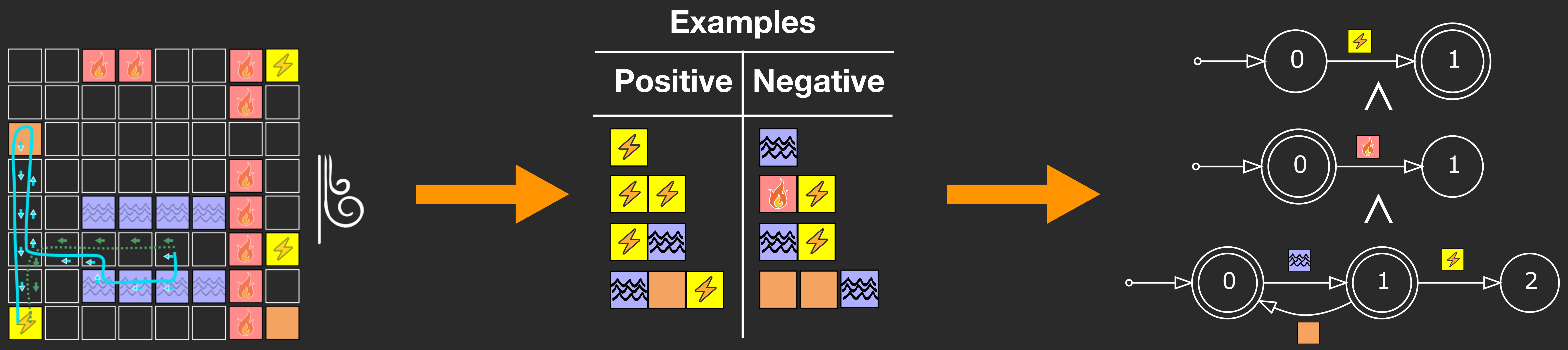
Learning DFA Decompositions from Examples and Demonstrations

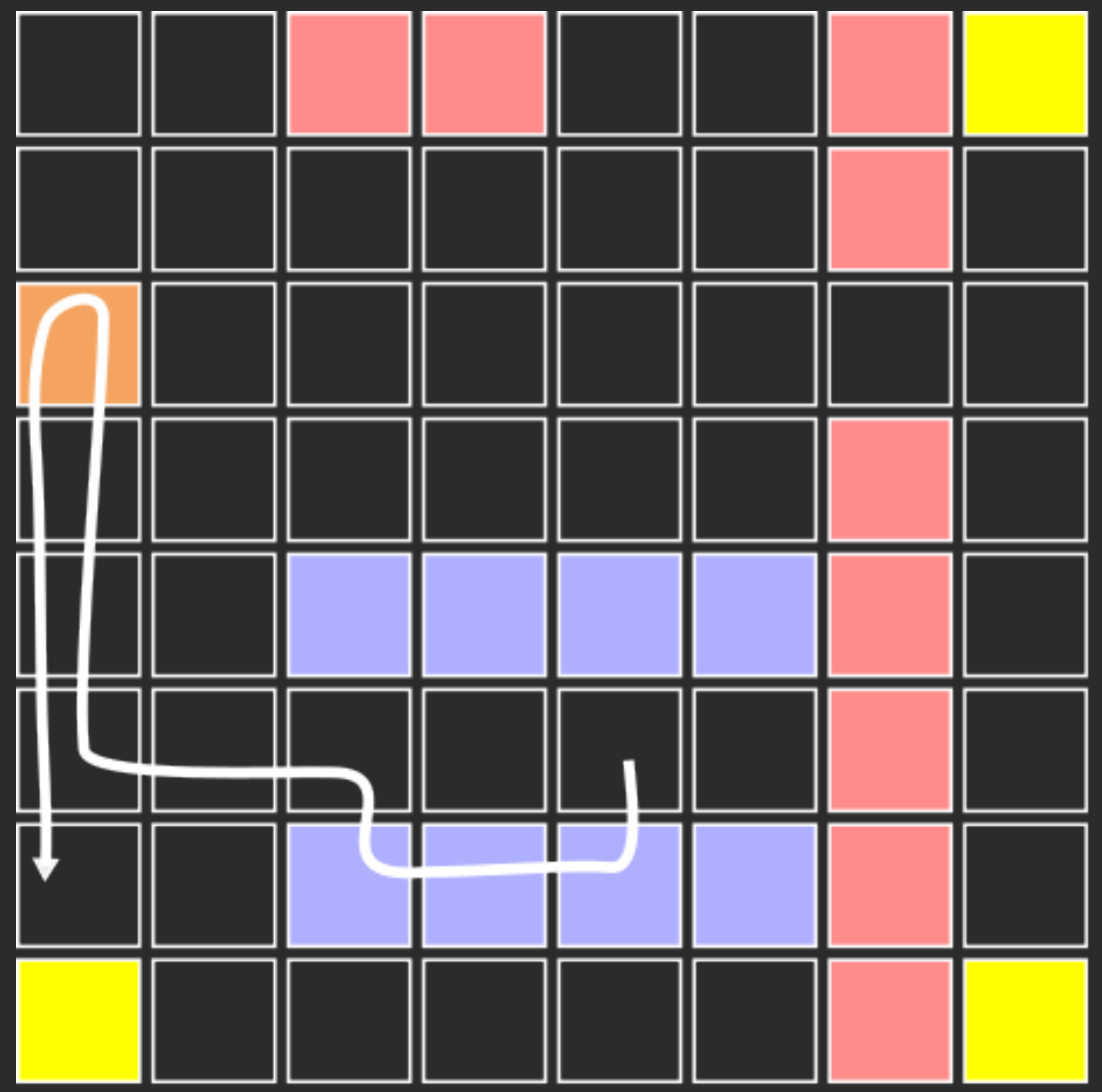


Niklas Lauffer*, Beyazit Yalcinkaya*, Marcell Vazquez-Chanlatte, Ameesh Shah, and Sanjit A. Seshia

*equal contribution

University of California, Berkeley

A simple gridworld



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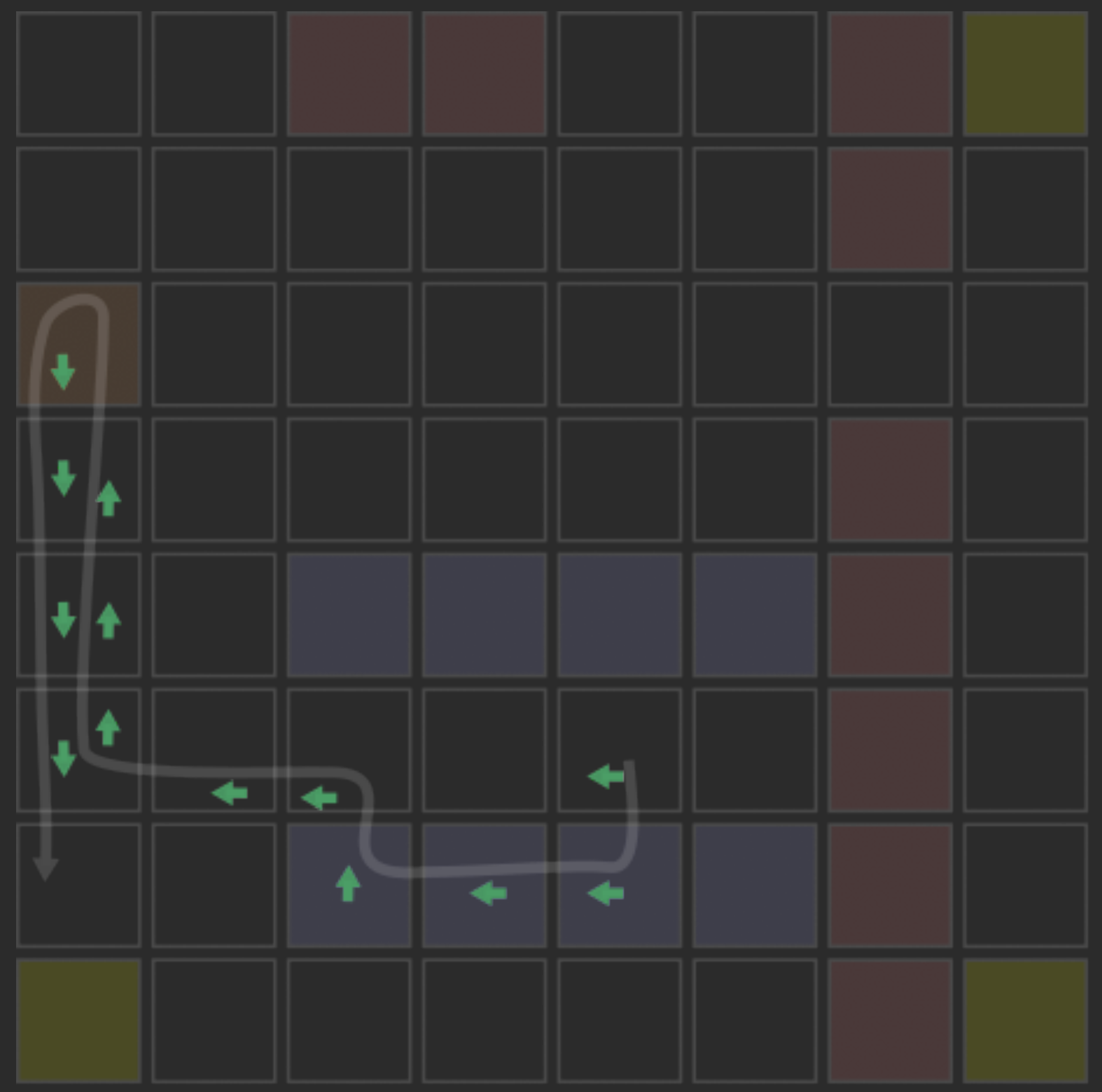

