What is Intelligence?

*** Intelligence= "The capacity to learn and solve problems"**

Characterized By the capability of:

1. **Reasoning-** Ability to Think Logically and draw conclusions
2. **Problem Solving**-Apply knowledge and skills and persevere
3. **Learning & Adapting-**Learn and modify behaviours
4. **Performing COMPLEX TASKS**- Coordination, planning, etc

What is an Intelligent system?

An intelligent system is one that:

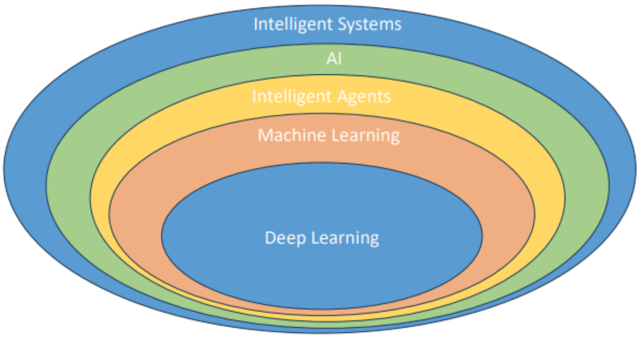
- Mimics human behaviours(reasoning) or Thinking patterns to perform complex tasks(Minsky's definition)
- **Learns** from the **environment** and **adjusts** its **behaviour** to deal with **changes** in environment or problems(AUTOMATIC LEARNING)

Intelligent systems display **Machine level intelligence, reasoning, and often learning, NOT ALWAYS SELF-ADAPTING**

Terms

1. Intelligent systems (IS)
2. Artificial Intelligence (AI)
3. Intelligent agents (IA)
4. Machine learning (ML)
5. Cognitive computing
6. Computational intelligence, machine intelligence, soft computing, etc.

IS vs AI vs IA vs ML vs DL vs ...



Paradigms Under which Ai can be Built

Thinking Humanly

If a system can simulate human thinking processes

Focus: Mimic Human Cognition

Goal:Model how humans think

Tools:Introspection, Psychology, brainscans

Thinking Rationally

If a system can apply logic to always draw valid conclusions

Focus:Apply logical rules

Goal: Derive correct conclusions via logic.

Origin: Aristotle's "laws of thought"

Challenge: Real problems involve uncertainty/incomplete data

Thinking Humanly	Thinking Rationally
"The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense." (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly	**Acting Rationally**
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)	"Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998) "AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

Figure 1.1 Some definitions of artificial intelligence, organized into four categories.

Acting Humanly

*If a system can **imitate human behaviour***

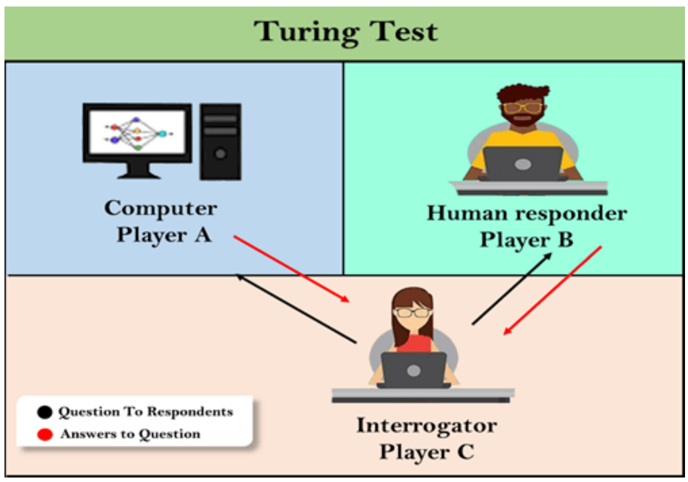
Needs:

Focus:Simulate human behaviour

Goal:Pass the Turning Test(1950)

- Natural language processing
- Knowledge representation
- Reasoning
- Machine Learning

Turning test adds: Vision and Robotics



Acting Rationally

*If a system can **make** the **best decision** for its **goals**, it acts rationally.*

