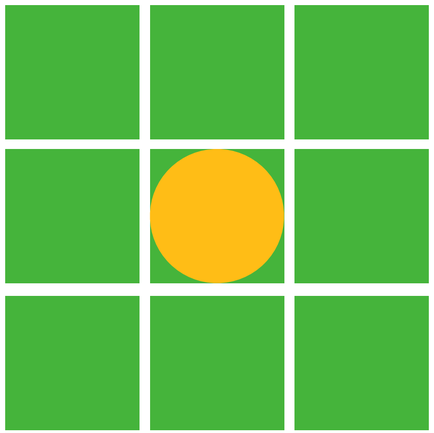
Universität Basel

# LMCut Heuristic with Different Precondition Choice Functions

## Bachelor Thesis Presentation

Aeneas Meier - 8. Dezember 2025

# Quick Story About *VisitAll*...

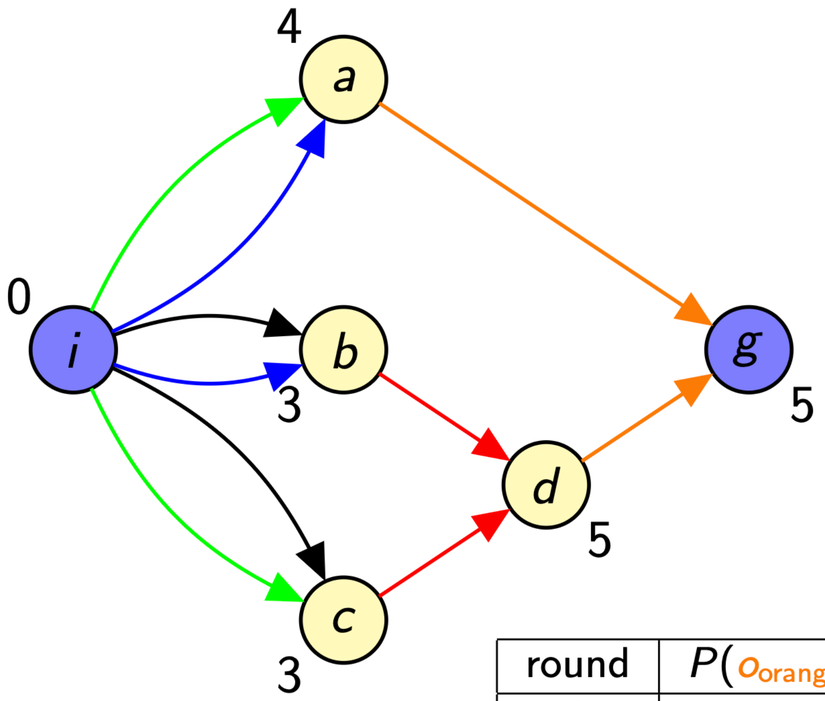


# Introduction

- **Background**: LMCut Heuristic
- **Introduced Changes**: Precondition Choice Functions and Tie-Breaking Strategies
- **Results und Discussion**: Experimental Evaluation and Theory

# LMCut Algorithm

## 1. Compute $h^{max}$ values of the variables




$o_{\text{blue}} = \langle \{i\}, \{a, b\}, \{\}, 4 \rangle$
$o_{\text{green}} = \langle \{i\}, \{a, c\}, \{\}, 5 \rangle$
$o_{\text{black}} = \langle \{i\}, \{b, c\}, \{\}, 3 \rangle$
$o_{\text{red}} = \langle \{b, c\}, \{d\}, \{\}, 2 \rangle$
$o_{\text{orange}} = \langle \{a, d\}, \{g\}, \{\}, 0 \rangle$

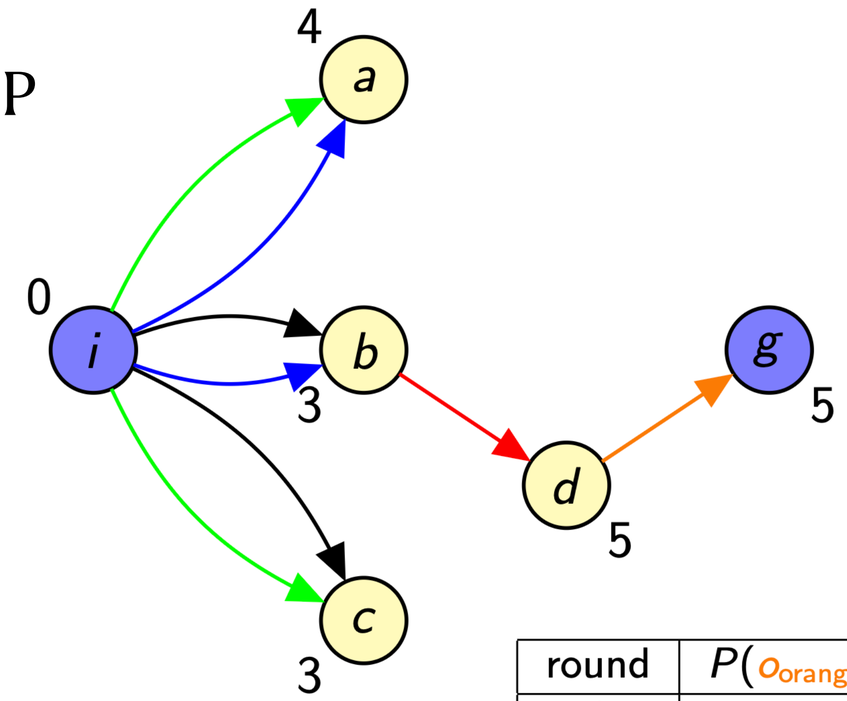
| round | $P(o_{\text{orange}})$ | $P(o_{\text{red}})$ | landmark | cost |
|---|---|---|---|---|
| 1 | | | | |
| | | | | |
| | | | | |
| | | | $h^{\text{LM-cut}}(I)$ | 0 |

SRC: https://ai.dmi.unibas.ch/_files/teaching/hs23/po/slides/po-g05.pdf

# LMCut Algorithm

## 2. Compute justification graph

PCF: O → P

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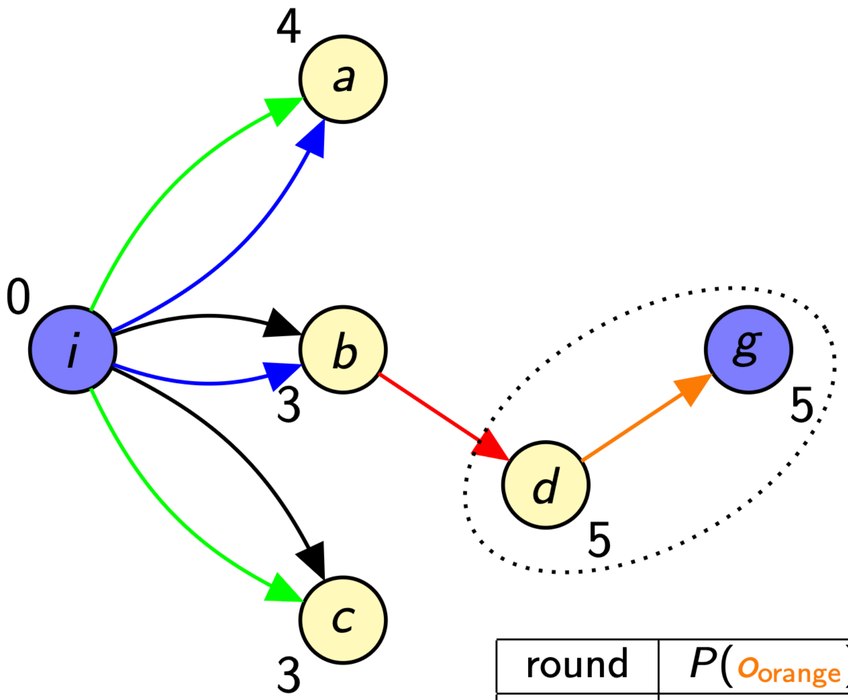
| round | $P(o_{\text{orange}})$ | $P(o_{\text{red}})$ | landmark | cost |
|---|---|---|---|---|
| 1 | d | b | | |
| | | | | |
| | | | | |
| | | | $h^{\text{LM-cut}}(I)$ | 0 |

SRC: https://ai.dmi.unibas.ch/_files/teaching/hs23/po/slides/po-g05.pdf

# LMCut Algorithm

## 3. Determine Goal Zone

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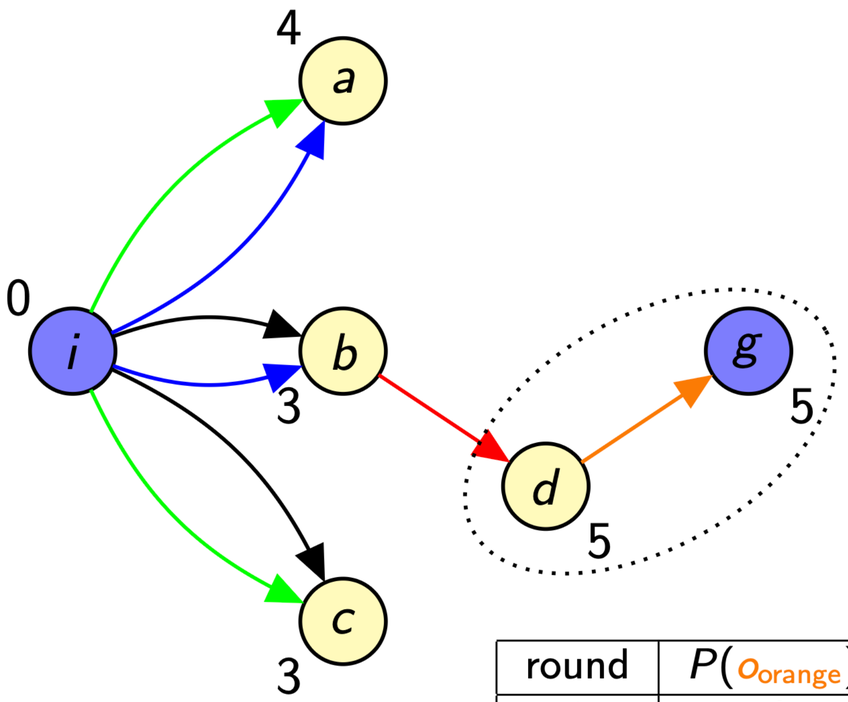
$o_{\text{orange}} = \langle \{a, d\}, \{g\}, \{\}, 0 \rangle$

| round | $P(o_{\text{orange}})$ | $P(o_{\text{red}})$ | landmark | cost |
|---|---|---|---|---|
| 1 | d | b | | |
| | | | | |
| | | | | |
| | | | $h^{\text{LM-cut}}(I)$ | 0 |