Actions = {↑ ↓ ← →}

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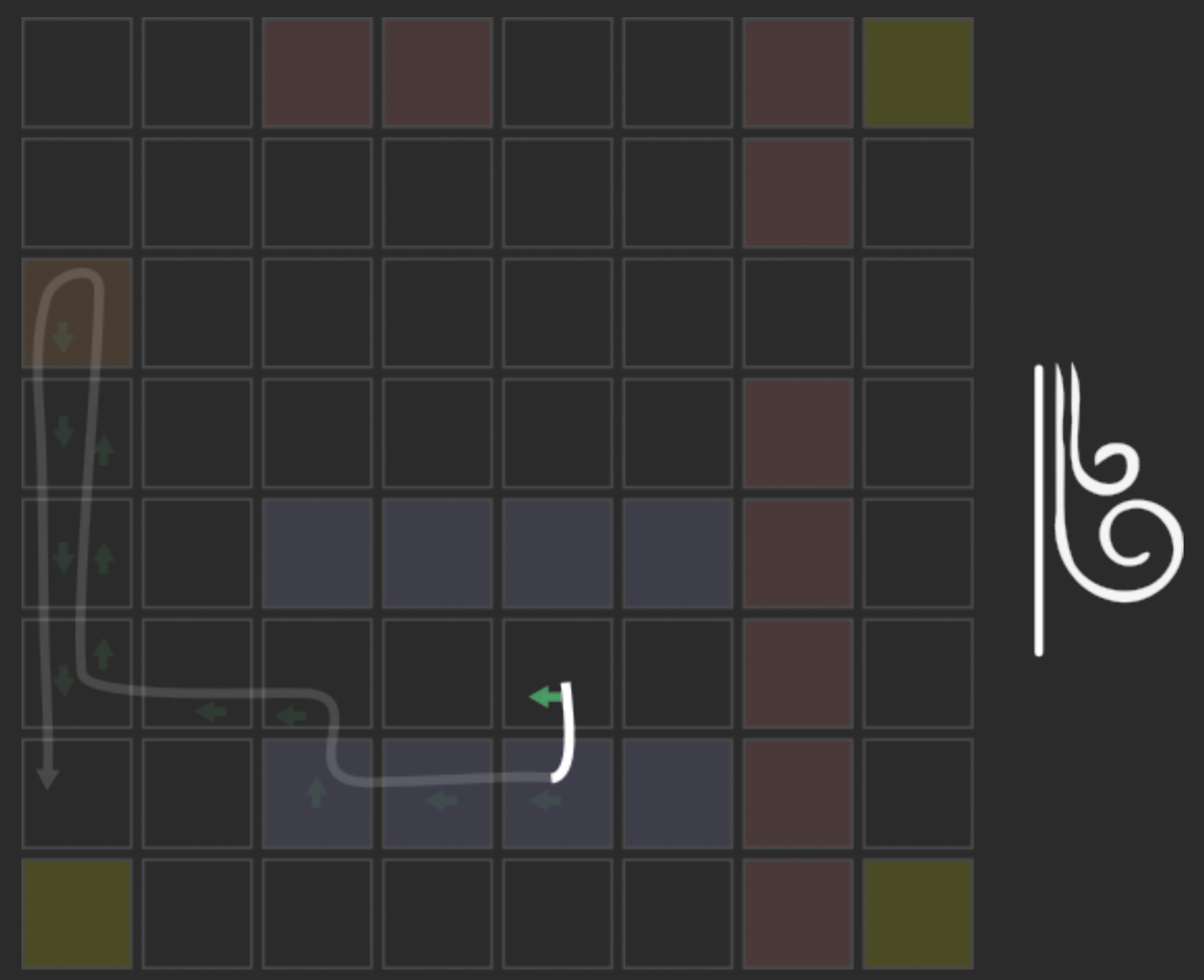

Actions = {↑ ↓ ← →}

Pr(slip ↓) = 1/32

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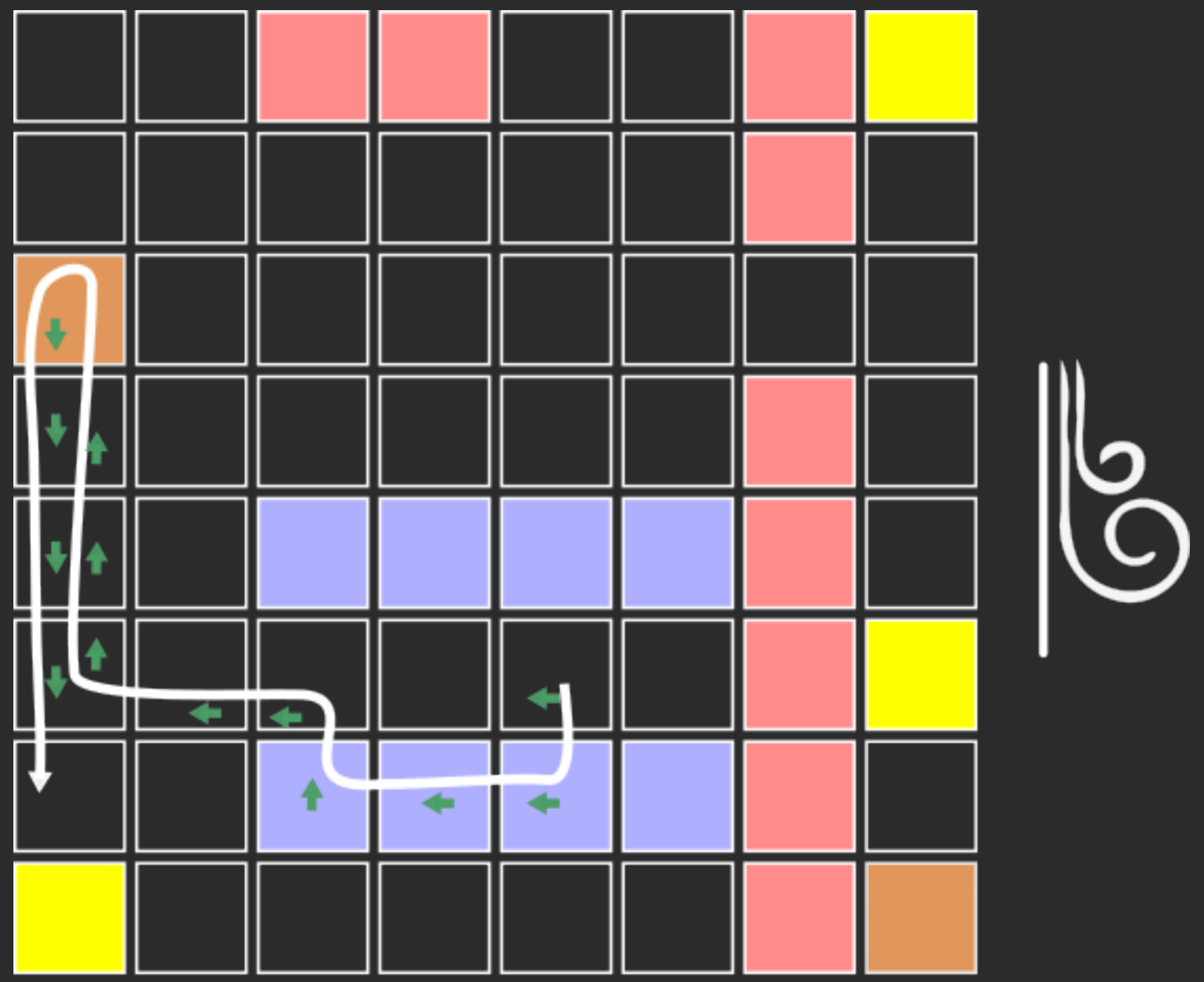

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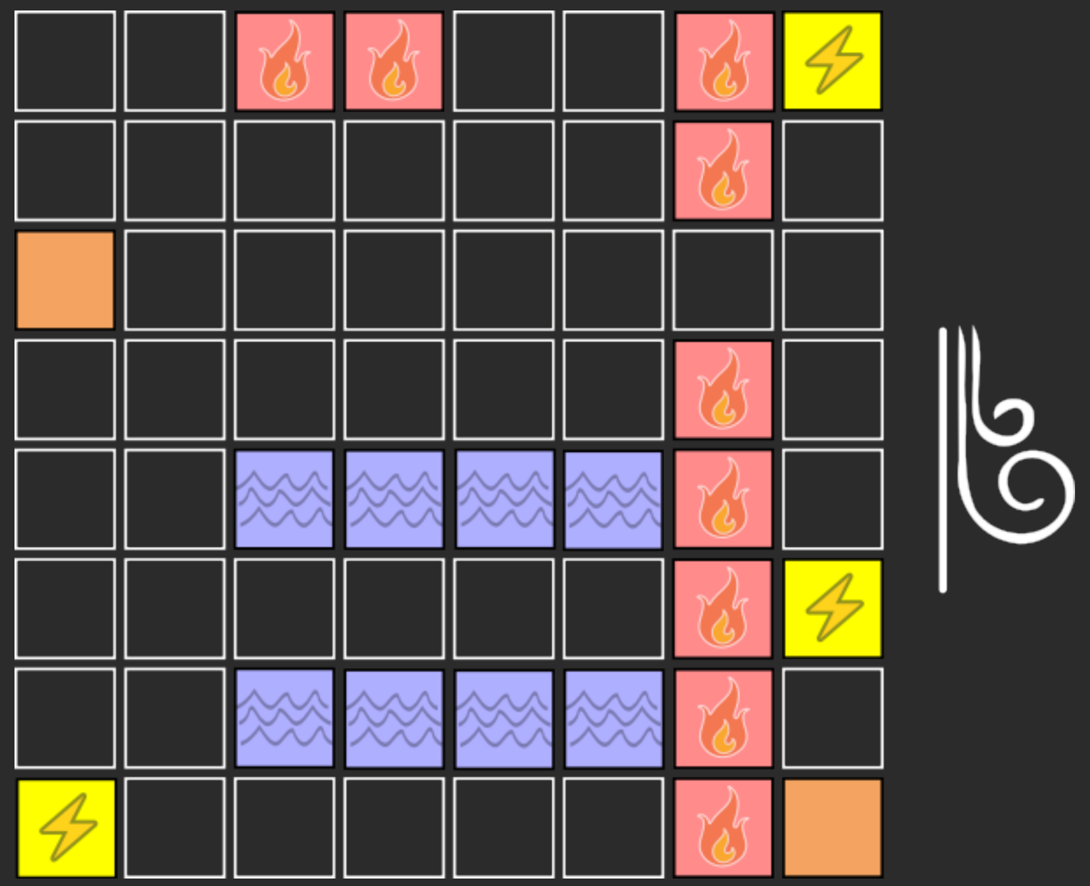
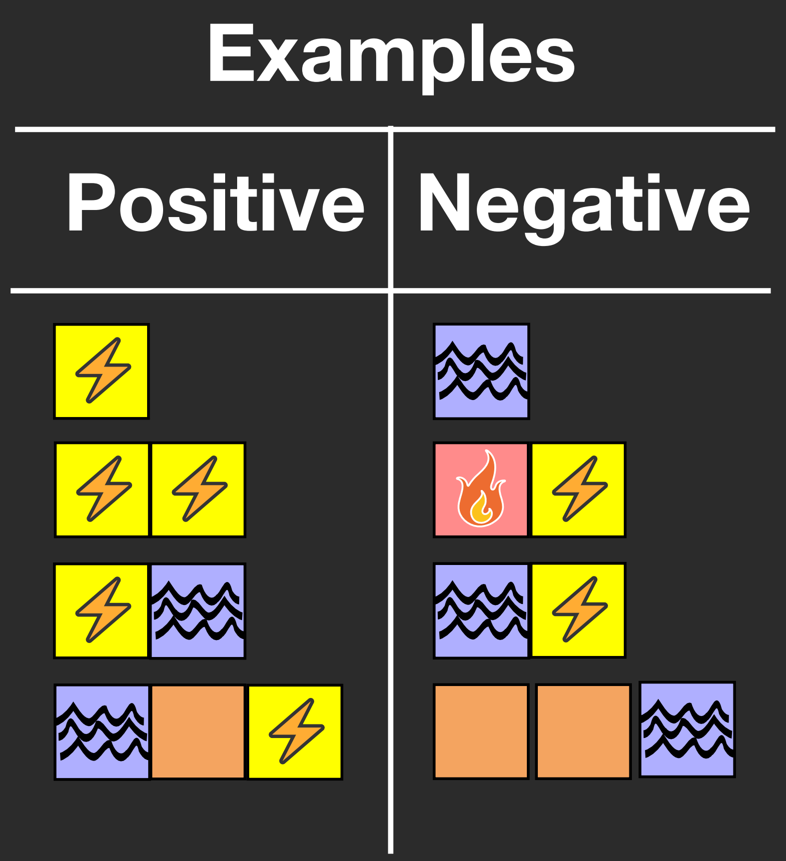
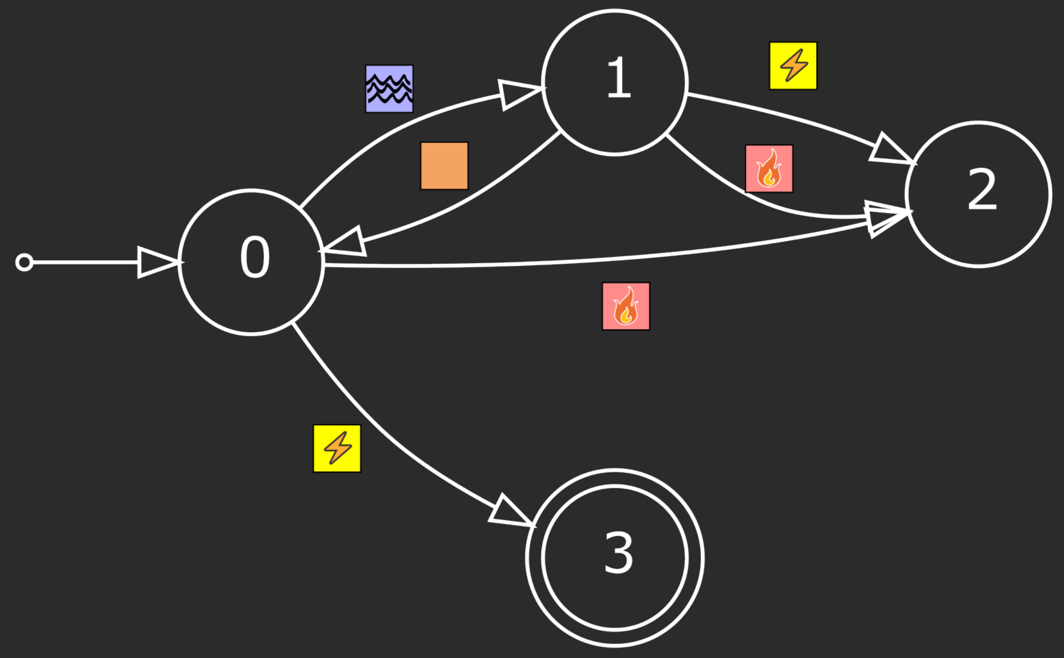
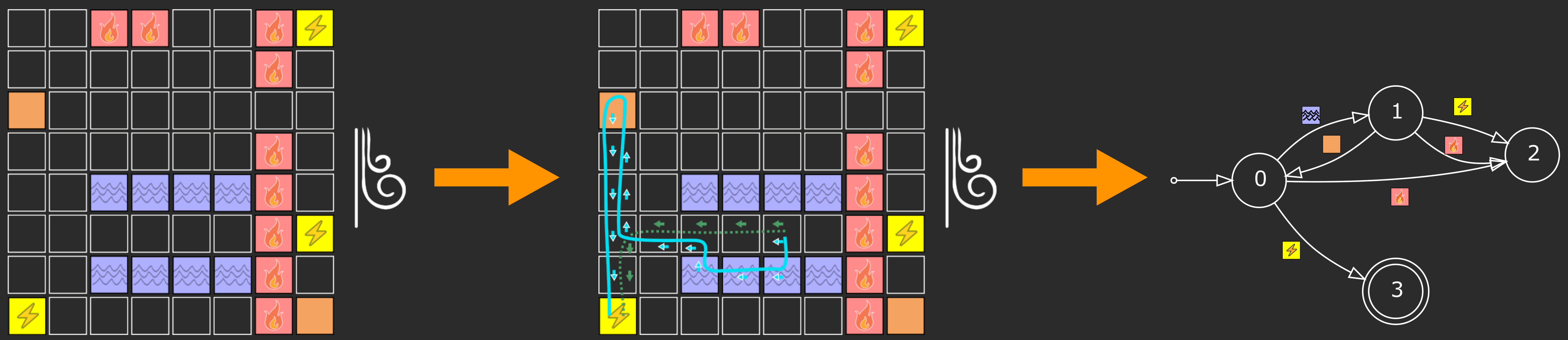
Specification mining



