Generating and Evaluating Unsolvable STRIPS Planning Instances for Classical Planning

Bachelor's Thesis

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UNI
BASEL

Contents

Goals of this thesis

Investigating unsolvability for classical planning

Recent work *"Distance"? Who Cares? Tailoring Merge-and-Shrink Heuristics to Detect Unsolvability* by Hoffmann et al. (ECAI'14)

- Finding suitable problem domains for unsolvable problems
- Constructing unsolvable problem instances
- Implementing a problem generator
- Evaluating different heuristics on generated unsolvable problems

Planning

Solving formalized problems we meet in real life

- set of variables
- initial state
- goal states
- set of actions
  - precondition --> effect
  - cost
- plan = sequence of actions from the initial state to a goal state

Either find a plan or prove that there is no such plan

Heuristics

Approximate the distance to a goal state

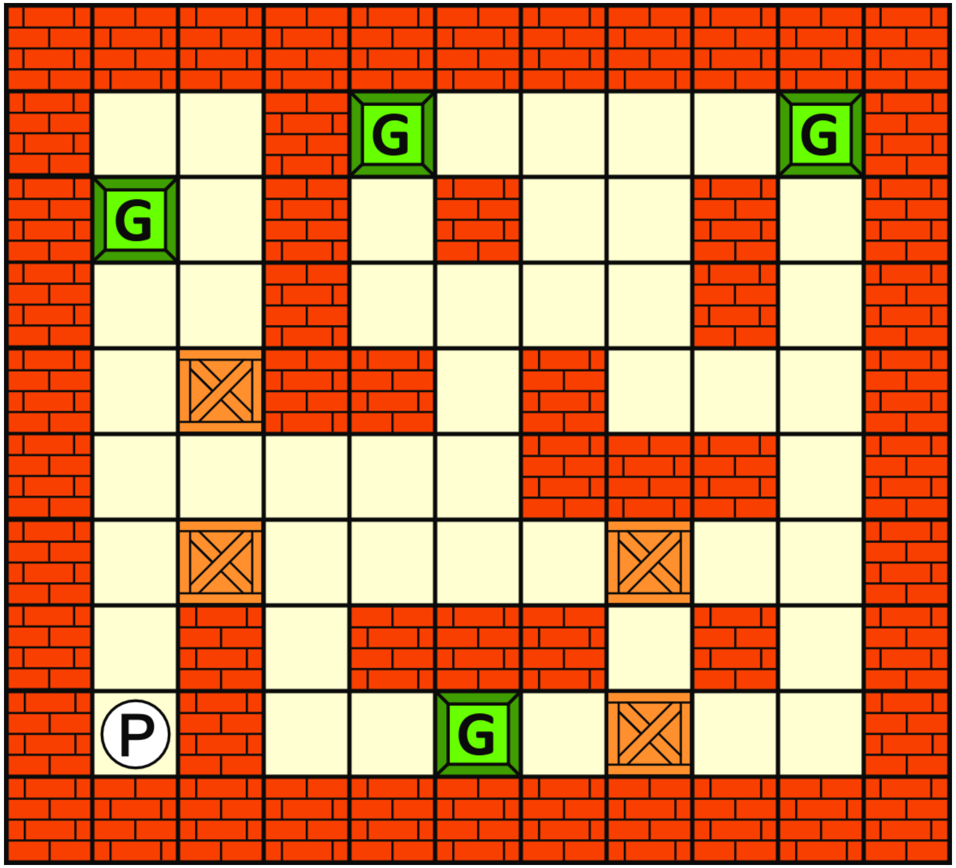
- as close as possible to real distance, as cheap as possible

Domain specific vs. domain independent

Admissible = never overestimate the distance

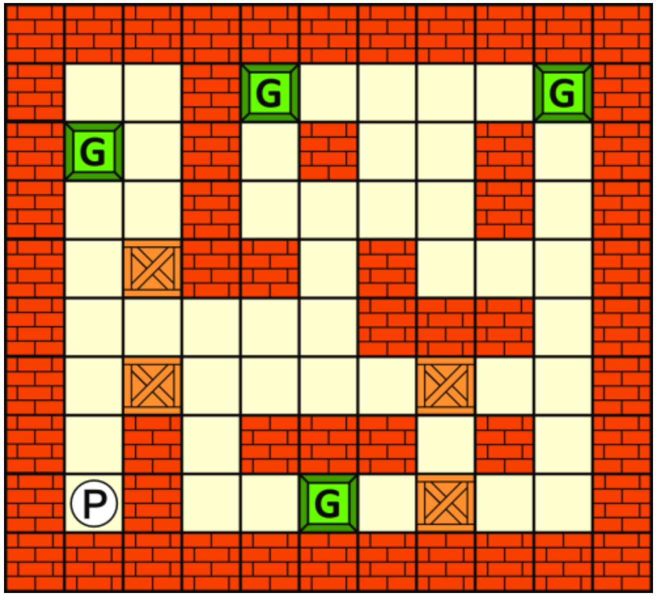
- Heuristic says ∞ → real distance is ∞ → cut off

Sokoban



P = Player, G = Goal field

Sokoban



P = Player, G = Goal field

- Goal: push all boxes on goal fields
  - order does not matter
  - a box can be moved on any goal
- Player can…
  - move horizontally and vertically
  - push only one box at a time
- Player cannot…
  - pull boxes
  - walk over walls or boxes
  - push boxes over wall or other boxes
- Difficulty:
  boxes can easily get into a dead end

