CSE 573: Artificial Intelligence

Search: Heuristics and Pattern DBs

Dan Weld

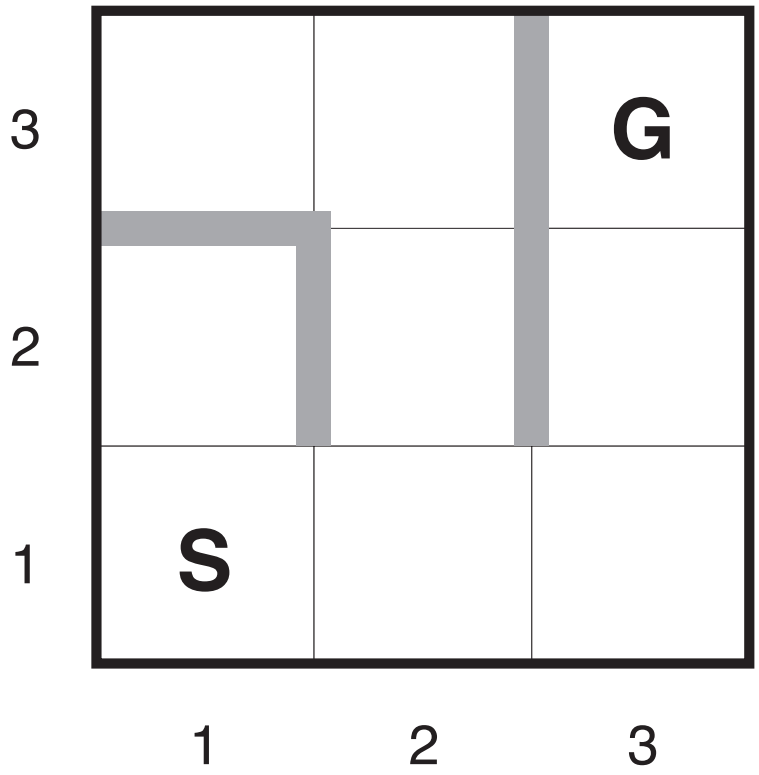
With slides from
Dan Weld, Dan Klein, Stuart Russell, Travis Mandel, Andrew Moore, Luke Zettlemoyer

Search thru a
Problem Space / State Space

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

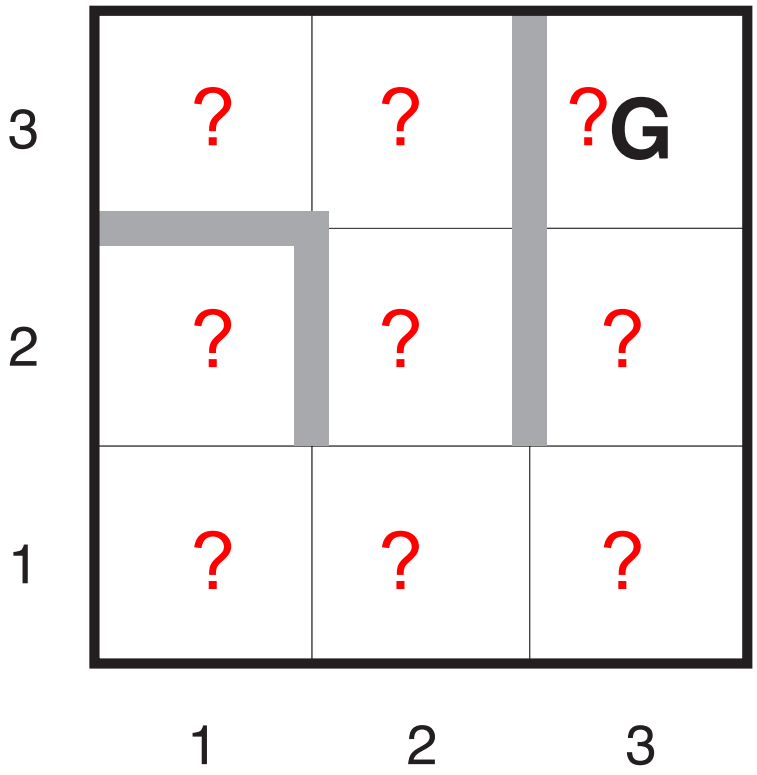
- Output:
  - Path: start $\Rightarrow$ a state satisfying goal test
  - [May require shortest path]
  - [Sometimes just need state passing test]

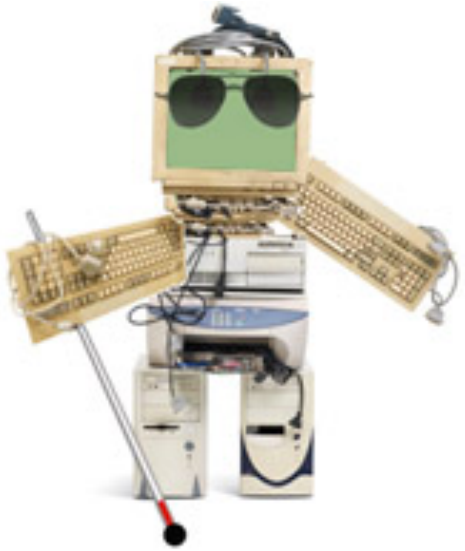
Search thru State Space



What if Robot is Blind?

