Artificial Intelligence

B.Tech(AIDS)_V Semester

Academic Year: 2024-2025

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Syllabus

UNIT - I

Introduction: The Foundation of AI, The History of AI, The State of art.**Intelligent agents**: Agent and Environments, Good Behavior, Nature of Environments, Structure of Agents

UNIT - II

Search Algorithms: State space representation, Search graph and Search tree. Random search, Search with closed and open list, Depth first and Breadth first search. Heuristic search, Best first search. A* algorithm, problem reduction, constraint satisfaction, Game Search, minmax algorithm, alpha beta pruning, constraint satisfaction problems.

UNIT - III

Knowledge & Reasoning: Knowledge-Based Logic Agents, Logic, First-Order Logic, Syntax-Semantics in FOL, Simple usage, Inference Procedure, Inference in FOL, Reduction, Inference Rules, Forward Chaining, Backward Chaining, Resolution.

UNIT - IV

Probabilistic Reasoning: Representing knowledge in an Uncertain Domain, The semantics of Bayesian networks, efficient representation of conditional distribution, Inference in Bayesian Networks, Inference in Temporal Models, Hidden Markov models. **Markov Decision Process:** MDP formulation, utility theory, utility functions, value iteration, policy iteration and partially observable MDPs.

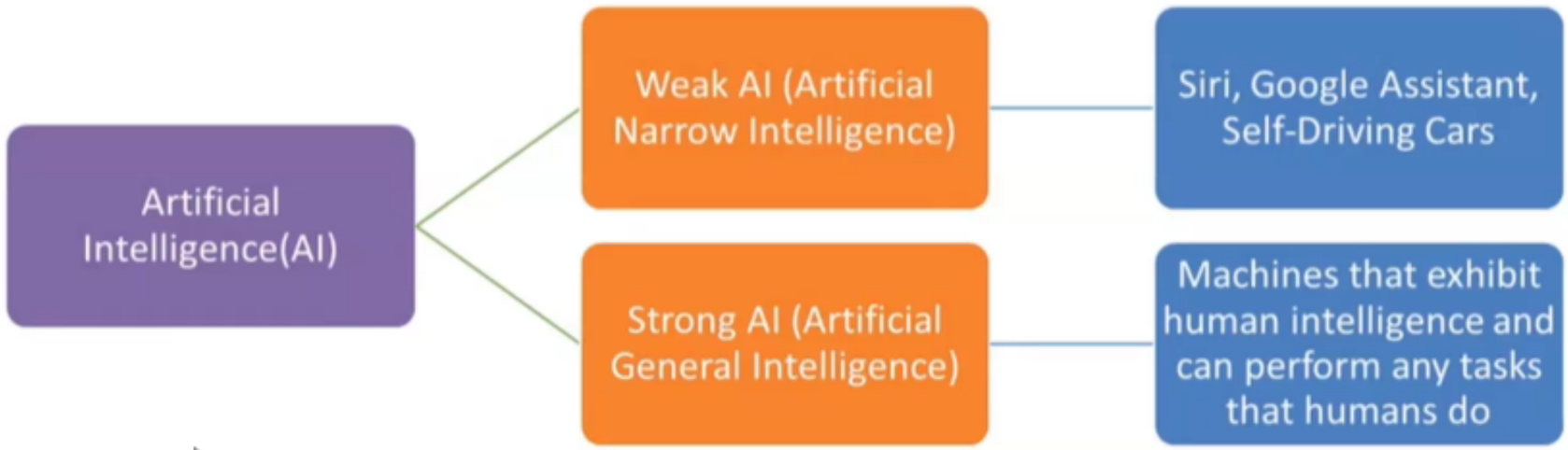
UNIT - V

Reinforcement Learning: Introduction**,** Passive reinforcement learning, Active Reinforcement Learning, Generalization in reinforcement learning, adaptive dynamic programming, temporal difference learning, active reinforcement learning- Q learning.

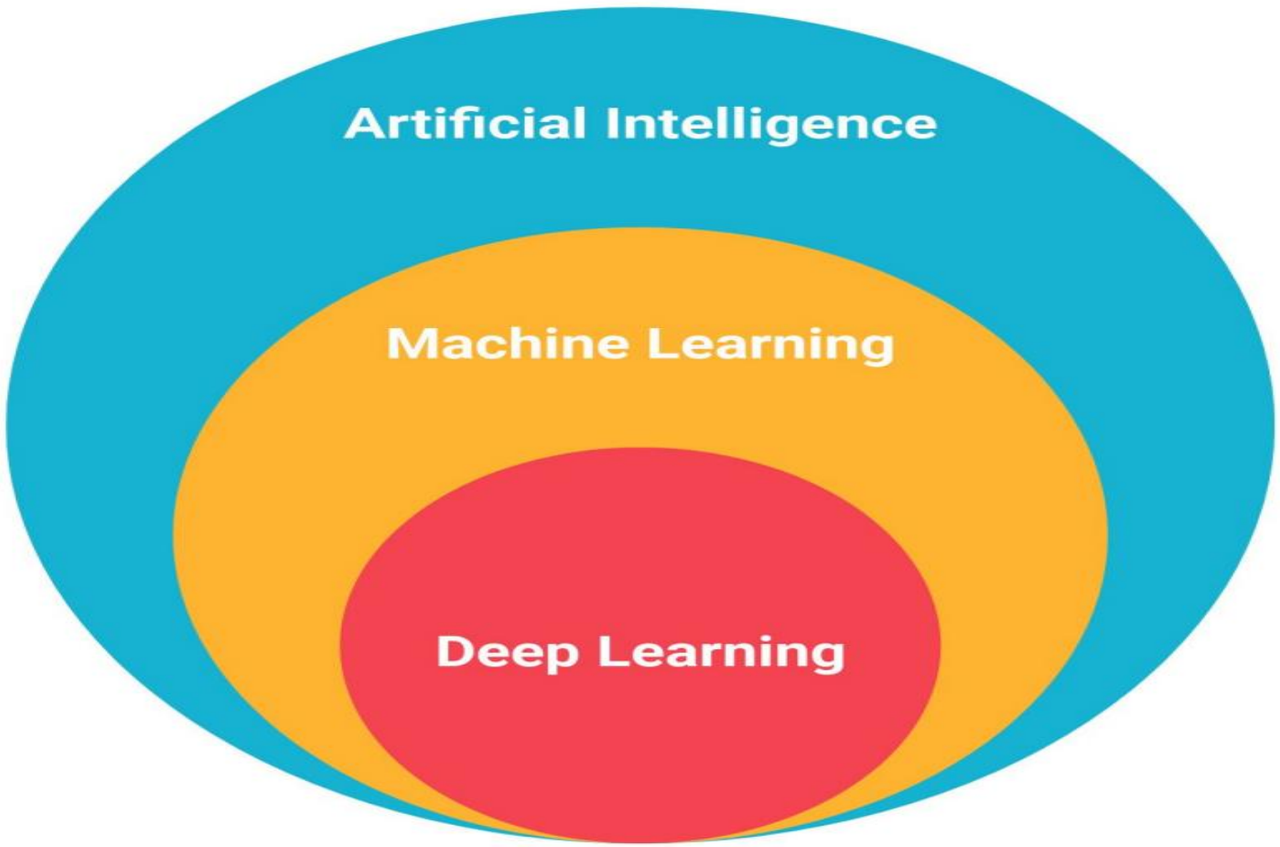
Course Outcomes

1. Define the role of agents and interaction with the environment to establish goals.
2. Identify and formulate search strategies to solve problems by applying suitable search strategy.
3. Understand probabilistic reasoning and Markov decision process to solve real world problems.
4. Design applications using Reinforcement Learning.
5. Apply AI concepts to solve the real-world problems

