ECE 448 Lecture 3: Rational Agents

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Contents

• Agent = Performance, Environment, Actions, Sensors (PEAS)
• What makes an agent *Rational*?
• What makes an agent *Autonomous*?
• Types of Agents: Reflex, Internal-State, Goal-Directed, Utility-Directed (RIGU)
• Properties of Environments: Observable, Deterministic, Episodic, Static, Continuous (ODESC)
Agents

• An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators.
Example: Vacuum-Agent

- **Environment** = tuple of variables:
  - Location, status of both rooms,
    e.g., \( S = \{ \text{Loc=}A, \text{Status=(Dirty, Dirty)} \} \)
- **Action** = variable drawn from a set:
  \( A \in \{ \text{Left, Right, Suck, NoOp} \} \)
- **Sensors** = tuple of variables:
  - Location, and status of Current Room Only
    e.g., \( S = \{ \text{Loc=}A, \text{Status = Dirty} \} \)

function Vacuum-Agent([location,status]) returns an action

- if \( \text{Loc=}A \)
  - if \( \text{Status=}\text{Dirty} \) then return Suck
  - else if I have never visited B then return Right
  - else return NoOp

- else
  - if \( \text{Status=}\text{Dirty} \) then return Suck
  - else if I have never visited A then return Left
  - else return NoOp
Specifying the task environment

- **PEAS**: **Performance, Environment, Actions, Sensors**
  - **P**: a function the agent is maximizing (or minimizing)
    - Assumed given
  - **E**: a formal representation for *world states*
    - For concreteness, a tuple \((\text{var}_1=\text{val}_1, \text{var}_2=\text{val}_2, \ldots, \text{var}_n=\text{val}_n)\)
  - **A**: actions that change the state according to a *transition model*
    - Given a state and action, what is the successor state (or distribution over successor states)?
  - **S**: observations that allow the agent to infer the world state
    - Often come in very different form than the state itself
    - E.g., in tracking, observations may be pixels and state variables 3D coordinates
PEAS Example: Autonomous taxi

• Performance measure
  • Safe, fast, legal, comfortable trip, maximize profits

• Environment
  • Roads, other traffic, pedestrians, customers

• Actuators
  • Steering wheel, accelerator, brake, signal, horn

• Sensors
  • Cameras, LIDAR, speedometer, GPS, odometer, engine sensors, keyboard
Another PEAS example: Spam filter

• **Performance measure**
  • Minimizing false positives, false negatives

• **Environment**
  • A user’s email account, email server

• **Actuators**
  • Mark as spam, delete, etc.

• **Sensors**
  • Incoming messages, other information about user’s account
Performance Measure

• An agent’s performance is measured by some performance or utility measure

• Utility = function of the current environment $E_t$, and of the history of all actions from time 1 to time $t$, $A_{1:(t-1)}$:

$$U_t = f(E_t, A_{1:(t-1)})$$

• Example: $U_t = \#$ currently dirty rooms $- \frac{1}{2}(\#$ non-NoOp Actions)
What makes an agent *Rational*?

- 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 the agent’s built-in knowledge.

- **Performance measure (utility function):** An *objective* criterion for success of an agent's behavior.

- **Expected utility:** the expected outcome of the action $A_t$:

$$EU(A_t) = \sum_{E_{t+1}} U_{t+1}(E_{t+1}, A_{1:t}) Pr\{E_{t+1} | A_{1:t}, S_{1:t}\}$$

- Can a rational agent make mistakes?
Back to the Vacuum-Agent

**function** Vacuum-Agent([[location, status]]) returns an action

- **if** Loc=A
  - **if** Status=Dirty *then* return Suck
  - *else if* I have never visited B *then* return Right
  - *else return* NoOp
- **else**
  - **if** Status=Dirty *then* return Suck
  - *else if* never visited A *then* Left
  - *else return* NoOp

- *Is this agent* Rational?
What makes an agent *Autonomous*?

- Russell & Norvig: “A system is autonomous to the extent that its behavior is determined by its own experience.”

- A Rational Agent might not be Autonomous, if its designer was capable of foreseeing the maximum-utility action for every environment.

- Example: Vacuum-Agent
Types of Agents

• Reflex agent: no concept of past, future, or value
  • Might still be Rational, if the environment is known to the designer with sufficient detail

• Internal-State agent: knows about the past

• Goal-Directed agent: knows about the past and future

• Utility-Directed agent: knows about past, future, and value
Reflex Agent
Internal-State Agent
Goal-Directed Agent
Utility-Directed Agent
PEAS

• **Performance measure:** Determined by the system designer, attempts to measure some intuitive description of behavior goodness.

• **Actions:** Determined by the system designer, usually trades off cost versus utility

• **Sensors:** Determined by the system designer, usually trades off cost versus utility

• **Environment:** Completely out of the control of the system designer.
Properties of Environments

• Fully observable vs. partially observable
• Deterministic vs. stochastic
• Episodic vs. sequential
• Static vs. dynamic
• Discrete vs. continuous
• Single agent vs. multi-agent
• Known vs. unknown
Fully observable vs. partially observable

• Do the agent's sensors give it access to the complete state of the environment?
  • For any given world state, are the values of all the variables known to the agent?

Source: L. Zettlemoyer
Deterministic vs. stochastic

• Is the next state of the environment completely determined by the current state and the agent’s action?
  • Is the transition model deterministic (unique successor state given current state and action) or stochastic (distribution over successor states given current state and action)?
  • strategic: the environment is deterministic except for the actions of other agents
Episodic vs. sequential

• Is the agent’s experience divided into unconnected episodes, or is it a coherent sequence of observations and actions?
  • Does each problem instance involve just one action or a series of actions that change the world state according to the transition model?
Static vs. dynamic

• Is the world changing while the agent is thinking?
  • **Semidynamic**: the environment does not change with the passage of time, but the agent's performance score does
Discrete vs. continuous

- Does the environment provide a countable (discrete) or uncountably infinite (continuous) number of distinct percepts, actions, and environment states?
  - Are the values of the state variables discrete or continuous?
  - Time can also evolve in a discrete or continuous fashion
  - “Distinct” = different values of utility
Single-agent vs. multiagent

• Is an agent operating by itself in the environment?
Known vs. unknown

• Are the rules of the environment (transition model and rewards associated with states) known to the agent?
  • Strictly speaking, not a property of the environment, but of the agent’s state of knowledge
Examples of different environments

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- Word jumble solver
- Chess with a clock
- Scrabble
- Autonomous driving
Preview of the course

• **Deterministic environments**: search, constraint satisfaction, logic
  • Can be *sequential* or *episodic*

• **Multi-agent, strategic environments**: minimax search, games
  • Can also be *stochastic*, *partially observable*

• **Stochastic environments**
  • *Episodic*: Bayesian networks, pattern classifiers
  • *Sequential, known*: Markov decision processes
  • *Sequential, unknown*: reinforcement learning