Focus:Use rational decision making

Goal:Act optimally in real-world environments

AI as a system that **ACTS Rationally = Intelligent Agents(IA)**

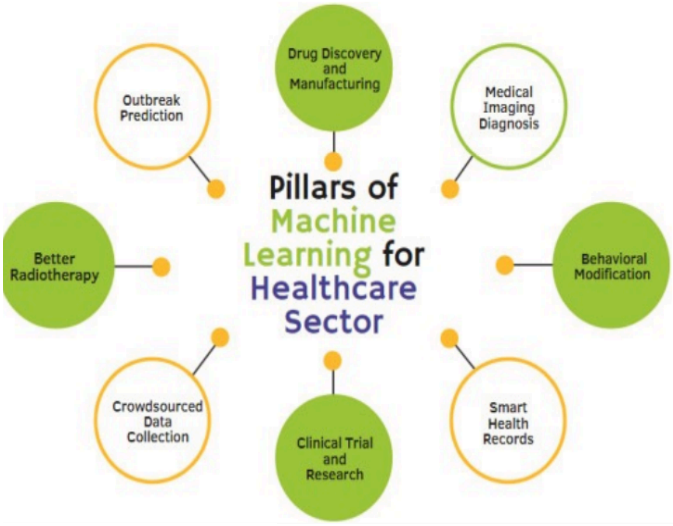
Intelligent Systems Examples

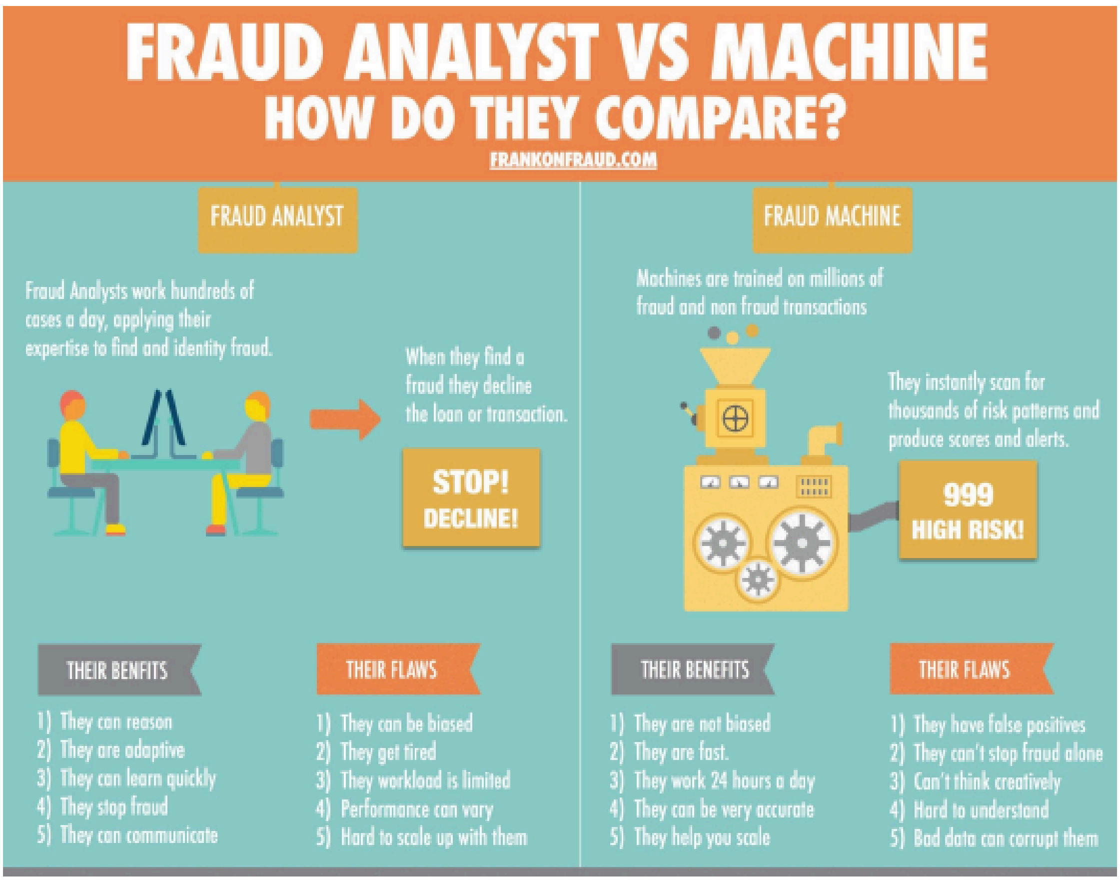
Recent Achievements of Intelligent Systems

- Google DeepMind
- Driverless Cars
- IBM Watson
- OpenAIs ChatGBT/Gemini/Llama 3

