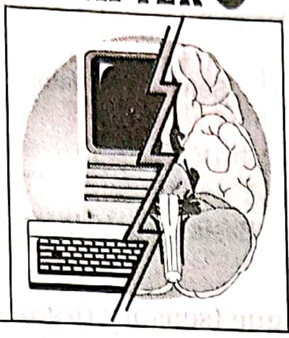
CHAPTER 5



Intelligent Agent

Learning Objectives

- To study the basic structure and need for intelligent agent
- To understand about the rational behaviour of an intelligent agent
- To know the various types of environment in which an intelligent agent needs to function
- To understand the various types and structures of intelligent agents with reference to complexity of problems
- To know about the various applications of intelligent agents

INTRODUCTION

Information is associated with context and information resources, and hence, is not isolated. Intelligence is a cumulative manifestation of different activities resulted from learning, sensing, understanding and knowledge augmentation. Intelligence has also an association with the environment. There is need to gather the information and process it to take an appropriate action. An agent is an entity that can perceive the information and act on that information to achieve the desired outcome. *Intelligent agent* in its simplest form, is an agent that is capable of making decisions and act most logically in the scenario.

Agents, the environment and the interaction between them are very important when we study intelligent agents. Figure 5.1 depicts the general structure and working of an agent. An agent interacts with the environment through sensors and actuators. Depending on its type, it keeps a track of the goal. A *sensor* allows the agent to sense environment and perceive the present state. An *actuator* allows the agent to take actions with reference to the environment perceived. Any human being is an agent, who senses the environment

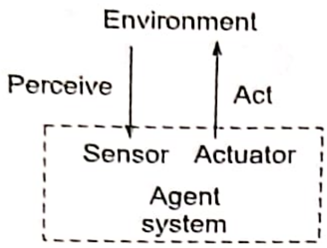


Figure 5.1 Basic structure of an agent.

through his/her eyes, ears, nose, tongue (sensory organs). He/she acts on the environment through hands, legs and other parts of the body. The sensory organs are the sensors in case of human being, while the actuators are the parts of the body which help him/her to take action. For example, consider an intelligent car, which has sensors such as cameras, ultrasonic waves and various other devices to measure distance, determine objects and calculate light and weather conditions. It has some mechanism to apply break as an actuator to act on the environment based on the perceived road, traffic and weather conditions.

5.1 WHAT IS AN INTELLIGENT AGENT?

Intelligent agent is an entity that works without assistance, interprets inputs, senses the environment, makes choices and ultimately, acts to achieve a goal. Intelligent agents have to learn and use knowledge to achieve their goals. The agents may be very simple or very complex. A reflex machine such as thermostat, a human being, community of human beings working together towards a goal are all examples of an intelligent agent. A typical relationship between the agent and the environment is depicted in Figure 5.2. It is the set of rules, (if-then) that drives the decisions of the agent towards the goal fulfilment. The rules could be domain rules that describe about the environment, inference rules for reasoning process along with the knowledge base.

An *intelligent agent* is an entity that is autonomous in nature, a good observant to detect the environmental changes, with a capacity to govern its actions in timely fashion to achieve the goals.

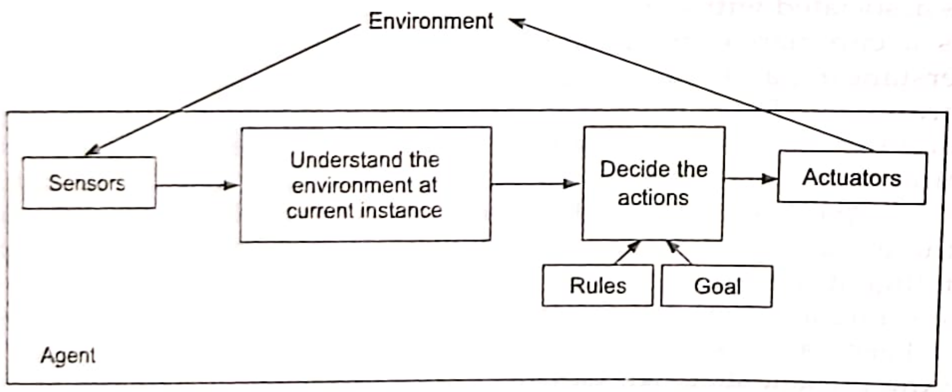


Figure 5.2 Agent-environment relationship.

EXAMPLES: Let us consider two examples. Consider an automatic attendance system. In the system, the fingerprint sensors sense the fingerprints. The actuator gives the message and the attendance is marked for the employee corresponding to the sensed fingerprint.

Other example is of auto-door opening and closing system. Here, a camera is used as sensor for sensing the existence of an object. When the camera senses that a person is standing in front of the door or close to the door, it gives this input to the agent program. The agent program gives command and then the actuator opens the door.

These two examples are discussed throughout the chapter and the need for intelligence is stressed at various stages.

5.1.1 Percept

Let us understand the concept of percept with regard to the agent's environment. Percept, in a broader sense, is the mental result or product of perceiving, as distinguished from the act of perceiving; an impression or sensation of something perceived. It can be about some view of the environment sensed and viewed by an agent. In case of intelligent agent, percept is agents' perpetual inputs at any instant. An agent, while observing has some percept at any moment of time. A percept sequence is the complete history of everything the agent has ever captured. The percept or rather the percept sequence is the window of the agent to the environment through which it observes the environment. Hence, an agent's choice of an action depends on the percept sequence.