SRC: https://ai.dmi.unibas.ch/_files/teaching/hs23/po/slides/po-g05.pdf

# LMCut Algorithm

## 4. Compute Cut



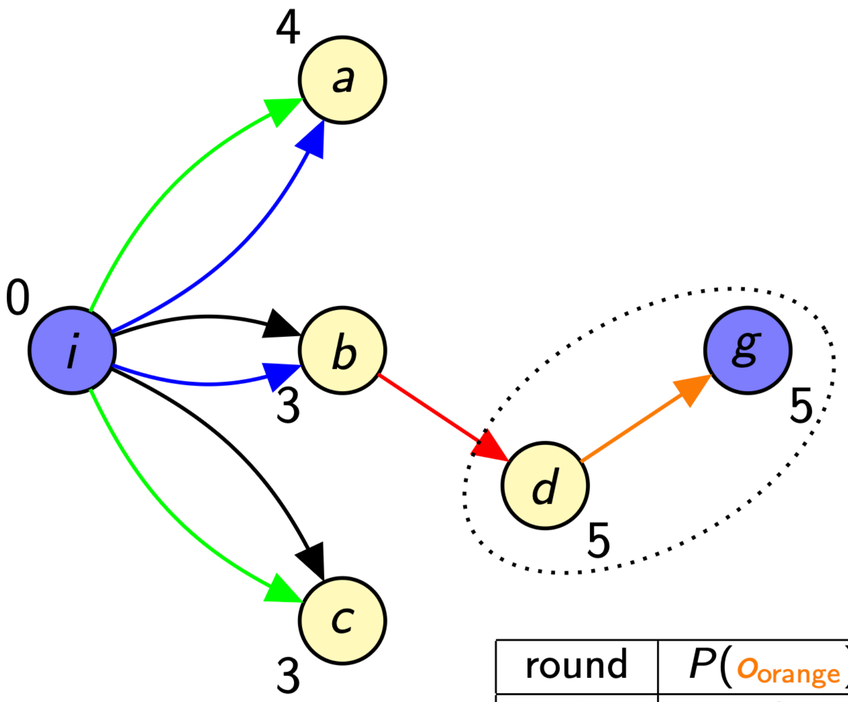

$o_{\text{blue}} = \langle \{i\}, \{a, b\}, \{\}, 4 \rangle$
$o_{\text{green}} = \langle \{i\}, \{a, c\}, \{\}, 5 \rangle$
$o_{\text{black}} = \langle \{i\}, \{b, c\}, \{\}, 3 \rangle$
$o_{\text{red}} = \langle \{b, c\}, \{d\}, \{\}, 2 \rangle$
$o_{\text{orange}} = \langle \{a, d\}, \{g\}, \{\}, 0 \rangle$

| round | $P(o_{\text{orange}})$ | $P(o_{\text{red}})$ | landmark | cost |
|---|---|---|---|---|
| 1 | d | b | $\{o_{\text{red}}\}$ | 2 |
| | | | | |
| | | | | |
| | | | $h^{\text{LM-cut}}(I)$ | 0 |

SRC: https://ai.dmi.unibas.ch/_files/teaching/hs23/po/slides/po-g05.pdf

# LMCut Algorithm

## 5. Increase $h^{\text{LMCut}}(I)$ by cost(L)



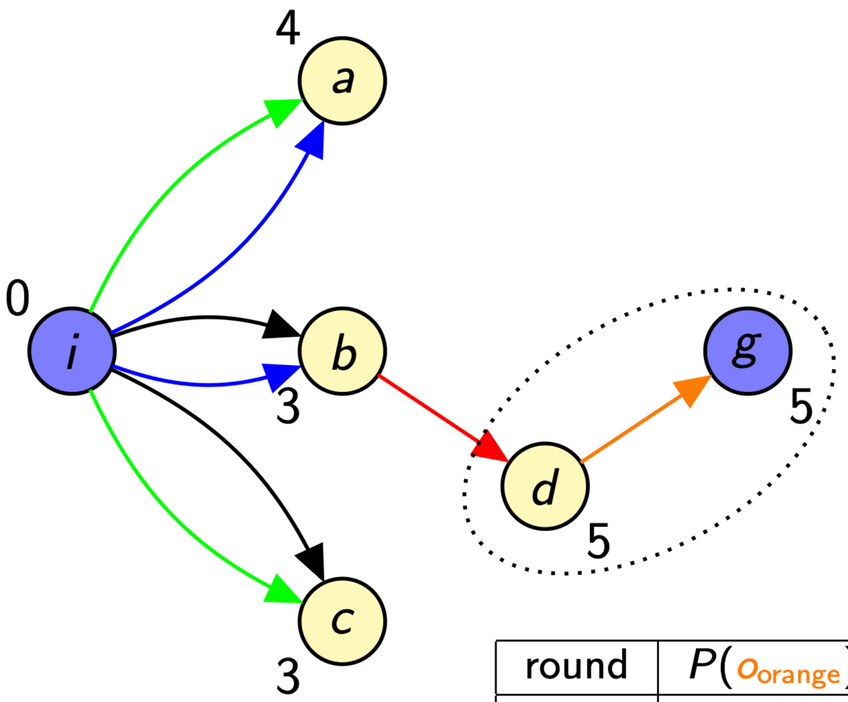

$$o_{\text{blue}} = \langle \{i\}, \{a, b\}, \{\}, 4 \rangle$$
$$o_{\text{green}} = \langle \{i\}, \{a, c\}, \{\}, 5 \rangle$$
$$o_{\text{black}} = \langle \{i\}, \{b, c\}, \{\}, 3 \rangle$$
$$o_{\text{red}} = \langle \{b, c\}, \{d\}, \{\}, 2 \rangle$$
$$o_{\text{orange}} = \langle \{a, d\}, \{g\}, \{\}, 0 \rangle$$

| round | $P(o_{\text{orange}})$ | $P(o_{\text{red}})$ | landmark | cost |
|---|---|---|---|---|
| 1 | d | b | $\{o_{\text{red}}\}$ | 2 |
| | | | | |
| | | | | |
| | | | $h^{\text{LM-cut}}(I)$ | 2 |

SRC: https://ai.dmi.unibas.ch/_files/teaching/hs23/po/slides/po-g05.pdf

# LMCut Algorithm

## 6. Decrease cost(o) by cost(L) for all o ∈ L




$o_{\text{blue}} = \langle \{i\}, \{a, b\}, \{\}, 4 \rangle$
$o_{\text{green}} = \langle \{i\}, \{a, c\}, \{\}, 5 \rangle$
$o_{\text{black}} = \langle \{i\}, \{b, c\}, \{\}, 3 \rangle$
$o_{\text{red}} = \langle \{b, c\}, \{d\}, \{\}, 0 \rangle$
$o_{\text{orange}} = \langle \{a, d\}, \{g\}, \{\}, 0 \rangle$

| round | $P(o_{\text{orange}})$ | $P(o_{\text{red}})$ | landmark | cost |
|---|---|---|---|---|
| 1 | d | b | $\{o_{\text{red}}\}$ | 2 |
| | | | | |
| | | | | |
| | | | $h^{\text{LM-cut}}(I)$ | 2 |

SRC: https://ai.dmi.unibas.ch/_files/teaching/hs23/po/slides/po-g05.pdf

# LMCut Algorithm

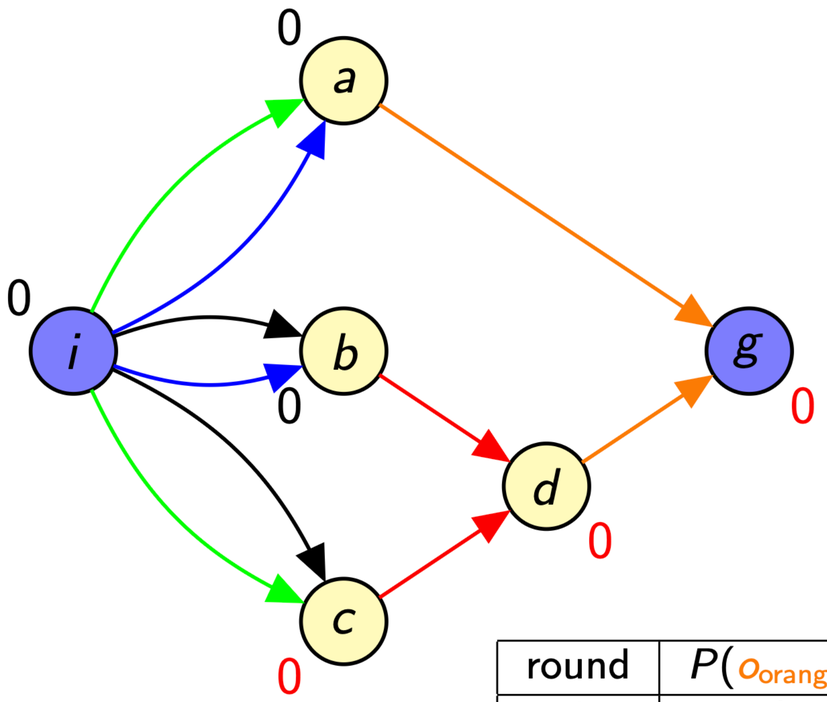
***Continue iterating***

• • •

SRC: https://ai.dmi.unibas.ch/_files/teaching/hs23/po/slides/po-g05.pdf

# LMCut Algorithm

## 1. Compute $h^{max}$ values of the variables. Stop if $h^{max}(g) = 0$.




$o_{\text{blue}} = \langle \{i\}, \{a, b\}, \{\}, 0 \rangle$
$o_{\text{green}} = \langle \{i\}, \{a, c\}, \{\}, 0 \rangle$
$o_{\text{black}} = \langle \{i\}, \{b, c\}, \{\}, 2 \rangle$
$o_{\text{red}} = \langle \{b, c\}, \{d\}, \{\}, 0 \rangle$
$o_{\text{orange}} = \langle \{a, d\}, \{g\}, \{\}, 0 \rangle$

| round | $P(o_{\text{orange}})$ | $P(o_{\text{red}})$ | landmark | cost |
|---|---|---|---|---|
| 1 | d | b | $\{o_{\text{red}}\}$ | 2 |
| 2 | a | b | $\{o_{\text{green}}, o_{\text{blue}}\}$ | 4 |
| 3 | d | c | $\{o_{\text{green}}, o_{\text{black}}\}$ | 1 |
| | | | $h^{\text{LM-cut}}(I)$ | 7 |