Intelligent systems in business

- **Microsoft 365 Copilot:**
    - Combines power of LARGE LANGUAGE MODELS(LLMS) with user data in Graph and apps.
    - Productivity based tool
- **Amazon delivery AIs:**
    - "Regionalization":Ships products to customers from closest warehouses,
    - Ai enabled tech analyse data and patterns to predict in demand Products and where.
- **Walmart**
    - Smarter substitution in online Orders and Brain corps robotic inventory scanners.
- **Visa, Mastercard and PayPal:**
    - using machine-learning algorithms to analyse data on customer behaviour:
    - Fraud detection
- **Pfizer, Genentech and Sanofi:**
    - Speed up Research and development efforts such as:
    - Drug discovery, diagnostics and allocation of resources
- **GE HealthCare:**
    - Digitalisation of health services.





Characteristics of Intelligent systems

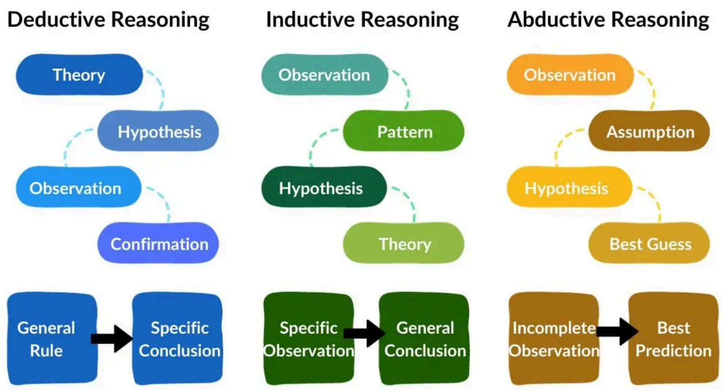
To be an intelligent System must posses ONE or MORE:

- Capability to **extract** and **store knowledge**
- **Human-**like **reasoning**
- Learning from **Experience** OR **Training**
- Dealing with imprecise expressions of facts(**UNCERTAINITY**)
- **Problem solving** through **process** similar to natural evolution
- Ability to **interact** and **deal** with other agents and beings

Recent Trends have seen **Large Language Models(LLMS)** and **MultiModal Foundation Models**(**MFMs**) gain Relevance.

These models enhance their capabilities with:

- Natural language understandings
- Speech recognition and synthesis(understanding)
- Image analysis and synthesis



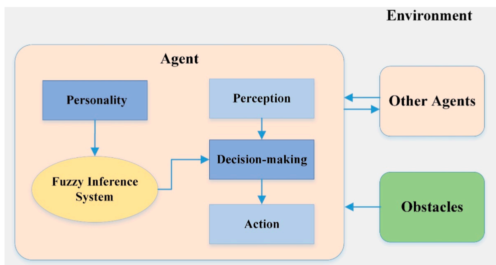
Knowledge representation and Reasoning

Systems must **represent** and **reason** with Info.
Common approaches include:

- Logic-based
- Tends to rely on
- Rule based expert systems
- Constraint satisfaction and optimization problems.

Machine Learning types:

- **Deep learning-**Neural networks with many layers
- **Reinforcement learning-**Learning via reward/punishment CONSEQUENCE
- **Deep reinforcement learning-**Combines DL and RL



Fuzzy Logic/Uncertainty

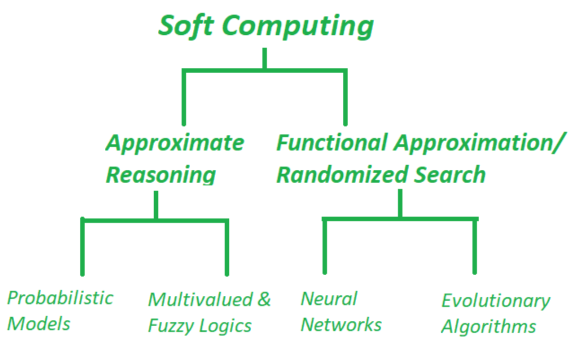
To manage vague or imprecise Info:

- Fuzzy Systems
- Rough Set Theory

These allow more flexible, human-like reasoning under uncertainty.

