasets	Implement, Develop, Demonstrate	Level 3-Apply Level 4-Analyze
DS-714.CO4	Analyse unsupervised learning techniques including clustering, mixture models, EM algorithm	Analyse, Compare	Level 4-Analyse
DS-714.CO5	Apply feature extraction and selection techniques for dimensionality reduction	Evaluate, Apply	Level 3-Apply
DS-714.CO6	Apply advanced PR techniques such as ANN, RBF, Fuzzy models, and HMM.	Apply, Construct	Level 3-Apply, Level 4-Analyse

7. Mapping of course outcomes to module / course content

Module	CO1	CO2	CO3	CO4	CO5	CO6
1	3	2	-	-	1	-
2	-	3	-	-	-	-
3	-	2	3	-	-	-
4	-	-	-	3	-	-
5	-	-	-	1	3	-
6	-	-	-	-	1	3

8. Mapping of the Course outcomes to Program Outcomes (PO)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	3	2	1	-	-	-	-	-	-	-	-	1
CO2	3	3	2	2	1	-	-	-	-	-	-	1
CO3	2	2	3	2	2	-	-	-	1	-	-	2
CO4	2	3	2	2	2	-	-	-	-	-	-	2
CO5	2	2	3	1	3	-	-	-	1	-	-	2
CO6	1	2	2	2	3	-	-	-	1	1	-	2

9. Mapping to Program Specific Outcome (PSO)

	PSO1	PSO2	PSO3	PSO4
CO1	2	2	1	1
CO2	3	3	2	1
CO3	3	2	3	2
CO4	2	3	2	2
CO5	2	3	2	2
CO6	2	2	3	2

References:

1. National Institute of Technology Meghalaya
2. National Institute of Technology Durgapur

*** End of the Syllabus ***

Course Name: Responsible Artificial Intelligence
Course Code: DS-721
(Semester- VII)
Course Broad Category: Open Elective (OE)

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1. Course Prerequisite: A course on Artificial Intelligence.

2. Course Learning Objectives:

The objective of the course is to know about the responsibility of artificial intelligence (AI) to make AI more useful for society and humanity. The course will also teach principles and practices to perform responsible AI.

3. **Teaching methodology and evaluation system for the course:**

Teaching methodology – Lectures and Presentations, Interactive Discussions and Case Studies.

Evaluation System –

A. Mid-Term Exam (40 Marks)- Formative Assessment [Continuous Assessment 1 (CIA-1)]
B. Internal Assessment (40 Marks)- Formative Assessment [Continuous Assessment 2(CIA-2)]
C. End-Semester Exam (60 Marks)- Summative Assessment.

4. Course Content:

Course Name: Responsible Artificial Intelligence
Course Code: DS-721
Hours per Week: 3L: 0T: 0P
Credits: 3

Module	Topics	45L
1	Artificial Intelligence Fundamentals.	3L
2	**Introduction to responsible AI:** Need for ethics in AI. AI for Society and Humanity	3L
3	**Fairness and Bias:** Sources of Biases, Exploratory data analysis, limitation of a dataset, Preprocessing, in processing and postprocessing to remove bias, Group fairness and Individual fairness, Counterfactual fairness	13L
4	**Interpretability and Explainability:** Interpretability through simplification and visualization, Intrinsic interpretable methods, Post	13L

	Hoc interpretability, Explainability through causality, Model agnostic Interpretation.	
5	**Ethics and Accountability:** Auditing AI models, fairness assessment, Principles for ethical practices	**4L**
6	**Privacy Preservation:** Attack models, Privacy-preserving Learning, Differential privacy, Federated learning	**9L**

5. Text Book:

1. Virginia Dignum, "Responsible Artificial Intelligence: How to Develop and Use AI in a Responsible Way" Springer Nature, 04-Nov-2019; ISBN-10 : 3030303705, ISBN-13 : 978-3030303709

2. Christoph Molnar "Interpretable Machine Learning" .Lulu, 1st edition, March 24, 2019; eBook. ISBN-10 : 0244768528, ISBN-13 : 978-0244768522