5.1.2 Agent Function

Agent behaviour is mathematically represented by agent function. This mapping is done in various ways. One of the simple ways is tabulating actions against percept sequences. Then, this table is used for mapping and selecting the action. This agent function is generally implemented by an internal program called *agent program*. While the agent function is an abstract mathematical representation, the agent program is implementation used for this mapping. So, an agent program is based on the agent function.

An agent program uses agent function to achieve the desired goal. The agent function maps from percept histories to actions. The same is represented below:

$$f : P \to A \tag{5.1}$$

where P is percept and A is action.

The agent program acts on physical architecture along with the sensor inputs and actuators to produce f in Eq. (5.1). So, the agent consists of architecture and program. We can say that the architecture is the scenario under consideration. Hence,

Agent = Architecture + Program

The sensors get the current percept (how the environment is looking at that particular instant) or a percept sequence. The program (agent program) uses that percept sequence to decide the actions and acts with the actuators to take the decided actions.

Sensors → Agent programs → Actuators

So, we can say that an agent is completely specified by the sensors, actuators, agent function and mapping of percept sequence to the actions. The operation of the agent is dependent on the function. A program should be appropriate for architecture, in turn, the architecture should be able to support the program recommended actions.

5.1.3 Representation of Agent Function as a Subset of Agent Program

Let us take the example of auto-door opening and closing system. There is a small area on both the sides of the door identified to be under surveillance. Two cameras, one inside and other outside, cover this area. A simple agent function is that if any person is standing in that area, open the door or else close.

So, a function is like

1. If area is empty, then close the door.
2. If area is occupied, then open the door.

An agent program uses this function to achieve this complete expected behaviour. The program takes care of following activities:

1. Continuous scanning of this area
2. Opening or closing of the door or keeping it in the same position based on the output of function
3. Handling all combinations and possible issues
4. Handling the exceptions to ensure the smooth functioning
5. Ultimately achieving the results in all possible scenarios

5.2 RATIONALITY AND RATIONAL AGENT

A *rational agent* is an agent that behaves logically and does the right things. *Rationality* is a normative concept that stands for acting based on logical reasoning. In artificial intelligence and even in other disciplines like economics, game theory, decision theory, a *rational agent* is an agent that chooses to perform an action which leads to an expected optimal result. This agent has clear preferences, models uncertainty via expected values and analyses all feasible actions. Along with all sensors and actuators, the agent is provided with complete specifications of the problem and the task to be performed. Based on this information, the agent performs the most logical actions. *Rational actions* are those which can make an agent the most successful. A *rational agent* provides or makes rational rather logical decisions. Typical examples of rational agents can be a person, governing body, decision authority, firm, machine or software.

The reason behind the discussion of rationality is that it determines how an intelligent agent needs to behave/act with respect to the environment to get the expected outcomes.

A *rational agent* is expected to select an action that would maximise the performance, having the evidence on the basis of percept sequence as well as the built-in knowledge.

So, the agent takes actions and decisions on the available percept sequence. The parameters that play a role in it are as follows:

1. Priorities and the preferences of the agent

2. Information available with the agent about its environment (This information is gathered based on the experiences or may be provided in some other form)
3. Possible actions an agent can perform
4. Estimated or the actual benefits and the chances of success of the actions

The question remains what is logical, rational or correct behaviour for an agent? To decide this behaviour, we need to have the performance measure.

5.3 PERFORMANCE MEASURES

Performance measures are the criteria for success of an agent's behaviour. They are used to track the performance of an agent.

When an agent faces the environment or is thrown in the environment, it reacts with a certain sequence of actions based on the percepts or percept sequences which it receives. These sequences of actions are along with the environment, and hence, result in the change of state of the environment. So, this sequence of actions make the environment to go through a number of states. If this sequence is desirable, then we can say the agent did very well. Since there are many parameters and also there is subjectivity in measurement, it is very tricky to measure the performance. It can be measured in terms of efficiency, speed, solutions obtained, energy consumed and so on. There is a thrust on having the objective performance measures.

Note: The performance measure should more be based on what one actually wants from environment, rather than how one thinks agent should behave.

Referring to the example mentioned previously of auto-door opening and closing system, the agent's performance can be measured by timely opening and closing of the door or time delay in opening or closing the door. A rational agent is expected to optimise the performance. For instance, consider a system used in an air-conditioned shop. Then, the agent actions should make sure that the door should not remain open unnecessarily, thereby affecting the performance of the air conditioner in the shop. Neither should the open-close action occur unnecessarily. A person wanting to come inside the shop should not have a long waiting time for the door to open. So, the time factor needs to be minimal. Optimality may include minimal electricity consumption, smooth functioning, less noise and timely actions.

5.4 RATIONALITY AND PERFORMANCE

Rationality is distinct from omniscience (all knowing with infinite knowledge). *Rationality* is not absolute, but it is with reference to the knowledge available with the agent and that knowledge is derived from the percept sequence to date. Agents can perform actions in order to modify future percepts so as to obtain useful information (information gathering and exploration). We can say now that an agent is autonomous if its behaviour is determined by its own experience (with the ability to learn and adapt).

As discussed earlier, rationality maximises the expected performance and it is different from the perfection, as perfection takes actions to maximise the actual performance.

The percept sequence also needs to be informative, rather than uninformative. Consider the case of auto-door opening and closing system. If only one side percept is available, then the door will not open or close if a person is standing on the other side. So, the rational action expects proper information gathering prior to the action. Doing actions in order to modify the future percepts can also be referred to as information gathering. Exploration and gathering need to work together to maximise the outcome.

In some cases, rationality expects agent to learn from the experience. The agent may have some prior knowledge of the environment, but as it gets experience it should modify and augment the knowledge to maximise the results. So, the agent, in some cases, relies completely on prior knowledge, while in the other case, it builds knowledge as it comes across new scenarios.

