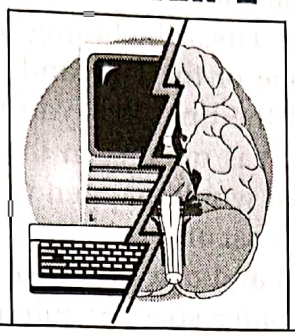
# CHAPTER 1



# Introduction to Artificial Intelligence

## INTRODUCTION

Suppose you are on the way to some trip and travelling by road. With a large number of toll collection booths and endless multiple queues in front of you, you possibly ask your friend—"Hey which lane do we line up?" and judgmentally a friend suggests one of them. (But possibly other queue would have made your car pass by faster. Is it not dependent on the people working at the booths?) Can we have artificial intelligence (AI) to resolve this?

Imagine you pass through the booth and the toll is auto-deducted by means of in-vehicle unit specially designed for your car. Sensors capture the vehicle number and deduct the pre-deposited amount from the in-built chip. Such electronic toll collection system is found at Ahmedabad–Mumbai highway and a couple of other places in India. This system needs to be made more intelligent to make it work in Indian context across the various roads and highways in India. Certain changes can make it highly effective in terms of time and manpower utilisation in Indian context. The improved system can help the government by means of analysis of the records of the amount collection on week days and other statistics. At present, there are semi-automatic toll collection systems at Bangkok. Just imagine a toll system that is intelligent and vehicle-based. Such a system can direct the vehicle to proper lane and will be able to keep a track record of regularity of payments. In case, some very regular payee misses, the detection on one of the occasion can be possible. This can be possible with a prepaid card-based toll collection, where a prepaid card is used or even there can be a vehicle number-based toll collection, where it is connected to the bank account of vehicle owner. It can be different for interior roads and expressways. Hence, intelligent system can revolutionise the simple application of toll collection and different intelligent system applications right from planning to decision-making, and thus, can help in building a better system.

A simple sub-application is discussed here. At present, it is possible to suggest you to line up at a particular lane. The moment you approach a toll booth, the AI system would analyse the vehicles at the different lanes (including analysis of density and the size or even detection of some failure at one of the lane and so on) and intimate you about the lane number you should go in and the time that you would take.

Let us take one more example. It is often seen that the loading of material in trucks for transport is done manually. What would happen when a robot is employed? A simple robot can assist in saving the labour cost and help in improving the efficiency of the work. Such a robot is tuned to lift an object and place it in the truck. But is there any intelligence involved in it? Does this robot consider space requirements? No, but an intelligent one will definitely do it. An intelligent robot would take up the object and place it efficiently such that the space of the truck is utilised to the fullest. Thus, an intelligent robot would overcome space and time complexities. To add further, a robot without intelligence would fail to operate if the road/path is full of obstacles, but an intelligent one would perceive this and take a different route and carry out the task. Moreover, such an intelligent system can consider weight, size, material of which the articles in the box are composed (whether articles in box are brittle and to be kept in a particular way). Also, it can scan size of box, determine other properties of the box and load different boxes optimally.

And the last but not the least, all of us have heard the story of 'Snow White'. Her stepmother asked to the magical mirror "Who is the most beautiful lady among all?" and she got a reply. We know that it is a fairy tale. But what would happen if we have something of this sort in real? An intelligent app that would suggest some outfit that we can wear! Adding to this, a talking mirror-cum-dresser that would show how an outfit would look on us! Is this all feasible?—Definitely. With AI, we can have all these options and it is not just about dressing, but it can involve suggesting a suitable costume based on your mood, occasion, profession and so on. There are a few garment and fashion designing companies that give some sort of these facilities to recommend the best dress for you. These systems are at very rudimentary stage at present. They analyse the person's parameters, as said earlier and suggest the best garments, colours and combinations for you. Thus, intelligent systems have potential to change the way we have been using our resources resulting in more efficient, smart and friendly systems. These systems can adapt to the requirement and needs of daily operations as well as some of the very specific tasks.