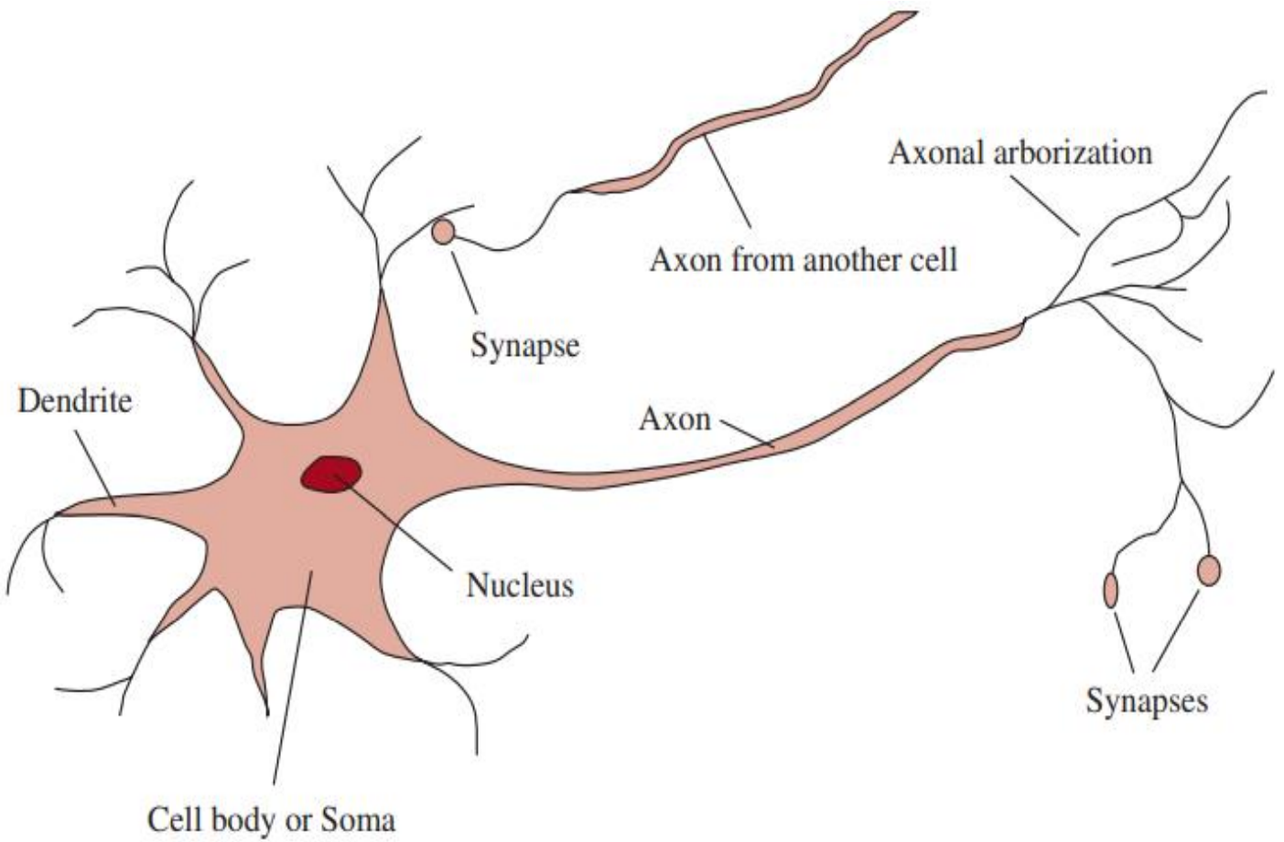
Introduction to Artificial Intelligence



Introduction to AI



Biological Neuron



Human Sensors Vs Artificial Sensors

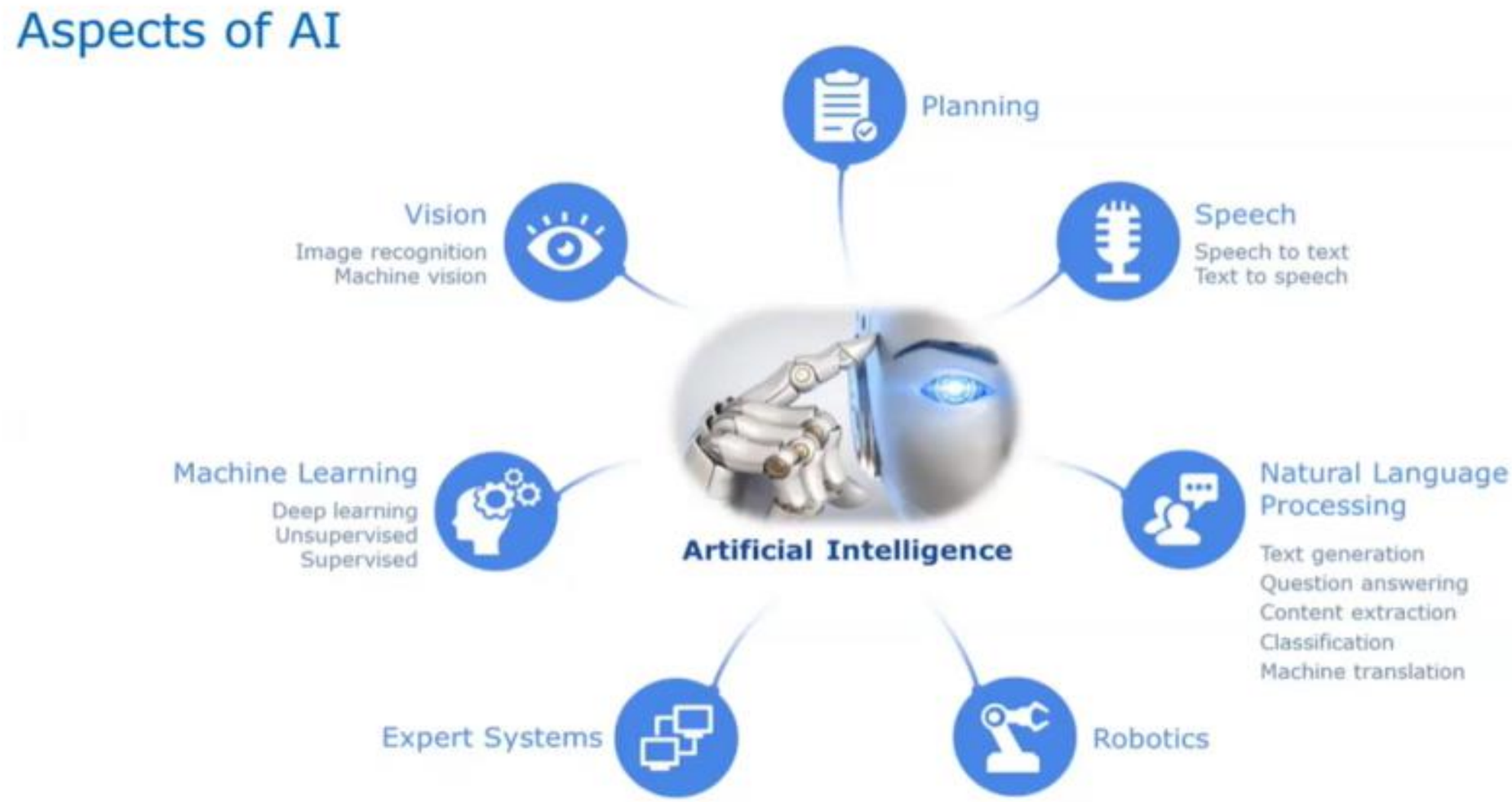
- Eyes
- Skin
- Ears
- Tongue
- Nose

Basic Computer capabilities to be acted as Human

1. Natural language processing: To communicate successfully in a human language
2. Knowledge representation: To store what it knows or hears
3. Automated reasoning to answer questions and to draw new conclusions
4. Machine learning: To adapt to new circumstances and to detect and extrapolate patterns.
5. Computer vision and speech recognition: To perceive the world
6. Robotics: To manipulate objects and move about.

Aspects of AI

Introduction to Artificial Intelligence



Definition of AI

"Intelligence: The ability to learn and solve problems"

Webster's Dictionary.

"Artificial intelligence (AI) is the intelligence exhibited by machines or software'

Wikipedia.

"The science and engineering of making intelligent machines"

McCarthy.

"The study and design of intelligent agents, where an intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success."

Russel and Norvig AI book.

Why AI

"Just as the Industrial Revolution freed up a lot of humanity from physical drudgery, I think AI has the potential to free up humanity from a lot of the mental drudgery."

Andrew Ng.

What is AI?

Four schools of thoughts (Russel & Norvig)

Thinking humanly	Thinking rationally
"The exciting new effort to make computers think... *machines with minds*, in the full and literal sense." (Haugeland, 1985)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985
Acting humanly	**Acting rationally**
"The study of how to make computers do things 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)

What is AI

Thinking humanly: cognitive approach

Requires to determine how humans think!
1960's "cognitive revolution".
Requires scientific theories of internal activities of the brain

- What level of abstraction? "Knowledge" or "circuits"?
- How to validate?

Today, Cognitive Science and Artificial Intelligence are distinct disciplines.

What is AI?

