DEPARTMENT OF BIOMEDICAL ENGINEERING

24AI671-FUNDAMENTALS OF DATA SCIENCE

UNIT IV- DATA ANALYTICS AND MACHINE LEARNING FUNDAMENTALS

4.1 INTRODUCTION TO MACHINE LEARNING

Machine Learning (ML) is a branch of Artificial Intelligence in which computers **learn from data and improve their performance with experience, without being explicitly programmed** for every situation. Instead of writing fixed rules, we give the computer many examples, and it finds the rules and patterns by itself. Arthur Samuel (1959) described it as the field that gives computers the ability to learn without being explicitly programmed.

A more formal definition by Tom Mitchell says: "A program is said to learn from experience E with respect to a task T and performance measure P, if its performance at T, measured by P, improves with experience E." For example, in spam detection the task T is classifying emails, the experience E is a set of emails already marked spam or not spam, and the performance P is the percentage of emails classified correctly.

Traditional Programming vs. Machine Learning

Point	Traditional Programming	Machine Learning
Input	Data + Rules (program)	Data + Expected results
Output	Result / Answer	Rules (the trained model)
Approach	Programmer writes every rule	Computer discovers rules from examples
Suitable for	Simple, well-defined problems	Complex problems with many variables, e.g. speech, images
Adaptability	Rules must be changed by hand	Model can be retrained with new data

Types of Machine Learning

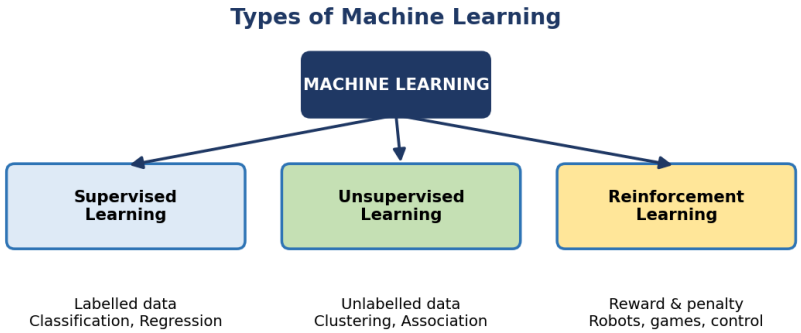


Fig 1.1 Types of machine learning

- **Supervised learning** – the model learns from **labelled data**, where the correct output is given for every input. Example: predicting house price, detecting spam.
- **Unsupervised learning** – the model finds hidden patterns in **unlabelled data**. Example: grouping customers with similar behaviour.
- **Semi-supervised learning** – uses a small amount of labelled data together with a large amount of unlabelled data.
- **Reinforcement learning** – an agent learns by interacting with an environment and receiving **rewards for good actions and penalties for bad actions**. Example: self-driving cars, game-playing robots.

Machine Learning Workflow

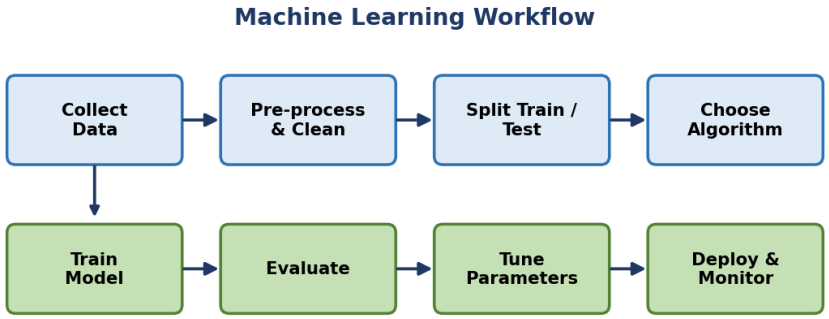


Fig 1.2 Steps in a machine learning project

- **Collect data** – from sensors, databases, files or the web.
- **Pre-process** – clean the data, handle missing values and outliers, scale and encode the features.
- **Split the data** – usually 70–80% for training and 20–30% for testing (sometimes a validation set is also kept).

- **Choose an algorithm** – depending on whether the problem is classification, regression or clustering.
- **Train the model** – the algorithm learns patterns from the training data.
- **Evaluate** – check performance on the unseen test data using suitable metrics.
- **Tune** – adjust hyper-parameters to improve the result.
- **Deploy and monitor** – use the model in real applications and retrain when accuracy falls.

Important Terms

Term	Meaning
Feature	An input variable used for prediction (e.g. temperature, age)
Label / Target	The output the model must predict (e.g. price, 'spam' / 'not spam')
Training data	Data used to teach the model
Test data	Unseen data used to check the model
Parameter	Value learned by the model from data (e.g. weights)
Hyper-parameter	Setting chosen by the user before training (e.g. learning rate, K in KNN)
Bias	Error from wrong or too simple assumptions in the model
Variance	Error from the model being too sensitive to the training data

Overfitting and Underfitting

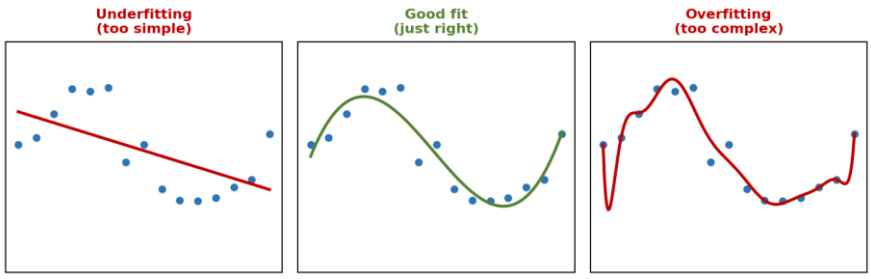


Fig 1.3 Underfitting, good fit and overfitting

- **Underfitting** – the model is too simple and performs poorly even on training data (high bias).

- **Overfitting** – the model memorises the training data including noise, so it performs well on training data but poorly on new data (high variance).
- **Remedies for overfitting:** more training data, simpler model, regularisation (L1/L2), cross-validation, dropout (in neural networks) and early stopping.
- **Remedies for underfitting:** a more complex model, more or better features and longer training.

Applications of Machine Learning

- Spam filtering, speech recognition and language translation.
- Medical diagnosis and disease prediction.
- Fraud detection in banking and credit scoring.
- Recommendation systems such as those used by online shops and video platforms.
- Predictive maintenance, quality inspection and process control in industry.
- Self-driving vehicles, robotics and smart grids.