Soft computing/computational intelligence

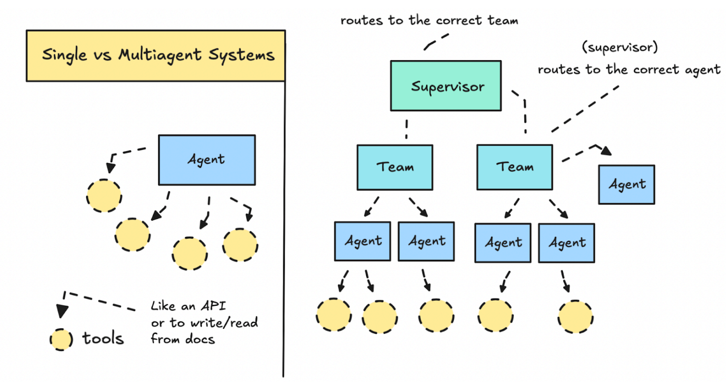
- **Evolutionary computing (EC)**
  - Genetic algorithm (GA
  - /Differential Evolution (DE)
- **Swarm Intelligence**
  - Particle Swarm Optimization (PSO)
  - Ant Colony Optimization (ACO)
- **Artificial Neural Networks (ANN)**



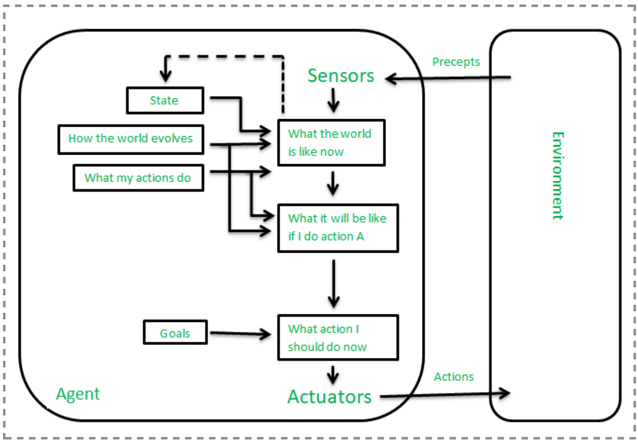
Multi agent systems

Involve multiple intelligent agents working together. Key features:

- Agent communication
- Automated negotiation
- Natural language processing(NLP)
- NL-based conversion agents.



Intelligent Agents



What is an Intelligent Agent?

A system that is capable of ***autonomous action*** in some ***environment*** in order to meet its ***design objectives.***

- **Autonomy**: The ability to act **independently,** exhibiting control over **one's** internal state.

Example-Self driving car

A self-driving car is driving down the street at 4:00 PM on a Tuesday. It approaches two parking spaces: One in front of a bank One across the street Its sensors detect a Clearway sign near the bank.

Performance measures:

- Maintain safety, reach destination, obey laws, passenger comfort,
    - **Legality: Did** the car obey traffic laws?
    - **Safety**:Did it avoid unsafe or sudden actions?
    - **Goal**: Did it park close to the destination?
    - **Comfort**: Was the ride smooth and without unnecessary delays?
    - **Efficiency**: Did the car make a prompt rational parking decision?

Environment:

- Roads, Intersections,Lanes, traffic signs, Pedestrians, Weather, other Vehicles
- Can be urban rural or highway

Actions:

- Steer, Park,Keep Driving, Honk NoOp

Sensor Percepts:

- Video,Sonar,speedometer, laser , odometer, engine sensors, microphone, Gps,
- [Location, Time, Day, SignStatus, ObstacleDetected]

Initial State:

Environment:Urban street with parking spaces, road signs, and light traffic
Percepts:**[Bank Street, 4:00PM, Tuesday, ClearWay Active,No Obstacle)**
Objective:Park legally and safely near the Bank
Goal:Choose the best legal parking space.
Default: Assault all spaces are valid unless restricted by signs or conditions
Available Spaces:

- Spot A:In front of Bank
- Spot B:Across Street

Constraints:Sign detected("CLEAWAY 3:30PM-6:30PM Mon-Fri")OR Obstacle detected ("Thing in spot")