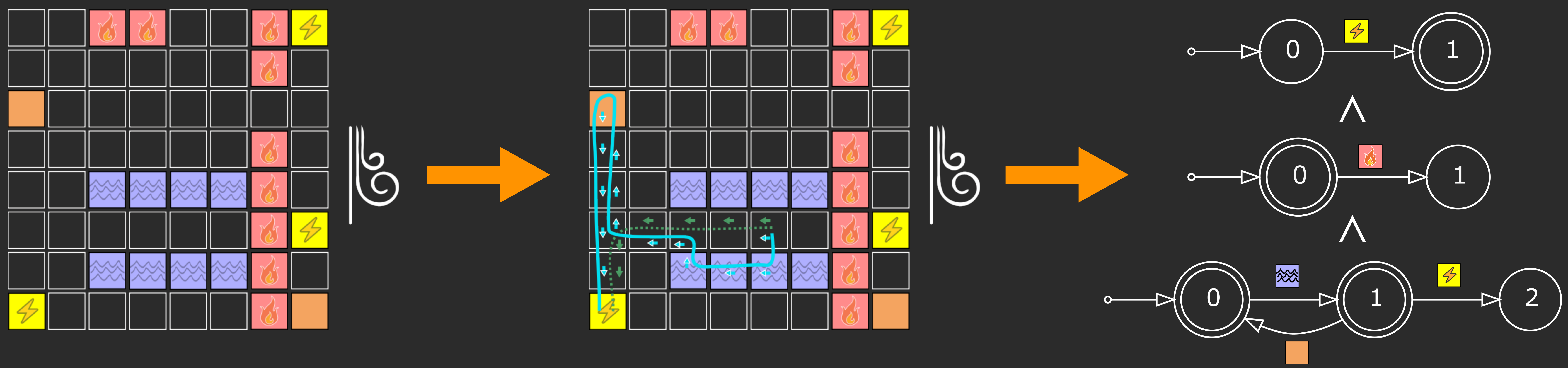




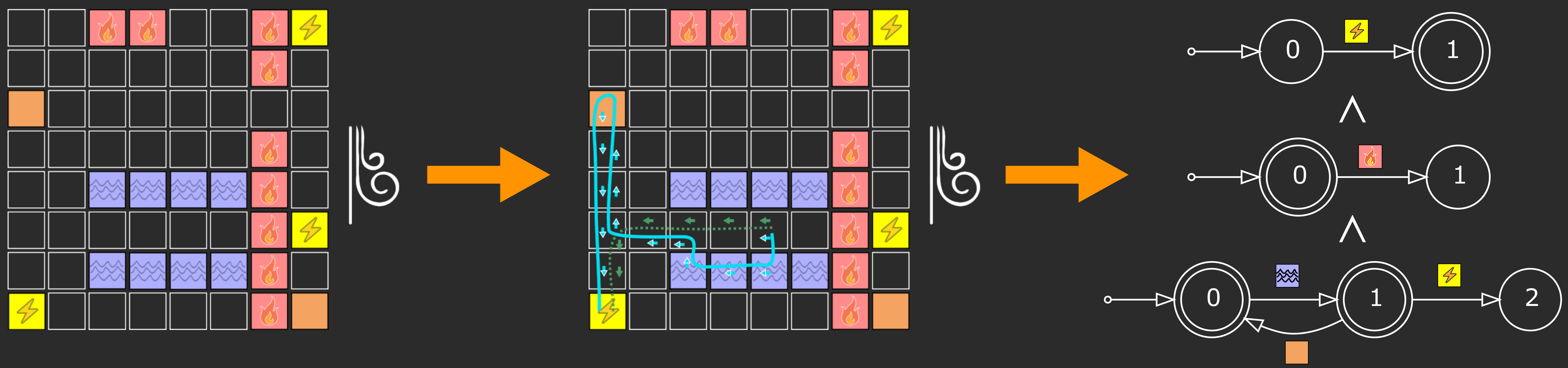
Learning from demonstrations



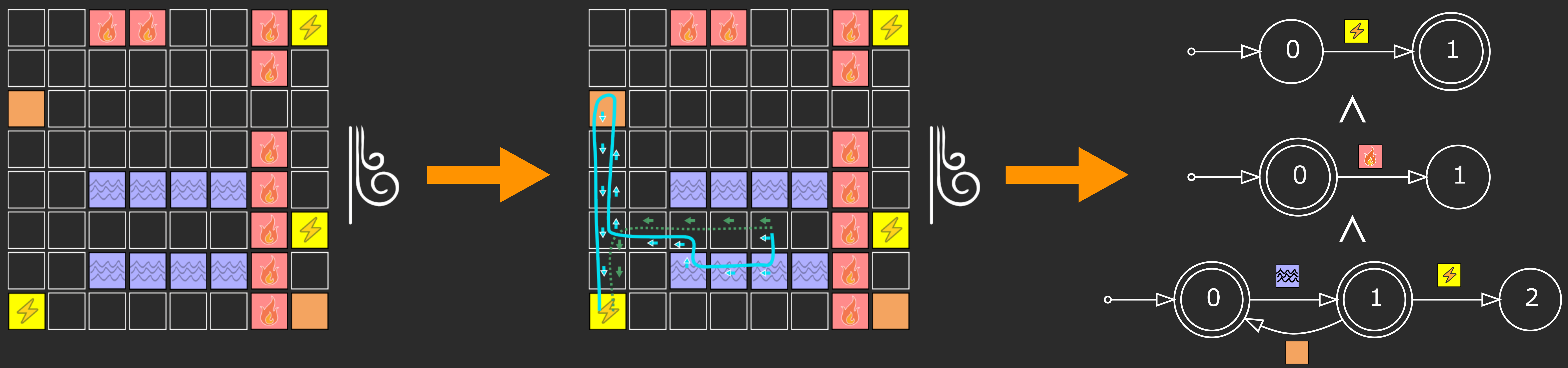
Learning decompositions



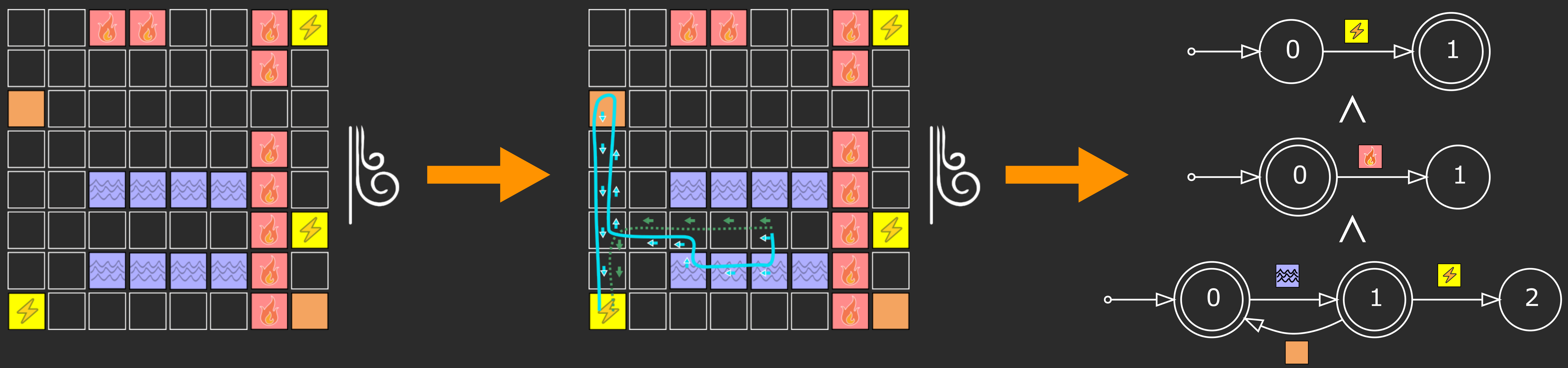
Monolithic specifications can often be difficult to understand



