PARIS: Planning Algorithms for Reconfiguring Independent Sets

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Context

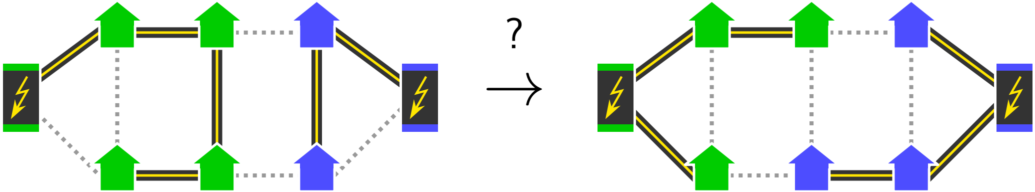
- CoRe Challenge 2022 (Combinatorial Reconfiguration)
- First iteration
- Submission **PARIS** based on planning

What's the problem?

Combinatorial Reconfiguration – Examples

Power Distribution

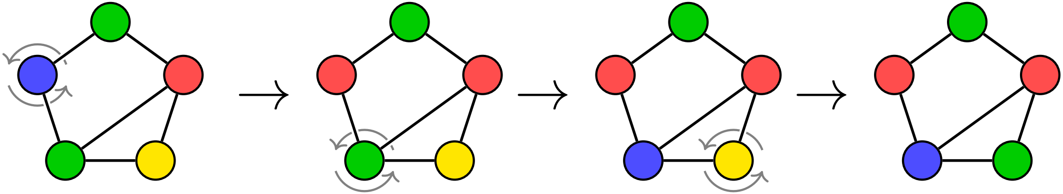
Reconfigure network while keeping all households connected.



Combinatorial Reconfiguration – Examples

Graph Coloring

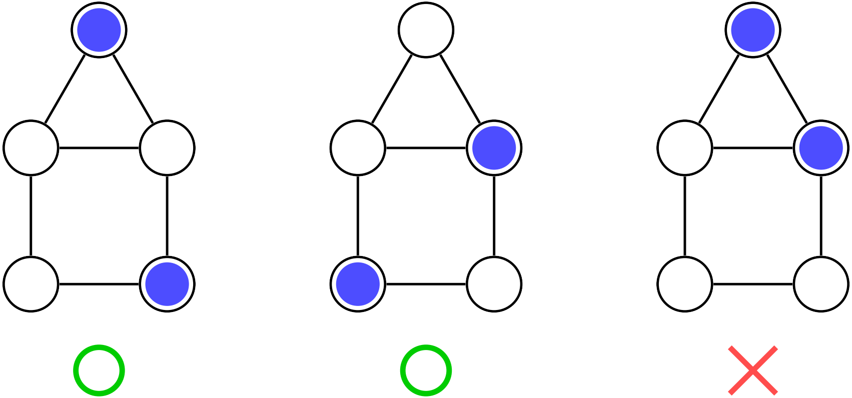
Change from one coloring to another via colorings.



Independent Sets

Independent Set

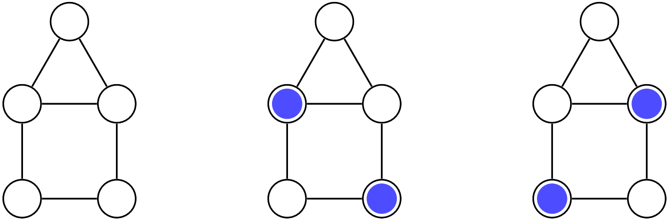
A set of vertices such that **no two are adjacent**.