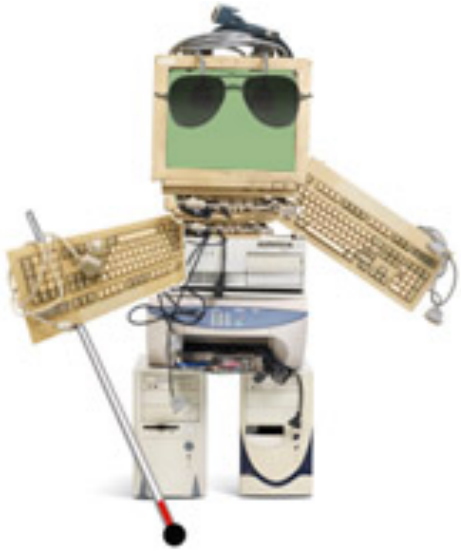
Moving into wall → noop





"Conformant Planning"

[Has a talking compass – knows which way is N]

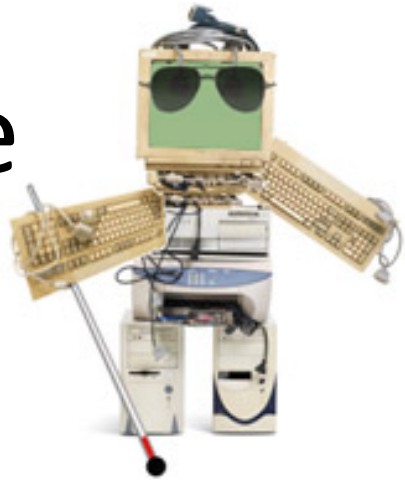


Conformant Planning

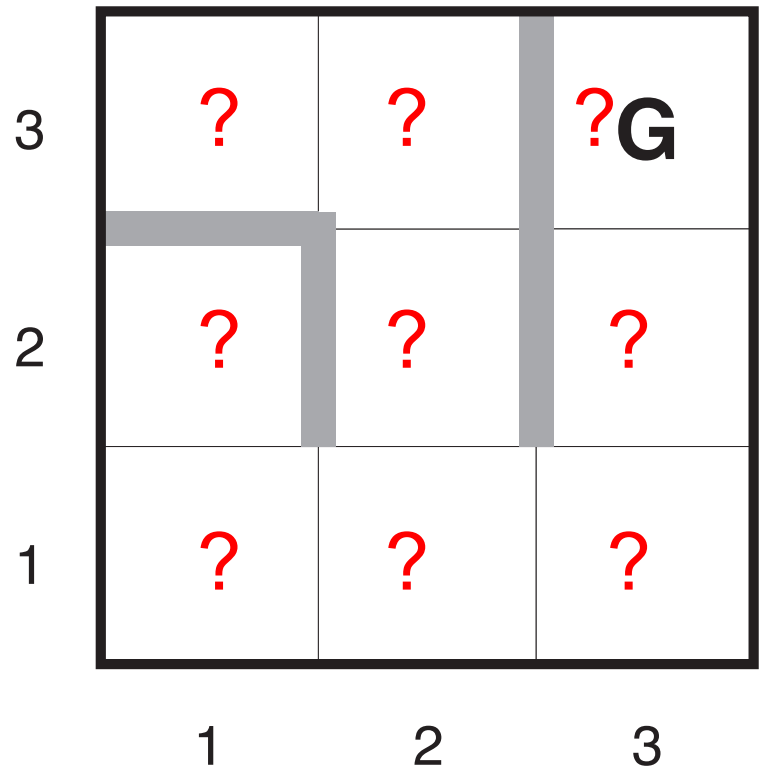
Sterilizing surgical gear

Bowl feeder

Search thru State Space

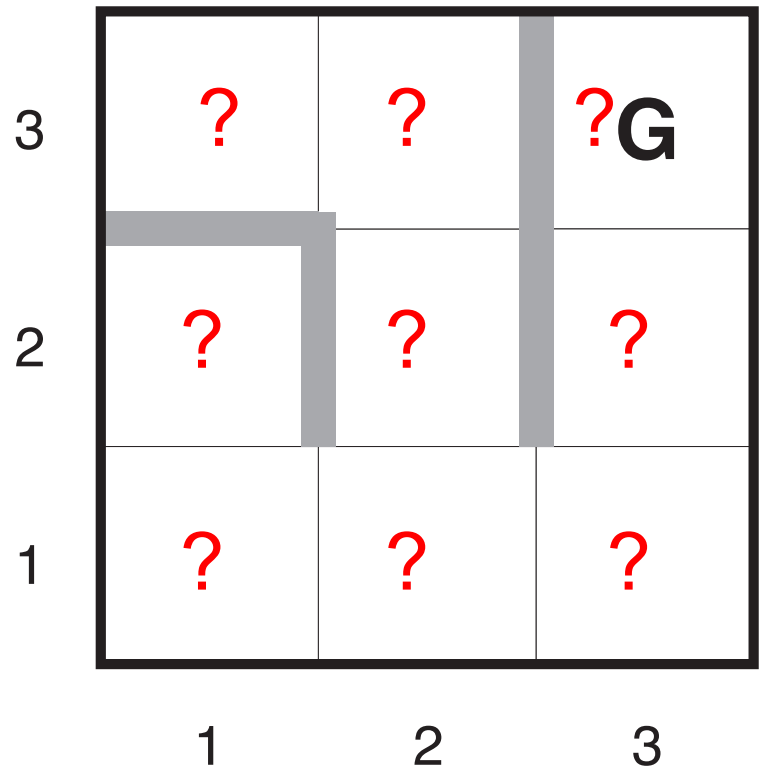


- States
  - SETS of states
  - "Belief state"
- Operators
  - Move actions
- Initial State
  - Set of all states
- Goal State