SRC: https://ai.dmi.unibas.ch/_files/teaching/hs23/po/slides/po-g05.pdf

# LMCut

## Precondition Choice Functions

- PCF$^{rd}$: Completely Random Choice

# LMCut

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- $PCF^{rd}$: Completely Random Choice
- $PCF^{rd-max}$: Random Choice With $h^{max}$ as Termination Criterion

# LMCut

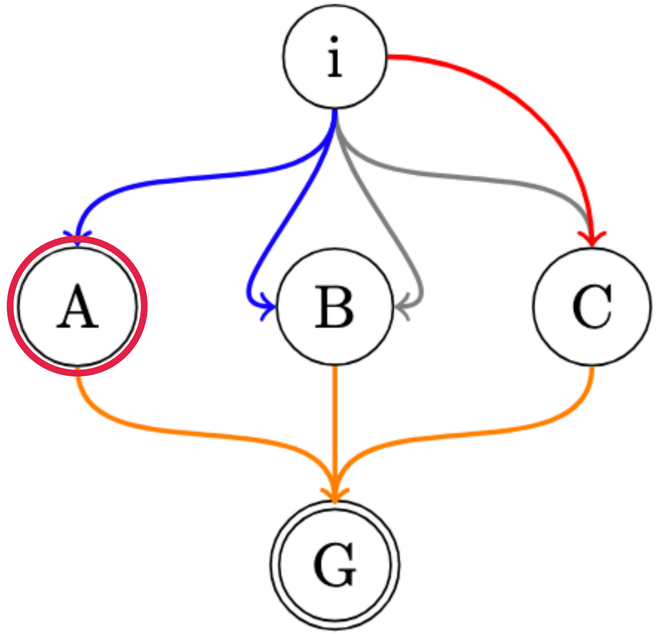
## Precondition Choice Functions

- $PCF^{rd}$: Completely Random Choice
- $PCF^{rd-max}$: Random Choice With $h^{max}$ as Termination Criterion
- $PCF^{hadd}$: Choosing Preconditions Based on $h^{add}$

# LMCut

## Tie-Breaking Strategies

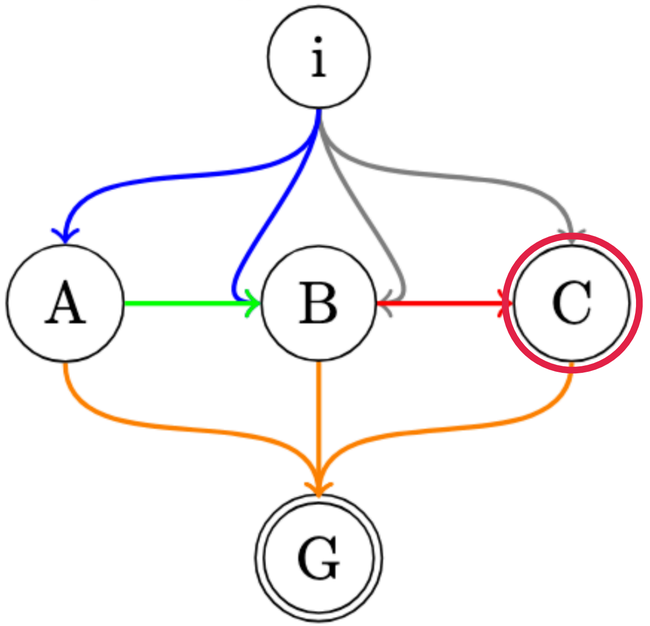
- $PCF_{e-min}$: Favor Preconditions being Effect of Lowest Number of Operators



# LMCut

## Tie-Breaking Strategies

- $PCF_{e-min}$: Favor Preconditions being Effect of Lowest Number of Operators
- $PCF_{p-min}$: Favor Preconditions being Precondition of Lowest N



# LMCut

## Tie-Breaking Strategies

- $\text{PCF}_{\text{e-min}}$: Favor Preconditions being Effect of Lowest Number of Operators
- $\text{PCF}_{\text{p-min}}$: Favor Preconditions being Precondition of Lowest Number of Operators
- $\text{PCF}_{\text{unused}}$: Favor Unused Preconditions

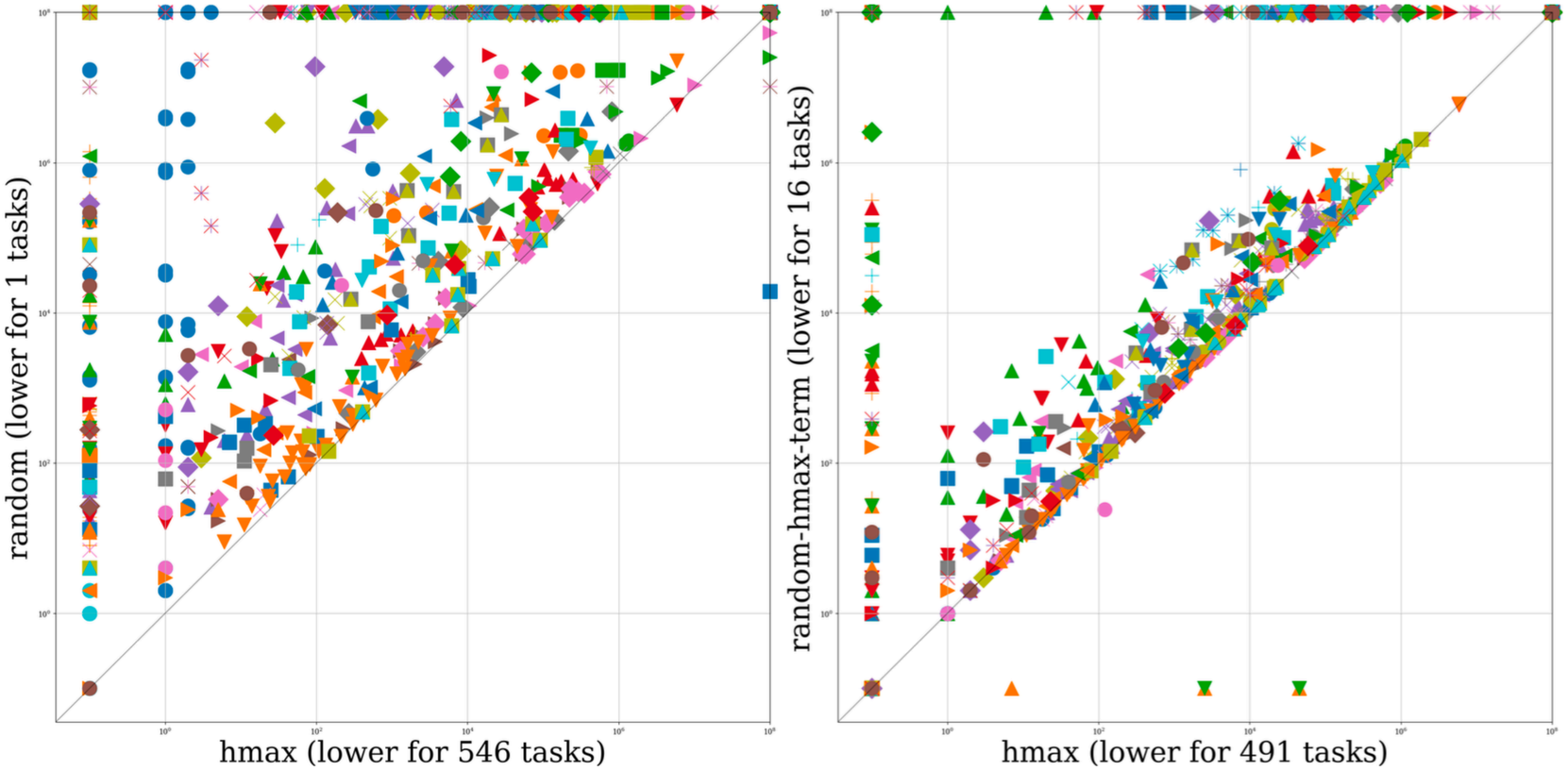
# LMCut

## Tie-Breaking Strategies

- $PCF_{e-min}$: Favor Preconditions being Effect of Lowest Number of Operators
- $PCF_{p-min}$: Favor Preconditions being Precondition of Lowest Number of Operators
- $PCF_{unused}$: Favor Unused Preconditions
- $PCF_{unused-n}$: Favor Less Frequently Used Preconditions