If the agent relies completely on prior knowledge of its designer than its own percepts, then the agent lacks autonomy. A rational agent is expected to be autonomous. It should learn from its percepts to compensate for partial, incomplete or even incorrect prior knowledge. This autonomy may not be complete. It should be need-based with an objective to optimise the outcome. The rational agent may become independent of prior knowledge in due course of time. We can say that it is the learning agent, a part of rational agent that can adapt to multiple situations and can handle complex problems. Learning agent can succeed in a variety of environments. In short, a rational agent should possess the following properties:

1. Ability to gather information
2. Ability to learn from the experience
3. Perform knowledge augmentation
4. Autonomy

A very simple example of rationality in case of automatic car is that the car is expected to slow down when the signal is yellow and should stop if the signal is red.

5.5 FLEXIBILITY AND INTELLIGENT AGENTS

Intelligence demands flexibility. Hence, agents need to be flexible. The flexibility equips the agent to negotiate with dynamic scenarios. To exhibit the required intelligence, we expect certain properties associated with flexibility from an intelligent agent.

By flexible, we mean that the system should be able to adapt with the changing scenarios and should exhibit rational behaviour in those changing conditions. For this purpose, it needs to be

1. **Responsive:** It should respond in timely fashion to the perceived environment.
2. **Pro-active:** It should exhibit opportunistic, goal-directed behaviour and take the initiative, wherever necessary.
3. **Social:** It should be able to interact when they are deemed appropriate with the other artificial agents, or humans in order to compete problem solving.

Other properties an intelligent agent should have are as follows:

1. **Mobility:** It is recommended that an intelligent agent should be mobile to accumulate knowledge and carry out desired work/decision-making.

2. **Veracity:** Intelligent agent should be truthful. It is not expected to hide information or lie.
3. **Benevolence:** It should avoid conflict and should do what is told.
4. **Rationality:** It should act to maximise the expected performance.
5. **Learning:** Performance is increased with learning. It should have learning ability that is essential for true autonomy.

We need to keep in mind that the agent acts and responds to the environment. To act, first it needs to sense. To sense and act, it needs to have the understanding, reasoning and learning.

5.6 TASK ENVIRONMENT AND ITS PROPERTIES

Intelligence is always defined, in association with environment. The *task environment* is the environment in which the task takes place. Clearly defining task environment along with the desired behaviour and task is necessary for appropriate design of the agent program. PEAS*, that is, performance measure, environment, agent's actuators, sensors must be specified for design of an intelligent agent.

Let us again consider the example of auto-door operating mechanism. Here, the performance measures are the timeliness of operation, electricity usage, smooth operations, noise generated, and efficiency. Similarly, the environment includes both sides of the door, tiles and object belonging to it, if any. Further, the actuators are the motors which push and pull the doors as well as the indicators, if any. Sensors are the cameras on both sides, along with a mechanism deployed for sensing the obstacles. These things specify the setting for an intelligent agent design.

Let us take one more example of a washing machine. The PEAS description for it is as follows:

P: Cleanliness of clothes, time taken, electricity consumed, water used, detergent used, noise made

E: Clothes, water tap, water, detergent

A: Motor rotating the drum/spindle, time indicator, operation completion alarm

S: Water level sensor, detergent sensor, cloth weight sensor, time clock.

In this way, the four descriptors can be specified in various automated agents. Table 5.1 specifies the typical PEAS in case of various agents.

TABLE 5.1 Agent Types and their PEAS Description

Medical diagnosis system
P: Accuracy of diagnosis, time taken, recovery time, expenses E: Patient, doctors, system, equipments A: Diagnosis decision, further treatments/tests/alerts, medicines S: Sensors for different health parameters like BP measuring, blood sugar measuring, heart beat track, ECG, EEG, symptoms of patient with regard to the disease, previous reports

* *Artificial Intelligence: A Modern Approach*, by Russel and Norvig, Pearson Education, 2003, New Delhi, India.

Auto-door operating system
P: Time taken, efficiency, idle time, response time, noise made E: Area on both sides of the door A: Motor closing and opening the door S: Camera on both sides, object sensing mechanism
Face authentication system
P: Time taken, accuracy, efficiency, handling ability in case of new face E: Face, area covered by camera A: Command or message indicating outcome S: Camera/Sensor sensing presence
Auto-car system
P: Time taken, accuracy, efficiency, safety E: Streets, pedestrians, other vehicles, traffic signals A: Steering wheel, accelerator, brake, horn S: Cameras, GPS signals, speedometer, engine sensors

One can have more sensors and actuators based on the system structure and the complexity of the system.

Let us discuss the role and use of these specifications in case of intelligent agents.

Performance measures are more about the specifications of desirability from the type of agent. It is more like a wish list or expectations from the agent. It includes efficiency, way of functioning, handling of scenarios, usage of resources and the final outcome. Environment includes the resources, area and surroundings related to the target task in which an agent is operating. This includes other objects and systems surrounding the agent. Actuators are the ones through which the agent takes actions with reference to the environment. These actions are physical actions. The typical actions are movements, changes, switching on, displaying something, closing door, etc. Sensors are the devices through which agent senses the status or states of the environment. There is a need for continuous sensing. It refers to checking of the properties of the environment which may affect the decision-making. Generally, the sensors are temperature sensors, cameras, motion sensors, etc. So, the PEAS description plays the core part in designing an agent. Hardware agents generally work in a restricted domain, whereas software agents can work across multiple domains. In the next section, we will discuss the types of environment.

