## 1.1 INTRODUCTION

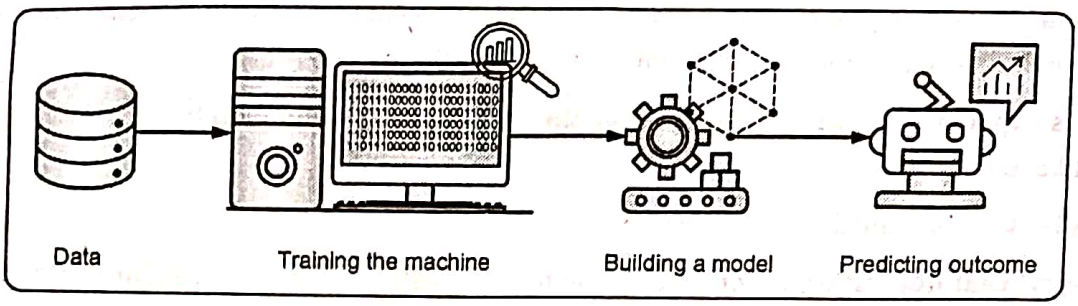
- The term "Machine Learning" or ML in short, was coined in 1959 by Arthur Samuel in the context of solving game of checkers by machine. The term refers to a computer program that can learn to produce a behaviour that is not explicitly programmed by the author of the program.
- Rather it is capable of showing behavior that the author may be completely unaware of. This behaviour is learned based on three factors:
  (1) Data that is consumed by the program,
  (2) A metric that quantifies the error or some form of distance between the current behavior and ideal behavior, and
  (3) A feedback mechanism that uses the quantified error to guide the program to produce better behavior in the subsequent events
- Machine learning is a subfield of AI and is, in many cases, the basis for AI technology. The goal of machine learning technology is to understand the structure of data and fit that data into specific models that are able to then be understood and used by humans for various applications throughout life.
- Traditional computer sciences are driven with algorithms that are human-created and managed, machine learning is driven by algorithms that the device itself can learn from and grow from. Beyond that, they are often built with a very specific purpose that enables them to specialize in specific areas of "knowledge" or capabilities.
- Everything from the face recognition capabilities in your phone to the self-driving technology in cars is derived from specialized forms of machine learning technology. It has become, and continues to become, a highly relevant and well researched part of our modern world.

### 1.1.1 What is Machine Learning ?

GQ. What is Machine Learning ?
GQ. What is the importance of Machine Learning ?

- Machine learning is a form of computer science technology whereby the machine itself has a complex range of "knowledge" that allows it to take certain data inputs and use complex statistical analysis strategies to create output values that fall within a specific range of knowledge, data, or information.
- "Machine learning focuses on the development of computer programs that can access data and use it to learn for themselves."
- Machine learning devices essentially take data, and use to look for patterns and other pieces of specified information to create predictions or recommendations.
- The goal is for computers to learn how to use data and information to be able to learn automatically, rather than requiring humans to intervene or assist with the learning process.

- A Machine Learning process begins by feeding the machine lots of data, by using this data the machine is trained to detect hidden insights and trends. These insights are then used to build a Machine Learning Model by using an algorithm in order to solve a problem.




(1A7)**Fig. 1.1.1 : What is machine learning?**

### 1.1.2 Why Is Machine Learning Important ?

- Ever since the technical revolution, we've been generating an immeasurable amount of data. As per research, we generate around 2.5 quintillion bytes of data every single day! It is estimated that by 2020, 1.7MB of data will be created every second for every person on earth.
- With the availability of so much data, it is finally possible to build predictive models that can study and analyze complex data to find useful insights and deliver more accurate results
- Machine learning and data mining, a component of machine learning, are crucial tools in the process to glean insights from massive datasets held by companies and researchers today.

**Here's a list of reasons why Machine Learning is so important :**

(1) **Increase in Data Generation :** Due to excessive production of data, we need a method that can be used to structure, analyze and draw useful insights from data. This is where Machine Learning comes in. It uses data to solve problems and find solutions to the most complex tasks faced by organizations.

(2) **Improve Decision Making :** By making use of various algorithms, Machine Learning can be used to make better business decisions.

(3) **Uncover patterns & trends in data :** Finding hidden patterns and extracting key insights from data is the most essential part of Machine Learning. By building predictive models and using statistical techniques, Machine Learning allows you to dig beneath the surface and explore the data at a minute scale. Understanding data and extracting patterns manually will take days, whereas Machine Learning algorithms can perform such computations in less than a second.

(4) **Solve complex problems :** From detecting the genes linked to the deadly ALS disease to building self-driving cars, Machine Learning can be used to solve the most complex problems.

### 1.1.3 Machine Learning Definitions

- **Algorithm :** A Machine Learning algorithm is a set of rules and statistical techniques used to learn patterns from data and draw significant information from it. It is the logic behind a Machine Learning model. An example of a Machine Learning algorithm is the Linear Regression algorithm.

- **Mode l :** A model is the main component of Machine Learning. A model is trained by using a Machine Learning Algorithm. An algorithm maps all the decisions that a model is supposed to take based on the given input, in order to get the correct output.
- **Predictor Variable :** It is a feature(s) of the data that can be used to predict the output.
- **Response Variable :** It is the feature or the output variable that needs to be predicted by using the predictor variable(s).
- **Training Data :** The Machine Learning model is built using the training data. The training data helps the model to identify key trends and patterns essential to predict the output.
- **Testing Data :** After the model is trained, it must be tested to evaluate how accurately it can predict an outcome. This is done by the testing data set.

### 1.1.4 Machine Learning Process

**GQ.** What are the various steps in machine learning process?

The Machine Learning process involves building a Predictive model that can be used to find a solution for a Problem Statement. To understand the Machine Learning process let's assume that a problem that needs to be solved by using Machine Learning. The problem is to predict the occurrence of rain in your local area by using Machine Learning. The below steps are followed in a Machine Learning process :

**Step 1 :** Define the objective of the Problem Statement

- At this step, we must understand what exactly needs to be predicted. In this case, the objective is to predict the possibility of rain by studying weather conditions.
- At this stage, it is also essential to take mental notes on what kind of data can be used to solve this problem or the type of approach you must follow to get to the solution.

**Step 2 :** Data Gathering

- At this stage, the questions are such as,
  - What kind of data is needed to solve this problem?
  - Is the data available?
  - How can I get the data?
- Once you know the types of data that is required, you must understand how you can derive this data. Data collection can be done manually or by web scraping.
- The data needed for weather forecasting includes measures such as humidity level, temperature, pressure, locality, whether or not you live in a hill station, etc. Such data must be collected and stored for analysis.

