Problem Spaces & Search

CSE 473

473 Topics
Agents & Environments
Problem Spaces
Search & Constraint Satisfaction
Knowledge Repr’n & Logical Reasoning
Machine Learning
Uncertainty: Repr’n & Reasoning
Robotics

Weak Methods

“In the knowledge lies the power…”
[Feigenbaum]

But what if no knowledge???

Generate & test: As weak as it gets
**Search thru a Problem Space / State Space**

**Input:**
- Set of states
- Operators [and costs] (successor function)
- Start state
- Goal state [test]

**Output:**
- Path: start at a state satisfying goal test
- [May require shortest path]

---

**Example: Route Planning**

**Input:**
- Set of states
- Operators [and costs]
- Start state
- Goal state (test)

**Output:**

---

**Example: N Queens**

**Input:**
- Set of states
- Operators [and costs]
- Start state
- Goal state (test)

**Output:**

---

**Search Strategies**

**Blind Search**
- Depth first search
- Breadth first search
- Iterative deepening search
- Iterative broadening search

**Informed Search**

**Constraint Satisfaction**

**Adversary Search**
Search Strategies

A search strategy is defined by picking the order of node expansion.

 Strategies are evaluated along the following dimensions:
  - completeness: does it always find a solution if one exists?
  - time complexity: number of nodes generated
  - space complexity: maximum number of nodes in memory
  - optimality: does it always find a least-cost solution?

Time and space complexity are measured in terms of:
  - \( b \): maximum branching factor of the search tree
  - \( d \): depth of the least-cost solution
  - \( m \): maximum depth of the state space (may be \( \infty \))

Breadth First Search

Maintain queue of nodes to visit

Evaluation
  - Complete?
    Yes
  - Time Complexity?
    \( O(b^d) \)
  - Space Complexity?
    \( O(b^d) \)

Depth First Search

Maintain stack of nodes to visit

Evaluation
  - Complete?
  - Time Complexity?
  - Space Complexity?

Memory a Limitation?

Suppose:
  - 2 GHz CPU
  - 1 GB main memory
  - 100 instructions / expansion
  - 5 bytes / node

200,000 expansions / sec
Memory filled in 100 sec ... < 2 minutes
Depth First Search

Maintain stack of nodes to visit

Evaluation

- Complete?
- Time Complexity?
- Space Complexity?
Depth First Search

Maintain stack of nodes to visit

Evaluation
  • Complete?
  • Time Complexity?
  • Space Complexity?
Depth First Search

Maintain stack of nodes to visit

Evaluation
- Complete?
- Time Complexity?
- Space Complexity?

Not for infinite spaces
- Time Complexity?
  \( O(b^m) \)
- Space Complexity?
  \( O(bm) \)
Iterative Deepening Search

DFS with limit; incrementally grow limit

Evaluation

- Complete? Yes
- Time Complexity? $O(b^d)$
- Space Complexity? $O(bd)$

Iterative deepening search

Number of nodes generated in a depth-limited search to depth $d$ with branching factor $b$:

$$N_{DLS} = b^0 + b^1 + b^2 + \ldots + b^{d-2} + b^{d-1} + b^d$$

Number of nodes generated in an iterative deepening search to depth $d$ with branching factor $b$:

$$N_{IDS} = (d+1)b^0 + d b^1 + (d-1)b^2 + \ldots + 3b^{d-2} + 2b^{d-1} + b^d$$

For $b = 10$, $d = 5$:

- $N_{DLS} = 1 + 10 + 100 + 1,000 + 10,000 + 100,000 = 111,111$
- $N_{IDS} = 6 + 50 + 400 + 3,000 + 20,000 + 100,000 = 123,456$

Overhead = \((123,456 - 111,111)/111,111 = 11\%\)

Forwards vs. Backwards

vs. Bidirectional
Repeated states

Failure to detect repeated states can turn a linear problem into an exponential one!

Graph search: Stores expanded nodes in a set called Closed and only adds new nodes to the fringe

Manipulator Control

Arm with two joints

Configuration space

Manipulator Control Path

State space

Configuration space

Manipulator Control Path

State space

Configuration space
Problem

All these methods are slow  (blind)

Solution  → add guidance ("heuristic estimate")
            → "informed search"