# Discussion

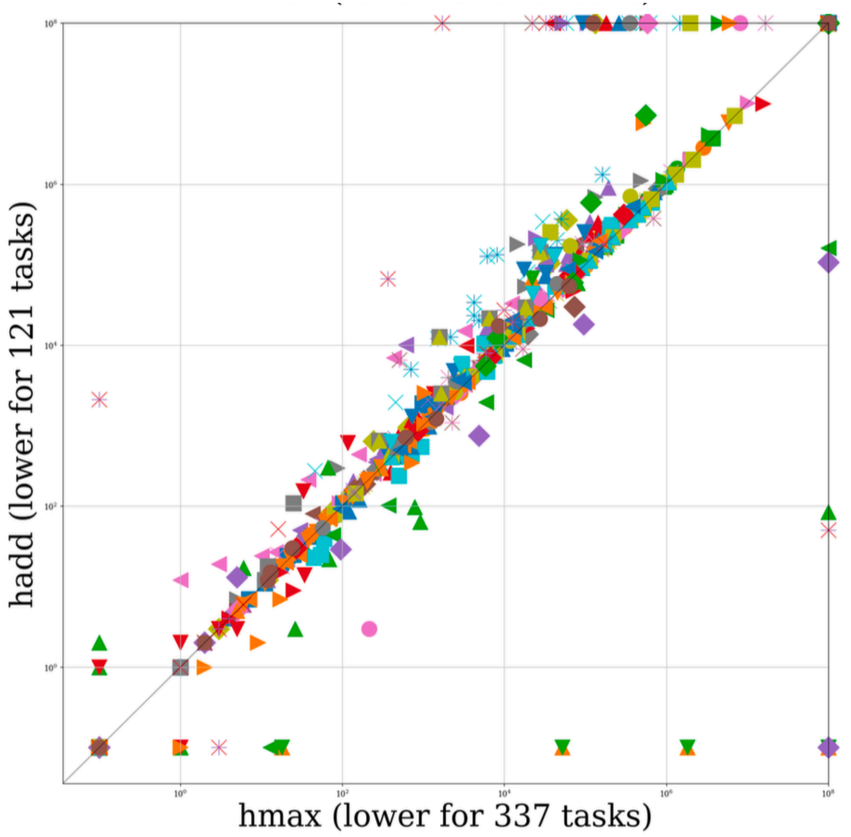
## Replacing Precondition Choice Functions




Node Expansions Until Last Jump

# Discussion

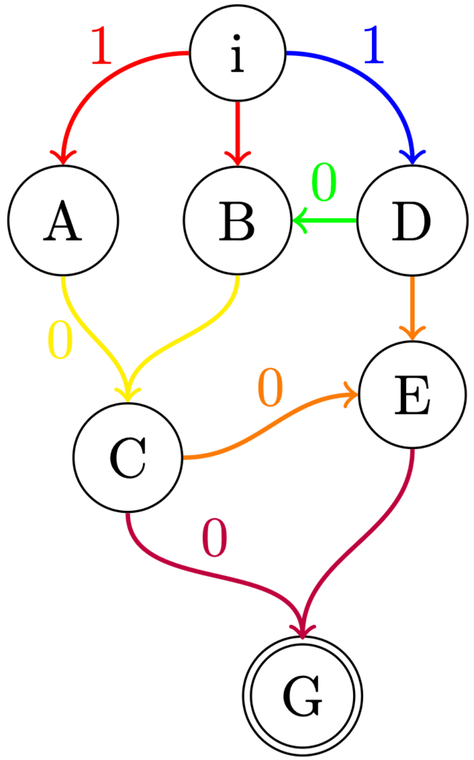
## Replacing Precondition Choice Functions




Node Expansions Until Last Jump

# Discussion

## Example For Different Outcomes Using Same Tie-Breaking

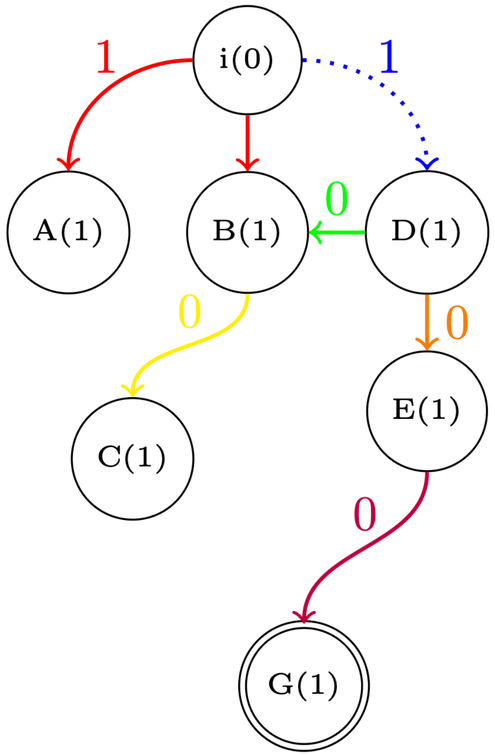



$$
\begin{aligned}
o_{red} &= \langle \{i\}, \{A, B\}, \{\}, 1 \rangle \\
o_{blue} &= \langle \{i\}, \{D\}, \{\}, 1 \rangle \\
o_{yellow} &= \langle \{A, B\}, \{C\}, \{\}, 0 \rangle \\
o_{green} &= \langle \{D\}, \{B\}, \{\}, 0 \rangle \\
o_{orange} &= \langle \{C, D\}, \{E\}, \{\}, 0 \rangle \\
o_{purple} &= \langle \{C, E\}, \{G\}, \{\}, 0 \rangle
\end{aligned}
$$

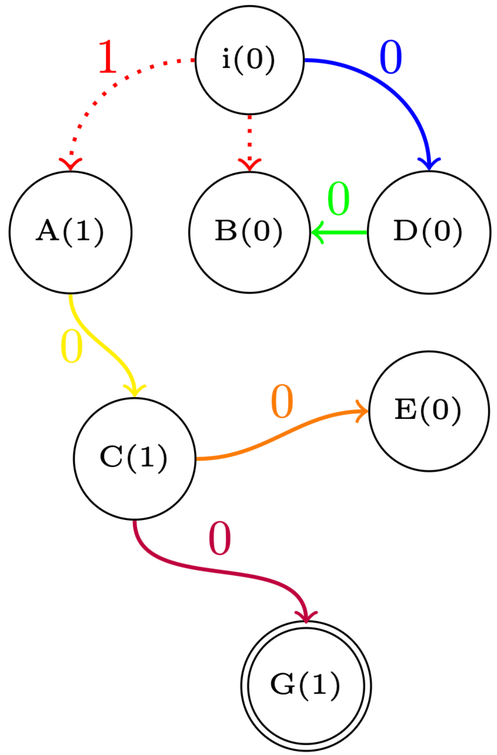
# Discussion

## LMCut$^{\text{hmax}}$

Iteration 1: $h^{\text{LMCut}}_{\text{hmax}}(I) = 1$



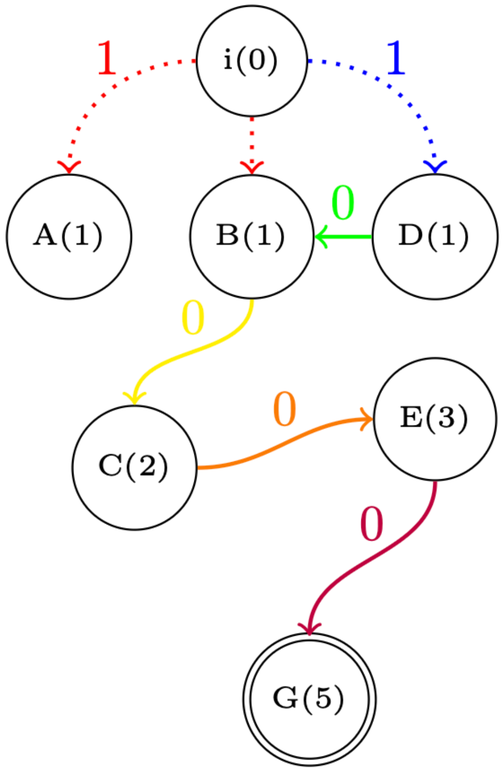

Iteration 2: $h^{\text{LMCut}}_{\text{hmax}}(I) = 2$



# Discussion

## LMCut$^{\text{hadd}}$

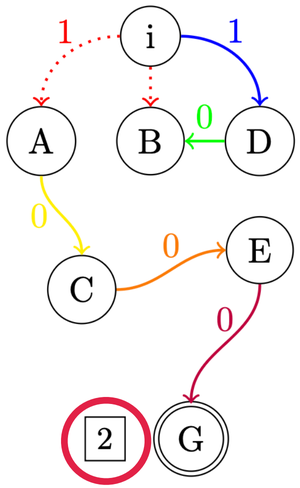
Iteration 1: $h^{\text{LMCut}}_{\text{hadd}}(I) = 1$

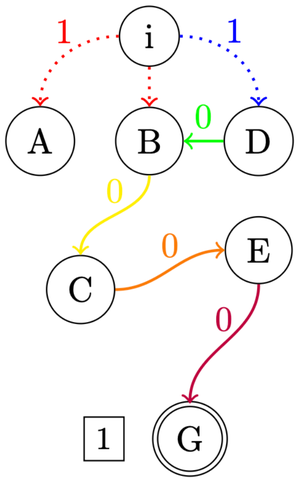


# Discussion

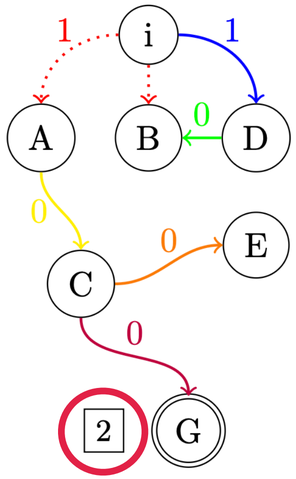
## Justification Graphs for All Valid Tie Breakings