**Step 3 :** Data Preparation

- **The data collected is almost never** in the right format. There will be a lot of inconsistencies in the data set such as missing values, redundant variables, duplicate values, etc.

- Removing such inconsistencies is very essential because they might lead to wrongful computations and predictions. Therefore, at this stage, the data set can be scanned for any inconsistencies and can be fixed then and there.

▶ **Step 4 :** Exploratory Data Analysis

- EDA or Exploratory Data Analysis is the brainstorming stage of Machine Learning. Data Exploration involves understanding the patterns and trends in the data. At this stage, all the useful insights are drawn and correlations between the variables are understood.
- For example, in the case of predicting rainfall, we know that there is a strong possibility of rain if the temperature has fallen low. Such correlations must be understood and mapped at this stage.

▶ **Step 5 :** Building a Machine Learning Model

- All the insights and patterns derived during Data Exploration are used to build the Machine Learning Model.
- This stage always begins by splitting the data set into two parts, training data, and testing data. The training data will be used to build and analyze the model. The logic of the model is based on the Machine Learning Algorithm that is being implemented.
- In the case of predicting rainfall, since the output will be in the form of True (if it will rain tomorrow) or False (no rain tomorrow), we can use a Classification Algorithm such as Logistic Regression.
- Choosing the right algorithm depends on the type of problem to be solved, the data set and the level of complexity of the problem.

▶ **Step 6 :** Model Evaluation & Optimization

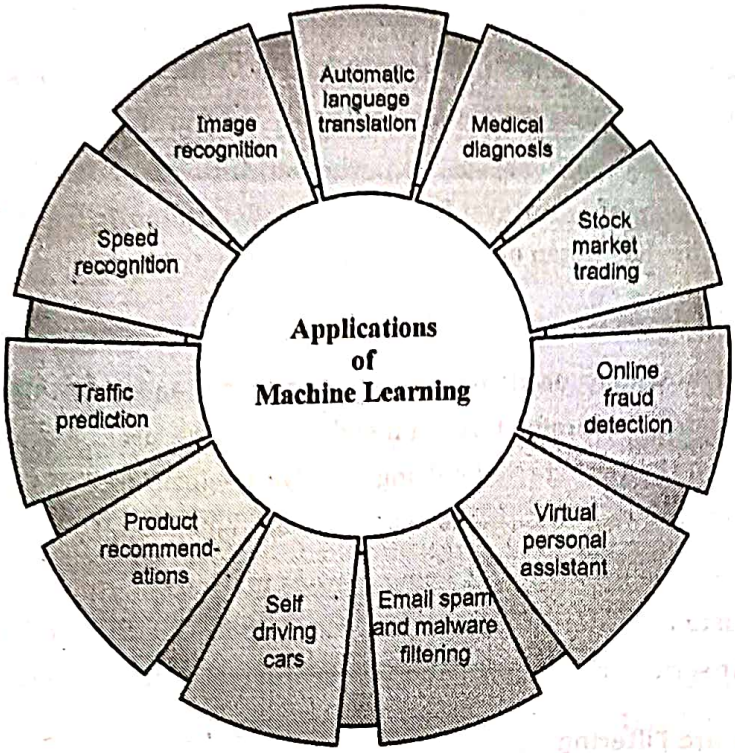
- After building a model by using the training data set, it is finally time to put the model to a test. The testing data set is used to check the efficiency of the model and how accurately it can predict the outcome.
- Once the accuracy is calculated, any further improvements in the model can be implemented at this stage. Methods like parameter tuning and cross-validation can be used to improve the performance of the model.

▶ **Step 7 :** Predictions

- Once the model is evaluated and improved, it is finally used to make predictions. The final output can be a Categorical variable (e.g. True or False) or it can be a Continuous Quantity (e.g. the predicted value of a stock).
- In this case, for predicting the occurrence of rainfall, the output will be a categorical variable.

### 1.1.5 Applications of Machine Learning

**GQ.** State various applications of machine learning?
**GQ.** What are the various applications of machine learning in Mechanical Engineering?




(1A8)**Fig 1.1.2 : Applications of machine learning**

**(1) Image Recognition**

- Image recognition is one of the most common applications of machine learning. It is used to identify objects, persons, places, digital images, etc. The popular use case of image recognition and face detection is, Automatic friend tagging suggestion.
- Facebook provides us a feature of auto friend tagging suggestion. Whenever we upload a photo with our Facebook friends, then we automatically get a tagging suggestion with name, and the technology behind this is machine learning's face detection and recognition algorithm.
- It is based on the Facebook project named "Deep Face," which is responsible for face recognition and person identification in the picture.

**(2) Speech Recognition**

- While using Google, we get an option of "Search by voice," it comes under speech recognition, and it's a popular application of machine learning.
- Speech recognition is a process of converting voice instructions into text, and it is also known as "Speech to text", or "Computer speech recognition."
- At present, machine learning algorithms are widely used by various applications of speech recognition. Google assistant, Siri, Cortana, and Alexa are using speech recognition technology to follow the voice instructions.

**(3) Traffic prediction**

- If we want to visit a new place, we take help of Google Maps, which shows us the correct path with the shortest route and predicts the traffic conditions.
- It predicts the traffic conditions such as whether traffic is cleared, slow-moving, or heavily congested with the help of two ways: Real Time location of the vehicle form Google Map app and sensors. Average time has taken on past days at the same time.

**(4) Product recommendations**

- Machine learning is widely used by various e-commerce and entertainment companies such as Amazon, Netflix, etc., for product recommendation to the user. Whenever we search for some product on Amazon, then we started getting an advertisement for the same product while internet surfing on the same browser and this is because of machine learning.
- Google understands the user interest using various machine learning algorithms and suggests the product as per customer interest. As similar, when we use Netflix, we find some recommendations for entertainment series, movies, etc., and this is also done with the help of machine learning.

**(5) Email Spam and Malware Filtering**

- Whenever we receive a new email, it is filtered automatically as important, normal, and spam. We always receive an important mail in our inbox with the important symbol and spam emails in our spam box, and the technology behind this is Machine learning.
- Some machine learning algorithms such as Multi-Layer Perceptron, Decision tree, and Naïve Bayes classifier are used for email spam filtering and malware detection.

**(6) Virtual Personal Assistant**

- We have various virtual personal assistants such as Google assistant, Alexa, Cortana, Siri. As the name suggests, they help us in finding the information using our voice instruction.
- These assistants can help us in various ways just by our voice instructions such as Play music, call someone, open an email, scheduling an appointment, etc. These virtual assistants use machine learning algorithms as an important part.
- These assistant record our voice instructions, send it over the server on a cloud, and decode it using ML algorithms and act accordingly.