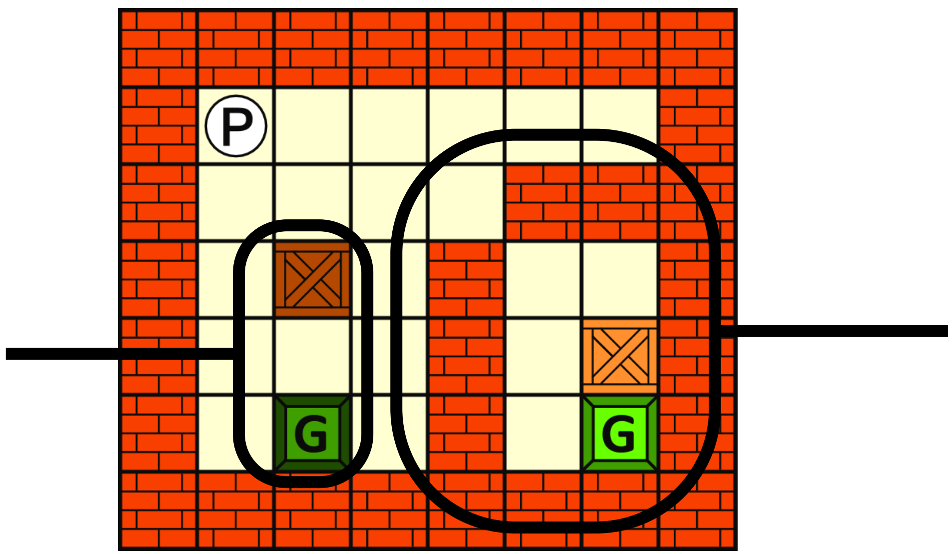
Unsolvable Sokoban Instances

Different kinds of unsolvability possible → ‘groups’

1. group ‘one box can never reach any goal’

Example:

random box
and goal field



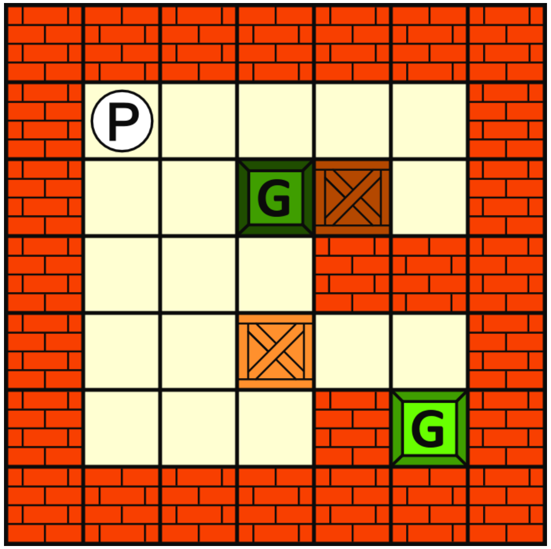
unsolvability
pattern

Mode 1

Unsolvable Sokoban Instances

2. group 'one goal cannot be reached'

Example:

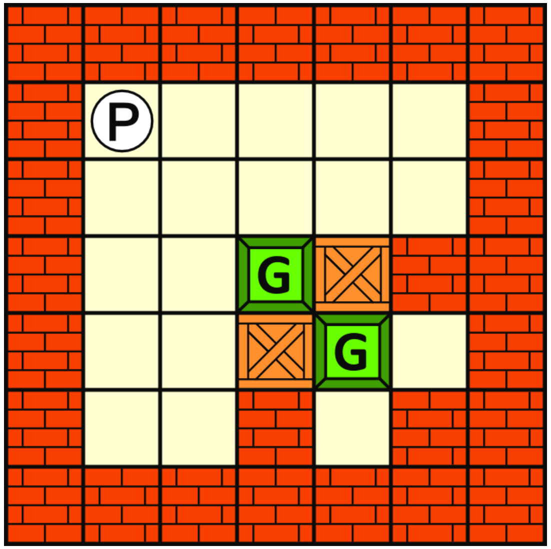


Mode 3

Unsolvable Sokoban Instances

3. group ‘two boxes block each other’

Example 1:

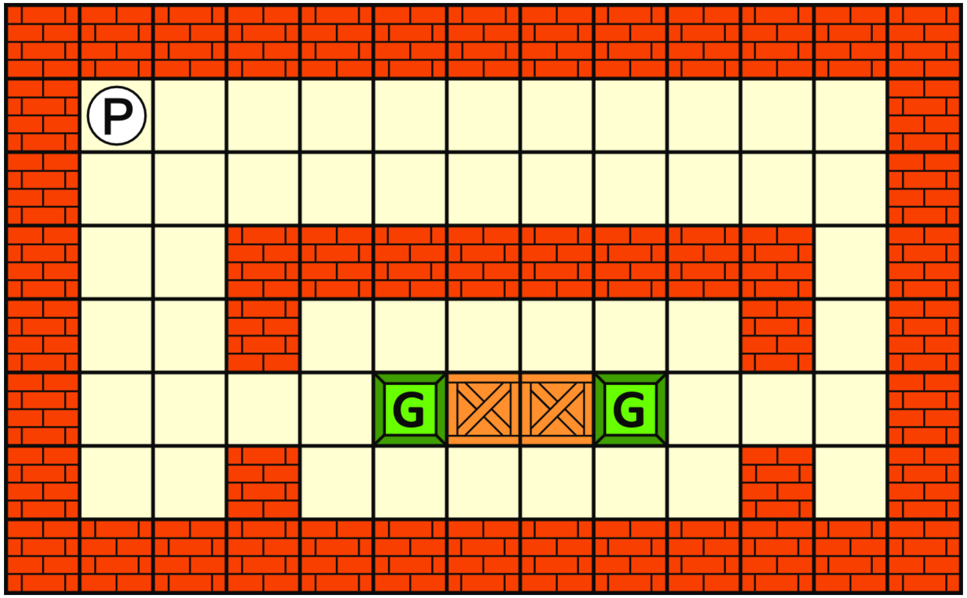


Mode 7

Unsolvable Sokoban Instances

3. group ‘two boxes block each other’

Example 2:

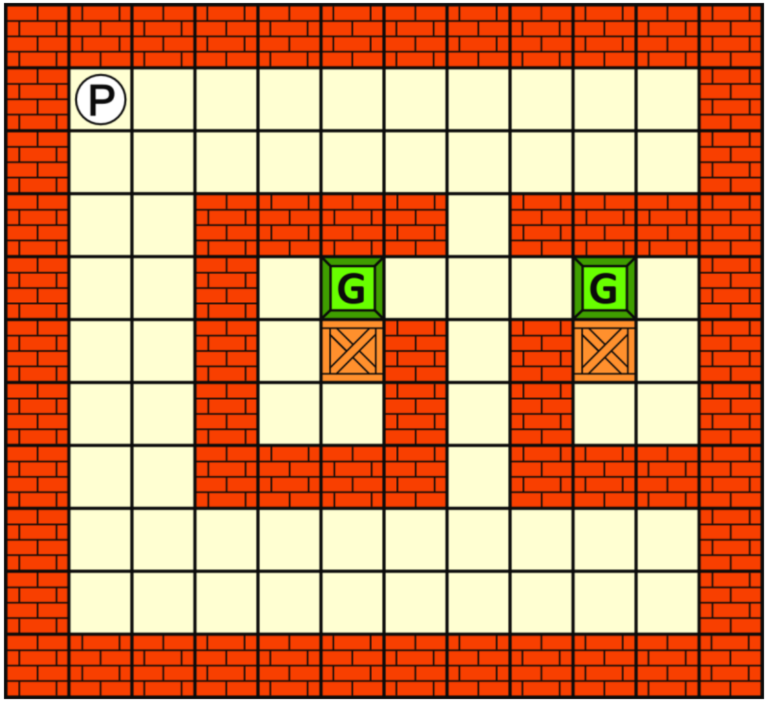


Mode 9

Unsolvable Sokoban Instances

4. group 'goal blocks player'

Example:



Mode 10

Sokoban Experiments

Limits: 3072 MB and 30 minutes

Used heuristics:

- blind heuristic (or blind search)
- maximum heuristic (h^{max})
- Pattern Database (PDB)
- Incremental Pattern Database (iPDB)
- Merge-and-Shrink (M&S)
  merge_strategy = merge_dfp
  shrink_strategy = shrink_bisimulation(max_states = 50000)
- h^2 (or generally h^m)

Sokoban Experiments

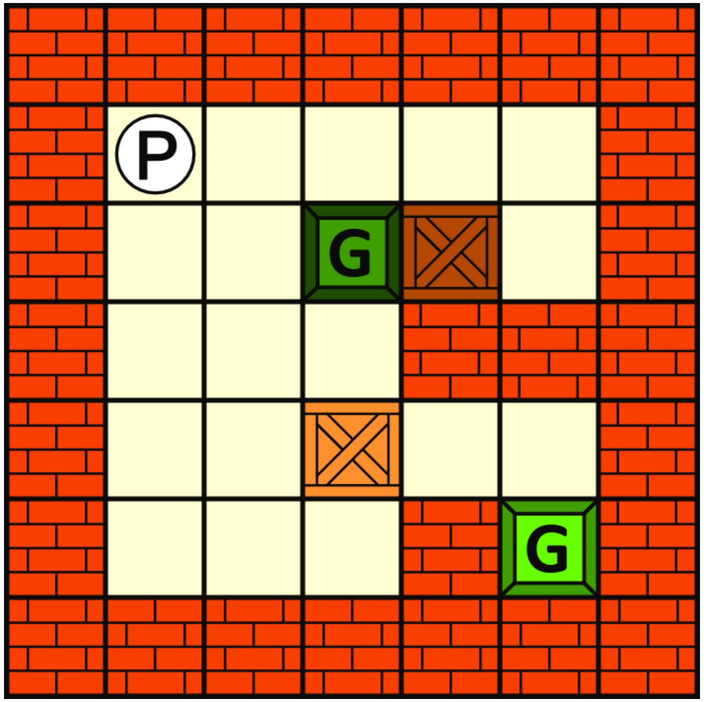
Not too easy, not too hard

How to find a suitable complexity?
(field size, number of boxes)

→ by trying around

Note: problems from the first group 'one box can never reach any goal' are solved by the pre-processing step

2. group ‘one goal cannot be reached’

