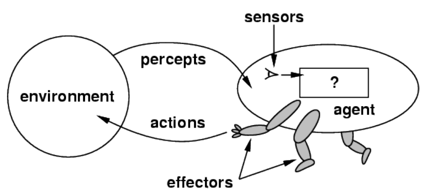
Artificial Intelligence
Class 2: Intelligent Agents



Today's Class

- What's an agent?
  - Definition of an agent
  - Rationality and autonomy
  - Types of agents
  - Properties of environments
- Broadly: a thing that does something, **with agency**

Agency is the capacity of individuals to act independently and to make their own free choices.

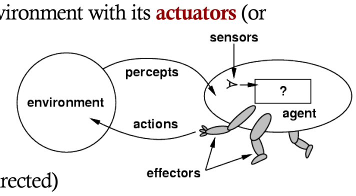
What is an Agent?

- An **intelligent** agent is:
  - A (usually) autonomous entity which…
  - Observes an environment (the world)
  - Acts on its environment in order to achieve goals
- An intelligent agent **may** learn
  - Not always
  - A simple "reflex agent" still counts as an agent
- Behaves in a **rational** manner
  - Not "optimal"

Shows "agency"

How Do You Design an Agent?

- An intelligent agent:
  - Perceives its environment via **sensors**
  - Acts upon that environment with its **actuators** (or **effectors**)
- Properties:
  - Autonomous
  - Reactive to the environment
  - Pro-active (goal-directed)
  - Interacts with other agents via the environment



Human Sensors/Percepts, Actuators/Actions

- Sensors:
  - Eyes (vision), ears (hearing), skin (touch), tongue (gustation), nose (olfaction), neuromuscular system (proprioception), …
- Percepts: "that which is perceived"
  - At the lowest level – electrical signals from these sensors
  - After preprocessing – objects in the visual field (location, textures, colors, …), auditory streams (pitch, loudness, direction), …
- Actuators/effectors:
  - Limbs, digits, eyes, tongue, …
- Actions:
  - Lift a finger, turn left, walk, run, carry an object, …

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The Point:
- Percepts and actions need to be *carefully defined*
- Sometimes at different levels of abstraction!

E.g.: Automated Taxi

- **Percepts:** Video, sonar, speedometer, odometer, engine sensors, keyboard input, microphone, GPS, …
- **Actions:** Turn, accelerate, brake, speak, display, …
- **Goals:** Maintain safety, reach destination, maximize profits (fuel, tire wear), obey laws, provide passenger comfort, …
- **Environment:** U.S. urban streets, freeways, traffic, pedestrians, weather, customers, …

Different aspects of driving may require different types of agent programs.

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Rationality

- An ideal **rational agent**, in every possible world state, does action(s) that **maximize its expected performance**
- Based on:
  - The percept sequence (world state)
  - Its knowledge (built-in and acquired)
- Rationality includes information gathering
  - If you don't know something, find out!
  - No "rational ignorance"
- Need a **performance measure**
  - False alarm (false positive) and false dismissal (false negative) rates, speed, resources required, effect on environment, constraints met, user satisfaction, …

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PEAS

- Agents must have:
- **P**erformance measure
- **E**nvironment
- **A**ctuators
- **S**ensors
- Must first specify the **setting** for intelligent agent design

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PEAS

- Agent: Part-picking robot
- Performance measure: Percentage of parts in correct bins
- Environment: Conveyor belt with parts, bins
- Actuators: Jointed arm and hand
- Sensors: Camera, joint angle sensors

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PEAS: Setting

- Specifying the setting
- Consider designing an automated taxi driver:
- Performance measure?
- Environment?
- Actuators?
- Sensors?