**(7) Online Fraud Detection**

- Machine learning is making our online transaction safe and secure by detecting fraud transaction.
- Whenever we perform some online transaction, there may be various ways that a fraudulent transaction can take place such as fake accounts, fake ids, and steal money in the middle of a transaction.

- So, to detect this, Feed Forward Neural network helps us by checking whether it is a genuine transaction or a fraud transaction.

**(8) Stock Market trading**

- Machine learning is widely used in stock market trading.
- In the stock market, there is always a risk of up and downs in shares, so for this machine learning's long short term memory neural network is used for the prediction of stock market trends.

**(9) Automatic Language Translation**

- Nowadays, if we visit a new place and we are not aware of the language then it is not a problem at all, as for this also machine learning helps us by converting the text into our known languages.
- Google's GNMT (Google Neural Machine Translation) provide this feature, which is a Neural Machine Learning that translates the text into our familiar language, and it called as automatic translation.

## 1.2 COMPARISON OF MACHINE LEARNING WITH TRADITIONAL PROGRAMMING

| Sr. No. | Machine Learning | Traditional Programming |
|---|---|---|
| 1. | Machine learning is not a manual process here the algorithm automatically formulate the rules from the data. | Traditional programming is a manual process. – i.e. a person or programmer creates the program. Without anyone has to manually formulate or code rules. |
| 2. | Machine learning approach   **Fig. A** | Traditional programming   **Fig.B** |
| 3. | With a subset of Artificial Intelligence (AI), machine learning is motivated by human learning behaviour.<br>Here we show the examples and machine figures out how to solve the problem by itself. | In T.P., we write down the exact steps required to solve the problem. |
| 4. | A machine learning algorithm takes an input and output and gives some logic which can be used to work with new input to give an output. | A traditional algorithm takes some input and some logic in the form of code and gives the output. |

## 1.3 ML VS AI VS DATA SCIENCE

- ML vs AI vs Data Science are interconnected but have different scopes. They follow different approaches and produce different results depending on the problem.
- Here we shall see how ML, AI and Data Science differ from each other.

| Aspects | Machine Learning | Artificial Intelligence | Data Science |
|---|---|---|---|
| Job roles | Machine Learning, Engineer, Data Architect, Data scientist, Data Mining specialist, cloud Architect and cyber security Analyst, and more. | Machine learning Engineer, Data scientist, Business intelligence. Developer, Big Data Architect, Research Scientist. | Data engineer, Data scientist, Data Analyst, Data Architect, Database Administrator, Machine learning engineer, statistician, Business Analyst, Data and Analytics Manager |
| Skills | Statistics, Probability Data Modelling. Programming skills, Applying ML Libraries and algorithms. Software design python. | Mathematical and Algorithms skills Probability and statistics Knowledge, Expertise in programming Awareness about Advanced Signal Processing techniques well versed with unix Tools. | Programming skills. Statistics Machine Learning, Multi-variable calculus and linear Algorithm, Data visualisation and Communication Software Engineering Data Intuition. |
| Salary | 1123 k/year Average base pay | 14.3 lakhs per annum | 1050 k/year Average base pay |

## 1.4 TYPES OF LEARNING

With the constant advancements in artificial intelligence, the field has become too big to specialize in all together. There are countless problems that can be solved with countless methods. Knowledge of an experienced AI researcher specialized in one field may mostly be useless for another field. Understanding the nature of different machine learning problems is very important. Even though the list of machine learning problems is very long, these problems can be grouped into three different learning approaches:

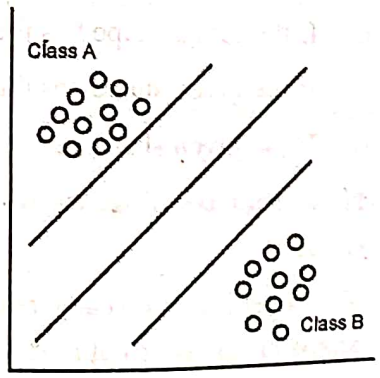
1. Supervised Learning;
2. Unsupervised Learning;
3. Reinforcement Learning.

Top machine learning approaches are categorized depending on the nature of their feedback mechanism for learning. Most of the machine learning problems may be addressed by adopting one of these approaches.

## 1.5 SUPERVISED LEARNING

**GQ.** What is supervised learning?
**GQ.** Explain supervised learning with the help of an example.
**GQ.** How supervised learning works?

- Learning that takes place based on a class of examples is referred to as supervised learning. It is learning based on labelled data. In short, while learning, the system has knowledge of a set of labelled data. This is one of the most common and frequently used learning methods
- The supervised learning method is comprised of a series of algorithms that build mathematical models of certain data sets that are capable of containing both inputs and the desired outputs for that particular machine.
- The data being inputted into the supervised learning method is known as training data, and essentially consists of training examples which contain one or more inputs and typically only one desired output. This output is known as a "supervisory signal."
- In the training examples for the supervised learning method, the training example is represented by an array, also known as a vector or a feature vector, and the training data is represented by a matrix.
- The algorithm uses the iterative optimization of an objective function to predict the output that will be associated with new inputs.
- Ideally, if the supervised learning algorithm is working properly, the machine will be able to correctly determine the output for the inputs that were not a part of the training data.
- Supervised learning uses classification and regression techniques to develop predictive models. Classification techniques predict categorical responses,
- Regression techniques predict continuous responses, for example, changes in temperature or fluctuations in power demand. Typical applications include electricity load forecasting and algorithmic trading.
- Let us begin by considering the simplest machine-learning task : supervised learning for classification. Let us take an example of classification of documents. In this particular case a learner learns based on the available documents and their classes. This is also referred to as labelled data.
- The program that can map the input documents to appropriate classes is called a classifier, because it assigns a class (i.e., document type) to an object (i.e., a document). The task of supervised learning is to construct a classifier given a set of classified training examples. A typical classification is depicted in Fig. 1.5.1.
- Fig. 1.5.1 represents a hyperplane that has been generated after learning, separating two classes - class A and class B in different parts. Each input point presents input–output instance from sample space. In case of document classification, these points are documents.

