



## Chapter 1

# Introduction to Machine Learning

### **OBJECTIVE OF THE CHAPTER:**

The objective of this chapter is to venture into the arena of machine learning. New comers struggle a lot to understand the philosophy of machine learning. Also, they do not know where to start from and which problem could be and should be solved using machine learning tools and techniques. This chapter intends to give the new comers a starting point to the journey in machine learning. It starts from a historical journey in this field and takes it forward to give a glimpse of the modern day applications.

### **1.1 INTRODUCTION**

It has been more than 20 years since a computer program defeated the reigning world champion in a game which is considered to need a lot of intelligence to play. The computer program was IBM's Deep Blue and it defeated world chess champion, Gary Kasparov. That was the time, probably, when the most number of people gave serious attention to a fast-evolving field in computer science or more specifically artificial intelligence – i.e. machine learning (ML).

As of today, machine learning is a mature technology area finding its application in almost every sphere of life. It can recommend toys to toddlers much in the same way as it can suggest a technology book to a geek or a rich title in literature to a writer. It predicts the future market to help amateur traders compete with seasoned stock traders. It helps an oncologist find whether a tumour is malignant or benign. It helps

in optimizing energy consumption thus helping the cause of Green Earth. Google has become one of the front-runners focusing a lot of its research on machine learning and artificial intelligence – Google self-driving car and Google Brain being two most ambitious projects of Google in its journey of innovation in the field of machine learning. In a nutshell, machine learning has become a way of life, no matter which-ever sphere of life we closely look at. But where did it all start from?

The foundation of machine learning started in the 18th and 19th centuries. The first related work dates back to 1763. In that year, Thomas Bayes's work 'An Essay towards solving a Problem in the Doctrine of Chances' was published two years after his death. This is the work underlying Bayes Theorem, a fundamental work on which a number of algorithms of machine learning is based upon. In 1812, the Bayes theorem was actually formalized by the French mathematician Pierre-Simon Laplace. The method of least squares, which is the foundational concept to solve regression problems, was formalized in 1805. In 1913, Andrey Markov came up with the concept of Markov chains.

However, the real start of focused work in the field of machine learning is considered to be Alan Turing's seminal work in 1950. In his paper 'Computing Machinery and Intelligence' (*Mind*, New Series, Vol. 59, No. 236, Oct., 1950, pp. 433–460), Turing posed the question 'Can machines think?' or in other words, 'Do machines have intelligence?' He was the first to propose that machines can 'learn' and become artificially intelligent. In 1952, Arthur Samuel of IBM laboratory started working on machine learning programs, and first developed programs that could play Checkers. In 1957, Frank Rosenblatt designed the first neural network program simulating the human brain. From then on, for the next 50 years, the journey of machine learning has been fascinating. A number of machine learning algorithms were formulated by different researchers, e.g. the nearest neighbour algorithm in 1969, recurrent neural network in 1982, support vector machines and random forest algorithms in 1995. The latest feather in the cap of machine learning development has been Google's AlphaGo program, which has beaten professional human Go player using machine learning techniques.

### Points to Ponder

- While Deep Blue was searching some 200 million positions per second, Kasparov was searching not more than 5–10 positions probably, per second. Yet he played almost at the same level. This clearly shows that humans have some trick up their sleeve that computers could not master yet.
- Go is a board game which can be played by two players. It was invented in China almost 2500 years ago and is considered to be the oldest board game. Though it has relatively simple rules, Go is a very complex game (more complex than chess) because of its larger board size and more number of possible moves.

The evolution of machine learning from 1950 is depicted in Figure 1.1.

The rapid development in the area of machine learning has triggered a question in everyone's mind – can machines learn better than human? To find its answer, the first

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- 1950** Alan Turing proposes “learning machine”
- 1952** Arthur Samuel developed first machine learning program that could play Checkers
- 1957** Frank Rosenblatt designed the first neural network program simulating human brain
- 1967** Nearest neighbour algorithm created – start of basic pattern recognition
- 1979** Stanford University students develop first self – driving cart that can navigate and avoid obstacles in a room
- 1982** Recurrent Neural Network developed
- 1989**
- Reinforcement Learning conceptualized
  - Beginning of commercialization of Machine Learning
- 1995** Random Forest and Support Vector machine algorithms developed
- 1997** IBM's Deep Blue beats the world chess champion Gary Kasparov
- 2006**
- First machine learning competition launched by Netflix
  - Geoffrey Hinton conceptualizes Deep Learning
- 2010** Kaggle, a website for machine learning competitions, launched
- 2011** IBM's Watson beats two human champions in Jeopardy
- 2016** Google's AlphaGo program beats unhandicapped professional human player

1 of machine learning

## 1.2 WHAT IS HUMAN LEARNING?

In cognitive science, learning is typically referred to as the process of gaining information through observation. And why do we need to learn? In our daily life, we need to carry out multiple activities. It may be a task as simple as walking down the street or doing the homework. Or it may be some complex task like deciding the angle in which a rocket should be launched so that it can have a particular trajectory. To do a task in a proper way, we need to have prior information on one or more things related to the task. Also, as we keep learning more or in other words acquiring more information, the efficiency in doing the tasks keep improving. For example, with more knowledge, the ability to do homework with less number of mistakes increases. In the same way, information from past rocket launches helps in taking the right precautions and makes more successful rocket launch. Thus, with more learning, tasks can be performed more efficiently.

## 1.3 TYPES OF HUMAN LEARNING

Thinking intuitively, human learning happens in one of the three ways – (1) either somebody who is an expert in the subject directly teaches us, (2) we build our own notion indirectly based on what we have learnt from the expert in the past, or (3) we do it ourselves, maybe after multiple attempts, some being unsuccessful. The first type of learning, we may call, falls under the category of learning directly under expert guidance, the second type falls under learning guided by knowledge gained from experts and the third type is learning by self or self-learning. Let's look at each of these types deeply using real-life examples and try to understand what they mean.

### 1.3.1 Learning under expert guidance

An infant may inculcate certain traits and characteristics, learning straight from its guardians. He calls his hand, a 'hand', because that is the information he gets from his parents. The sky is 'blue' to him because that is what his parents have taught him. We say that the baby 'learns' things from his parents.

The next phase of life is when the baby starts going to school. In school, he starts with basic familiarization of alphabets and digits. Then the baby learns how to form words from the alphabets and numbers from the digits. Slowly more complex learning happens in the form of sentences, paragraphs, complex mathematics, science, etc. The baby is able to learn all these things from his teacher who already has knowledge on these areas.

Then starts higher studies where the person learns about more complex, application-oriented skills. Engineering students get skilled in one of the disciplines like civil, computer science, electrical, mechanical, etc. medical students learn about anatomy, physiology, pharmacology, etc. There are some experts, in general the teachers, in the respective field who have in-depth subject matter knowledge, who help the students in learning these skills.

Then the person starts working as a professional in some field. Though he might have gone through enough theoretical learning in the respective field, he still needs

to learn more about the hands-on application of the knowledge that he has acquired. The professional mentors, by virtue of the knowledge that they have gained through years of hands-on experience, help all new comers in the field to learn on-job.

In all phases of life of a human being, there is an element of guided learning. This learning is imparted by someone, purely because of the fact that he/she has already gathered the knowledge by virtue of his/her experience in that field. So guided learning is the process of gaining information from a person having sufficient knowledge due to the past experience.

### **1.3.2 Learning guided by knowledge gained from experts**

An essential part of learning also happens with the knowledge which has been imparted by teacher or mentor at some point of time in some other form/context. For example, a baby can group together all objects of same colour even if his parents have not specifically taught him to do so. He is able to do so because at some point of time or other his parents have told him which colour is blue, which is red, which is green, etc. A grown-up kid can select one odd word from a set of words because it is a verb and other words being all nouns. He could do this because of his ability to label the words as verbs or nouns, taught by his English teacher long back. In a professional role, a person is able to make out to which customers he should market a campaign from the knowledge about preference that was given by his boss long back.

In all these situations, there is no direct learning. It is some past information shared on some different context, which is used as a learning to make decisions.

### **1.3.3 Learning by self**

In many situations, humans are left to learn on their own. A classic example is a baby learning to walk through obstacles. He bumps on to obstacles and falls down multiple times till he learns that whenever there is an obstacle, he needs to cross over it. He faces the same challenge while learning to ride a cycle as a kid or drive a car as an adult. Not all things are taught by others. A lot of things need to be learnt only from mistakes made in the past. We tend to form a check list on things that we should do, and things that we should not do, based on our experiences.

## **1.4 WHAT IS MACHINE LEARNING?**

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Before answering the question ‘What is machine learning?’ more fundamental questions that peep into one’s mind are

- Do machines really learn?
- If so, how do they learn?
- Which problem can we consider as a well-posed learning problem? What are the important features that are required to well-define a learning problem?

At the onset, it is important to formalize the definition of machine learning. This will itself address the first question, i.e. if machines really learn. There are multiple ways to define machine learning. But the one which is perhaps most relevant, concise and accepted universally is the one stated by Tom M. Mitchell, Professor of Machine Learning Department, School of Computer Science, Carnegie Mellon University. Tom M. Mitchell has defined machine learning as

**'A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.'**

What this essentially means is that a machine can be considered to learn if it is able to gather experience by doing a certain task and improve its performance in doing the similar tasks in the future. When we talk about past experience, it means past data related to the task. This data is an input to the machine from some source.

In the context of the learning to play checkers, E represents the experience of playing the game, T represents the task of playing checkers and P is the performance measure indicated by the percentage of games won by the player. The same mapping can be applied for any other machine learning problem, for example, image classification problem. In context of image classification, E represents the past data with images having labels or assigned classes (for example whether the image is of a class cat or a class dog or a class elephant etc.), T is the task of assigning class to new, unlabelled images and P is the performance measure indicated by the percentage of images correctly classified.

The first step in any project is defining your problem. Even if the most powerful algorithm is used, the results will be meaningless if the wrong problem is solved.

#### 1.4.1 How do machines learn?

The basic machine learning process can be divided into three parts.

1. **Data Input:** Past data or information is utilized as a basis for future decision-making
2. **Abstraction:** The input data is represented in a broader way through the underlying algorithm
3. **Generalization:** The abstracted representation is generalized to form a framework for making decisions

Figure 1.2 is a schematic representation of the machine learning process.

Let's put the things in perspective of the human learning process and try to understand the machine learning process more clearly. Reason is, in some sense, machine learning process tries to emulate the process in which humans learn to a large extent.

Let's consider the situation of typical process of learning from classroom and books and preparing for the examination. It is a tendency of many students to try and memorize (we often call it 'learn by heart') as many things as possible. This may work well when the scope of learning is not so vast. Also, the kinds of questions which are asked in the examination are pretty much simple and straightforward. The questions can be answered by simply writing the same things which have been memorized. However, as the scope gets broader and the questions asked in the examination gets more complex, the strategy of memorizing doesn't work well. The number of topics may get too vast for a student to memorize. Also, the capability of memorizing varies from student to student. Together with that, since the questions get more complex, a direct reproduction of the things memorized may not help. The situation continues to get worse as the student graduates to higher classes.

So, what we see in the case of human learning is that just by great memorizing and perfect recall, i.e. just based on knowledge input, students can do well in the examinations only till a certain stage. Beyond that, a better learning strategy needs to be adopted:

1. to be able to deal with the vastness of the subject matter and the related issues in memorizing it
2. to be able to answer questions where a direct answer has not been learnt

A good option is to figure out the key points or ideas amongst a vast pool of knowledge. This helps in creating an outline of topics and a conceptual mapping of those outlined topics with the entire knowledge pool. For example, a broad pool of knowledge may consist of all living animals and their characteristics such as whether they live in land or water, whether they lay eggs, whether they have scales or fur or none, etc. It is a difficult task for any student to memorize the characteristics of all living animals – no matter how much photographic memory he/she may possess. It is better to draw a notion about the basic groups that all living animals belong to and the characteristics which define each of the basic groups. The basic groups of animals are invertebrates and vertebrates. Vertebrates are further grouped as mammals, reptiles, amphibians, fishes, and birds. Here, we have mapped animal groups and their salient characteristics.