So, artificial intelligence can help in making our life simple not only for taking decisions but also for the other aspects. Thus, artificial intelligence is slowly becoming a part of our day-to-day life and an essential part of all modern equipment as well. It is required for automated climate control in a car or an automated manufacturing unit in industry—Whether it is a washing machine or microwave oven—artificial intelligence is everywhere. These AI-based tools and techniques have not only improved accuracy but also made it possible to perform tasks, which were otherwise impossible without AI.

If we think about AI in holistic way, then it includes learning, searching and problem solving. The purpose of AI is to empower machine to solve the problems by making the machine intelligent. Whenever the term *intelligence* is referred, it is always referred in relevance with the human intelligence. In some cases, it is referred with reference to the reasonability in decision-making or the action taken. *AI* is defined by Rich and Knight as follows:

"AI is the study of how to make computers do things which, at the moment, people do better."

This definition catches the crux of AI and defines its purpose. This definition has its own limitations and covers one of the basic aspects of AI. It is not an easy task to define AI and all the books have done decent efforts to define AI based on some of its important facets. AI can be defined as follows:

It deals with the science that is about the efforts of making a machine behave intelligently and respond in a way as human would have responded and in due process, deliver reasonable answers. In other words, a branch of science and engineering that focuses on making machine intelligent is widely known as *AI*.

The scientists such as George Boole have led the foundation of AI logic years ago. Then, for last five decades many scientists were part of the movement of making machine intelligent. A broad categorisation of AI functions and objectives includes reasonable decision-making, demonstration of intelligence like humans and computational modelling to solve decision problems. In context with the above broad categorisation, AI can be defined in different ways as follows:

1. Machines which can think and have a capability to react like human beings
2. Systems that respond intelligently in the same way as the humans do
3. Computational models to solve various complex decision-making problems
4. Study of intelligent agents

The approaches followed while studying and representing AI include various empirical approaches—one coming from the philosophy of comparison with human and human reactions in case of different situations, while another is about use of mathematics and models for optimisation with reference to the desired outcome.

The horizon of AI includes techniques for knowledge transmission, knowledge representation, automated reasoning, and this is used to empower machines to behave intelligently. The purpose of overall data analysis and knowledge augmentation is to make machines learn and solve complex real-life, problems. AI is actually an ensemble of technologies, interactions and allied platforms which takes part in helping machine to demonstrate intelligence and reasonability. The human way of thinking, responding and decision-making is the only expectations and reference in this process.

Cognitive models deal with the computer knowledge-based models for AI. Various experimental techniques and theories about working and representation of human mind are part of the cognitive models. The study of human psychology and psychological analysis with reference to decision process is studied in these cognitive models. The fields of cognitive science and AI go hand in hand and have their application in natural language processing.

Further, for any action, there is an expected response from the aspect of rationality. Intelligent machines need to demonstrate the rational behaviour. We expect a human to react in a particular way to a given situation or respond to a particular decision scenario. Similarly, there is also an expectation from an intelligent machine to react rationally.

## 1.1 ARTIFICIAL INTELLIGENCE—HISTORY AND FOUNDATION

AI has been a part of mainstream research since last 60 years. But AI philosophy is as o as one thousand years. Statistics, analysis of patterns, use of formal systems have be

parts of research for many years. Many philosophers including the great Aristotle tried to describe and represent human process of thinking and decision-making using symbols. In 20th century, the ideas in fiction started to realise in the form of computer. Indian and Greek philosophers developed various methods for formal reasoning. This was a structured approach towards problem solving. In the 1940s, Zuse devised high-level programming language and wrote the first chess program that could demonstrate chess playing. Before that chess playing was considered an intelligent activity that was not possible for machine. Later on, Leibniz envisioned and formulated a language of reasoning, where he mapped symbols for reasoning. When mathematical logic came to help in twentieth century, it assured that AI is very much possible.

