Unit 1: Intelligent System and Intelligent Agent

What is the definition of intelligence

Intelligence is the ability to solve complex problems or make decisions that benefit the actor. It can also be defined as the sum of mental capacities such as abstract thinking, understanding, communication, reasoning, learning and memory formation, action planning, and problem solving.

Intelligence can have different meanings to different people. For example, different lifeforms can have different types of intelligence because they have different evolutionary roots and have adapted to different environments.

Synonyms of intelligence include:

- The ability to learn or understand
- To deal with new or trying situations

How and why did intelligence evolve?

Intelligence can be defined as the ability to solve complex problems or make decisions with outcomes benefiting the actor, and has evolved in lifeforms to adapt to diverse environments for their survival and reproduction. For animals, problem-solving and decision-making are functions of their nervous systems, including the brain, so intelligence is closely related to the nervous system.

What are intelligent systems?

Intelligent systems are technologically advanced machines that perceive and respond to the world around them. Intelligent systems can take many forms, from automated vacuums such as the Roomba to facial recognition programs to Amazon's personalized shopping suggestions.

Our department focuses on two main areas within intelligent systems: how machines perceive their environment and how those machines interact with that environment.

One way that such systems can perceive their environment is through vision. The study of how computers can understand and interpret visual information from

static images and video sequences emerged in the late 1950s and early 1960s. It has since grown into a powerful technology that is central to the country's industrial, commercial, and government sectors. The key factors that have contributed to this growth are the exponential growth of processor speed and memory capacity as well as algorithmic advances.

The field of intelligent systems also focuses on how these systems interact with human users in changing and dynamic physical and social environments. Early robots possessed little autonomy in making decisions: they assumed a predictable world and perfumed the same action(s) repeatedly under the same conditions. Today, a robot is considered to be an autonomous system that can sense the environment and can act in a physical world in order to achieve some goals.

Applications of intelligent systems

Intelligent systems are poised to fill a growing number of roles in today's society, including:

- Factory automation
- Field and service robotics
- Assistive robotics
- Military applications
- Medical care
- Education
- Entertainment
- Visual inspection
- Character recognition
- Human identification using various biometric modalities (e.g. face, fingerprint, iris, hand)
- Visual surveillance
- Intelligent transportation
-

Challenges in intelligent systems

Research in intelligent systems faces numerous challenges, many of which relate to representing a dynamic physical world computationally.

1. **Uncertainty**: Physical sensors/effectors provide limited, noisy and inaccurate information/action. Therefore, any actions the system takes may be incorrect both due to noise in the sensors and due to the limitations in executing those actions.

2. **Dynamic world**: The physical world changes continuously, requiring that decisions be made at fast time scales to accommodate for the changes in the environment.
3. **Time-consuming computation**: Searching for the optimal path to a goal requires extensive search through a very large state space, which is computationally expensive. The drawback of spending too much time on computation is that the world may change in the meantime, thus rendering the computed plan obsolete.
4. **Mapping**: A lot of information is lost in the transformation from the 3D world to the 2D world. Computer vision must deal with challenges including changes in perspective, lighting and scale; background clutter or motion; and grouping items with intra/inter-class variation.

An intelligent system is a computer system that can gather, analyse, and respond to data. It can also communicate with other agents, such as users or other computer systems. Intelligent systems are made up of hardware and software.

What is an intelligent system and how does it work? -
An intelligent system is an advanced computer system that can gather, analyse and respond to the data it collects from its surrounding environment. It can work and communicate with other agents, such as users or other computer systems. It can also learn from experience and adapt according to current data.

The main structure of the intelligent system. -
The intelligent system includes hardware and software. The hardware generally consists of a processor (CPU), memory (memory, hard disk, etc.), display devices (monitors, projectors, etc.), input devices (mouse, keyboard, etc.), sensing devices (sensors, etc.), sensors, scanners, etc.) and other components.