Independent Set Reconfiguration

Input

- graph
- initial set
- goal set



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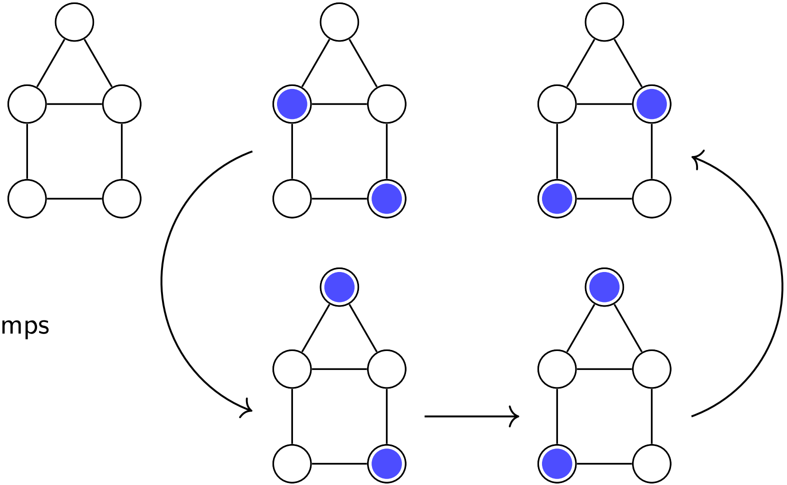


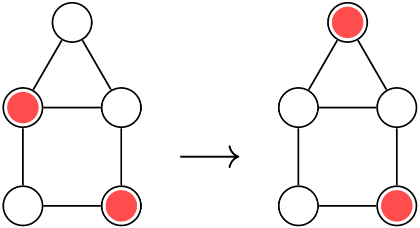
Output

- sequence of token jumps

Planning Encoding

Single action

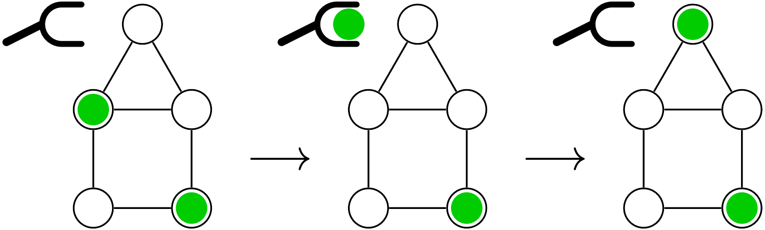
- move



Split action

- pick
- place

→ SAS$^+$



Competition

Solver Tracks

- Existent
- Shortest
- Longest

$\times$

- Single-engine
- Portfolio

Graph Tracks

- 10
- 50
- 100

No resource limits; solutions are submitted

Competition Results – Solver Tracks

	existent	shortest	longest
single-engine	1	3	1
portfolio	1 3	2	1 3

Existent Track

- Any solution
- similar to *agile* IPC track

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Existent Track

- Any solution
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PARIS

- GBFS + Landmarks (70min)

Competitors

2 Answer Set Programming

3 Greedy heuristic search + Bounded Model Checking

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Existent Track

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PARIS

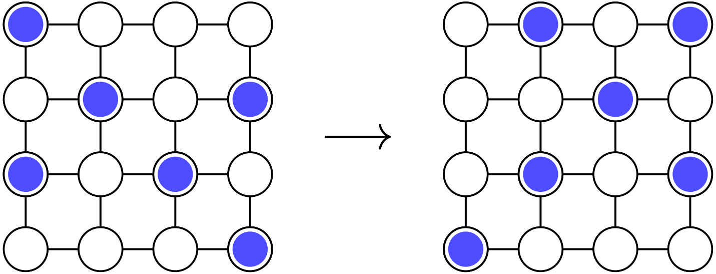
1. **Counter abstraction** (10s)
2. Symbolic search (70min)
3. A^* + Landmarks (70min)
4. GBFS + Landmarks (70min)
5. **Counter abstraction** (14h)