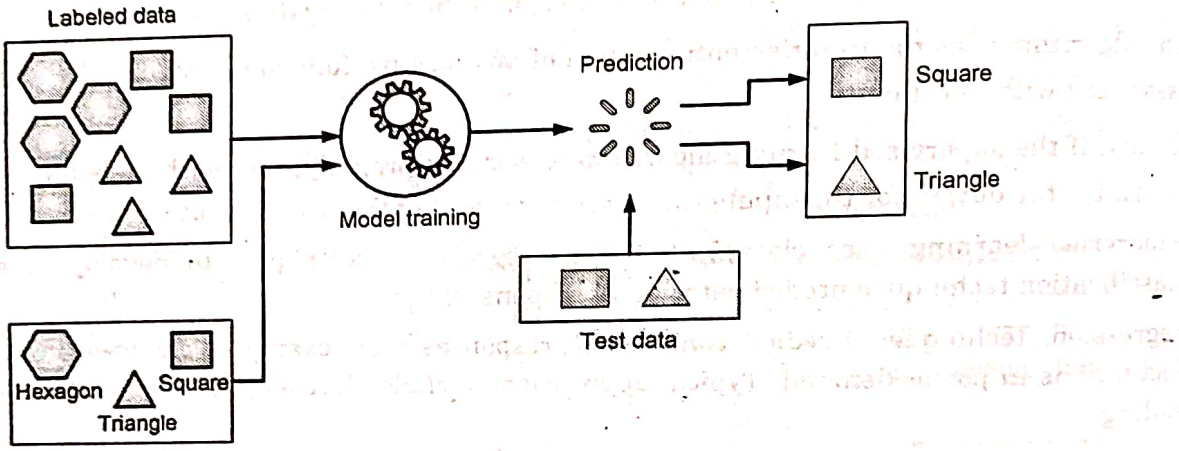



(1D1) **Fig. 1.5.1 : Supervised learning**

- Learning computes a separating line or hyperplane among documents. An unknown document type will be decided by its position with respect to a separator.
- There are a number of challenges in supervised classification such as generalization, selection of right data for learning, and dealing with variations. Labelled examples are used for training in case of supervised learning. The set of labelled examples provided to the learning algorithm is called the *training set*.
- Supervised learning is not just about classification, but it is the overall process that with guidelines maps to the most appropriate decision.

### 1.5.1 How Supervised Learning Works?

- In supervised learning, models are trained using labelled dataset, where the model learns about each type of data. Once the training process is completed, the model is tested on the basis of test data (a subset of the training set), and then it predicts the output.
- The working of Supervised learning can be easily understood by the below example and diagram (Fig. 1.5.2).




(1D2)**Fig. 1.5.2 How Supervised learning works?**

- Suppose we have a dataset of different types of shapes which includes square, rectangle, triangle, and Polygon. Now the first step is that we need to train the model for each shape.
  - If the given shape has four sides, and all the sides are equal, then it will be labelled as a **Square**.
  - If the given shape has three sides, then it will be labelled as a **triangle**.
  - If the given shape has six equal sides then it will be labelled as **hexagon**.
- Now, after training, we test our model using the test set, and the task of the model is to identify the shape.
- The machine is already trained on all types of shapes, and when it finds a new shape, it classifies the shape on the bases of a number of sides, and predicts the output.
- Following are the steps involved in Supervised Learning :
  - First Determine the type of training dataset

- Collect/Gather the labelled training data.
- Split the training dataset into training **dataset, test dataset, and validation dataset.**
- Determine the input features of the training dataset, which should have enough knowledge so that the model can accurately predict the output.
- Determine the suitable algorithm for the model, such as support vector machine, decision tree, etc.
- Execute the algorithm on the training dataset. Sometimes we need validation sets as the control parameters, which are the subset of training datasets.
- Evaluate the accuracy of the model by providing the test set. If the model predicts the correct output, which means our model is accurate.

- Supervised learning can be further divided into two types of problems: Regression and Classification.

**Regression**

Regression algorithms are used if there is a relationship between the input variable and the output variable. It is used for the prediction of continuous variables, such as Weather forecasting, Market Trends, etc. Below are some popular Regression algorithms which come under supervised learning :

- Linear Regression
- Regression Trees
- Non-Linear Regression
- Bayesian Linear Regression
- Polynomial Regression

**Classification**

Classification algorithms are used when the output variable is categorical, which means there are two classes such as Yes-No, Male-Female, True-false, etc.

- Random Forest
- Logistic Regression
- Decision Trees
- Support vector Machines

### 1.5.2 Advantages of Supervised Learning

(1) With the help of supervised learning, the model can predict the output on the basis of prior experiences.

(2) In supervised learning, we can have an exact idea about the classes of objects.

(3) Supervised learning model helps us to solve various real-world problems such as **fraud detection, spam filtering,** etc.

### 1.5.3 Disadvantages of Supervised Learning

(1) Supervised learning models are not suitable for handling the complex tasks.

(2) Supervised learning cannot predict the correct output if the test data is different from the training dataset.

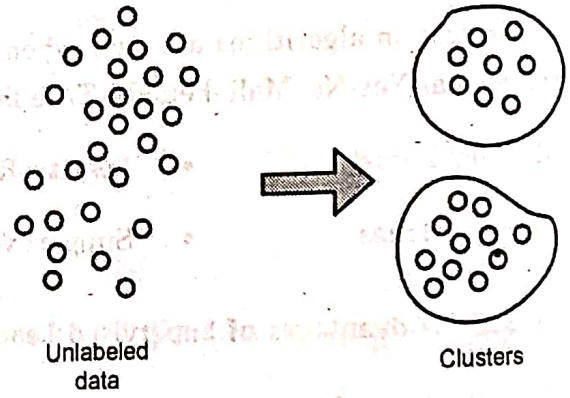
(3) Training required lots of computation times.

(4) In supervised learning, we need enough knowledge about the classes of object.

## 1.6 UNSUPERVISED LEARNING

GQ. What is Unsupervised Learning?
GQ. What are the types of unsupervised learning?
GQ. What are the advantages and disadvantages of unsupervised learning?

- Unsupervised learning refers to learning from unlabeled data. It is based more on similarity and differences than on anything else. In this type of learning, all similar items are clustered together in a particular class where the label of a class is not known.
- It is not possible to learn in a supervised way in the absence of properly labeled data. In these scenarios there is need to learn in an unsupervised way. Here the learning is based more on similarities and differences that are visible. These differences and similarities are mathematically represented in unsupervised learning.
- Given a large collection of objects, we often want to be able to understand these objects and visualize their relationships. For an example based on similarities, a kid can separate birds from other animals. It may use some property or similarity while separating, such as the birds have wings.
- The criterion in initial stages is the most visible aspects of those objects. Linnaeus devoted much of his life to arranging living organisms into a hierarchy of classes, with the goal of arranging similar organisms together at all levels of the hierarchy. Many unsupervised learning algorithms create similar hierarchical arrangements based on similarity-based mappings.
- The task of hierarchical clustering is to arrange a set of objects into a hierarchy such that similar objects are grouped together. Non-hierarchical clustering seeks to partition the data into some number of disjoint clusters. The process of clustering is depicted in Fig. 1.6.1.
- A learner is fed with a set of scattered points, and it generates two clusters with representative centroids after learning. Clusters show that points with similar properties and closeness are grouped together.




