***Artificial intelligence and Machine Learning***

**Introduction and objectives**

Machine learning is a sub field of AI that involves understanding the structure of data, uncovering complex patterns in the give dataset and further feed analysed data into algorithms to make predictions or classifications. Machine learning algorithms learn to improve as they process large amount of data overtime.

The main objectives of Machine Learning include Prediction of outcomes, Classification and labelling, Automation of labour- intensive tasks and anomaly detection.

**Machine Learning Pre- Requisites**

**Libraries –** scikit learn, NUMpy, TensorFlow, PyTorch.

Machine learning requires key mathematical concepts in order to understand the algorithms, this includes

**Linear Algebra** – Matrices, vectors, eigen values, eigen vectors.

Eigen values – solves system of linear differential equations.

Consider a n x n matrix A;

Ax = lambda x

Where x is the eigen vector

And lambda is the eigen value. (eigen values are non- trivial (must be a non zero vector))

**Regression** – Bayesian regression.

**Statistics & Probability** – Hypothesis testing, Sampling distributions, Bayes theorem

**Hypothesis Testing**: A statistical method for testing a hypothesis about a population parameter.

* Defining the null hypothesis H0 and the alternative hypothesis H1​.
* Choosing a significance level α.

**BAYES THEOREM** –

P(A∣B)= P(B∣A)⋅P(A)​ / P(B)

Where P(A|B) is the probability of condition when event A is occurring while event B has already occurred.

**Optimization Techniques** – Gradient descent optimisation.

**Calculus** – Integration, Partial Differentiation.

**Machine Learning workflow-**

**Data Collection**: Understanding different data sources and data collection techniques.

**Model Training and Tuning**: Techniques for training models, selecting hyperparameters, and evaluating performance.

**Model Evaluation**: Knowledge of metrics for model evaluation (accuracy, precision, recall, F1 score).

**Metrics Definitions and Fromulas –**

**Where,** TP – True Positive

FP – False Positive

TN – True Negative

FN – False Negative

**Accuracy** measures the proportion of correct predictions out of all predictions

**Accuracy = TP + TN / TP + TN + FP + FN**

**Precision** measures the proportion of true positive predictions out of all positive predictions.

**Precision = TP / TP + FP**

**Recall** measures the proportion of true positives out of all actual positives

**Recall = TP / TP + FN**

**F-1 score** is the harmonic mean of precision and recall.

**F-1 score = 2 x Precision + Recall = 2 x TP / 2 x TP + FP + FN**

**Precision × Recall​**

**Machine Learning Algorithms in Artificial Intelligence**

**Supervised learning** – In supervised learning, algorithms learn from labeled datasets, where each data point has an associated output (label). The model uses this information to understand the relationship between input features and output labels.

Examples – Linear regression (relationship between independent and dependent variables.)

**Unsupervised learning** - Unsupervised learning algorithms work with unlabeled data, so they don't have predefined outputs to guide learning. Instead, they try to find structure or patterns within the data.

**Examples** – k means clustering, k nearest neighbours etc

**Reinforcement learning** - In reinforcement learning, an agent learns by interacting with an environment and receiving rewards or penalties for actions taken.

**Examples** – DQN

Deep learning - Each layer of neurons in the network learns increasingly abstract representations of the data.

**Examples** – CNN , RNN.

**Use case of ML algorithms in Real- World**

* **Image classification-** object detection, and face recognition (using CNNs, RNNs, and Transformers).
* **Natural Language Processing**: Sentiment analysis, machine translation, and summarization (using LSTMs, RNNs, Transformers).

**Transformers**

This mechanism assigns different weights to each word in a sentence, allowing the model to focus on the most relevant words while encoding the input. For example, in the sentence – The dog was resting on the couch, it was tired. The model must recognise that “it” in the sentence refers to the dog.

Structure – Encoder / decoder, BERT uses encoder(to understand the language) only structure where as GPT used decoder(for language generation) only structure.

* **Large Language Models**

LLMs are advanced models built on transformer architecture and trained on massive amounts of text data to understand and generate human-like language.

**Pre - training and Fine-tuning** - LLMs are typically trained in two phases. First, they undergo unsupervised pre-training, where they learn general language patterns from large datasets. Then, they are fine-tuned on specific tasks (such as translation or summarization) to make their responses more task-specific.