  - Set of just goal state(s)



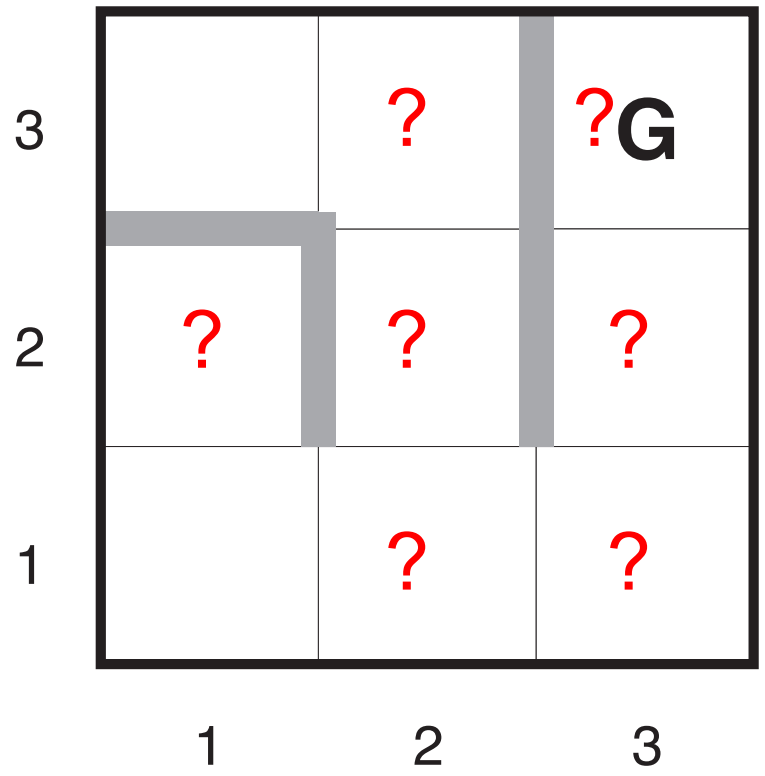
Soln: R, D, D, R, R, U, U

- States
  - SETS of states
  - "Belief state"
- Operators
  - Move actions
- Initial State
  - Set of all states
- Goal State
  - Set of just goal states



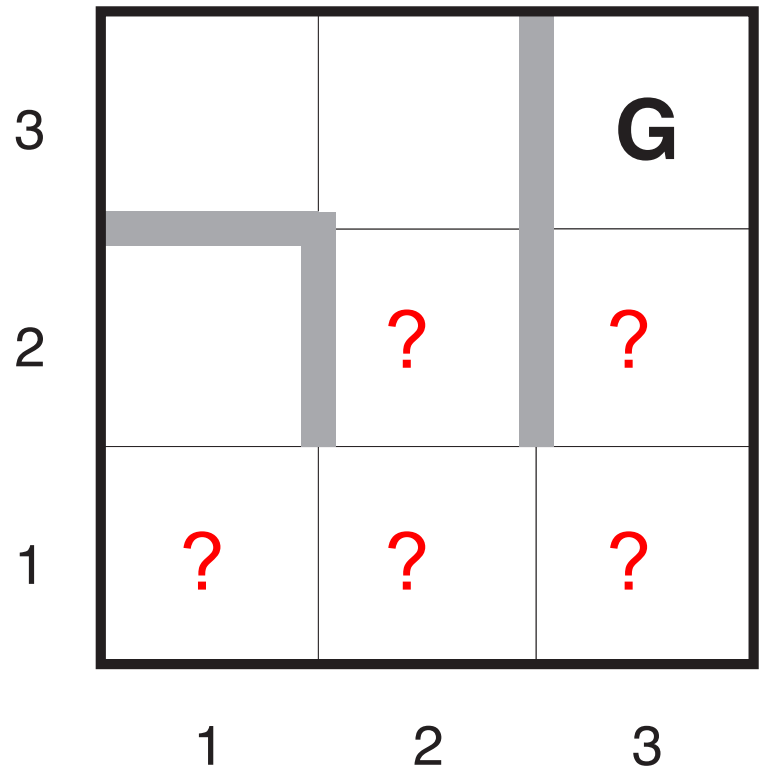
Move Right

- States
  - SETS of states
  - “Belief state”
- Operators
  - Move actions
- Initial State
  - Set of all states
- Goal State
  - Set of just goal states



