Intelligent Agents

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Course Information

- Blackboard
- Topics
- Work schedule
- Grading
- Resources

Agents

- An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators (Russel and Norvig)
- A persistent computation that can perceive, reason, act and communicate (Singh and Huhns)
- Sensors: Eyes, cameras, sensors
- Actuators: Legs, motors, messaging devices

Agent vs. Object

- Communicate
  - Request agents to perform an action
  - Call methods of objects
- Reason
  - Agents reason based on the state of the world and perform actions
  - Objects always do what they are told
- Adapt
  - Agents can learn to act differently in different circumstances
  - Objects do not change their behavior over time

Agent Characteristics

- Autonomous
  - Freedom to act independently
  - Choose its own actions
  - Decide on other agents that it will interact with or to trust
- Heterogeneous
  - Could be designed and implemented by different parties
  - No need to expose internal properties
  - Might have to comply with some common requirements
- Self-interested

Self-interested

- Represent principals (users, businesses)
- Principals (and thus the agents) may have contradicting preferences, commitments, or goals
- Agent is responsible for promoting the interest of its principal
- Ex. Your agent talks to Amazon.com agent to settle on a price for a travel book

Generic agent architecture

- Environment can be in one of the following states: $S = \{s_0, s_1, \ldots s_n\}$
- The agent can do one of the given actions: $A = \{a_0, a_1, \ldots a_n\}$
- Deterministic behavior: Takes a sequence of states and determines the action to take
- The actions can be non-deterministic, such that $SxA \rightarrow \rho\{S\}$

Example

Consider an agent that checks its user's e-mails and takes an action based on how important the email is and the current context of the user. The importance of the email is indicated in the email. The user's context could be meeting, holiday or home. If the user is at holiday, she does not want to receive any emails. If the user is at home, then she would like the agent to only display the unimportant emails but beep for the important emails. If the user is at a meeting, she wants the agent to display all types of messages.

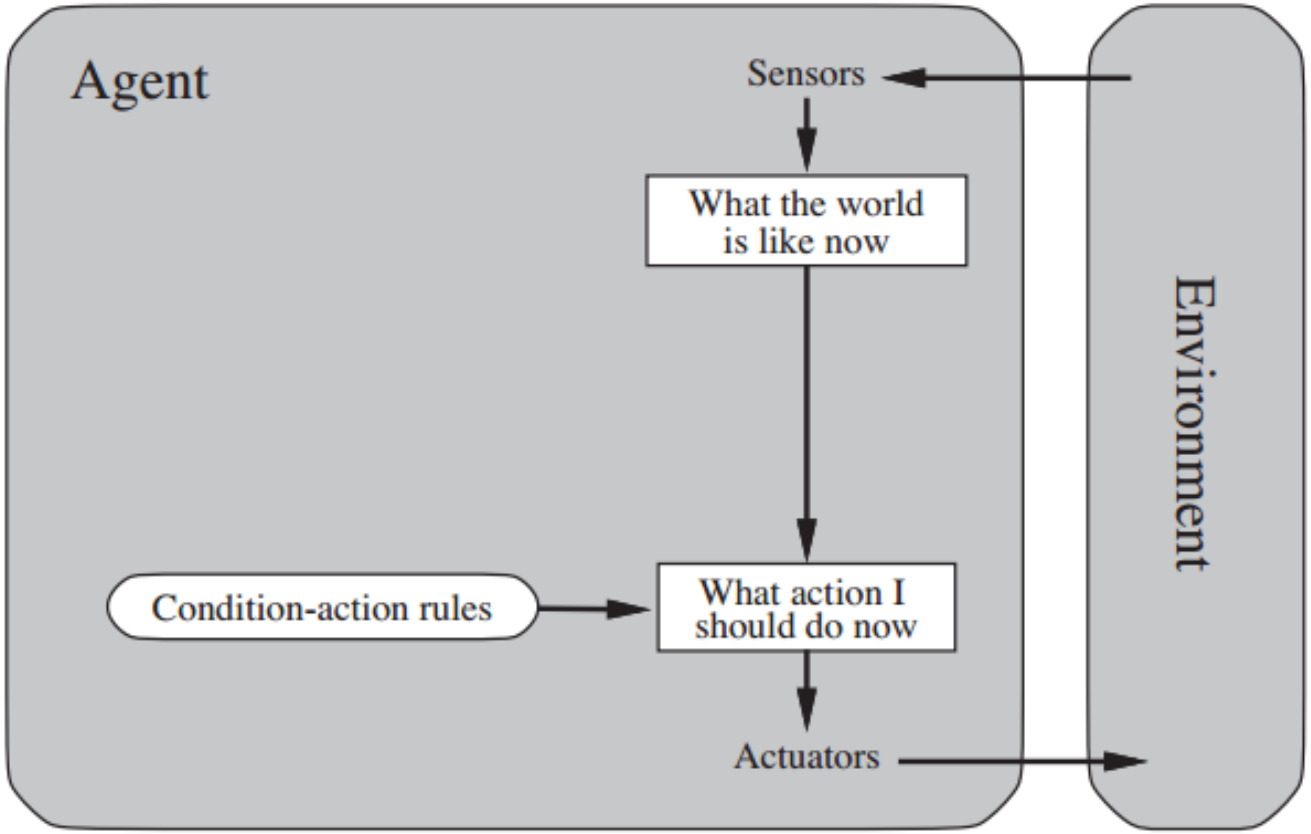
- States?
- Actions?
- Deterministic?