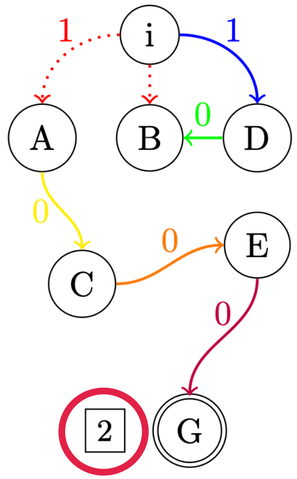
$LMCut^{hadd}$

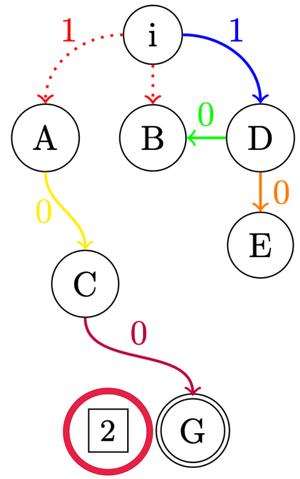


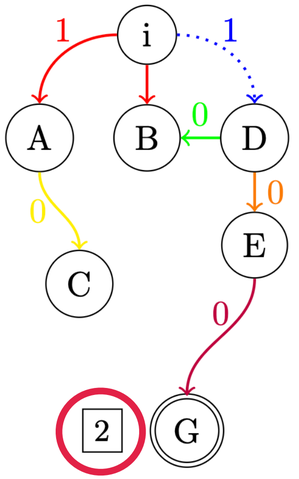



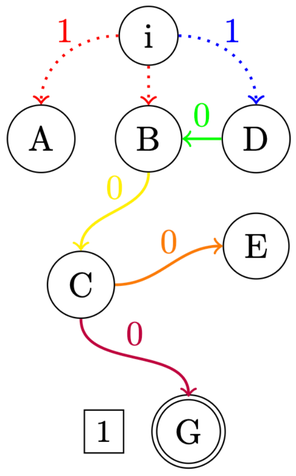

$LMCut^{hmax}$

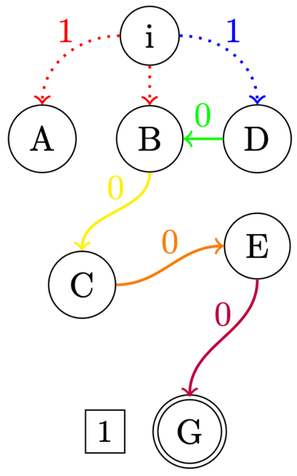


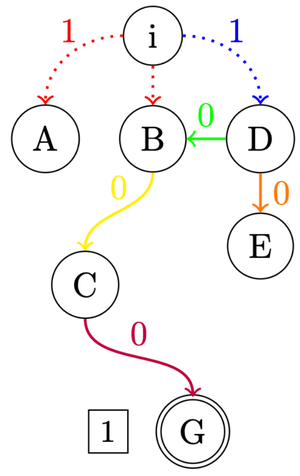



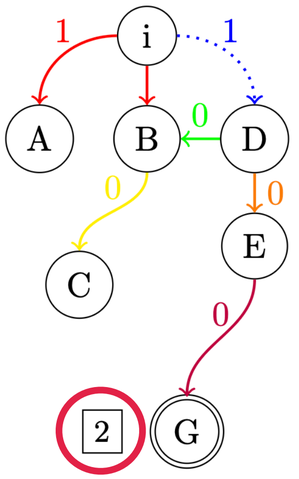



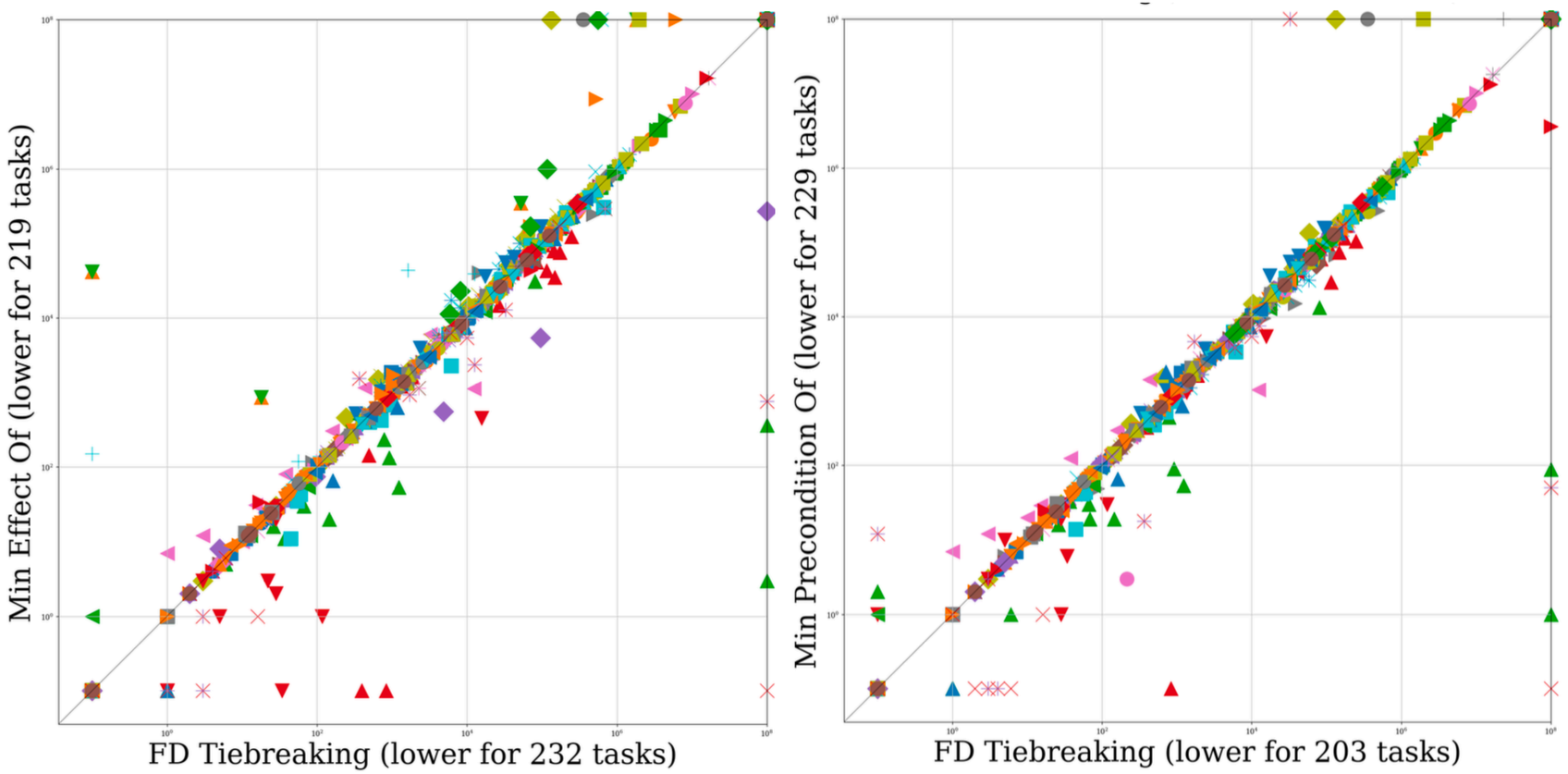



# Discussion

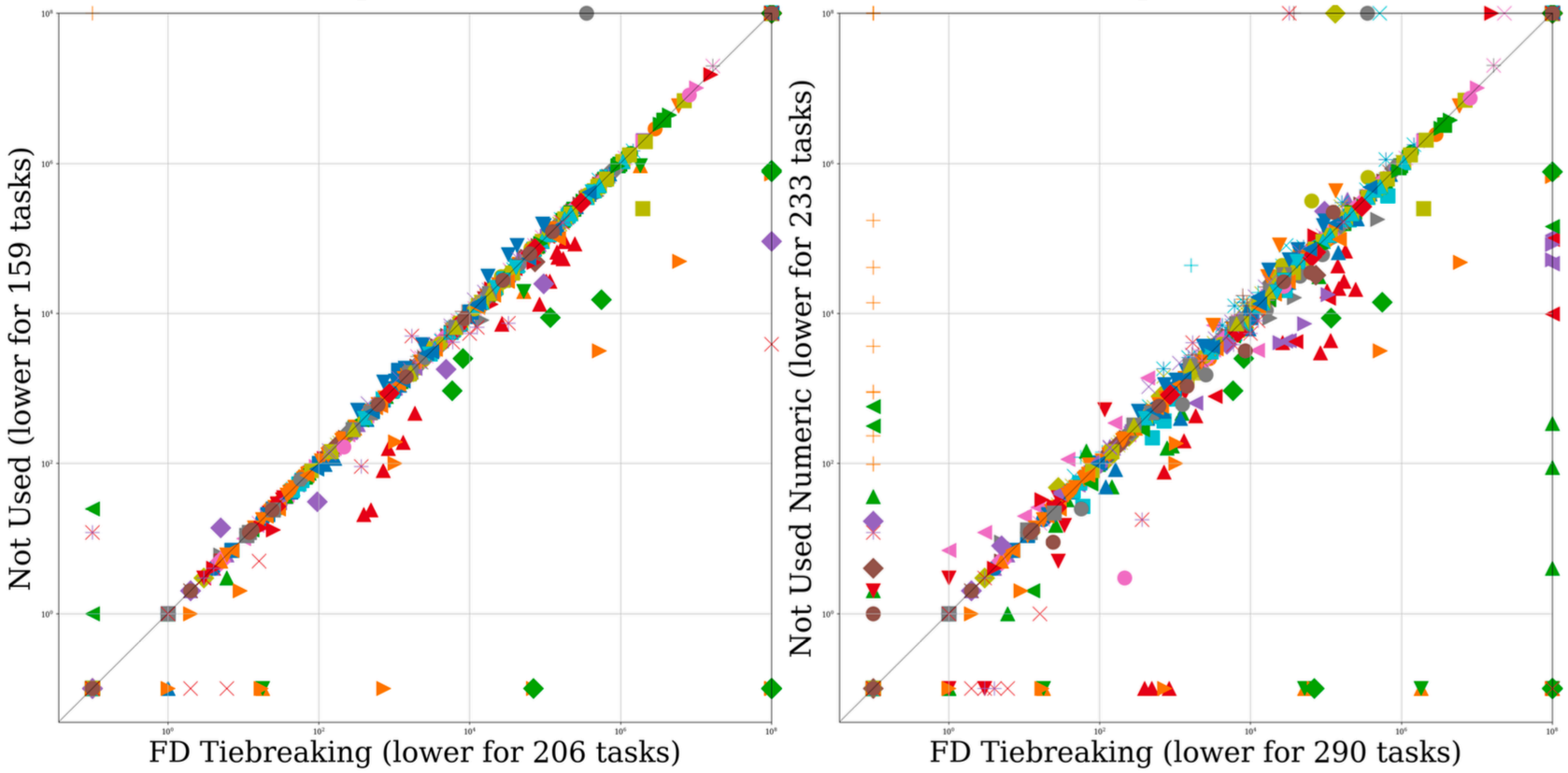
