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
Dynamic Bayesian Networks
Markov Decision Processes

Weak Methods

"In the knowledge lies the power…"
[Feigenbaum]

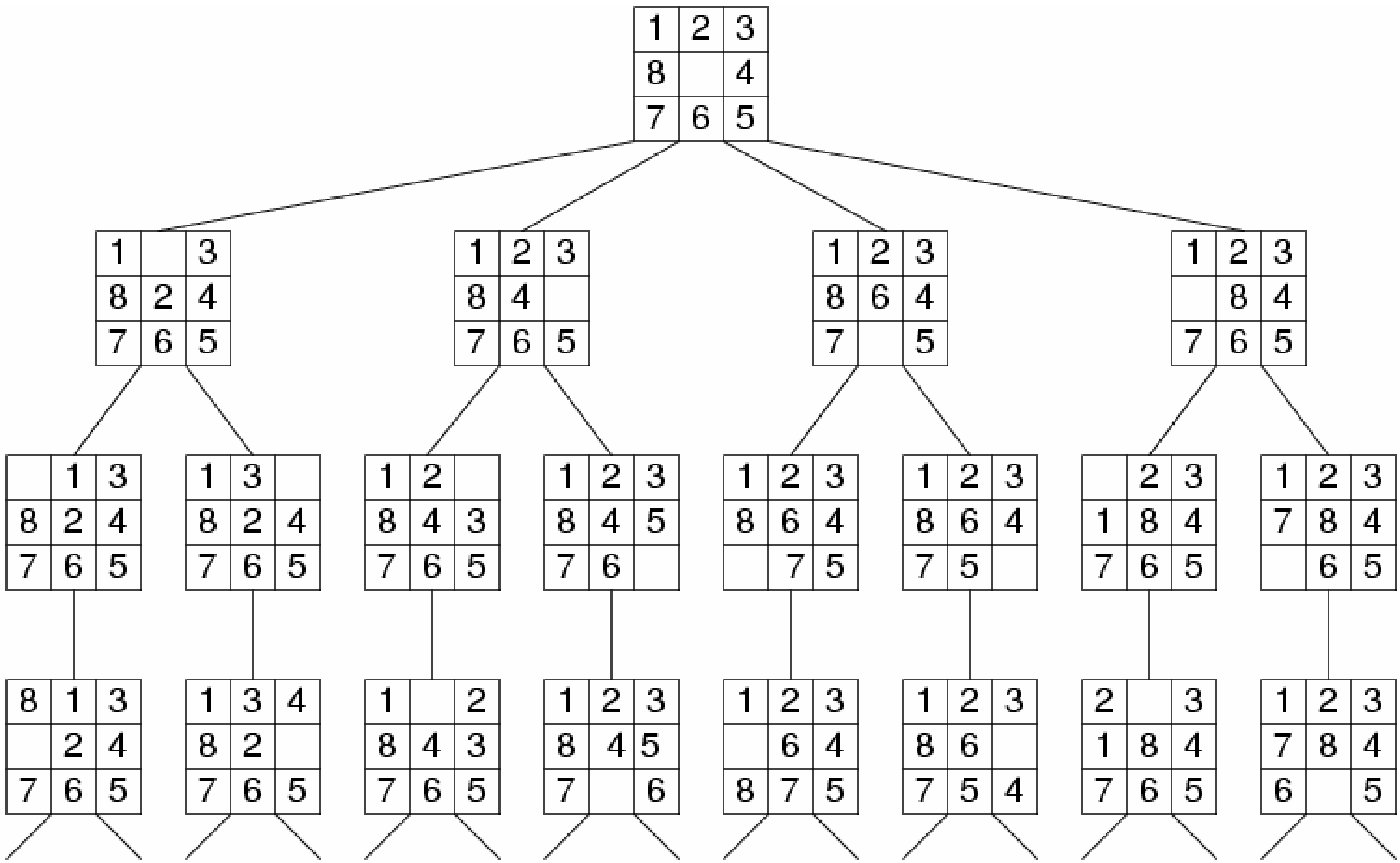
But what if no knowledge????

Generate & Test

As weak as it gets…

Works on semi-decidable problems!