System-level specifications are often conjunctions of sub-specifications



Inductive bias matters when learning from few demonstrations



Contributions

1. SAT-based encoding for identifying a DFA decomposition of a specific size from labeled examples

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2. An algorithm for enumerating the full Pareto-frontier of decompositions

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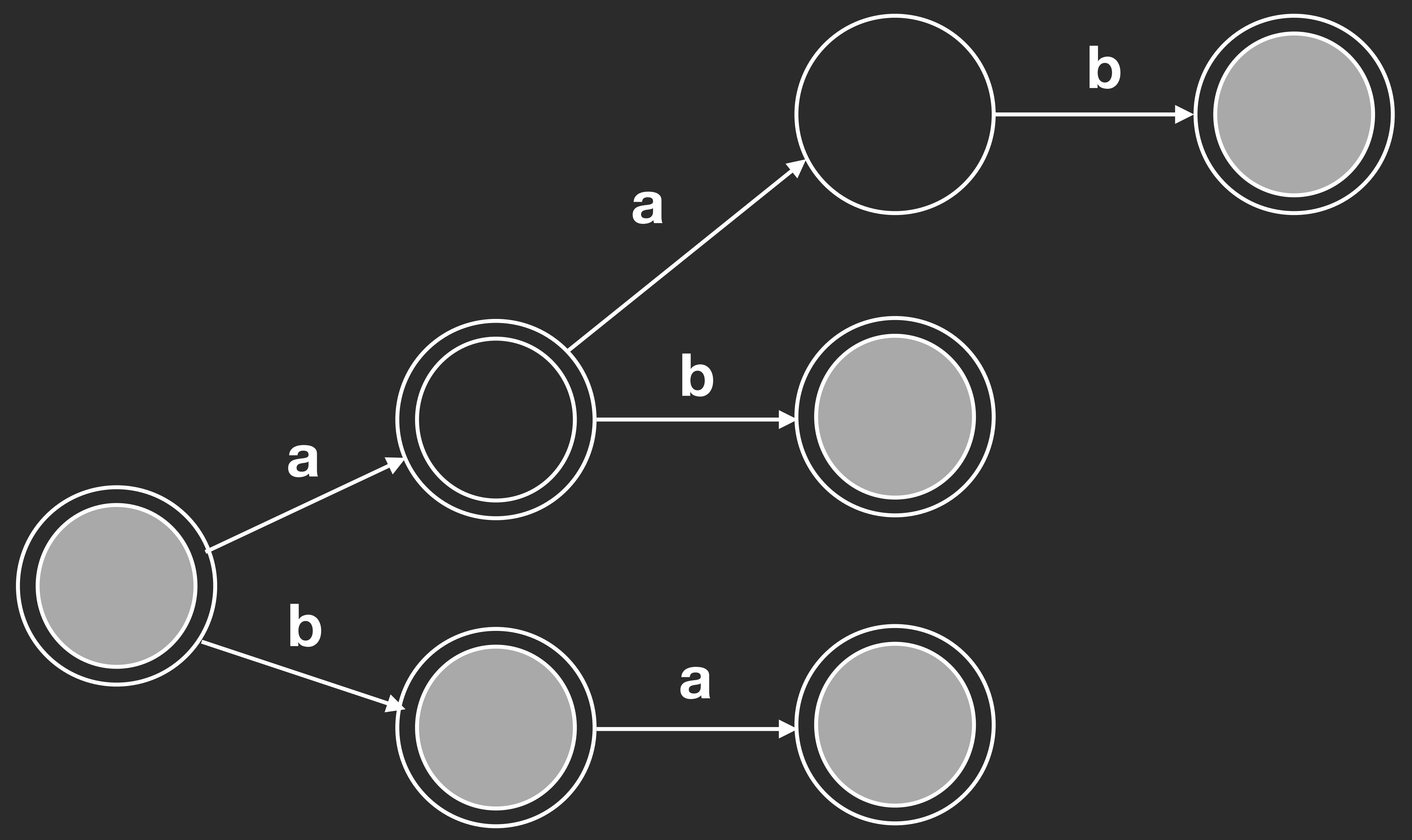
3. Experimental analysis and extension to learning from demonstrations

Structure of the talk

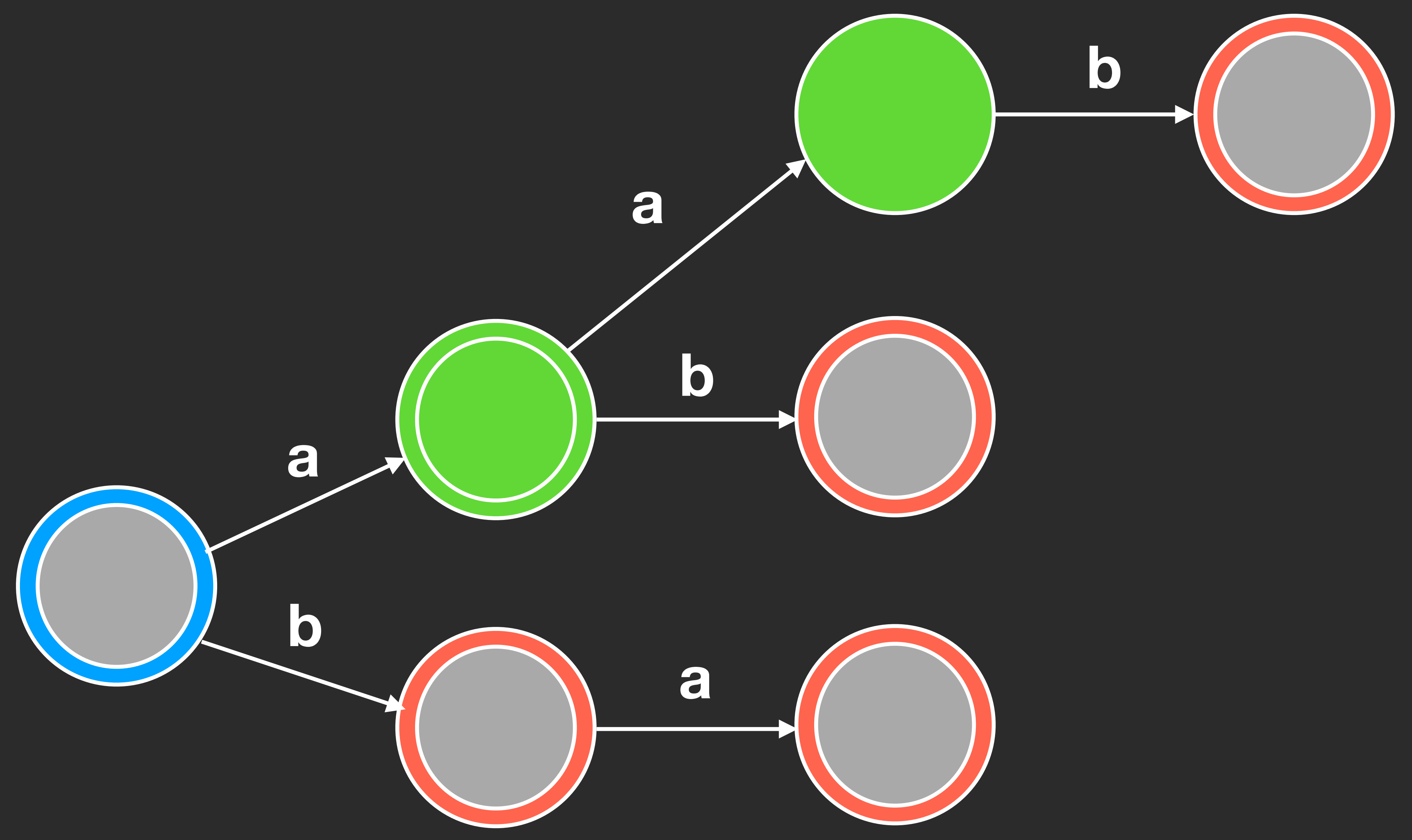
1. Technical details
2. Scalability analysis
3. Learning from demonstrations

State merging via coloring



Positive: {a} **Negative: {Ø, b, ba, ab, aab}**

State merging via coloring



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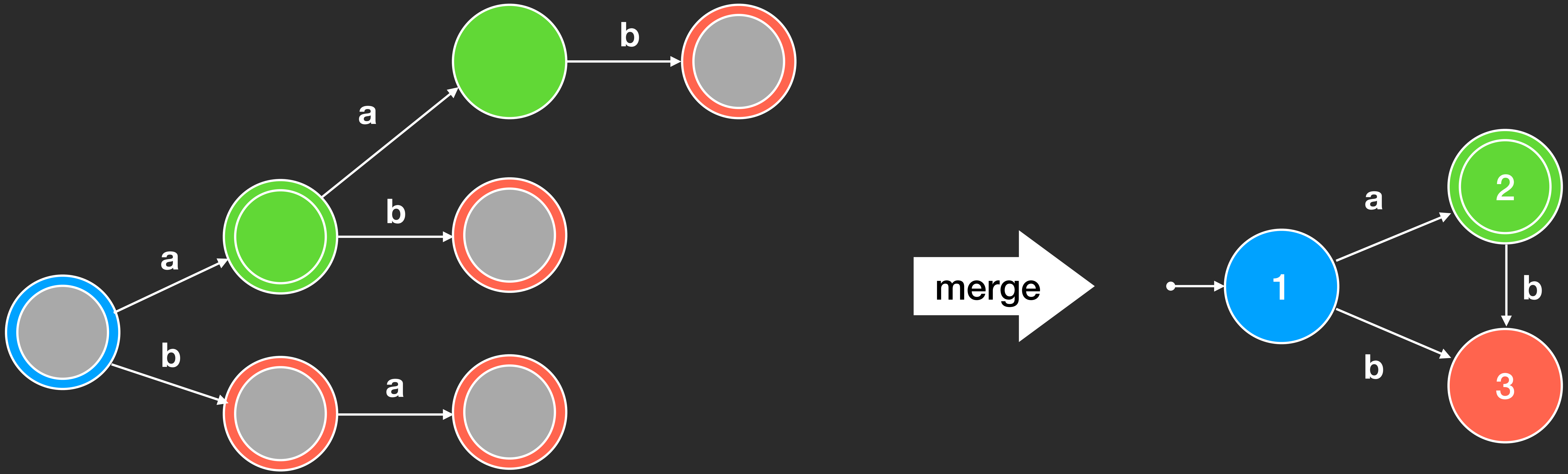