(1D3)**Fig. 1.6.1 : Unsupervised learning**

- Unsupervised learning is a set of algorithms where the only information being uploaded is inputs. The device itself, then, is responsible for grouping together and creating ideal outputs based on the data it discovers. Often, unsupervised learning algorithms have certain goals, but they are not controlled in any manner.
- Instead, the developers believe that they have created strong enough inputs to ultimately program the machine to create stronger results than they themselves possibly could. The idea here is that the machine is programmed to run flawlessly to the point where it can be intuitive and inventive in the most effective manner possible.

- The information in the algorithms being run by unsupervised learning methods is not labelled, classified, or categorized by humans. Instead, the unsupervised algorithm rejects responding to feedback in favour of identifying commonalities in the data. It then reacts based on the presence, or absence, of such commonalities in each new piece of data that is being inputted into the machine itself.
- It is used to draw inferences from datasets consisting of input data without labelled responses. Clustering is the most common unsupervised learning technique. It is used for exploratory data analysis to find hidden patterns or groupings in data. Applications for clustering include gene sequence analysis, market research, and object recognition.

### 1.6.1 Types of Unsupervised Learning Algorithm

The unsupervised learning algorithm can be further categorized into two types of problems:

1. Clustering 2. Association

**(1) Clustering**

Clustering is a method of grouping the objects into clusters such that objects with most similarities remains into a group and has less or no similarities with the objects of another group. Cluster analysis finds the commonalities between the data objects and categorizes them as per the presence and absence of those commonalities.

**(2) Association**

An association rule is an unsupervised learning method which is used for finding the relationships between variables in the large database. It determines the set of items that occurs together in the dataset. Association rule makes marketing strategy more effective. Such as people who buy X item (suppose a bread) are also tend to purchase Y (Butter/Jam) item. A typical example of Association rule is Market Basket Analysis.

Below is the list of some popular unsupervised learning algorithms :

- K-means clustering
- KNN (k-nearest neighbors)
- Hierarchal clustering
- Anomaly detection
- Neural Networks
- Principle Component Analysis
- Independent Component Analysis
- Apriori algorithm
- Singular value decomposition

### 1.6.2 Advantages of Unsupervised Learning

(1) Unsupervised learning is used for more complex tasks as compared to supervised learning because, in unsupervised learning, we don't have labeled input data.

(2) Unsupervised learning is preferable as it is easy to get unlabeled data in comparison to labeled data.

### 1.6.3 Disadvantages of Unsupervised Learning

(1) Unsupervised learning is intrinsically more difficult than supervised learning as it does not have corresponding output.

(2) The result of the unsupervised learning algorithm might be less accurate as input data is not labeled, and algorithms do not know the exact output in advance.

In practical scenarios there is always need to learn from both labeled and unlabeled data. Even while learning in an unsupervised way, there is the need to make the best use of labeled data available. This is referred to as semi supervised learning. Semi supervised learning is making the best use of two paradigms of learning - that is, learning based on similarity and learning based on inputs from a teacher. Semi supervised learning tries to get the best of both the worlds.

### 1.6.4 Difference between Supervised and Unsupervised Learning

**GQ. What is the difference between supervised learning and unsupervised learning?**

- Supervised and Unsupervised learning are the two techniques of machine learning. But both the techniques are used in different scenarios and with different datasets. Below the explanation of both learning methods along with their difference table is given.
- Supervised learning is a machine learning method in which models are trained using labeled data. In supervised learning, models need to find the mapping function to map the input variable (X) with the output variable (Y).

$$Y = f(X)$$

- Supervised learning needs supervision to train the model, which is similar to as a student learns things in the presence of a teacher. Supervised learning can be used for two types of problems: Classification and Regression.
- **Example :** Suppose we have an image of different types of fruits. The task of our supervised learning model is to identify the fruits and classify them accordingly. So to identify the image in supervised learning, we will give the input data as well as output for that, which means we will train the model by the shape, size, color, and taste of each fruit. Once the training is completed, we will test the model by giving the new set of fruit. The model will identify the fruit and predict the output using a suitable algorithm.
- Unsupervised learning is another machine learning method in which patterns inferred from the unlabeled input data. The goal of unsupervised learning is to find the structure and patterns from the input data. Unsupervised learning does not need any supervision. Instead, it finds patterns from the data by its own.
- Unsupervised learning can be used for two types of problems: Clustering and Association.
- **Example :** To understand the unsupervised learning, we will use the example given above. So unlike supervised learning, here we will not provide any supervision to the model. We will just provide the input dataset to the model and allow the model to find the patterns from the data. With the help of a suitable algorithm, the model will train itself and divide the fruits into different groups according to the most similar features between them.

- **The main differences between Supervised and Unsupervised learning are given following Table 1.6.1 :**

