Einführung in die KI

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LaTeX version: SCHOUTER

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1 Introduction

1.1 What is AI?

Literature:

- Empfohlenes Begleitbuch: Russel and Norvig, Artificial Intelligence: A Modern Approach, 4. Edition 2020.

1.1.1 Definitionen (Definitions)

1.1.2 Definitions

There is no easy, official definition for AI. Two classic definitions are:

- **John McCarthy (1971):** "The science and engineering of making intelligent machines, especially intelligent computer programs." AI does not have to confine itself to methods that are biologically observable.
- **Marvin Minsky (1969):** "The science of making machines do things that would require intelligence if done by men".

1.1.3 Categories of AI

AI definitions can be classified along two dimensions

1. Thought processes/reasoning vs. behavior/action
2. Success according to human standards vs. success according to an ideal concept of intelligence (rationality)

- **Systems that think like humans:**
  - Cognitive Science.
  - Builds on cognitive models validated by psychological experiments and neurological data.
- **Systems that act like humans:**
  - The **Turing Test**
- **Systems that think rationally:**
  - Focus on "Laws of Thoughts," correct argument processes.
- **Systems that act rationally:**
  - Focus on "doing the right thing" (**Rational Behavior**).
  - A rationally acting system maximizes the achievement of its goals based on the available information.
  - This is more general than rational thinking (as a provably correct action often does not exist) and more amenable to analysis.

1.1.4 General vs. Narrow AI

- **General (Strong) AI:** Can handle *any* intellectual task that a human can. This is a research goal.
- **Narrow (Weak) AI:** Is specified to deal with a *concrete* or a set of specified tasks. This is what we currently use primarily.

1.2 What is Intelligence?

1.2.1 The Turing Test

- **Question:** When does a system behave intelligently?

- **Assumption:** An entity is intelligent if it cannot be distinguished from another intelligent entity by observing its behavior.
- **Test:** A human interrogator interacts "blind" (e.g., via text) with two players (A and B), one of whom is a human and one a computer.
- **Goal:** If the interrogator cannot determine which player... is a computer... the computer is said to pass the test.
- **Relevance:** The test is still relevant, requires major components of AI (knowledge, reasoning, language, learning), but is hard/not reproducible and not amenable to mathematical analysis.

1.2.2 The Chinese Room Argument

- **Question:** Is intelligence the same as intelligent behavior?
- **Assumption:** Even if a machine behaves in an intelligent manner, it does not have to be intelligent at all (i.e., without understanding).
- **Thought Experiment:** A person who doesn't know Chinese is locked in a room. They receive Chinese notes (questions) and have a detailed instruction book telling them which Chinese symbols (answers) to output based on the input symbols, without understanding it at all.
- **Result:** From the outside, the room "understands" Chinese (it behaves intelligently), but the person inside understands nothing.
- **Follow-up Question:** Is a self-driving car intelligent?

1.3 Foundations, Taxonomy & Limits

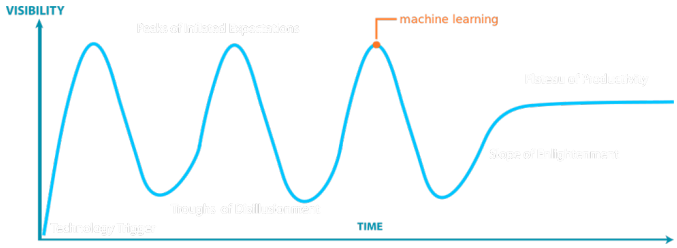
1.3.1 Foundations of AI

AI is an interdisciplinary field built on contributions from many areas:

- **Philosophy:** Logic, reasoning, rationality, mind as a physical system.
- **Mathematics:** Formal representation and proof, computation, probability.
- **Psychology:** adaptation, phenomena of perception and motor control.
- **Economics:** formal theory of rational decisions, game theory.
- **Linguistics:** knowledge representation, grammar.
- **Neuroscience:** physical substrate for mental activities.
- **Control theory:** ...optimal agent design.