Competitors

2 IDA^* + Breadth-first search

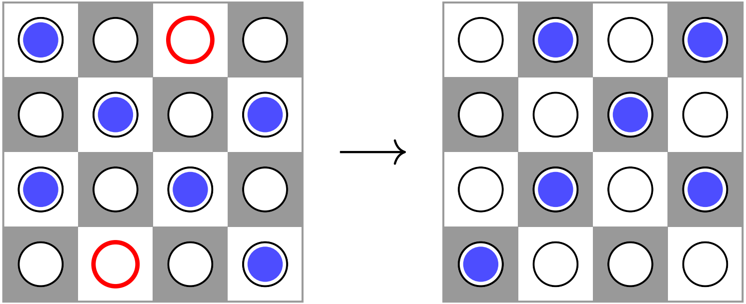
Counter Abstraction – Motivation

- Grid instances
- 4×4 to 200×200



Counter Abstraction – Motivation

- Grid instances
- 4×4 to 200×200
- 1–2 gaps
- $n \times n$ unsolvable if fewer than $n/2$ gaps



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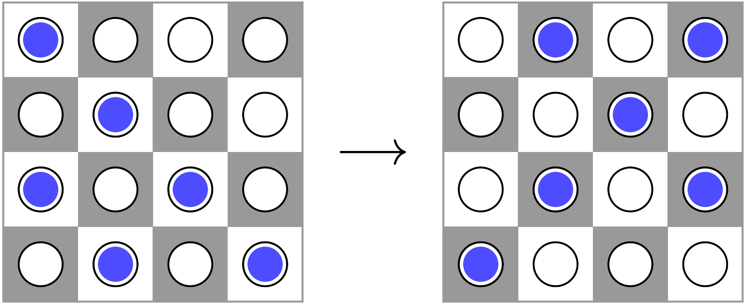

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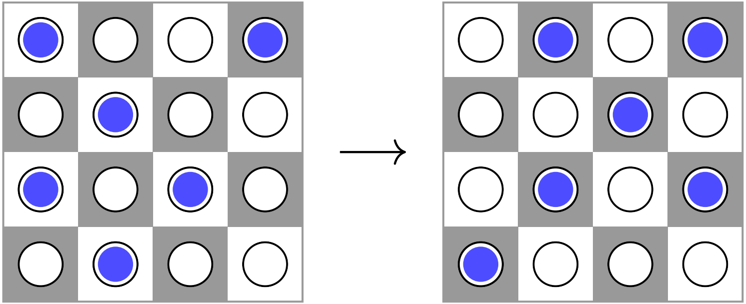

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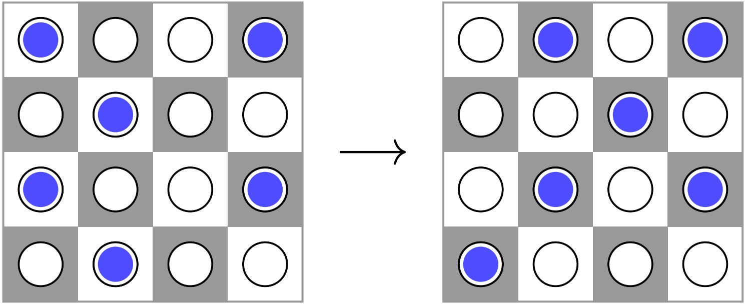

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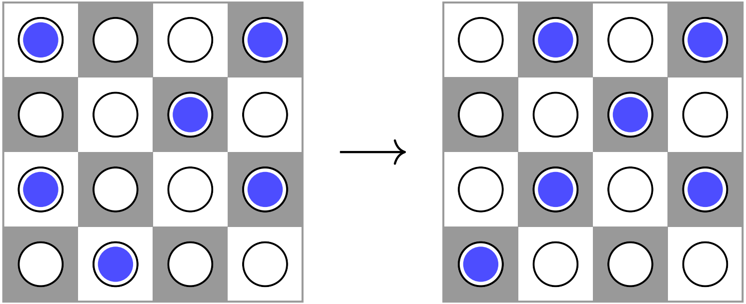