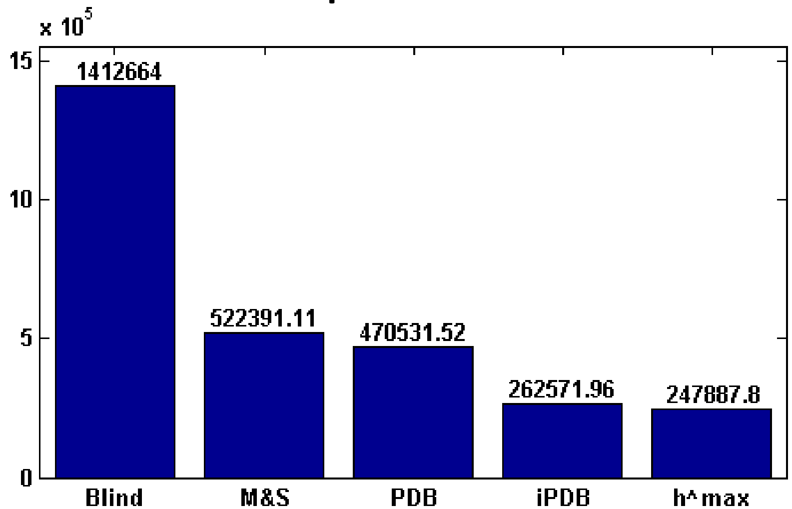


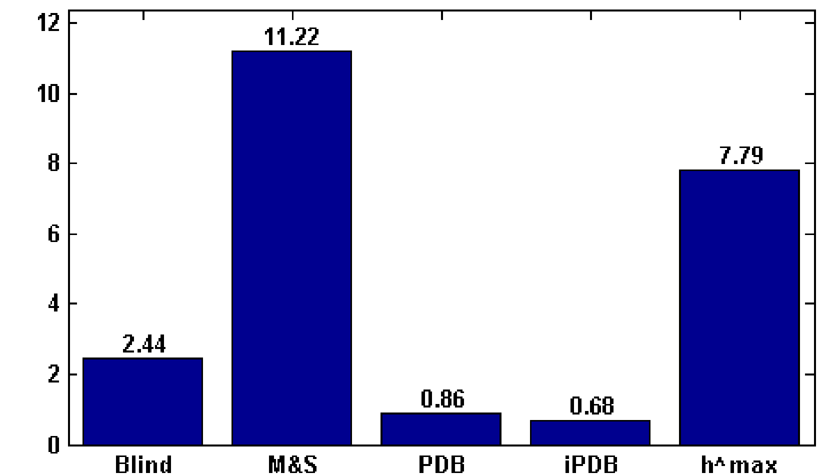
Mode 3

2. group ‘one goal cannot be reached’

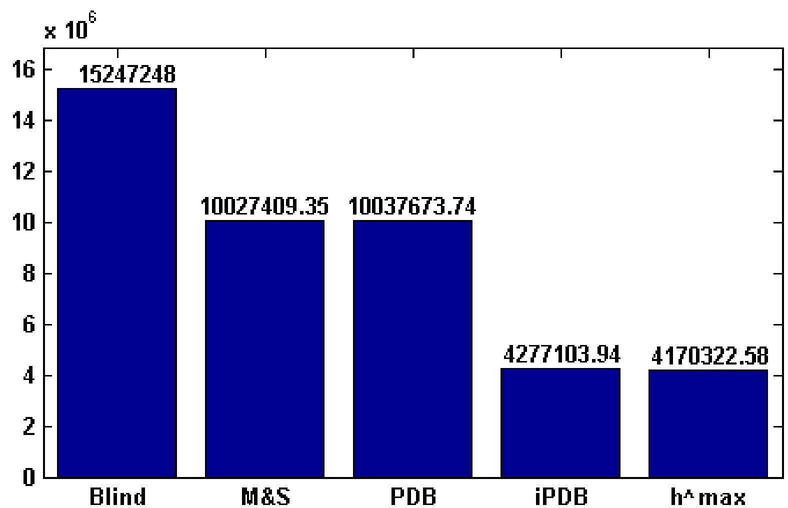
Mode 3 Expansions Total Time (sec)

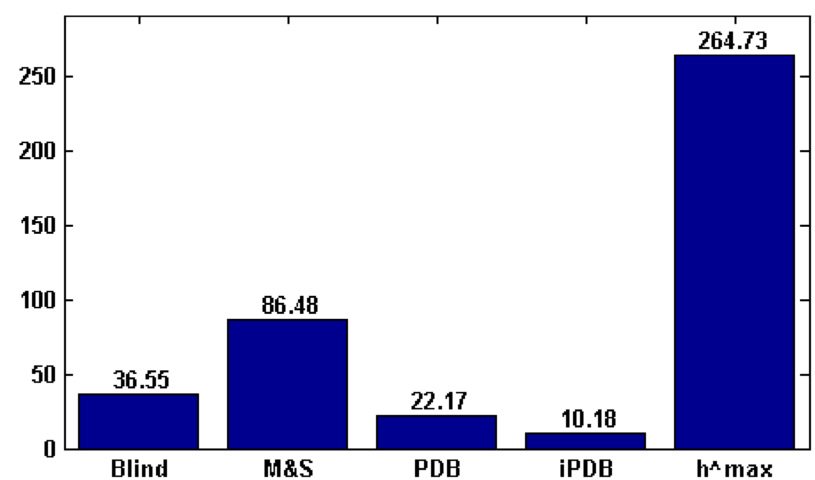
Easy



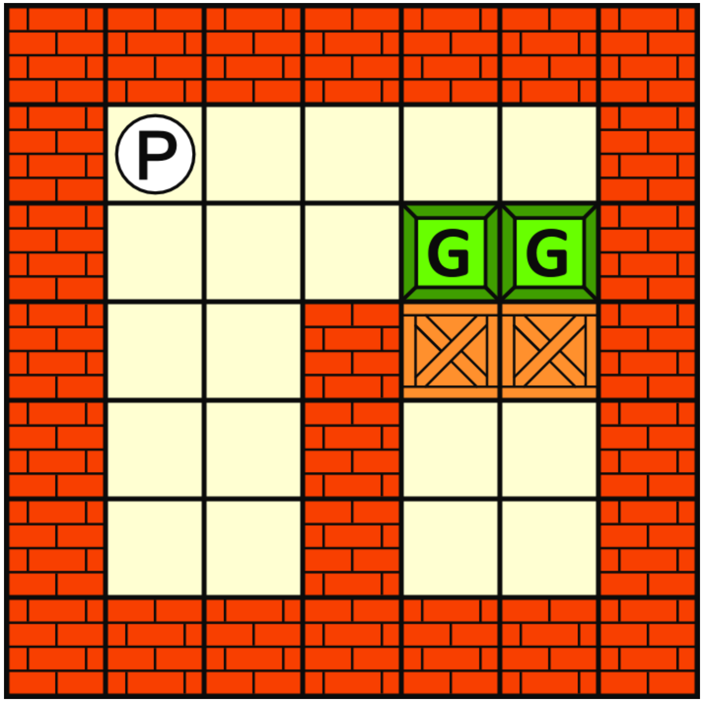


Hard





3. group ‘two boxes block each other’