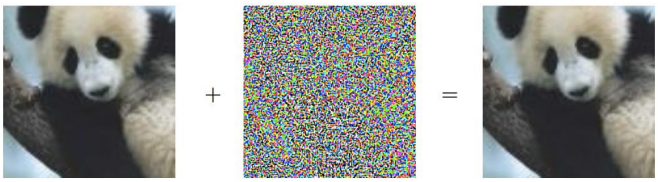
1.3.2 Taxonomy and History

- **Taxonomy: Artificial Intelligence** is the broadest field. **Machine Learning (ML)** is a subfield of AI. **Deep Learning** is a subfield of ML.
- **Subdisciplines of AI:** Include Machine Learning, Deep Learning, Search and Optimization, Robotics, Natural Language Processing (NLP), Computer Vision (CV), and Cognitive Science.
- **History:** The development of AI occurred in cycles, often called "AI Winters". Hype phases ("Peaks of Inflated Expectations") existed for "neural networks", "expert systems", and "machine learning".



1.3.3 Limits of Current AI

- **"A.I. is harder than you think":**
  - Current AI is often isolated to single problems.
  - AI models are **not without bias**.
  - There are **fundamental differences** in how AI perceives the world/environment.
- **AI can be tricked (Adversarial Examples):**
  - AI systems can be manipulated by perturbations (noise) often invisible to humans.
  - Example: An image of a "panda" is classified as a "gibbon" with high confidence after adding noise.



"panda"
57.7% confidence

"gibbon"
99.3 % confidence

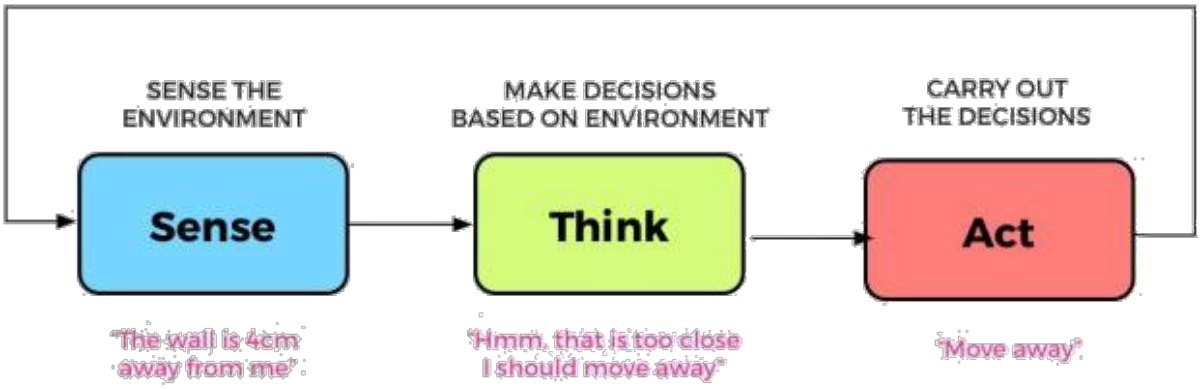
2 AI Systems: Agents and Environments

Definition: AI System

An AI system is defined as the study of (rational) **agents** and their **environments**. The system has two main parts:

1. **Agent:** Anything that can be viewed as perceiving its environment through **sensors** and acting upon that environment through **actuators**.
2. **Environment:** The surroundings or conditions in which the agent lives or operates. This can be real (e.g., streets for a self-driving car) or artificial (e.g., a chessboard).

The agent follows a continuous **Sense** → **Think** → **Act** loop.



2.1 Rationality

Rationality

- A **rational agent** is one that "does the right thing".
- A **rational action** is one that maximizes the agent's performance and yields the best positive outcome.
- **Key Point:** Rationality maximizes **expected** performance, not necessarily the *optimal* outcome. E.g., not playing the lottery is rational (positive expected outcome), even if playing could lead to the optimal outcome (winning).
- Rationality is **not** omniscient. An omniscient agent would know the *actual* outcome of its actions, which is impossible in reality.