Allan Turing devised a simple test of intelligence in 1950, where the response of machine is expected to be intelligent enough so that it is difficult to find out whether it is machine or human sitting on the other side. Since then, there is a quest for intelligent algorithm to build AI-based system to meet the expectations.

In 1956, John McCarthy insisted and made AI as a topic for conference at Dartmouth. In 1958, he (MIT) invented the Lisp language, which later became popular for AI-related programming.

Initially, AI was focussed on common sense reasoning and obvious reaction. In this common sense reasoning, AI was expected to perform some sort of general problem solving. The problem solving and decision-making was based on set of simple hypothesis. The problems were simple and did not require large knowledge base.

Slowly research began to handle large amount of knowledge and more complex relationships. It included domains like speech recognition and analysis, image processing and medical diagnosis. The complexity of the tasks and inferring mechanism kept on increasing. In case of noisy data and large information base for extraction of information, there were more challenges for the researchers. They slowly started developing intelligent systems to handle these complex research problems.

## 1.2 BIRTH OF ARTIFICIAL INTELLIGENCE

John McCarthy at Dartmouth College worked on research in the areas of automata theory, neural nets and study of intelligence. McCarthy gave a new term for AI, i.e., 'computational rationality'. Dartmouth is a place where formal workshop and conference on AI took place. This helped in exploring the field of AI, and the research in this field started to gain momentum. This further helped in realising the AI-related thoughts and ideas. The various concepts like intelligence, knowledge, reasoning, thoughts, cognition and learning started to formulate a platform for AI research. These concepts were further explored from the perspective of applying knowledge to perform a desired activity. These activities range from the normal activities to complex activities. This started a movement of building intelligent systems.

AI is one of the major components of intelligent systems. Let us take an example of simple mechanical intelligent system.

Figure 1.1 depicts a small example of a traditional mechanical intelligent system. Here, once the water reaches to a certain level, the water tap is closed to avoid overflow. In washing machines, these systems were replaced with the sensor-based level detector. Later,

fuzzy logic came into the picture that allowed deciding the level of water dynamically based on the quantity of clothes. So, we are now having machines, with fuzzy logic included.

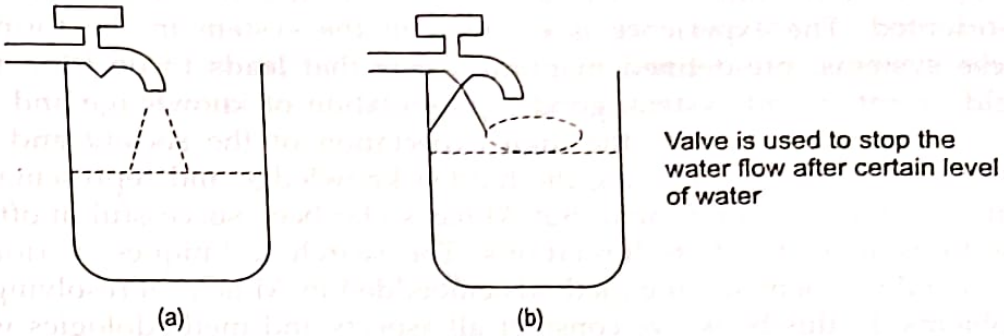



**Figure 1.1** Mechanical intelligent system.

Traditional intelligent systems are the examples, wherein the knowledge acquired in past is programmed in the system. These systems were later replaced by electronic systems, which used some static historical knowledge to take decisions in future.

Let us consider an example related to traffic management to understand how the growth and evolution of AI can help in making things simple and manageable. We are aware of the growing traffic scenario and how much difficult it is to commute.

