Foundations of Artificial Intelligence

4. Introduction: Environments and Problem Solving Methods

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February 25, 2019

Introduction: Overview

Chapter overview: introduction

- 1. What is Artificial Intelligence?
- 2. AI Past and Present
- 3. Rational Agents
- 4. Environments and Problem Solving Methods

4.1 Environments of Rational Agents

AI Problems

AI Problems

AI problem: performance measure + agent model + environment

German: Performance-Mass, Agentenmodell, Umgebung

- agent model:
  - Which actions are at the agent's disposal?
  - Which observations can it make?
- environment:
  - Which aspects of the world are relevant for the agent?
  - How does the world react to the agent's actions?
  - Which observations does it send to the agent?

Example Problem: Autonomous Taxi

Example (Autonomous Taxi)

environment:

- streets, vehicles, pedestrians, weather, ...

performance measure:

- punctuality, safety, profit, legality, comfort, ...

agent model:

- actions: steering, accelerating, braking, changing gears, honking, ...
- observations: cameras, acceleration sensors, GPS, touchpad, ...

Example Problem: Web Shopping Bot

Example (Web Shopping Bot)

environment:

- web pages, products, sellers, ...

performance measure:

- cost and quality of bought products, shipping time, ...

agent model:

- actions: querying the user, following links, filling in forms, ...
- observations: HTML pages (text, images, scripts, metadata), user input, ...

Classification of Environments

- properties of environment determine character of an AI problem
- classify according to criteria such as:
  - static vs. dynamic
  - deterministic vs. non-deterministic vs. stochastic
  - fully vs. partially vs. not observable
  - discrete vs. continuous
  - single-agent vs. multi-agent

Properties of Environments

Example (Properties of Environments)

	Rubik's Cube	backgammon	shopping bot	taxi
static	yes	(yes)	(yes)	no
deterministic				
observability				
discrete				
agents				

static vs. dynamic

Does the state of the environment change
while the agent is contemplating its next action?

German: statisch, dynamisch

Properties of Environments

Example (Properties of Environments)

	Rubik's Cube	backgammon	shopping bot	taxi
static	yes	(yes)	(yes)	no
deterministic	yes	stochastic	(yes)	no
observability				
discrete				
agents				

deterministic vs. non-deterministic vs. stochastic

Is the next state of the environment fully determined by the current state and the agent's next action?

If not: is the next state affected by randomness?

German: deterministisch, nichtdeterministisch, stochastisch

Properties of Environments

Example (Properties of Environments)

	Rubik's Cube	backgammon	shopping bot	taxi
static	yes	(yes)	(yes)	no
deterministic	yes	stochastic	(yes)	no
observability	fully	fully	partially	partially
discrete				
agents				

completely vs. partially vs. not observable

Do the agent's observations fully determine
the state of the environment?

If not: can the agent at least determine
some aspects of the state of the environment?

German: vollständig/teilweise/nicht beobachtbar

Properties of Environments

Example (Properties of Environments)

	Rubik's Cube	backgammon	shopping bot	taxi
static	yes	(yes)	(yes)	no
deterministic	yes	stochastic	(yes)	no
observability	fully	fully	partially	partially
discrete	yes	yes	yes	no
agents				

discrete vs. continuous

Is the environment's state given by discrete
or by continuous parameters?

also applies to: actions of the agent, observations, elapsing time

German: diskret, stetig

Properties of Environments

Example (Properties of Environments)

	Rubik's Cube	backgammon	shopping bot	taxi
static	yes	(yes)	(yes)	no
deterministic	yes	stochastic	(yes)	no
observability	fully	fully	partially	partially
discrete	yes	yes	yes	no
agents	1	2 (adversaries)	(1)	many

single-agent vs. multi-agent

Must other agents be considered?

If yes: do the agents behave cooperatively, selfishly, or are they adversaries?

German: ein/mehrere Agenten; Gegenspieler

Properties of Environments

Example (Properties of Environments)

	Rubik's Cube	backgammon	shopping bot	taxi
static	yes	(yes)	(yes)	no
deterministic	yes	stochastic	(yes)	no
observability	fully	fully	partially	partially
discrete	yes	yes	yes	no
agents	1	2 (adversaries)	(1)	many

suitable problem solving algorithms

Environments of different kinds (according to these criteria) usually require different algorithms.