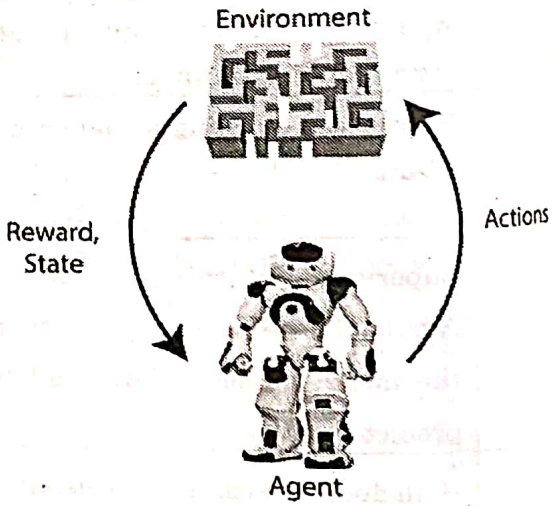
**Table 1.6.1**

| Sr. No. | Supervised Learning | Unsupervised Learning |
|---|---|---|
| 1. | Supervised learning algorithms are trained using labeled data. | Unsupervised learning algorithms are trained using unlabeled data. |
| 2. | Supervised learning model takes direct feedback to check if it is predicting correct output or not. | Unsupervised learning model does not take any feedback. |
| 3. | Supervised learning model predicts the output. | Unsupervised learning model finds the hidden patterns in data. |
| 4. | In supervised learning, input data is provided to the model along with the output. | In unsupervised learning, only input data is provided to the model. |
| 5. | The goal of supervised learning is to train the model so that it can predict the output when it is given new data. | The goal of unsupervised learning is to find the hidden patterns and useful insights from the unknown dataset. |
| 6. | Supervised learning needs supervision to train the model. | Unsupervised learning does not need any supervision to train the model. |
| 7. | Supervised learning can be categorized in Classification and Regression problems. | Unsupervised Learning can be classified in Clustering and Associations problems. |
| 8. | Supervised learning can be used for those cases where we know the input as well as corresponding outputs. | Unsupervised learning can be used for those cases where we have only input data and no corresponding output data. |
| 9. | Supervised learning model produces an accurate result. | Unsupervised learning model may give less accurate result as compared to supervised learning. |
| 10. | Supervised learning is not close to true Artificial intelligence as in this, we first train the model for each data, and then only it can predict the correct output. | Unsupervised learning is more close to the true Artificial Intelligence as it learns similarly as a child learns daily routine things by his experiences. |
| 11. | It includes various algorithms such as Linear Regression, Logistic Regression, Support Vector Machine, Multi-class Classification, Decision tree, Bayesian Logic, etc. | It includes various algorithms such as Clustering, KNN, and Apriori algorithm. |

## 1.7 REINFORCEMENT LEARNING

**GQ.** What is Reinforcement Learning? Explain with an example.

- Reinforcement Learning is a feedback-based Machine learning technique in which an agent learns to behave in an environment by performing the actions and seeing the results of actions. For each good action, the agent gets positive feedback, and for each bad action, the agent gets negative feedback or penalty.
- In Reinforcement Learning, the agent learns automatically using feedbacks without any labeled data, unlike supervised learning.
- Since there is no labelled data, so the agent is bound to learn by its experience only.
- RL solves a specific type of problem where decision making is sequential, and the goal is long-term, such as game-playing, robotics, etc.
- The agent interacts with the environment and explores it by itself. The primary goal of an agent in reinforcement learning is to improve the performance by getting the maximum positive rewards.
- The agent learns with the process of hit and trial, and based on the experience, it learns to perform the task in a better way. Hence, we can say that "Reinforcement learning is a type of machine learning method where an intelligent agent (computer program) interacts with the environment and learns to act within that." How a Robotic dog learns the movement of his arms is an example of Reinforcement learning.
- It is a core part of Artificial intelligence, and all AI agent works on the concept of reinforcement learning. Here we do not need to pre-program the agent, as it learns from its own experience without any human intervention.
- **Example :** Suppose there is an AI agent present within a maze environment, and his goal is to find the diamond. The agent interacts with the environment by performing some actions, and based on those actions, the state of the agent gets changed, and it also receives a reward or penalty as feedback.
- The agent continues doing these three things (take action, change state/remain in the same state, and get feedback), and by doing these actions, he learns and explores the environment.




(1D4) **Fig. 1.7.1**

- The agent learns that what actions lead to positive feedback or rewards and what actions lead to negative feedback penalty. As a positive reward, the agent gets a positive point, and as a penalty, it gets a negative point.

- For machine learning, the environment is typically represented by an "MDP" or Markov Decision Process.
- These algorithms do not necessarily assume knowledge, but instead are used when exact models are infeasible. In other words, they are not quite as precise or exact, but they will still serve a strong method in various applications throughout different technology systems.
- The key features of Reinforcement Learning are mentioned below.
  - In RL, the agent is not instructed about the environment and what actions need to be taken.
  - It is based on the hit and trial process.
  - The agent takes the next action and changes states according to the feedback of the previous action.
  - The agent may get a delayed reward.
  - The environment is stochastic, and the agent needs to explore it to reach to get the maximum positive rewards.

### 1.7.1 Approaches to Implement Reinforcement Learning

**GQ.** What are the approaches for Reinforcement Learning?

There are mainly three ways to implement reinforcement-learning in ML, which are :

1. **Value-based :** The value-based approach is about to find the optimal value function, which is the maximum value at a state under any policy. Therefore, the agent expects the long-term return at any state(s) under policy $\pi$.
2. **Policy-based :** Policy-based approach is to find the optimal policy for the maximum future rewards without using the value function. In this approach, the agent tries to apply such a policy that the action performed in each step helps to maximize the future reward. The policy-based approach has mainly two types of policy :
   - **Deterministic :** The same action is produced by the policy ($\pi$) at any state.
   - **Stochastic :** In this policy, probability determines the produced action.
3. **Model-based :** In the model-based approach, a virtual model is created for the environment, and the agent explores that environment to learn it. There is no particular solution or algorithm for this approach because the model representation is different for each environment.

Here are important characteristics of reinforcement learning

- There is no supervisor, only a real number or reward signal
- Sequential decision making
- Time plays a crucial role in Reinforcement problems
- Feedback is always delayed, not instantaneous
- Agent's actions determine the subsequent data it receives

RL can be used in almost any application. It is a learning based on experience algorithm, a decisi maker algorithm, an algorithm that learns autonomously, an optimization algorithm that over time lear to maximize its reward, the reward can be defined by the engineer to reach the objective of the problem.

### 1.7.2 Challenges of Reinforcement Learning

Here are the major challenges you will face while doing Reinforcement earning :

(1) Feature/reward design which should be very involved

(2) Parameters may affect the speed of learning.

(3) Realistic environments can have partial observability.

(4) Too much Reinforcement may lead to an overload of states which can diminish the results.

(5) Realistic environments can be non-stationary.

### 1.7.3 Applications of Reinforcement Learning

Here are applications of Reinforcement Learning :

(1) Robotics for industrial automation.

(2) Business strategy planning

(3) Machine learning and data processing

(4) Aircraft control and robot motion control

(5) It helps you to create training systems that provide custom instruction and materials according to the requirement of students.

### 1.7.4 Reinforcement Learning vs. Supervised Learning

GQ. What is the difference between Reinforcement Learning and Supervised Learning ?