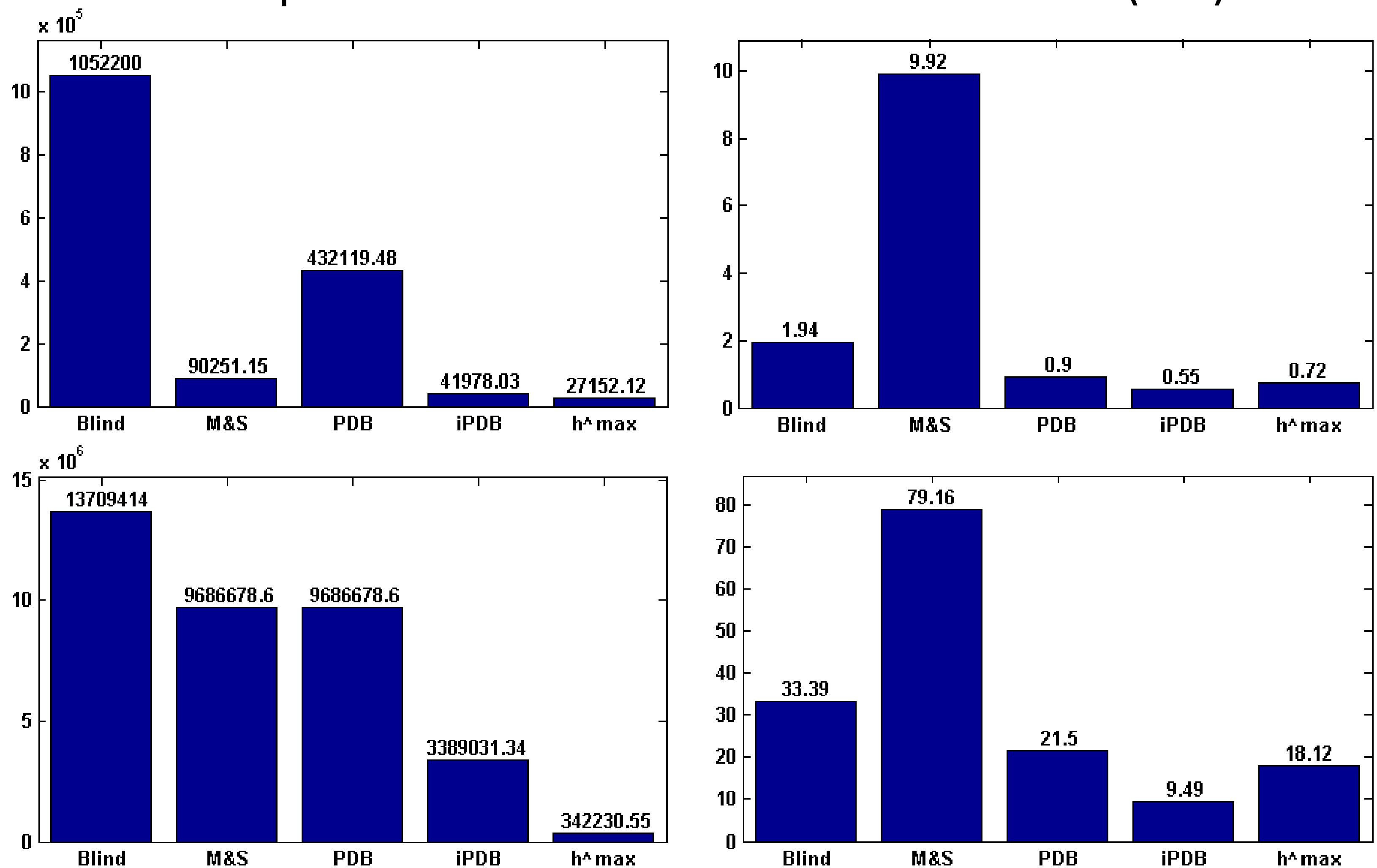
Mode 8

3. group ‘two boxes block each other

Mode 8 Expansions Total Time (sec)