3 Thinking rationally: Laws of thoughts.

- Codify "right thinking" with **logic**.
- Several Greek schools developed various forms of logic: *notation* and *rules of derivation* for thoughts.
- Problems:

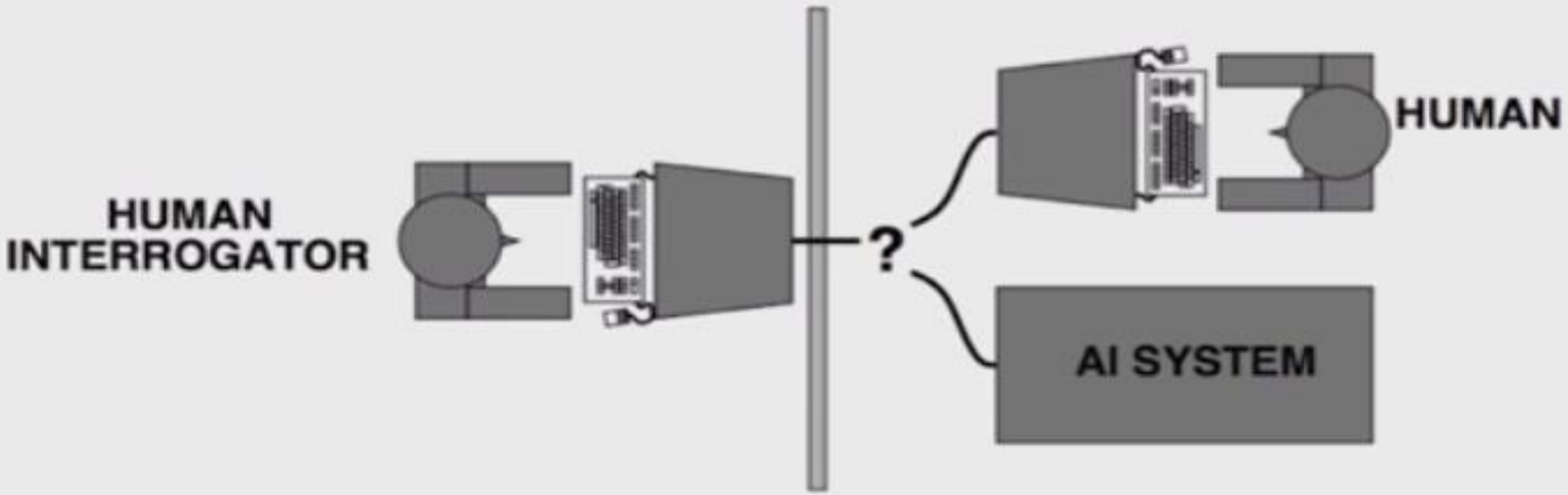
  1. Not all knowledge can be expressed with logical notations.
  2. Computational blow up.

What is AI?

(2) **Acting humanly:**

machines do things...

- **Turing test (Alan Turing 1950)**: A computer passes the test of intelligence, if it can fool a human interrogator.



- **Major components of AI:** knowledge, reasoning, language, understanding, learning.

What is AI?

Acting rationally:

- The right thing: that which is expected to maximize goal achievement, given the available information.
- A **rational agent** is one that acts so as to achieve the best outcome, or when there is uncertainty, the best expected outcome.
- Aristotle (Nicomachean Ethics):
  "Every art and every inquiry, and similarly every action and pursuit, is thought to aim at some good."

What is AI?

Acting humanly:

Applications of AI

Handwriting recognition (check, zipcode)

Applications of AI

Speech recognition

- Virtual assistants: Siri (Apple), Echo (Amazon), Google Now, Cortana (Microsoft).
- "They" helps get things done: send an email, make an appointment, find a restaurant, tell you the weather and more.
- Leverage deep neural networks to handle **speech recognition** and **natural language understanding**.

Applications of AI

Machine translation

- Historical motivation: translate Russian to English.
- First systems using **mechanical translation** (one-to-one correspondence) failed!
- "Out of sight, out of mind" $\Rightarrow$ "Invisible, imbecile".

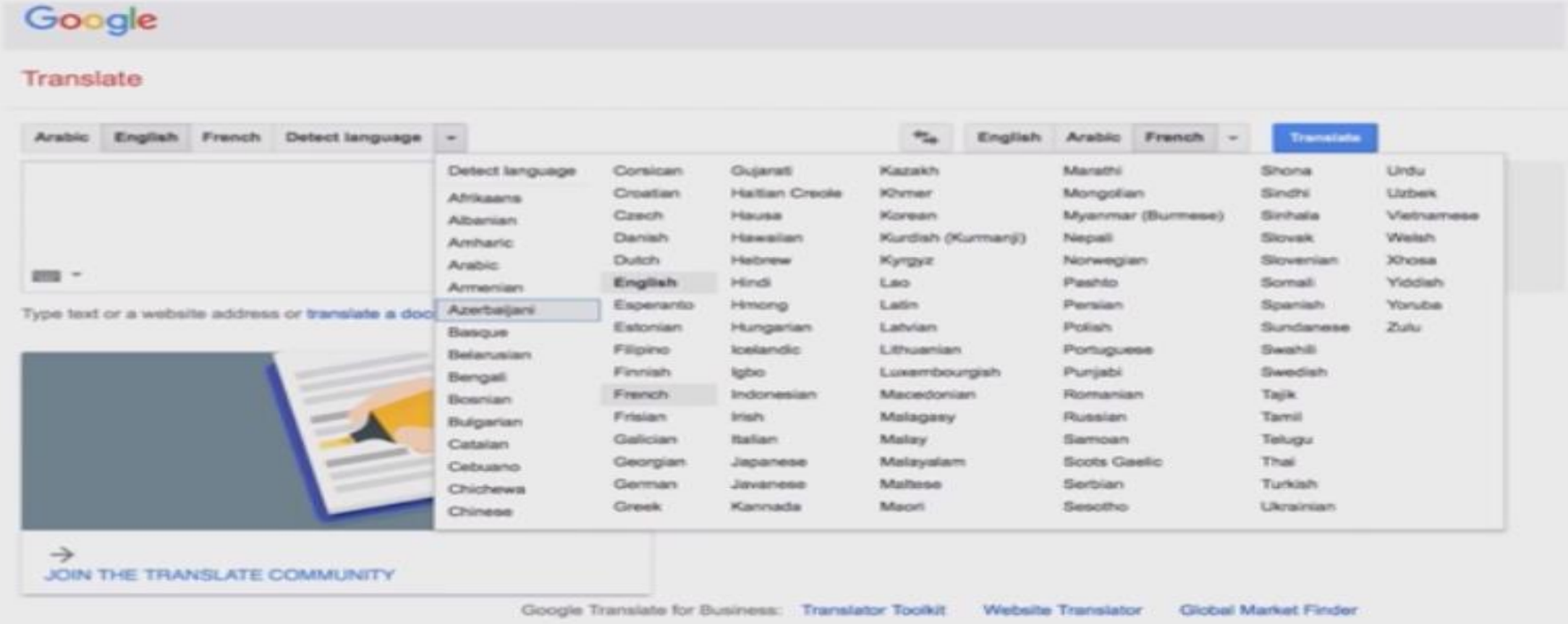
Applications of AI

Machine translation

- MT has gone through ups and downs.
- Today, **Statistical Machine Translation** leverages the vast amounts of **available translated corpuses**.
- While there is room for improvement, machine translation has made significant progress.