1. Invertebrate: Do not have backbones and skeletons
2. Vertebrate
  - (a) Fishes: Always live in water and lay eggs
  - (b) Amphibians: Semi-aquatic i.e. may live in water or land; smooth skin; lay eggs
  - (c) Reptiles: Semi-aquatic like amphibians: scaly skin; lay eggs

Moving to the machine learning paradigm, the vast pool of knowledge is available from the data input. However, rather than using it in entirety, a concept map, much in line with the animal group to characteristic mapping explained above, is drawn from the input data. This is nothing but knowledge abstraction as performed by the machine. In the end, the abstracted mapping from the input data can be applied to make critical conclusions. For example, if the group of an animal is given, understanding of the characteristics can be automatically made. Reversely, if the characteristic of an unknown animal is given, a definite conclusion can be made about the animal group it belongs to. This is generalization in context of machine learning.

#### **1.4.1.1 Abstraction**

During the machine learning process, knowledge is fed in the form of input data. However, the data cannot be used in the original shape and form. As we saw in the example above, abstraction helps in deriving a conceptual map based on the input data. This map, or a **model** as it is known in the machine learning paradigm, is summarized knowledge representation of the raw data. The model may be in any one of the following forms

- Computational blocks like if/else rules
- Mathematical equations
- Specific data structures like trees or graphs
- Logical groupings of similar observations

The choice of the model used to solve a specific learning problem is a human task. The decision related to the choice of model is taken based on multiple aspects, some of which are listed below:

- The type of problem to be solved: Whether the problem is related to forecast or prediction, analysis of trend, understanding the different segments or groups of objects, etc.
- Nature of the input data: How exhaustive the input data is, whether the data has no values for many fields, the data types, etc.
- Domain of the problem: If the problem is in a business critical domain with a high rate of data input and need for immediate inference, e.g. fraud detection problem in banking domain.

Once the model is chosen, the next task is to fit the model based on the input data. Let's understand this with an example. In a case where the model is represented by a mathematical equation, say ' $y = c_1 + c_2x$ ' (the model is known as simple linear regression which we will study in a later chapter), based on the input data, we have to find out the values of  $c_1$  and  $c_2$ . Otherwise, the equation (or the model) is of no use. So, fitting the model, in this case, means finding the values of the unknown coefficients or constants of the equation or the model. This process of fitting the model based on the input data is known as training. Also, the input data based on which the model is being finalized is known as **training data**.

### 1.4.1.2 Generalization

The first part of machine learning process is abstraction i.e. abstract the knowledge which comes as input data in the form of a model. However, this abstraction process, or more popularly training the model, is just one part of machine learning. The other key part is to tune up the abstracted knowledge to a form which can be used to take future decisions. This is achieved as a part of generalization. This part is quite difficult to achieve. This is because the model is trained based on a finite set of data, which may possess a limited set of characteristics. But when we want to apply the model to take decision on a set of unknown data, usually termed as test data, we may encounter two problems:

1. The trained model is aligned with the training data too much, hence may not portray the actual trend.
2. The test data possess certain characteristics apparently unknown to the training data.

Hence, a precise approach of decision-making will not work. An approximate or heuristic approach, much like gut-feeling-based decision-making in human beings, has to be adopted. This approach has the risk of not making a correct decision – quite obviously because certain assumptions that are made may not be true in reality. But just like machines, same mistakes can be made by humans too when a decision is made based on intuition or gut-feeling – in a situation where exact reason-based decision-making is not possible.

### 1.4.2 Well-posed learning problem

For defining a new problem, which can be solved using machine learning, a simple framework, highlighted below, can be used. This framework also helps in deciding whether the problem is a right candidate to be solved using machine learning. The framework involves answering three questions:

1. What is the problem?
2. Why does the problem need to be solved?
3. How to solve the problem?

#### Step 1: What is the Problem?

A number of information should be collected to know what is the problem.

**Informal description of the problem**, e.g. I need a program that will prompt the next word as and when I type a word.

#### Formalism

Use Tom Mitchell's machine learning formalism stated above to define the T, P, and E for the problem.

For example:

- Task (T): Prompt the next word when I type a word.

**Assumptions** - Create a list of assumptions about the problem.

### **Similar problems**

What other problems have you seen or can you think of that are similar to the problem that you are trying to solve?

### **Step 2: Why does the problem need to be solved?**

#### **Motivation**

What is the motivation for solving the problem? What requirement will it fulfil?

For example, does this problem solve any long-standing business issue like finding out potentially fraudulent transactions? Or the purpose is more trivial like trying to suggest some movies for upcoming weekend.

#### **Solution benefits**

Consider the benefits of solving the problem. What capabilities does it enable?

It is important to clearly understand the benefits of solving the problem. These benefits can be articulated to sell the project.

#### **Solution use**

How will the solution to the problem be used and the life time of the solution is expected to have?

### **Step 3: How would I solve the problem?**

Try to explore how to solve the problem manually.

Detail out step-by-step data collection, data preparation, and program design to solve the problem. Collect all these details and update the previous sections of the problem definition, especially the assumptions.

### **Summary**

- **Step 1: What is the problem?** Describe the problem informally and formally and list assumptions and similar problems.
- **Step 2: Why does the problem need to be solved?** List the motivation for solving the problem, the benefits that the solution will provide and how the solution will be used.
- **Step 3: How would I solve the problem?** Describe how the problem would be solved manually to flush domain knowledge.

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### **Did you know?**

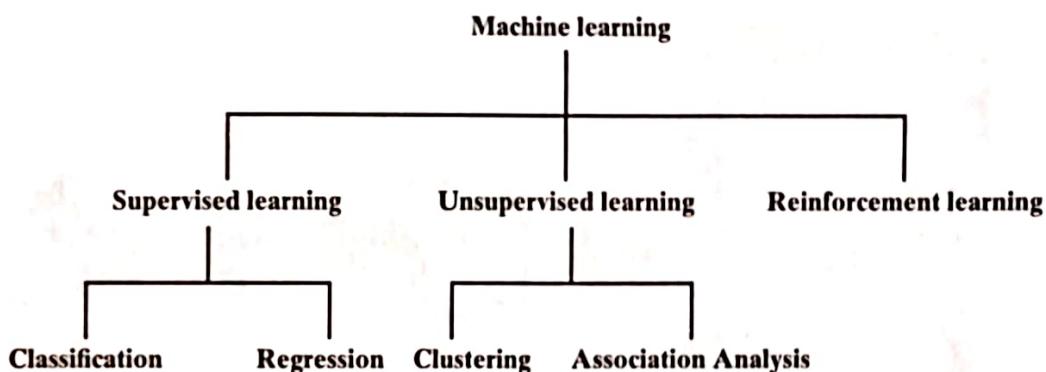
Sony created a series of robotic pets called Aibo. It was built in 1998. Although most models sold were dog-like, other inspirations included lion-cubs. It could express emotions and could also recognize its owner. In 2006, Aibo was added to the Carnegie Mellon University's 'Robot Hall of Fame'. A new generation of Aibo was launched in Japan in January 2018.

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## 1.5 TYPES OF MACHINE LEARNING

As highlighted in Figure 1.3, Machine learning can be classified into three broad categories:

1. Supervised learning – Also called predictive learning. A machine predicts the class of unknown objects based on prior class-related information of similar objects.
2. Unsupervised learning – Also called descriptive learning. A machine finds patterns in unknown objects by grouping similar objects together.
3. Reinforcement learning – A machine learns to act on its own to achieve the given goals.



**FIG. 1.3**  
Types of machine learning

### Did you know?

Many video games are based on artificial intelligence technique called Expert System. This technique can imitate areas of human behaviour, with a goal to mimic the human ability of senses, perception, and reasoning.

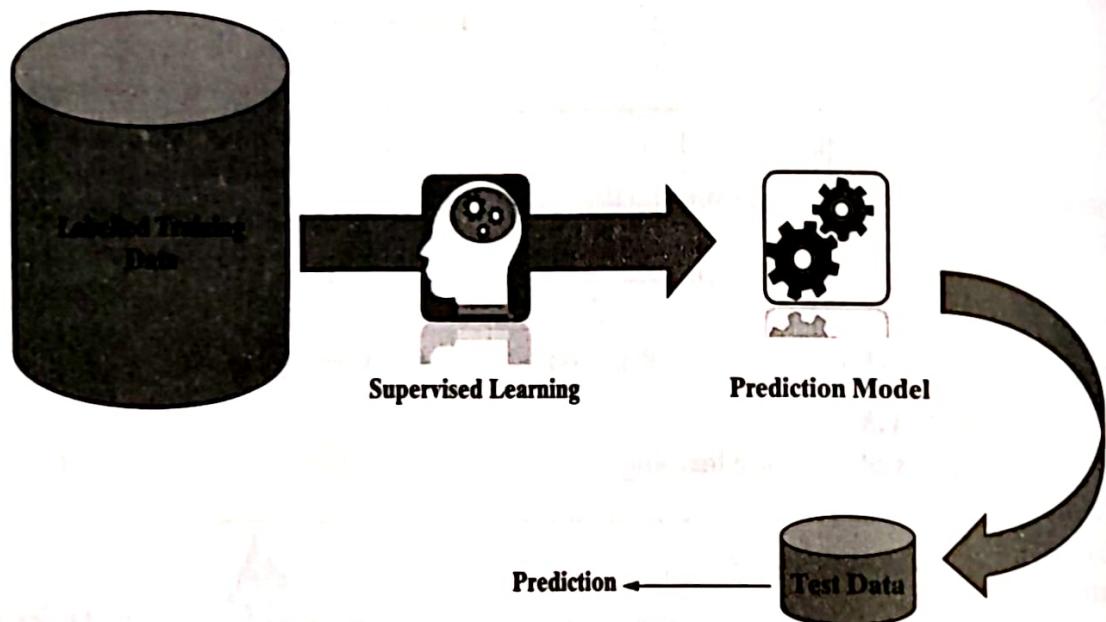
#### 1.5.1 Supervised learning

The major motivation of supervised learning is to learn from past information. So what kind of past information does the machine need for supervised learning? It is the information about the task which the machine has to execute. In context of the definition of machine learning, this past information is the experience. Let's try to understand it with an example.

Say a machine is getting images of different objects as input and the task is to segregate the images by either shape or colour of the object. If it is by shape, the images which are of round-shaped objects need to be separated from images of triangular-shaped objects, etc. If the segregation needs to happen based on colour, images of blue objects need to be separated from images of green objects. But how can the machine know what is round shape, or triangular shape? Same way, how can the machine distinguish image of an object based on whether it is blue or green in colour? A machine is very much like a little child whose parents or adults need to guide him with the basic information on shape and colour before he can start doing the task. A machine needs the basic

information to be provided to it. This basic input, or the experience in the paradigm of machine learning, is given in the form of **training data**. Training data is the past information on a specific task. In context of the image segregation problem, training data will have past data on different aspects or features on a number of images, along with a tag on whether the image is round or triangular, or blue or green in colour. The tag is called '**label**' and we say that the training data is labelled in case of supervised learning.

Figure 1.4 is a simple depiction of the supervised learning process. Labelled training data containing past information comes as an input. Based on the training data, the machine builds a predictive model that can be used on test data to assign a label for each record in the test data.



**FIG. 1.4**  
**Supervised learning**

Some examples of supervised learning are

- Predicting the results of a game
- Predicting whether a tumour is malignant or benign
- Predicting the price of domains like real estate, stocks, etc.
- Classifying texts such as classifying a set of emails as spam or non-spam

Now, let's consider two of the above examples, say 'predicting whether a tumour is malignant or benign' and 'predicting price of domains such as real estate'. Are these two problems same in nature? The answer is 'no'. Though both of them are prediction problems, in one case we are trying to predict which category or class an unknown data belongs to whereas in the other case we are trying to predict an absolute value and not a class. When we are trying to predict a categorical or nominal variable, the problem is known as a **classification** problem. Whereas when we are trying to predict a real-valued variable, the problem falls under the category of **regression**.