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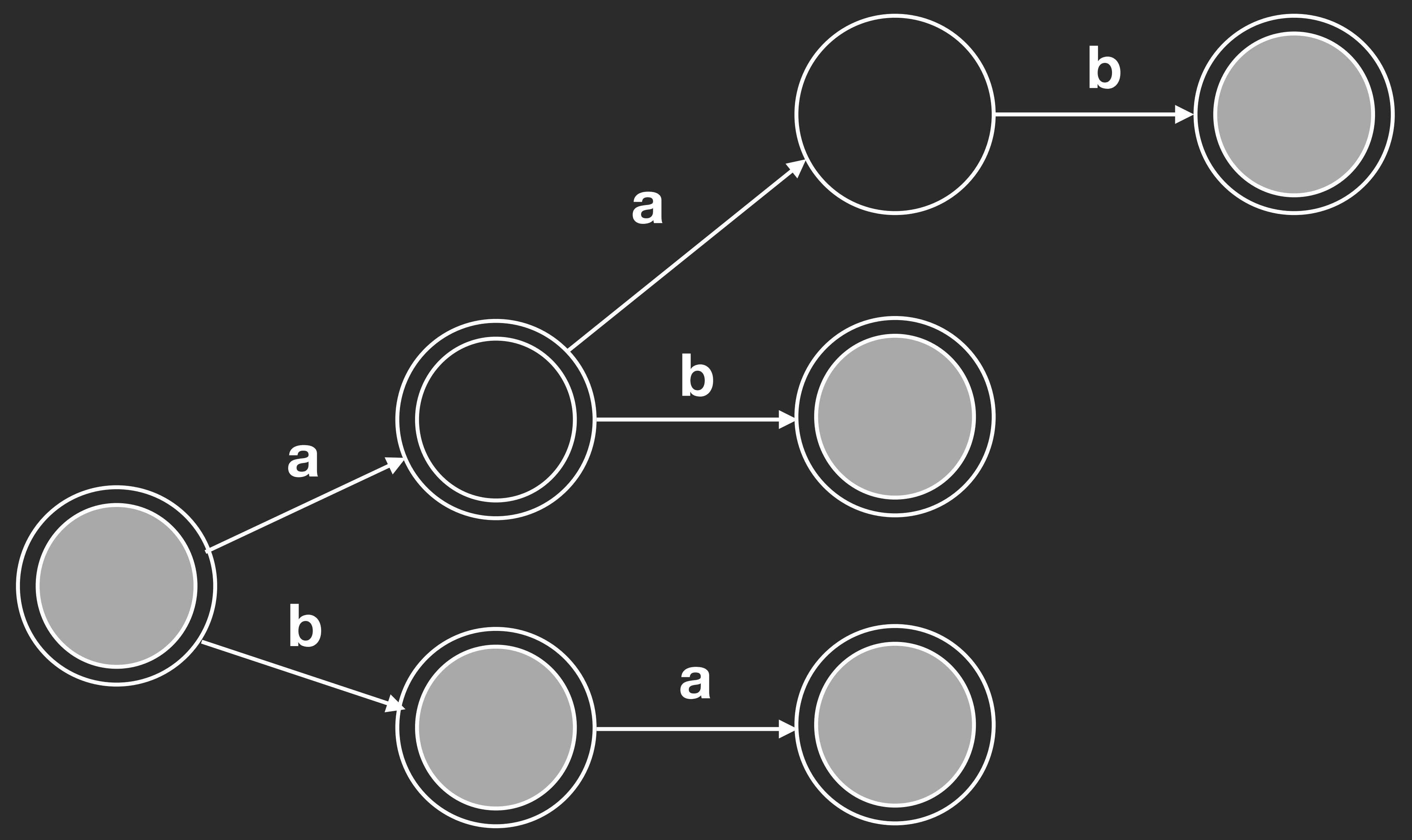
State merging for decompositions



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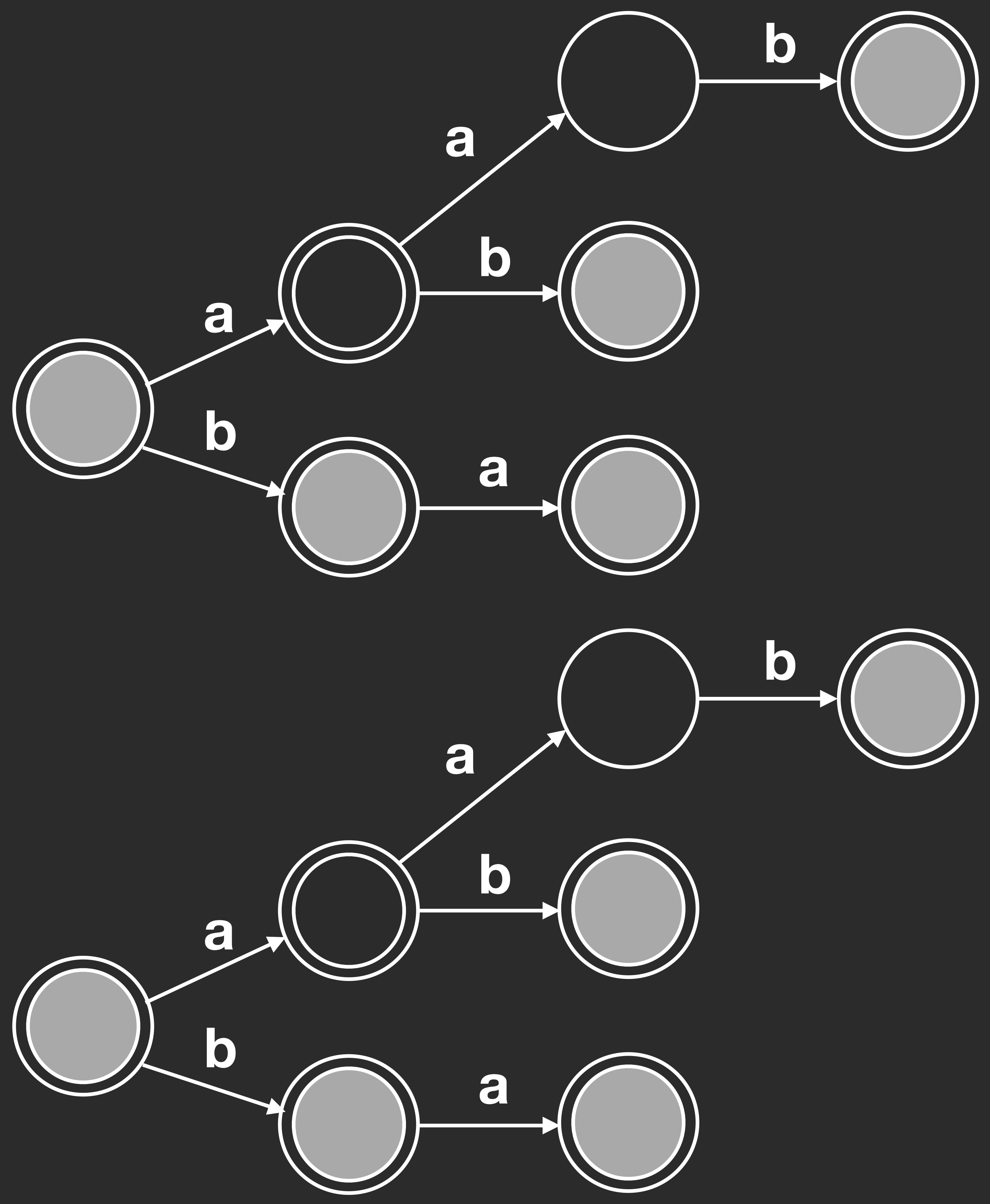

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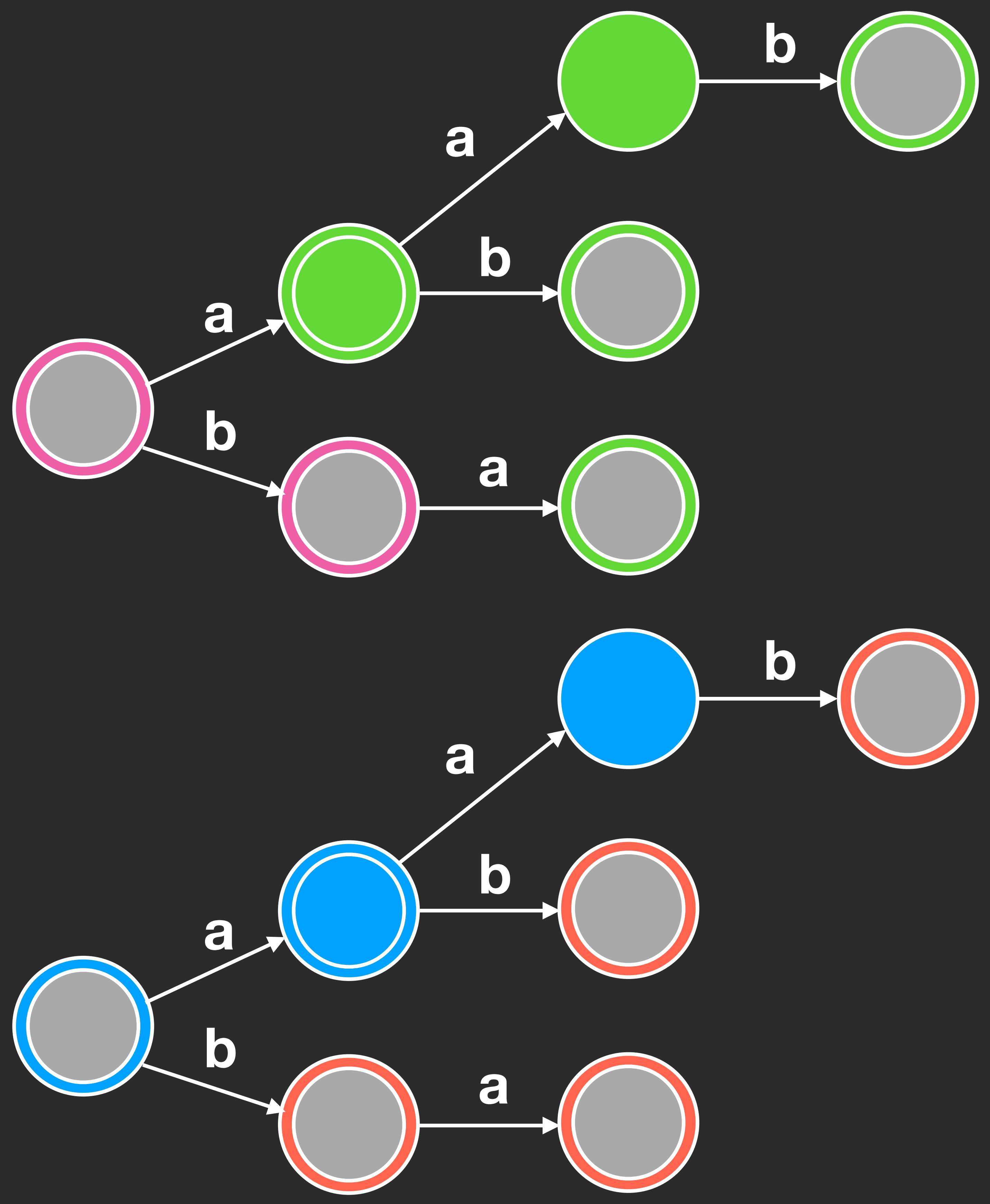