The hardware of an intelligent system includes:

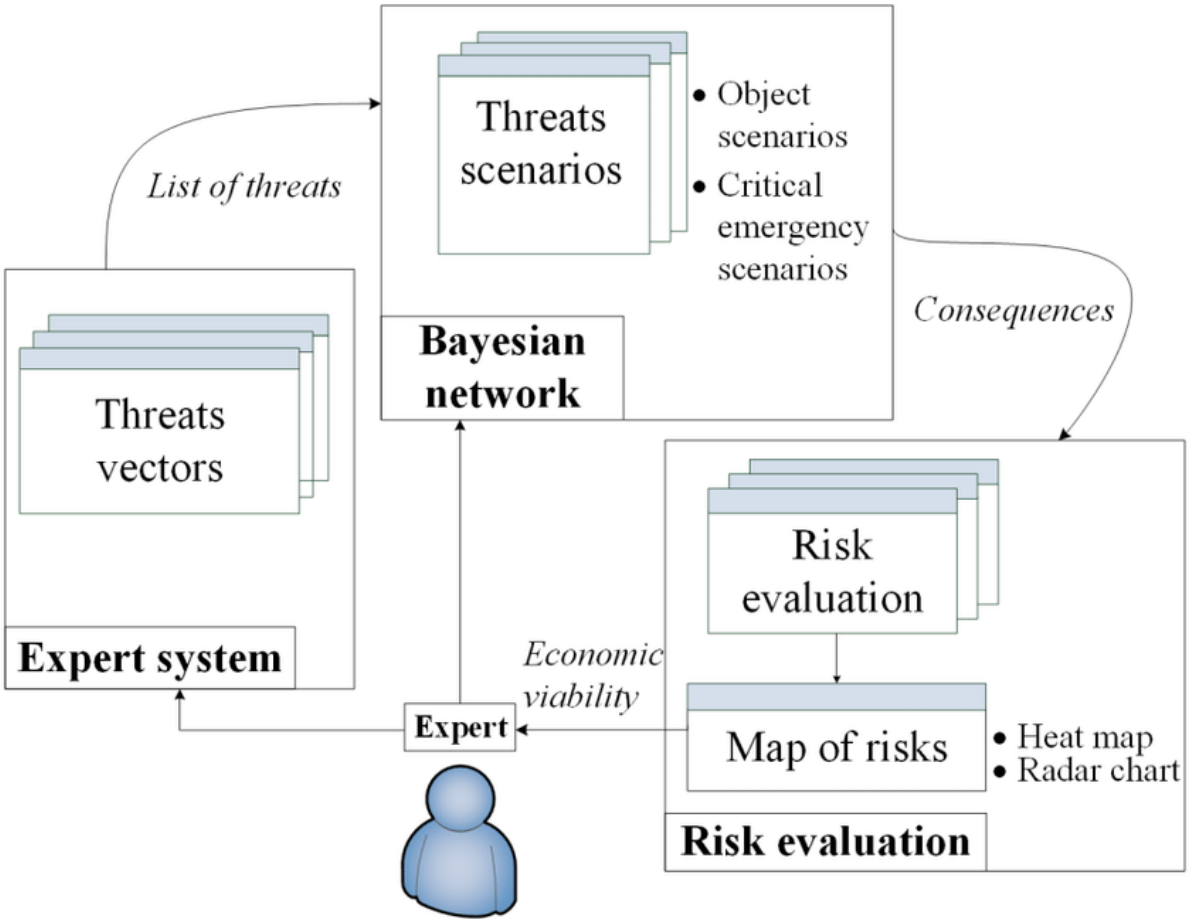
Processor (CPU), Memory, Display devices, Input devices, Sensing devices, other components.

The software of an intelligent system includes:

- Process interface
- Software interfaces
- Man-machine interface

Intelligent systems can have many forms, such as:

- Automated vacuums
- Facial recognition programs
- Amazon's personalized shopping suggestions
- Autonomous cars
- Drones
- Speech recognition programs



Is Bayesian network AI?

Bayesian networks hold immense significance in the field of AI, primarily due to their ability to model uncertainty and make inferences based on probabilistic reasoning. Their importance stems from their impact on decision making, reasoning under uncertainty, and their widespread applications in diverse domains.

Biological brain model neural model

Neural network models are based on the neurons and synapses in the brain. They simulate a large number of interconnected processing units that mimic abstract neurons. These processing units are arranged in layers.

Neural network models are simplified models of how the human brain processes information. The lessons learned from these models can be used to create artificial intelligence and robotics.