**Note:**

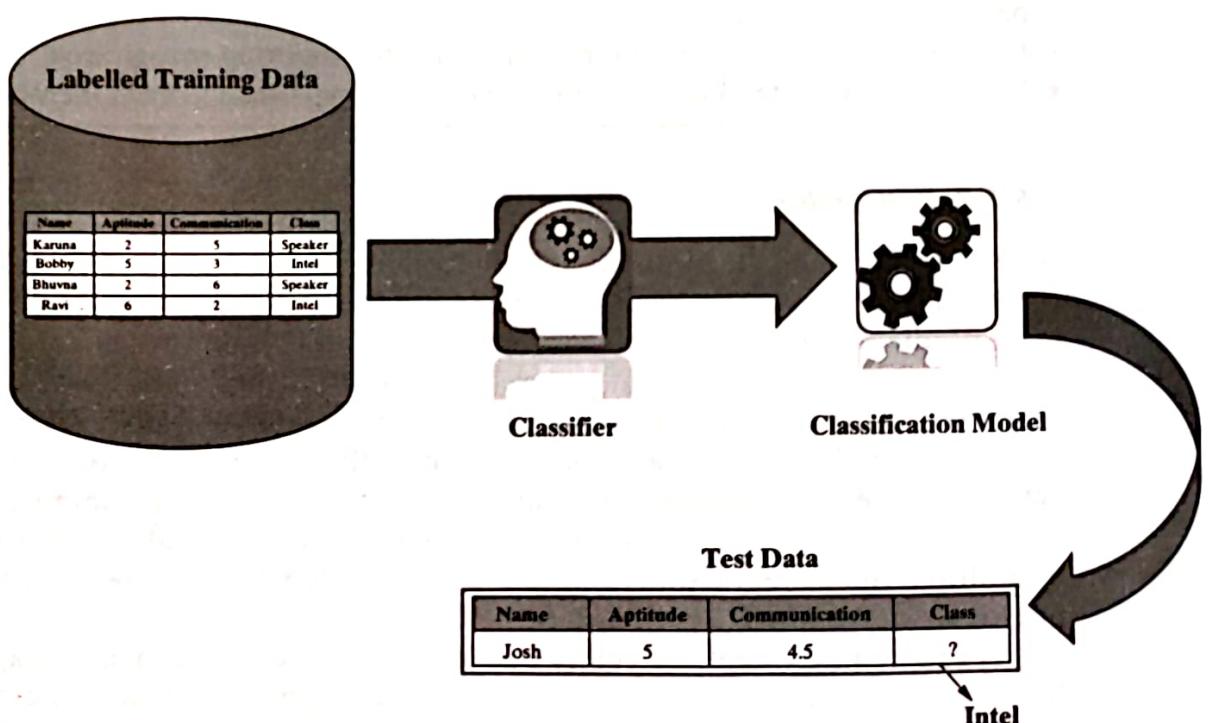
Supervised machine learning is as good as the data used to train it. If the training data is of poor quality, the prediction will also be far from being precise.

Let's try to understand these two areas of supervised learning, i.e. classification and regression in more details.

### 1.5.1.1 Classification

Let's discuss how to segregate the images of objects based on the shape. If the image is of a round object, it is put under one category, while if the image is of a triangular object, it is put under another category. In which category the machine should put an image of unknown category, also called a **test data** in machine learning parlance, depends on the information it gets from the past data, which we have called as training data. Since the training data has a label or category defined for each and every image, the machine has to map a new image or test data to a set of images to which it is similar to and assign the same label or category to the test data.

So we observe that the whole problem revolves around assigning a label or category or class to a test data based on the label or category or class information that is imparted by the training data. Since the target objective is to assign a class label, this type of problem as classification problem. Figure 1.5 depicts the typical process of classification.



**FIG. 1.5**  
**Classification**

There are number of popular machine learning algorithms which help in solving classification problems. To name a few, Naïve Bayes, Decision tree, and k-Nearest Neighbour algorithms are adopted by many machine learning practitioners.

A critical classification problem in context of banking domain is identifying potential fraudulent transactions. Since there are millions of transactions which have to be scrutinized and assured whether it might be a fraud transaction, it is not possible for any human being to carry out this task. Machine learning is effectively leveraged to do this task and this is a classic case of classification. Based on the past transaction data, specifically the ones labelled as fraudulent, all new incoming transactions are marked or labelled as normal or suspicious. The suspicious transactions are subsequently segregated for a closer review.

In summary, classification is a type of supervised learning where a target feature, which is of type categorical, is predicted for test data based on the information imparted by training data. The target categorical feature is known as **class**.

Some typical classification problems include:

- Image classification
- Prediction of disease
- Win-loss prediction of games
- Prediction of natural calamity like earthquake, flood, etc.
- Recognition of handwriting

### **Did you know?**

- Machine learning saves life – ML can spot 52% of breast cancer cells, a year before patients are diagnosed.
- US Postal Service uses machine learning for handwriting recognition.
- Facebook's news feed uses machine learning to personalize each member's feed.

#### **1.5.1.2. Regression**

In linear regression, the objective is to predict numerical features like real estate or stock price, temperature, marks in an examination, sales revenue, etc. The underlying predictor variable and the target variable are continuous in nature. In case of linear regression, a straight line relationship is ‘fitted’ between the predictor variables and the target variables, using the statistical concept of least squares method. As in the case of least squares method, the sum of square of error between actual and predicted values of the target variable is tried to be minimized. In case of simple linear regression, there is only one predictor variable whereas in case of multiple linear regression, multiple predictor variables can be included in the model.

Let's take the example of yearly budgeting exercise of the sales managers. They have to give sales prediction for the next year based on sales figure of previous years vis-à-vis investment being put in. Obviously, the data related to past as well as the data to be predicted are continuous in nature. In a basic approach, a simple linear regression model can be applied with investment as predictor variable and sales revenue as the target variable.

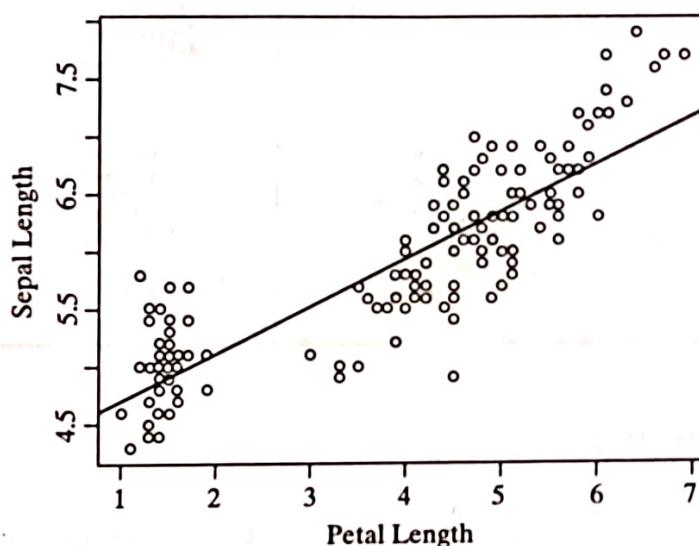
Figure 1.6 shows a typical simple regression model, where regression line is fitted based on values of target variable with respect to different values of predictor variable. A typical linear regression model can be represented in the form –

$$y = \alpha + \beta x$$

where 'x' is the predictor variable and 'y' is the target variable.

The input data come from a famous multivariate data set named Iris introduced by the British statistician and biologist Ronald Fisher. The data set consists of 50 samples from each of three species of Iris – *Iris setosa*, *Iris virginica*, and *Iris versicolor*. Four features were measured for each sample – sepal length, sepal width, petal length, and petal width. These features can uniquely discriminate the different species of the flower.

The Iris data set is typically used as a training data for solving the classification problem of predicting the flower species based on feature values. However, we can also demonstrate regression using this data set, by predicting the value of one feature using another feature as predictor. In Figure 1.6, petal length is a predictor variable which, when fitted in the simple linear regression model, helps in predicting the value of the target variable sepal length.



**FIG. 1.6**  
Regression

Typical applications of regression can be seen in

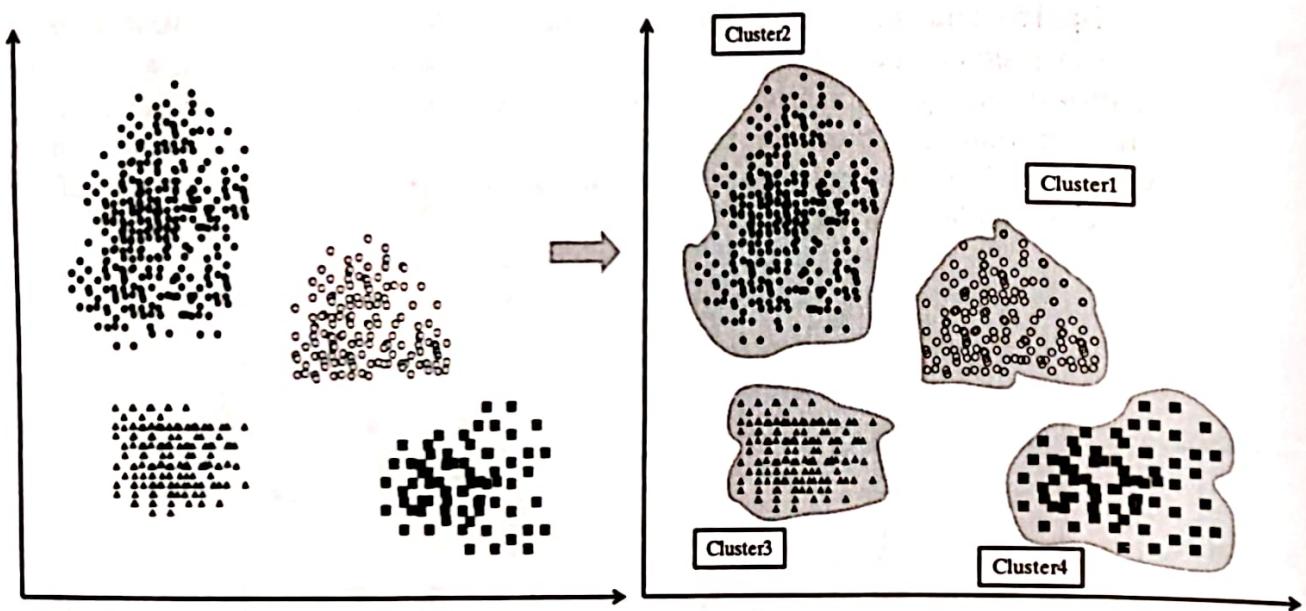
- Demand forecasting in retail
- Sales prediction for managers
- Price prediction in real estate
- Weather forecast
- Skill demand forecast in job market

### 1.5.2 Unsupervised learning

Unlike supervised learning, in unsupervised learning, there is no labelled training data to learn from and no prediction to be made. In unsupervised learning, the objective is to take a dataset as input and try to find natural groupings or patterns within the data

elements or records. Therefore, unsupervised learning is often termed as **descriptive model** and the process of unsupervised learning is referred as **pattern discovery** or **knowledge discovery**. One critical application of unsupervised learning is customer segmentation.

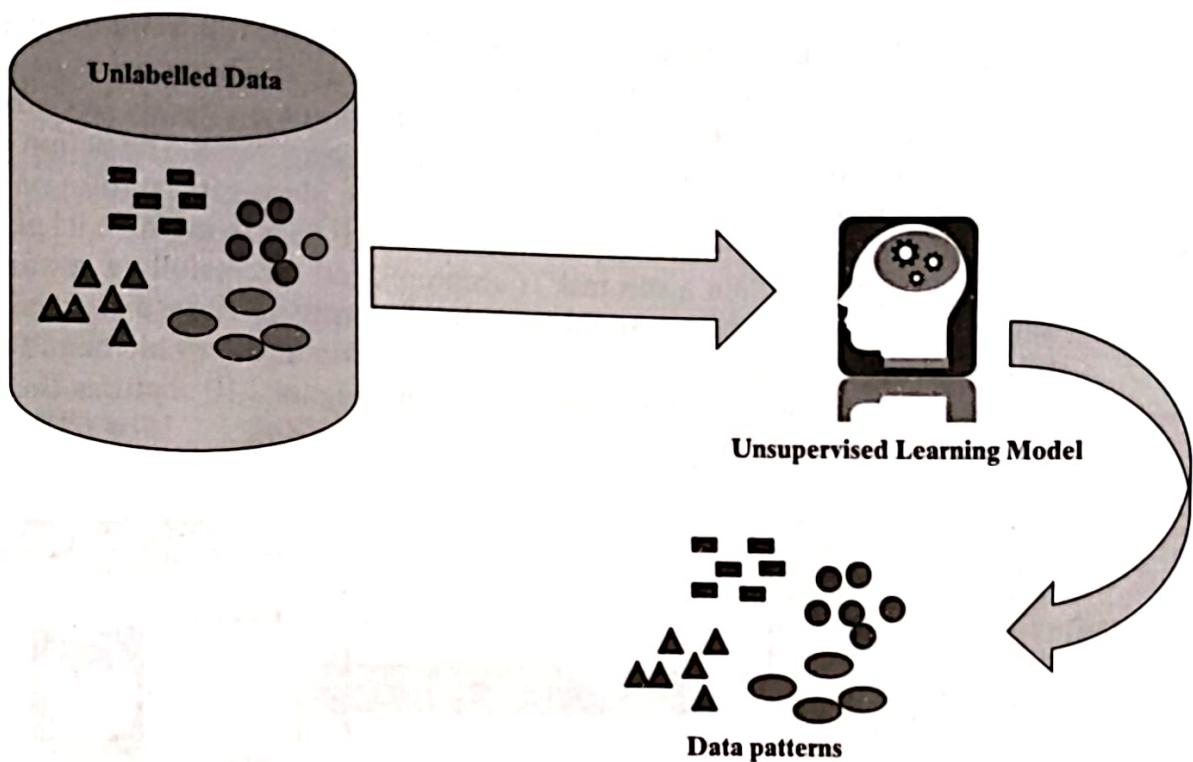
Clustering is the main type of unsupervised learning. It intends to group or organize similar objects together. For that reason, objects belonging to the same cluster are quite similar to each other while objects belonging to different clusters are quite dissimilar. Hence, the objective of clustering to discover the intrinsic grouping of unlabelled data and form clusters, as depicted in Figure 1.7. Different measures of similarity can be applied for clustering. One of the most commonly adopted similarity



**FIG. 1.7**  
**Distance-based clustering**

measure is distance. Two data items are considered as a part of the same cluster if the distance between them is less. In the same way, if the distance between the data items is high, the items do not generally belong to the same cluster. This is also known as **distance-based clustering**. Figure 1.8 depicts the process of clustering at a high level.