1. First, we begin with the history of the signals to control the traffic traditionally. They were based on some historic information. The switching time was static and independent of the road conditions, which did not account for the peak hours. This would have been sufficient if there had not been any change in the traffic.
2. The increase in the traffic resulted in total chaos. Gradually, there was a need for a tuner system that could change the signal timings with respect to the peak hours of the traffic. Was AI involved here? It could be just a simple decision-making system with a little intelligence to have the control of the signal or even manual setting could be done with no intelligence at all.
3. Gradually, the need for an intelligent system arised. A traffic jam at one road crossing could impact many roads. So, an observer with sensors like a camera to detect the current traffic conditions evolved an intelligent traffic monitor and controller that would tune the signal timing with this jam. This could be set up at every signal in operation. AI techniques, thus, can help us in solving problems in a better way.
4. At present, there is a need for an intelligent signal controller, wherein all the signals are synchronised and they can be controlled with a centralised controller. An AI-based system (that can consider events such as election rallies, major accidents, construction of road) can help in capturing the current scene at a particular route, and accordingly, dynamically change the signals timings. This information can even include the analysis and statistics of the traffic density to help in deciding the timings. The same should be reflected and transferred to the signals in proximity. It would, in turn, suggest the route too intelligently that would turn off some signals owing to some environment conditions. Such a system would need complex and advanced techniques of AI and is indeed a challenge to have one in country like India.

Thus, there is a need for AI-based systems, which are expected to react in dynamic situation and even when some information is absent.

To take up decisions, one needs to learn. The learning systems are data as well as experiment-oriented. The experience is encoded in the system in the form of data or rules. In these systems, pre-defined mapping exists that leads to decision rules. So, in order to build an intelligent system, good representation of knowledge and information is essential. AI struggled to meet the high expectation of the society and researchers because of the limitations in capturing the hidden knowledge and representation of that knowledge in decision-friendly format. But AI has so far been successful in offering many practical solutions in spite of its limitations. The search techniques, various learning methodologies and problem-solving methods embedded in AI help in resolving important practical problems. In this book, we consider all aspects and methodologies which come under AI. The purpose of this book is to realise and understand the practical aspects of AI. This book also covers the advanced and allied aspects of AI like pattern analytics, intelligent system modelling, concurrency aspects and applications of intelligent systems with reference to big data.

## 1.3 AI TECHNIQUES

AI deals with a large spectrum of problems. The spectrum of AI applications is spread across the domains, and even across the complexities of problems. This includes the following:

1. Various day-to-day practical problems
2. Different identification and authentication problems with their applications in security
3. Various classification problems resulting in decision-making
4. Interdependent and cross-domain problems

The generalisation may become very difficult in case of these problems, as there is a very little commonality among these different problems. But most of these problems are complex and hard to resolve. The very reason of the complexity is the dynamic nature of these problems unlike some routine mathematical problems. AI techniques need to look at these problems from analysis perspective and from the perspective of research initiatives to resolve them.

AI techniques need to be built from the problem-solving perspectives. The points raising need for AI technique are discussed below:

1. Need for analysis of voluminous and large amount of data. This data may not be confined to a single domain but may spread across the domains.
2. The analysis should be followed by the characterisation of miscellaneous data, then mapping of this data with reference to built-in knowledge, and then, building the knowledge further in this process.
3. Dealing with the constantly changing scenarios and situations, and the dynamic nature of data, the system and technique should react to the new scenario and situation. The situations are dynamic in nature, and static handling may not be useful.

4. The way in which data appears, the way it is used, the way it is organised and the way it should be used are different. Blindly using the data as it comes may result in wrong decisions.
5. Though in some cases, the huge data is available, but the relevant data is limited. Identification of relevant data, irrelevant data and outliers, and further, effective knowledge building based on limited relevant data are the challenges in front of AI techniques.