Table 1.7.1

| Parameters | Reinforcement Learning | Supervised Learning |
|---|---|---|
| Decision style | Reinforcement learning helps you to take your decisions sequentially. | In this method, a decision is made on the input given at the beginning. |
| Works on | Works on interacting with the environment. | Works on examples or given sample data. |
| Dependency on decision | In RL method learning decision is dependent. Therefore, you should give labels to all the dependent decisions. | Supervised learning the decisions which are independent of each other, so labels are given for every decision. |
| Best suited | Supports and work better in AI, where human interaction is prevalent. | It is mostly operated with an interactive software system or applications. |
| Example | Chess game | Object recognition |

## 1.8 INTRODUCTION TO SEMI-SUPERVISED LEARNING

(1) Semi-Supervised learning is a type of Machine Learning algorithm that represents the intermediate ground between Supervised and Unsupervised learning algorithms. It uses the combination of labeled and unlabeled datasets during the training period.

(2) Before understanding the Semi-Supervised learning, you should know the main categories of Machine Learning algorithms. Machine Learning consists of three main categories: Supervised Learning, Unsupervised Learning, and Reinforcement Learning

(3) Further, the basic difference between Supervised and unsupervised learning is that supervised learning datasets consist of an output label training data associated with each tuple, and unsupervised datasets do not consist the same. Semi-supervised learning is an important category that lies between the Supervised and Unsupervised machine learning. Although Semi-supervised learning is the middle ground between supervised and unsupervised learning and operates on the data that consists of a few labels, it mostly consists of unlabeled data. As labels are costly, but for the corporate purpose, it may have few labels.

(4) The basic disadvantage of supervised learning is that it requires hand-labeling by ML specialists or data scientists, and it also requires a high cost to process. Further unsupervised learning also has a limited spectrum for its applications. To overcome these drawbacks of supervised learning and unsupervised learning algorithms, the concept of Semi-supervised learning is introduced. In this algorithm, training data is a combination of both labeled and unlabeled data. However, labeled data exists with a very small amount while it consists of a huge amount of unlabeled data. Initially, similar data is clustered along with an unsupervised learning algorithm, and further, it helps to label the unlabeled data into labeled data. It is why label data is a comparatively, more expensive acquisition than unlabeled data.

(5) We can imagine these algorithms with an example. Supervised learning is where a student is under the supervision of an instructor at home and college. Further, if that student is self-analyzing the same concept without any help from the instructor, it comes under unsupervised learning. Under semi-supervised learning, the student has to revise itself after analyzing the same concept under the guidance of an instructor at college.

A Semi-Supervised algorithm assumes the following about the data:

1. **Continuity Assumption :** The algorithm assumes that the points which are closer to each other are more likely to have the same output label.
2. **Cluster Assumption :** The data can be divided into discrete clusters and points in the same cluster are more likely to share an output label.
3. **Manifold Assumption :** The data lie on a manifold of much lower dimension than the input space.

This assumption allows the use of distances and densities which are defined on a manifold.

**Practical Applications of Semi Semi-Supervised learning :**

1. **Speech Analysis :** Since labelling of audio files is very intensive task, semi-supervised learning is a natural approach to solve this problem.
2. **Internet Content Classification :** Labeling each webpage is impractical and unfeasible process and uses Semi-Supervised learning algorithms.
3. **Protein- Sequence Classification :** Since DNA strands are very large in size, hence here Semi-Supervised learning is must in this field.

## 1.9 MODELS OF MACHINE LEARNING

### 1.9.1 Geometric Models

- In Geometric models, features could be described as points in two dimensions (x- and y-axis) or a three-dimensional space (x, y, and z). Even when features are not intrinsically geometric, they could be modelled in a geometric manner (for example, temperature as a function of time can be modelled in two axes). In geometric models, there are two ways we could impose similarity.
- We could use geometric concepts like lines or planes to segment (classify) the instance space. These are called Linear models
- Alternatively, we can use the geometric notion of distance to represent similarity. In this case, if two points are close together, they have similar values for features and thus can be classed as similar. We call such models as Distance-based models

### 1.9.2 Probabilistic Models

- In contrast to **deterministic models**, where the relationship between quantities is already known, Probabilistic models are based on the assumption that relationship between quantities which is reasonably accurate but other components are also taken into consideration.
- Thus probabilistic models are statistical models, which give probability distributions to account for these components.
- Probabilistic models from the basis in other areas such as machine learning, artificial intelligence, and data analysis. Their formulation and solution rest on the two basic rules of probability theory, that is, the sum rule and product rule.
- **We mention an example :** if one lives in a cold climate, one knows that traffic tends to be more difficult when snow falls and covers the roads.
- We can go a step further and make a hypothesis : There will be a strong correlation between snowy weather and increased traffic incidents.
- Probabilistic models are used in a variety of disciplines, including statistical physics, quantum mechanics and theoretical computer science.

### 1.9.3 Logical Models

- Logical models use a logical expression to divide the instance space into segments and hence construct grouping models. A logical expression is an expression that returns a Boolean value, i.e., a True or False outcome. Once the data is grouped using a logical expression, the data is divided into homogeneous groupings for the problem we are trying to solve.
- There are two types of logical models: Tree models and Rule models.
  - Rule models consist of a collection of implications or IF-THEN rules. For tree-based models, the 'if-part' defines a segment and the 'then-part' defines the behaviour of the model for this segment. Rule models follow the same reasoning
  - Tree models can be seen as a particular type of rule model where the if- parts of the rules are organised in a tree structure. Both Tree models and Rule models use the same approach to supervised learning

### 1.9.4 Groping Models

- Tree models repeatedly split the instance space into smaller subsets.
- Trees are usually of limited depth and don't contain all the available features.
- Subsets at the leaves of the tree partition the instance space with some finite resolution.
- Instances filtered into the same leaf of the tree are treated the same, regardless of any features not in the tree that might be able to distinguish them.

### 1.9.5 Grading Model

- They don't use the notion of segment
- Forms one global model over instance space
- Grading models are (usually) able to distinguish between arbitrary instances, no matter how similar they are
- Resolution is, in theory, infinite, particularly when working in a Cartesian instance space.
- Support vector machines and other geometric classifiers are examples of grading models.
- They work in a Cartesian instance space.
- Exploit the minutest differences between instances

### 1.9.6 Groping and Grading Models

- The key difference between grouping and grading models is the way they handle the instance space

**Grouping models**

- Grouping models break up the instance space into groups or segments, the number of which is determined at training time.

- They have fixed resolution cannot distinguish instances beyond a resolution
- At the finest resolution grouping models assign the majority class to all instances that fall into the segment.
- Determine the right segments and label all the objects in that segment.

### 1.9.7 Groping versus Grading Models

- Some models combine the features of both grouping and grading models.
- Linear classifiers are a prime example of a grading model.
- Instances on a line or plane parallel to the decision boundary can't be distinguished by a linear model.
- There are infinitely many segments.