Other than clustering of data and getting a summarized view from it, one more variant of unsupervised learning is **association analysis**. As a part of association analysis, the association between data elements is identified. Let's try to understand the approach of association analysis in context of one of the most common examples, i.e. market basket analysis as shown in Figure 1.9. From past transaction data in a grocery store, it may be observed that most of the customers who have bought item A, have also bought item B and item C or at least one of them. This means that there is a strong association of the event 'purchase of item A' with the event 'purchase of item B' or 'purchase of item C'. Identifying these sorts of associations is the goal of association analysis. This helps in boosting up sales pipeline, hence a critical input for the sales group. Critical applications of association analysis include market basket analysis and recommender systems.



**FIG. 1.8**  
Unsupervised learning

TransID	Items Bought
1	{Butter, Bread}
2	{Diaper, Bread, Milk, Beer}
3	{Milk, Chicken, Beer, Diaper}
4	{Bread, Diaper, Chicken, Beer}
5	{Diaper, Beer, Cookies, Ice cream}
...	...

Market Basket transactions  
Frequent itemsets  $\rightarrow$  (Diaper, Beer)  
Possible association: Diaper  $\rightarrow$  Beer

**FIG. 1.9**  
Market basket analysis

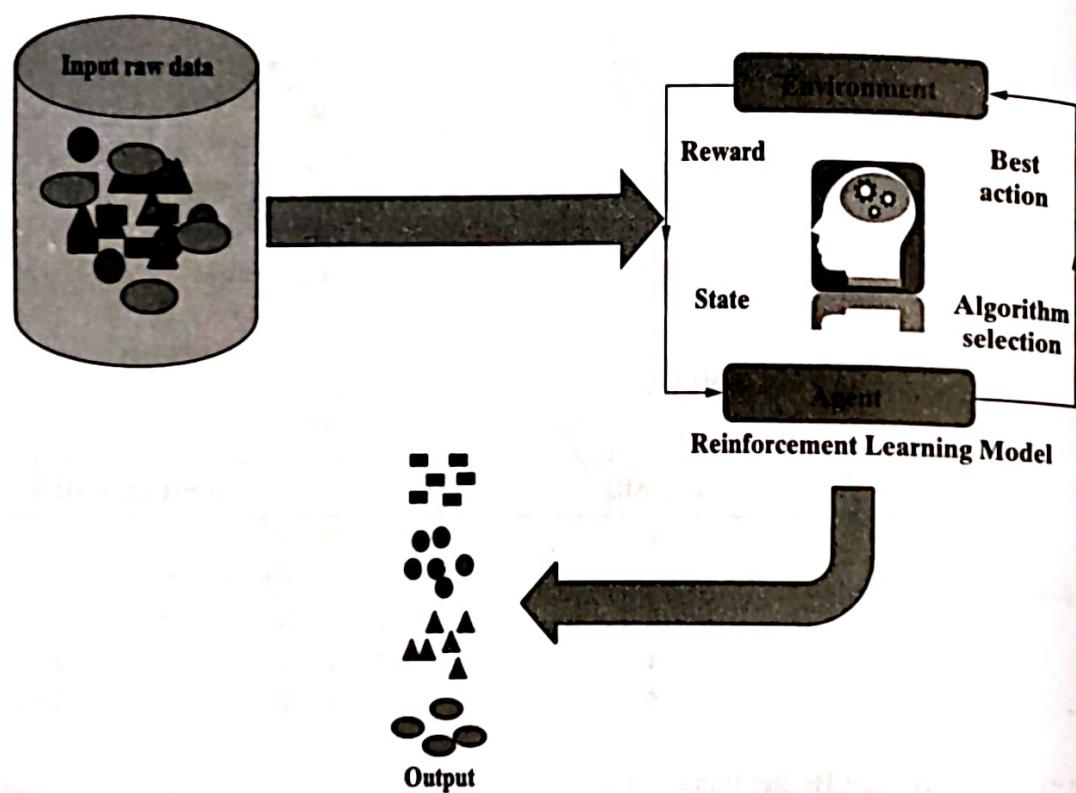
### 1.5.3 Reinforcement learning

We have seen babies learn to walk without any prior knowledge of how to do it. Often we wonder how they really do it. They do it in a relatively simple way.

First they notice somebody else walking around, for example parents or anyone living around. They understand that legs have to be used, one at a time, to take a step. While walking, sometimes they fall down hitting an obstacle, whereas other times they are able to walk smoothly avoiding bumpy obstacles. When they are able to walk overcoming the obstacle, their parents are elated and appreciate the baby with loud claps / or may be a chocolates. When they fall down while circumventing an obstacle,

obviously their parents do not give claps or chocolates. Slowly a time comes when the babies learn from mistakes and are able to walk with much ease.

In the same way, machines often learn to do tasks autonomously. Let's try to understand in context of the example of the child learning to walk. The action tried to be achieved is walking, the child is the agent and the place with hurdles on which the child is trying to walk resembles the environment. It tries to improve its performance of doing the task. When a sub-task is accomplished successfully, a reward is given. When a sub-task is not executed correctly, obviously no reward is given. This continues till the machine is able to complete execution of the whole task. This process of learning is known as reinforcement learning. Figure 1.10 captures the high-level process of reinforcement learning.



**FIG. 1.10**  
Reinforcement learning

One contemporary example of reinforcement learning is self-driving cars. The critical information which it needs to take care of are speed and speed limit in different road segments, traffic conditions, road conditions, weather conditions, etc. The tasks that have to be taken care of are start/stop, accelerate/decelerate, turn to left / right, etc.

Further details on reinforcement learning have been kept out of the scope of this book.

#### Points to ponder:

- Reinforcement learning is getting more and more attention from both industry and academia. Annual publications count in the area of reinforcement learning in Google Scholar support this view.

- While Deep Blue used brute force to defeat the human chess champion, AlphaGo used RL to defeat the best human Go player.
- RL is an effective tool for personalized online marketing. It considers the demographic details and browsing history of the user real-time to show most relevant advertisements.

#### 1.5.4 Comparison – supervised, unsupervised, and reinforcement learning

SUPERVISED	UNSUPERVISED	REINFORCEMENT
This type of learning is used when you know how to classify a given data, or in other words classes or labels are available.	This type of learning is used when there is no idea about the class or label of a particular data. The model has to find pattern in the data.	This type of learning is used when there is no idea about the class or label of a particular data. The model has to do the classification – it will get rewarded if the classification is correct, else get punished.
Labelled training data is needed. Model is built based on training data.	Any unknown and unlabelled data set is given to the model as input and records are grouped.	The model learns and updates itself through reward/punishment.
The model performance can be evaluated based on how many misclassifications have been done based on a comparison between predicted and actual values.	Difficult to measure whether the model did something useful or interesting. Homogeneity of records grouped together is the only measure.	Model is evaluated by means of the reward function after it had some time to learn.
There are two types of supervised learning problems – classification and regression. Simplest one to understand.	There are two types of unsupervised learning problems – clustering and association. More difficult to understand and implement than supervised learning.	No such types. Most complex to understand and apply.
Standard algorithms include <ul style="list-style-type: none"> <li>• Naïve Bayes</li> <li>• <math>k</math>-nearest neighbour (kNN)</li> <li>• Decision tree</li> <li>• Linear regression</li> <li>• Logistic regression</li> <li>• Support Vector Machine (SVM), etc.</li> </ul>	Standard algorithms are <ul style="list-style-type: none"> <li>• <math>k</math>-means</li> <li>• Principal Component Analysis (PCA)</li> <li>• Self-organizing map (SOM)</li> <li>• Apriori algorithm</li> <li>• DBSCAN etc.</li> </ul>	Standard algorithms are <ul style="list-style-type: none"> <li>• Q-learning</li> <li>• Sarsa</li> </ul>
Practical applications include <ul style="list-style-type: none"> <li>• Handwriting recognition</li> <li>• Stock market prediction</li> <li>• Disease prediction</li> <li>• Fraud detection, etc.</li> </ul>	Practical applications include <ul style="list-style-type: none"> <li>• Market basket analysis</li> <li>• Recommender systems</li> <li>• Customer segmentation, etc.</li> </ul>	Practical applications include <ul style="list-style-type: none"> <li>• Self-driving cars</li> <li>• Intelligent robots</li> <li>• AlphaGo Zero (the latest version of DeepMind's AI system playing Go)</li> </ul>

## 1.6 PROBLEMS NOT TO BE SOLVED USING MACHINE LEARNING

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Machine learning should not be applied to tasks in which humans are very effective or frequent human intervention is needed. For example, air traffic control is a very complex task needing intense human involvement. At the same time, for very simple tasks which can be implemented using traditional programming paradigms, there is no sense of using machine learning. For example, simple rule-driven or formula-based applications like price calculator engine, dispute tracking application, etc. do not need machine learning techniques.

Machine learning should be used only when the business process has some lapses. If the task is already optimized, incorporating machine learning will not serve to justify the return on investment.

For situations where training data is not sufficient, machine learning cannot be used effectively. This is because, with small training data sets, the impact of bad data is exponentially worse. For the quality of prediction or recommendation to be good, the training data should be sizeable.

## 1.7 APPLICATIONS OF MACHINE LEARNING

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Wherever there is a substantial amount of past data, machine learning can be used to generate actionable insight from the data. Though machine learning is adopted in multiple forms in every business domain, we have covered below three major domains just to give some idea about what type of actions can be done using machine learning.

### 1.7.1 Banking and finance

In the banking industry, fraudulent transactions, especially the ones related to credit cards, are extremely prevalent. Since the volumes as well as velocity of the transactions are extremely high, high performance machine learning solutions are implemented by almost all leading banks across the globe. The models work on a real-time basis, i.e. the fraudulent transactions are spotted and prevented right at the time of occurrence. This helps in avoiding a lot of operational hassles in settling the disputes that customers will otherwise raise against those fraudulent transactions.

Customers of a bank are often offered lucrative proposals by other competitor banks. Proposals like higher bank interest, lower processing charge of loans, zero balance savings accounts, no overdraft penalty, etc. are offered to customers, with the intent that the customer switches over to the competitor bank. Also, sometimes customers get demotivated by the poor quality of services of the banks and shift to competitor banks. Machine learning helps in preventing or at least reducing the customer churn. Both descriptive and predictive learning can be applied for reducing customer churn. Using descriptive learning, the specific pockets of problem, i.e. a specific bank or a specific zone or a specific type of offering like car loan, may be spotted where maximum churn is happening. Quite obviously, these are troubled areas where further investigation needs to be done to find and fix the root cause. Using predictive learning, the set of vulnerable customers who may leave the bank very soon, can be identified. Proper action can be taken to make sure that the customers stay back.

### 1.7.2 Insurance

Insurance industry is extremely data intensive. For that reason, machine learning is extensively used in the insurance industry. Two major areas in the insurance industry where machine learning is used are risk prediction during new customer onboarding and claims management. During customer onboarding, based on the past information the risk profile of a new customer needs to be predicted. Based on the quantum of risk predicted, the quote is generated for the prospective customer. When a customer claim comes for settlement, past information related to historic claims along with the adjustor notes are considered to predict whether there is any possibility of the claim to be fraudulent. Other than the past information related to the specific customer, information related to similar customers, i.e. customer belonging to the same geographical location, age group, ethnic group, etc., are also considered to formulate the model.