Example:
Fragment of 8-Puzzle Problem Space



Search thru a Problem Space / State Space

Input:

- Set of states
- Operators [and costs]
- Start state
- Goal state [test]

Output:

- Path: start $\Rightarrow$ 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

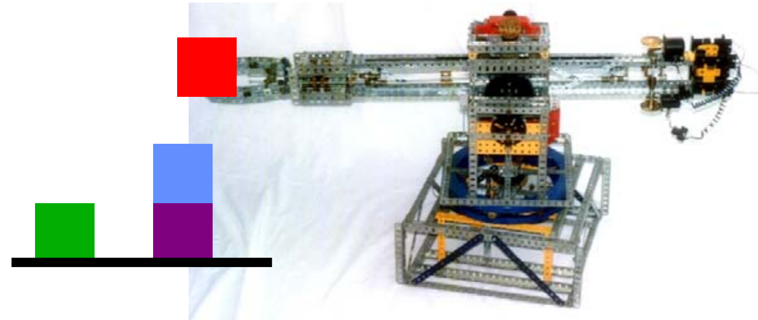
		Q	
Q			
			Q
	Q		

Input:

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

Output

Example: Blocks World



Input:

- Set of states

  Partially specified plans

- Operators [and costs]

  Plan modification operators

- Start state

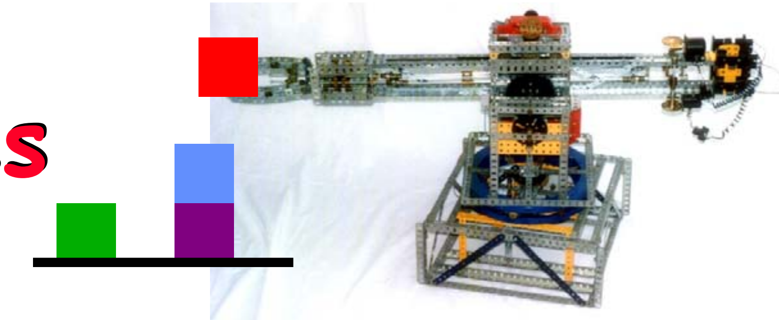
  The null plan (no actions)

- Goal state (test)

  A plan which provably achieves

  The desired world configuration

Multiple Problem Spaces



Real World

- States of the world (e.g. block configurations)
- Actions (take one world-state to another)

Robot's Head

Problem Space 1

- PS states =
  - models of world states
- Operators =
  - models of actions

Problem Space 2

- PS states =
  - partially spec. plan
- Operators =
  - plan modification ops

Classifying Search

GUESSING ("Tree Search")

- Guess how to extend a partial solution to a problem.
- Generates a tree of (partial) solutions.
- The leafs of the tree are either "failures" or represent complete solutions

SIMPLIFYING ("Inference")

- Infer new, stronger constraints by combining one or more constraints (without any "guessing")

Example: $X+2Y = 3$

$X+Y = 1$

therefore $Y = 2$

WANDERING ("Markov chain")

- Perform a (biased) random walk through the space of (partial or total) solutions

Guessing – State Space Search

1. BFS
2. DFS
3. Iterative Deepening
4. Bidirectional
5. Best-first search
6. A*
7. Game tree
8. Davis-Putnam (logic)
9. Cutset conditioning (probability)

Simplification – Constraint Propagation

1. Forward Checking
2. Path Consistency (Waltz labeling, temporal algebra)
3. Resolution
4. "Bucket Algorithm"

Wandering – Randomized Search

1. Hillclimbing
2. Simulated annealing
3. Walksat
4. Monte-Carlo Methods

Constraint Satisfaction

Search Strategies v2

Blind Search

- Depth first search
- Breadth first search
- Iterative deepening search
- Iterative broadening search

Informed Search

Constraint Satisfaction

Adversary Search

Depth First Search

Maintain stack of nodes to visit

Evaluation

- Complete?