Rational agent

- The performance measure for success
- What the agent perceived so far
- What the agent knows about the environment
- The actions that the agent can perform

An ideal rational agent: for each possible percept sequence, it acts to maximize its expected utility, on the basis of its knowledge and the evidence from the percept sequence.

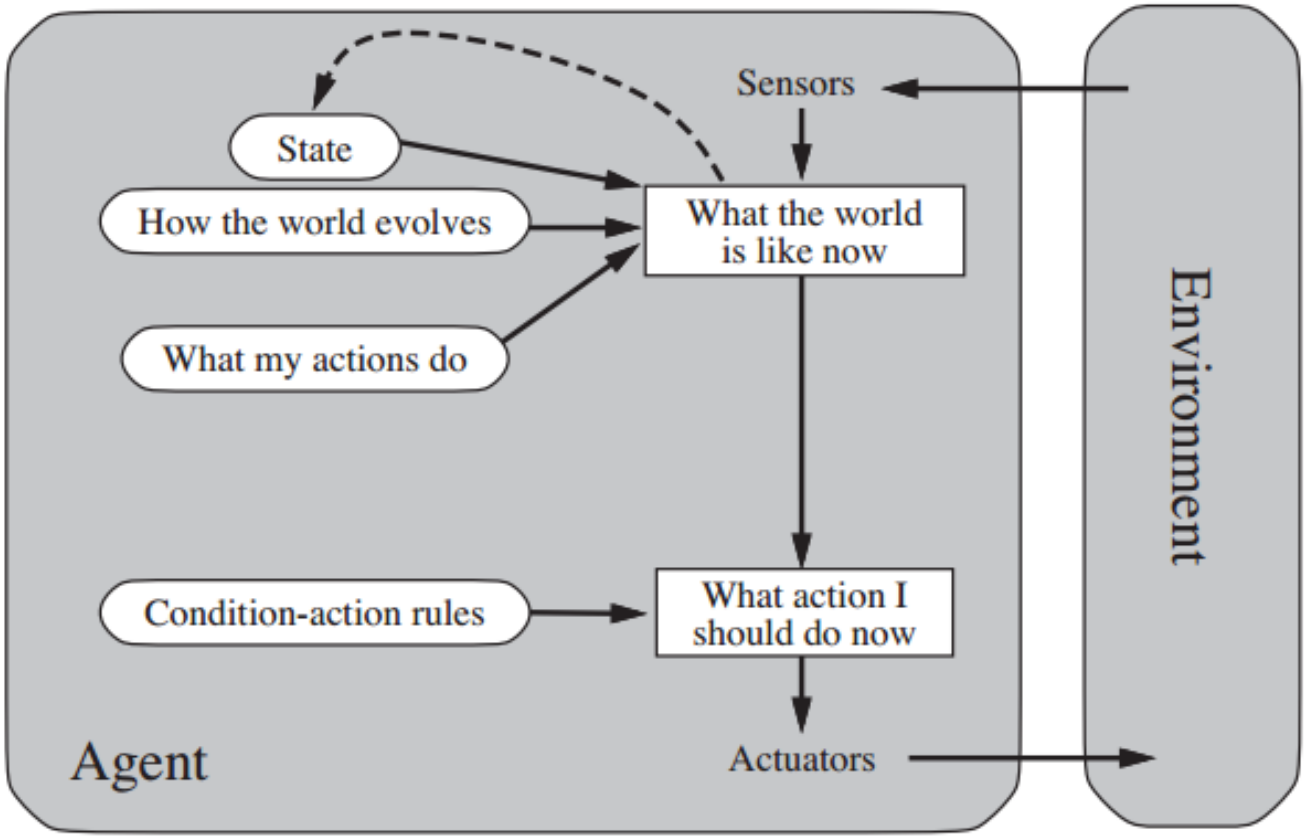
Reflex agents[1]