### 1.7.3 Healthcare

Wearable device data form a rich source for applying machine learning and predict the health conditions of the person real time. In case there is some health issue which is predicted by the learning model, immediately the person is alerted to take preventive action. In case of some extreme problem, doctors or healthcare providers in the vicinity of the person can be alerted. Suppose an elderly person goes for a morning walk in a park close to his house. Suddenly, while walking, his blood pressure shoots up beyond a certain limit, which is tracked by the wearable. The wearable data is sent to a remote server and a machine learning algorithm is constantly analyzing the streaming data. It also has the history of the elderly person and persons of similar age group. The model predicts some fatality unless immediate action is taken. Alert can be sent to the person to immediately stop walking and take rest. Also, doctors and healthcare providers can be alerted to be on standby.

Machine learning along with computer vision also plays a crucial role in disease diagnosis from medical imaging.

## 1.8 STATE-OF-THE-ART LANGUAGES/TOOLS IN MACHINE LEARNING

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The algorithms related to different machine learning tasks are known to all and can be implemented using any language/platform. It can be implemented using a Java platform or C / C++ language or in .NET. However, there are certain languages and tools which have been developed with a focus for implementing machine learning. Few of them, which are most widely used, are covered below.

### 1.8.1 Python

Python is one of the most popular, open source programming language widely adopted by machine learning community. It was designed by Guido van Rossum and was first released in 1991. The reference implementation of Python, i.e. CPython, is managed by Python Software Foundation, which is a non-profit organization.

Python has very strong libraries for advanced mathematical functionalities (NumPy), algorithms and mathematical tools (SciPy) and numerical plotting (matplotlib). Built on these libraries, there is a machine learning library named **scikit-learn**, which has various classification, regression, and clustering algorithms embedded in it.

### 1.8.2 R

R is a language for statistical computing and data analysis. It is an open source language, extremely popular in the academic community – especially among statisticians and data miners. R is considered as a variant of S, a GNU project which was developed at Bell Laboratories. Currently, it is supported by the R Foundation for statistical computing.

R is a very simple programming language with a huge set of libraries available for different stages of machine learning. Some of the libraries standing out in terms of popularity are plyr/dplyr (for data transformation), caret ('Classification and Regression Training' for classification), RJava (to facilitate integration with Java), tm (for text mining), ggplot2 (for data visualization). Other than the libraries, certain packages like Shiny and R Markdown have been developed around R to develop interactive web applications, documents and dashboards on R without much effort.

### 1.8.3 Matlab

MATLAB (matrix laboratory) is a licenced commercial software with a robust support for a wide range of numerical computing. MATLAB has a huge user base across industry and academia. MATLAB is developed by MathWorks, a company founded in 1984. Being proprietary software, MATLAB is developed much more professionally, tested rigorously, and has comprehensive documentation.

MATLAB also provides extensive support of statistical functions and has a huge number of machine learning algorithms in-built. It also has the ability to scale up for large datasets by parallel processing on clusters and cloud.

### 1.8.4 SAS

SAS (earlier known as 'Statistical Analysis System') is another licenced commercial software which provides strong support for

the Social Sciences) is a popular package supporting specialized data mining and statistical analysis. Originally popular for statistical analysis in social science (as the name reflects), SPSS is now popular in other fields as well.

Released in 2012, **Julia** is an open source, liberal licence programming language for numerical analysis and computational science. It has baked in all good things of MATLAB, Python, R, and other programming languages used for machine learning for which it is gaining steady attention from machine learning development community. Another big point in favour of Julia is its ability to implement high-performance machine learning algorithms.

## 1.9 ISSUES IN MACHINE LEARNING

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Machine learning is a field which is relatively new and still evolving. Also, the level of research and kind of use of machine learning tools and technologies varies drastically from country to country. The laws and regulations, cultural background, emotional maturity of people differ drastically in different countries. All these factors make the use of machine learning and the issues originating out of machine learning usage are quite different.

The biggest fear and issue arising out of machine learning is related to privacy and the breach of it. The primary focus of learning is on analyzing data, both past and current, and coming up with insight from the data. This insight may be related to people and the facts revealed might be private enough to be kept confidential. Also, different people have a different preference when it comes to sharing of information. While some people may be open to sharing some level of information publicly, some other people may not want to share it even to all friends and keep it restricted just to family members. Classic examples are a birth date (not the day, but the date as a whole), photographs of a dinner date with family, educational background, etc. Some people share them with all in the social platforms like Facebook while others do not, or if they do, they may restrict it to friends only. When machine learning algorithms are implemented using those information, inadvertently people may get upset. For example, if there is a learning algorithm to do preference-based customer segmentation and the output of the analysis is used for sending targeted marketing campaigns, it will hurt the emotion of people and actually do more harm than good. In certain countries, such events may result in legal actions to be taken by the people affected.

Even if there is no breach of privacy, there may be situations where actions were taken based on machine learning may create an adverse reaction. Let's take the example of knowledge discovery exercise done before starting an election campaign. If a specific area reveals an ethnic majority or skewness of a certain demographic factor, and the campaign pitch carries a message keeping that in mind, it might actually upset the voters and cause an adverse result.

So a very critical consideration before applying machine learning is that proper human judgement should be exercised before using any outcome from machine learning. Only then the decision taken will be beneficial and also not result in any adverse impact.

## 1.10 SUMMARY

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- Machine learning imbibes the philosophy of human learning, i.e. learning from expert guidance and from experience.
- The basic machine learning process can be divided into three parts.
  - ❖ Data Input: Past data or information is utilized as a basis for future decision-making.
  - ❖ Abstraction: The input data is represented in a summarized way
  - ❖ Generalization: The abstracted representation is generalized to form a framework for making decisions.
- Before starting to solve any problem using machine learning, it should be decided whether the problem is a right problem to be solved using machine learning.
- Machine learning can be classified into three broad categories:
  - ❖ Supervised learning: Also called predictive learning. The objective of this learning is to predict class/value of unknown objects based on prior information of similar objects. Examples: predicting whether a tumour is malignant or benign, price prediction in domains such as real estate, stocks, etc.
  - ❖ Unsupervised learning: Also called descriptive learning, helps in finding groups or patterns in unknown objects by grouping similar objects together. Examples: customer segmentation, recommender systems, etc.
  - ❖ Reinforcement learning: A machine learns to act on its own to achieve the given goals. Examples: self-driving cars, intelligent robots, etc.
- Machine learning has been adopted by various industry domains such as Banking and Financial Services, Insurance, Healthcare, Life Sciences, etc. to solve problems.
- Some of the most adopted platforms to implement machine learning include Python, R, MATLAB, SAS, SPSS, etc.
- To avoid ethical issues, the critical consideration is required before applying machine learning and using any outcome from machine learning.

## SAMPLE QUESTIONS

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### MULTIPLE-CHOICE QUESTIONS (1 MARK EACH):

1. Machine learning is \_\_\_ field.
 

(a) Inter-disciplinary	(b) Single
(c) Multi-disciplinary	(d) All of the above
2. A computer program is said to learn from \_\_\_\_\_ E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with E.
 

(a) Training	(b) Experience
(c) Database	(d) Algorithm

3. \_\_\_\_\_ has been used to train vehicles to steer correctly and autonomously on road.
- (a) Machine learning
  - (b) Data mining
  - (c) Neural networks
  - (d) Robotics
4. Any hypothesis find an approximation of the target function over a sufficiently large set of training examples will also approximate the target function well over other unobserved examples. This is called \_\_\_\_\_.
- (a) Hypothesis
  - (b) Inductive hypothesis
  - (c) Learning
  - (d) Concept learning
5. Factors which affect performance of a learner system does not include
- (a) Representation scheme used
  - (b) Training scenario
  - (c) Type of feedback
  - (d) Good data structures
6. Different learning methods does not include
- (a) Memorization
  - (b) Analogy
  - (c) Deduction
  - (d) Introduction
7. A model of language consists of the categories which does not include
- (a) Language units
  - (b) Role structure of units
  - (c) System constraints
  - (d) Structural units
8. How many types are available in machine learning?
- (a) 1
  - (b) 2
  - (c) 3
  - (d) 4
9. The  $k$ -means algorithm is a
- (a) Supervised learning algorithm
  - (b) Unsupervised learning algorithm
  - (c) Semi-supervised learning algorithm
  - (d) Weakly supervised learning algorithm
10. The Q-learning algorithm is a
- (a) Supervised learning algorithm
  - (b) Unsupervised learning algorithm
  - (c) Semi-supervised learning algorithm
  - (d) Reinforcement learning algorithm
11. This type of learning to be used when there is no idea about the class or label of a particular data
- (a) Supervised learning algorithm
  - (b) Unsupervised learning algorithm
  - (c) Semi-supervised learning algorithm
  - (d) Reinforcement learning algorithm
12. The model learns and updates itself through reward/punishment in case of
- (a) Supervised learning algorithm
  - (b) Unsupervised learning algorithm
  - (c) Semi-supervised learning algorithm

**SHORT-ANSWER TYPE QUESTIONS (5 MARKS EACH):**

1. What is human learning? Give any two examples.
2. What are the types of human learning? Are there equivalent forms of machine learning?
3. What is machine learning? What are key tasks of machine learning?
4. Explain the concept of penalty and reward in reinforcement learning.
5. What are concepts of learning as search?
6. What are different objectives of machine learning? How are these related with human learning?
7. Define machine learning and explain the different elements with a real example.
8. Explain the process of abstraction with an example.
9. What is generalization? What role does it play in the process of machine learning?
10. What is classification? Explain the key differences between classification and regression.
11. What is regression? Give example of some practical problems solved using regression.
12. Explain the process of clustering in details.
13. Write short notes on any two of the following:
  - (a) Application of machine learning algorithms
  - (b) Supervised learning
  - (c) Unsupervised learning
  - (d) Reinforcement learning

**LONG-ANSWER TYPE QUESTIONS (10 MARKS QUESTIONS):**

1. What is machine learning? Explain any two business applications of machine learning. What are the possible ethical issues of machine learning applications?
2. Explain how human learning happens:
  - (a) Under direct guidance of experts
  - (b) Under indirect guidance of experts
  - (c) Self-learning
3. Explain the different forms of machine learning with a few examples.
4. Compare the different types of machine learning.
5. What do you mean by a well-posed learning problem? Explain important features that are required to well-define a learning problem.
6. Can all problems be solved using machine learning? Explain your response in detail.
7. What are different tools and technologies available for solving problems in machine learning? Give details about any two of them.
8. What are the different types of supervised learning? Explain them with a sample application in each area.
9. What are the different types of unsupervised learning? Explain them difference with a sample application in each area.

10. Explain, in details, the process of machine learning.
- (a) Write short notes on any two:
- (i) MATLAB
  - (ii) Application of machine learning in Healthcare
  - (iii) Market basket analysis
  - (iv) Simple linear regression
- (b) Write the difference between (any two):
- (i) Abstraction and generalization
  - (ii) Supervised and unsupervised learning
  - (iii) Classification and regression

## Chapter 2

# Preparing to Model

### **OBJECTIVE OF THE CHAPTER:**

This chapter gives a detailed view of how to understand the incoming data and create basic understanding about the nature and quality of the data. This information, in turn, helps to select and then how to apply the model. So, the knowledge imparted in this chapter helps a beginner take the first step towards effective modelling and solving a machine learning problem.

### **2.1 INTRODUCTION**

In the last chapter, we got introduced to machine learning. In the beginning, we got a glimpse of the journey of machine learning as an evolving technology. It all started as a proposition from the renowned computer scientist Alan Turing – machines can ‘learn’ and become artificially intelligent. Gradually, through the next few decades path-breaking innovations came in from Arthur Samuel, Frank Rosenblatt, John Hopfield, Christopher Watkins, Geoffrey Hinton and many other computer scientists. They shaped up concepts of Neural Networks, Recurrent Neural Network, Reinforcement Learning, Deep Learning, etc. which took machine learning to new heights. In parallel, interesting applications of machine learning kept on happening, with organizations like IBM and Google taking a lead. What started with IBM’s Deep Blue beating the world chess champion Gary Kasparov, continued with IBM’s Watson beating two human champions in a Jeopardy competition.

Google also started with a series of innovations applying machine learning. The Google Brain, Sibyl, Waymo, AlphaGo programs – are all extremely advanced applications of machine learning which have taken the technology a few notches up. Now we can see an all-pervasive presence of machine learning technology in all walks of life.