The main objective of AI techniques is to capture knowledge based on the data and information. There are different scenarios and the relevant data is captured. The AI techniques need to handle different problems. The broad categorisation of these problems can be as follows:

1. Structured problems
2. Unstructured problems
3. Linear problems
4. Non-linear problems

## 1.4 PROBLEM SOLVING WITH AI

AI has been very well used to solve structured problems. The *well-structured problems* are some of the very commonly faced problems during day-to-day life. These problems yield a right answer or right inference when an appropriate algorithm is applied. While *ill-structured problems* are the problems which do not yield a particular answer. In this case, there is possibility of more than one answer, and even a particular situation decides the correctness of the answer. Interestingly, ill-structured problems represent many of the real-world problems.

Some of the well-structured problems are given below:

1. Solving a quadratic equation to find out the value of X
2. Calculating path of the trajectory when a missile is fired
3. Calculating speed of ball when it reaches to batsman
4. Network flow analysis problems

Some examples of the ill-structured problems are given below:

1. Predicting how to dispose wet waste safely
2. Analysis of theoretical prepositions and adequacy of the same in a particular scenario
3. Identifying the security threats in big social gatherings

Solving ill-structured problems is challenging, since no list of specific and ordered operations or steps exists for them. Further, there is no well-defined criterion to evaluate the correctness of the outcome.

The behaviour of a typical well-structured problem is depicted in Figure 1.2, while the same for a ill-structured problem is depicted in Figure 1.3.

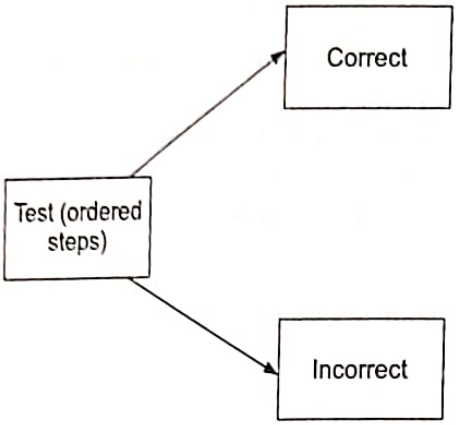



**Figure 1.2** A typical well-structured problem analysis.

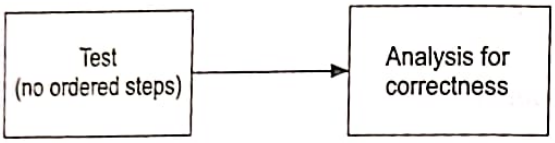



**Figure 1.3** A typical ill-structured problem analysis.

Generally, abstracting the problem is possible in case of structured problems. The similarities and well-defined steps even allow some sort of generalisation in case of well-structured problems. The well-defined steps and well-defined way to measure accuracy allow to head systematically towards the goal state. In case of ill-structured problems, the uniqueness of problems and solution demands high level of problem-specific intelligence and makes it difficult to generalise.

EXAMPLES: A typical well-structured problem is the tic-tac-toe, shown in Figure 1.4.

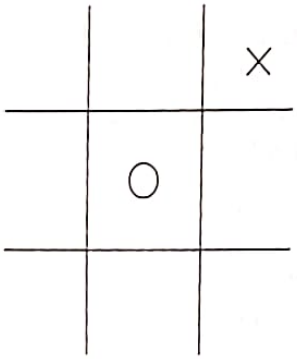


**Figure 1.4** Tic-tac-toe.

Here, the final decision will depend on the value associated with all nine positions of tic-tac-toe. The legal values will be player 1 marked, player 2 marked and not marked. In this well-structured problem, solution will try to optimise chances of player 1 while minimising player 2 chances.

On the other hand unstructured problems are difficult to represent and model. There are possibilities of more than one goal states in case of unstructured problems. In most of

the cases, exact goal state is not known. For example, systems to improve life expectancy of human being, expanding the business.

*Linear problems* are the ones which definitely have a solution or there will not be any solution. Speaking with respect to AI problem solving, these problems are the ones that typically fall under the classification category. Whereas, the problems that are not linear have to undergo some transformation for getting solution.