Easy

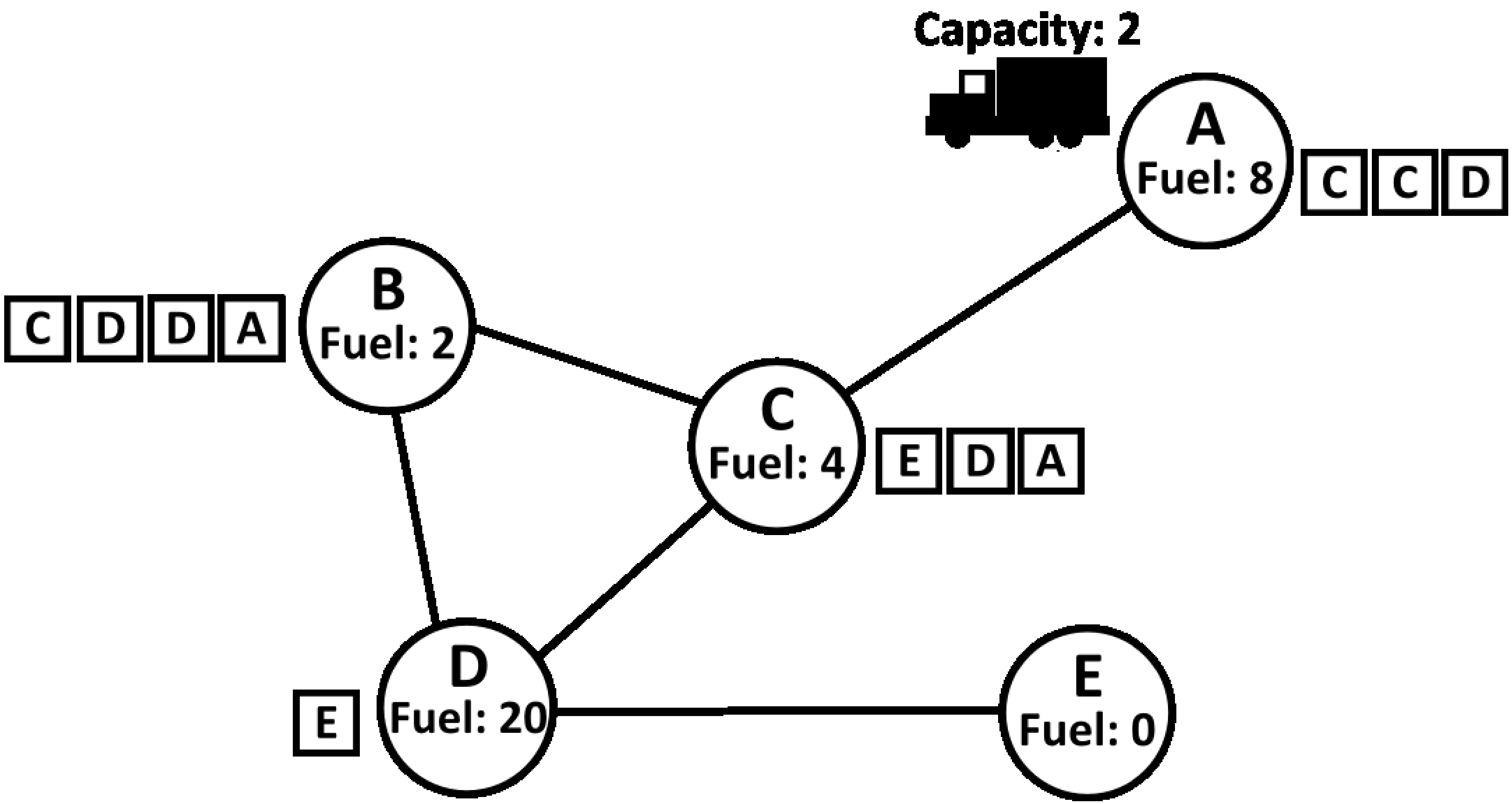
Hard



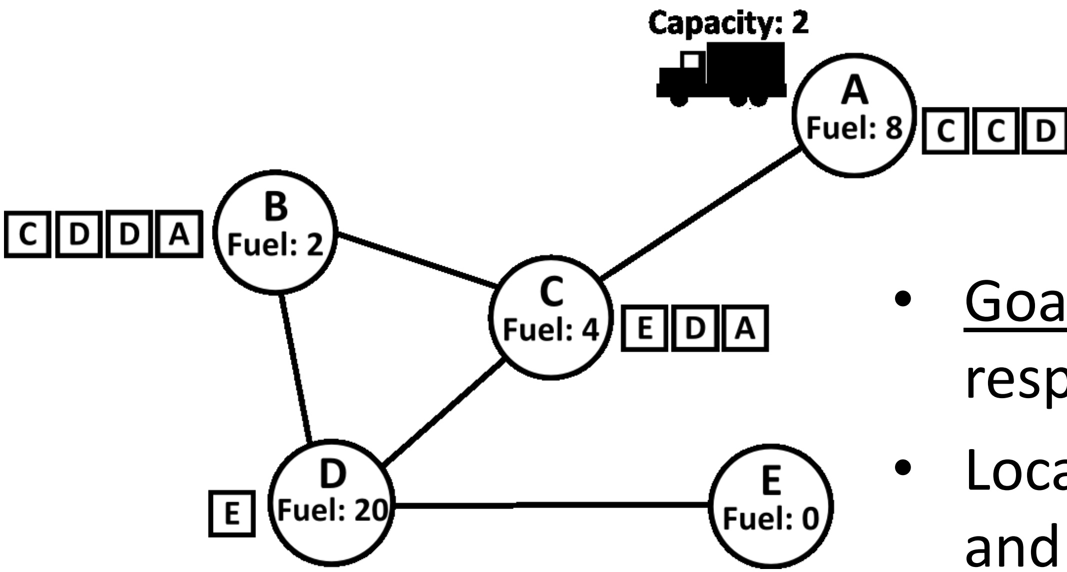
Conclusion for Sokoban

- iPDB and PDB
  - always a better than blind search
- M&S
  - slow but scales well
- h^{max}
  - always good in terms of memory
  - fast on certain instances but slow on all others
    - group ‘two boxes block each other’ problems good for delete relaxation heuristics

NoMystery


Capacity: 2
A
Fuel: 8
C
C
D
B
Fuel: 2
C
D
D
A
C
Fuel: 4
E
D
A
D
Fuel: 20
E
E
Fuel: 0

NoMystery



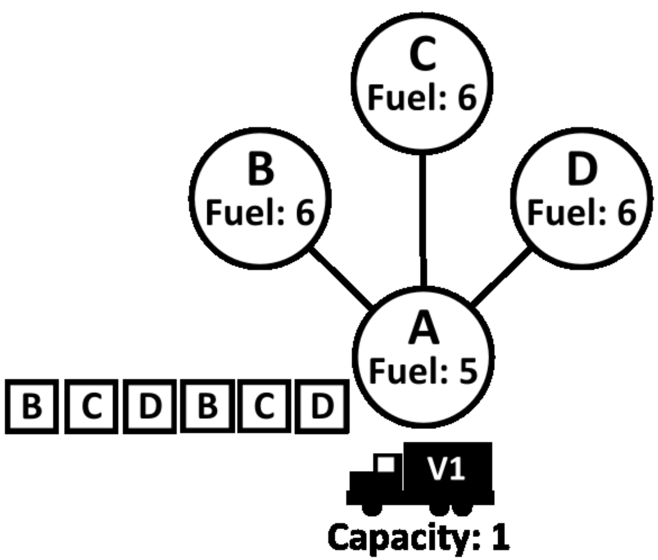
- Goal: move all packages to their respective destination
- Locations can have packages and fuel on them