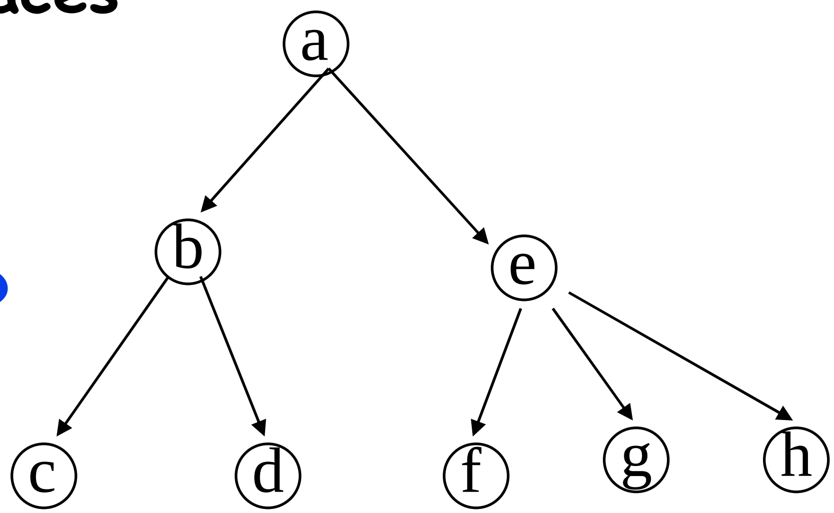
  Not for infinite spaces

- Time Complexity?

  O(b^d)

- Space Complexity?

  O(d)



Breadth First Search

Maintain queue of nodes to visit

Evaluation

- Complete?

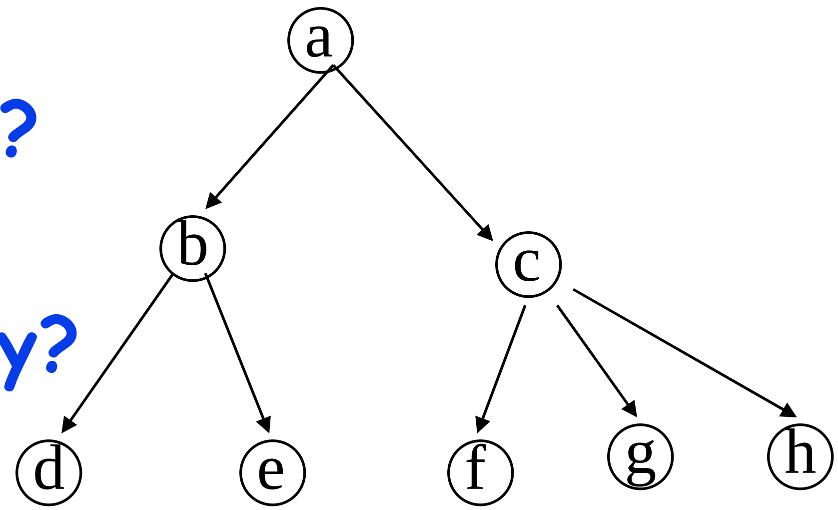
  Yes

- Time Complexity?

  O(b^d)

- Space Complexity?

  O(b^d)



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

Iterative Deepening Search

DFS with limit; incrementally grow limit

Evaluation

- Complete?

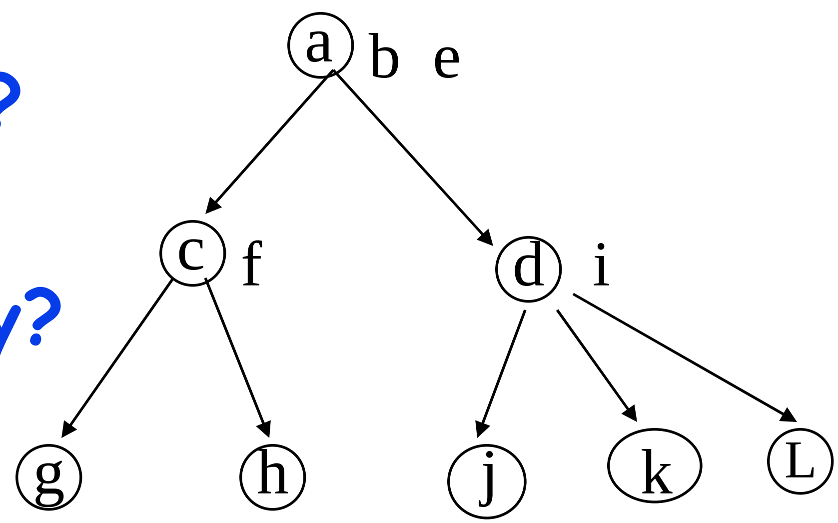
  Yes

- Time Complexity?