6. Course Outcomes:

After completion of the course students will be able to

Course Outcomes	Details	Action Verb	Knowledge Level
DS-721.CO1	To be able to state aspects of responsible AI such as fairness, accountability, bias, privacy etc.	State	Level 1-Remember
DS-721.CO2	To be able to assess the fairness and ethics of AI modules.	Assess	Level 5-Evaluate
DS-721.CO3	To be able to enforce fairness in models and remove bias in data	Enforce, Remove	Level 3-Apply, Level 4-Analyse
DS-721.CO4	To be able to preserve the privacy of individuals while learning from them	Preserve	Level 3-Apply
DS-721.CO5	To be able to develop responsible AI modules for given practical problems and estimate the trade off with accuracy.	Develop, Estimate	Level 5-Evaluate Level 6-Create

7. Mapping of course outcomes to module / course content

Module	CO1	CO2	CO3	CO4	CO5
1	3	1	-	-	1
2	3	3	1	-	2
3	2	3	3	1	3
4	1	2	2	-	3
5	2	3	2	-	2
6	1	2	3	1	2

8. Mapping of the Course outcomes to Program Outcomes (PO)

Mapping of COs with POs and PSOs (Course Articulation Matrix):

CO / PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	2	1	1	1	2	1	1	3	1	2	1	2
CO2	2	2	2	1	2	1	1	3	1	3	1	2
CO3	3	2	3	2	3	1	1	3	2	2	1	2
CO4	2	2	2	2	3	1	1	3	1	2	1	2
CO5	3	3	3	2	3	2	1	3	2	2	2	3

9.Mapping to Program Specific Outcome (PSO)

	PSO1	**PSO2**	**PSO3**	**PSO4**
CO1	2	1	2	3
CO2	2	2	2	3
CO3	3	2	3	3
CO4	2	1	2	3
CO5	3	3	3	3

Reference: IIT PALAKKAD

**** End of Syllabus*****

Course Name: Large Language Model
Course Code: DS-725
(Semester- VII)
Course Broad Category: Open Elective (OE)

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1. Course Prerequisite: Statistical Natural Language Processing, Linear Algebra, Probability and Statistics, Python Programming, Introduction to Machine Learning, Deep Reinforcement Learning

2. Course Learning Objectives:

Upon successful completion of the course, students will be able to:

- Large Language Models (LLMs) have revolutionized the field of Natural Language Processing (NLP).
- However, the application of LLMs has not limited to NLP.
- This course will introduce the fundamentals of LLMs and go in-depth into various techniques to develop LLMs, scaling laws.
- It will cover various LLM architectures.
- It will teach how to fine-tune LLMs using parameter efficient techniques, and how LLMs could be used in conjunction with external knowledge sources such as vector databases.
- We will have a more mathematical and rigorous approach towards understanding LLMs.

3. Teaching methodology and evaluation system for the course:

Teaching methodology

Lectures and Presentations, Learning Management System (LMS), Interactive Discussions and Case Studies, Industry Lecture.