A **performance measure** is a function that evaluates a sequence of actions.

General Rule for Design

Design the performance measure based on the **desired outcome**, not the desired agent behaviour.

2.2 Characteristics of Environments

The design of an agent heavily depends on the type of environment it operates in. Environments are characterized along several key dimensions.

Environment Dimensions

- **Discrete vs. Continuous:** Does the environment have a limited, countable number of distinct states (e.g., chess) or is it continuous (e.g., position and speed of a self-driving car)?
- **Observable vs. Partially/Unobservable:** Can the agent's sensors determine the *complete* state of the environment at each time point? If not, it is **partially observable** (e.g., a taxi cannot know pedestrian intentions, poker agent cannot see opponent's cards).
- **Static vs. Dynamic:** Does the environment change while the agent is acting/deliberating? A crossword puzzle is **static**; taxi driving is **dynamic** (other cars move).
- **Single Agent vs. Multiple Agents:** Is the agent operating by itself? Or does the environment contain other agents (e.g., other drivers, poker players)?
- **Accessible vs. Inaccessible:** Can the agent obtain *complete and accurate* information about the environment's state?
- **Deterministic vs. Non-deterministic (Stochastic):** Is the next state of the environment completely determined by the current state and the agent's action? Chess is **deterministic**. A self-driving car is **non-deterministic** (turning the wheel can have slightly different effects due to road friction, wind, etc.).
- **Episodic vs. Sequential:** In an **episodic** environment, the agent's experience is divided into "episodes". The quality of its action depends only on the current episode (perceive → act). In a **sequential** environment, the agent requires memory of past actions to make the best decision.

Key Distinction: Observable vs. Accessible

- **Accessibility** concerns the environment itself: whether the information exists and can *in principle* be obtained.
- **Observability** concerns the agent's *sensors*: whether they can actually perceive that information.

Environment	Discrete?	Observable?	Static?	Single Agent?	Accessible?	Deterministic?	Episodic?
Chess	Discrete	Observable	Static	Multi-Agent	Accessible	Deterministic	Sequential
Solitaire	Discrete	Observable	Static	Single Agent	Accessible	Deterministic	Sequential
Poker	Discrete	Partially Observable	Static	Multi-Agent	Partially Accessible	Stochastic	Sequential
Self-Driving	Continuous	Partially Observable	Dynamic	Single Agent	Inaccessible	Stochastic	Sequential
Medical Diagnosis	Discrete	Partially Observable	Static	Single Agent	Inaccessible	Stochastic	Episodic

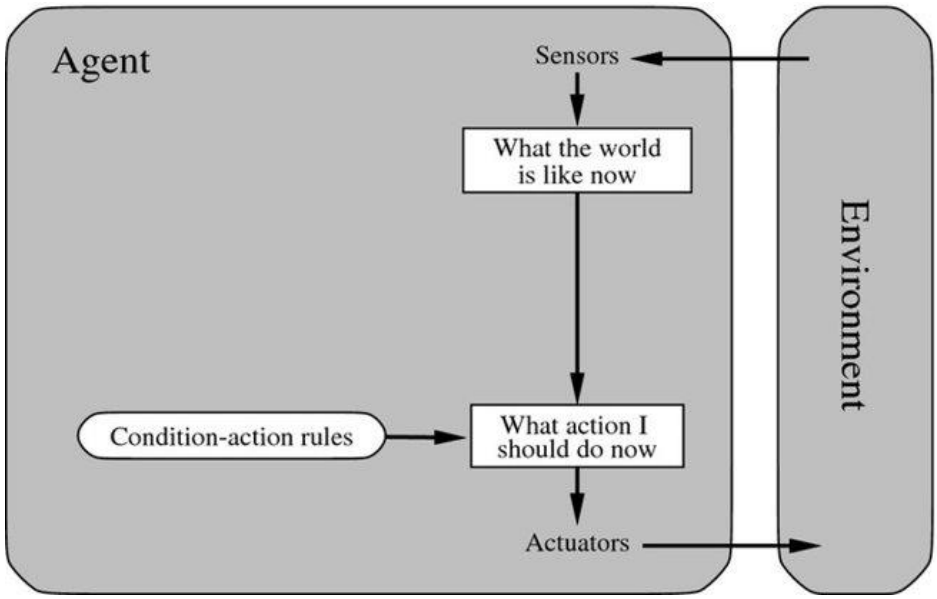
Characteristics of various environments

2.3 Types of Agents

Agents are categorized based on their perceived intelligence and complexity.