  O(b^d)

- Space Complexity?

  O(d)

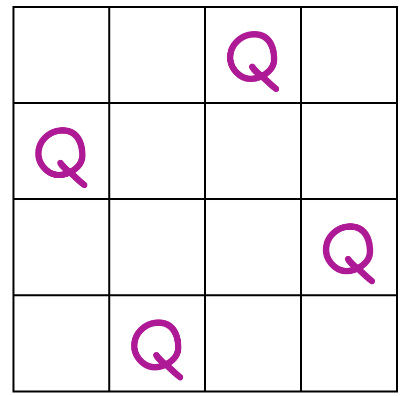


Cost of Iterative Deepening

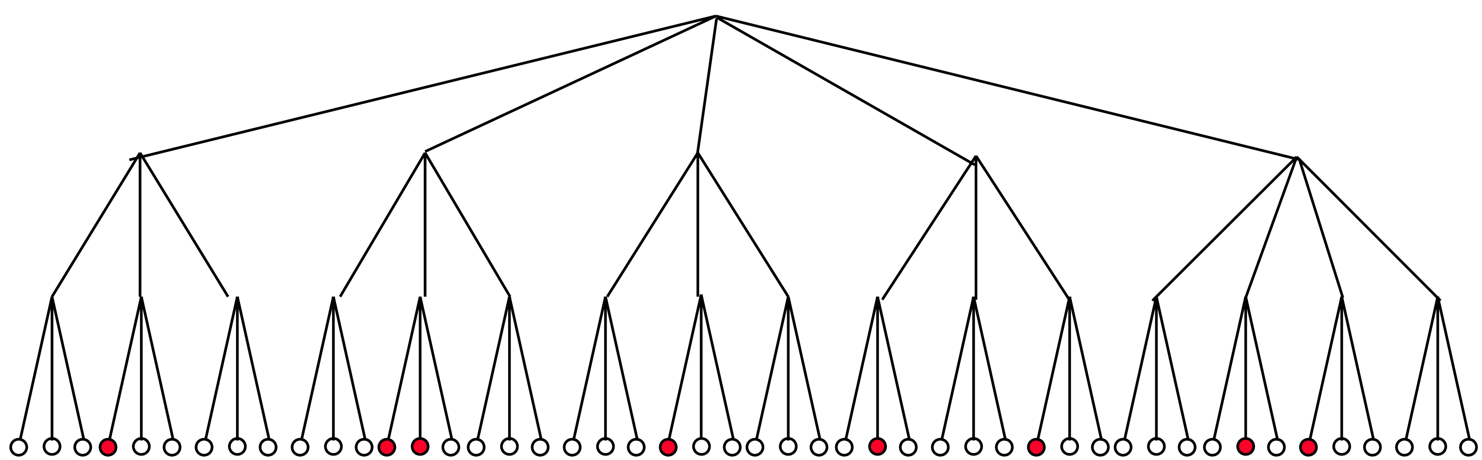
b	ratio ID to DFS
2	3
3	2
5	1.5
10	1.2
25	1.08
100	1.02