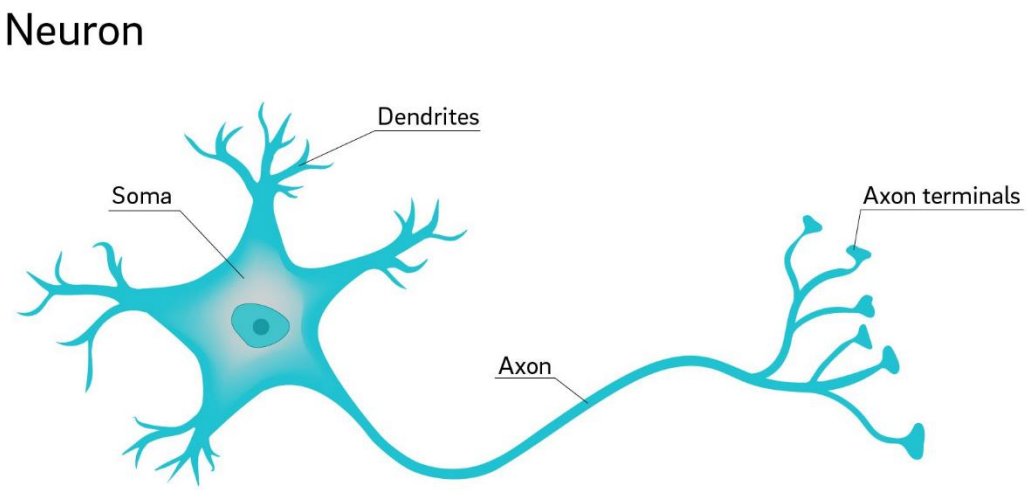
Biological neural networks are made up of neurons that are chemically connected or functionally associated. These connections, called synapses, are usually formed from axons to dendrites.

The human brain has about 86 billion neurons and more than 100 trillion synapses. In artificial neural networks, the number of neurons is about 10 to 1000.

Humans have made several attempts to mimic the biological systems, and one of them is artificial neural networks inspired by the biological neural networks in living organisms. However, they are very much different in several ways. For example, the birds had inspired humans to create airplanes, and the four-legged animals inspired us to develop cars.

The artificial counterparts are definitely more powerful and make our life better. The perceptron's, who are the predecessors of artificial neurons, were created to mimic certain parts of a biological neuron such as dendrite, axon, and cell body using mathematical models, electronics, and whatever limited information we have of biological neural networks.

Components and Working of Biological Neural Networks



In living organisms, the brain is the control unit of the neural network, and it has different subunits that take care of vision, senses, movement, and hearing. The brain is connected with a dense network of nerves to the rest of the body's sensors and actors. There are approximately 10^{11} neurons in the brain, and these are the building blocks of the complete central nervous system of the living body.

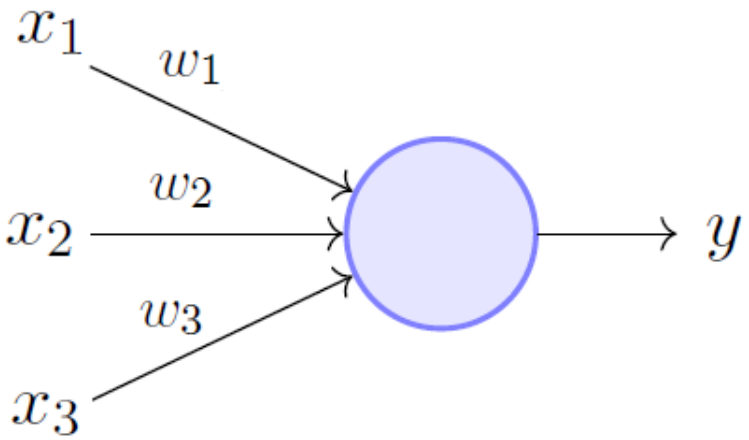
The neuron is the fundamental building block of neural networks. In the biological systems, a neuron is a cell just like any other cell of the body, which has a DNA code and is generated in the same way as the other cells. Though it might have different DNA, the function is similar in all the organisms. A neuron comprises three major parts: the cell body (also called Soma), the dendrites, and the axon. The dendrites are like fibres branched in different directions and are connected to many cells in that cluster.

Dendrites receive the signals from surrounding neurons, and the axon transmits the signal to the other neurons. At the ending terminal of the axon, the contact with the dendrite is made through a synapse. Axon is a long fiber that transports the output signal as electric impulses along its length. Each neuron has one axon. Axons pass impulses from one neuron to another like a domino effect.

