Search Problems

Russell and Norvig:
Chap. 3, Sect. 3.1 - 3.2

Slides by Jean-Claude Latombe, from an introductory AI course
given at Stanford University Winter 2004 (used with permission).

Goal-Based Agent

Goal: One way towards maximizing performance measure - to be rational

Can it find a sequence of actions achieving its goals, when no single action will do?

Problem-Solving Agent

• Actions
• Initial state
• Goal test

Graph searching
Example: 8-puzzle

Initial state:

```
8 2
3 4 7
5 1 6
```

Goal state:

```
1 2 3 4 5 6
7 8
```

Size of the state space = $9!/2 = 181,440$

- 15-puzzle: $6.5 \times 10^{12}$ states, 0.18 seconds
- 24-puzzle: $5 \times 10^{25}$ states, 6 days
- 10 millions states/second

12 billion years
Search Problem

- State space
- Initial state
- Successor function
- Goal test
- Path cost

State space:
- each state is an abstract representation of the environment (not "world state")
- the state space is discrete

Initial state:

Successor function:

Goal test:

Path cost:
Search Problem

- State space
- Initial state
- Successor function:
  - [state \rightarrow \text{subset of states}]
  - an abstract representation of the possible actions (discrete)
- Goal test
- Path cost

Search Problem

- State space
- Initial state
- Successor function
- Goal test:
  - usually a condition
  - sometimes the description of a state
- Path cost

Search Problem

- State space
- Initial state
- Successor function
- Goal test
- Path cost:
  - [path \rightarrow \text{positive number}]
  - usually, path cost = sum of step costs
  - e.g., number of moves of the empty tile
Simple Agent Algorithm

Problem-Solving-Agent
1. initial-state $\leftrightarrow$ sense/read state
2. goal $\leftrightarrow$ select/read goal
3. successor $\leftrightarrow$ select/read action models
4. problem $\leftrightarrow$ (initial-state, goal, successor)
5. solution $\leftrightarrow$ search(problem)
6. perform(solution)

An Old Idea: The Labyrinth and the Ariadne Thread

Theseus, a Greek hero, came to Crete to slay the Minotaur, a monster who lived in a Labyrinth. Ariadne gave Theseus a ball of yarn which he unwound as he entered the Labyrinth. After killing the Minotaur, Theseus traced the thread back to the entrance of the Labyrinth, rejoined Ariadne, and successfully escaped Crete.

Example: 8-queens

Place 8 queens in a chessboard so that no two queens are in the same row, column, or diagonal.

A solution

Not a solution
Example: 8-queens

Formulation #1:
- States: any arrangement of $0$ to $8$ queens on the board
- Initial state: $0$ queens on the board
- Successor function: add a queen in any square
- Goal test: $8$ queens on the board, none attacked

$\rightarrow 64^8$ states with $8$ queens

Example: 8-queens

Formulation #2:
- States: any arrangement of $k = 0$ to $8$ queens in the $k$ leftmost columns with none attacked
- Initial state: $0$ queens on the board
- Successor function: add a queen to any square in the leftmost empty column such that it is not attacked by any other queen
- Goal test: $8$ queens on the board

$\rightarrow 2,057$ states

Example: Robot navigation

What is the state space?
Example: Robot navigation #1

Cost of one horizontal/vertical step = 1
Cost of one diagonal step = $\sqrt{2}$

Example: Robot navigation #1

Example: Robot navigation #2
Example: Assembly Planning

- **State**: Collection of sub-assemblies
- **Initial state**: All sub-assemblies are individual parts

- **Goal state**: Complete assembly
- **Successor function**: Merge two subassemblies (check for collision)
- **Cost function**: Longest sequence of assembly operation
Assumptions in Basic Search

- The environment is static
- The environment is discretizable
- The environment is observable
- The actions are deterministic

Search Problem Formulation

- Real-world environment $\rightarrow$ Abstraction

Validity:
- Can the solution be executed?
Search Problem Formulation

Real-world environment → Abstraction

- Validity:
  - Can the solution be executed?
  - Does the state space contain the solution?
Search Problem Formulation

- Real-world environment $\rightarrow$ Abstraction
  - Validity:
    - Can the solution be executed?
    - Does the state space contain the solution?
  - Usefulness
    - Is the abstract problem easier than the real-world problem?
Search Problem Formulation

- Real-world environment → Abstraction
  - Validity:
    - Can the solution be executed?
    - Does the state space contain the solution?
  - Usefulness
    - Is the abstract problem easier than the real-world problem?
- Without abstraction an agent would be swamped by the complexity of the real world

Search Problem Variants

- One or several initial states
- One or several goal states
- The solution is the path or a goal node
  - In the 8-puzzle problem, it is the path to a goal node
  - In the 8-queen problem, it is a goal node

Search Problem Variants

- One or several initial states
- One or several goal states
- The solution is the path or a goal node
- Any, or the best, or all solutions
Important Parameters

- Number of states in state space
- Distribution of goal states
- Size of memory needed to store a state
- Running time of the successor function

There exist techniques to solve N-queens problems efficiently!

Stating a problem as a search problem is not always a good idea!
Applications

- Route finding: airline travel, networks
- Pipe routing, VLSI routing
- Pharmaceutical drug design
- Robot motion planning
- Video games

Summary

- Problem-solving agent
- State space, successor function, search
- Examples: 8-puzzle, 8-queens, route finding, robot navigation, assembly planning
- Assumptions of basic search
- Important parameters