When to Use Iterative Deepening

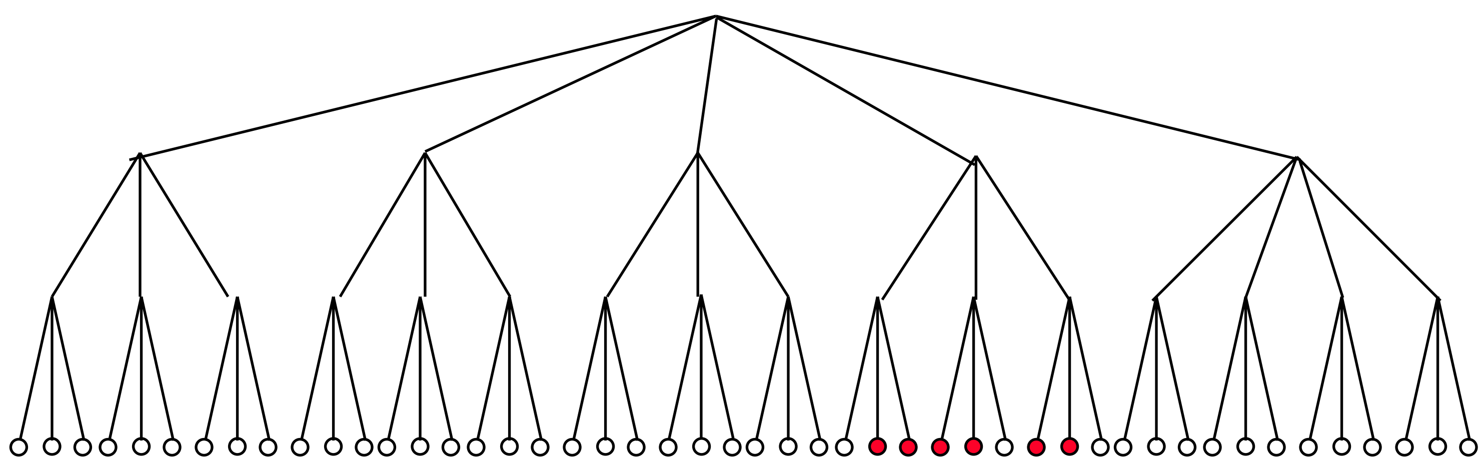
N Queens?