Applications of AI

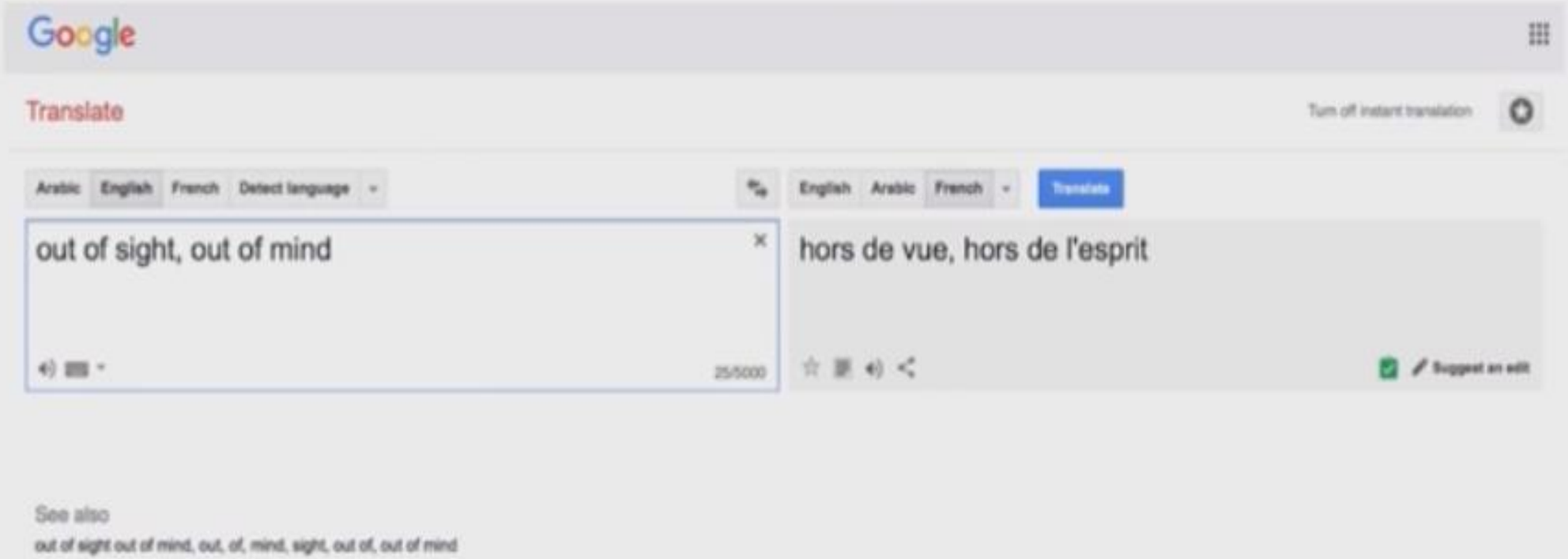
Machine translation



100+ languages

Applications of AI

Machine translation



Applications of AI

Robotics: Awesome robots today! NAO, ASIMO, and more!

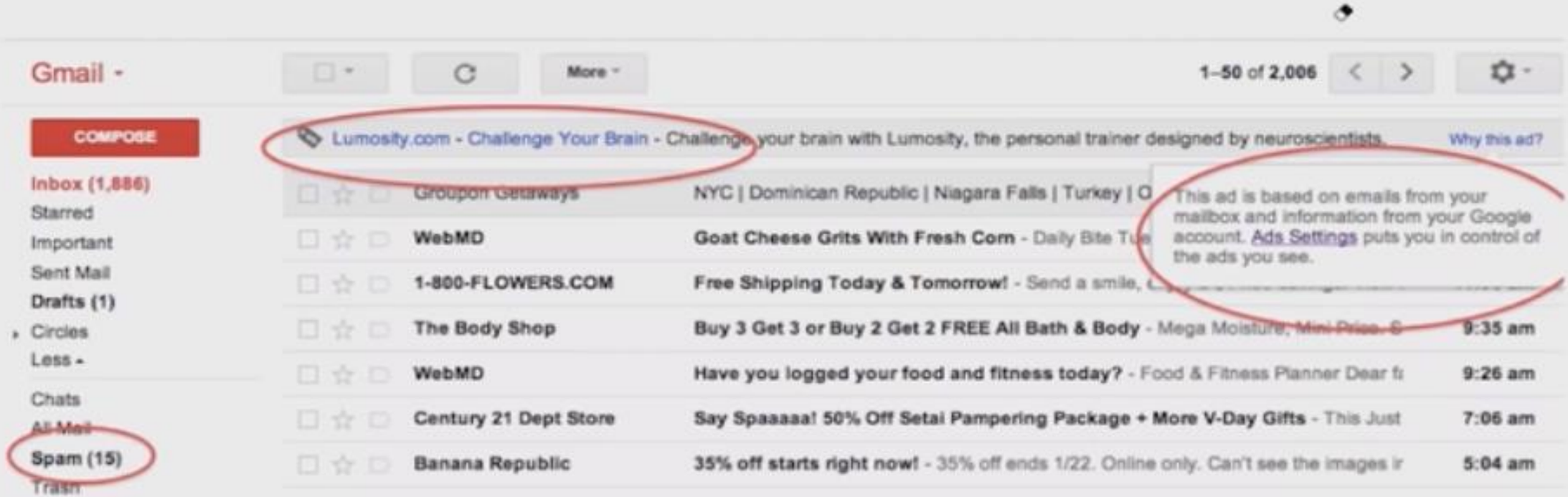
Credit: By Momotarou2012, via Wikimedia Commons.

Applications of AI

Recommendation systems (collaborative filtering)

Applications of AI

Email



Applications of AI

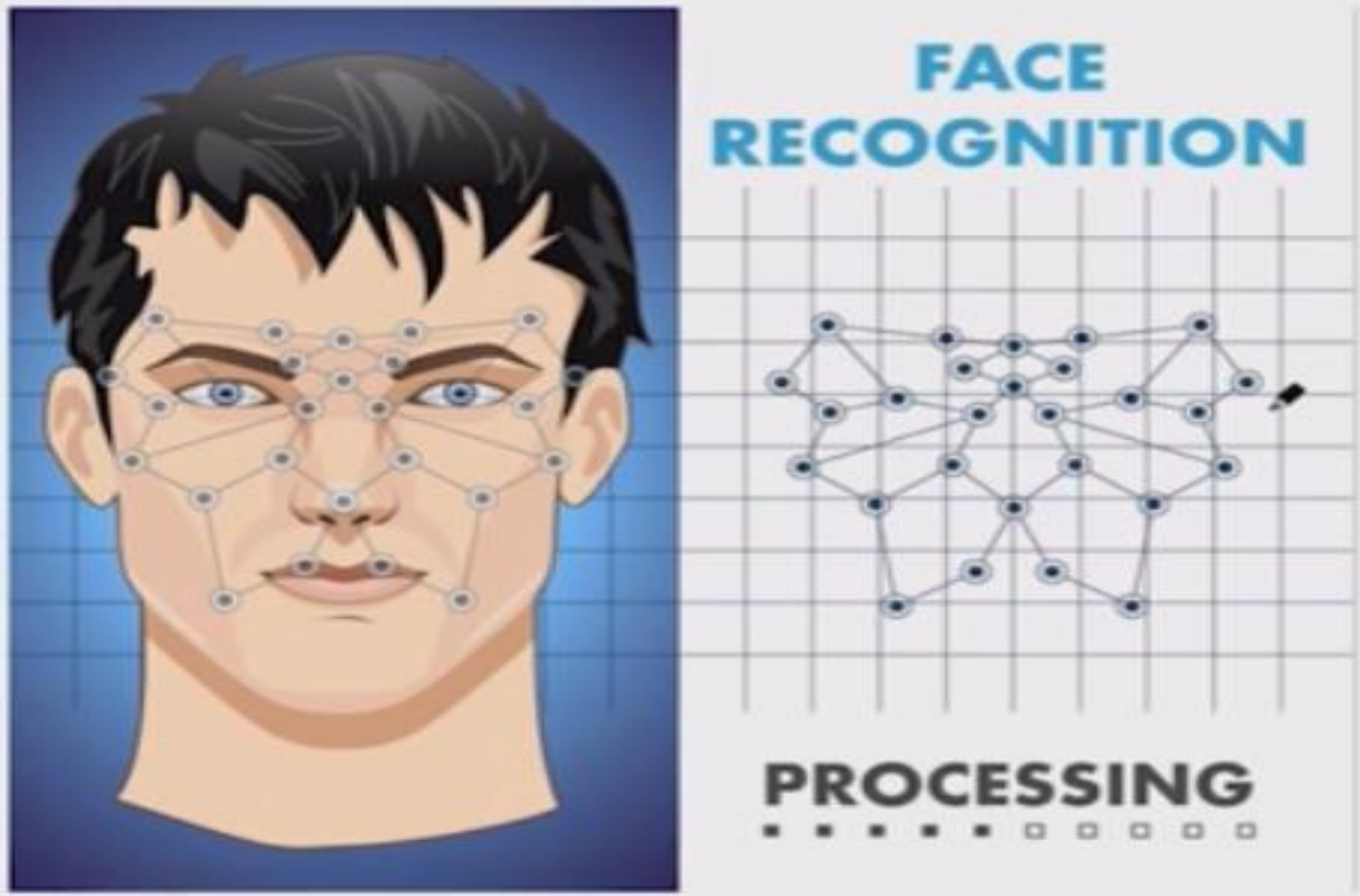
Face detection

Viola-Jones method.