The "real world" combines all unpleasant (in the sense of: difficult to handle) properties.

4.2 Problem Solving Methods

Three Approaches to Problem Solving

We can solve a concrete AI problem (e.g., backgammon) in several ways:

Three Problem Solving Methods

1. problem-specific: implement algorithm "by hand"
2. general: create problem description + use general algorithm (solver)
3. learning: learn (aspects of) algorithm from experience

German: problemspezifisch, allgemein, lernend

- all three approaches have strengths and weaknesses (which?)
- combinations are possible
- we will mostly focus on general algorithms, but also consider other approaches

General Problem Solvers

General problem solving:

problem instance $\Longrightarrow$ language $\Longrightarrow$ solver $\Longrightarrow$ solution

1. models to classify, define and understand problems
   - What is a problem instance?
   - What is a solution?
   - What is a good/optimal solution?
2. languages to represent problem instances
3. algorithms to find solutions

German: Probleminstanz, Sprache, Solver/Löser, Lösung, Modelle

Languages are Key!

The Key to General Problem Solving

Compactly describe complex models in declarative languages!

Two roles for declarative languages:

- specification: need a description of the model
- computation: algorithmically exploit problem structure

4.3 Classification of AI Topics

Classification of AI Topics

Many areas of AI are essentially characterized by

- the properties of environments they consider and
- which of the three problem solving approaches they use.

We conclude the introduction by giving some examples

- within this course and
- beyond the course ("advanced topics").

Examples: Classification of AI Topics

Course Topic: Informed Search Algorithms

environment:

- static vs. dynamic
- deterministic vs. non-deterministic vs. stochastic
- fully vs. partially vs. not observable
- discrete vs. continuous
- single-agent vs. multi-agent

problem solving method:

- problem-specific vs. general vs. learning

Examples: Classification of AI Topics

Course Topic: Constraint Satisfaction Problems

environment:

- static vs. dynamic
- deterministic vs. non-deterministic vs. stochastic
- fully vs. partially vs. not observable
- discrete vs. continuous
- single-agent vs. multi-agent

problem solving method:

- problem-specific vs. general vs. learning

Examples: Classification of AI Topics

Course Topic: Board Games

environment:

- static vs. dynamic
- deterministic vs. non-deterministic vs. stochastic
- fully vs. partially vs. not observable
- discrete vs. continuous
- single-agent vs. multi-agent (adversarial)

problem solving method:

- problem-specific vs. general vs. learning

Examples: Classification of AI Topics

Advanced Topic: General Game Playing

environment:

- static vs. dynamic
- deterministic vs. non-deterministic vs. (stochastic)
- fully vs. partially vs. not observable
- discrete vs. continuous
- single-agent vs. multi-agent (adversarial)

problem solving method:

- problem-specific vs. general vs. learning

Examples: Classification of AI Topics

Course Topic: Classical Planning

environment:

- static vs. dynamic
- deterministic vs. non-deterministic vs. stochastic
- fully vs. partially vs. not observable
- discrete vs. continuous
- single-agent vs. multi-agent

problem solving method:

- problem-specific vs. general vs. learning

Examples: Classification of AI Topics

Course Topic: Acting under Uncertainty

environment:

- static vs. dynamic
- deterministic vs. non-deterministic vs. stochastic
- fully vs. partially vs. not observable
- discrete vs. continuous
- single-agent vs. multi-agent

problem solving method:

- problem-specific vs. general vs. learning

Examples: Classification of AI Topics

Advanced Topic: Reinforcement Learning

environment:

- static vs. dynamic
- deterministic vs. non-deterministic vs. stochastic
- fully vs. partially vs. not observable
- discrete vs. continuous
- single-agent vs. multi-agent

problem solving method:

- problem-specific vs. general vs. learning

4.4 Summary

Summary (1)

AI problem: performance measure + agent model + environment

Properties of environment critical for choice of suitable algorithm:

- static vs. dynamic
- deterministic vs. non-deterministic vs. stochastic
- fully vs. partially vs. not observable
- discrete vs. continuous
- single-agent vs. multi-agent

Summary (2)

Three problem solving methods:

- problem-specific
- general
- learning

general problem solvers:

- models characterize problem instances mathematically
- languages describe models compactly
- algorithms use languages as problem description and to exploit problem structure