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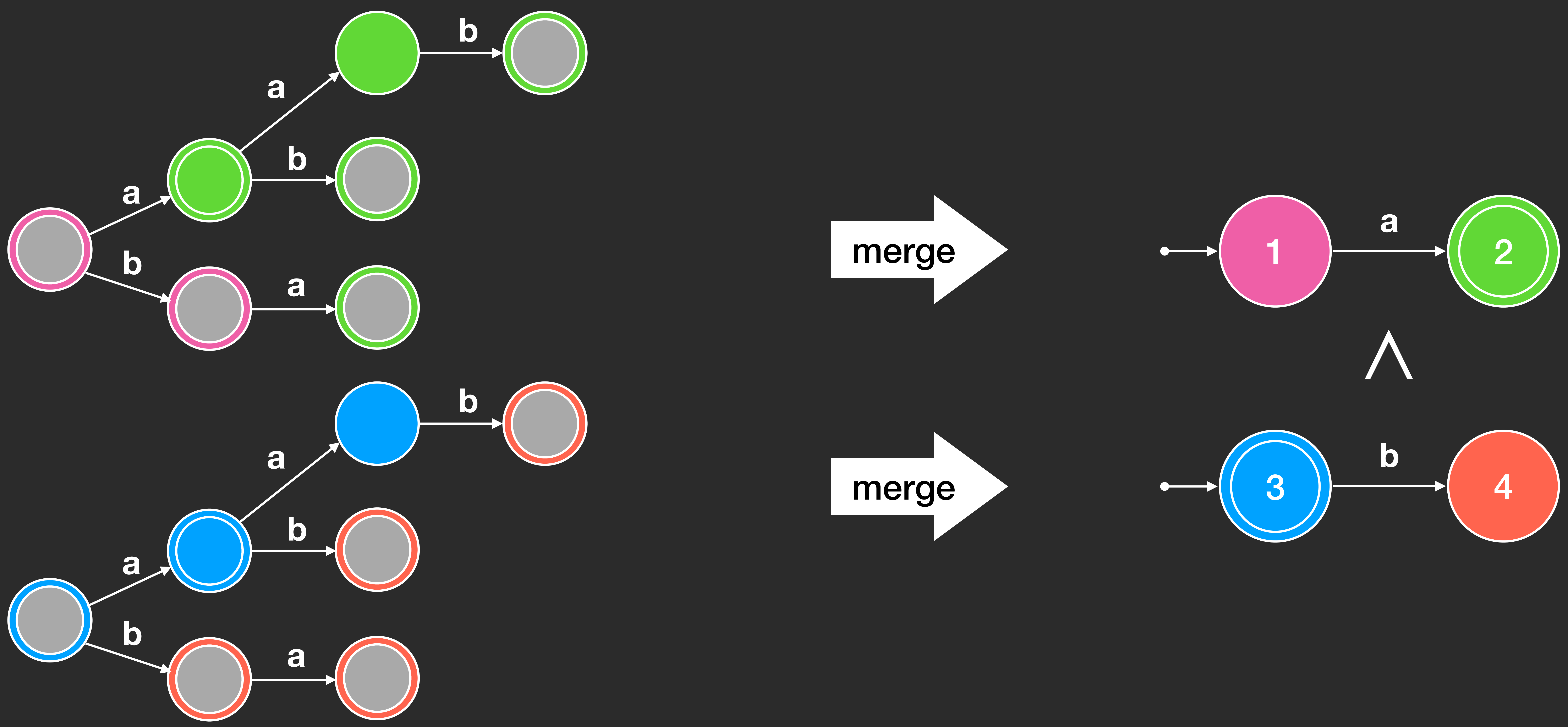

Positive: {a} **Negative: {Ø, b, ba, ab, aab}**

A SAT encoding

Implemented as an extension of existing work*

*Ulyantsev, Vladimir & Zakirzyanov, Ilya & Shalyto, Anatoly. (2015). BFS-based Symmetry Breaking Predicates for DFA Identification

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Implemented as an extension of existing work*

- Each negative example must be rejected by *at least* one DFA:

$$\bigwedge_{v \in V_-} \bigvee_{k \in [n]} \bigwedge_{i \in [m_k]} x^k_{v,i} \implies \neg z^k_i .$$

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- Accepting and rejecting states of *individual* prefix trees cannot be merged:

$$\bigwedge_{v_- \in V_-} \bigwedge_{v_+ \in V_+} \bigwedge_{k \in [n]} \bigwedge_{i \in [m_k]} (x^k_{v_-,i} \wedge \neg z^k_i) \implies \neg x^k_{v_+,i}$$

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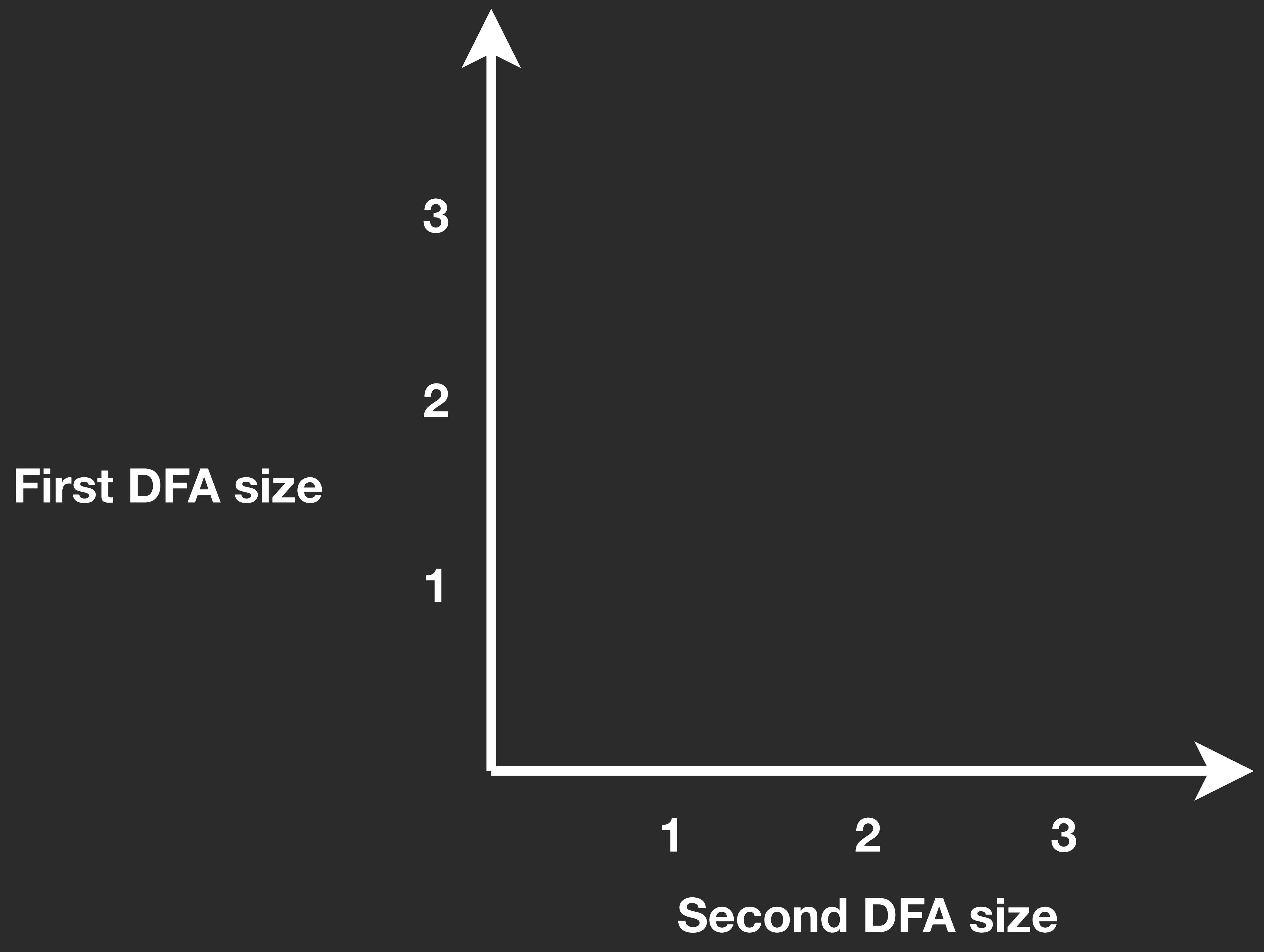
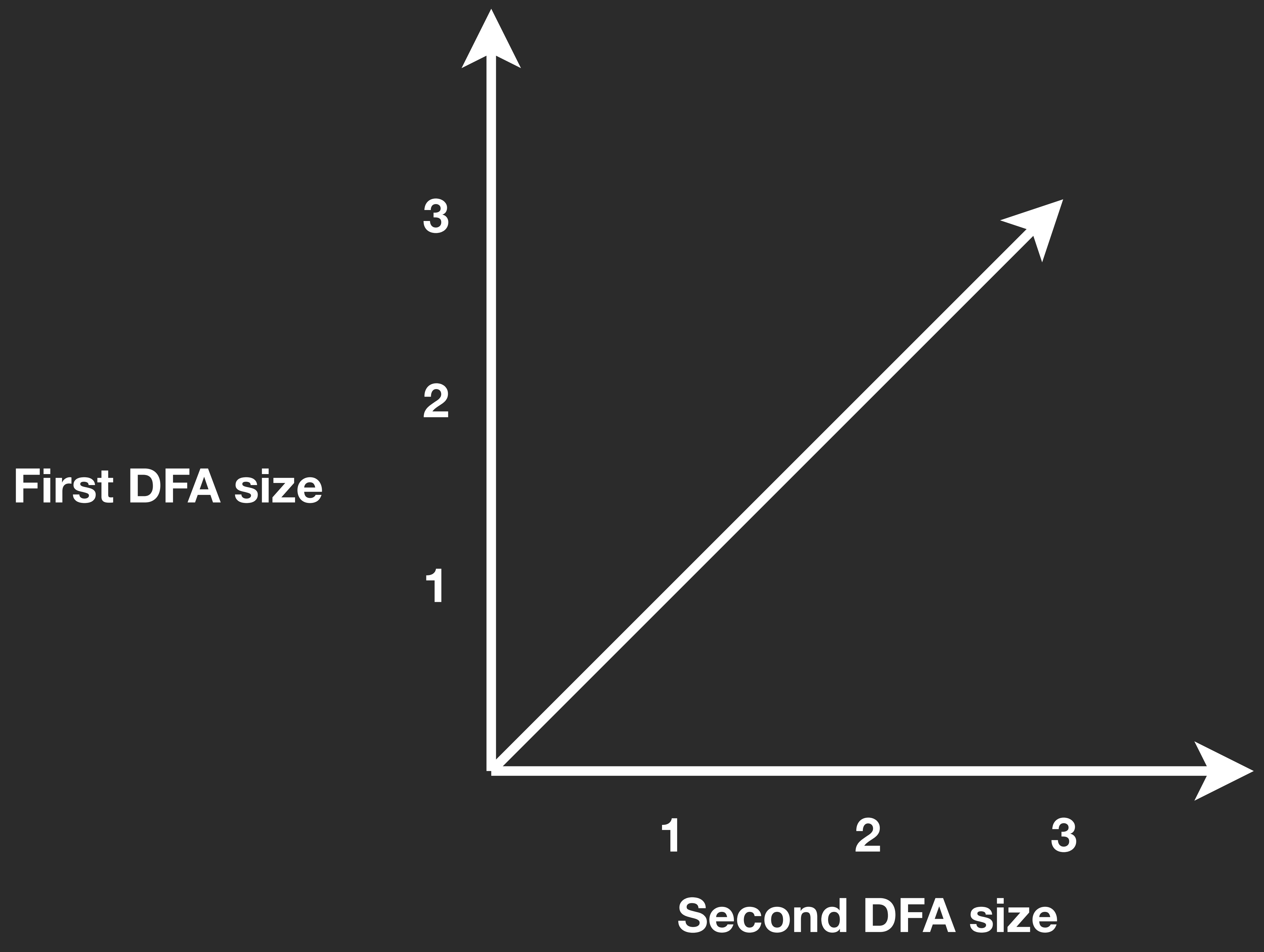
Finding the Pareto front of minimality