## 1.10 PARAMETRIC AND NON-PARAMETRIC MODELS

- Machine learning models can be parametric or non-parametric.
- Parametric models are those that require the application of some parameters before they can be used to make predictions.
- Non-parametric models do not rely on any specific parameter setting and hence they often produce more accurate results.

We mention the difference between Parametric and Non-Parametric Methods.

| Sr. No. | Parametric Methods | Non-Parametric Methods |
|---|---|---|
| 1. | Parametric methods use a fixed number of parameters to build the model. | Non-parametric methods use flexible number of parameters to build the model. |
| 2. | Parametric analysis is for testing group means. | A non-parametric analysis is for testing medians. |
| 3. | It is applicable only for variables. | It is applicable for both variable and Attribute. |
| 4. | It always considers strong assumptions about data. | It generally considers fewer assumptions and data. |
| 5. | Parametric methods require lesser data than Non-parametric methods. | Non-parametric methods require much more data than parametric methods. |
| 6. | Parametric data handles intervals data or ration data. | Non-parametric methods handle original data. |
| 7. | Parametric methods follow normal distribution. | There is no assumed distribution in non-parametric methods. |

| Sr. No. | Parametric Methods | Non-Parametric Methods |
|---|---|---|
| 8. | The output generated by parametric methods can be easily affected by outliers. | The output generated cannot be seriously affected by outliers. |
| 9. | Parametric methods function well in many situations but its performance is at peak (top) when the spread of each group is different. | Non-parametric Methods can perform well in many situations but its performance is at the top when the spread of each group is the same. |
| 10. | Parametric Methods have more statistical power than Non-Parametric methods. | Non-parametric methods have less statistical power than parametric methods. |
| 11. | As for as the computation is concerned, these methods are computationally faster than the Non-parametric methods. **Examples :** Logistic Regression, Naive Bayes Model etc. | As far as the computation is concerned, these methods are computationally slower than the parametric methods. **Examples :** KNN, Decision Tree Model, etc. |

## 1.11 IMPORTANT ELEMENTS OF MACHINE LEARNING

### 1.11.1 Data Formats

- Each data format represents how the input data is represented in memory.
- Each machine learning application performs well for a particular data format and worse for others. Choosing the correct format is a major **optimisation technique.**
- There are four types of data formats ; which are commonly used.

(1) NHWC
(2) NCHW
(3) NCDHW
(4) NDHWC

Each letter in the formats denotes a particular aspect or dimension of the data :

(i) **N : Batch size :** is the number of images passed together as a group for inference.

(ii) **C : Channel :** is the number of data components that make a data point for the input data. It is 3 for opaque images and 4 for transparent images.

(iii) **W : Width :** is the width / measurement in x – axis of the input data.

(iv) **H : Height :** Is the height / measurement in y – axis of the input data.

(v) **D : Depth :** is the depth of the input data.

**(1) NHWC**

NHWC, denotes (Batch size, Height, Width, Channel). This implies that there is a 4D array where the first dimension represents batch size and accordingly. This 4D array is laid out in memory in row - major order. [ commonly used data : images ]

**(2) NCHW**

NCHW denotes (Batch Size, Channel, Height, Width). This means that there is a 4D array where the first dimension represents batch size and so on.

This 4D array is laid out in memory in row–major order. [Commonly used data – images]

**(3) NCDHW**

NCDHW denotes (Batch Size, Channel, Depth, Height, Width). This means that there is a 5D array where the first dimension represents batch size and so on. This 5D array is laid out in memory in row major order. [Commonly used data : Video]

**(4) NDHWC**

NDHWC denotes (Batch Size, Depth, Height, Width, Channel). This means there is a 5D array where the first dimension represents batch size and accordingly.

This 5D array is laid out in memory in row major order.

Commonly used data : Video

Software : Tensor flow

### 1.11.2 Learnability

- Learnability is a quality of products and interfaces that allows users to become familiar with them. It makes good use of all their features and capabilities.
- A very learnable product is sometimes said to be intuitive because the user can immediately grasp how to interact with the system.
- First time lerarnability refers to the degree of ease with which a user can learn a newly developed system without referring to its documentation, e.g., manuals, user guides or frequently asked questions (FAQ) lists.
- One elements of first – time learnability is discoverability, i.e. ; the degree of ease with which the user can find all the elements and features of the new system.
- Learnability over time is the capacity of a user to gain experience in working with a given system through repeated interaction.
- Comparatively simple systems with good learnability are said to have short or steep learning curves. It implies that most learning associated with the system happens quickly.
- More complex systems involve a longer learning curve.
- In software testing **learnability**, according to ISO 9126, is the **capability** of a software product to enable the user to learn how to use it.
- Lernability is considered as an aspect of **usability** and is of major **concern** in the **design** of complex

- In computational learning theory, **learnability** is the mathematical analysis of machine learning. It is also employed in **language acquisition** in arguments within linguistics.
- The skill of learnability confers a future value by making one agile (active). It is a **currency** that is rewarded with better employability and high growth prospects. Learning does not and with school or college

### 1.11.3 Statistical learning Approaches

- **Statistical learning theory** is a framework for machine learning – drawing from the fields of statistics and functional analysis.
- Statistical learning theory deals with the statistical inference problem of finding a predictive function based on data.
- Statistical learning theory has led to successful applications in fields such as computer vision, speech recognition and bioinformatics.
- Statistical learning is a set of tool for understanding data.
- These tools come under two classes : Supervised learning and Unsupervised learning.
- Statistical learning is mathematical intensive which is based on the coefficient estimator and requires a good understanding of data.
- On the other hand, Machine Learning identifies patterns from the dataset through it the iterations which does not require much human effort.

**Lexical Acquisition**

- The role of statistical learning in language acquisition is well documented in **lexical acquisition.**
- One important contribution to infant's understanding of segmenting words from a speech is their ability to recognize statistical regularities of the speech, that is heard from their environment.

**Statistical Algorithm**

- Statistical algorithms **create a statistical model of the input data,** which is in most cases represented as a probabilistic tree data structure.
- Subsequences with a higher frequency are represented with shorter codes.
- The type of algorithm used is linear regression. It is the popular algorithm in machine learning and statistics.
- This model will assume a linear relationship between the input and the output variable.
- It is represented in the form of linear equation which has a set of inputs and a predictive output.

**Types of statistical analysis**

(i) Descriptive statistical analysis. (ii) Inferential statistical analysis,

(iii) Associational statistical analysis ; (iv) Predictive analysis,

(v) Prescriptive analysis (vi) Exploratory data analysis

(vii) Causal analysis (viii) Data collection

*Chapter Ends ...*

□□□