In case of non-linear problems, the relationship between input and output is not linear. Further decisions cannot be separated by simple linear classification function.

## 1.5 AI MODELS

One important aspect of building AI solutions is modelling the problem. Dunker introduced 'maze hypothesis' as a part of the psychological theory. In this particular hypothesis, the creative and intelligent tasks handled by human beings are modelled like a set of maze of paths from an initial node to a certain or resultant node. Human at any point of time analyses maze; for choices, he could find those which can lead to goal. These choices and maze-based approach can help in solving many multialternative solution problems.

Slowly, it became evident that all problems cannot be solved using maze models or the approach described above. This brought more focus on logic theory machines. Effective application of logic theory machines is found very useful in general problem solving, even this is found very useful for a wide spectrum of problems like chess problem. Chess can be viewed as a controlled environment in which computer is given a situation and a goal.

Figure 1.5 depicts the complexity of model building with reference to data and knowledge mapping.

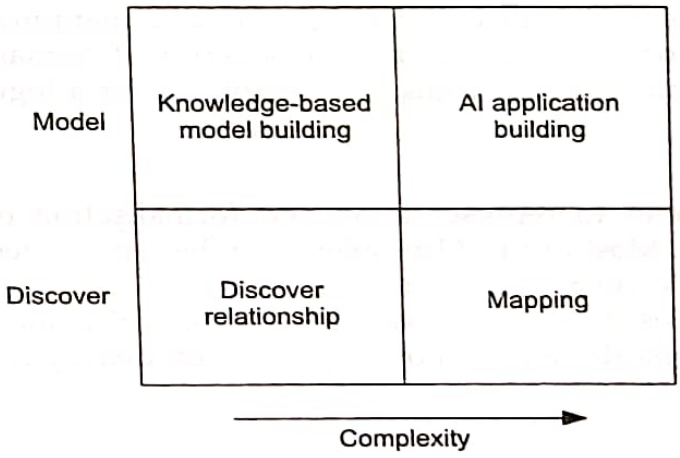



**Figure 1.5** Model building and complexity.

A typical chess scenario is given in Figure 1.6. This is a much complex scenario than tic-tac-toe, but is still constrained. The chess program provided a sort of background for AI research. Two aspects that could be viewed from chess program were knowledge-based search and knowledge acquisition and representation. Models used for applications like chess programs were not effective for the other applications.

The advent of natural language processing and the need for man-machine dialogue made it more evident that the models used so far had their own limitations. Then, the formal models were proposed to solve AI problems. The requirement of complex problem solving gave birth to dynamic inductive models. Human behaviour and psychological study-based inductive dynamic models for creative problem solving slowly became popular.

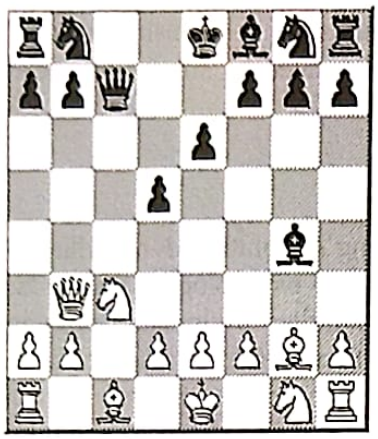


Figure 1.6 Chess: A complex scenario.

Let us have a look at the models.

### *Semiotic Models*

These models are based on sign processes or signification and communication. The process of carrying meaning depends on codes. Semioticians classify signs or sign systems in relation to the problem. This meaning assignment and mapping process depends on the use of codes based on individual sounds or letters that humans use to form words or movements. In computers, these signs are determined for a logical sequence.

### *Statistical Models*

Statistical models refer to representation and formalisation of relationships through statistical techniques. Most of the AI problems can be represented as statistical or pattern matching problems. Various learning models from AI perspective are based on statistics. The historical data is used here in decision-making. Statistical model employs probabilistic approaches and is typically a collection of probability density functions and distribution functions.