Version 1:Sign Detected And Clearway active	Version 2:Sign Obscured and Obstacle in place
1. Spot A: **Percept**:[Bank, 4:00Pm,Tuesday,Clearway Active, No obstacle] **Action**: Keep driving(DO NOT PARK) 2. Spot B: **Percept**:[Across Street, 4:00 PM, Tuesday, No Sign, No Obstacle] **Action**:Steer and Park 3. Finish: Goal Complete **Action**: NoOp	1. **Spot A:** Percept:[Bank Street, 4:00 PM, Tuesday, No Sign, Obstacle Detected] **Action**:**Keep driving(DO NOT PARK)** 2. **Spot B:** **Percept**:[Across Street, 4:00 PM, Tuesday, No Sign, No Obstacle] **Action**:Steer and Park 3. **Finish**: Goal Complete **Action**: NoOp

Action Sequence

At Spot A → If Clearway Active OR Obstacle Present → Keep Driving
At Spot B → If No Sign and No Obstacle → Park
Finish → NoOp

Agent Type	Performance Measure	Environment	Actuators	Sensors
Taxi driver	Safe, fast, legal, comfortable trip, maximize profits	Roads, other traffic, pedestrians, customers	Steering, accelerator, brake, signal, horn, display	Cameras, sonar, speedometer, GPS, odometer, accelerometer, engine sensors, keyboard

Figure 2.4 PEAS description of the task environment for an automated taxi.

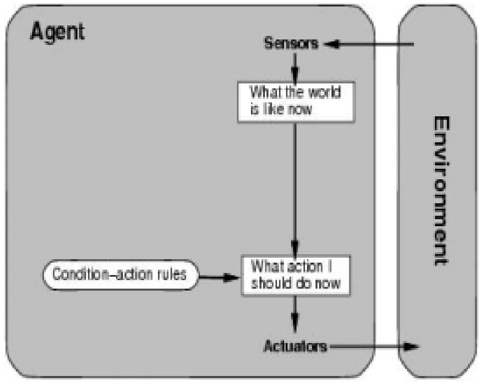
Agent Types (including LLM-based)

Agents can be classified based on how they make decisions:

Simple Reflex

Acts **only on the current percept**, ignoring past data or state.

- Selects actions based **only on the current percept**.
- **Ignore** the **history** of percepts or internal state.
- Uses **condition-action rules(If-Then)**.
- **Efficient** but limited to **fully observable** environments, Due to lack of memory/learning and inflexibility.
  - Example (Vacuum Agent):
  - If status = dirty → suck
  - Else if at A → move right
  - Else → move left



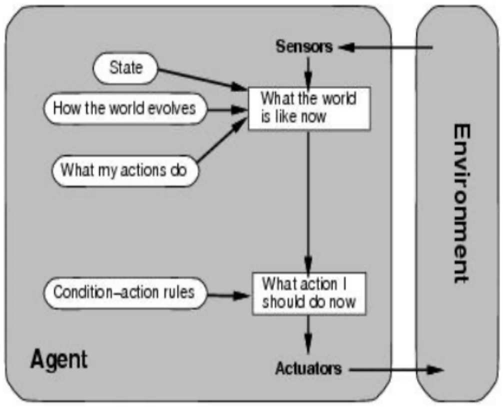
Model-Based Reflex(REFLEX AND STATE)

Uses **current percept + internal memory** to make better decisions.

- Handles **partially observable environments.**
- **Maintains** an **internal state** for world tracking(**model of the world)**
  - Over time update state using world-knowledge
    - How does the world change?
    - How do actions affect the world.
  - Combines **reflex behavior** with **internal memory**.

Reflex + memory = better decisions

Example:A vacuum that remembers which rooms were cleaned, and avoids repeating.



Goal-based

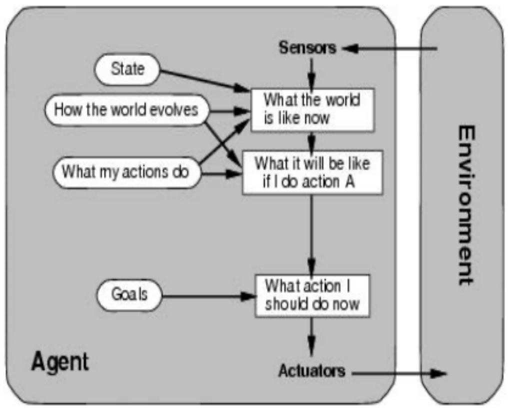
Chooses actions that lead toward a **defined goal**.

- Requires a **goal** to evaluate which situations are desirable.(goal representation)
  - Plans sequences of actions to **achieve the goal**.
  - Involves **search and planning** techniques.
  - Consider the **future** when deciding.
  - More **flexible** because knowledge is **explicitly represented and modifiable**.