We have also seen the types of human learning and how that, in some ways, can be related to the types of machine learning – supervised, unsupervised, and reinforcement. Supervised learning, as we saw, implies learning from past data, also called training data, which has got known values or classes. Machines can ‘learn’ or get ‘trained’ from the past data and assign classes or values to unknown data, termed as test data. This helps in solving problems related to prediction. This is much like human learning through expert guidance as happens for infants from parents or students through teachers. So, supervised learning in case of machines can be perceived as guided learning from human inputs. Unsupervised machine learning doesn’t have labelled data to learn from. It tries to find patterns in unlabelled data. This is much like human beings trying to group together objects of similar shape. This learning is not guided by labelled inputs but uses the knowledge gained from the labels themselves. Last but not the least is reinforcement learning in which machine tries to learn by itself through penalty/reward mechanism – again pretty much in the same way as human self-learning happens.

Lastly, we saw some of the applications of machine learning in different domains such as banking and finance, insurance, and healthcare. Fraud detection is a critical business case which is implemented in almost all banks across the world and uses machine learning predominantly. Risk prediction for new customers is a similar critical case in the insurance industry which finds the application of machine learning. In the healthcare sector, disease prediction makes wide use of machine learning, especially in the developed countries.

While development in machine learning technology has been extensive and its implementation has become widespread, to start as a practitioner, we need to gain some basic understanding. We need to understand how to apply the array of tools and technologies available in the machine learning to solve a problem. In fact, that is going to be very specific to the kind of problem that we are trying to solve. If it is a prediction problem, the kind of activities that will be involved is going to be completely different vis-à-vis if it is a problem where we are trying to unfold a pattern in a data without any past knowledge about the data. So how a machine learning project looks like or what are the salient activities that form the core of a machine learning project will depend on whether it is in the area of supervised or unsupervised or reinforcement learning area. However, irrespective of the variation, some foundational knowledge needs to be built before we start with the core machine learning concepts and key algorithms. In this section, we will have a quick look at a few typical machine learning activities and focus on some of the foundational concepts that all practitioners need to gain as pre-requisites before starting their journey in the area of machine learning.

**Points to Ponder**

No man is perfect. The same is applicable for machines. To increase the level of accuracy of a machine, human participation should be added to the machine learning process. In short, incorporating human intervention is the recipe for the success of machine learning.

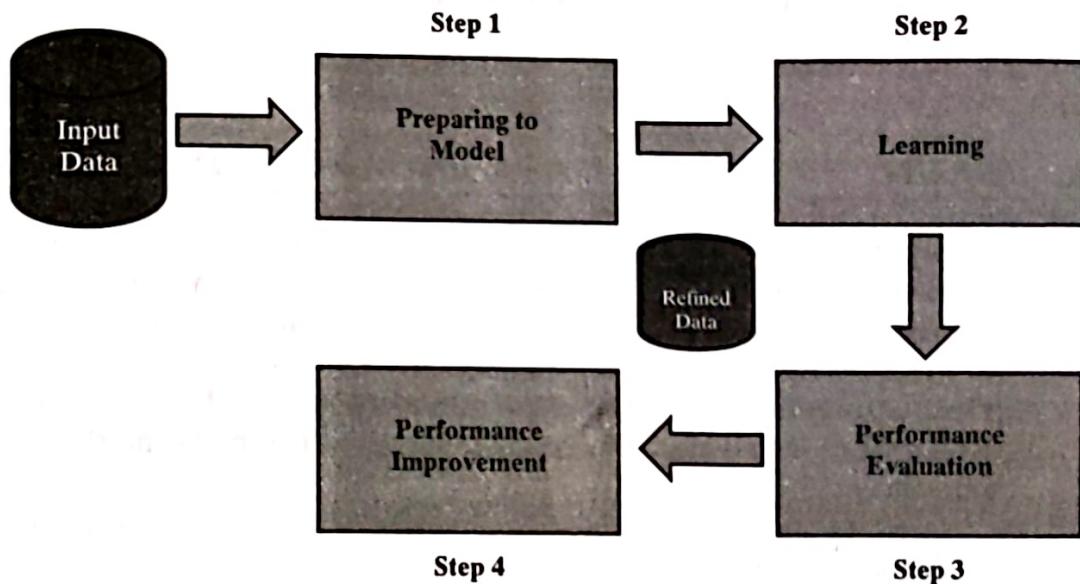
## **2.2 MACHINE LEARNING ACTIVITIES**

The first step in machine learning activity starts with data. In case of supervised learning, it is the labelled training data set followed by test data which is not labelled. In case of unsupervised learning, there is no question of labelled data but the task is to find patterns in the input data. A thorough review and exploration of the data is needed to understand the type of the data, the quality of the data and relationship between the different data elements. Based on that, multiple pre-processing activities may need to be done on the input data before we can go ahead with core machine learning activities. Following are the typical **preparation** activities done once the input data comes into the machine learning system:

- Understand the type of data in the given input data set.
- Explore the data to understand the nature and quality.
- Explore the relationships amongst the data elements, e.g. inter-feature relationship.
- Find potential issues in data.
- Do the necessary remediation, e.g. impute missing data values, etc., if needed.
- Apply pre-processing steps, as necessary.
- Once the data is prepared for modelling, then the learning tasks start off. As a part of it, do the following activities:
  - ❖ The input data is first divided into parts – the training data and the test data (called holdout). This step is applicable for supervised learning only.
  - ❖ Consider different models or learning algorithms for selection.
  - ❖ Train the model based on the training data for supervised learning problem and apply to unknown data. Directly apply the chosen unsupervised model on the input data for unsupervised learning problem.

After the model is selected, trained (for supervised learning), and applied on input data, the performance of the model is evaluated. Based on options available, specific actions can be taken to improve the performance of the model, if possible.

Figure 2.1 depicts the four-step process of machine learning.



**FIG. 2.1**  
Detailed process of machine learning

Table 2.1 contains a summary of steps and activities involved:

**Table 2.1**  
*Activities in Machine Learning*

Step #	Step Name	Activities Involved
Step 1	Preparing to Model	<ul style="list-style-type: none"> <li>Understand the type of data in the given input data set</li> <li>Explore the data to understand data quality</li> <li>Explore the relationships amongst the data elements, e.g. inter-feature relationship</li> <li>Find potential issues in data</li> <li>Remediate data, if needed</li> <li>Apply following pre-processing steps, as necessary:           <ul style="list-style-type: none"> <li>✓ Dimensionality reduction</li> <li>✓ Feature subset selection</li> </ul> </li> </ul>
Step 2	Learning	<ul style="list-style-type: none"> <li>Data partitioning/holdout</li> <li>Model selection</li> <li>Cross-validation</li> </ul>
Step 3	Performance evaluation	<ul style="list-style-type: none"> <li>Examine the model performance, e.g. confusion matrix in case of classification</li> <li>Visualize performance trade-offs using ROC curves</li> </ul>
Step 4	Performance improvement	<ul style="list-style-type: none"> <li>Tuning the model</li> <li>Ensembling</li> <li>Bagging</li> <li>Boosting</li> </ul>

In this chapter, we will cover the first part, i.e. preparing to model. The remaining parts, i.e. learning, performance evaluation, and performance improvement will be covered in Chapter 3.

### **2.3 BASIC TYPES OF DATA IN MACHINE LEARNING**

Before starting with types of data, let's first understand what a data set is and what are the elements of a data set. A data set is a collection of related information or records. The information may be on some entity or some subject area. For example (Fig. 2.2), we may have a data set on students in which each record consists of information about a specific student. Again, we can have a data set on student performance which has records providing performance, i.e. marks on the individual subjects.

Each row of a data set is called a record. Each data set also has multiple attributes, each of which gives information on a specific characteristic. For example,

**Student data set:**

<b>Roll Number</b>	<b>Name</b>	<b>Gender</b>	<b>Age</b>
129/011	Mihir Karmarkar	M	14
129/012	Geeta Iyer	F	15
129/013	Chanda Bose	F	14
129/014	Sreenu Subramanian	M	14
129/015	Pallav Gupta	M	16
129/016	Gajanan Sharma	M	15

**Student performance data set:**

<b>Roll Number</b>	<b>Maths</b>	<b>Science</b>	<b>Percentage</b>
129/011	89	45	89.33%
129/012	89	47	90.67%
129/013	68	29	64.67%
129/014	83	38	80.67%
129/015	57	23	53.33%
129/016	78	35	75.33%

**FIG. 2.2**  
**Examples of data set**

in the data set on students, there are four attributes namely Roll Number, Name, Gender, and Age, each of which understandably is a specific characteristic about the student entity. Attributes can also be termed as feature, variable, dimension or field. Both the data sets, Student and Student Performance, are having four features or dimensions; hence they are told to have four-dimensional data space. A row or

record represents a point in the four-dimensional data space as each row has specific values for each of the four attributes or features. Value of an attribute, quite understandably, may vary from record to record. For example, if we refer to the first two records in the Student data set, the value of attributes Name, Gender, and Age are different (Fig. 2.3).

Roll Number	Name	Gender	Age
129/011	Mihir Karmarkar	(M)	(14)
129/012	Geeta Iyer	(F)	(15)

**FIG. 2.3****Data set records and attributes**

Now that a context of data sets is given, let's try to understand the different types of data that we generally come across in machine learning problems. Data can broadly be divided into following two types:

1. Qualitative data
2. Quantitative data

**Qualitative data** provides information about the quality of an object or information which cannot be measured. For example, if we consider the quality of performance of students in terms of 'Good', 'Average', and 'Poor', it falls under the category of qualitative data. Also, name or roll number of students are information that cannot be measured using some scale of measurement. So they would fall under qualitative data. Qualitative data is also called **categorical data**. Qualitative data can be further subdivided into two types as follows:

1. Nominal data
2. Ordinal data

**Nominal data** is one which has no numeric value, but a named value. It is used for assigning named values to attributes. Nominal values cannot be quantified. Examples of nominal data are

1. Blood group: A, B, O, AB, etc.
2. Nationality: Indian, American, British, etc.
3. Gender: Male, Female, Other

#### **Note:**

A special case of nominal data is when only two labels are possible, e.g. pass/fail as a result of an examination. This sub-type of nominal data is called 'dichotomous'.

It is obvious, mathematical operations such as addition, subtraction, multiplication, etc. cannot be performed on nominal data. For that reason, statistical functions such

as mean, variance, etc. can also not be applied on nominal data. However, a basic count is possible. So mode, i.e. most frequently occurring value, can be identified for nominal data.

**Ordinal data**, in addition to possessing the properties of nominal data, can also be naturally ordered. This means ordinal data also assigns named values to attributes but unlike nominal data, they can be arranged in a sequence of increasing or decreasing value so that we can say whether a value is better than or greater than another value. Examples of ordinal data are

1. Customer satisfaction: 'Very Happy', 'Happy', 'Unhappy', etc.
2. Grades: A, B, C, etc.
3. Hardness of Metal: 'Very Hard', 'Hard', 'Soft', etc.

Like nominal data, basic counting is possible for ordinal data. Hence, the mode can be identified. Since ordering is possible in case of ordinal data, median, and quartiles can be identified in addition. Mean can still not be calculated.

**Quantitative data** relates to information about the quantity of an object – hence it can be measured. For example, if we consider the attribute 'marks', it can be measured using a scale of measurement. Quantitative data is also termed as numeric data. There are two types of quantitative data:

1. Interval data
2. Ratio data

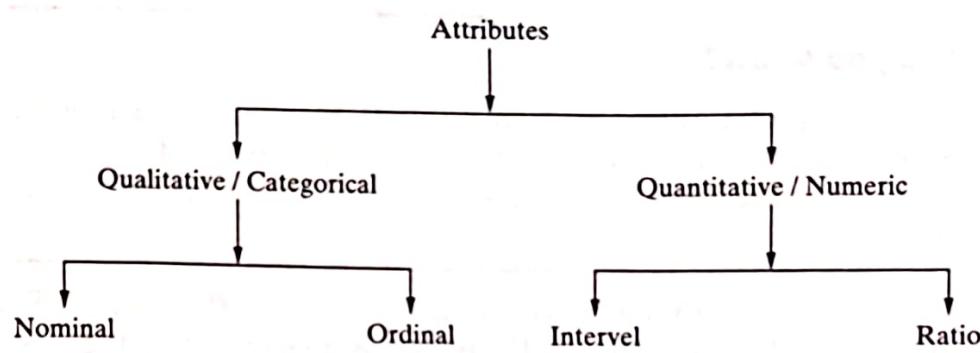
**Interval data** is numeric data for which not only the order is known, but the exact difference between values is also known. An ideal example of interval data is Celsius temperature. The difference between each value remains the same in Celsius temperature. For example, the difference between  $12^{\circ}\text{C}$  and  $18^{\circ}\text{C}$  degrees is measurable and is  $6^{\circ}\text{C}$  as in the case of difference between  $15.5^{\circ}\text{C}$  and  $21.5^{\circ}\text{C}$ . Other examples include date, time, etc.