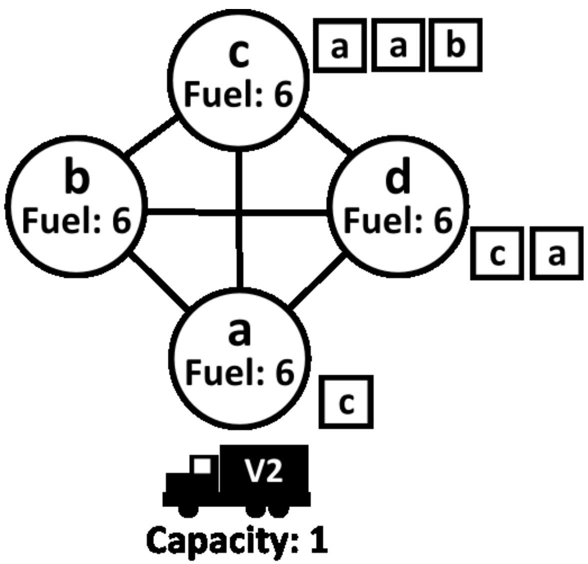
- Vehicles…
  - can load packages up to their capacity limit
  - need one unit fuel to leave a location
- Difficulty: delivering all packages with the given amount of fuel

Unsolvable NoMystery Instances

Only one kind of non-trivial unsolvability: lack of fuel

Structure: two subgraphs





Unsolvable NoMystery Instances

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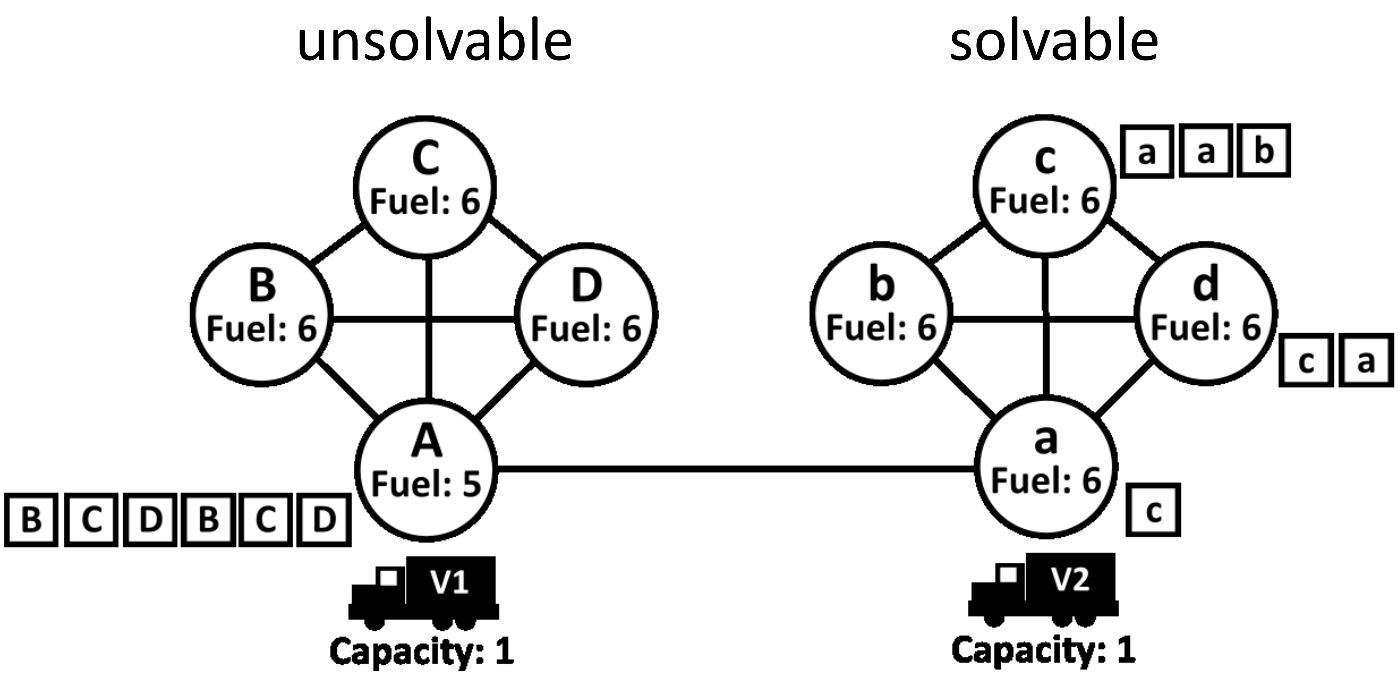
Structure: two subgraphs



NoMystery Experiments

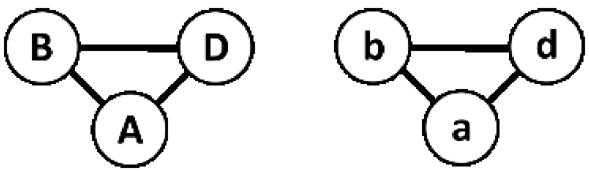
Same limits and heuristics used as for Sokoban

Complexity comes from:

- number of nodes
- number of packages
- connecting subgraphs
- structure of the unsolvable subgraph (star vs. clique)

NoMystery Experiments

unsolvable solvable



packages in the solvable subgraph

packages in the unsolvable subgraph

time (sec)
expansions

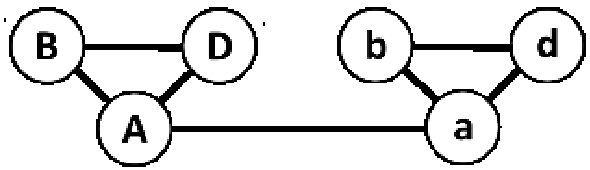
2	Blind	M&S	PDB	iPDB	h^max
4	5.14	0.1	2.54	3.54	7.83
	2 185 021	0	896 463	551 109	895 257
5	38.23	0.52	31.87	23.81	61.66
	13 924 406	0	9 662 215	4 602 906	6 153 606