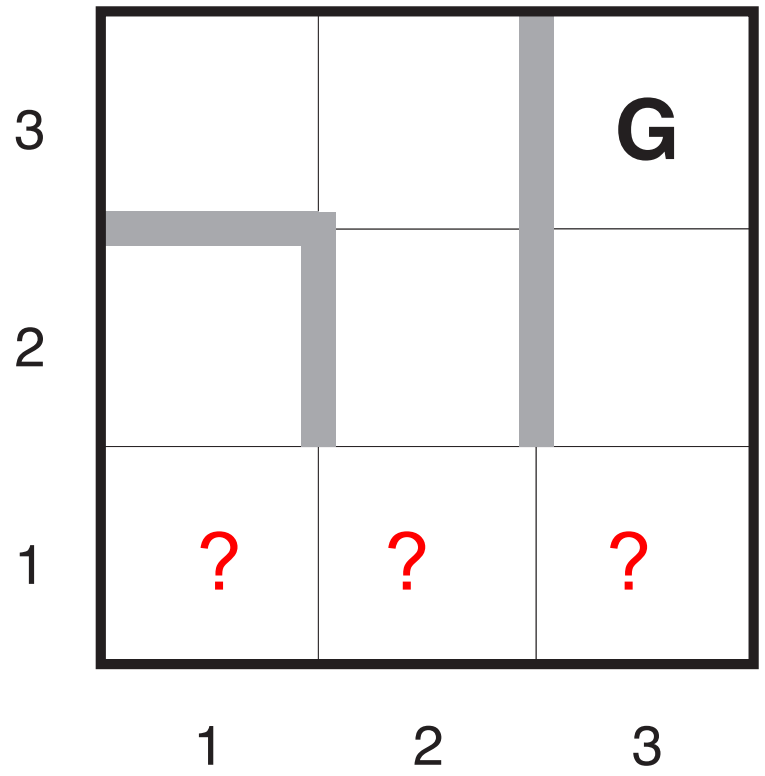
Move Down

- States
  - SETS of states
  - “Belief state”
- Operators
  - Move actions
- Initial State
  - Set of all states
- Goal State
  - Set of just goal states



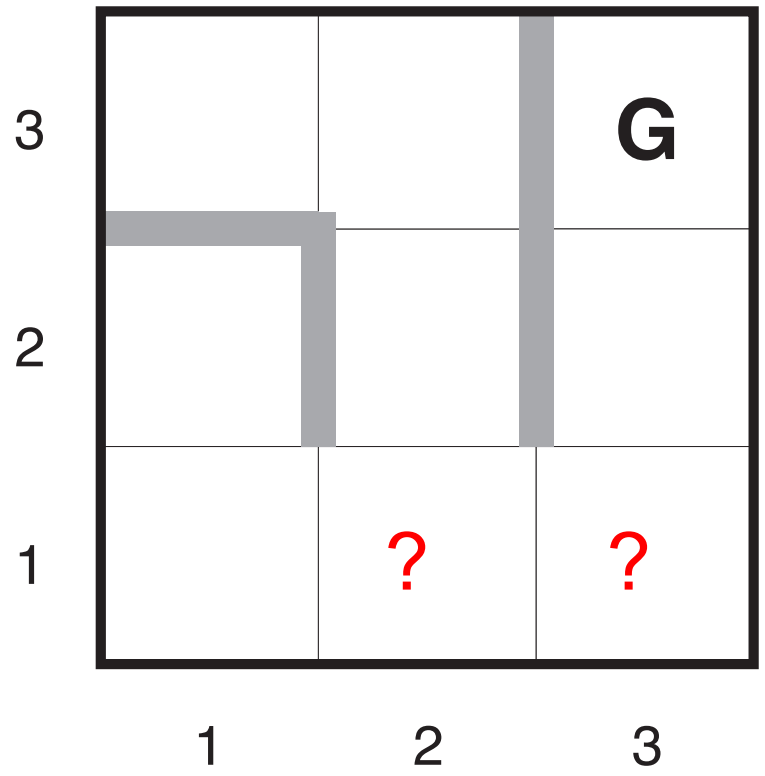
Move Down

- States
  - SETS of states
  - "Belief state"
- Operators
  - Move actions
- Initial State
  - Set of all states
- Goal State
  - Set of just goal states