Why Understand Biological Neural Networks?

For creating mathematical models for artificial neural networks, theoretical analysis of biological neural networks is essential as they have a very close relationship. And this understanding of the brain's neural networks has opened horizons for the development of artificial neural network systems and adaptive systems designed to learn and adapt to the situations and inputs.

Image caption: An artificial neuron



Perceptron Model (Minsky-Papert in 1969)

Biological Neural Networks vs Artificial Neural Networks

The human brain consists of about 86 billion neurons and more than 100 trillion synapses. In artificial neural networks, the number of neurons is about 10 to 1000. But we cannot compare biological and artificial neural networks' capabilities based on just the number of neurons. There are other factors also that need to be considered. There are many layers in artificial neural networks, and they are interconnected to solve classification problems.

Biological neural networks tolerate a great deal of ambiguity in data. However, artificial neural networks require somewhat precise, structured, and formatted data to tolerate ambiguity. Biological neural networks are fault-tolerant to a certain level, and the minor failures will not always result in memory loss.

The brain can recover and heal to an extent. But the artificial neural networks are not designed for fault tolerance or self-regeneration. We can still sometimes recover by saving the model's current weight values and continuing the training from the saved state.

Talking about power consumption, the brain requires about 20% of all the human body's energy, equivalent to about 20 watts, which is exceptionally efficient. But computers need an enormous amount of computational power to solve the same problem, and they also generate a lot of heat during computation.

Artificial neural networks were inspired by **the biological neural network**s of the human body. The modelling of **biological neural network**s was a crucial step in the development of artificial neural networks. Many scientists attempted to understand the working of the brain. Artificial neural networks today are being used for various applications, some are biologically related, and most of them are engineering related.

Even though **biological neural network**s and artificial neural networks are similar in function, they still have many differences. Many attempts have been made to understand the complex mechanism of **biological neural network**s. Yet, they still hold many secrets to unlock and inspire the future of artificial intelligence.

What is an intelligent agent?

An intelligent agent is a program that can make decisions or perform a service based on its environment, user input and experiences. These programs can be used to autonomously gather information on a regular, programmed schedule or when prompted by the user in real time. An intelligent agent is also referred to as a bot, which is short for *robot.*

Typically, an agent program, using parameters the user has provided, searches all or some part of the internet, gathers information the user is interested in, and presents it to them on a periodic or requested basis. Data intelligent agents can extract any specifiable information, such as keywords or publication date.

Agents that use artificial intelligence (AI) and machine learning use sensors, such as microphones and cameras, to collect user input. They also use effectors, such as fingers and wheels, to affect their environment, as well as actuators, such as speakers and screens, to deliver agent output. The practice of having information brought to a user by an agent is called push notification technology.

Common characteristics of intelligent agents are adaptation based on experience, real-time problem-solving, analysis of error or success rates, and the use of memory-based storage and retrieval.

For enterprises, intelligent agents can be used in data science applications such as data mining and data analytics, as well as for customer service and support. Consumers use intelligent agents to compare the prices of similar products and get notifications when a website update occurs.

Intelligent agents are also similar to software agents, which are autonomous computer programs.

An intelligent agent interacts with its environment through sensors and actuators.

Types of intelligent agents

Types of intelligent agents are defined by their range of agent functions and capabilities and their degree of intelligence:

- **Simple reflex agents.** These agents function in a current state, ignoring past history. Responses are based on the event-condition-action rule, or ECA rule, where a user initiates an event and then the agent refers to a list of preset rules and preprogrammed outcomes.
- **Model-based reflex agents.** These agents take action in the same way as a reflex agent, but they have a more comprehensive view of their environments. A model of the world is programmed into the internal system that incorporates the agent's history.
- **Goal-based agents.** These agents, also referred to as rational agents, expand on the information that model-based agents store by also including goal information or information about desirable situations.
- **Utility-based agents.** These agents are similar to goal-based agents, but they provide an extra utility measurement that rates each possible scenario on its desired result, and then choose the action that maximizes the outcome. Rating criteria examples include the probability of success or the resources required.
- **Learning agents.** These agents have the ability to gradually improve and become more knowledgeable about an environment over time

through an additional learning algorithm or element. The learning element uses feedback on performance measures to determine how performance elements should be changed to improve gradually. This concept describes how an AI system should operate.