5.6.1 Environment Types

There are various ways to define the environments in which the agents operate. It is necessary to consider the types based on the way the environment appears to the agent.

***Fully Observable* (*versus partially observable*)**

A *fully observable environment* is the one, where the sensors of the agent can detect all aspects that are relevant. In short, the agent sensors describe the environment fully or at each point, the environment is entirely observable. A crossword puzzle is a fully observable environment, whereas in case of automated car driving system, it is partially observable. A fully observable environment can also be termed as *accessible environment*, while the rest of the environment can be termed as *inaccessible environment*. Let us talk about Angry Birds and Temple Run games. The environment for Angry Birds can be said to be fully observable, but for Temple Run, it is partially observable.

Deterministic (*versus stochastic*)

In case of deterministic environment, the next state of the environment is described completely by the current state as well as by the action of the agent. The uncertainty factor is not an issue to be looked at in case of fully observable deterministic environment. This property, whether the environment is deterministic or stochastic, is decided from the point of view of the agent. The car system environment is clearly stochastic (as you never know about the traffic!). The environment is said to be *strategic* if it is deterministic, except for the actions of the other agents. Most of the real-life environments are non-deterministic.

Discrete (*versus continuous*)

A discrete environment has a limited/finite number of distinct and clearly defined percepts and actions. While in continuous environment those cannot be clearly defined. Chess has a finite number of discrete states, while it is not the case with football. Hence, chess environment is discrete, while that of football is continuous.

Episodic (*versus sequential*)

Think in real life, everything is in episodes. Had it been the case that the actions or the decisions taken on the previous day (considering this to be one episode) do not impact the current ones (this rarely happens, but just to understand the concept), the environment would have been episodic. One acts based on what one perceives at that instance, rather than depending on or taking into account the things that have occurred previously. In typical terms, the agent's environment is divided into atomic episodes. Each episode or the current scene consists of agent's perception and action. So, action choice in an episode, which wholly depends only on that episode. If we look at the classification problems, we will find them to be episodic, as the decision of classification depends only on that particular element and not on previous elements or previous decisions. In sequential environment, the present decision may impact future decisions unlike episodic. Chess, auto-car and football are the examples of sequential environment. Obviously, episodic environment is much simpler to model as compared to sequential environment. Let us talk about games—Angry Birds and Temple Run. Angry Birds is an example that will fall under the episodic. Think of Temple Run—is it episodic or sequential?

Static (*versus dynamic*)

We are familiar with the word *static*. As it suggests, things are at a standstill. In an agent environment, it would be static if it does not change unless the agent takes action. Things change from one state of the agent to another. So, we can say that the environment is unchanged while an agent is deliberating. In the sense, the entire scenario remains the same as it was when the agent is acting on. Just contrast is the case with **dynamic** environment, where the environment changes while the agent is taking action. A *semi-dynamic environment* is the one, where the environment does not change with the time slab, but the agent's performance does. In real life, many examples are dynamic. Crossword is a static environment. Car driving (traffic issue again!) is an example of dynamic environment. Chess is an example of semi-dynamic environment, whereas temple run is, of course, an example of dynamic environment.

Single (versus multi-agent)

Now, the discussion is moved to multi-agents environment. There can be a need for more than one agent in the system. So, the environment can be a single agent or multi-agent. Chess may be a two-agent environment, while football is a multi-agent environment. Similarly, an agent solving crossword is a single agent environment. The multi-agents environments can either be competitive or co-operative. Competitive means they are actually competing to come up with the goals, whereas co-operative means assisting each other. Clearly, chess is an example of competitive. Football can be categorised as multi-agent, with some co-operative and some competitive agents in picture.

Table 5.2 describes the types of the environments for some examples. The environment type largely determines the agent design. The real world is, of course, partially observable, stochastic, sequential, dynamic, continuous and multi-agent.

TABLE 5.2 Examples of Different Types of Environments

	Chess with a clock	*Chess without a clock*	*Car driving*	*Image analysis*
Fully observable	Yes	Yes	No	Yes
Deterministic	Strategic	Strategic	No	Yes
Discrete	Yes	Yes	No	Yes
Episodic	No	No	No	Yes
Static	Semi	Yes	No	Semi
Single agent	No	No	No	Yes

5.7 TYPES OF AGENT

Agents can be of many types. Agent types can be decided based on the complexity and functionality of the agent. Simple agents like table-driven agents work on the basis of simple lookup table. These agents can handle simple task like temperature control, colour selection, directing to particular location and so on. This table is the knowledge base with the agent. For any percept, the action is mapped from the table and executed. This agent can be extended to simple rule-based agents. Here, the action is based on some set of logical rules. The decision-making takes place in the form of rules that direct for right action based on the percept. These types of agent belong to simple category that are based on the knowledge built in advance and rarely modify that. So, they exploit the already known things to take the best possible action. Complex agents are expected to interact with the environment in different possible ways. These complex agents are expected to explore new routes and paths in the absence of knowledge available. These agents are expected to learn from the experience and update the knowledge base. The agent's complexity changes with respect to environment complexity and the intelligence agent is expected to exhibit. In case of dynamic environment, we expect the agent to deliberate with all intelligence and to take into account changes in the environment. These types of scenarios demand more and more intelligence. So, the complexity of environment contributes to complexity of the architecture of agent. The agent can be classified based on these complexities and expected intelligence. The five basic types of agents are as follows:

1. Table-driven agents
2. Simple reflex agents
3. Model-based reflex agents
4. Goal-based agents
5. Utility-based agents

Apart from these, we have also learning agents. We will study them in further sections.