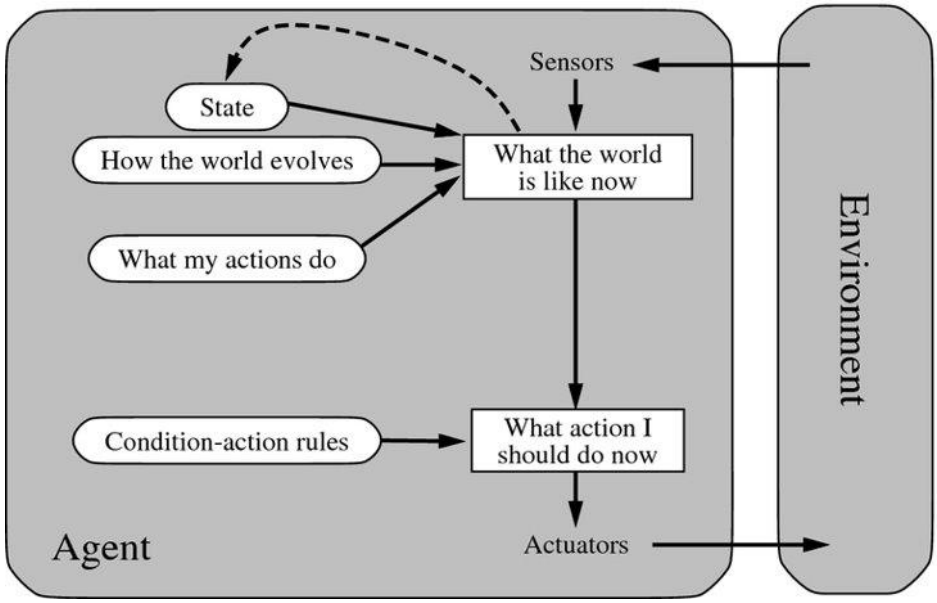
2.3.1 Reflex Agent

- Selects actions based **only on the current percept**, ignoring the percept history.
- Implemented with simple **condition-action rules**.
- Example: A thermostat (IF temp $< 20°C$ → turn on heater).
- **Problem:** Very limited. No knowledge of anything it cannot actively perceive.