Face detection

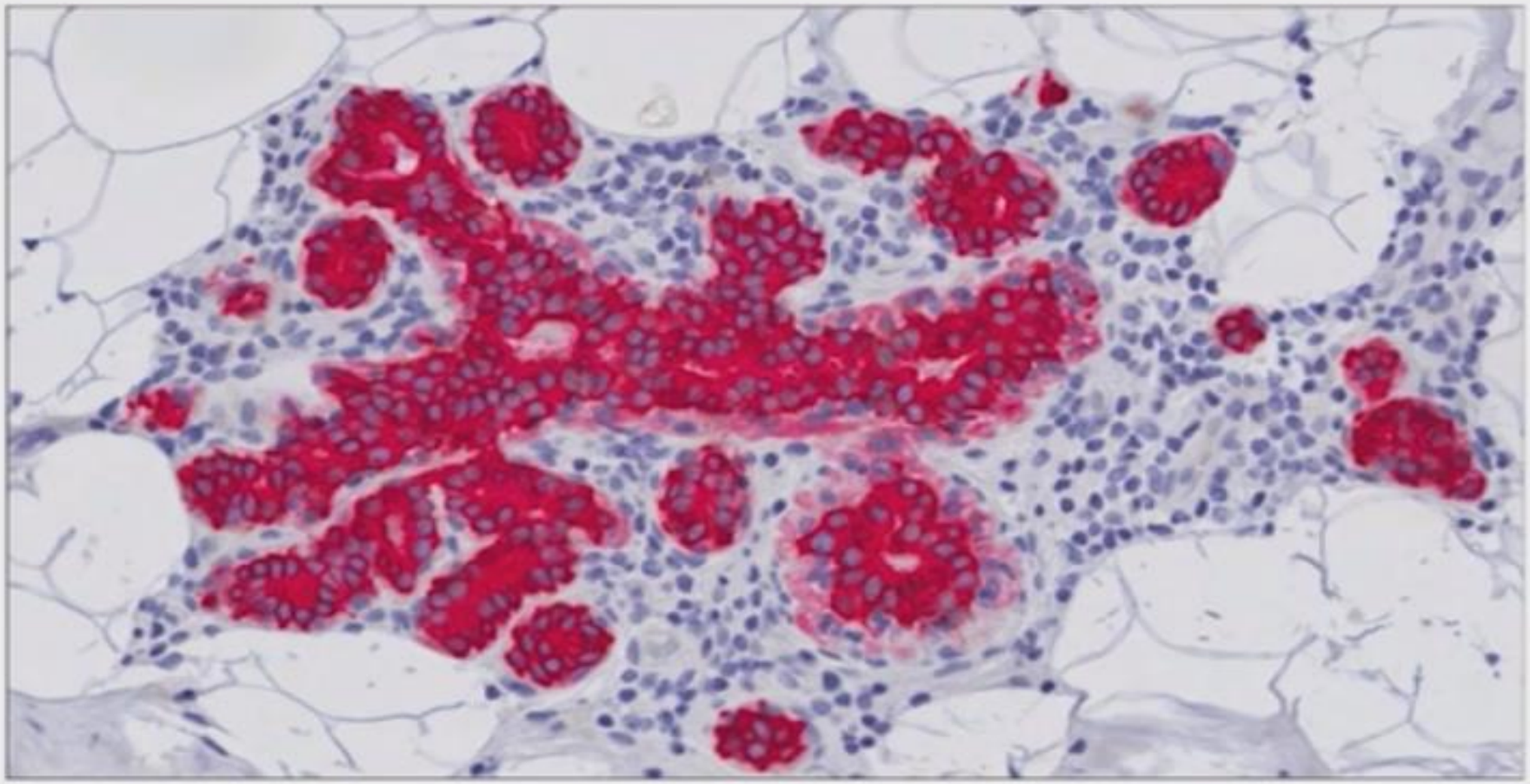
Viola-Jones method.

Face recognition



Applications of AI

Detection of breast cancer in mammography images



Chess (1997): Kasparov vs. IBM Deep Blue

(Left) Copyright 2007, S.M.S.I., Inc. - Owen Williams, The Kasparov Agency, via Wikimedia Commons (Right) By James the photographer, via Wikimedia Commons

Powerful search algorithms!

Jeopardy! (2011): Humans vs. IBM Watson

By Rosemaryetoufee (Own work), via Wikimedia Commons

Natural Language Understanding and information extraction!

Autonomous driving

By User Spaceape on en.wikipedia, via Wikimedia Commons

- DARPA Grand Challenge
  - 2005: 132 miles
  - 2007: Urban challenge
  - 2009: Google self-driving car

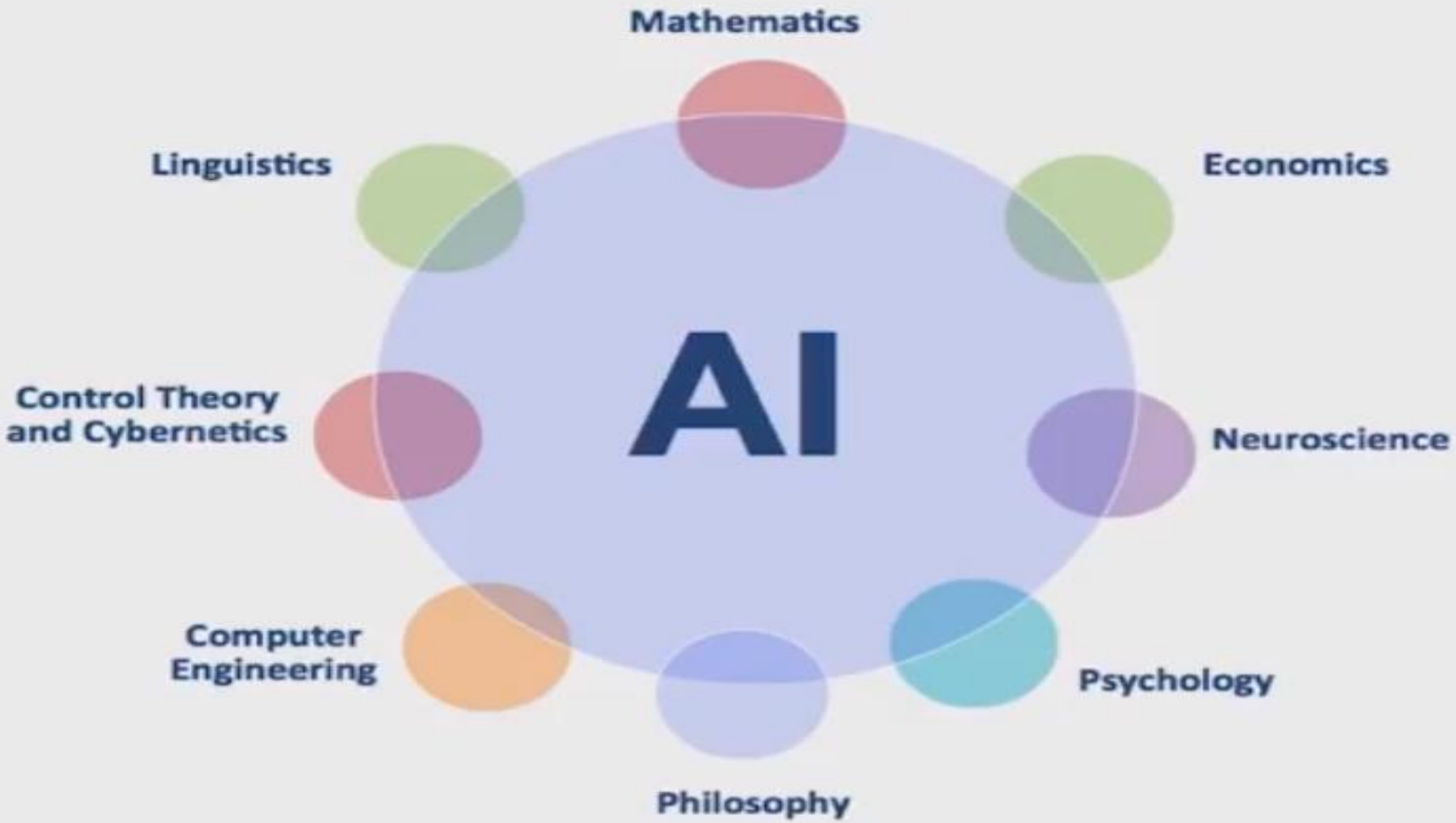
Applications

- **Natural Language Processing (NLP)**: concerned with the interactions between computers and human languages.

- **Vision/perception**: concerned with image processing and building computer vision agents. Goals: information extraction for tasks such as manipulation, navigation, and object recognition.