Search Space with Uniform Structure



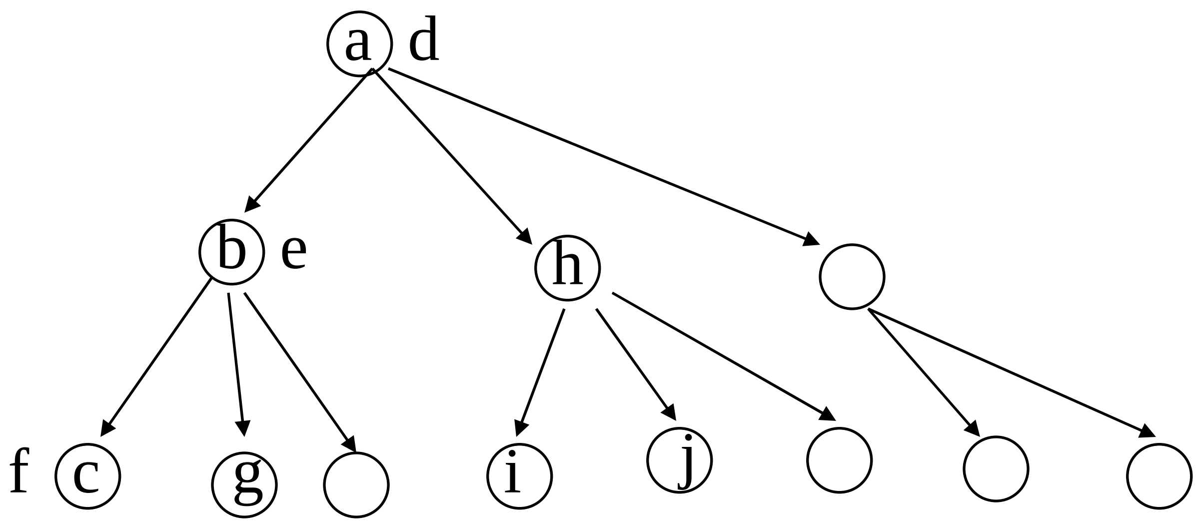
Search Space with Clustered Structure



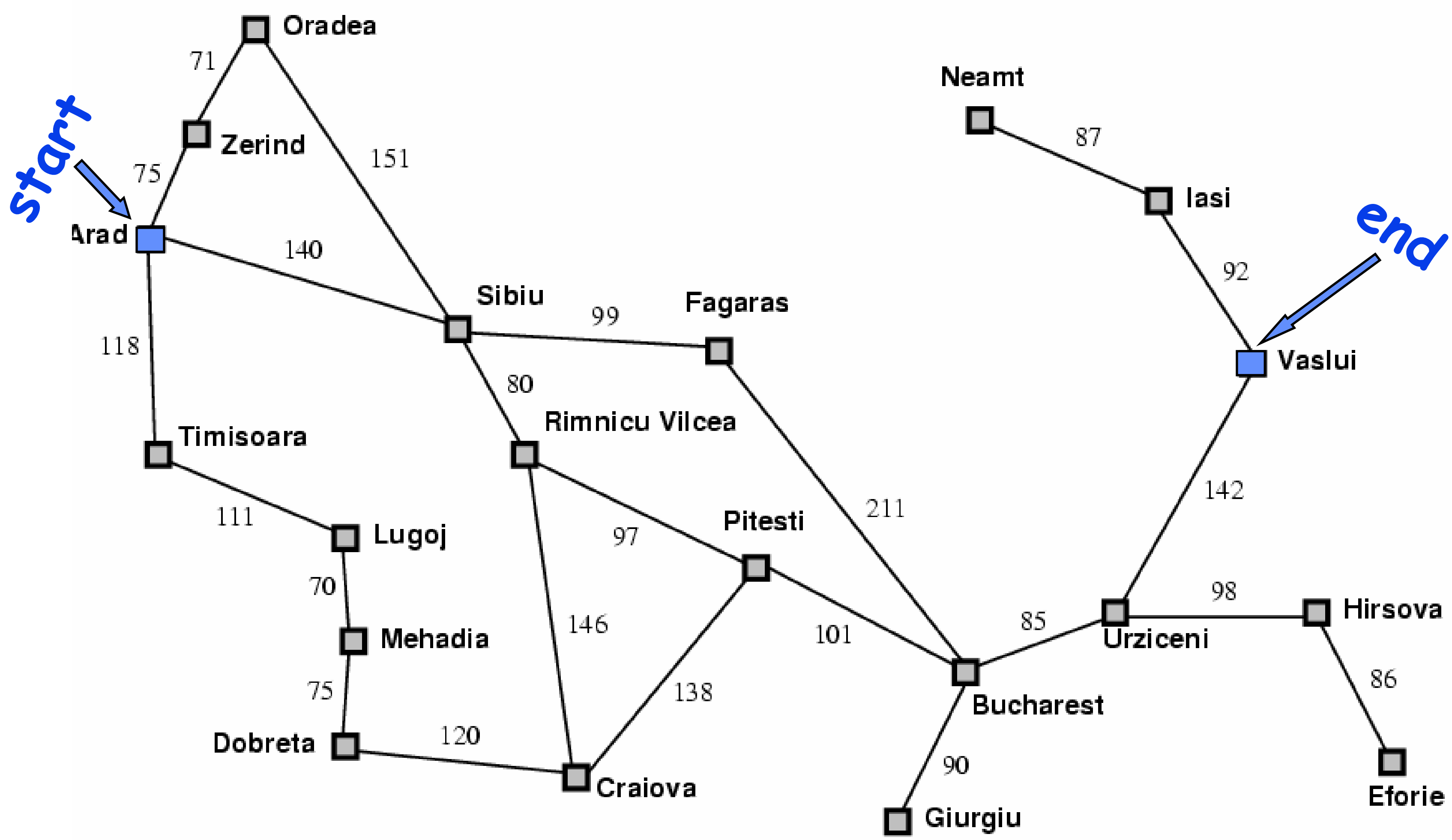
Iterative Broadening Search

What if know solutions lay at depth N?