Table-driven Agents

Table-driven agents are based on simple table. The table entries are used to determine the action with reference to percept or percept sequence. Though it is one of the easiest ways to implement the agent, it suffers from many drawbacks, which are listed below:

1. **Size of table:** As the complexity increases, the table size goes on increasing. For practical problems, it results in huge size tables.
2. **Time to build the table:** The agent works on the table that is the result of the knowledge acquired. Since knowledge acquisition is a complex task, it takes a long time to build the table.
3. **No autonomy:** All the actions are built-in. So neither flexibility, nor autonomy.
4. **Time required for learning:** Even with learning, it takes long time to learn the entries.

Simple Reflex Agents

It is one of the simple rule-based agent that takes into account only the current percept. It selects action on the basis of the current percept (ignoring the percept history and independent of the location). Based on the condition, an action is decided that is based on rules (action driven by condition). This is one of the simplest types of agent with limited intelligence. It cannot handle the complex decision scenarios, and hence, is useful only in fully observable environment. Figure 5.3 depicts simple reflex agents. An example with reference to automatic intelligent door operation is given below:

If a person is observed in the (observation area), then initiate (door opening action)—(detect and act)

General purpose interpreter for the condition detection and action-based rules is used in these types of agents. Then, the rules for specific task for environment can be

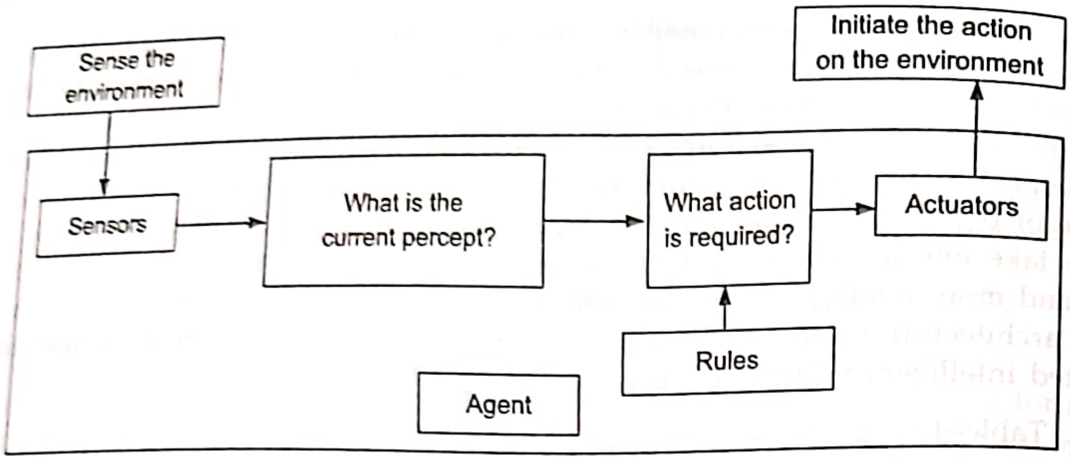


Figure 5.3 Simple reflex agents.

developed. These types of agents are very useful if the decisions can be made on only the current percept. But, as discussed earlier, due to limited intelligence, it cannot cope up with even a minor change in the system and may result in disaster. Simple reflex agents may get stuck in an infinite loop in case of unavailability of some sensors due to fix and hard coded rules. Use of randomise simple reflex agents can solve this problem to some extent. In this case, the agent randomises its action. Though randomistation can be preferred in multi-agent environment, in single agent environment, randomisation may impact rational behaviour.

Model-based Reflex Agents

In many real-life problems, the issues are faced due to partially observable environment. Without keeping track of the world and previous states, the agent cannot see a way of overcoming partially observable environment. In these types of agents, some sort of internal state, which depends on percept history, is maintained and that reflects some of the unobserved aspects of the current state. It is possible that some information is captured in the previous state and it throws light on unobserved aspects in present state. For example, if the previous frame of camera captures a vehicle that is not seen in present state, then it allows us to take decision to apply break. For this type of model, we need to know

1. How is the world evolved independent of agent?
2. How does the agent's own action affect the world?

Incorporating these two things in determining the unobserved aspects is called *model*. A model keeps track of how the world evolved and the past sequence of percept to determine the unseen part. Model-based intelligent agents have wide applications compared to simple reflex agents. Figure 5.4 depicts the model-based reflex agents.

Goal-based Agents

In many cases, only knowledge of the current state is not enough. The knowledge about how the world is evolved is definitely more useful. But it is also important to know the goal for decision-making. In some cases, absence of knowledge about the goal can make decision-making very difficult. Some description about the goal or the desirable state can