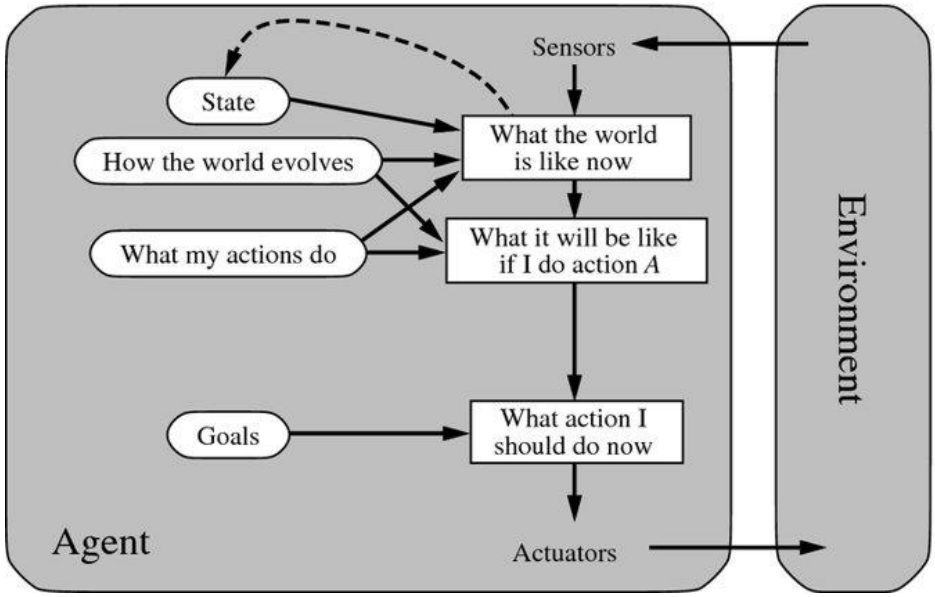
2.3.2 Model-based Agent

- These agents **keep track of the world state**.
- They maintain an **internal state (a world model)** that describes how the world evolves and how the agent's actions affect it.
- This allows the agent to handle partially observable environments.
- Example: A warehouse robot tracking inventory positions.



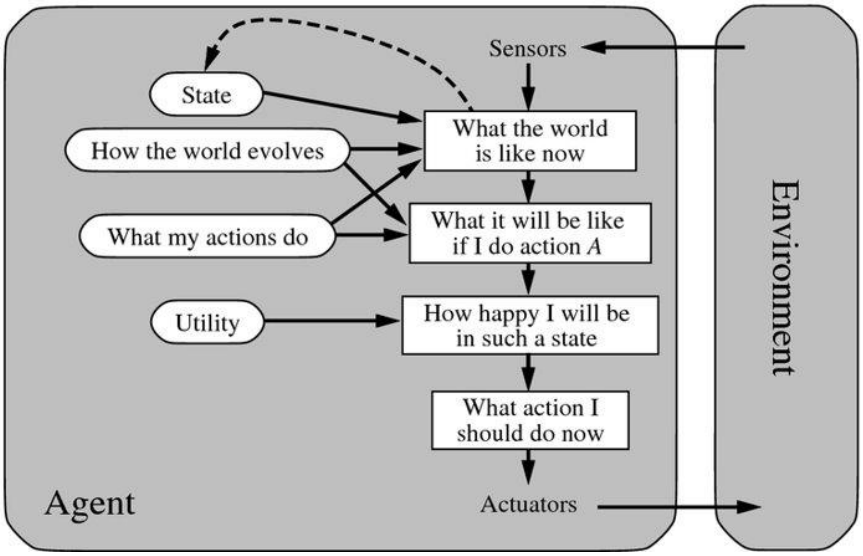
2.3.3 Goal-based Agent

- Builds on a model-based agent, but also knows what states are **desirable** (i.e., it has **goals**).
- This allows the agent to make decisions by considering the future, asking "What will happen if I do action A?" and "Will that action achieve my goal?".
- Example: A chess agent whose goal is to checkmate the opponent.