## Tie-Breaking Strategies




Node Expansions Until Last Jump

# Discussion

## Tie-Breaking Strategies

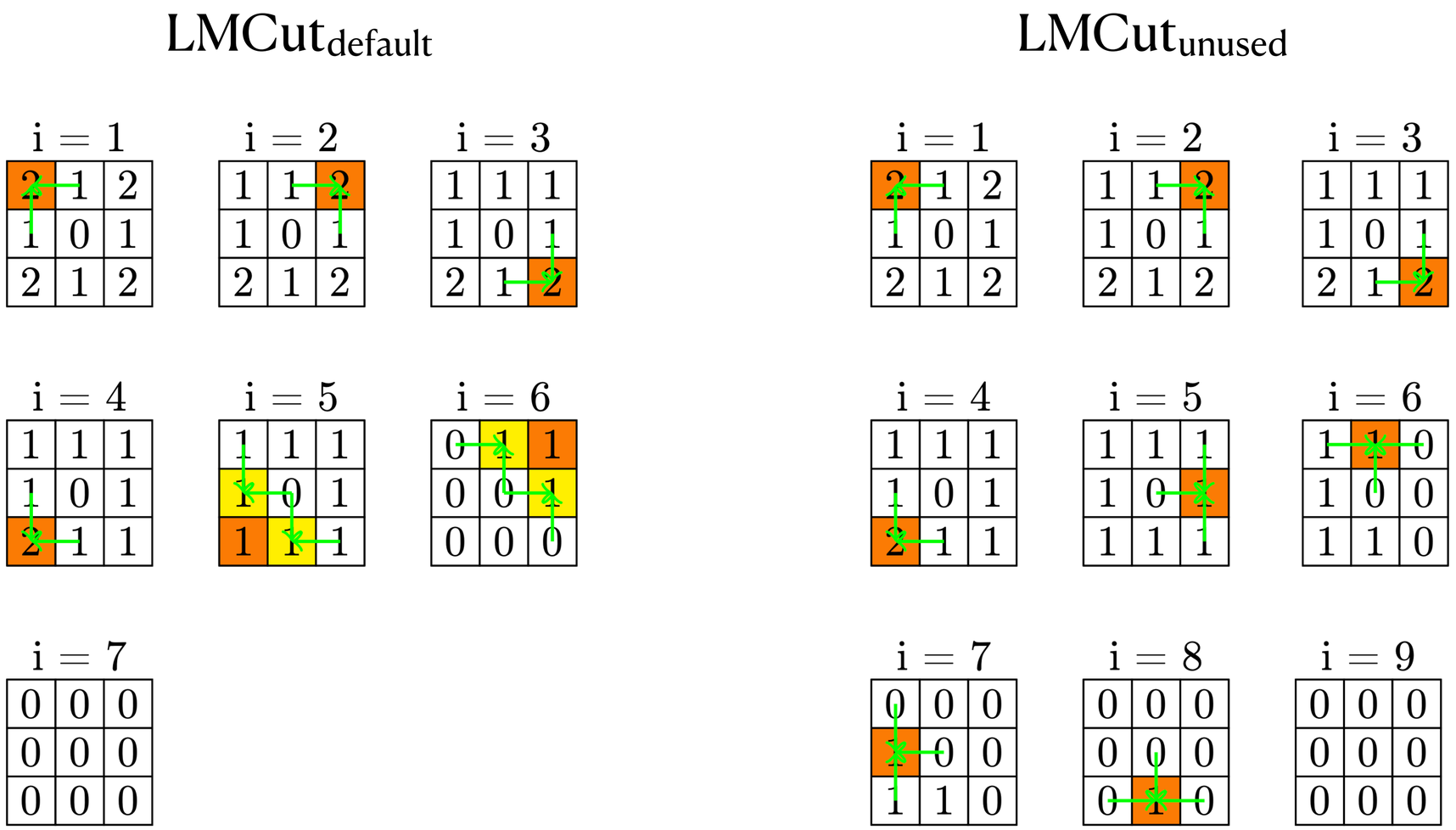



Node Expansions Until Last Jump

# Discussion

## Tie-Breaking Strategies

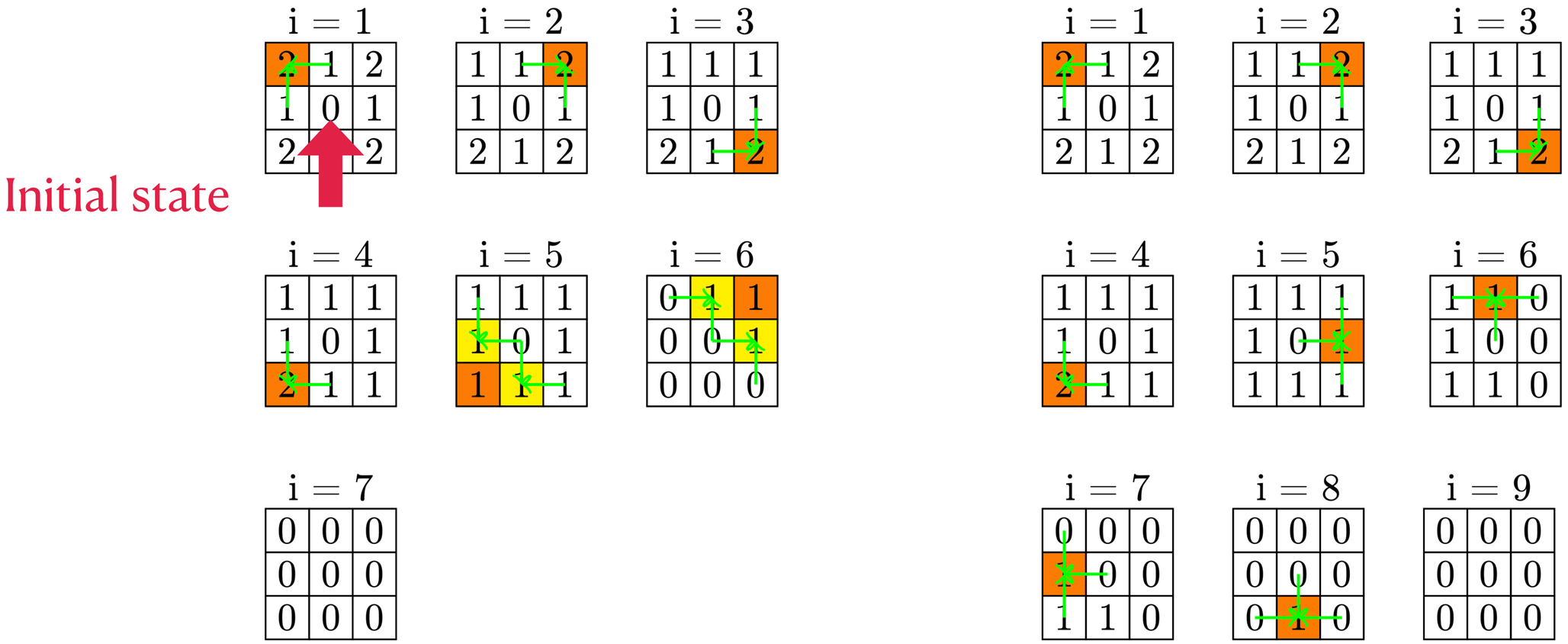
Selected Precondition
Goal Zone
Cut Set Operators



# Discussion

## Tie-Breaking Strategies

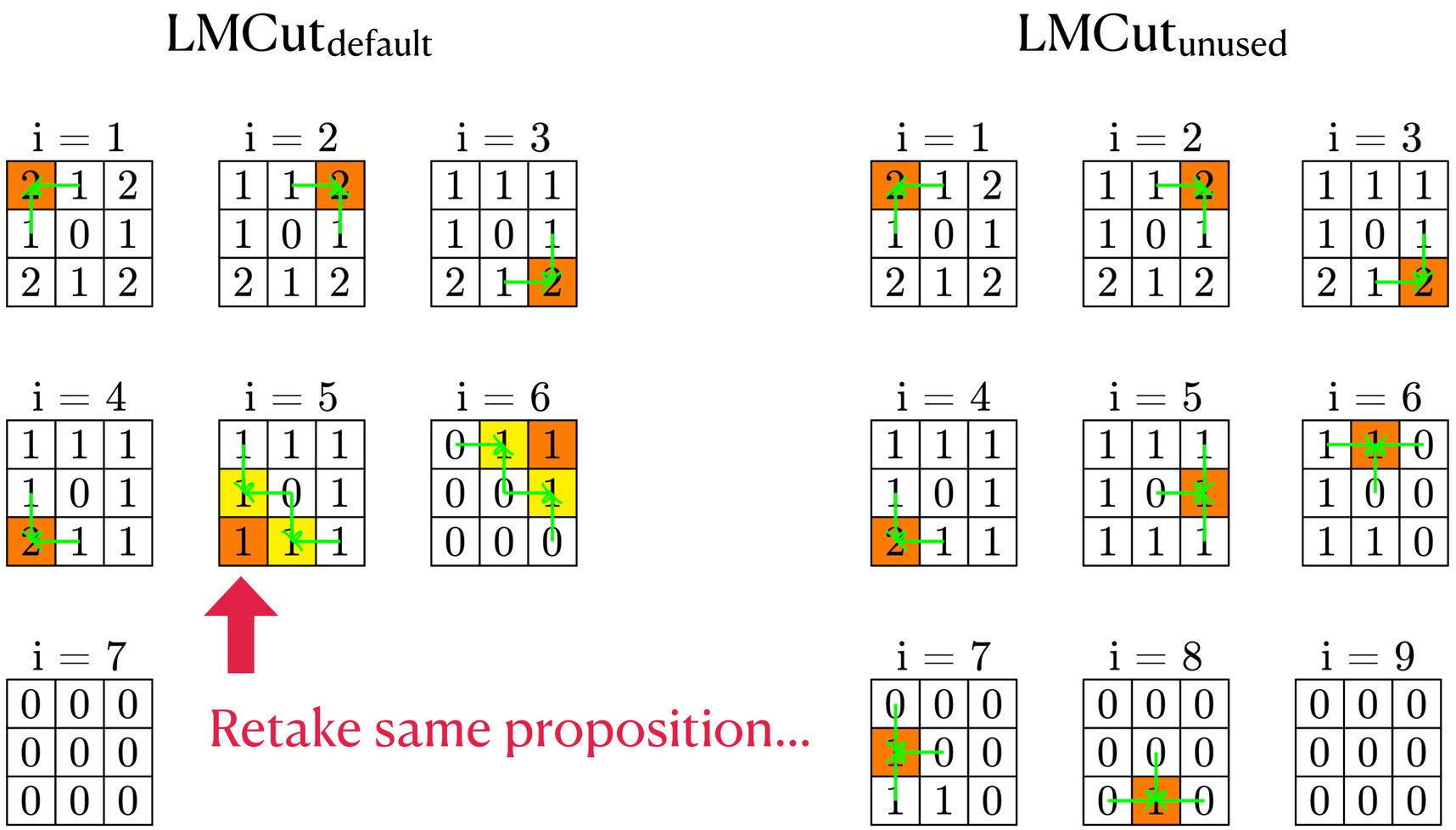
Selected Precondition
Goal Zone
Cut Set Operators