- **Robotics**: concerned with intelligent agents that manipulate the physical world. Different aspects: planning of robot motion, vision and object recognition.

Foundation of AI



Foundation of AI

- **Philosophy**
  - Logic, methods of reasoning.
  - Mind as physical system that operates as a set of rules.
  - Foundations of learning, language, rationality.
- **Mathematics**
  - Logic: Formal representation and proof.
  - Computation, algorithms.
  - Probability.
- **Economics**
  - Formal theory of rational decisions.
  - Combined decision theory and probability theory for decision making under uncertainty.
  - Game theory.
  - Markov decision processes.

Foundation of AI

- **Neuroscience**
  - Study of brain functioning.
  - How brains and computers are (dis)similar.
- **Psychology**
  - How do we think and act?
  - Cognitive psychology perceives the brain as an information processing machine.
  - Led to the development of the field *cognitive science*: how could computer models be used to study *language, memory, and thinking* from a psychological perspective.
- **Computer engineering**
  - Cares about how to build powerful machines to make AI possible.
  - E.g., Self-driving cars are possible today thanks to advances in computer engineering.

Foundation of AI

- **Control theory and cybernetics**
  - Design simple optimal agents receiving feedback from the environment.
  - Modern control theory design systems that maximize an objective function over time.

- **Linguistics**
  - How are language and thinking related.
  - Modern linguistics + AI = Computational linguistics (Natural language processing).

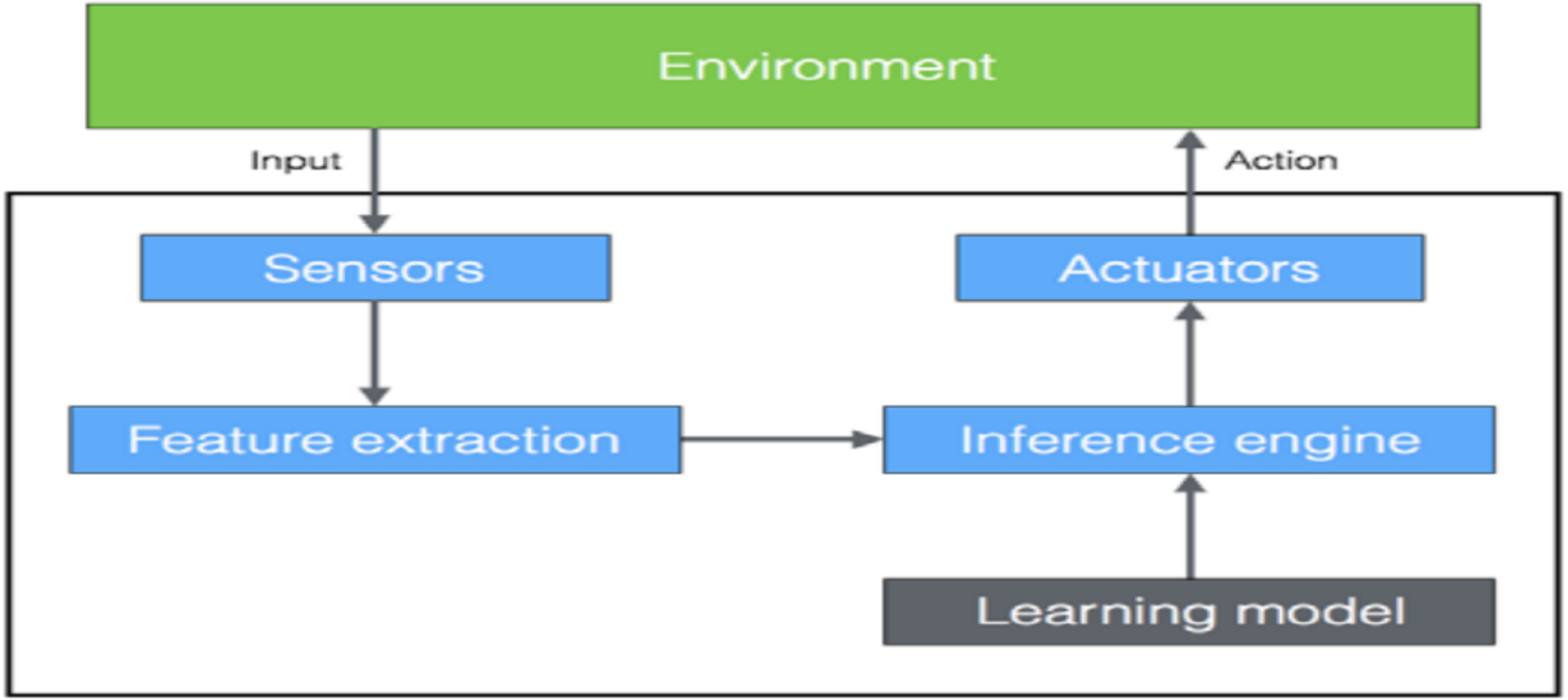
State-of-the-art applications

- Speech recognition
- Autonomous planning and scheduling
- Financial forecasting
- Game playing, video games
- Spam fighting
- Logistics planning
- Robotics (household, surgery, navigation)
- Machine translation
- Information extraction
- VLSI layout
- Automatic assembly
- Sentiment analysis
- Fraud detection
- Recommendation systems
- Web search engines
- Autonomous cars
- Energy optimization
- Question answering systems
- Social network analysis
- Medical diagnosis, imaging
- Route finding
- Traveling salesperson
- Protein design
- Document summarization
- Transportation/scheduling
- Computer animation

1. Rational intelligent agents
2. Search agents (uninformed search, informed search)
3. Adversarial search/games
4. Machine Learning (ML)
5. Constraint satisfaction problems (CSPs)
6. Logic (propositional logic, first order logic)
7. Markov Decision Processes (MDPs) and Reinforcement Learning (RL)
8. Application to Natural language Processing (NLP)
9. Application to vision and robotics

- AI is a hard (computational complexity, language, vision, etc), and a broad field with high impact on humanity and society.
- What can AI do for us is already amazing!
- AI systems do not have to model human/nature but can act like or be inspired by human/nature.
- How human think is beyond the scope of this course.
- Rational (do the right thing) agents are central to our approach of AI.
- Note that rationality is not always possible in complicated environment but we will still aim to build rational agents.

Agent



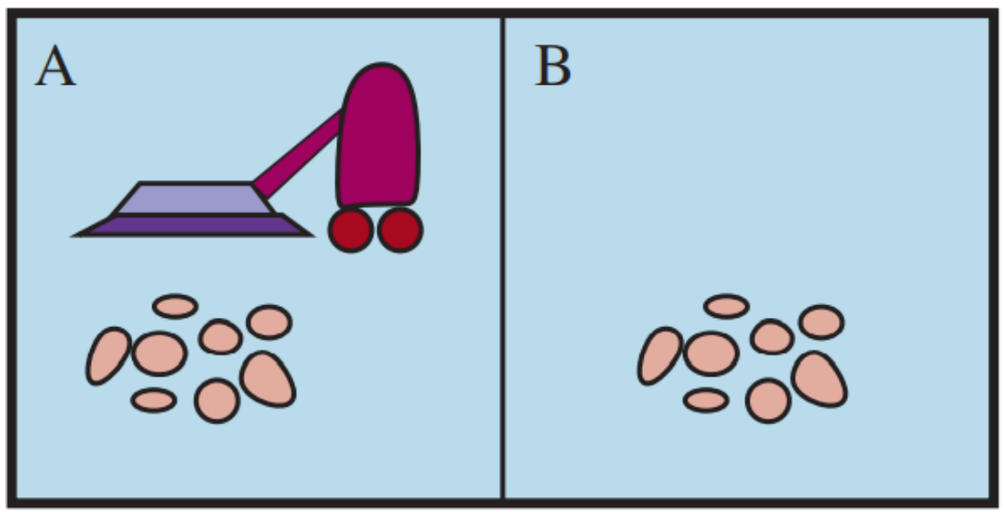
Intelligent agent

Agents and Environments

- Percept
- Percept Sequence
- An agent’s choice of action at any given instant can depend on its built-in knowledge and on the entire percept sequence observed to date, but not on anything it hasn’t perceived.
- Agent’s behavior: is described by the agent function.
- Agent function: is an abstract mathematical description
- Agent program: is a concrete implementation, running within some physical system.