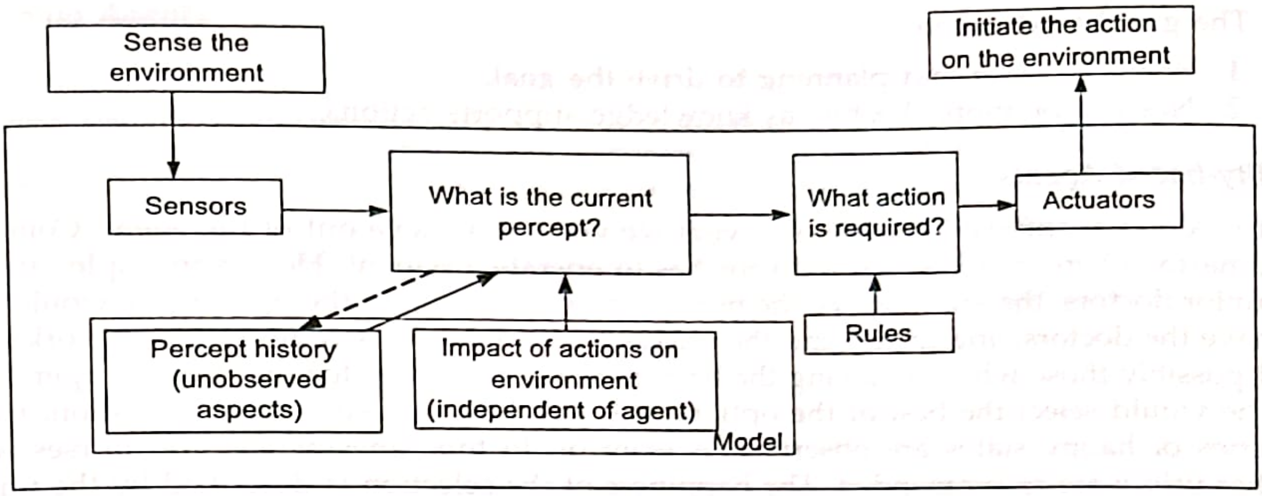


Figure 5.4 Model-based reflex agents.

always be very useful. For example, in case of car driving, knowledge about the customer destination can help in decision-making. In some cases the destination might not be the actual location, but some description about the budget, hotel near airport, or budget leisure hotel in Goa near Kolwa beach.

The goal-based action may be very complicated and may need a sequence of actions. Chapter 9 discusses about the decisions related to the sequence of actions. The decision-making scenario is different in this case than that of a simple reflex agent. Here, decision-making checks the impact of the actions with reference to the goal. The combination of how the world evolves and the understanding of the goal description makes this agent more useful in scenarios with higher complexity. Figure 5.5 depicts a goal-based agent.

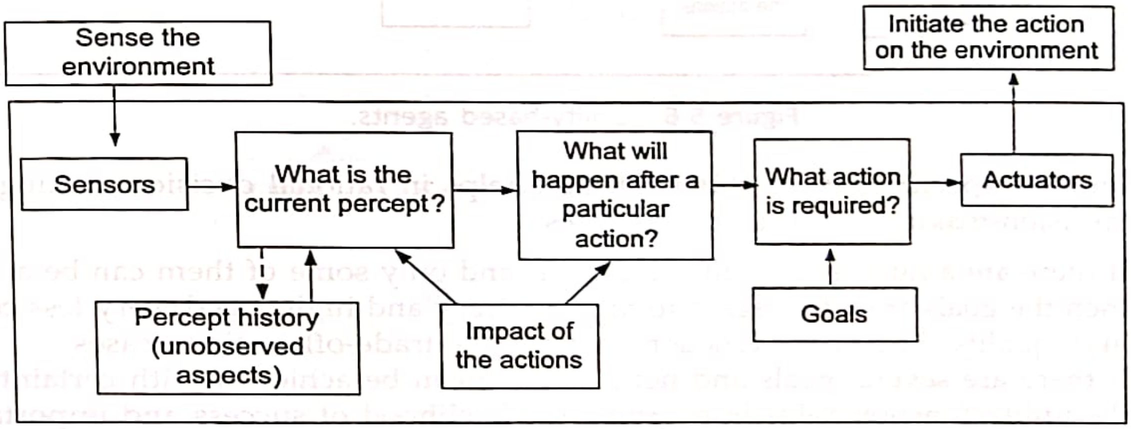


Figure 5.5 Goal-based agents.

The goal-based agents appear less efficient but more flexible. It keeps building knowledge with reference to goal, and hence, can very easily be used in different locations. We can see the resemblance to the model-based agents. But here, more amount of time is actually required for the reasoning process, as it is goal-directed.

The goal-based agents

1. Require search and planning to drive the goal.
2. Need to be more flexible, as knowledge supports actions.

Utility-based Agents

Just goal is not sufficient to describe what we want to achieve out of the agent. Consider a scenario, where in a hospital a doctor has to operate a patient. He has multiple options of junior doctors, the anesthetists, the nurses and so on. Among the options, he would like to have the doctors, anesthetist and the nurses with whom he is comfortable to work with and possibly those who are having the best track record earlier for that type of operation. So, he would select the best of the options that will lead to a successful operation. Here, a series of happy states are observed. A team of doctors, anesthetists and nurses with higher utility are recommended. The happiness of the selection is described by the utility function. Utility function is most often a real number that maps to degree of happiness. The utility-based agent structure is depicted in Figure 5.6.

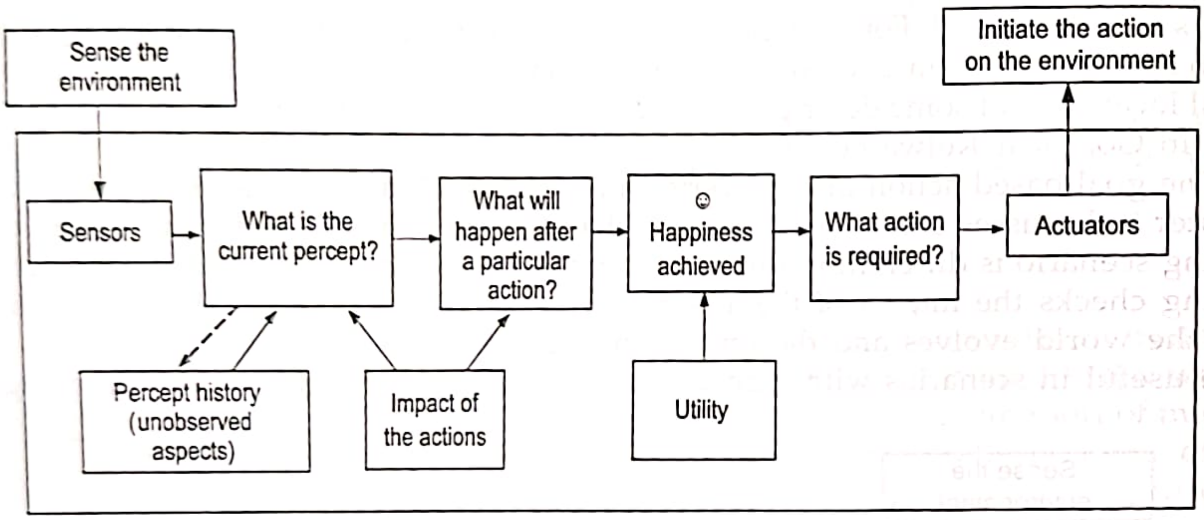


Figure 5.6 Utility-based agents.