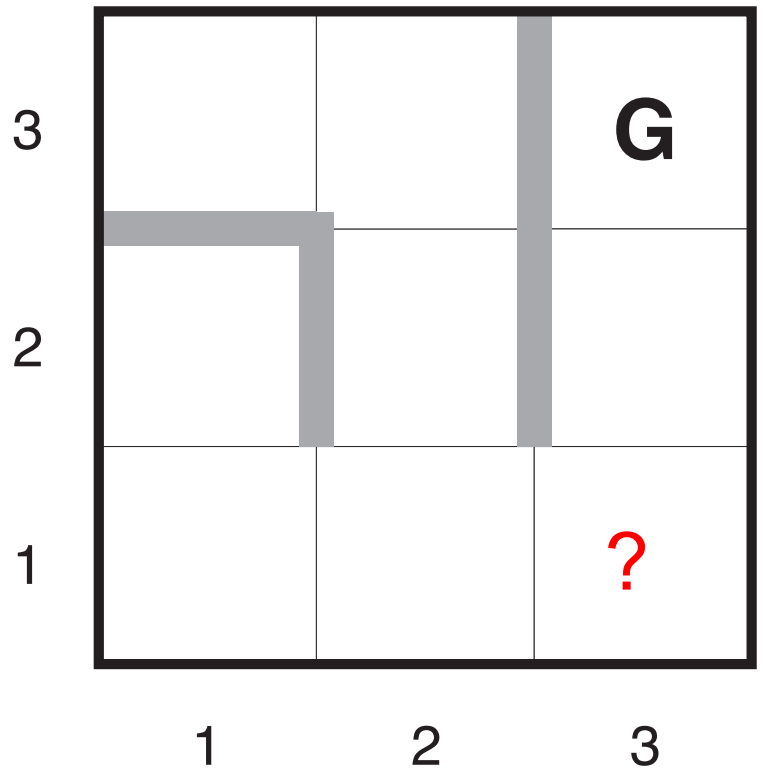
Move Right

- States
  - SETS of states
  - "Belief state"
- Operators
  - Move actions
- Initial State
  - Set of all states
- Goal State
  - Set of just goal states



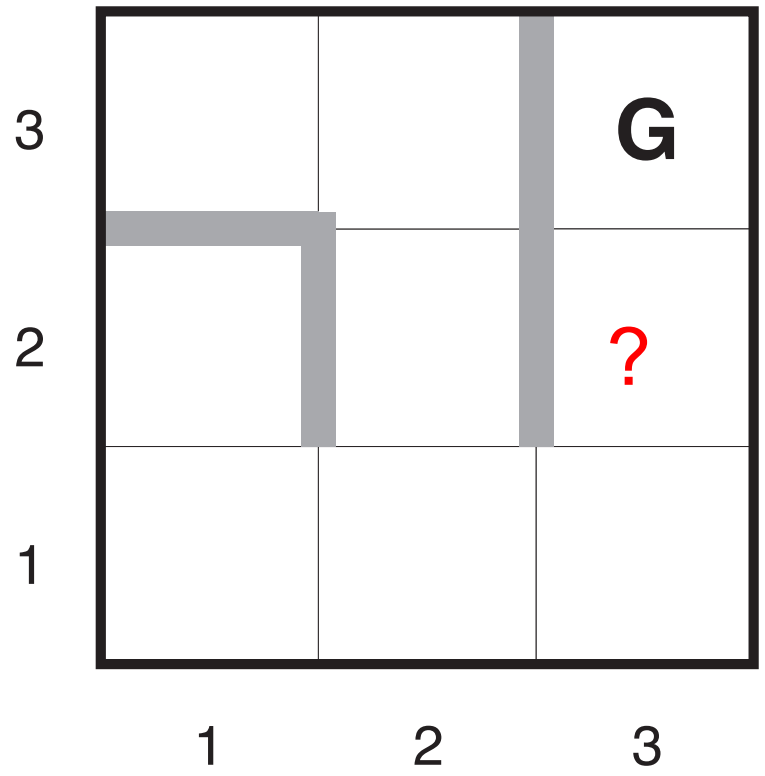
Move Right

- States
  - SETS of states
  - “Belief state”
- Operators
  - Move actions
- Initial State
  - Set of all states
- Goal State
  - Set of just goal states



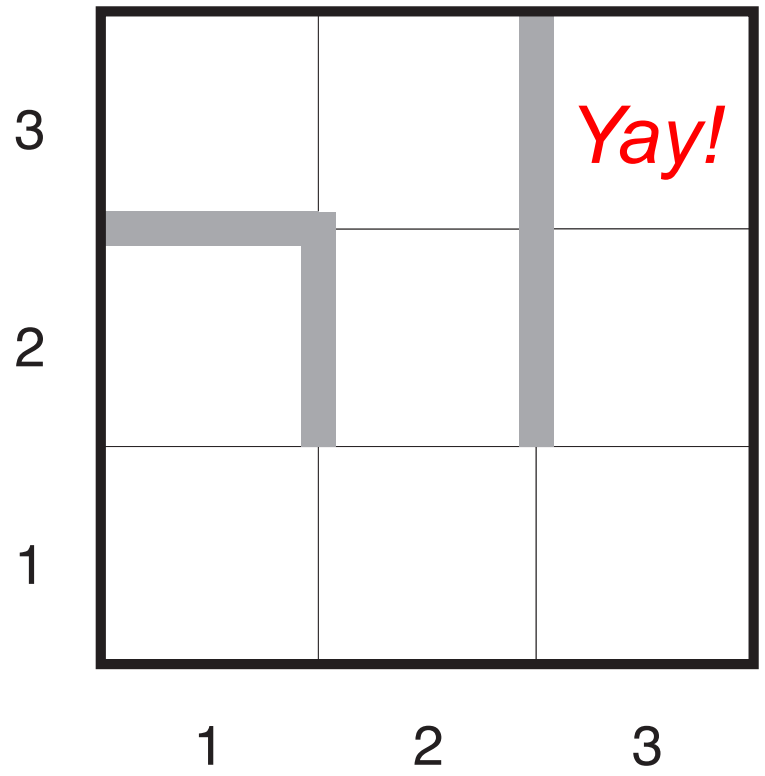
Move Up

- States
  - SETS of states
  - “Belief state”
- Operators
  - Move actions
- Initial State
  - Set of all states
- Goal State
  - Set of just goal states