Finding the Pareto front of minimality



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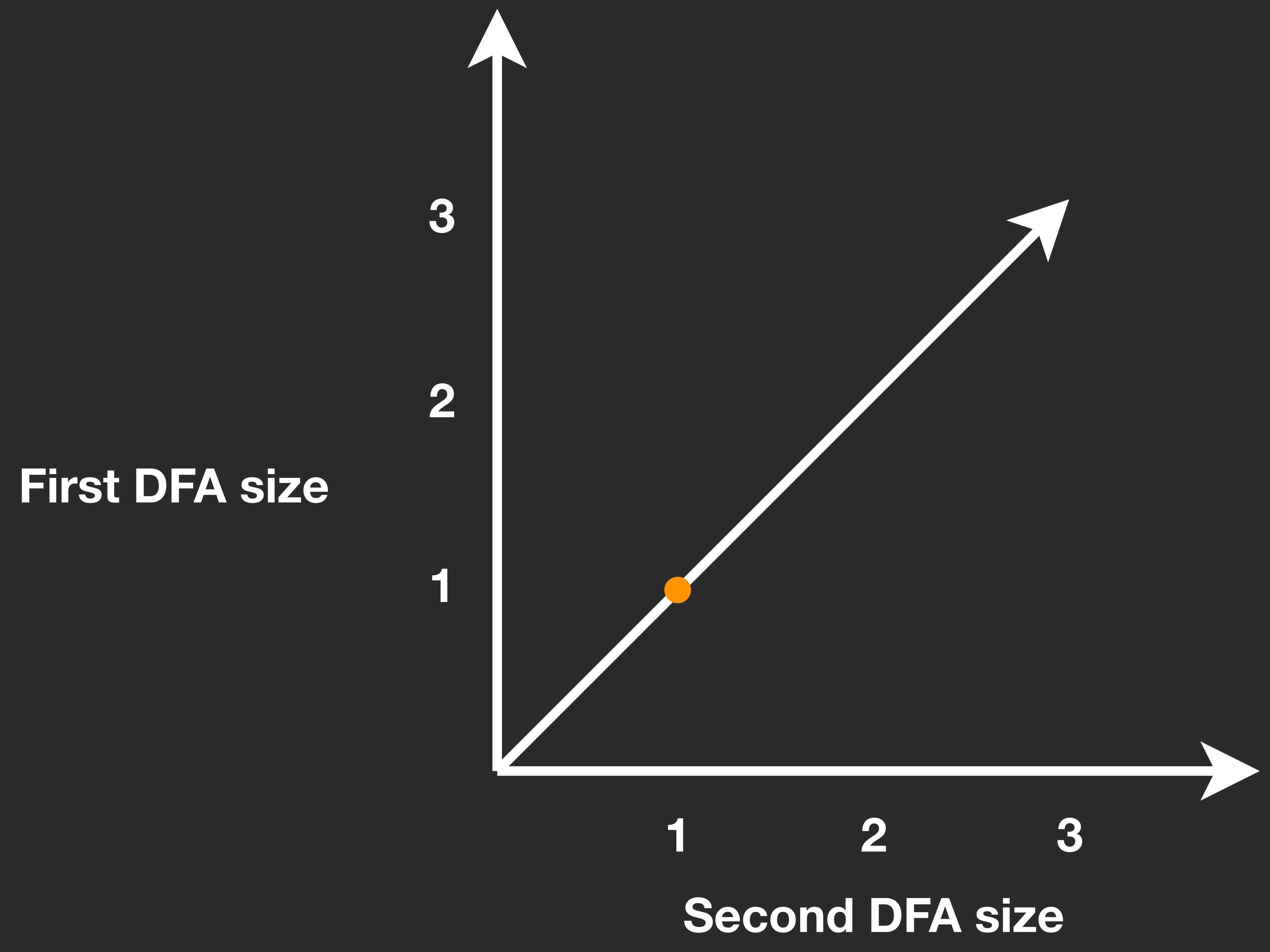

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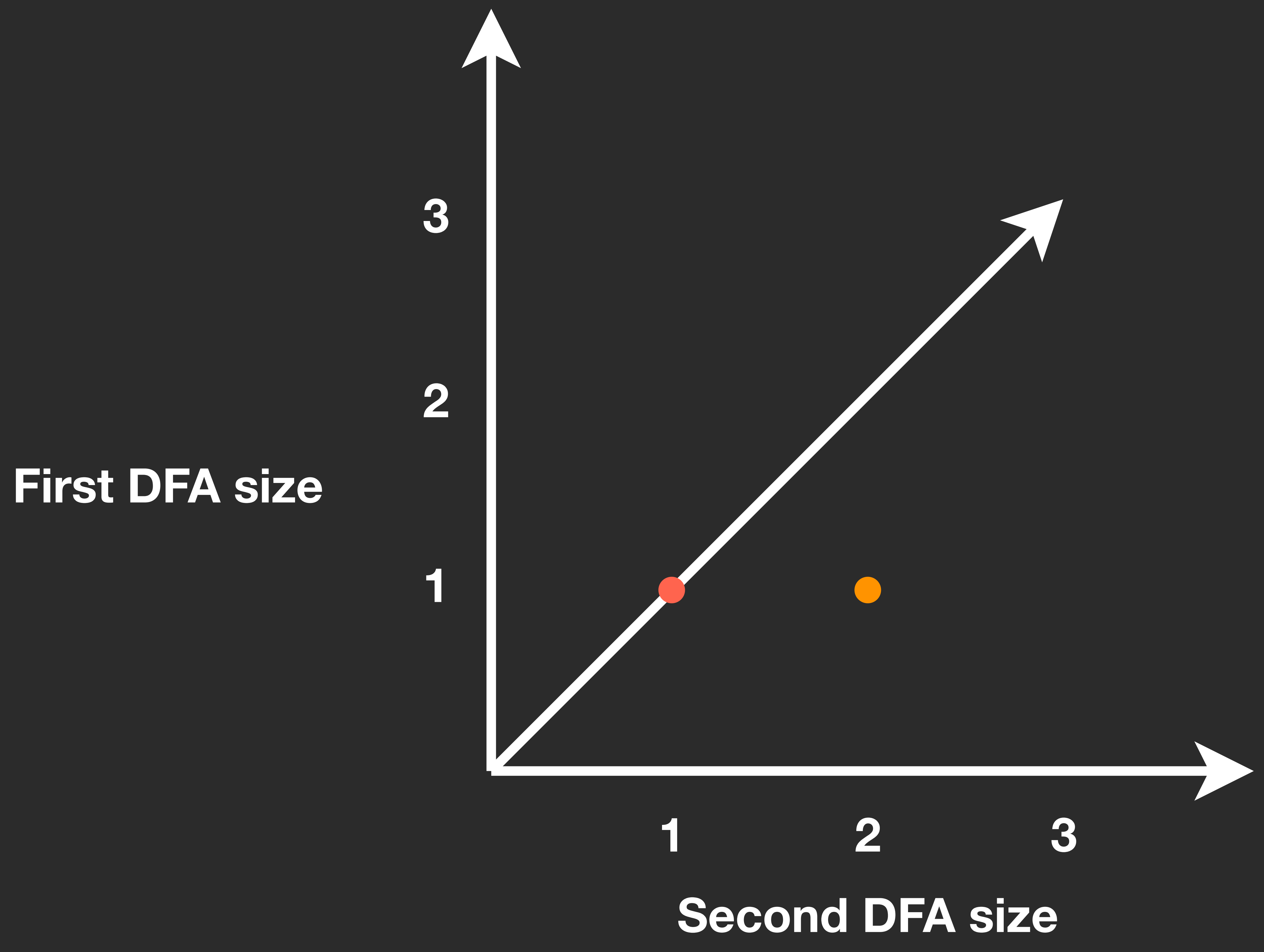

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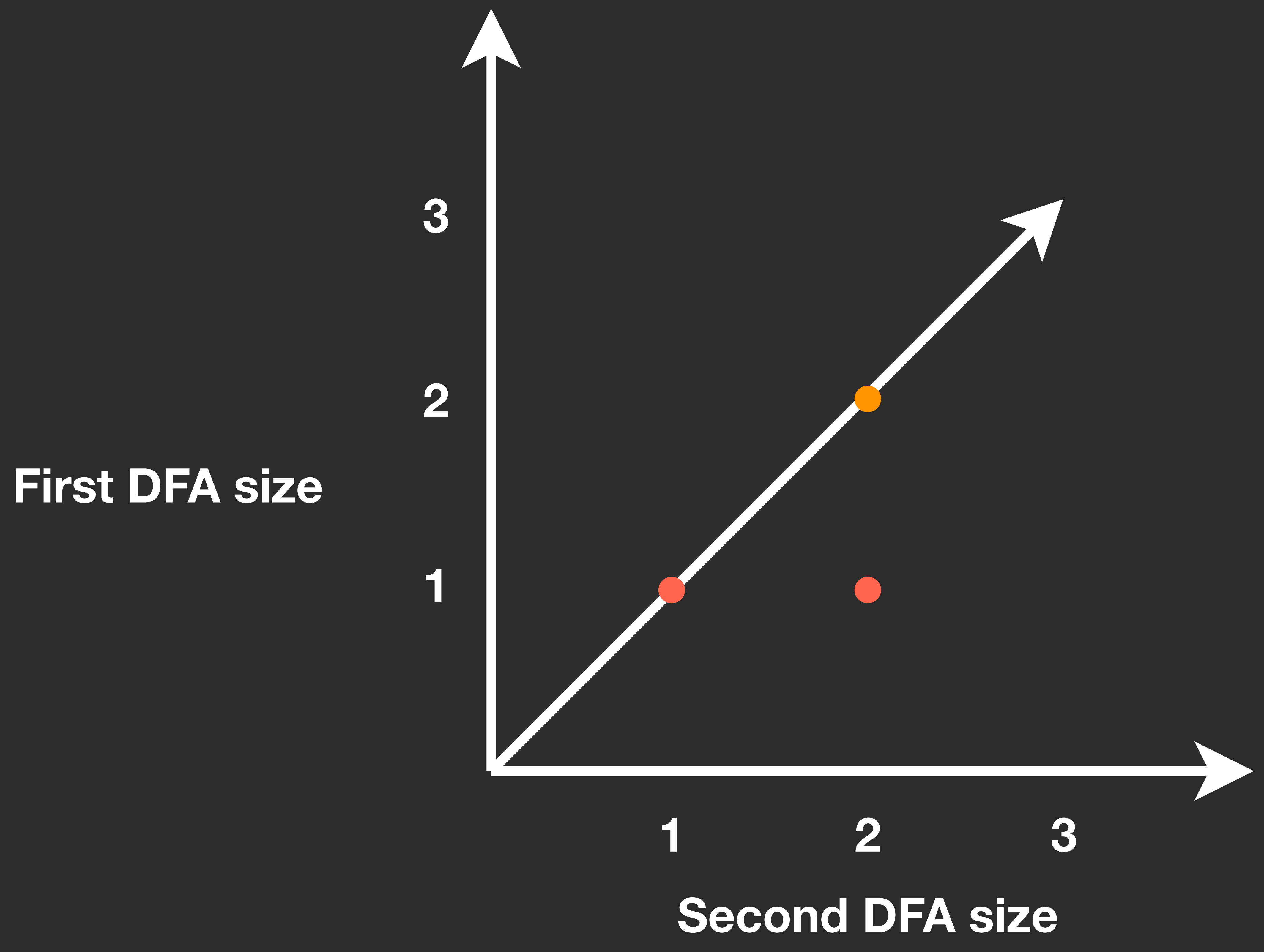