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Autonomy

- An autonomous system is one that:
  - **Determines its own behavior**
  - Not all its decisions are included in its design
- It is not autonomous if all decisions are made by its designer according to *a priori* decisions
- "Good" autonomous agents need:
  - Enough built-in knowledge to survive
  - The ability to learn
- In practice this can be a bit slippery

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Some Types of Agent

1. Table-driven agents
   - Use a percept sequence/action table to find the next action
   - Implemented by a (large) **lookup table**
2. Simple reflex agents
   - Based on **condition-action rules**
   - Implemented with a **production system**
   - Stateless devices which do not have memory of past world states
3. Agents with memory
   - Have **internal state**
   - Used to keep track of past states of the world

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Some Types of Agent

4. Agents with goals
   - Have internal state information, *plus…*
   - **Goal information** about desirable situations
   - Agents of this kind can **take future events** into consideration
5. Utility-based agents
   - Base their decisions on classic **axiomatic utility theory**
   - In order to **act rationally**

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(1) Table-Driven Agents

- Table lookup of:
  - Percept-action pairs mapping
  - Every possible state → best action
- Problems:
  - **Too big** to generate and store (chess: 10^{120})
  - Don't know **non-perceptual** parts of state
    - E.g., background knowledge
  - Not **adaptive to changes** in the environment
    - Must update entire table
  - No **looping**
    - Can't condition actions on previous actions/states

www.quora.com/How-do-you-know-if-your-chess-pieces-are-in-strategic-position

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(2) Simple Reflex Agents

- **Rule-based reasoning**
  - To map from percepts to optimal action
  - Each rule handles a **collection of perceived states**
    - "If your rook is threatened…"

- Problems
  - Still usually too big to generate and to store
  - Still no knowledge of non-perceptual parts of state
  - Still not adaptive to changes in the environment
    - Change by updating collection of rules
  - Actions still not conditional on previous state

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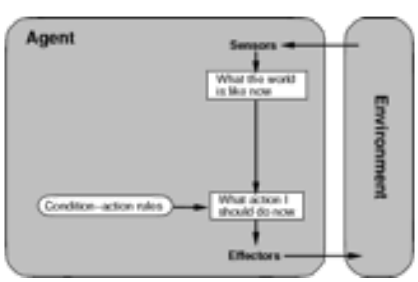
(1) Table-Driven/Reflex Agent



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(3) Agents With Memory

- Encode "internal state" of the world
  - Used to remember the past (earlier percepts)
- Why?
  - Sensors rarely give the whole state of the world at each input
  - So, must build up environment model over time
  - "State" is used to encode different "worlds"
  - Different worlds generate the same (immediate) percepts
- Requires ability to represent **change** in the world
  - Could represent just the latest state
  - But then can't reason about hypothetical courses of action

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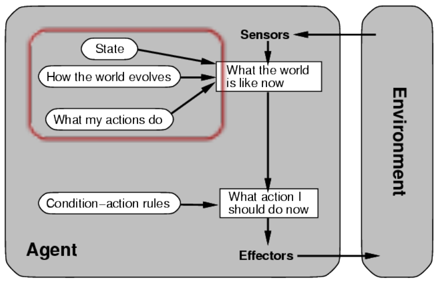
(3) Architecture for an Agent with Memory



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(4) Goal-Based Agents

- Choose actions that achieve a goal
  - Which may be given, or computed by the agent
- A goal is a **description of a desirable state**
  - Need goals to decide what situations are "good"
  - Keeping track of the current state is often not enough
- Deliberative instead of reactive
  - Must consider sequences of actions to get to goal
  - Involves thinking about the future
  - *"What will happen if I do...?"*

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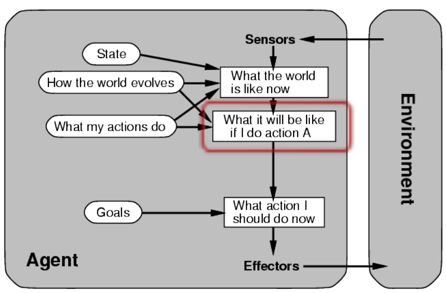
(4) Architecture for Goal-Based Agent



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(5) Utility-Based Agents

- How to choose from multiple alternatives?
  - What action is best?
- What state is best?
  - Goals → crude distinction between "happy" / "unhappy" states
  - Often need a more general performance measure (how "happy"?)
- Utility function gives success or happiness at a given state
- Can compare choice between:
  - Conflicting goals
  - Likelihood of success
  - Importance of goal (if achievement is uncertain)