# Discussion

## Tie-Breaking Strategies

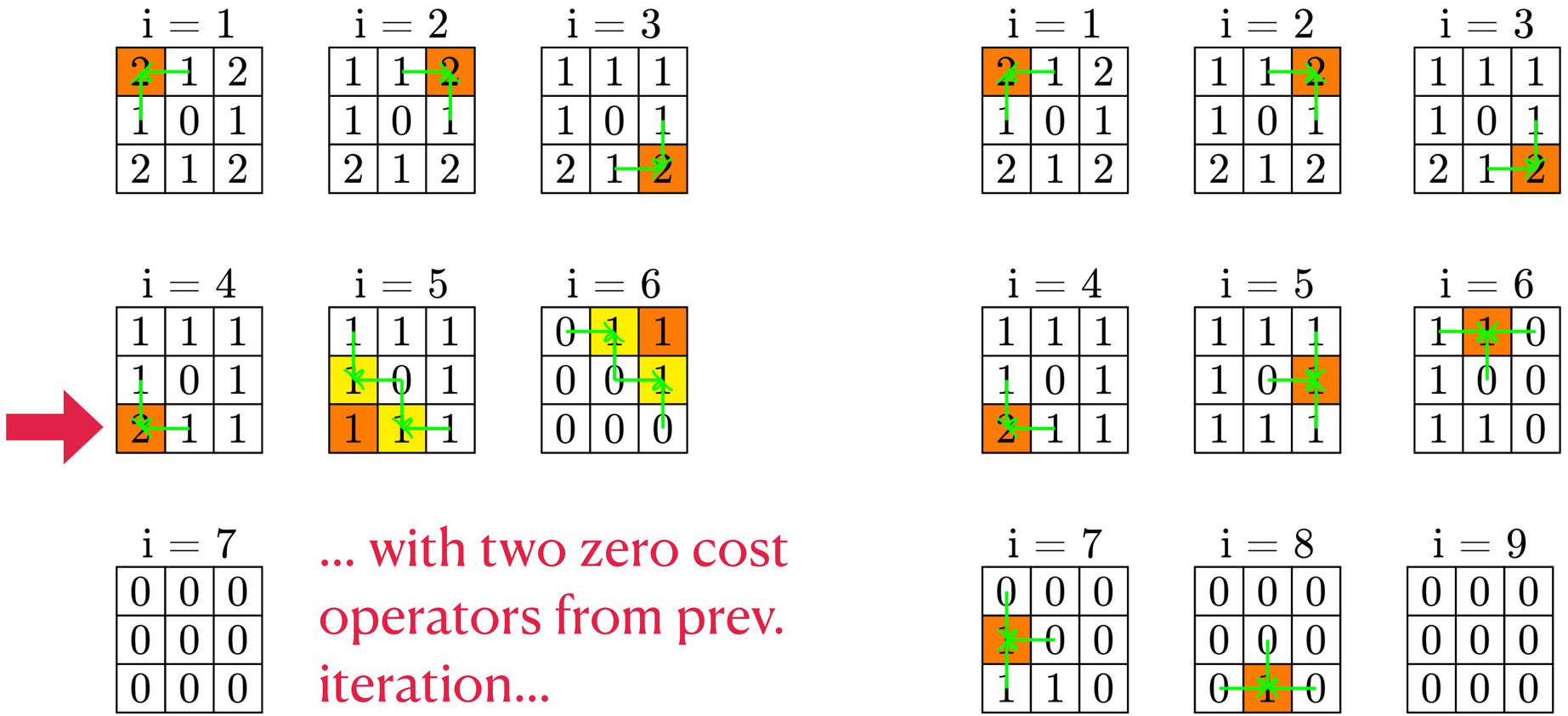
Selected Precondition
Goal Zone
Cut Set Operators



# Discussion

## Tie-Breaking Strategies

Selected Precondition
Goal Zone
Cut Set Operators

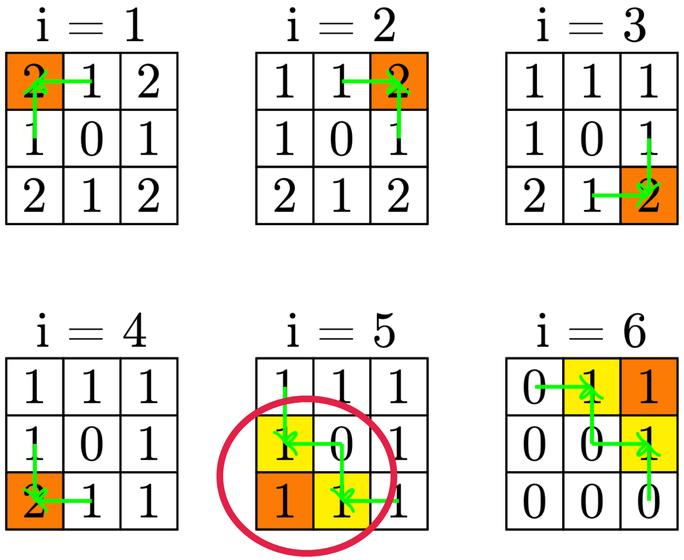


# Discussion

## Tie-Breaking Strategies

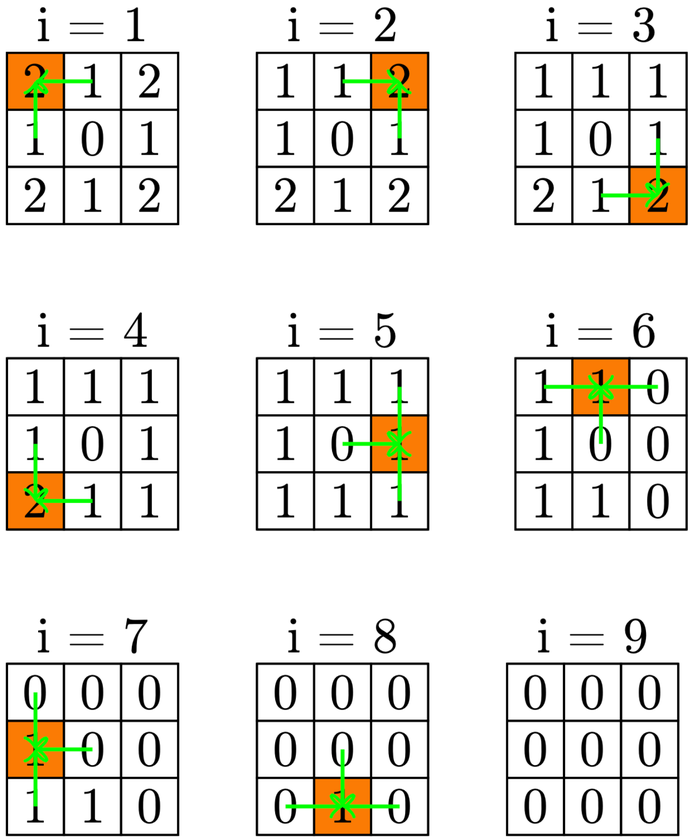
Selected Precondition
Goal Zone
Cut Set Operators

### $\text{LMCut}_{\text{default}}$




... leads to growing goal zone...