## 1.6 DATA ACQUISITION AND LEARNING ASPECTS IN AI

This section will introduce various AI-related topics on data acquisition and machine learning.

1. ***Knowledge discovery—Data mining and machine learning:*** We start with some simple terms, i.e., information and data. Information can be referred to as pattern underlying the data, whereas the data refers to recorded facts. So, we define *data mining* or *knowledge discovery*

as the extraction of meaningful information that is previously unknown and can be useful potentially ahead. It is more concerned with data analysis and use of some techniques to identify and recognise the patterns that would yield good predictions. The mining process includes data cleaning, preprocessing, identifying and interpreting the patterns, understanding the application and generating the target data with the consolidated patterns.

*Machine learning*, as described by Tom Mitchell, is a field concerned with the study of algorithms that will improve its performance with experience. It is all about making machine behave intelligently based on the past experience.

Let us have a look at the relation between knowledge discovery and machine learning. *Knowledge discovery* is about finding understandable knowledge, while *machine learning* is more focussed on improving performance of an agent. Machine learning can be thought of as a broader concept, which has mining playing an implicit part. There is actually a very fuzzy distinction between them.

That is all about the concepts' part, but what about the applications? Data mining is a tool and holds core part in business intelligence (BI). Data mining plays a critical role in case of accurate and complex decision-making. Consider a simple example of a bank which wants to access credit risk of customers. Let us say Ram applies for loan. Should the loan be approved? Data about past credit history, timely payments, security, age, salary are some of the factors that are looked upon. Bank generally develops models using machine learning methods, with the parameters mentioned. The results predict whether Ram would default on loan or not.

**2. *Computational learning theory* (*COLT*):** Currently, a lot of research is done to study and analyse algorithms. In COLT, formal mathematical models are defined. These models help in analyzing the efficiency and complexity in terms of computation, prediction and feasibility of the algorithms. The analysis done provides a framework to take appropriate decisions for building better algorithms that would be effective in terms of data and time.

The computational learning theory finds its importance in the field of machine learning, pattern recognition, statistics and many more. With regard to machine learning, the goal of COLT is to inductively learn the target function. Learning theories help in understanding the explicit relevant aspects of the learner and the environment to classify easy and hard learning problems and in turn guiding the design learning systems. There are two frameworks for analysing the patterns—one is Probably Approximately Correct (PAC) and the other is mistake bound. The former identifies the classes of hypothesis that possibly can/cannot be learnt, whereas the latter tries to learn target function to series of trials.

**3. *Neural and evolutionary computation*:** A new technique in computation, i.e., neural and evolutionary computation is enabled to speed up the mining of data. Computation techniques that are based on biological properties fall under the category of evolutionary computing. Evolutionary computing is related to the study and use of these properties, consisting of evolutionary algorithms (of which genetic algorithm has been the most popular) that are basically used to solve multidimensional problem. The evolutionary computing finds its applications from the telecom domain to the financial decision-making, with optimisation as the base criterion.

In case of neural computing, the neural behaviour of human beings is stimulated to enable machine to learn. An artificial neural network is formed or configured for some specific application like pattern recognition or classification.

**4. *Intelligent agents and multi-agent systems:*** Intelligent agents and multi-agent systems (MAS) is a core part of intelligent systems, which allows timely decision-making in complex scenarios. An *agent* in simple terms, is a software program that assists user. An *intelligent agent* is the one which is flexible in terms of its action to get the desired outcome. It is goal-directed, reacts with the environment and acts accordingly. Consider an example of a student, who is pursuing a course in web designing. He uses search engine to get some notes for the subject. An intelligent agent will observe that he accesses the sites, which give him the detailed examples of the topics. So, each time he fires some query, the agent will give up sites that he is likely to refer based on the past experience. After some days, when he refers to the sites with illustrations, then the agent would need to change its behaviour pattern and act accordingly.