Move Up

- States
  - SETS of states
  - “Belief state”
- Operators
  - Move actions
- Initial State
  - Set of all states
- Goal State
  - Set of just goal states



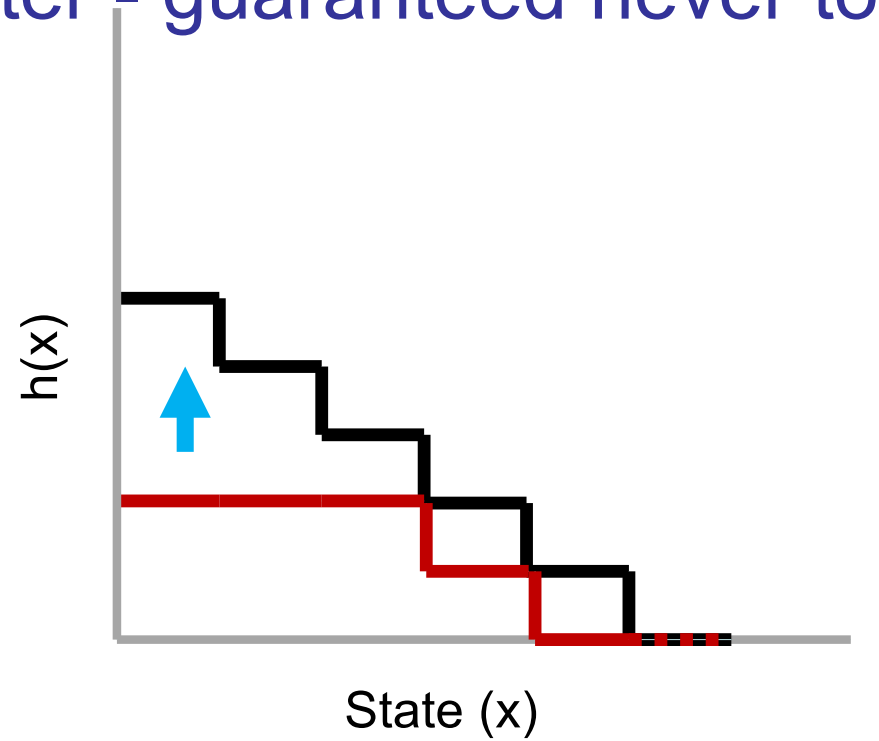
Heuristics

It’s what makes search actually work

Dominance

If $h_2(n) \geq h_1(n)$ for all n (both admissible)
then h_2 dominates h_1

h_2 is better - guaranteed never to expand more nodes.



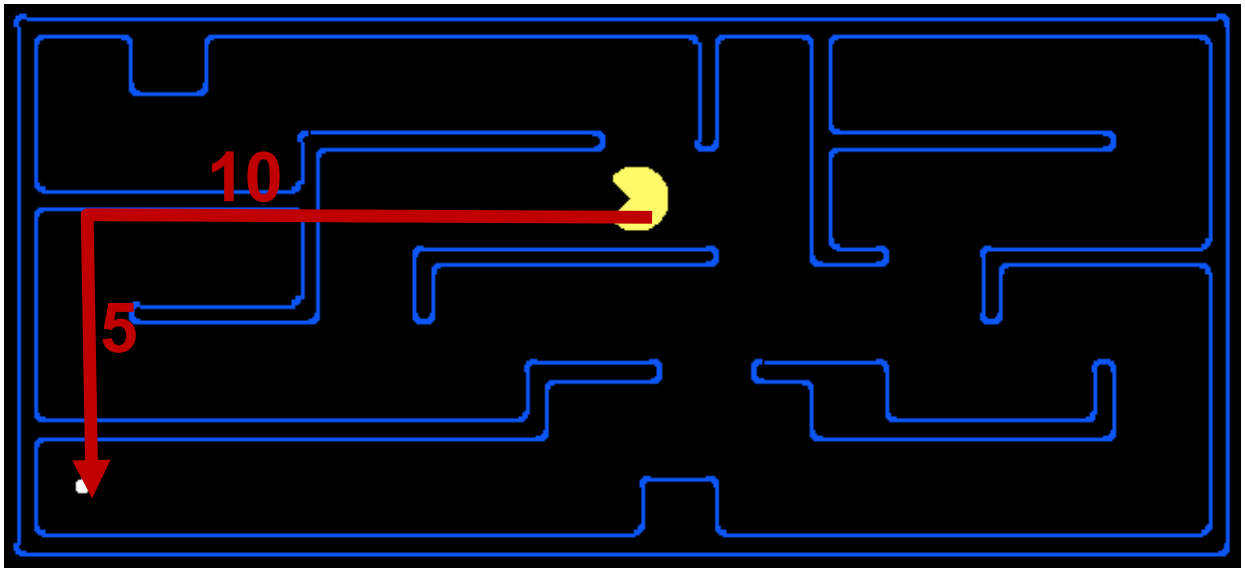
Admissable Heuristics

- f(x) = g(x) + h(x)
- g: cost so far
- h: underestimate of remaining costs

Where do heuristics come from?