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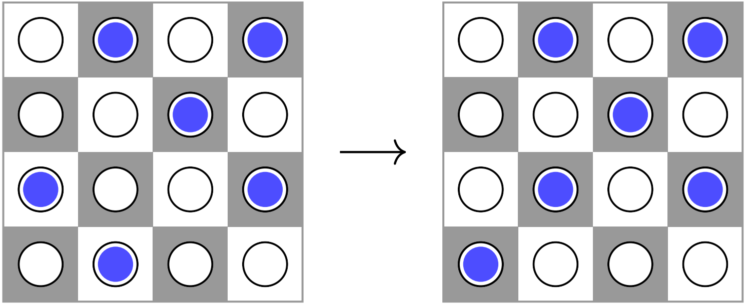

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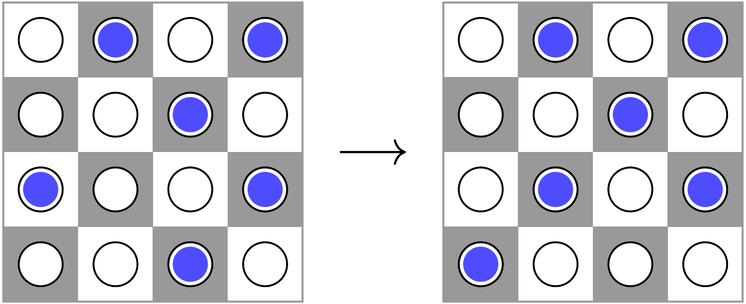

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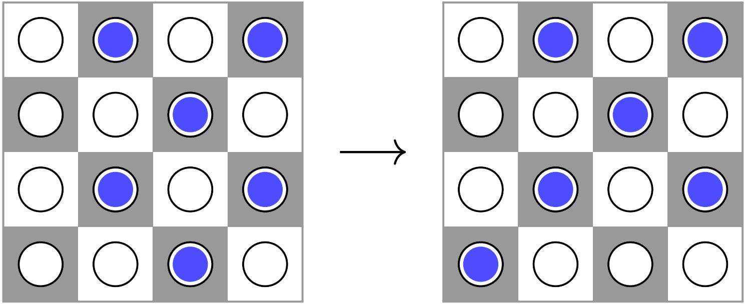

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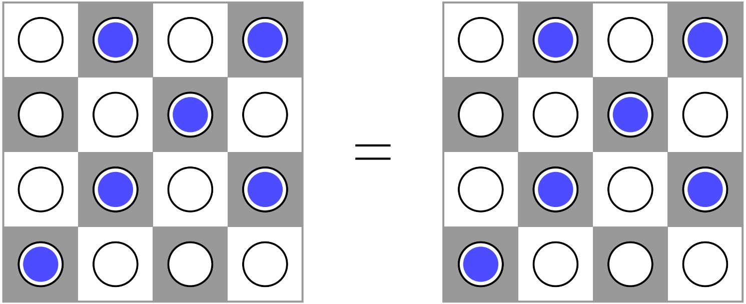
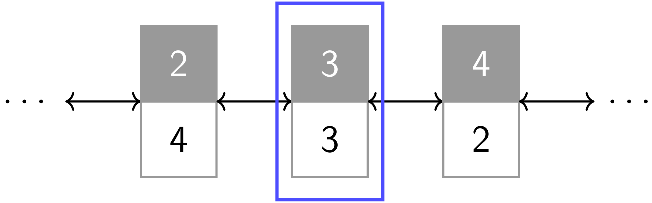
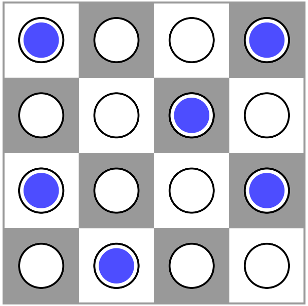


Counter Abstraction

- Color the graph
- Count number of tokens on each color
- Abstract states:





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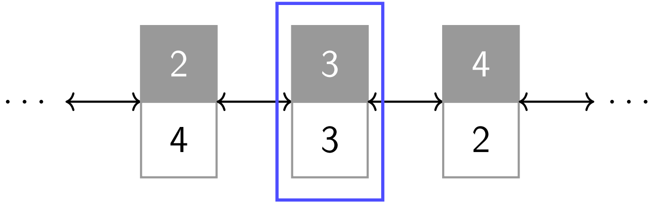
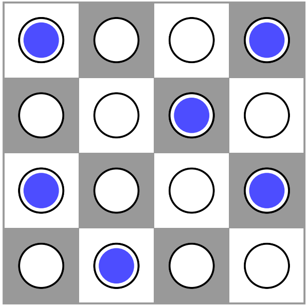


- Encode independent set + count constraints as **MIP**
- If constraints unsatisfiable for abstract state → **prune**
- Fully explored abstract state space → **unsolvable**



Competition Results – Solver Tracks

	existent	shortest	longest
single-engine	1	3	1
portfolio	1, 3	2	1, 3

Shortest Track

- Shortest solution among competitors
- similar to *satisficing* IPC track

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PARIS

- GBFS + Landmarks (70min)

Competitors

1 Answer Set Programming

2 Reinforcement Learning

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3 Answer Set Programming

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- Longest loopless solution among competitors
- no IPC equivalent

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PARIS

- Symbolic top-k search (70min)

Competitors

2 Answer Set Programming

3 Bounded Model Checking

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Longest Track

- Longest loopless solution among competitors
- no IPC equivalent

PARIS

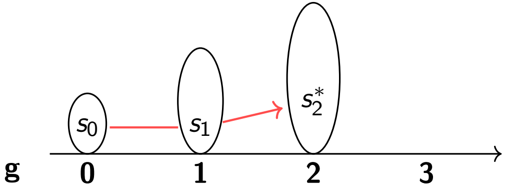
1. GBFS + Landmarks (5min)
2. **Symbolic top-k search** (65min)

Competitors

2 Answer Set Programming

Symbolic Top-k Search

- Run loopless symbolic top-k search
- Reconstruct **one** plan per cost
- **Iteratively** find longer plans



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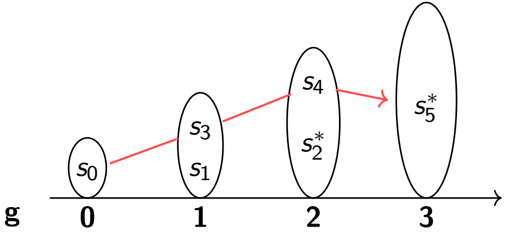

Competition Results – Graph Track

	10	50	100
PARIS	3	2	2

Graph

- Find difficult graphs
- Fixed number of nodes
- Longest optimal sequence

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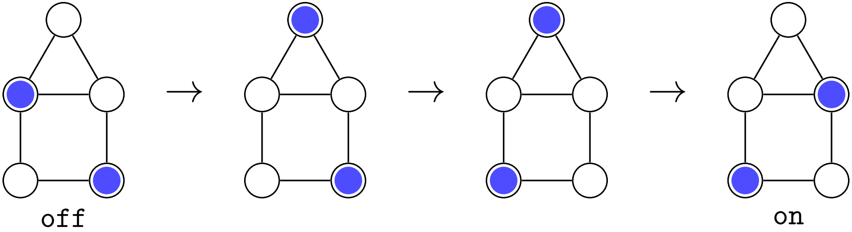
- Great graphs (pretty)