The capacity of an intelligent agent is restricted, and is dependent on the knowledge it has, the available resources and the different perspectives. The percept of individual agent is always limited. Complex tasks and decision-making demand combination of more than one percept of different intelligent agents. Hence, in many cases group of intelligent agents are required to solve the problems. This is a scenario of multi-agent system. So, in MAS, every agent's capability and its computation efficiency is exploited so that the overall performance is improved.

**5. *Multi-perspective integrated intelligence:*** For any problem to solve, each and every individual can have his own perspective. Some information might be present in some perspective, while it could be missing in other perspective, which could be effective in terms of decision-making. Utilising and exploiting this knowledge from different perspectives to build up an intelligent system giving accurate results, builds the Multi-perspective Intelligence (MPI) framework. Consider a scenario, where you want to apply for a job in a renowned company. You tend to seek feedback from some employees. Each will have his own perspective in relation to management, working environment, appraisals and so on. Some friend of yours might not be working, but is acquainted with the company. He would also have a different perspective. Based on this knowledge, possibly you could land upon a decision whether to take up the job or not. Information collected from different perspectives is used for final decision-making. This information collection can be continuous or discrete.

These learning approaches work in association with respect to the application they would be suited for. As said earlier, there is a very fuzzy line of distinction between them. And a good understanding of requirements and domain will result into accurate predictions and decision-making for solving a problem. The topics introduced here are just to make you aware of the type of work done with AI, though we will be discussing most them in detail in further chapters.

## SUMMARY

Artificial intelligence has been a part of active scientific and engineering research for the last six decades. AI has gone through various stages of research during this period. Slowly, AI has become a part of the mainstream research, and many existing products and technologies are based on AI. The machines and equipment we use in our day-to-day life in some way or other use AI. Selection of model, analysis of data and building

knowledge are some of the important aspects of building AI system. A large number of applications of AI need to be studied along with the practical aspects of AI to build a real-life AI solution. We want every appliance and every activity performed by machine to be intelligent. This intelligence is about understanding the problem at hand as well as the scenario and acting reasonably. (Intelligence is multi-faceted entity and this book tries to look at these facets more pragmatically).

## KEYWORDS

1. **Semiotic models:** The models which are based on sign processes or signification and communication.
2. **Formal system:** It is a system based on assignment of meanings to the symbols.
3. **Natural language processing:** A computer science and linguistic branch dealing with the interactions between human being and machines/computers is known as natural language processing.
4. **Maze models:** Creative and intelligent tasks handled by human being are modelled like a set of maze of paths from an initial node to a certain or resultant node.
5. **Well-structured problems:** These problems yield a right answer or right inference when an appropriate algorithm is applied.
6. **Ill-structured problems:** These are the problems which do not yield a particular answer. In this case, there is possibility of more than one answer, and even a particular situation decides the correctness of the answer.
7. **Linear problem:** It is the problem which can be solved or where decision can be obtained by linear solution.
8. **Non-linear problem:** It is the problem which cannot be solved or separated by linear equations.

## CONCEPT REVIEW QUESTIONS

1. Give example of one ill-structured problem with description and elaborate the method for solving that problem.
2. Describe various AI models.
3. Explain the model building concepts in AI.
4. What are the statistical models?
5. List various equipment in day-to-day life, where AI is used.
6. List milestones in AI evolution.

## CRITICAL THINKING EXERCISE

1. Analyse knowledge-based complexity for the AI application for chess and tic-tac-toe.
2. Try to map different AI models with AI products.
3. List applications where formal systems are used.
4. Associate evolutionary systems with traditional one from technology aspects.

## PROJECT WORK

1. Program a simple intelligent system for tic-tac-toe.
2. Draw a flow diagram where you use evolutionary system for washing machine.