Evaluation System –

A. Mid-Term Exam (40 Marks) - Summative Assessment (CIA-1)

B. Internal Assessment (40 Marks)- Formative Continuous Assessment [Continuous Assessment 1 (CIA-2)]

C. End-Semester Exam (60 Marks)- Summative Assessment.

4. Course Content:

Course Name: Large Language Model

Course Code: DS-725
Hours per Week: 3L: 0T: 0P
Credits: 3

Module	Topics	Lectures (45L)
1	**Classical Language Modeling (CLM):** n-grams, smoothing, class-based, brown clustering, etc. **Neural Language Modeling (NLM):** Word Embeddings, Word2Vec, Feed Forward Neural LM, Contextualization, Sub-tokenization and Subword information, etc. . CNN, RNN, LSTM, GRU, Sequence-to-Sequence Models, Greedy Decoding, Beam search	7L
2	**Transformers for Language Modeling:** Encoder Models, Encoder-Decoder Model, Decoder Models, Pre-trained LMs (PLMs), objective functions for training, etc. Other Decoding Strategies: Nucleus Sampling, Temperature Sampling, Top-k Sampling, Self and Multi-Head Attention, Positional Encoding and Layer Normalization **Introduction to Large Language Models (LLMs):** PLMs vs LLMs, LLM families	6L
3	**Scaling Laws:** Kaplan's law, Chinchilla Law **Training LLMs from Scratch:** Selecting the corpus, cleaning and pre-processing, deciding hyper-parameters using scaling laws, training, etc.	6L
4	**Providing Human Feedback:** RLHF, DPO, etc. **Emergent Properties in LLMs:** Prompting techniques (zero shot, few shot, etc.), Chain of Thought, Tree of Thought, X of Thought, etc.	7L
5	**Parameter Efficient Fine-Tuning (PEFT):** Transfer Learning, Soft-Prompting, Adaptors, LoRA (and variants). **Using LLMs with Vector Databases:** Retrieval Augmented Generation and related techniques.	9L
6	**Understanding LLM inner workings:** Mechanistic Interpretability, Overview of recently popular models such as GPT-4, Llama-3, Claude-3,Mistral, and Gemini. Ethical NLP – Bias and Toxicity	5L

5. References:

Textbooks:

1. Daniel Jurafsky and James H. Martin, Speech and Language Processing, 3rd Edition (Draft), Pearson.
2. Lewis Tunstall, Leandro von Werra, and Thomas Wolf, Natural Language Processing with Transformers, O'Reilly Media, 2022.

3. Palash Goyal, Sumit Pandey, Karan Jain, Deep Learning for Natural Language Processing, Apress, 2018.

Reference Books:

1. Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press, 2016.
2. Aurelien Géron, Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow, 3rd Edition, O'Reilly Media.
3. Denis Rothman, Transformers for Natural Language Processing, 2nd Edition, Packt Publishing, 2022.
4. Sebastian Raschka, Yuxi (Hayden) Liu, Vahid Mirjalili, Machine Learning with PyTorch and Scikit-Learn, Packt Publishing, 2022.

6. Course Outcomes (CO):

On completion of the course students will be able to

Course Outcomes	Details	Action Verb	Knowledge Level
DS-725.CO1	Understand classical and neural language modeling approaches including n-grams, embeddings, and sequence models.	Explain	Level 2-Understand
DS-725.CO2	Analyze transformer architectures, attention mechanisms, and decoding strategies used in modern language models.	Analyze	Level 4-Analyze
DS-725.CO3	Apply scaling laws and design choices for training large language models from scratch.	Apply	Level 3-Apply
DS-725.CO4	Evaluate human-feedback-based methods such as RLHF and DPO and understand emergent properties like prompting techniques.	Evaluate	Level 5-Evaluate
DS-725.CO5	Implement parameter-efficient fine-tuning techniques (PEFT) and integrate LLMs with vector databases for RAG systems.	Implement	Level 3-Apply
DS-725.CO6	Examine interpretability approaches and compare recently developed LLMs with focus on ethics, bias, and toxicity.	Examine	Level 4-Analyze

7. Mapping of course outcomes to module / course content

Course Outcome (CO)	Mapped Course Content / Module Topics
CO1	**Classical Language Modeling (CLM):** n-grams, smoothing, class-based, brown clustering, etc. **Neural Language Modeling (NLM):** Word Embeddings, Word2Vec, Feed Forward Neural LM, Contextualization, Sub-tokenization and Subword information, etc. . CNN, RNN, LSTM, GRU, Sequence-to-Sequence Models, Greedy Decoding, Beam search

