Artificial Intelligence
Class 2: Intelligent Agents
Bookkeeping

• Due last night:
  • Introduction survey
  • Academic integrity \{ If you haven’t done these, do! \}

• HW 1
  • Writing sections: 2 readings, 1 short essay, 6 questions
    • http://tiny.cc/mc-what-is-ai
    • http://ai100.stanford.edu/2016-report
  • Coding problems: out this afternoon
    • We will update on Piazza

• Due **11:59pm, 9/19**
Today’s Class

• What’s an agent?
  • Definition of an agent
  • Rationality and autonomy
  • Types of agents
  • Properties of environments
Pre-Reading: Quiz

- What are sensors and percepts?
- What are actuators (aka effectors) and actions?
- What are the six environment characteristics that R&N use to characterize different problem spaces?

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<th>Deterministic</th>
<th>Static</th>
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<td># of Agents</td>
<td>Episodic</td>
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How Do You Design an Agent?

- **An intelligent agent:**
  - Perceives its environment via **sensors**
  - Acts upon that environment with its **effectors** (or **actuators**)

- **A discrete agent:**
  - Receives **percepts** one at a time
  - Maps this percept sequence to a sequence of discrete **actions**

- **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**: Steer, accelerate, brake, horn, 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!**
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, …
Autonomy

• An autonomous system determines its own behavior

• But not if all its decisions are included in its design
  • I.e., 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
Some Types of Agent (1)

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
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**
(1) Table-Driven Agents

• Table lookup of:
  • Percept-action pairs mapping
  • Every possible perceived state $\leftrightarrow$ optimal action for that state

• Problems:
  • Too big to generate and store
    • Chess has about $10^{120}$ states, for example
  • No knowledge of non-perceptual parts of the current state
    • E.g., background knowledge
  • Not adaptive to changes in the environment
    • Change by updating entire table
  • No looping
    • Can’t make actions conditional on previous actions/states
(1) Table-Driven/Reflex Agent

Agent

Sensors

What the world is like now

Condition-action rules

What action I should do now

Effectors

Environment
(2) Simple Reflex Agents

- **Rule-based reasoning**
  - To map from percepts to optimal action
  - Each rule handles a collection of perceived states

- **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
(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 “world states”
  - 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

- Example: Rodney Brooks’ Subsumption Architecture.
(3) Architecture for an Agent with Memory
(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...?”
(4) Architecture for Goal-Based Agent
(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)
(4) Architecture for a complete utility-based agent
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.

These should be familiar!
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 need not deal with uncertainty.
Properties of Environments

- **Episodic/Sequential**
  - An *episodic* environment means that subsequent episodes do not depend on what actions occurred in previous episodes.
  - In a *sequential* environment, the 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.
• **Discrete/Continuous**
  • If the number of distinct percepts and actions is limited, the environment is *discrete*, otherwise it is *continuous*.

• **Single agent/Multi-agent**
  • If the environment contains other intelligent agents, the agent needs to be concerned about strategic, game-theoretic aspects of the environment (for either cooperative *or* competitive agents)
  • Most engineering environments don’t have multi-agent properties, whereas most social and economic systems get their complexity from the interactions of (more or less) rational agents.
## Characteristics of Environments

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→ Lots of (most?) real-world domains fall into the hardest case! ←
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
  • Rather than built-in knowledge
  • I.e., a priori world knowledge by the designer
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