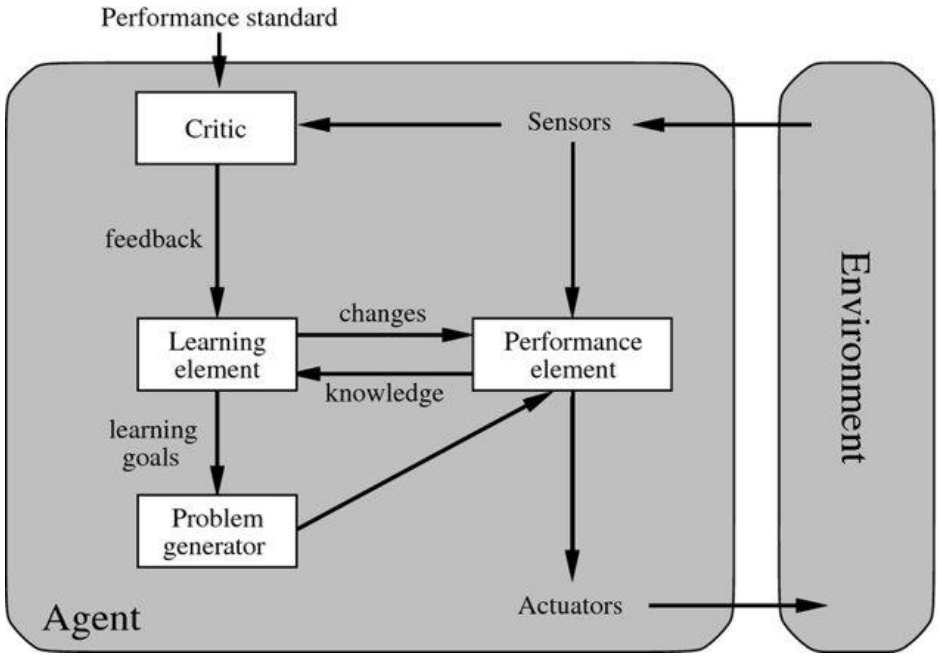
2.3.4 Utility-based Agent

- Goals provide a binary distinction (achieved / not-achieved). A **utility function** provides a continuous scale, rating each state based on the desired result ("how happy" the agent is).
- This is crucial for resolving **conflicting goals** (e.g., is speed or safety more important for a self-driving car?).
- Allows the agent to choose the action that maximizes its **expected utility**.



2.3.5 Learning Agent

- Employs a **learning element** to gradually improve and become more knowledgeable over time.
- Can learn from its past experiences and adapt automatically.
- More robust in unknown environments.



Four Components of a Learning Agent

1. **Learning Element:** Responsible for making improvements by learning from the environment.
2. **Critic:** Gives feedback on how well the agent is doing with respect to a fixed performance standard.
3. **Performance Element:** Responsible for selecting actions (this is the "agent" part).
4. **Problem Generator:** Responsible for suggesting actions that will lead to new (and potentially informative) experiences.

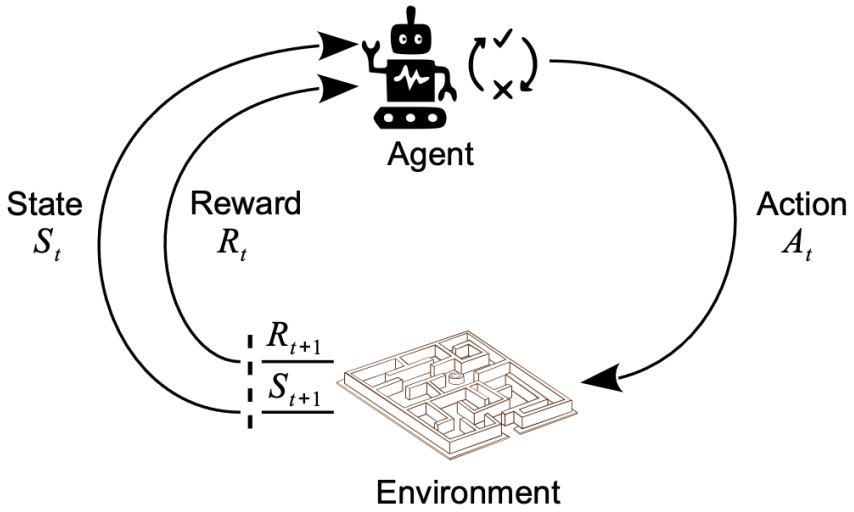
Agent Types Summary

- **Reflex agent:** reacts.
- **Model-based agent:** remembers.
- **Goal-based agent:** plans.
- **Utility-based agent:** optimizes.
- **Learning agent:** improves itself over time.

2.4 How to Make Agents Intelligent

There are several high-level approaches to selecting intelligent actions:

- **Search Algorithms:** Understand "finding a good action" as a search problem and use tree-based algorithms to find a solution (path to a goal).
- **Reinforcement Learning (RL):** Based on trial and error, similar to animal conditioning. The agent receives **rewards** (positive) or **pain/punishments** (negative) from the environment and learns to choose actions that maximize its cumulative reward.



- **Genetic Algorithms (GAs):** Inspired by Darwinian evolution ("survival of the fittest"). A **population** of agents is generated, evaluated by a **performance function**, and the best ones are "bred" (using **crossover** and **mutation**) to create a new, potentially better, generation.