3	Blind	M&S	PDB	iPDB	h^max
3	5.86	0.1	3.11	4.01	8.73
	2 380 287	0	998 764	451 576	941 492
4	53.90	0.1	45.84	29.02	88.26
	19 666 149	0	13 489 572	5 009 911	8 958 822

4	Blind	M&S	PDB	iPDB	h^max
2	3.32	0.16	0.1	0.84	4.48
	1 421 283	0	0	64 604	440 475
3	50.63	0.18	46.19	23.34	76.15
	17 058 074	0	12 964 993	3 944 435	7 267 801

NoMystery Experiments

unsolvable solvable



	2					
	Blind	M&S	PDB	iPDB	h^max	h^2
2	0.12	0.46	0.19	0.73	0.1	307.95
	59 866	0	59 866	1 121	6 665	458
3	3.99	3.54	4.48	2.00	2.07	
	1 617 191	345 740	1 617 191	124 493	136 435	
4	55.19	28.43	62.18	14.60	39.47	
	18 925 914	4 772 500	18 925 914	2 170 003	1 980 173	

	3				
	Blind	M&S	PDB	iPDB	h^max
2	1.39	2.16	1.69	1.01	0.96
	618 529	188 171	618 529	13 544	58 571
3	71.37	47.97	80.50	10.94	50.49
	23 146 257	8 311 707	23 146 257	1 416 266	2 350 471

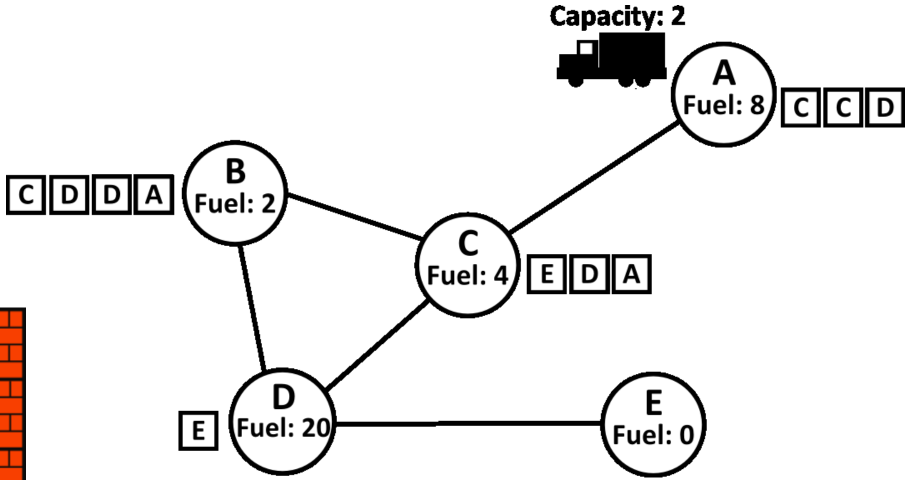
Conclusion for NoMystery

- PDB
  - usually bad choice
  - only good for unconnected subgraphs with few packages
- M&S
  - very efficient on unconnected subgraphs
  - not bad connected subgraphs
- iPDB
  - best choice for connected subgraphs
  - good on unconnected subgraphs
- h^{max}
  - not bad in terms of memory
  - usually slower than other heuristics

Conclusion Overall

- Heuristics can be more efficient than blind search
- Sometimes a trade-off between time and memory
- Blind search requires a lot of memory but is often fast
- iPDB is never a bad choice for Sokoban and NoMystery
- h^{max} is good for certain Sokoban instances
- M&S is good for unconnected NoMystery instances

Questions?



Capacity: 2
A
Fuel: 8
C C D
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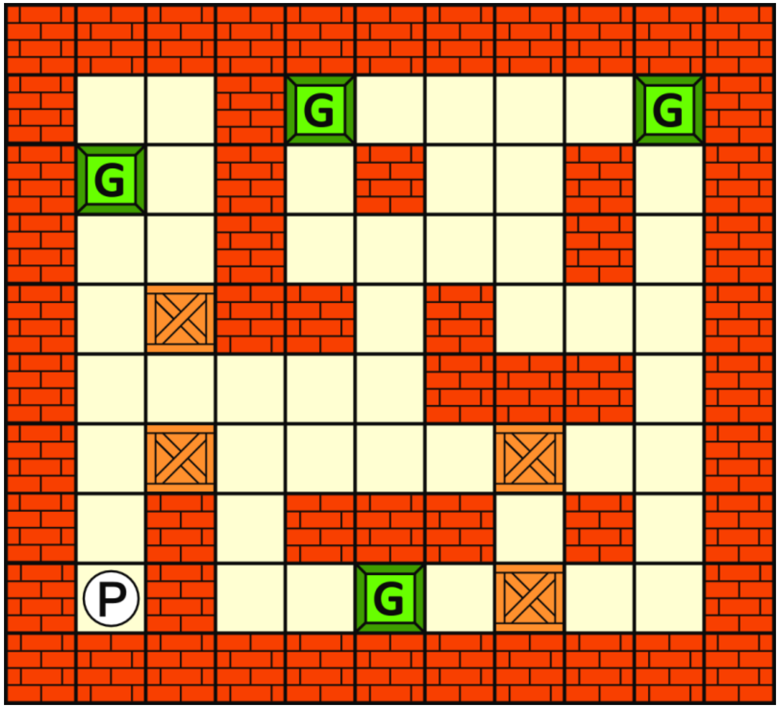
Fuel: 2
C D D A
C
Fuel: 4
E D A
D
Fuel: 20
E
E
Fuel: 0



G
G
G
G
P