- Select action based on the current percept
- Require a large condition-action rules for realistic scenarios

[1] Stuart J Russell and Peter Norvig. *Artificial intelligence: a modern approach*. 2016.

Reflex agents with state

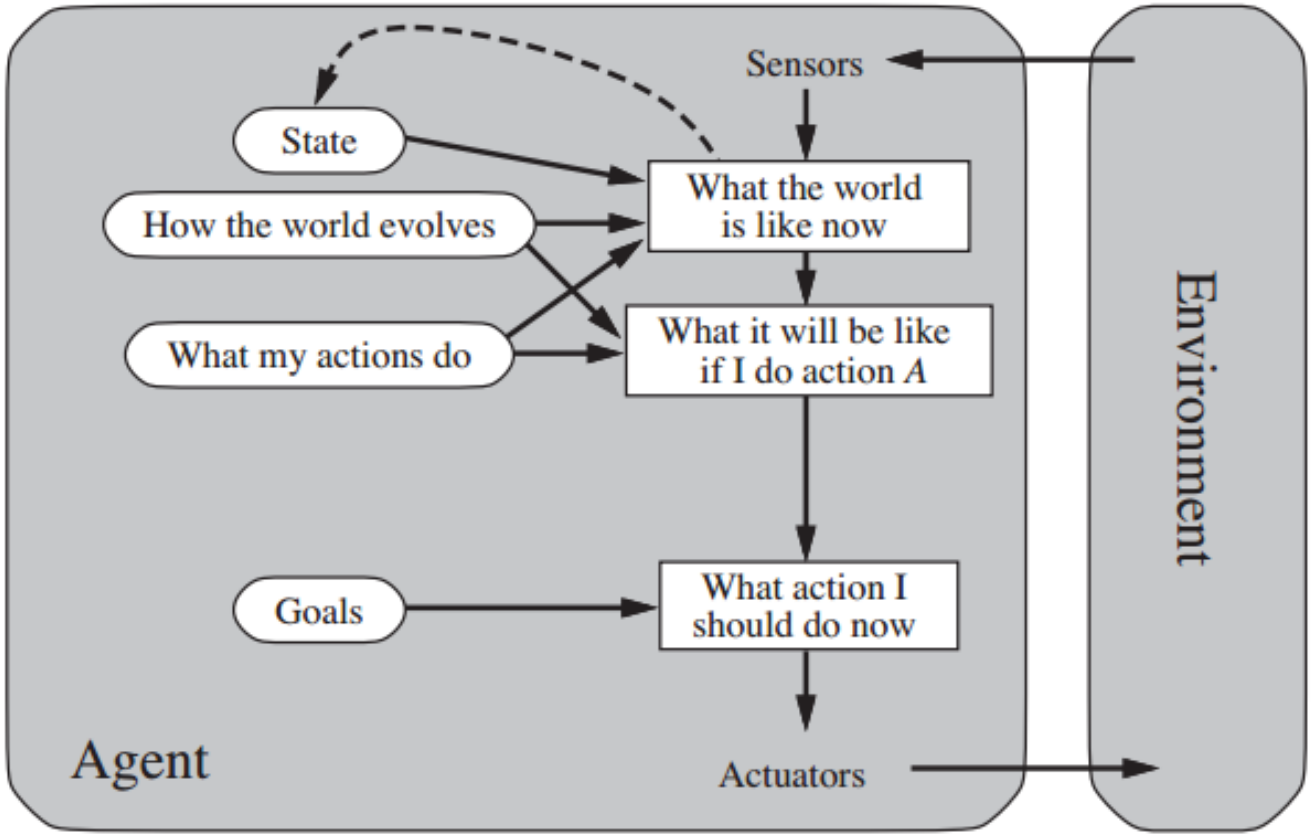


- How the world evolves is a model of the world
- Remember the past through internal state

Reflex agents with state