For interval data, mathematical operations such as addition and subtraction are possible. For that reason, for interval data, the central tendency can be measured by mean, median, or mode. Standard deviation can also be calculated.

However, interval data do not have something called a 'true zero' value. For example, there is nothing called '0 temperature' or 'no temperature'. Hence, only addition and subtraction applies for interval data. The ratio cannot be applied. This means, we can say a temperature of  $40^{\circ}\text{C}$  is equal to the temperature of  $20^{\circ}\text{C} +$  temperature of  $20^{\circ}\text{C}$ . However, we cannot say the temperature of  $40^{\circ}\text{C}$  means it is twice as hot as in temperature of  $20^{\circ}\text{C}$ .

**Ratio data** represents numeric data for which exact value can be measured. Absolute zero is available for ratio data. Also, these variables can be added, subtracted, multiplied, or divided. The central tendency can be measured by mean, median, or mode and methods of dispersion such as standard deviation. Examples of ratio data include height, weight, age, salary, etc.

Figure 2.4 gives a summarized view of different types of data that we may find in a typical machine learning problem.

**FIG. 2.4****Types of data**

Apart from the approach detailed above, attributes can also be categorized into types based on a number of values that can be assigned. The attributes can be either discrete or continuous based on this factor.

Discrete attributes can assume a finite or countably infinite number of values. Nominal attributes such as roll number, street number, pin code, etc. can have a finite number of values whereas numeric attributes such as count, rank of students, etc. can have countably infinite values. A special type of discrete attribute which can assume two values only is called binary attribute. Examples of binary attribute include male/female, positive/negative, yes/no, etc.

Continuous attributes can assume any possible value which is a real number. Examples of continuous attribute include length, height, weight, price, etc.

**Note:**

In general, nominal and ordinal attributes are discrete. On the other hand, interval and ratio attributes are continuous, barring a few exceptions, e.g. 'count' attribute.

## **2.4 EXPLORING STRUCTURE OF DATA**

- By now, we understand that in machine learning, we come across two basic data types – numeric and categorical. With this context in mind, we can delve deeper into understanding a data set. We need to understand that in a data set, which of the attributes are numeric and which are categorical in nature. This is because, the approach of exploring numeric data is different than the approach of exploring categorical data. In case of a standard data set, we may have the data dictionary available for reference. Data dictionary is a metadata repository, i.e. the repository of all information related to the structure of each data element contained in the data set. The data dictionary gives detailed information on each of the attributes – the description as well as the data type and other relevant details. In case the data dictionary is not available, we need to use standard library function of the machine learning tool that we are using and get the details. For the time being, let us move ahead with a standard data set from UCI machine learning repository.

**Did you know?**

University of California, Irvine (UCI) Machine Learning Repository (<http://archive.ics.uci.edu/ml/index.php>) is a collection of 400+ data sets which serve as benchmarks for researchers and practitioners in the machine learning community.

The data set that we take as a reference is the Auto MPG data set available in the UCI repository. Figure 2.5 is a snapshot of the first few rows of the data set.

mpg	cylinder	displace- ment	horse- power	weight	accel- eration	model year	origin	car name
18	8	307	130	3504	12	70	1	Chevrolet chevelle malibu
15	8	350	165	3693	11.5	70	1	Buick skylark 320
18	8	318	150	3436	11	70	1	Plymouth satellite
16	8	304	150	3433	12	70	1	Amc rebel sst
17	8	302	140	3449	10.5	70	1	Ford torino
15	8	429	198	4341	10	70	1	Ford galaxie 500
14	8	454	220	4354	9	70	1	Chevrolet impala
14	8	440	215	4312	8.5	70	1	Plymouth fury iii
14	8	455	225	4425	10	70	1	Pontiac catalina
15	8	390	190	3850	8.5	70	1	Amc acbassador dpl
15	8	383	170	3563	10	70	1	Dodge challenger se
14	8	340	160	3609	8	70	1	Plymouth ' cuda 340
15	8	400	150	3761	9.5	70	1	Chevrolet monte carlo
14	8	455	225	3086	10	70	1	Buick estate wagon (sw)
24	4	113	95	2372	15	70	3	Toyota corona mark ii
22	6	198	95	2933	15.5	70	1	Plymouth duster
18	6	199	97	2774	15.5	70	1	Amc hornet

**FIG. 2.5**  
Auto MPG data set

As is quite evident from the data, the attributes such as ‘mpg’, ‘cylinders’, ‘displacement’, ‘horsepower’, ‘weight’, ‘acceleration’, ‘model year’, and ‘origin’ are all numeric. Out of these attributes, ‘cylinders’, ‘model year’, and ‘origin’ are discrete in nature as the only finite number of values can be assumed by these attributes. The remaining of

the numeric attributes, i.e. ‘mpg’, ‘displacement’, ‘horsepower’, ‘weight’, and ‘acceleration’ can assume any real value.

**Note:**

Since the attributes ‘cylinders’ or ‘origin’ have a small number of possible values, one may prefer to treat it as a categorical or qualitative attribute and explore in that way. Anyways, we will treat these attributes as numeric or quantitative as we are trying to show data exploration and related nuances in this section.

Hence, these attributes are continuous in nature. The only remaining attribute ‘car name’ is of type categorical, or more specifically nominal. This data set is regarding prediction of fuel consumption in miles per gallon, i.e. the numeric attribute ‘mpg’ is the target attribute.

With this understanding of the data set attributes, we can start exploring the numeric and categorical attributes separately.

## 2.4.1 Exploring numerical data

There are two most effective mathematical plots to explore numerical data – box plot and histogram. We will explore all these plots one by one, starting with the most critical one, which is the box plot.

### 2.4.1.1 Understanding central tendency

To understand the nature of numeric variables, we can apply the measures of central tendency of data, i.e. mean and median. In statistics, measures of central tendency help us understand the central point of a set of data. Mean, by definition, is a sum of all data values divided by the count of data elements. For example, mean of a set of observations – 21, 89, 34, 67, and 96 is calculated as below.

$$\text{Mean} = \frac{21 + 89 + 34 + 67 + 96}{5} = 61.4$$

If the above set of numbers represents marks of 5 students in a class, the mean marks, or the falling in the middle of the range is 61.4.

Median, on contrary, is the value of the element appearing in the middle of an ordered list of data elements. If we consider the above 5 data elements, the ordered list would be – 21, 34, 67, 89, and 96. Since there are 5 data elements, the 3rd element in the ordered list is considered as the median. Hence, the median value of this set of data is 67.

There might be a natural curiosity to understand why two measures of central tendency are reviewed. The reason is mean and median are impacted differently by data values appearing at the beginning or at the end of the range. Mean being calculated from the cumulative sum of data values, is impacted if too many data elements are having values closer to the far end of the range, i.e. close to the maximum or minimum values. It is especially sensitive to outliers, i.e. the values which are unusually high or

low, compared to the other values. Mean is likely to get shifted drastically even due to the presence of a small number of outliers. If we observe that for certain attributes the deviation between values of mean and median are quite high, we should investigate those attributes further and try to find out the root cause along with the need for remediation.

So, in the context of the Auto MPG data set, let's try to find out for each of the numeric attributes the values of mean and median. We can also find out if the deviation between these values is large. In Figure 2.6, the comparison between mean and median for all the attributes has been shown. We can see that for the attributes such as 'mpg', 'weight', 'acceleration', and 'model.year' the deviation between mean and median is not significant which means the chance of these attributes having too many outlier values is less. However, the deviation is significant for the attributes 'cylinders', 'displacement' and 'origin'. So, we need to further drill down and look at some more statistics for these attributes. Also, there is some problem in the values of the attribute 'horsepower' because of which the mean and median calculation is not possible.

	<b>mpg</b>	<b>cylinders</b>	<b>dis- place- ment</b>	<b>horse- power</b>	<b>weight</b>	<b>accel- eration</b>	<b>model year</b>	<b>origin</b>
Median	23	4	148.5	?	2804	15.5	76	1
Mean	23.51	5.455	193.4	?	2970	15.57	76.01	1.573
Deviation	2.17	26.67%	23.22%		5.59%	0.45%	0.01%	36.43%
	Low	High	High		Low	Low	Low	High

**FIG. 2.6****Mean vs. Median for Auto MPG**

With a bit of investigation, we can find out that the problem is occurring because of the 6 data elements, as shown in Figure 2.7, do not have value for the attribute 'horsepower'.

<b>mpg</b>	<b>cylinders</b>	<b>displace- ment</b>	<b>horse- power</b>	<b>weight</b>	<b>accel- eration</b>	<b>model year</b>	<b>origin</b>	<b>car name</b>
25	4	98	?	2046	19	71	1	Ford pinto
21	6	200	?	2875	17	74	1	Ford maverick
40.9	4	85	?	1835	17.3	80	2	Renault lecar deluxe
23.6	4	140	?	2905	14.3	80	1	Ford mustang cobra
34.5	4	100	?	2320	15.8	81	2	Renault 18i
23	4	151	?	3035	20.5	82	1	Amc concord di

**FIG. 2.7****Missing values of attribute 'horsepower' in Auto MPG**

For that reason, the attribute 'horsepower' is not treated as a numeric. That's why the operations applicable on numeric variables, like mean or median, are failing. So we have to first remediate the missing values of the attribute 'horsepower' before being able to do any kind of exploration. However, we will cover the approach of remediation of missing values a little later.

### 2.4.1.2 Understanding data spread

Now that we have explored the central tendency of the different numeric attributes, we have a clear idea of which attributes have a large deviation between mean and median. Let's look closely at those attributes. To drill down more, we need to look at the entire range of values of the attributes, though not at the level of data elements as that may be too vast to review manually. So we will take a granular view of the data spread in the form of

1. Dispersion of data
2. Position of the different data values

#### 2.4.1.2.1 Measuring data dispersion

Consider the data values of two attributes

1. Attribute 1 values : 44, 46, 48, 45, and 47
2. Attribute 2 values : 34, 46, 59, 39, and 52

Both the set of values have a mean and median of 46. However, the first set of values that is of attribute 1 is more concentrated or clustered around the mean/median value whereas the second set of values of attribute 2 is quite spread out or dispersed. To measure the extent of dispersion of a data, or to find out how much the different values of a data are spread out, the variance of the data is measured. The variance of a data is measured using the formula given below:

$$\text{Variance } (x) = \frac{\sum_{i=1}^n x_i^2}{n} - \left( \frac{\sum_{i=1}^n x_i}{n} \right)^2, \text{ where } x \text{ is the variable or attribute whose variance is to be measured and } n \text{ is the number of observations or values of variable } x.$$

Standard deviation of a data is measured as follows:

$$\text{Standard deviation } (x) = \sqrt{\text{Variance } (x)}$$

Larger value of variance or standard deviation indicates more dispersion in the data and vice versa. In the above example, let's calculate the variance of attribute 1 and that of attribute 2. For attribute 1,

$$\begin{aligned} \text{Variance } &= \frac{\sum_{i=1}^n x_i^2}{n} - \left( \frac{\sum_{i=1}^n x_i}{n} \right)^2 \\ &= \frac{44^2 + 46^2 + 48^2 + 45^2 + 47^2}{5} - \left( \frac{44 + 46 + 48 + 45 + 47}{5} \right)^2 \end{aligned}$$

$$= \frac{1936 + 2116 + 2304 + 2025 + 2209}{5} - \left(\frac{230}{5}\right)^2 = \frac{10590}{5} - (46)^2 = 2$$

For attribute 2,

$$\begin{aligned} \text{Variance} &= \frac{\sum_{i=1}^n x_i^2}{n} - \left(\frac{\sum_{i=1}^n x_i}{n}\right)^2 \\ &= \frac{34^2 + 46^2 + 59^2 + 39^2 + 52^2}{5} - \left(\frac{34 + 46 + 59 + 39 + 52}{5}\right)^2 \\ &= \frac{1156 + 2116 + 3481 + 1521 + 2704}{5} - \left(\frac{230}{5}\right)^2 = \frac{10978}{5} - (46)^2 = 79.6 \end{aligned}$$

So it is quite clear from the measure that attribute 1 values are quite concentrated around the mean while attribute 2 values are extremely spread out. Since this data was small, a visual inspection and understanding were possible and that matches with the measured value.