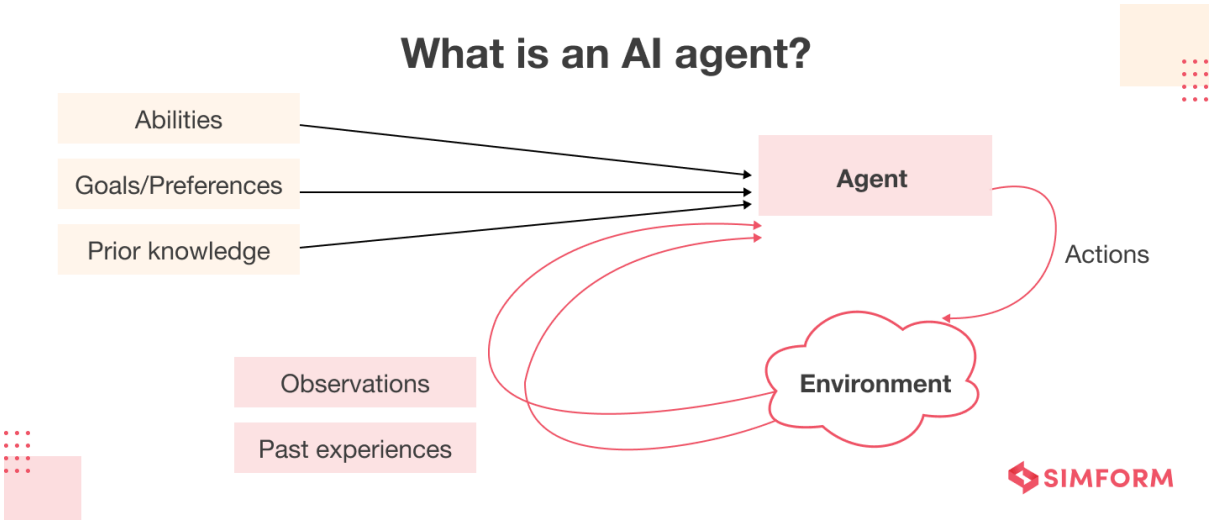
Examples of intelligent agents

AI assistants such as Alexa and Siri are examples of intelligent AI agents that use sensors to perceive a user request and automatically collect data from the internet without the user's help. They can gather information about their observable environments, such as weather and time.

Google Assistant is another example of an intelligent AI agent. It uses machine learning and natural language processing technology to answer users' questions and perform tasks, such as calling contacts stated in voice commands.

Tech vendors are now developing more autonomous AI agents that require less human intervention and oversight, as demonstrated by OpenAI's release of GPT-4. A fully autonomous agent would be considered artificial general intelligence, where AI agents are sentient and don't require guidance from human agents at all, but that's currently theoretical and not yet realistic.

What is an AI agent? What is an autonomous AI agent?



AI agents have been around since the 1980s when computer scientists began exploring how to develop smart software that could interact like humans. Since then, the concept has evolved to include AI agents that can make decisions and complete tasks independently.

An AI agent is a software program designed to interact with its environment, perceive the data it receives, and take actions based on that data to achieve specific goals. AI agents simulate intelligent behaviour, and they can be as simple as rule-based systems or as complex as advanced machine learning models. They use predetermined rules or trained models to make decisions and might need external control or supervision.

An autonomous AI agent is an advanced software program that can operate independently without human control. It can think, act, and learn on its own, without needing constant input from humans. These agents are widely used in different industries, like healthcare, finance, and banking, to make things run smoother and more efficiently. They can adjust to new situations, learn from their experiences, and make decisions using their own internal systems.

For example:

- AutoGPT is an AI agent that can generate human-like text responses. It can comprehend the context of the conversation and generate relevant responses accordingly.
- BabyAGI is an autonomous AI agent that can independently learn and perform tasks like understanding natural language, analyzing images, identifying objects, following simple commands, etc.
- AgentGPT is an intelligent virtual agent designed to interact with customers and provide them with personalized recommendations. It can understand natural language and provide relevant responses based on customer queries.

Both AI tools and AI agents can perform tasks autonomously to an extent. So what sets them apart? What qualifies an AI tool as an agent? Let's find out!