A complete specification of utility function helps in rational decision-making. It can help in decision-making in the following cases:

1. If there are a number of conflicting goals and only some of them can be achieved, then the goals are with regard to high accuracy and high speed, very less cost and high quality. The utility function specifies the trade-off in these cases.
2. If there are several goals and none of them can be achieved with certainty, then the utility function helps in mapping the likelihood of success and importance of goal in order to take decision.
3. Problems related to route selection and modifications, if any.

So, precisely, utility-based agents are useful when:

1. Not only goals, but means are also important.
2. Some series of actions are safer, quicker and reliable.
3. Happy and unhappy states are required to be distinguished.

Learning Agents

An agent many times needs to operate individually in an unknown environment. The already provided knowledge may not allow an agent to operate in an unknown or a new situations/scenarios. This makes it necessary for the agents to have an ability to learn and explore. This ability to learn can allow an agent to respond to new or unknown scenarios in a logical way. Further, the learning can help in making improvement in behaviour as it proceeds or comes across more and more scenarios. Most importantly, it allows an agent to learn from experience. Following are the two important elements in learning agents:

1. Performance element
2. Learning element

The learning element is responsible for making improvements, while the performance element is responsible for the selection of external actions. Here, the performance element is an agent without the learning element. Any simple or complex agent when supported with learning elements forms a learning agent. The learning element needs a feedback based on the measurement of performance that how the agent is doing. It is the critic or the reviewer element that provides this feedback required for learning. Critic evaluates agent's success and gives feedback accordingly. Based on the design of performance element, many designs for learning agent are possible. The feedback may come in the form of penalty or reward. This penalty or reward helps in improving the performance of an agent and in building the knowledge base.

Another important part is the task generator or problem generator. It suggests actions that generate new examples or experiences. This, in turn, aids in training the system further. Figure 5.7 depicts the architecture of learning agent.

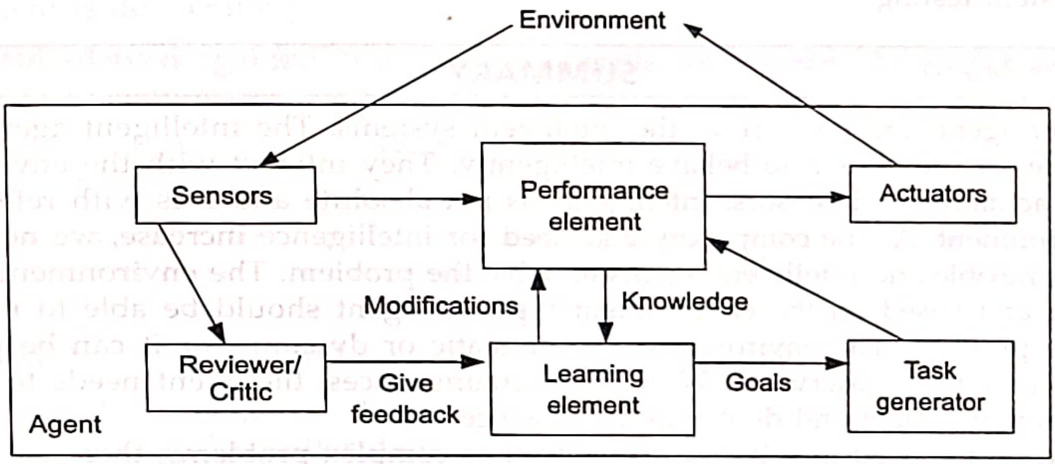


Figure 5.7 Learning agent.

Learning in an intelligent agent. It is the process of modification of each component of agent to bring the components into a closer agreement with the available feedback information, thereby improving the overall performance of the agent.

5.8 OTHER ASPECTS OF INTELLIGENT AGENTS

As the complexity of the system increases, it may require multiple agents. Applications to solve problems that are not solved or to solve already solved problems in a better way through learning can lead to the agents with dynamic learning capabilities. Some complex and practical scenarios in real life can be handled only by multi-agent systems with co-operative learning abilities. There are many applications of intelligent agents. Right from the vacuum cleaner, water purifiers to the flight control systems, intelligent agents help in various products. Some of the application domains of intelligent agents are listed below:

1. Process control
2. Manufacturing
3. Traffic control
4. Information management
5. E-commerce
6. Business process management
7. Medical domain, monitoring, etc.
8. Games

Drawbacks: Agents have been very useful, but suffer from some drawbacks like

1. No overall system controllers
2. No global perspective

While developing the agents, we need various clear specifications and problem definitions. Some of the bottlenecks in agent development are listed below:

1. Requirement specifications
2. System design
3. System implementation
4. System testing

SUMMARY

Intelligent agents are the core of the intelligent systems. The intelligent agents make it possible for the system to behave intelligently. They interact with the environment through actuators and sensors. Intelligence is not absolute and it is with reference to the environment. As the complexity and need for intelligence increase, we need more complex, flexible and intelligent agents to solve the problem. The environment is ever-changing and based on the environment type, an agent should be able to react and solve the problem. The environment can be static or dynamic, or it can be partially observable or fully observable. With these circumstances, the agent needs to interact with the environment and deliberate intelligence.