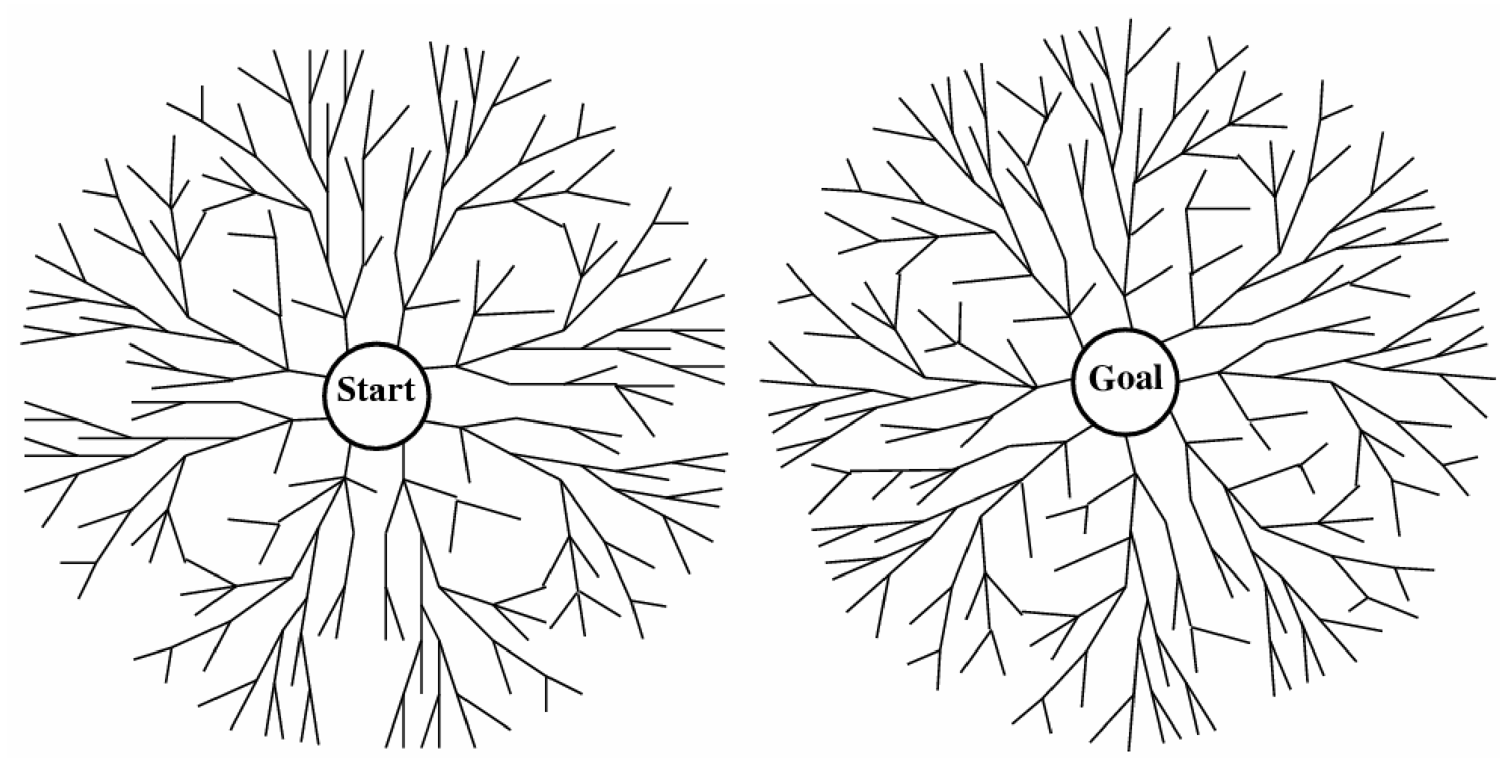
No sense in doing iterative *deepening*



Forwards vs. Backwards



vs. Bidirectional



Problem

All these methods are slow (blind)

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

… next time …

Recap: Search thru a Problem Space / State Space

Input:

- Set of states
- Operators [and costs]
- Start state
- Goal state [test]

Output:

- Path: start $\Rightarrow$ a state satisfying goal test
- [May require shortest path]

Cryptarithmetic

```
  SEND
+ MORE
------
 MONEY
```

Input:

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

Output:

Concept Learning

Labeled Training Examples

<p1,blond,32,mc,ok>

<p2,red,47,visa,ok>

<p3,blond,23,cash,ter>

<p4,…

Output: f: <pn…> → {ok, ter}

Input:

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

Output:

Symbolic Integration

E.g. $\int x^2 e^x \, dx =$

$$e^x(x^2-2x+2) + C$$

Operators:

Integration by parts

Integration by substitution

...