- Ex: The agent does not want to receive more than three emails a day.
- Agent state, world state, history?
- When is a set of condition-action rules not enough?

Goal-based agents



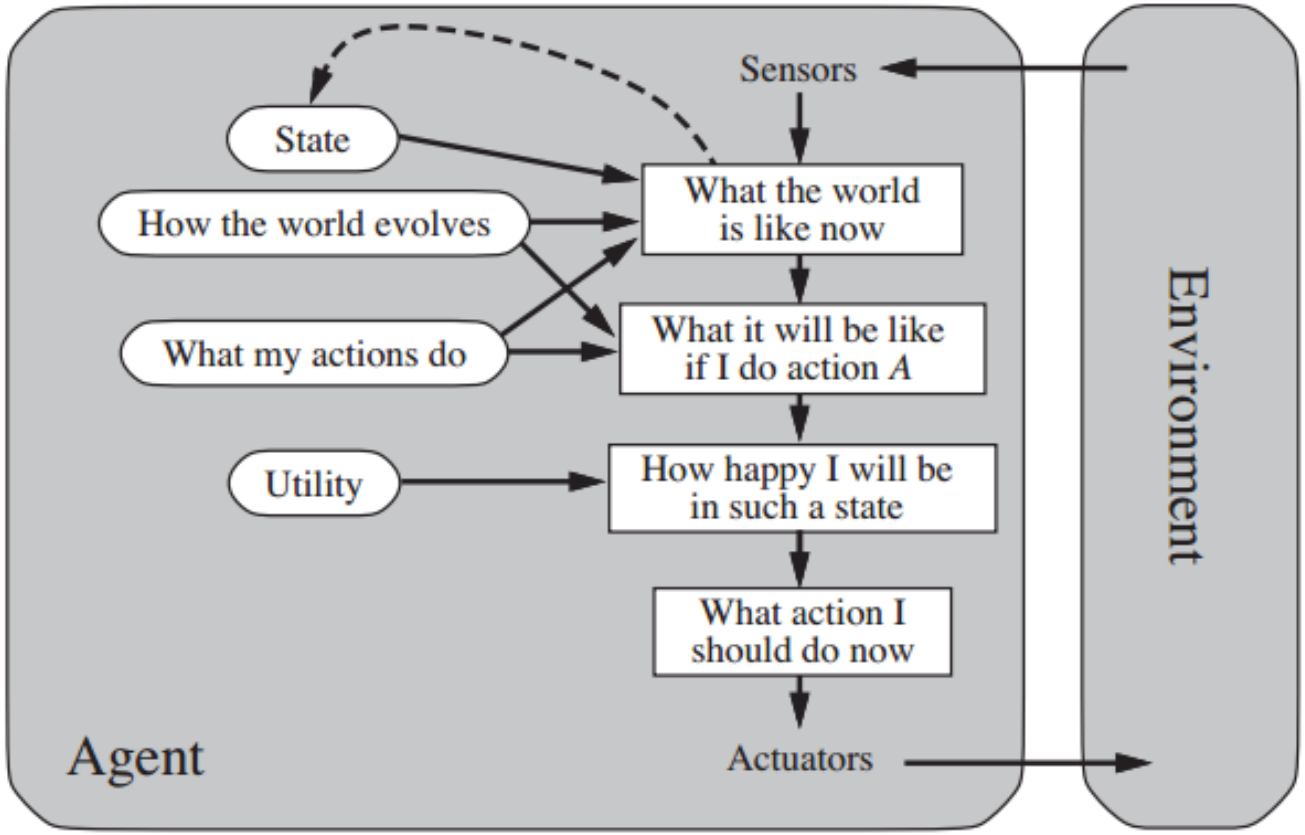
- Goal: Formulate the conditions
- Ex: Have a MS degree, Completed 20 credits
- Identify (goal) state(s) where the goal holds
- Perform actions that will take the agent to a goal state
- If a sequence of actions is necessary, *plan*.