Competitors

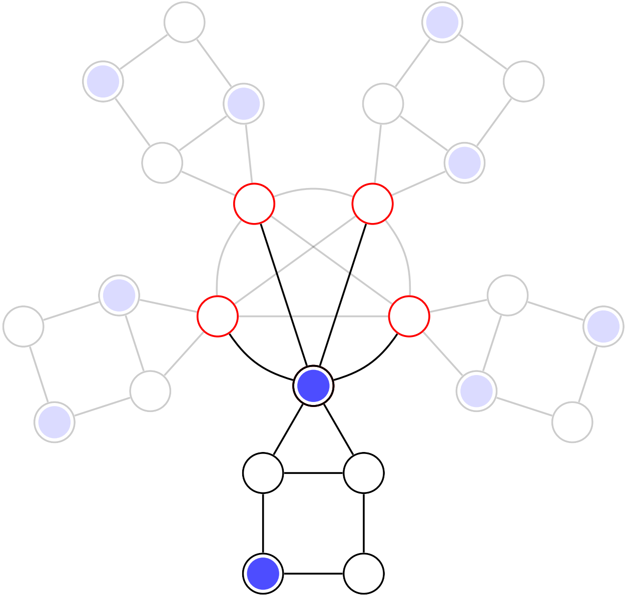
1 Slightly “better” graphs (not pretty)

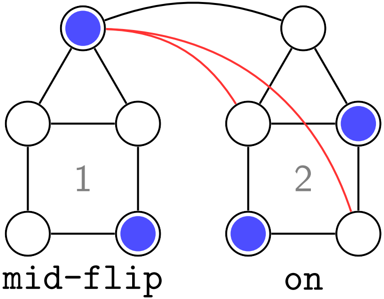
The House Widget



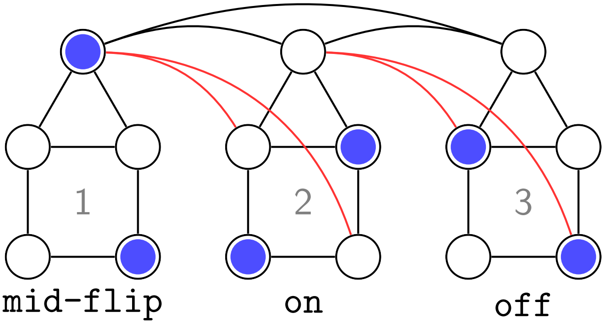
- Optimal for $n = 5$
- Cannot fit more than 2 tokens
- “Anchor” is occupied throughout flip

- Anchors fully connected and occupied during flip
- One flip at a time





- Rule 1: house $k+1$ must be on



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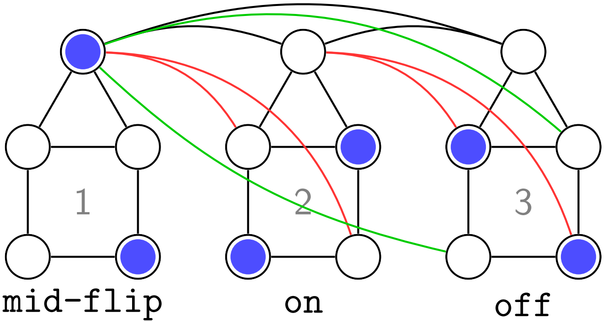
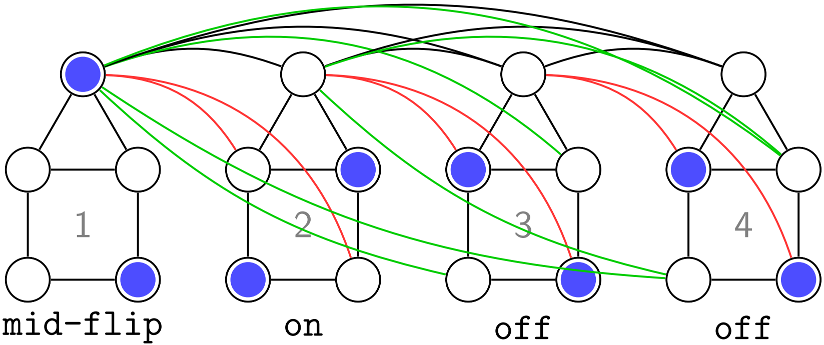


- Rule 1: house $k+1$ must be on
- Rule 2: houses $\geq k+2$ must be off



- Rule 1: house $k+1$ must be on
- Rule 2: houses $\geq k+2$ must be off
- Start: $\langle$off, off, ..., off$\rangle$
- Goal: $\langle$on, off, ..., off$\rangle$