CO2	**Transformers for Language Modeling:** Encoder Models, Encoder-Decoder Model, Decoder Models, Pre-trained LMs (PLMs), objective functions for training, etc. Other Decoding Strategies: Nucleus Sampling, Temperature Sampling, Top-k Sampling, Self and Multi-Head Attention, Positional Encoding and Layer Normalization **Introduction to Large Language Models (LLMs):** PLMs vs LLMs, LLM families
CO3	**Scaling Laws:** Kaplan's law, Chinchilla Law **Training LLMs from Scratch:** Selecting the corpus, cleaning and pre-processing, deciding hyper-parameters using scaling laws, training, etc.
CO4	**Providing Human Feedback:** RLHF, DPO, etc. **Emergent Properties in LLMs:** Prompting techniques (zero shot, few shot, etc.), Chain of Thought, Tree of Thought, X of Thought, etc.
CO5	**Parameter Efficient Fine-Tuning (PEFT):** Transfer Learning, Soft-Prompting, Adaptors, LoRA (and variants). **Using LLMs with Vector Databases:** Retireval Augmented Generation and related techniques.
CO6	**Understanding LLM inner workings:** Mechanistic Interpretability, Overview of recently popular models such as GPT-4, Llama-3, Claude-3,Mistral, and Gemini. Ethical NLP – Bias and Toxicity

8. Mapping of the Course outcomes to Program Outcomes (PO) (1 = Low, 2 = Moderate, 3 = High)

Mapping of COs with POs and PSOs (Course Articulation Matrix):

CO / PO	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**
CO1	3	2	1	1	2	1	1	1	–	–	–	1
CO2	2	3	2	2	3	1	1	1	–	–	–	2
CO3	1	2	3	3	3	1	1	1	–	–	–	2
CO4	1	2	2	3	2	2	1	1	–	2	–	2
CO5	1	2	3	3	3	2	1	1	–	2	–	2
CO6	2	2	1	2	1	3	3	3	–	2	–	3

9. Mapping to Program Specific Outcome (PSO)

CO / PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	–
CO2	3	3	2	–
CO3	3	3	3	–
CO4	2	3	3	1
CO5	3	3	3	2
CO6	3	2	3	3

Reference:

1. IIT Kanpur https://www.cse.iitk.ac.in/pages/CS781.html

2. NPTEL Course https://onlinecourses.nptel.ac.in/noc25_cs45/preview

*** End of the Syllabus ***

Name: Time Series Analysis
Course Code: DS-734
(Semester- VII)
Course Broad Category: Open Elective (OE)

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1. **Course Prerequisite:** Basic knowledge of statistics, probability, linear algebra, and programming (preferably Python or R). Familiarity with data analysis and introductory machine learning concepts will be beneficial.

2. Course Learning Objectives:

- Understand Time Series Concepts & Components
- Apply Basic & Classical Forecasting Methods
- Implement Exponential Smoothing & ARIMA Models
- Analyze Time Series with Machine Learning & Advanced Models
- Interpret Results & Apply Methods to Real-World Case Studies

3. Teaching methodology and evaluation system for the course:

Teaching methodology – Lectures and Presentations, Interactive Discussions and Case Studies.

Evaluation System –

. Mid-Term Exam (40 Marks)- Formative Assessment [Continuous Assessment 1 (CIA-1)]
B. Internal Assessment (40 Marks)- Formative Assessment [Continuous Assessment 2(CIA-2)]
C. End-Semester Exam (60 Marks)- Summative Assessment.

4. Course Content:

Course Name: Time Series Analysis
Course Code: DS-734
Hours per Week: 3L: 0T: 0P
Credits: 3

Module	**Topics**	**45 L**
1.	**Introduction to Time Series:** Definition of Time Series**,** Classification of Time Series**,** Components of Time Series (Trend, Seasonality, Cyclic, Irregular) Time Series ,Forecasting Method vs Forecasting Model, Single-Step vs Multi Step-Ahead Forecasting, Point vs Interval Forecasting, Time Plot, Seasonal Plot, Seasonal Subseries Plot,	10L