Characteristics of an AI agent

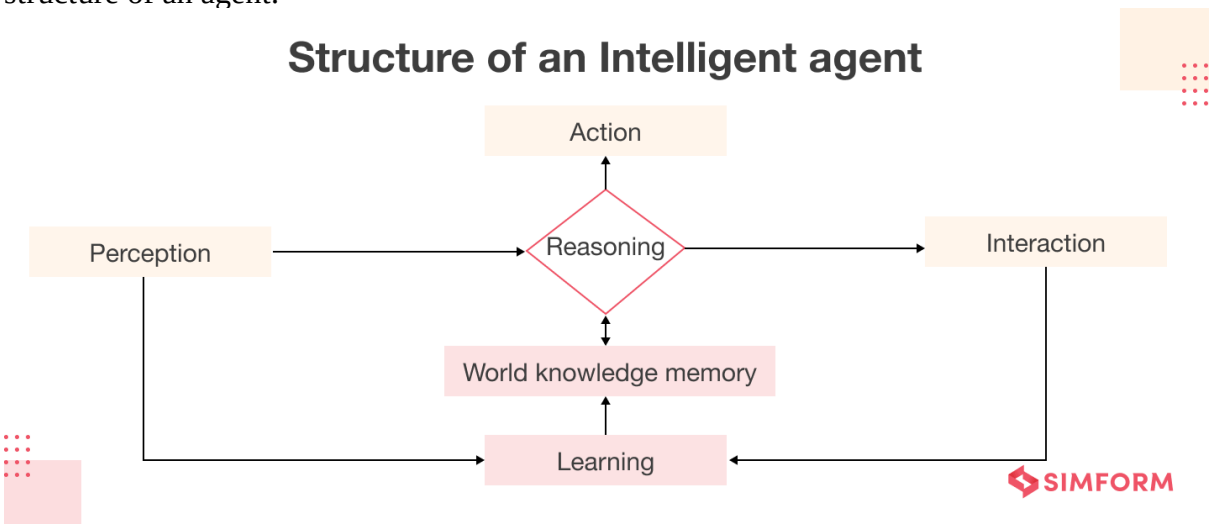
While AI tools and agents are software programs designed to automate tasks, specific key characteristics differentiate AI agents as more sophisticated AI software.

You can consider an AI tool as an AI agent when it has the following characteristics:

- **Autonomy:** An AI virtual agent is capable of performing tasks independently without requiring constant human intervention or input.
- **Perception:** The agent function senses and interprets the environment they operate in through various sensors, such as cameras or microphones.
- **Reactivity:** An AI agent can assess the environment and respond accordingly to achieve its goals.

- **Reasoning and decision-making:** AI agents are intelligent tools that can analyze data and make decisions to achieve goals. They use reasoning techniques and algorithms to process information and take appropriate actions.
- **Learning:** They can learn and enhance their performance through machine, deep, and reinforcement learning elements and techniques.
- **Communication:** AI agents can communicate with other agents or humans using different methods, like understanding and responding to natural language, recognizing speech, and exchanging messages through text.
- **Goal-oriented:** They are designed to achieve specific goals, which can be pre-defined or learned through interactions with the environment.

So far, we have a basic understanding of an agent in AI or intelligent agent definition. But how does an AI agent work? Let's break it down in the next section as we understand the structure of an agent.



At its core, an AI agent is made up of four components: the environment, sensors, actuators, and the decision-making mechanism.

1. Environment

The environment refers to the area or domain in which an AI agent operates. It can be a physical space, like a factory floor, or a digital space, like a website.

2. Sensors

Sensors are the tools that an AI agent uses to perceive its environment. These can be cameras, microphones, or any other sensory input that the AI agent can use to understand what is happening around it.

3. Actuators

Actuators are the tools that an AI agent uses to interact with its environment. These can be things like robotic arms, computer screens, or any other device the AI agent can use to change the environment.

4. Decision-making mechanism

A decision-making mechanism is the brain of an AI agent. It processes the information gathered by the sensors and decides what action to take using the actuators. The decision-making mechanism is where the real magic happens.

AI agents use various decision-making mechanisms, such as rule-based systems, expert systems, and neural networks, to make informed choices and perform tasks effectively.

