PARIS: Planning Algorithms for Reconfiguring Independent Sets

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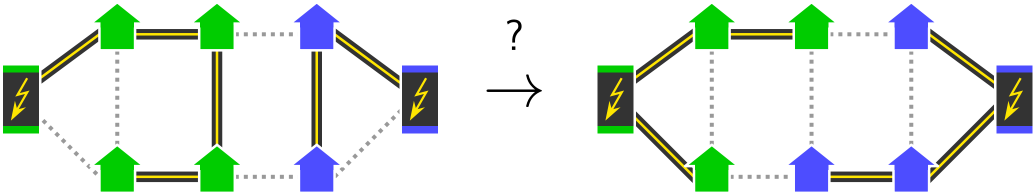
Combinatorial Reconfiguration

Reconfiguration Problem

Transform a solution into another solution so that **all intermediate steps are also solutions**.



Power Distribution

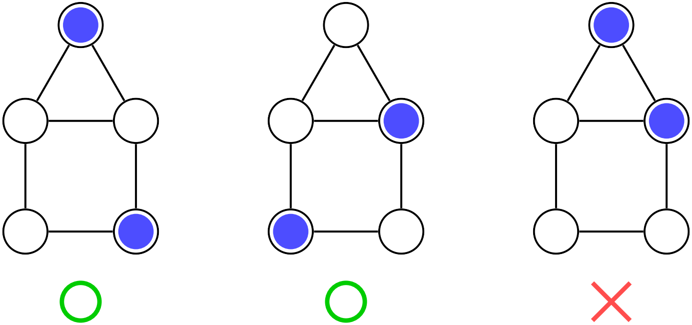
Reconfigure network while keeping all households connected.

Independent Sets

Many such **reconfiguration problems** can be cast to and analyzed using the **Independent Set Reconfiguration (ISR)** problem.

Independent Set (IS)

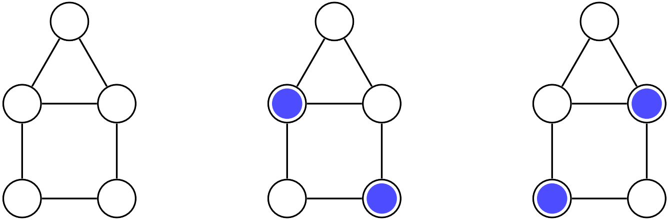
A set of vertices/nodes of a graph such that **no two are adjacent**.



Independent Set Reconfiguration

Input

- Graph
- Initial set
- Goal set



Output

- Sequence of token jumps

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- Initial set
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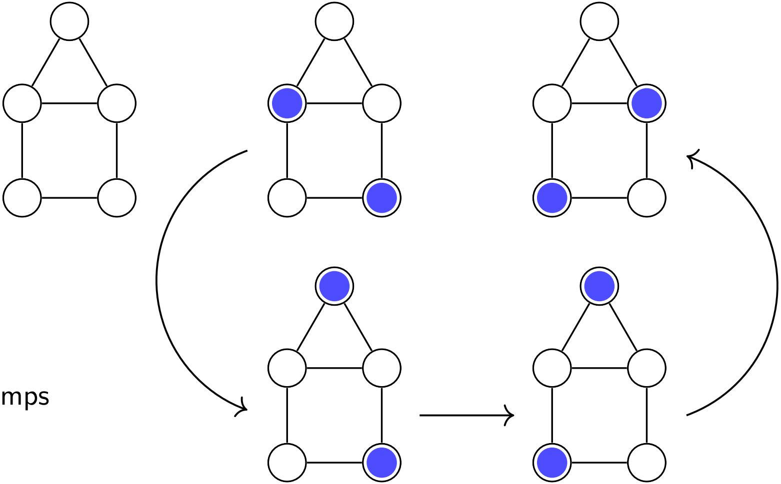

Output

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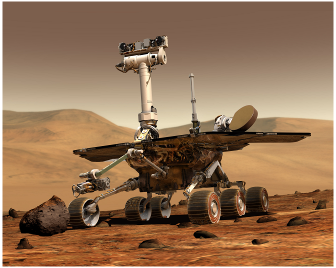
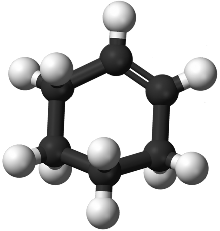
Classical Planning





Compact Description of State Spaces

- **State variables**: Describe the world
- **States**: Assignments to these variables
- **Actions**: Define transitions between states

$\rightsquigarrow$ **Objective**: Find a plan from an initial state to a goal state

Independent Set Reconfiguration as Classical Planning

Theoretical Contribution

Sound, complete, and optimality preserving formulations of ISR as planning problem.