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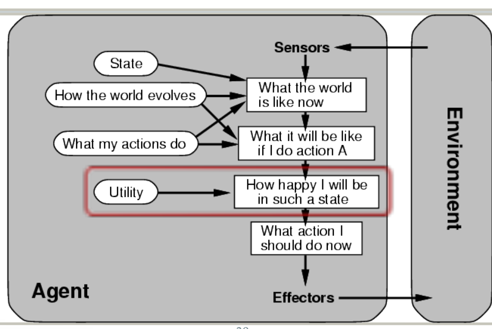
(4) Architecture for a complete utility-based agent



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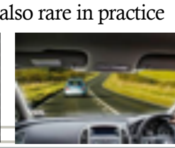
Properties of Environments

- **Fully observable/Partially observable**
  - If an agent's sensors give it access to the **complete state of the environment**, the environment is **fully observable**
  - Such environments are convenient
    - No need to keep track of the changes in the environment
    - No need to guess or reason about non-observed things
  - Such environments are also rare in practice

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Properties of Environments

- **Deterministic/Stochastic**.
  - An environment is **deterministic** if:
    - The next state of the environment is completely determined by
      - The current state of the environment
      - The action of the agent
  - In a **stochastic** environment, there are multiple, unpredictable outcomes.
- In a fully observable, deterministic environment, the agent has no *uncertainty.*

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Properties of Environments II

- **Episodic/Sequential.**
  - **Episodic:** subsequent episodes do not depend on what actions occurred in previous episodes.
  - **Sequential** environment: Agent engages in a series of connected episodes.
  - Such environments do not require the agent to plan ahead.
- **Static/Dynamic**
  - A static environment does not change while the agent is thinking.
  - The passage of time as an agent deliberates is irrelevant.
  - The agent doesn't need to observe the world during deliberation.

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Properties of Environments III

- **Discrete/Continuous**
  - If the number of distinct percepts and actions is limited, the environment is **discrete**, otherwise it is **continuous**.
    - Receives **percepts** describing the world one at a time
    - Maps this percept sequence to a sequence of discrete **actions**
- **Single agent/Multi-agent**
  - Whether the environment contains other intelligent agents.
  - In multi-agent environments, there are game-theoretic concerns (for either cooperative *or* competitive agents)
  - Single-agent environments are still more common.

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Characteristics of Environments

	Fully observable?	Deterministic?	Episodic?	Static?	Discrete?	Single agent?
Solitaire						
Chess						
Taxi driving						
Internet shopping						
Medical diagnosis						

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Characteristics of Environments

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Solitaire	**No**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
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Taxi driving	**No**	**No**	**No**	**No**	**No**	**No**
Internet shopping						
Medical diagnosis						

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Characteristics of Environments

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Solitaire	No	Yes	Yes	Yes	Yes	Yes
Backgammon	Yes	Yes	Yes	Yes	Yes	No
Taxi driving	No	No	No	No	No	No
Internet shopping	**No**	**No**	**No**	**No**	**Yes**	**No**
Medical diagnosis						

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Medical diagnosis	**No**	**No**	**No**	**No**	**No**	**Yes**

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Internet shopping	No	No	No	No	Yes	No
Medical diagnosis	**No**	**No**	**No**	**No**	**No**	**Yes**

→ Lots of (most?) real-world domains fall into the hardest cases! ←

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Summary: Agents

- An **agent:**
  - Perceives and acts in an environment
  - Has an architecture
  - Is implemented by an agent program(s)
- An **ideal agent:**
  - Always chooses the "right" action
    - Which is, that which maximizes its expected performance
  - Given its percept sequence so far!
- An **autonomous agent:**
  - Uses its *own experience* to learn and make decisions
  - Not built-in knowledge, i.e., *a priori* world knowledge by the designer

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Summary: Agents

- **Representing knowledge** is important for successful agent design
  - Percepts, actions and their effects, constraints, …
- The most challenging environments are:
  - Partially observable
  - Stochastic
  - Sequential
  - Dynamic
  - Continuous
  - Contain multiple intelligent agents

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