Relaxed Problems

Derive admissible heuristic from exact cost of a solution to a relaxed version of problem

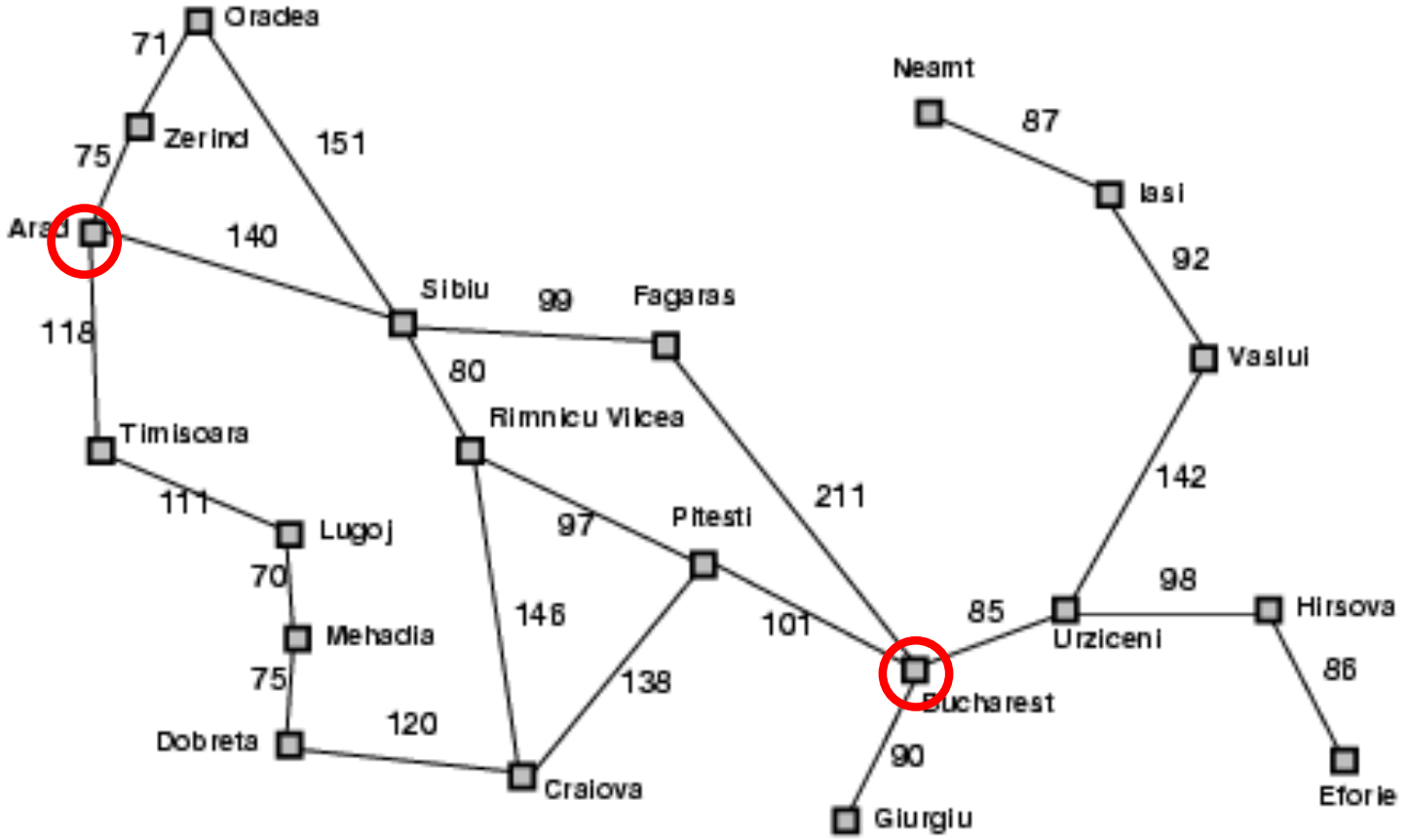


Eg Manhattan distance – what is relaxed?