Based on the need to solve simple as well as complex problems, there are various agents that are designed. The simple reflex and table-based agents are suitable for simple applications, with less uncertainties and known environment. To deal with the other aspects of complexity, we need model-based, goal-based and utility-based agents. For high end applications, we expect the agents to learn from the experience and improve the behaviour over the time. The agent is expected to behave reasonably well in the unknown and new scenarios. There is wide range of applications of intelligent agents, and learning from experience can give an edge to the ability of intelligent agents.

KEYWORDS

1. **Agent:** An agent is an entity that can perceive information and act on that information.
2. **Intelligent agent:** It is an entity that is autonomous in nature, a good observant to detect the environment changes with a capacity to govern its actions in timely fashion to achieve the goals.
3. **Percept:** It is the window of the agent to the environment.
4. **Rational agent:** It is an agent that selects an action that would maximise the performance, based on percept sequence and built-in knowledge.
5. **Fully observable environment:** It is the environment, where the sensors of the agent can detect all the relevant aspects.
6. **Deterministic environment:** It is the environment, where the next state of the environment is described completely by the current state as well as by the action of the agent.
7. **Discrete environment:** It is the environment that has limited/finite number of distinct clearly defined percepts and actions.
8. **Episodic environment:** It is the environment which is divided into atomic episodes comprising agent's perception and action.
9. **Sequential environment:** It is the environment, where the present decision impacts the future decisions.
10. **Static environment:** It is the environment that remains unchanged while the agent is deliberating.
11. **Table-driven agents:** It is based on simple table, where the entries are used to determine an action with respect to percept.
12. **Simple reflex agents:** It is a simple rule-based agent that takes into account only the current percept.
13. **Model-based reflex agents:** In these, the agent uses internal state, which depends on percept history, is maintained and reflects some of the unobserved aspects of the current state.
14. **Goal-based agent:** It keeps building knowledge with reference to goal.
15. **Utility-based agent:** On the basis of utility function, it maps the degree of happiness so that better decisions are taken.
16. **Learning agents:** These are the agents with an ability to learn and respond in unknown scenarios.

MULTIPLE CHOICE QUESTIONS

1. In what type of agent category will an internet book shopping agent fall?
   (a) Simple reflex (b) Model-based
   (c) Goal-based (d) Utility-based
2. Which of the following best defines a multi-agent environment?
   (a) Multiple intelligent agents operating in competition
   (b) Multiple intelligent agents that can share their knowledge and skills to get the solution to a complex problem
   (c) Groups of intelligent agents processing information in a fixed sequence set
   (d) Intelligent agents operating competitively as well as co-operatively
3. A rational agent is defined as
   (a) An agent that takes action according to its percept sequence
   (b) An agent that takes decision based on infinite knowledge base
   (c) An agent that tries to maximise its actual performance
   (d) An agent that thinks that it always takes correct decisions
4. If the agents are operating in distributed environment, then the agents
   (a) Are centralised
   (b) Share some common knowledge
   (c) Independently solve and get the best answer
   (d) Are decentralised
5. In what type of environment does an internet book shopping agent operate in?
   (a) Fully observable (b) Episodic
   (c) Discrete (d) Static
6. In what type of environment does a backgammon game operate in?
   (a) Fully observable (b) deterministic
   (c) Episodic (d) Discrete
7. We can say that an agent is autonomous when
   (a) Its behaviour is based on its experiences
   (b) Its behaviour is governed entirely on the current percept
   (c) It possesses social characteristics
   (d) None of the above
8. Among the domains—planning, game playing, diagnosis and internet-based systems, for which domains, intelligent agent is most suited/applicable?
   (a) All of them
   (b) Planning, game playing
   (c) Diagnosis, game playing, internet-based systems
   (d) Game playing, internet-based systems
9. Consider a scenario, where a student has a set of queries to be resolved. Among the staff members available in the college, he approaches specific staff members, who are able to solve and assist him in resolving the queries. In such a case, the staff member selection would more appropriately described/mapped to be
   (a) Goal based agent (b) Simple reflex agent
   (c) Utility agent (d) Both (a) and (c)

10. Which of the following cannot be a property of intelligent agent?
    (a) Rationality (b) Pro-active
    (c) Veracity (d) Deterministic

CONCEPT REVIEW QUESTIONS

1. What is an intelligent agent?
2. Distinguish between an agent and an intelligent agent.
3. Discuss about the rational behaviour of an intelligent agent.
4. What are the types of agents? Discuss the significance of types with reference to complex agents.

CRITICAL THINKING EXERCISE

1. Discuss with reference to agent types, buyer agents and seller agents in E-business.
2. Architect intelligent agents in network management.
3. What types of intelligent agents exist in business intelligence? Discuss about the rational behaviour of an agent.
4. Select all parameters required to develop a learning agent for collision detection of vehicles. How does your learning program deal with partially observable environment in this case?

PROJECT WORK

1. Develop an agent program for auto-door operation in a mall. Discuss about the performance measures.
2. Develop an agent architecture for football and discuss the need for learning capabilities of the agent in this scenario.
3. Implement a program for learning agent for a lift, where
   (a) The lift would halt at a particular floor based on the identity of the individual.
   (b) There would be energy optimisation through elimination of redundant operation.