CS2109S

AY22/23 Sem 2

github.com/jasonqiu212

01. Introduction

- **Agent** - Anything that can perceive its environment through sensors and acting upon that env. through actuators
- **Agent Function** - Maps from percept histories to actions
- **Rational Agent** - Chooses an action that is expected to maximize its performance measure, given by percept sequence and built-in knowledge
- **Autonomous Agent** - If behavior is determined by its own expereince

Performance Measure of Function

- Motivation: For an agent to do the right thing, need a measure of goodness
- Performance vs. Cost

1. Best for whom?
2. What are we optimizing?
3. What information is available?
4. What are the side effects and costs?

Defining the Problem: PEAS

1. Performance measure
2. Environment
3. Actuators
4. Sensors

Characterizing the Environment

1. **Fully observable** - (vs. Partially) Agent's sensors can access complete state of env. all the time
2. **Deterministic** - (vs. Stochastic) Next state of env. is determined by **current state** and **action executed by agent**
   - **Strategic** - If env. is deterministic except for actions of other agents
3. **Episodic** - (vs. Sequential) Agent's experience is divided into atomic **episodes**, where each episode includes perceiving and an action, and **action depends on episode** itself
4. **Static** - (vs. Dynamic) Env. is unchanged while agent is deciding
   - **Semi** - Time does not affect env., but affects performance score
5. **Discrete** - (vs. Continuous) Discrete num. of percepts and actions
6. **Single Agent** - (vs. Multi-agent) Agent operating by itself in an env.

Implementing Agents (in ascending complexity)

1. **Simple Reflex Agents** - Fixed conditional rules
2. **Model-based Reflex Agents** - Stores percept history to make decisions about internal model of world with conditional rules. Eg. Roomba
3. **Goal-based Agents** - Keep in mind a goal and action aims to achieve it
4. **Utility-based Agents** - Find best way to achieve goal
5. **Learning Agents** - Learn from previous experiences

Exploitation vs. Exploration

- **Exploitation** - Maximize expected utility using current knowledge of world
- **Exploration** - Learn more about the world to improve future gains. May not always maximize performance measure.

02. Searching

- Deterministic, fully observable
- **Tree Search** - Can revisit nodes
- **Graph Search** - Tracks visited (Tree Search + Memoization)
- **Uninformed Search** - Uses only information available in problem definition

Formulating the Problem

1. How to represent state in problem?
2. Initial state
3. Actions: Successor function
4. Goal test
5. Path cost

- **Abstraction Function** - Maps abstracted representation to real world state
- **Representation Invariant** - $I(c) = \textbf{True} \rightarrow \exists a \textbf{ s.t. } AF(c) = a$

Breadth-first Search

- Idea: Expand shallowest unexpanded node using **queue**
- Given: b: Branching factor and d: Depth of optimal solution
- Complete: Yes (if tree is finite)
- Time: $O(b^{d+1})$
- Space: $O(b^d)$
- Optimal: Yes (if cost $= 1$)
- BFS is Uniform-cost Search with same cost

Uniform-cost Search

- Idea: Expand least-cost unexpanded node using **priority queue** (Dijkstra's)
- Given: C^*: Cost of optimal solution
- Complete: Yes (if step cost $\geq \epsilon$ where $\epsilon \geq 0$)
- Time: $O(b^{(C^*/\epsilon)})$ (C^*/ϵ is approx. number of layers)
- Space: $O(b^{(C^*/\epsilon)})$
- Optimal: Yes

Depth-first Search

- Idea: Expand deepest unexpanded node using **stack**
- Given: m: Maximum depth of tree
- Complete: No (fails with infinite depth or loops)
- Time: $O(b^m)$
- Space: $O(bm)$ (better than BFS)
- Optimal: No

Depth-limited Search

- DFS with depth limit l where nodes at depth l have no children
- Time: $b^0 + b^1 + ... + b^{(d-1)} + b^d = O(b^d)$

Iterative Deepening Search

- Idea: Try different depths for depth-limited search
- Complete: Yes
- Time: $(d+1)b^0 + db^1 + ... + b^d = O(b^d)$ (More overhead than DLS)
- Space: $O(bd)$

Summary

	BFS	Uniform Cost	DFS	DLS	IDS
Complete	Yes	Yes	No	No	Yes
Time	$O(b^d)$	$O(b^{C^*/\epsilon})$	$O(b^m)$	$O(b^l)$	$O(b^d)$
Space	$O(b^d)$	$O(b^{C^*/\epsilon})$	$O(bm)$	$O(bl)$	$O(bd)$
Optimal	Yes	Yes	No	No	No

Bidirectional Search

- Idea: Search both forwards from initial state and backwards from goal state. Stop when searches meet.
- Time: $O(2b^{d/2})$
- Operators must be reversible
- Can have many goal states
- How to check if node intersects with other half?