Example: Vacuum Cleaner

- Percept
- Percept sequence
- Agent function: Maps any given percept sequence to an action
- Agent program:is a concrete implementation, running within some physical system



Partial tabulation of a simple agent function for the vacuum-cleaner world

Percept sequence	Action
$[A, Clean]$	$Right$
$[A, Dirty]$	$Suck$
$[B, Clean]$	$Left$
$[B, Dirty]$	$Suck$
$[A, Clean], [A, Clean]$	$Right$
$[A, Clean], [A, Dirty]$	$Suck$
$\vdots$	$\vdots$
$[A, Clean], [A, Clean], [A, Clean]$	$Right$
$[A, Clean], [A, Clean], [A, Dirty]$	$Suck$
$\vdots$	$\vdots$

Intelligent Agents

- **Agent:** An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators.
- **Rational agents: I**s one that does the right thing
- **Intelligent**
- **Environment**
- **Sensor Agent**
- **Actuator:** is a part of a device or machine that helps it to achieve physical movements by converting energy, often electrical, air, or hydraulic.

- **Consequentialism**: Agent's behavior by its Consequentialism consequences, it generates a sequence of actions according to the percepts it receives
- **Performance measure**: Evaluates any Performance measure by given sequence of environment states
- **Rational depends on four things**:
  - The performance measure that defines the criterion of success.
  - The agent's prior knowledge of the environment.
  - The actions that the agent can perform.
  - The agent's percept sequence up to date

A definition of a rational agent

- For each possible percept sequence, a rational agent should select an action that is expected to maximize its performance measure, given the evidence provided by the percept sequence and whatever built-in knowledge the agent has.
- Rationality
  - Rationality maximizes expected performance
  - perfection maximizes actual performance
  - Information gathering—is an important part of rationality

The Nature of Environments

- Task environment:
  - Performance,
  - Environment,
  - Actuators,
  - Sensors

  To design an agent, the first step must always be to specify the task environment as fully as possible.

Properties of task environments(Ex: Autonomous Vehicle)

Agent Type	Performance Measure	Environment	Actuators	Sensors
Taxi driver	Safe, fast, legal, comfortable trip, maximize profits, minimize impact on other road users	Roads, other traffic, police, pedestrians, customers, weather	Steering, accelerator, brake, signal, horn, display, speech	Cameras, radar, speedometer, GPS, engine sensors, accelerometer, microphones, touchscreen

Examples of agent types and their PEAS descriptions.

Agent Type	Performance Measure	Environment	Actuators	Sensors
Medical diagnosis system	Healthy patient, reduced costs	Patient, hospital, staff	Display of questions, tests, diagnoses, treatments, referrals	Keyboard entry of symptoms, findings, patient's answers
Satellite image analysis system	Correct image categorization	Downlink from orbiting satellite	Display of scene categorization	Color pixel arrays
Part-picking robot	Percentage of parts in correct bins	Conveyor belt with parts; bins	Jointed arm and hand	Camera, joint angle sensors
Refinery controller	Purity, yield, safety	Refinery, operators	Valves, pumps, heaters, displays	Temperature, pressure, chemical sensors
Interactive English tutor	Student's score on test	Set of students, testing agency	Display of exercises, suggestions, corrections	Keyboard entry

Properties of task environments

- Fully observable
- Partially observable
- Un observable
- Single-agent
- Multiagent
- Competitive multiagent environment
- Cooperative multiagent environment

- **Deterministic**
- **Nondeterministic**
- If the next state of the environment is completely Deterministic determined by the current state and the action executed by the agent(s), then it is called deterministic;
- Otherwise, it is called nondeterministic.
- An agent need not worry about uncertainty in a fully observable, deterministic environment
- If the environment is partially observable, it could appear to be nondeterministic.

- **Stochastic**
- **Episodic:**Agent’s experience is divided into atomic episodes
- The next episode does not depend on the actions taken in previous episodes
- **Sequential**
- **Static**
- **Dynamic**
- **Semi dynamic**
- **Discrete**
- **Continuous**
- **Known**
- **Unknown**
- **Environment class.**

The Structure of Agents

Agent program

Agent architecture:this program will run on computing device with physical sensors and actuators

Agent = architecture +program.

The job of AI is to design an agent program that implements the agent function-the mapping from percepts to actions.

The **architecture might** be just an ordinary PC, or it might be a robotic car with several onboard computers, cameras, and other sensors.

In general, the architecture makes the percepts from the sensors available to the program, runs the program, and feeds the program's action choices to the actuators as **they are generated**.

Agent Programs

- Take the current percept as input and Agent function from the sensors and return an action to the actuators
- Agent function depends on the entire percept history
- The agent program has no choice except to take just the current percept as input.
- If the agent's actions need to depend on the entire percept sequence, the agents will have to remember the percepts

```
function TABLE-DRIVEN-AGENT(percept) returns an action
    persistent: percepts, a sequence, initially empty
                table, a table of actions, indexed by percept sequences, initially fully specified

    append percept to the end of percepts
    action ← LOOKUP(percepts, table)
    return action
```

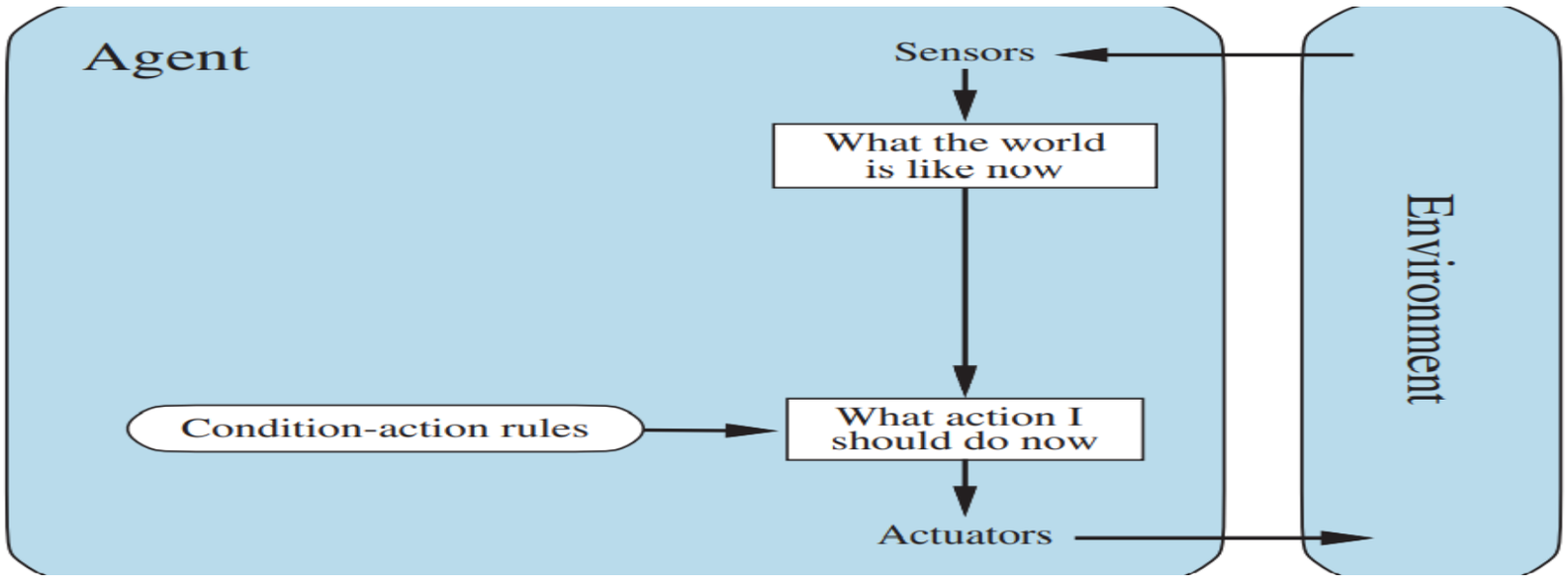
Basic kinds of agent programs

- Simple reflex agents;
- Model-based reflex agents;
- Goal-based agents; and
- Utility-based agents.