### $\text{LMCut}_{\text{unused}}$

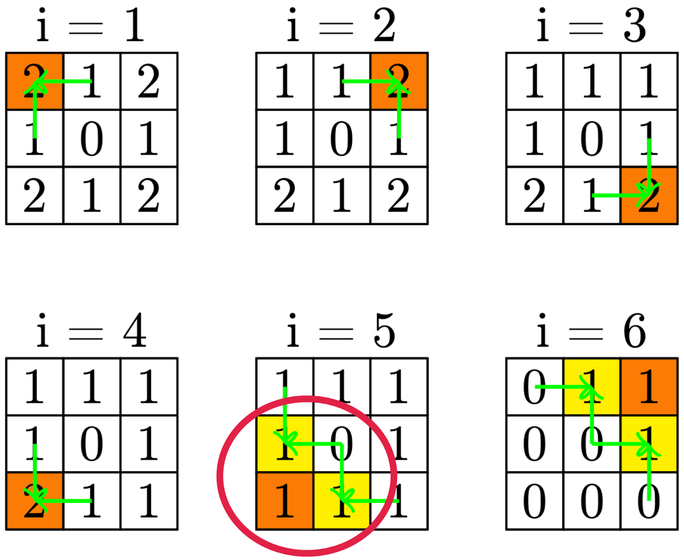


# Discussion

## Tie-Breaking Strategies

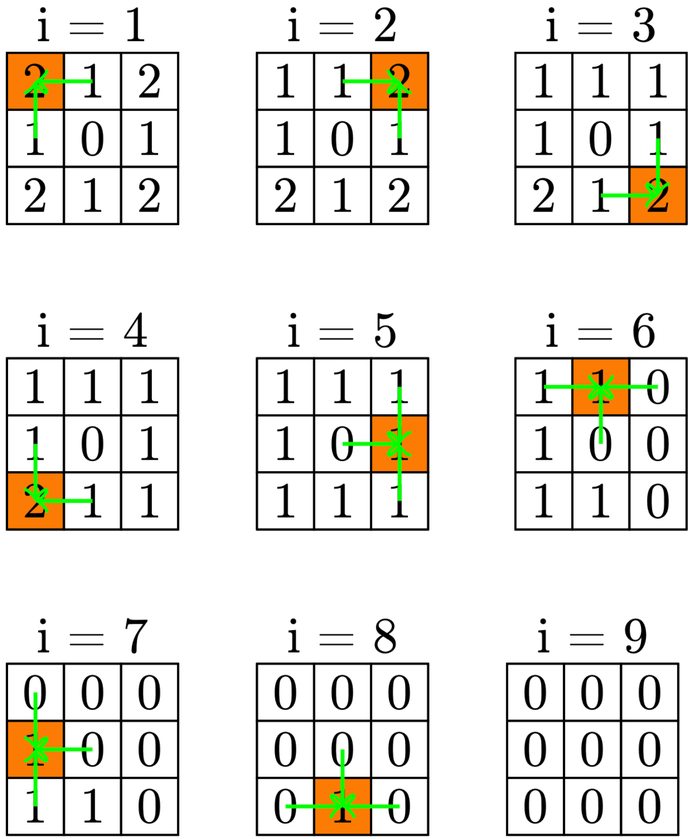
Selected Precondition
Goal Zone
Cut Set Operators

### $\text{LMCut}_{\text{default}}$




... thus, larger cut set.

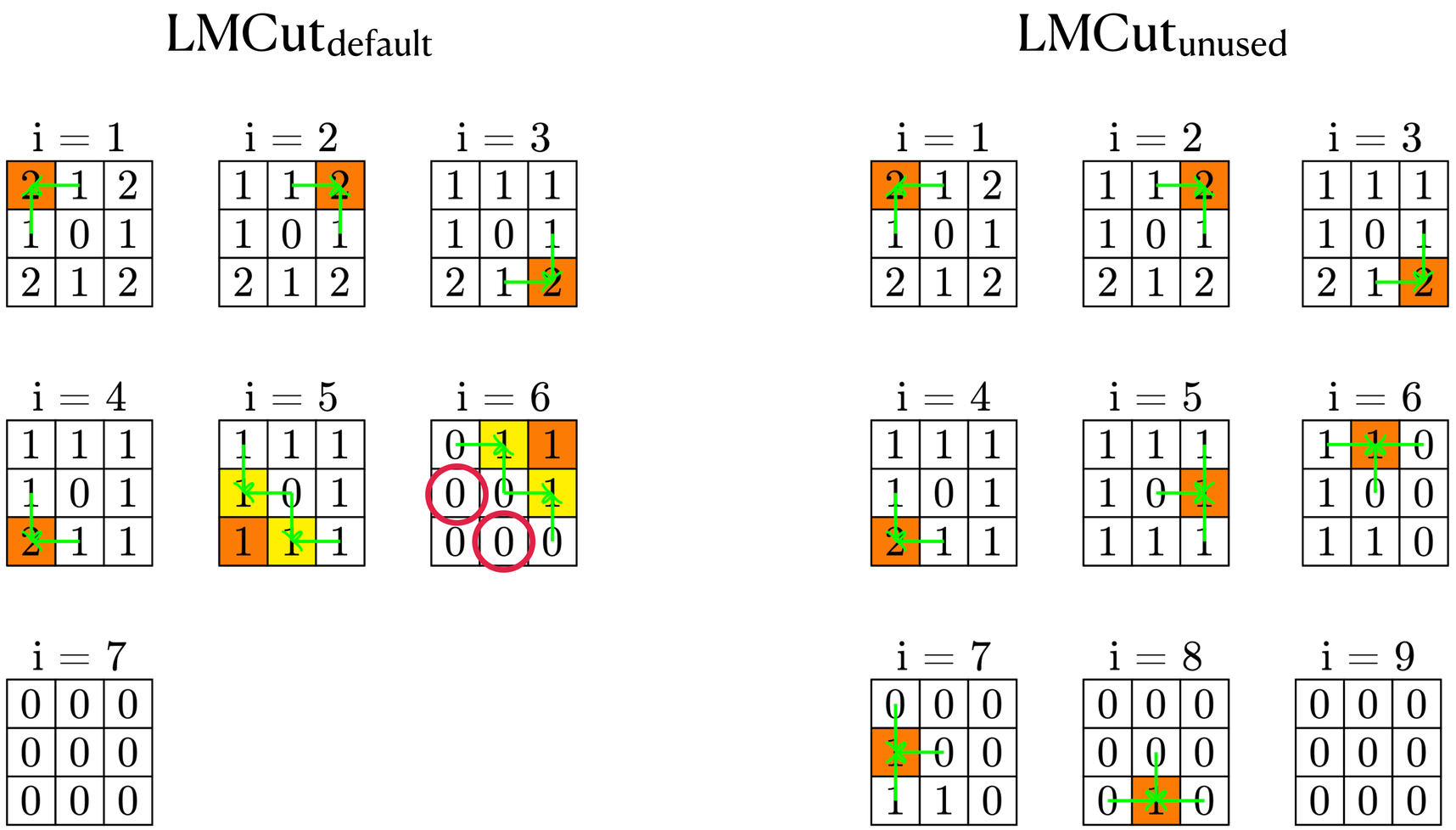
### $\text{LMCut}_{\text{unused}}$



# Discussion

## Tie-Breaking Strategies

Selected Precondition
Goal Zone
Cut Set Operators

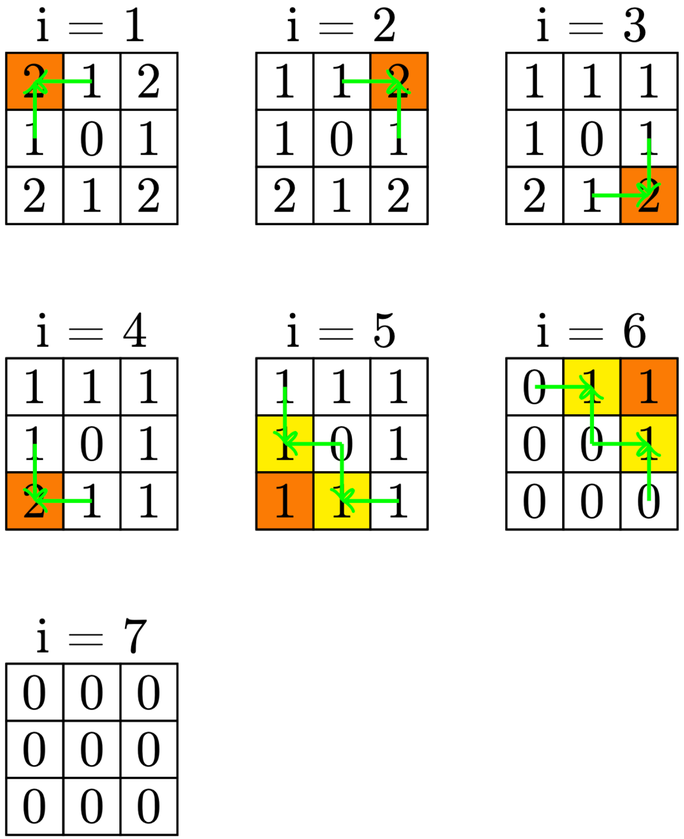


# Discussion

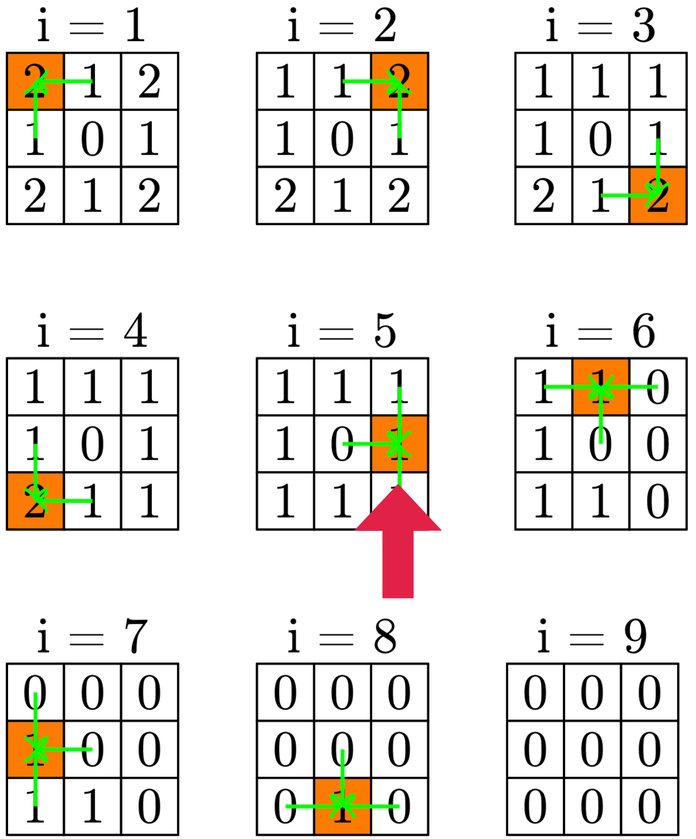
## Tie-Breaking Strategies

Selected Precondition
Goal Zone
Cut Set Operators

### $\text{LMCut}_{\text{default}}$




### $\text{LMCut}_{\text{unused}}$




Prevent retaking same precondition

# Thanks!

## Questions?