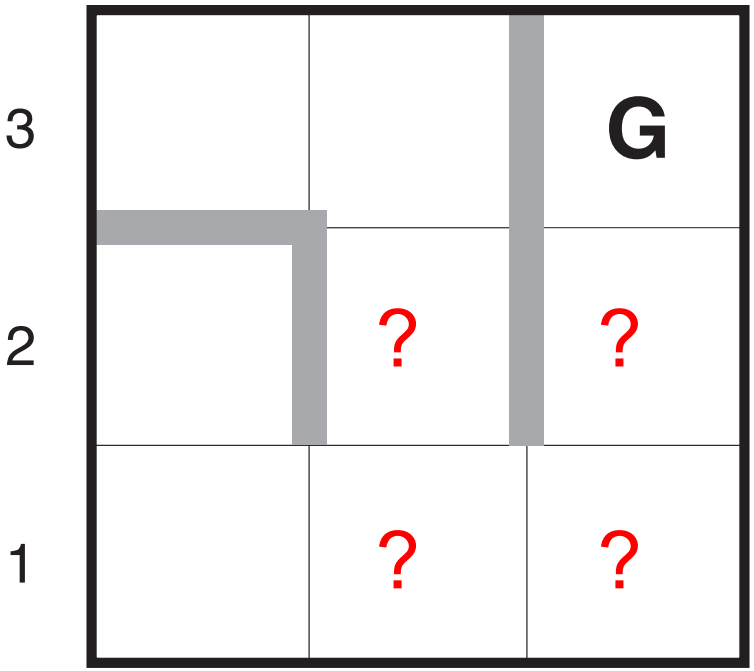
Cost of optimal soln to relaxed problem ≤ cost of optimal soln for real problem

What's being relaxed?

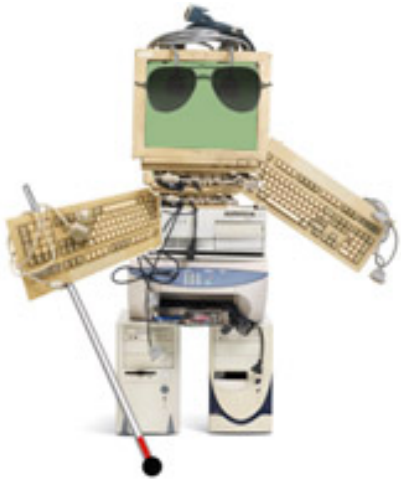
Heuristic = Euclidean distance



Straight–line distance to Bucharest	
Arad	366
Bucharest	0
Craiova	160
Dobreta	242
Eforie	161
Fagaras	176
Giurgiu	77
Hirsova	151
Iasi	226
Lugoj	244
Mehadia	241
Neamt	234
Oradea	380
Pitesti	10
Rimnicu Vilcea	193
Sibiu	253
Timisoara	329
Urziceni	80
Vaslui	199
Zerind	374



- States
  - SETS of states
  - "Belief state"
- Goal State
  - Set of just goal state(s)



Heuristics?

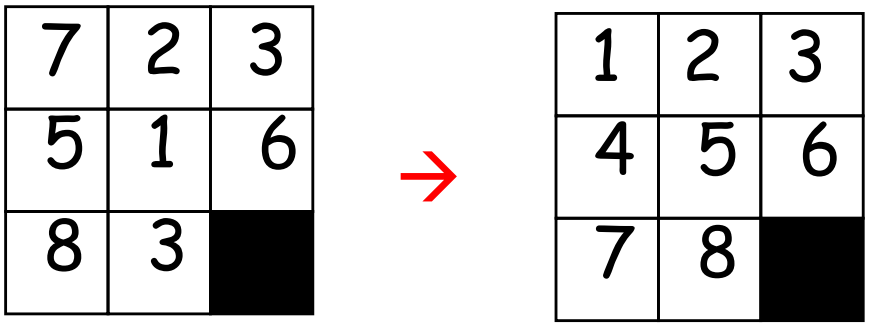
Relaxed Problem?

- What if it weren't blind?
- Max # moves from any state in belief state

Also… (admissable?)

- Number of states in belief state

Heuristics for eight puzzle

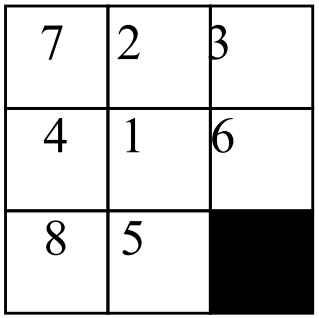


- What can we relax?

h1 = number of tiles in wrong place

h2 = Σ distances of tiles from correct loc

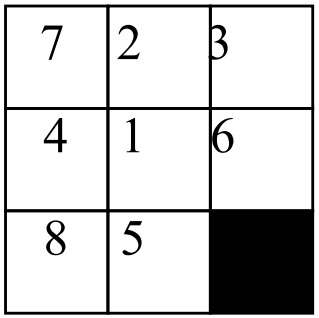
Importance of Heuristics



h1 = number of tiles in wrong place

D	IDS	A*(h1)
2	10	6
4	112	13
6	680	20
8	6384	39
10	47127	93
12	364404	227
14	3473941	539
18		3056
24		39135

Importance of Heuristics



h1 = number of tiles in wrong place

h2 = Σ distances of tiles from correct loc

D	IDS	A*(h1)	A*(h2)
2	10	6	6
4	112	13	12
6	680	20	18
8	6384	39	25
10	47127	93	39
12	364404	227	73
14	3473941	539	113
18		3056	363
24		39135	1641

Decrease effective branching factor

Need More Power!

Performance of Manhattan Distance Heuristic

- 8 Puzzle < 1 second
- 15 Puzzle 1 minute
- 24 Puzzle 65000 years

Need even better heuristics!

Adapted from Richard Korf presentation