#### 2.4.1.2.2 Measuring data value position

When the data values of an attribute are arranged in an increasing order, we have seen earlier that median gives the central data value, which divides the entire data set into two halves. Similarly, if the first half of the data is divided into two halves so that each half consists of one-quarter of the data set, then that median of the first half is known as first quartile or  $Q_1$ . In the same way, if the second half of the data is divided into two halves, then that median of the second half is known as third quartile or  $Q_3$ . The overall median is also known as second quartile or  $Q_2$ . So, any data set has five values - minimum, first quartile ( $Q_1$ ), median ( $Q_2$ ), third quartile ( $Q_3$ ), and maximum.

Let's review these values for the attributes 'cylinders', 'displacement', and 'origin'. Figure 2.8 captures a summary of the range of statistics for the attributes. If we take the example of the attribute 'displacement', we can see that the difference between minimum value and  $Q_1$  is 36.2 and the difference between  $Q_1$  and median is 44.3. On the contrary, the difference between median and  $Q_3$  is 113.5 and  $Q_3$  and the maximum value is 193. In other words, the larger values are more spread out than the smaller ones. This helps in understanding why the value of mean is much higher than that of the median for the attribute 'displacement'. Similarly, in case of attribute 'cylinders', we can observe that the difference between minimum value and median is 1 whereas the difference between median and the maximum value is 4. For the attribute 'origin', the difference between minimum value and median is 0 whereas the difference between median and the maximum value is 2.

	cylinders	displacement	origin
Minimum	3	68	1
Q1	4	104.2	1
Median	4	148.5	1
Q3	8	262	2
Maximum	8	455	3

**FIG. 2.8**  
Attribute value drill-down for Auto MPG

#### Note:

Quantiles refer to specific points in a data set which divide the data set into equal parts or equally sized quantities. There are specific variants of quantile, the one dividing data set into four parts being termed as quartile. Another such popular variant is percentile, which divides the data set into 100 parts.

However, we still cannot ascertain whether there is any outlier present in the data. For that, we can better adopt some means to visualize the data. Box plot is an excellent visualization medium for numeric data.

## 2.4.2 Plotting and exploring numerical data

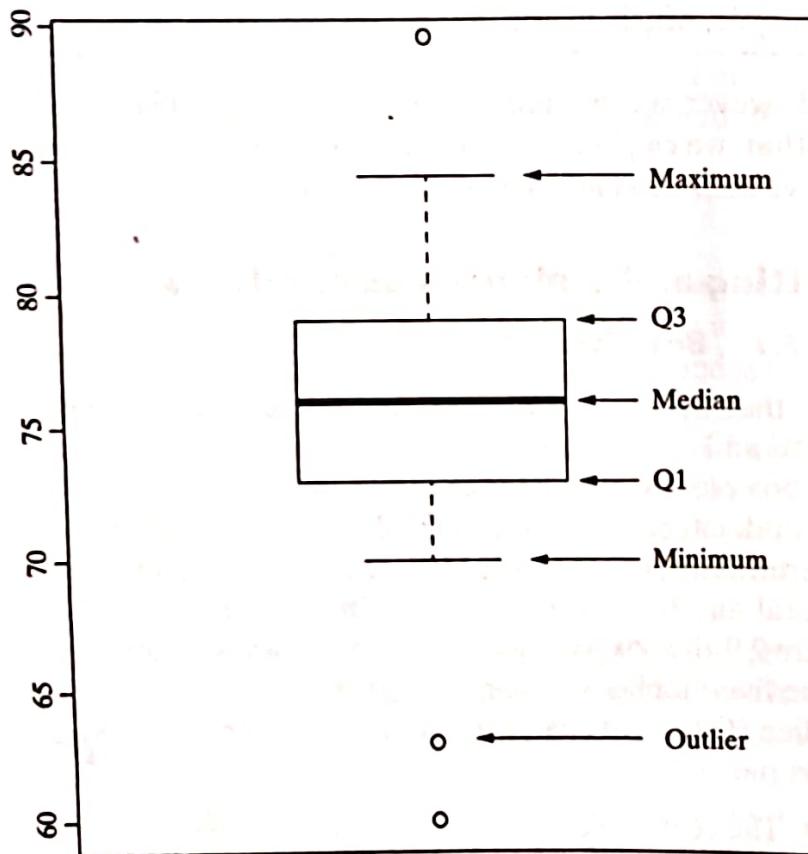
### 2.4.2.1 Box plots

Now that we have a fairly clear understanding of the data set attributes in terms of spread and central tendency, let's try to make an attempt to visualize the whole thing as a box-plot. A box plot is an extremely effective mechanism to get a one-shot view and understand the nature of the data. But before we get to review the box plot for different attributes of Auto MPG data set, let's first try to understand a box plot in general and the interpretation of different aspects in a box plot. As we can see in Figure 2.9, the box plot (also called box and whisker plot) gives a standard visualization of the five-number summary statistics of a data, namely minimum, first quartile (Q1), median (Q2), third quartile (Q3), and maximum. Below is a detailed interpretation of a box plot.

- The central rectangle or the box spans from first to third quartile (i.e. Q1 to Q3), thus giving the inter-quartile range (IQR).
- Median is given by the line or band within the box.
- The lower whisker extends up to 1.5 times of the inter-quartile range (or IQR) from the bottom of the box, i.e. the first quartile or Q1. However, the actual length of the lower whisker depends on the lowest data value that falls within ( $Q1 - 1.5 \text{ times of IQR}$ ). Let's try to understand this with an example. Say for a specific set of data,  $Q1 = 73$ , median = 76 and  $Q3 = 79$ . Hence, IQR will be 6 (i.e.  $Q3 - Q1$ ).

So, lower whisker can extend maximum till  $(Q1 - 1.5 \times IQR) = 73 - 1.5 \times 6 = 64$ . However, say there are lower range data values such as 70, 63, and 60. So, the lower whisker will come at 70 as this is the lowest data value larger than 64.

- The upper whisker extends up to 1.5 times of the inter-quartile range (or IQR) from the top of the box, i.e. the third quartile or Q3. Similar to lower whisker, the actual length of the upper whisker will also depend on the highest data value that falls within  $(Q3 + 1.5 \times IQR) = 79 + 1.5 \times 6 = 88$ . If there is higher range of data values like 82, 84, and 89. So, the upper whisker will come at 84 as this is the highest data value lower than 88.
- The data values coming beyond the lower or upper whiskers are the ones which are of unusually low or high values respectively. These are the outliers, which may deserve special consideration.

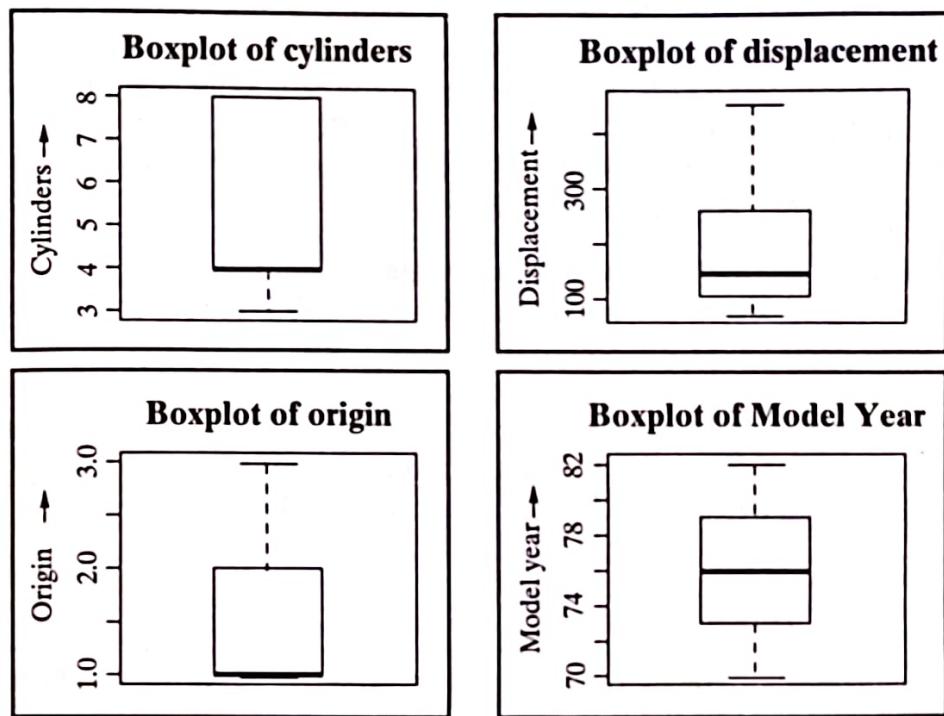


**FIG. 2.9**  
Box plot

**Note:**

There are different variants of box plots. The one covered above is the Tukey box plot. Famous mathematician John W. Tukey introduced this type of box plot in 1969.

Let's visualize the box plot for the three attributes - 'cylinders', 'displacement', and 'origin'. We will also review the box plot of another attribute in which the deviation between mean and median is very little and see what the basic difference in the respective box plots is. Figure 2.10 presents the respective box plots.



**FIG. 2.10**  
Box plot of Auto MPG attributes

#### 2.4.2.1.1 Analysing box plot for 'cylinders'

The box plot for attribute 'cylinders' looks pretty weird in shape. The upper whisker is missing, the band for median falls at the bottom of the box, even the lower whisker is pretty small compared to the length of the box! Is everything right?

The answer is a big YES, and you can figure it out if you delve a little deeper into the actual data values of the attribute. The attribute 'cylinders' is discrete in nature having values from 3 to 8. Table 2.2 captures the frequency and cumulative frequency of it.

**Table 2.2**  
*Frequency of "Cylinders" Attribute*

Cylinders	Frequency	Cumulative Frequency
3	4	4
4	204	208 (= 4 + 204)
5	3	211 (= 208 + 3)
6	84	295 (= 211 + 84)
7	0	295 (= 295 + 0)
8	103	398 (= 295 + 103)

the median is closer to the bottom of the box (which represents Q1). The value of IQR, in this case, is 157.8. So the lower whisker can be 1.5 times 157.8 less than Q1. But minimum data value for the attribute ‘displacement’ is 68. So, the lower whisker at 15%  $[(Q1 - \text{minimum}) / 1.5 \times \text{IQR}] = [(104.2 - 68) / (1.5 \times 157.8)] = 15\%$  of the permissible length. On the other hand, the maximum data value is 455. So the upper whisker is 81%  $[(\text{maximum} - Q3) / 1.5 \times \text{IQR}] = [(455 - 262) / (1.5 \times 157.8)] = 81\%$  of the permissible length. This is why the upper whisker is much longer than the lower whisker.

#### 2.4.2.1.4 Analysing box plot for ‘model Year’

The box plot for the attribute ‘model. year’ looks perfect. Let’s validate is it really what expected to be.

For the attribute ‘model.year’:

First quartile, Q1 = 73

Median, Q2 = 76

Third quartile, Q3 = 79

So, the difference between median and Q1 is exactly equal to Q3 and median (both are 3). That is why the band for the median is exactly equidistant from the bottom and top of the box.

$$\text{IQR} = Q3 - Q1 = 79 - 73 = 6$$

Difference between Q1 and minimum data value (i.e. 70) is also same as maximum data value (i.e. 82) and Q3 (both are 3). So both lower and upper whiskers are expected to be of the same size which is 33%  $[3 / (1.5 \times 6)]$  of the permissible length.

#### 2.4.2.2 Histogram

Histogram is another plot which helps in effective visualization of numeric attributes. It helps in understanding the distribution of a numeric data into series of intervals, also termed as ‘bins’. The important difference between histogram and box plot is

- The focus of histogram is to plot ranges of data values (acting as ‘bins’), the number of data elements in each range will depend on the data distribution. Based on that, the size of each bar corresponding to the different ranges will vary.
- The focus of box plot is to divide the data elements in a data set into four equal portions, such that each portion contains an equal number of data elements.

Histograms might be of different shapes depending on the nature of the data, e.g. skewness. Figure 2.11 provides a depiction of different shapes of the histogram that are generally created. These patterns give us a quick understanding of the data and thus act as a great data exploration tool.