The agent program for a simple reflex agent in the two-location vacuum environment

Simple Reflex Agents

- Simple reflex agents
  - These agents select actions on the basis Simple reflex agent of the current percept, ignoring the rest of the percept history
  - Agent program using if-then-else statements, it is simple enough that it can also be implemented as a Boolean circuit(Vacuum)



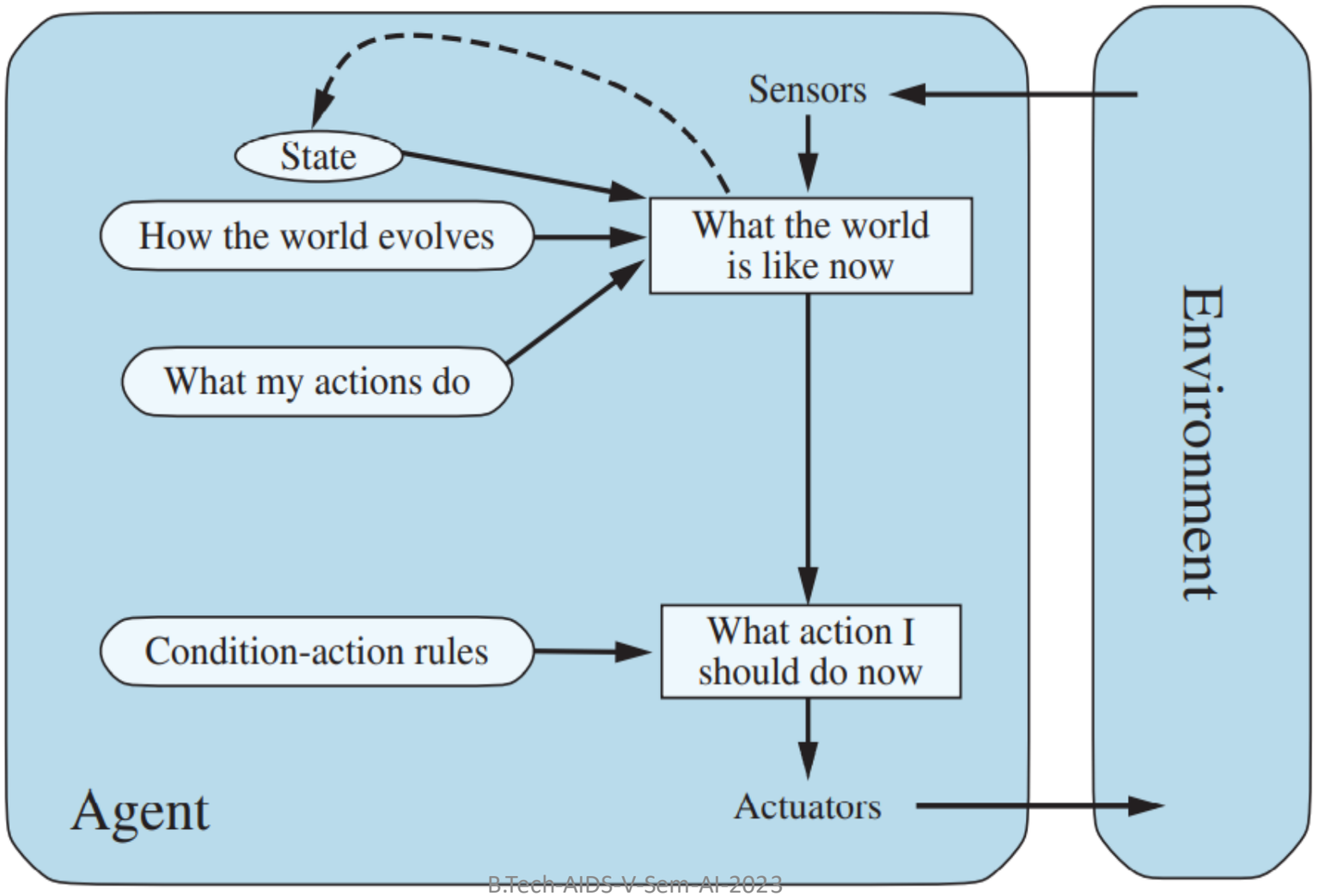
Simple Reflex Agents

```
function SIMPLE-REFLEX-AGENT(percept) returns an action
    persistent: rules, a set of condition–action rules

    state ← INTERPRET-INPUT(percept)
    rule ← RULE-MATCH(state, rules)
    action ← rule.ACTION
    return action
```

To Escape from infinite loops is possible if the agent can randomize its actions.

Model-based Reflex Agents



- **Internal State:** The agent should maintain some sort of internal state that depends on the percept history and thereby reflects at least some of the unobserved aspects of the current state.
- Internal state information requires two kinds of knowledge based on time:
  - How the world changes over time
  - How the state of the world is reflected in the agent's percepts
- **Transition model**
- **Sensor model**
- **Model-Based Agent**:Together, the transition model and sensor model allow an agent to keep track of the state of the world—to the extent possible given the limitations of the agent's sensors.

Model-based Reflex Agents

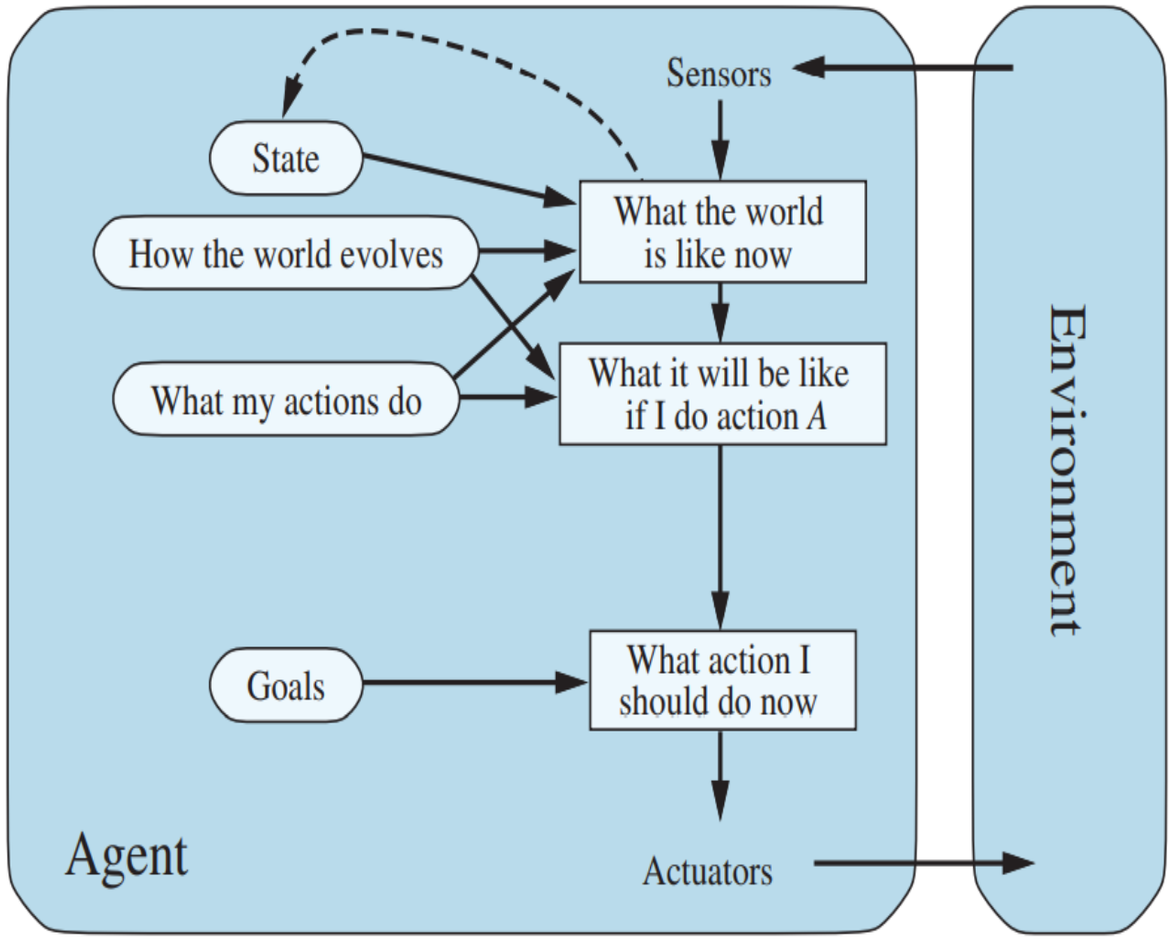
function MODEL-BASED-REFLEX-AGENT(*percept*) **returns** an action

persistent: *state*, the agent's current conception of the world state
transition_model, a description of how the next state depends on the current state and action
sensor_model, a description of how the current world state is reflected in the agent's percepts
rules, a set of condition–action rules
action, the most recent action, initially none

state ← UPDATE-STATE(*state*, *action*, *percept*, *transition_model*, *sensor_model*)
rule ← RULE-MATCH(*state*, *rules*)
action ← *rule*.ACTION
return *action*

Goal-based agents

- **As well as a current state description, the agent needs some sort of goal information that Goal describes situations that are desirable**



Utility-based agents

An agent's utility function is essentially an internalization of the performance measure.