5. Learning system

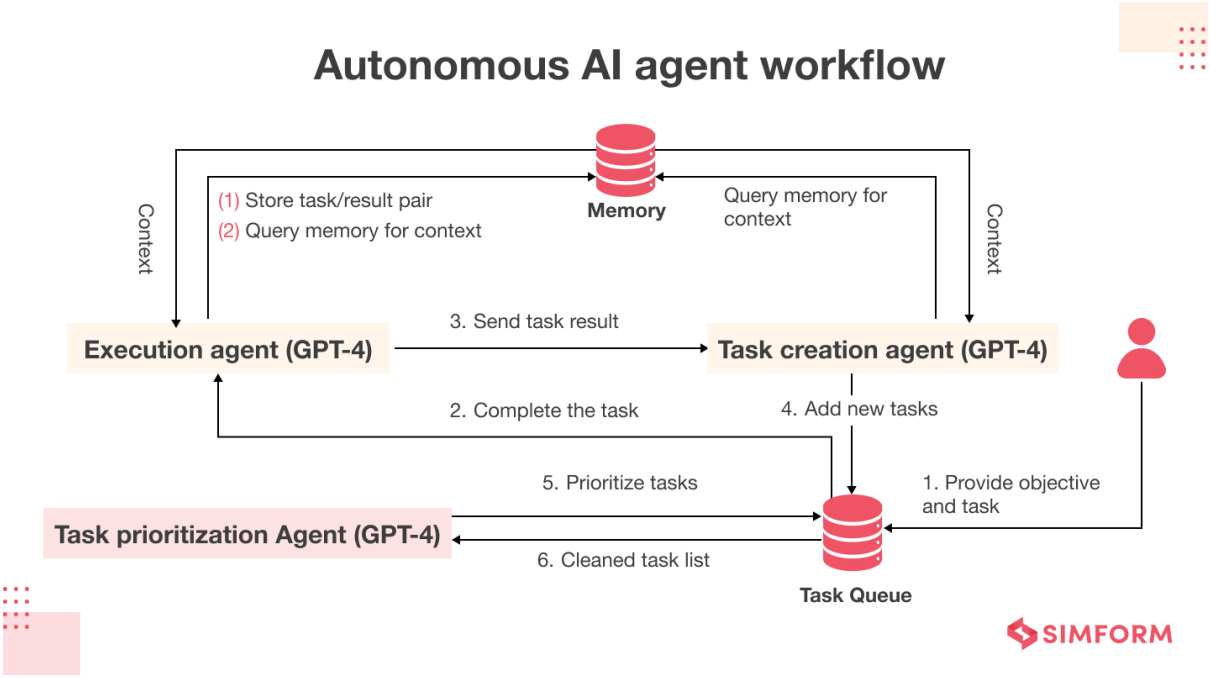
The learning system enables the AI agent to learn from its experiences and interactions with the environment. It uses techniques like reinforcement learning, supervised learning, and unsupervised learning to improve the performance of the AI agent over time.

By understanding the environment, sensors, actuators, and decision-making mechanisms, developers can create AI agents to perform specific tasks accurately and efficiently. As AI technology evolves, we can expect new types of AI agents with even more sophisticated structures and capabilities.

With the AI agent definition and intelligent agent purpose known to you, it's time to dive deeper into the agent function and analyze how an AI agent works in our upcoming section.

How does an AI agent work?

An AI agent works by perceiving its environment, processing information, and taking action to achieve specific goals or tasks. The process usually involves the following steps:



Step 1: Perceiving the environment

An autonomous AI agent first needs to gather information about its environment. It can do so using sensors or collecting data from various sources.

Step 2: Processing input data

The agent takes the knowledge gathered in Step 1 and prepares it for processing. This may include organizing the data, creating a knowledge base, or making internal representations that the agent can understand and work with.

Step 3: Decision-making

The agent uses reasoning techniques like logic or statistical analysis to make an informed decision based on its knowledge base and goals. This can involve applying pre-determined rules or machine learning algorithms.

Step 4: Planning and executing an action

The agent makes a plan or a series of steps to reach its goals. This may involve creating a step-by-step strategy, optimizing resource allocation, or considering various limitations and priorities. Based on its plan, the agent executes all the steps to achieve the desired goal. It can also receive feedback or new information from the environment, which can be used to adjust its future actions or update its knowledge base.

Step 5: Learning and Improvement

After taking action, the agent can learn from its own experiences. This feedback loop allows the agent to improve performance and adapt to new situations and environments.