Example (Shopping Agent):

- Goal: Buy a phone under $500
- If found and affordable → Buy
- Else → Search again or Compare

Useful in **complex environments** where multiple steps are needed to reach a goal.



Utility-based

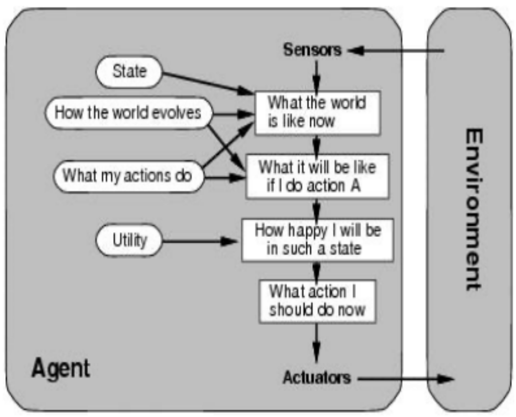
Chooses the **best** action based on a **utility function**.

- Some goals can be achieved in **multiple ways**; some are **better than others**.
- Uses a **utility function** to rank outcomes or states.
- Helps the agent:
  - Choose between **conflicting goals**.
  - **Prioritize** based on **success likelihood** or **desirability**.
- Improves upon pure goal-based agents by allowing **preference-based decisions**.

Example (Smart Light Agent):

- If room occupied & brightness < 70% → increase brightness
- If unoccupied & brightness > 10% → dim
- Else → turn off

More realistic and practical when agents must balance trade-offs.



Agent types: learning

Agent Programs and Learning

- All previous **agent programs** describe **methods for selecting actions**.
- However, they **do not explain how the agent program itself is created**.
- **Learning mechanisms** are used to generate or improve agent programs.
- Instead of instructing agents, we can **teach them** through data and feedback.
- **Advantage**: Agents become more **robust** in **initially unknown environments**.

Learning Agent

Learns and improves its behavior over time through experience.

- Can **adapt** to unknown or changing environments
- Adds a **learning component** to any of the above types
- Learns from:
  - **Experience (e.g. trial & error)**
  - **Feedback (e.g. success/failure)**
  - **Exploration (e.g. trying new actions)**

Components:

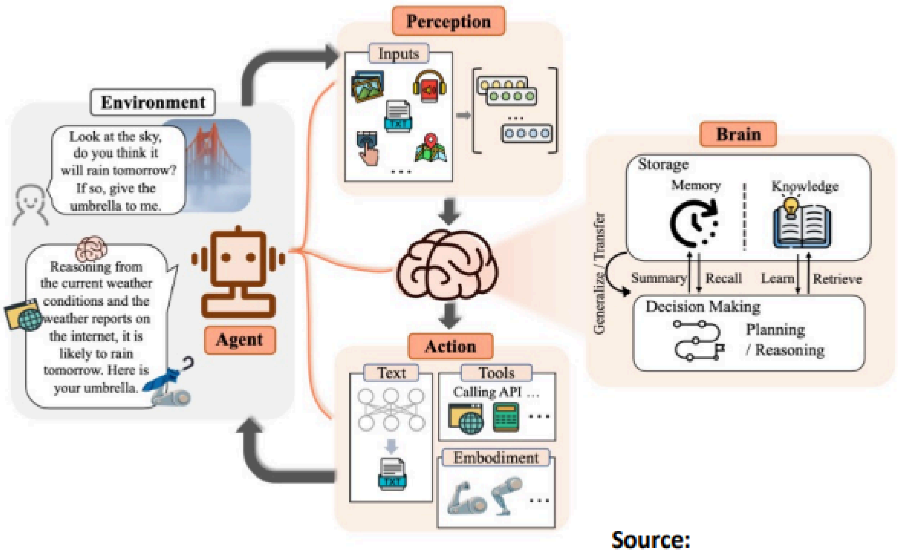
- **Performance Element**: Chooses actions
- **Learning Element**: Improves behavior
- **Critic**: Provides feedback
- **Problem Generator**: Suggests new actions to explore

Example:

An LLM-based chatbot that improves responses over time by learning from user feedback.

- Becomes better over time, especially in **unknown or dynamic environments**.

1. The Birth of An Agent: Construction of LLM-based Agents



Source:
https://github.com/WooooDyy/LLM-Agent-Paper-List

1.1 Brain: Primarily Composed of An LLM