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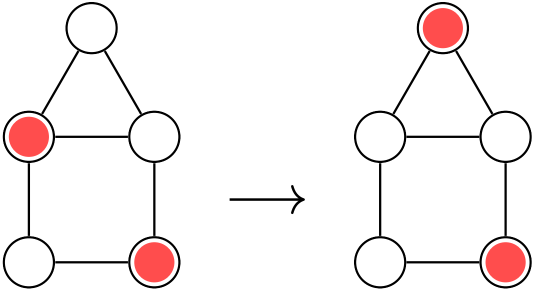
Sound, complete, and optimality preserving formulations of ISR as planning problem.

- **State variables**: Binary variable for each node to represent token presence
- **Single action**: Move token (IS condition encoded as precondition)



Independent Set Reconfiguration as Classical Planning

Alternative Formulation

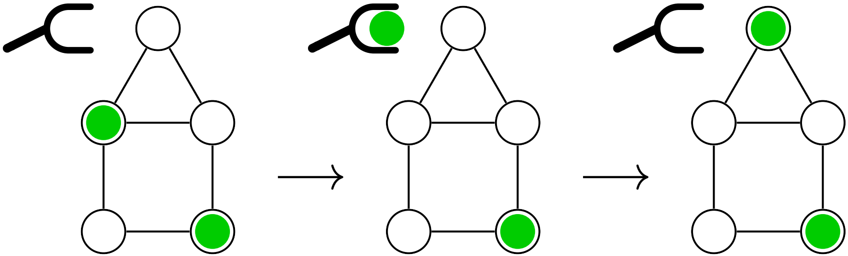
Split action representation $\rightsquigarrow$ more natural and **more compact**!

Independent Set Reconfiguration as Classical Planning

Alternative Formulation

Split action representation $\rightsquigarrow$ more natural and **more compact**!

- **State variables**: Binary variable for each node to represent token presence + **a binary variable for token holding**
- **Pick-up action**: Pick-up a token (precondition: gripper is empty)
- **Place action**: Place a token respecting IS condition



Combinatorial Reconfiguration Competition

- Toolbox of classical planning applicable
    - Search algorithms, heuristics, pruning techniques, . . .
- **1st Combinatorial Reconfiguration Competition in 2022**

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Solver Tracks

- Existent
- Shortest
- Longest

$\times$

- Single-engine
- Portfolio

- Solutions are submitted
- All teams used **different resources**

Competition Results

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

Existent Track

- Any solution + Unsolvability
- similar to *agile* IPC track + Unsolvability IPC

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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

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Shortest Track

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

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PARIS-Portfolio

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Competitors-Single

1 Answer Set Programming

Competitors-Portfolio

1 IDA* + Breadth-first search

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- Longest loopless solution among competitors
- no IPC equivalent

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PARIS

- *Symbolic top-k search* (70min)

PARIS-Portfolio

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

Competitors

2 Answer Set Programming

Experiments with Fair Resource Allocation

How meaningful are these results since each team/approach was able to use different resources?

Experiments with Fair Resource Allocation

- Per-task comparison
- PARIS vs. other competitors:
  - Better: +
  - Worse: −

	existent		shortest		longest	
	+	−	+	−	+	−
JunKa.	168	21	158	13	217	13
Reconf.	76	0	61	0	205	1
Recongo	82	0	39	0	210	3
Telematik	19	0	17	9	202	1
Toda	111	0	198	0	210	47

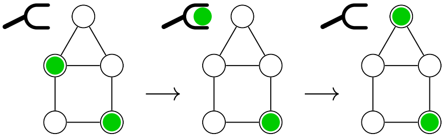
Conclusions

Summary:

- Combinatorial reconfiguration problem

$\rightsquigarrow$ Independent set reconfiguration (ISR)

- Formulations of ISR as classical planning
  - Complete, sound, optimality preserving
- State-of-the-art empirical performance



Future Work:

- **Planning techniques**: Improving our understanding of effective planning techniques for ISR
- **Strengthening Synergy**: Drawing stronger connections between the fields of reconfiguration and planning