Module	Topics	45 L
	Scatter Plots, Lag Plots Autocorrelation (ACF) and Partial Autocorrelation (PACF) Plots, White Noise	
2.	**Forecasting Methods:** Average Method**,** Naïve Method**,** Seasonal Naïve Method**,** Drift Method. Point Forecast Accuracy Measures, Interval Forecast Accuracy Measures, Scale-Dependent & Scale-Independent Accuracy Measures.	10L
3.	**Simple Exponential Smoothing**, Trend Methods, Holt-Winters Seasonal Method, Taxonomy of Exponential Smoothing Models, Innovation State Space Model, Model Estimation, Forecasting with ETS, Autoregressive (AR) Model, Moving Average (MA) Model, Seasonal ARIMA (SARIMA) Models	10L
4.	**Machine Learning for Time Series**: Overview of ML forecasting methods, Regression models, Tree-based model, Neural Networks	6L
5.	**Hierarchical Time Series Forecasting**: Bottom-Up Approach, Top-Down Approach, Middle-Out Approach, Optimal Combination Approach, Min-Trace Approach Multivariate Time Series Analysis: Analysis of multiple time-dependent variables, Granger Causality, Co-integration Real-World Applications & Case Studies: Finance, Economic Environmental Science, Other domain-specific applications	9L

5. Books:

1. Time Series Analysis and Its Applications: With R Examples

   Author: Robert H. Shumway and David S. Stoffer,

   Publisher: Springer.

2. Introduction to time series and forecasting

   Author: Rob J. Hyndman

6. **COURSE OUTCOMES (COs)**

On completion of the course students will be able to

Course Outcomes	**Details**	**Action Verb**	**Knowledge Level**
DS-734.CO1	Explain the fundamental concepts, components, classifications, and graphical analysis of time series data, including trend, seasonality, cyclic behavior, ACF/PACF, and white noise patterns.	Understand	Level 1-Understand
DS-734.CO2	Apply basic forecasting methods such as average, naïve, seasonal naïve, and drift techniques, and evaluate forecast performance using point and interval accuracy measures.	Apply	Level 3-Apply
DS-734.CO3	Analyze and interpret exponential smoothing models, AR, MA, ARIMA/SARIMA models, and their respective estimation and diagnostic procedures for effective time series forecasting.	Analyze	Level 4-Analyze
DS-734.CO4	Evaluate machine learning–based forecasting approaches, including regression models, tree-based models, and neural networks, for their suitability in handling complex time series patterns.	Evaluate	Level 5-Evaluate
DS-734.CO5	Design and develop hierarchical and multivariate time series forecasting frameworks using techniques such as bottom-up, top-down, optimal combination, Granger causality, and cointegration.	Create	Level 6-Create
DS-734.CO6	Construct and apply appropriate time series models to real-world datasets from finance, economics, environmental science, and other domains, and justify model selection based on forecasting objectives.	Create	Level 6-Create

7. Mapping of course outcomes to module / course content

	CO1	CO2	CO3	CO4	CO5	CO6
M1	**3**	1	1	1	1	2
M2	1	**3**	2	1	1	2
M3	1	2	**3**	1	1	2
M4	1	1	2	**3**	2	2
M5	1	1	1	2	**3**	**3**

8. Mapping of the Course outcomes to Program Outcomes (PO)

Mapping of COs with POs and PSOs (Course Articulation Matrix):

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	**3**	2	1	1	2	1	1	1	1	2	1	1
CO2	2	**3**	2	2	2	1	1	1	1	2	1	1
CO3	2	2	**3**	3	2	1	1	1	1	2	1	1
CO4	1	2	3	**3**	3	2	1	1	1	2	1	2
CO5	1	2	2	3	**3**	2	1	1	2	3	1	2
CO6	1	2	2	2	3	**3**	1	1	2	3	2	3

9. Mapping to Program Specific Outcome (PSO)

	PSO1	PSO2	PSO3	PSO4
CO1	**3**	2	2	1
CO2	3	**3**	2	1
CO3	3	**3**	**3**	1
CO4	2	**3**	**3**	1
CO5	**3**	3	**3**	2
CO6	**3**	**3**	3	**3**

Reference: NIT Rourkela

***** End of Syllabus*****