In conclusion, autonomous AI agents collect and analyze data, preprocess it, make decisions based on machine learning algorithms, take action, and receive feedback. Now, let us simplify the working of an autonomous AI agent by taking the example of AutoGPT and BabyAGI, the modern-day and most commonly used autonomous agents.

Characteristics of an Agent

Types of Agents

Agents can be grouped into five classes based on their degree of perceived intelligence and capability :

Simple Reflex Agents

Model-Based Reflex Agents

Goal-Based Agents

Utility-Based Agents

Learning Agent

Multi-agent systems

Hierarchical agents

Simple Reflex Agents

Simple reflex agents ignore the rest of the percept history and act only on the basis of the current percept. Percept history is the history of all that an agent has perceived to date. The agent function is based on the condition-action rule. A condition-action rule is a rule that maps a state i.e., a condition to an action. If the condition is true, then the action is taken, else not. This agent function only succeeds when the environment is fully observable. For simple reflex agents operating in partially observable environments, infinite loops are often unavoidable. It may be possible to escape from infinite loops if the agent can randomize its actions.

Goal-Based Agents

These kinds of agents take decisions based on how far they are currently from their goal(description of desirable situations). Their every action is intended to reduce their distance from the goal. This allows the agent a way to choose among multiple possibilities, selecting the one which reaches a goal state. The knowledge that supports its decisions is represented explicitly and can be modified, which makes these agents more flexible. They usually require search and planning. The goal-based agent's behavior can easily be changed.

Utility-Based Agents

The agents which are developed having their end uses as building blocks are called utility-based agents. When there are multiple possible alternatives, then to decide which one is best, utility-based agents are used. They choose actions based on a preference (utility) for each state. Sometimes achieving the desired goal is not enough. We may look for a quicker, safer, cheaper trip to reach a destination. Agent happiness should be taken into consideration. Utility describes how "happy" the agent is. Because of the uncertainty in the world, a utility agent chooses the action that maximizes the expected utility. A utility function maps a state onto a real number which describes the associated degree of happiness.

Uses of Agents

Agents are used in a wide range of applications in artificial intelligence, including:

Robotics: Agents can be used to control robots and automate tasks in manufacturing, transportation, and other industries.

Smart homes and buildings: Agents can be used to control heating, lighting, and other systems in smart homes and buildings, optimizing energy use and improving comfort.

Transportation systems: Agents can be used to manage traffic flow, optimize routes for autonomous vehicles, and improve logistics and supply chain management.

Healthcare: Agents can be used to monitor patients, provide personalized treatment plans, and optimize healthcare resource allocation.

Finance: Agents can be used for automated trading, fraud detection, and risk management in the financial industry.

Games: Agents can be used to create intelligent opponents in games and simulations, providing a more challenging and realistic experience for players.

Natural language processing: Agents can be used for language translation, question answering, and chatbots that can communicate with users in natural language.

Cybersecurity: Agents can be used for intrusion detection, malware analysis, and network security.

Environmental monitoring: Agents can be used to monitor and manage natural resources, track climate change, and improve environmental sustainability.

Social media: Agents can be used to analyse social media data, identify trends and patterns, and provide personalized recommendations to users.

Environment

In artificial intelligence (AI), an environment is the surroundings of an agent. It includes the physical environment, digital platforms, and virtualized worlds where AI models and algorithms are used.

Agent Environment in Artificial Intelligence (AI)

The environment provides the agent with something to sense and act upon. The agent takes input from the environment through sensors and delivers the output to the environment through actuators.

Environments can be classified as fully observable or partially observable. The classification depends on the extent to which the agent has access to information about the current state of the environment.

Here are some examples of fully observable environments:

Board games like chess or checkers

Here are some examples of partially observable environments:

Driving a car in traffic

Environment Program

In artificial intelligence (AI), an environment is the setting in which AI functions. This can include real-world, digital, and simulated environments.

19 Aug 2023 — The term "environment" in AI refers to the setting in which AI functions, which might include real-world, digital, and simulated environments.

An agent's environment is everything in the world that surrounds it. It is where the agent lives and operates, and it provides the agent with something to sense and act upon.

An agent takes input from the environment through sensors and delivers the output to the environment through actuators.

Here are some features of an agent's environment:

Fully observable vs partially observable: If an agent sensor can sense or access the complete state of an environment at each point of time, then it is a fully observable environment.

Deterministic environment: In this environment the output is determined based on a specific state.