Course Title: Machine Learning and Applications			
Course Code: UDS 301	**No. of credits: 4**	**L-T-P:** 30-15-30	**Learning hours: 60**
			L: Lectures**; T:** Tutorials**; P:** Practicals
Pre-requisite (if any): Data Mining & Analysis (UDS 205)			
Department: Natural and Applied Sciences			
Course Coordinator: Dr Adwitiya Sinha		**Course Instructor:**	
Contact Details:			
Course Type: Major		**Course Offered in:** Semester-4	

Course Description

This course introduces fundamental machine learning paradigms, models, and their applications in artificial intelligence driven solutions. It covers supervised and unsupervised learning, model evaluation techniques, explainable AI, and performance analysis. Through hands-on programming using Python and tools like Scikit-Learn, Shap, Optuna, and PyCaret. Students will develop practical skills in building and optimizing machine learning models. By the end, students will learn to integrate theoretical concepts with real-world case studies, thus enabling them to explore AI-based decision-making and predictive analytics.

Course Objectives

- Understand fundamentals of machine learning techniques and their applications in AI.
- Apply supervised and unsupervised learning models to real-world datasets.
- Design and evaluate machine learning solutions with performance optimization techniques.

Course Content

Module	Topic	L	T	P
1	**Introduction to Machine Learning and AI**			
	The focus of this module is on the basic fundamentals, paradigms, importance, and applications of machine learning. Following topics will be covered: Significance of Machine Learning, Applications in AI, Evolution, Paradigms of Machine Learning: Descriptive and Predictive Models; Types: Supervised, Unsupervised, Semi-Supervised, Reinforcement Learning, Ensemble Learning, Active Learning, and other methods of learning, Machine Learning algorithms. Introductory ML hands-on session with Python programming using Scipy and Scikit Learn.	6	2	4
2	**Model Building & Performance Analysis**			
	This module highlights the model building process and broad ways of evaluating performance. Following topics will be addressed in this module: Concept of Model Building, Class Balancing, Data Augmentation, Overfitting, Underfitting, Model Features and Hyperparameters, Target Function, Loss function, Error Function, Objective Function, Model Training Methods (Holdout, k-Fold Cross-validation, Bootsrapping), Performance Parameters, Explainable AI (XAI). Practical sessions with baseline machine learning models	8	3	6

	using Scikit Learn and Imbalanced-Learn. Introductory hands-on with XAI using Shap.			
3	**Supervised Machine Leaning**			
	The purpose of this module is to introduce the importance and implementation of supervised machine learning models. The major topics to be covered in module include: Supervised Machine Learning Algorithms: Regression methods, SVM, k-NN, Tree-based models, Hyperparameter Tuning and Optimization, Confusion Matrix, Model Accuracy, Sensitivity, Specificity, Precision, Recall, Kappa, ROC and AUC curves, Error Handling, Residual Analysis and Transformation, Regularization, Feature Importance Analysis, Explainable Models, Building Pipelines. Practical using Python hands-on session with case studies in Shap, Scikit Learn, and Optuna.	8	5	10
4	**Unsupervised Machine Leaning**			
	This module encompasses through the understanding of unsupervised models in machine learning and dimensionality reduction for improving model performance. This will include the following contents: Unsupervised Machine Learning: Clustering and Association Analysis, Elbow Method, Silhouette Coefficient, density-based clustering, grid-based clustering. Applications of Dimensionality Reduction, Lasso and Ridge Regularization, Feature Extraction, Principal Component Analysis, Linear Discriminant Analysis, Singular Value Decomposition. Hands-on session with real-world case studies using YellowBrick and PyCaret.	8	5	10
	Total	**30**	**15**	**30**

Practical Sessions	Introductory ML hands-on session with Python programming using Scipy and Scikit Learn.	-	-	4
	Practical sessions with baseline machine learning models using Scikit Learn and Imbalanced-Learn. Introductory hands-on with XAI using Shap.			6
	Python hands-on session with case studies using Shap, Scikit Learn, Optuna	-	-	10
	Hands-on session with real-world case studies using Yellow-Brick and PyCaret.	-	-	10
	Total Practical Sessions	**-**	**-**	**30**

Evaluation Criteria

- Minor Test: Written test [at the end of teaching of modules 1 and 2] -- 20%
- Major Test: Written test [end of semester, full syllabus, modules 1, 2, 3, and 4] -- 40%
- Practical Test: Practical test [including modules 2, 3 and 4] -- 20%
- Project-based learning: Project demonstration and report [at end of module 4] -- 20%

Learning Outcomes

By the end of the course, students will:

- understand real-world significance of machine learning and AI
  [Module 1 and 2; Minor Test]
- develop in-depth knowledge of supervised and unsupervised learning
  [Module 2 and 3; Practical Test]
- gain insights on performance analysis of machine learning models
  [Module 1, 2, 3, and 4; Project-based learning and Major Test]

Pedagogical Approach

- The course will provide knowledge on the application and implementation of machine learning through classroom discussions, lectures, tutorials, and assessments.
- The course will enable students to explore different techniques of AI-centric model building.

Reading Resources Recommended (* = suggested readings)

- * Jung, Alexander. (2022). *Machine Learning: The Basics*. Springer
- Carbonell, J.G., Michalski, R.S. & Mitchell, T.M. (2013). *Machine Learning: An Artificial Intelligence Approach*. Springer Berlin Heidelberg Publications, Springer.
- Julian, David. (2016). *Designing Machine Learning Systems with Python*. Packt Publishing.
- Andreas C. Müller & Sarah Guido. (2016). *Introduction to Machine Learning with Python*. O'Reilly Publications.
- Kelleher, J. D., Mac Namee, B., & D'arcy, A. (2020). *Fundamentals of Machine Learning for Predictive Data Analytics*: Algorithms, Worked Examples, and Case Studies. MIT press.

Official Documentations of Tools/Libraries

- ScikitLearn, URL: scikit-learn.org/stable
- PyCaret, URL: pycaret.readthedocs.io/en/latest
- Yellow Brick, URL: scikit-yb.org/en/latest
- Optuna, A hyperparameter optimization framework, URL: optuna.readthedocs.io/en/stable
- Shap, URL: shap.readthedocs.io/en/latest

Student Responsibilities: The students are required:

- To be regular and attentive in theory classes and lab sessions
- To come prepared with readings that would be given in the theory class
- To come prepared in lab with readings from respective theory concepts taught in the class
- To sincerely participate in the day-to-day lab activities
- To incorporate real-word datasets as case-studies in project-based learning
- To submit assignments and project works on or before the deadlines

Course Designed by:

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Course Reviewers:

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