DEPARTMENT OF PHYSICS
BANGABASI COLLEGE, KOLKATA

ADD-ON COURSE

Title: Applications of Computational Techniques in Research Methodology of Physics

Course Description: This course aims to introduce undergraduate students to the application of machine learning techniques in research methodology within the field of physics. Students will learn the fundamental concepts of machine learning and explore various ways it can be utilized to enhance research in physics. The course will cover basic machine learning algorithms, data preprocessing techniques, and their application in solving problems relevant to physics research. Practical exercises and projects will provide hands-on experience in implementing machine learning algorithms to analyze and interpret physics data.

Course Objectives:

1. Understand the basic principles of machine learning and its relevance to physics research methodology.
2. Gain proficiency in using machine learning algorithms to analyze and interpret physics data.
3. Learn data preprocessing techniques essential for handling physics datasets.
4. Explore real-world applications of machine learning in various branches of physics research.
5. Develop skills in designing and implementing machine learning models for specific physics research problems.
6. Enhance critical thinking and problem-solving abilities through practical exercises and projects.

Course Outline:

Module 1: Introduction to Machine Learning (**5 Lectures/Lab Classes**)

- Overview of machine learning concepts and terminology
- Types of machine learning: supervised learning, unsupervised learning, and reinforcement learning
- Introduction to Python programming language and libraries for machine learning (e.g., NumPy, pandas, scikit-learn)

Module 2: Data Preprocessing for Physics Datasets (**5 Lectures/Lab Classes**)

- Data cleaning: handling missing values, outlier detection, and data normalization
- Feature scaling and feature engineering techniques for physics data
- Introduction to data visualization for exploratory data analysis

Module 3: Supervised Learning Algorithms (**5 Lectures/Lab Classes**)

- Linear regression and its application in physics research
- Classification algorithms: logistic regression, decision trees, and random forests
- Evaluation metrics for classification models (accuracy, precision, recall, F1-score)

Module 4: Unsupervised Learning Algorithms (**5 Lectures/Lab Classes**)

- Clustering algorithms: k-means clustering, hierarchical clustering
- Dimensionality reduction techniques: principal component analysis (PCA), t-distributed stochastic neighbor embedding (t-SNE)
- Applications of unsupervised learning in physics research (e.g., pattern recognition, anomaly detection)

Module 5: Advanced Topics in Machine Learning for Physics Research (**5 Lectures/Lab Classes**)

- Introduction to neural networks and deep learning
- Convolutional neural networks (CNNs) for image analysis in physics

- Recurrent neural networks (RNNs) for time-series data analysis in physics

Module 6: Case Studies and Applications in Physics Research (**5 Lectures/Lab Classes**)

- Application of machine learning in astrophysics, particle physics, condensed matter physics, and other branches of physics
- Hands-on projects: analyzing real-world physics datasets using machine learning techniques
- Ethical considerations and challenges in applying machine learning to physics research

Assessment:

- Weekly assignments to reinforce understanding of concepts covered in lectures
- Mid-term project: implementing a supervised learning algorithm to analyze a physics dataset
- Final project: designing and implementing a machine learning model to address a specific research problem in physics
- Participation in discussions and group activities during lectures and lab sessions

Prerequisites:

- Basic knowledge of calculus, linear algebra, and probability theory
- Familiarity with programming fundamentals (preferably in Python)

Resources:

Textbooks:

- "Introduction to Machine Learning with Python" by Andreas C. Müller and Sarah Guido
- "Pattern Recognition and Machine Learning" by Christopher M. Bishop

Online resources:

- Coursera courses on machine learning and data science
- GitHub repositories with machine learning tutorials and projects

Research papers and articles on the application of machine learning in physics

Course Outcome:

- By the end of this course, students will have a solid foundation in machine learning techniques and their applications in physics research methodology, empowering them to tackle complex research problems in their future academic and professional pursuits.

Resource Person: Dr. Sunanda Patra, Assistant Professor in Physics, Bangabasi Evening College & Prof. Satyajit Ray, SACT, Bangabasi College

Course Co-ordinator: Dr. Ankan Mukherjee, Assistant Professor in Physics, Bangabasi College

Eligibility:

This course is compulsory for Semester-VI Physics Honours students of Bangabasi College. However, some students outside this domain may be also admitted with prior permission from the College Authority. They must contact the course coordinator immediately at the commencement of the even semester.

Course Fees:

NIL