Goals[2]

- Goal types:
  - Perform goal: Related to an action
  - Achieve goal: Satisfy a desired condition
  - Maintain goal: Continue to establish a condition
  - Query goal: Obtain piece of information
- Goal operations:
  - Adopt: Based on intentions
  - Activate: Start working on it (e.g., executing plans)
  - Suspend: Delay (e.g., another goal has a priority)
  - Drop: Remove from the goal list all together (e.g., not important anymore or not attainable)

[2] M Birna Van Riemsdijk, Mehdi Dastani, and Michael Winikoff. "Goals in agent systems: a unifying framework". In: *AAMAS*. 2008.

Utility-based agents



- Utility: How good is a state?
- Does not have a notion of a goal
- Enables comparison between states even when none are perfect or more than one good state exists

BDI agents

- Beliefs: What the agent thinks is true (may not be correct)
- Desires: The set of states that the agent would like to be in (may be inconsistent)
- Intentions:
  - A subset of desires for which the agent will act towards
  - Consistent with each other
  - Possible actions should lead to intentions

Revising beliefs

- Why: Perceive information that contradicts old belief
- Ex: Current belief: Course ends at 15:00. Talk to a friend who says it ends at 15:15
- Rules for belief revision:
  - New belief overrides old belief
  - Keep both old and new belief but handle inconsistency
  - Assign probabilities

Revising intentions

- Why: Intention is no longer possible to be achieved
- Ex: Current intention: To be in class at 10:00 but it's already 10:15
- Rules for intention revision:
  - Drop the intention
  - Update the intention in a way that is doable (e.g., be there at 10:30)
- Modified intention means choosing different actions

Knowledge (1)

- Knowledge=”True” belief?
- Knowledge representation for reasoning
  - Expressed in machine-understandable form
  - Logic (Description Logic, Propositional Logic, FOL)
- Two aspects:
  - Syntax: Describe what a sentence is. Allowed sequences of characters, words, etc.
  - Semantics: Determines the facts that the sentence corresponds to
- Example: $x \leq y$
- Need precise syntax and semantics to reason

Knowledge (2)

- Facts in real world vs. representation in agents
- Reasoning derives new knowledge
- Reasoning on facts and representation should yield the same knowledge
- Entailment: Deriving new sentences based on old ones $KB \models \alpha$
- Inference procedure:
  - Generate all sentences entailed by KB
  - Check if alpha is entailed by KB
  - Sound: If the procedure generates entailed sentences only
  - Complete: If the procedure has a proof for every entailed sentence
- Known inference procedures?

Knowledge-based agents

- Includes a knowledge base and an inference engine
- Different components of agent architectures can use knowledge
- Ex: How the world evolves, What my actions do
- Actions are chosen based on the reasoning on the knowledge

Developing agents (1)

- Depends on your agent architecture
- Agent programming languages (Agent0, Golog, 3APL)
  - Particularly useful for BDI agents
  - Constructs for beliefs, goals, etc.
  - Specify rules to reason on these (update, delete)
  - Use an interpreter which will track which rules are fired and make modifications accordingly

Developing agents (2)

- Depends on your agent architecture
- Java, Python
  - Better support for Web standards
  - Easy integration with existing APIs
  - Possible back-end of Prolog for processing logical formulas
- Development environments
  - JADE: Available libraries for agent templates
  - Madkit: Enforce an organization model so that each agent plays a role in the MAS
  - OO2APL, Jason, ...