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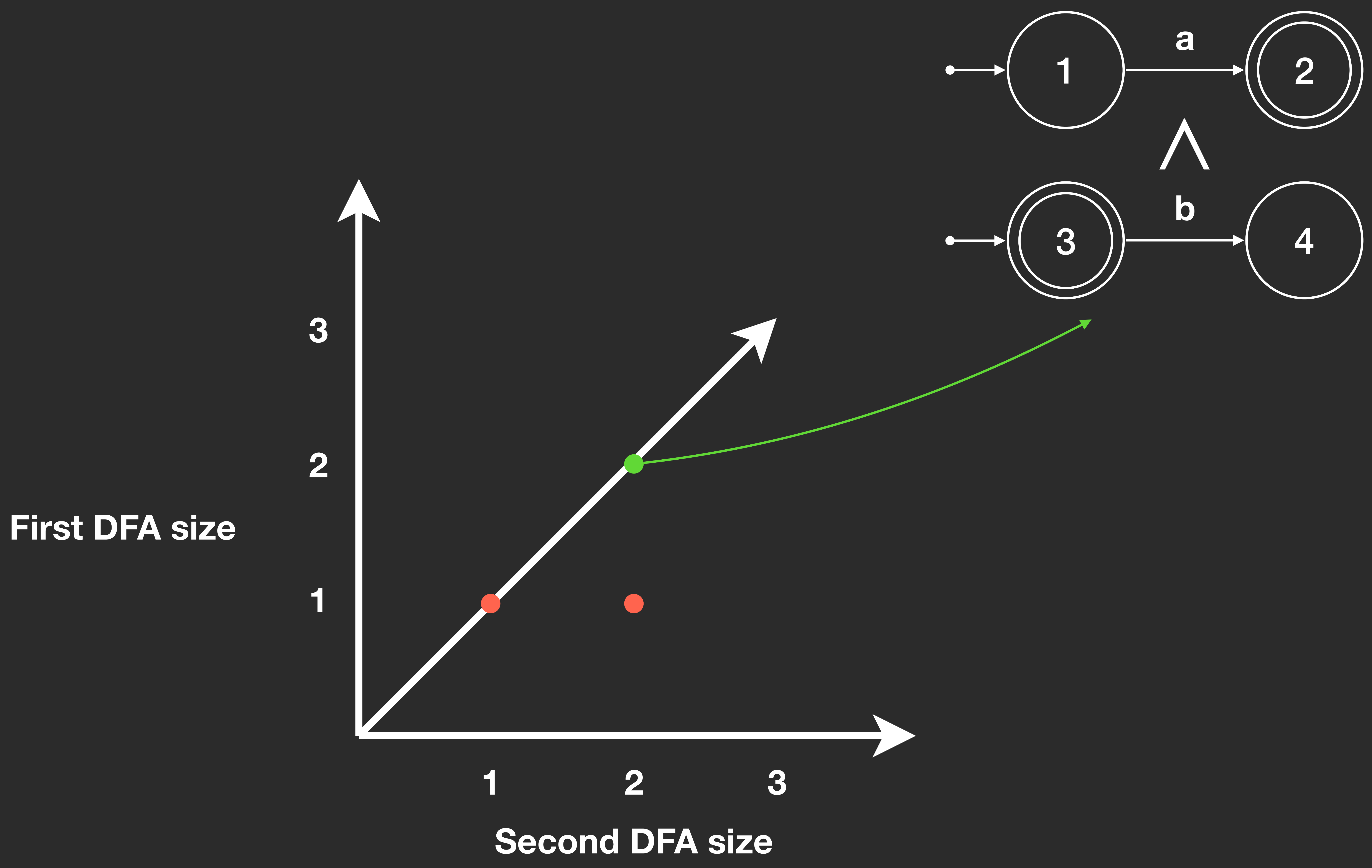

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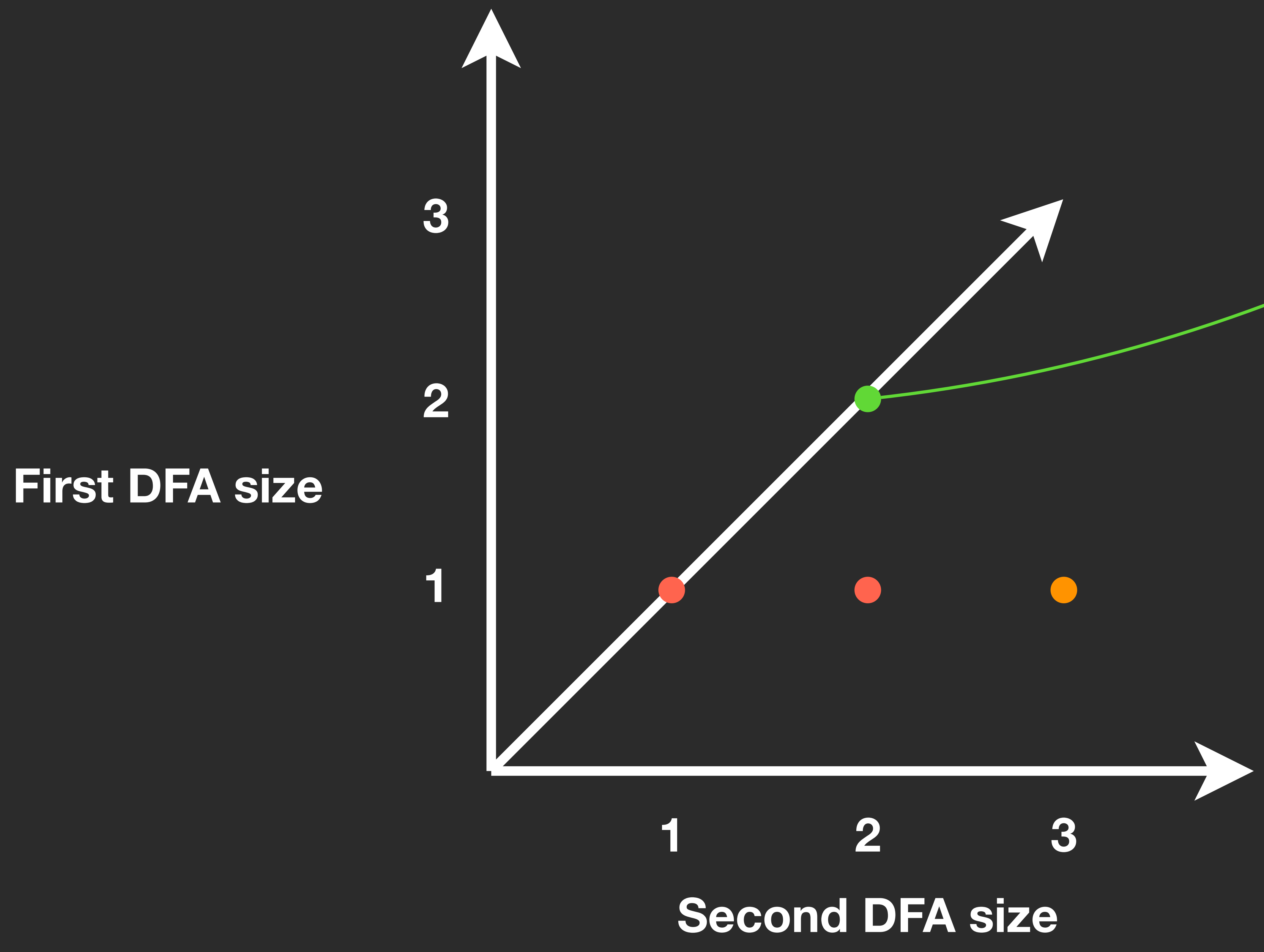

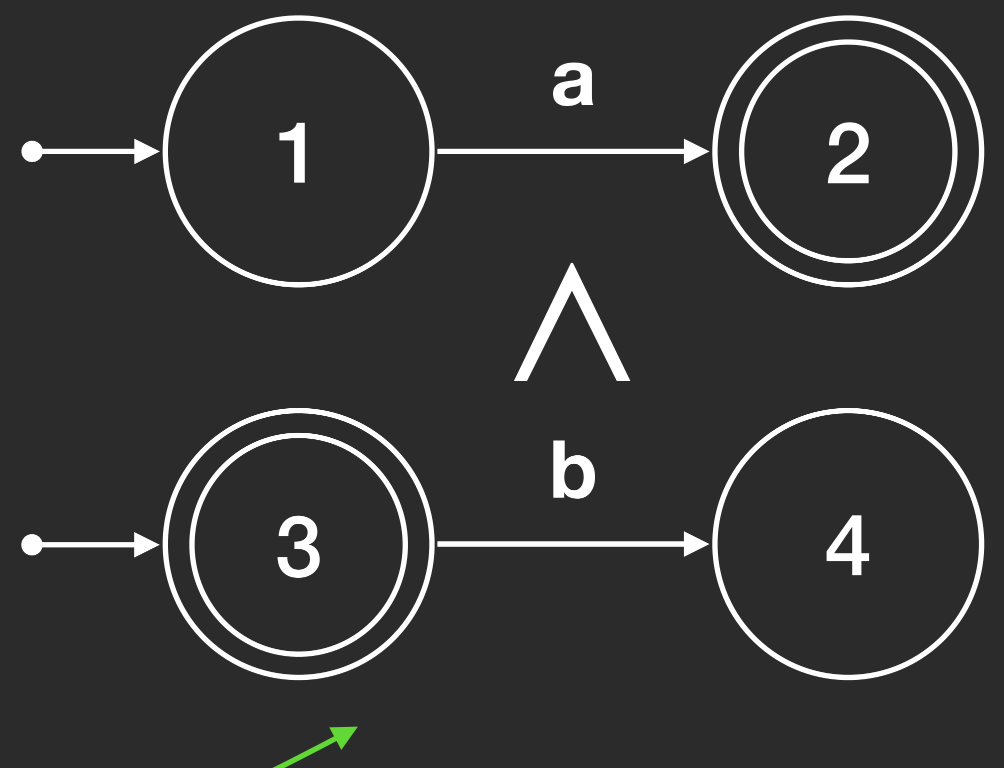

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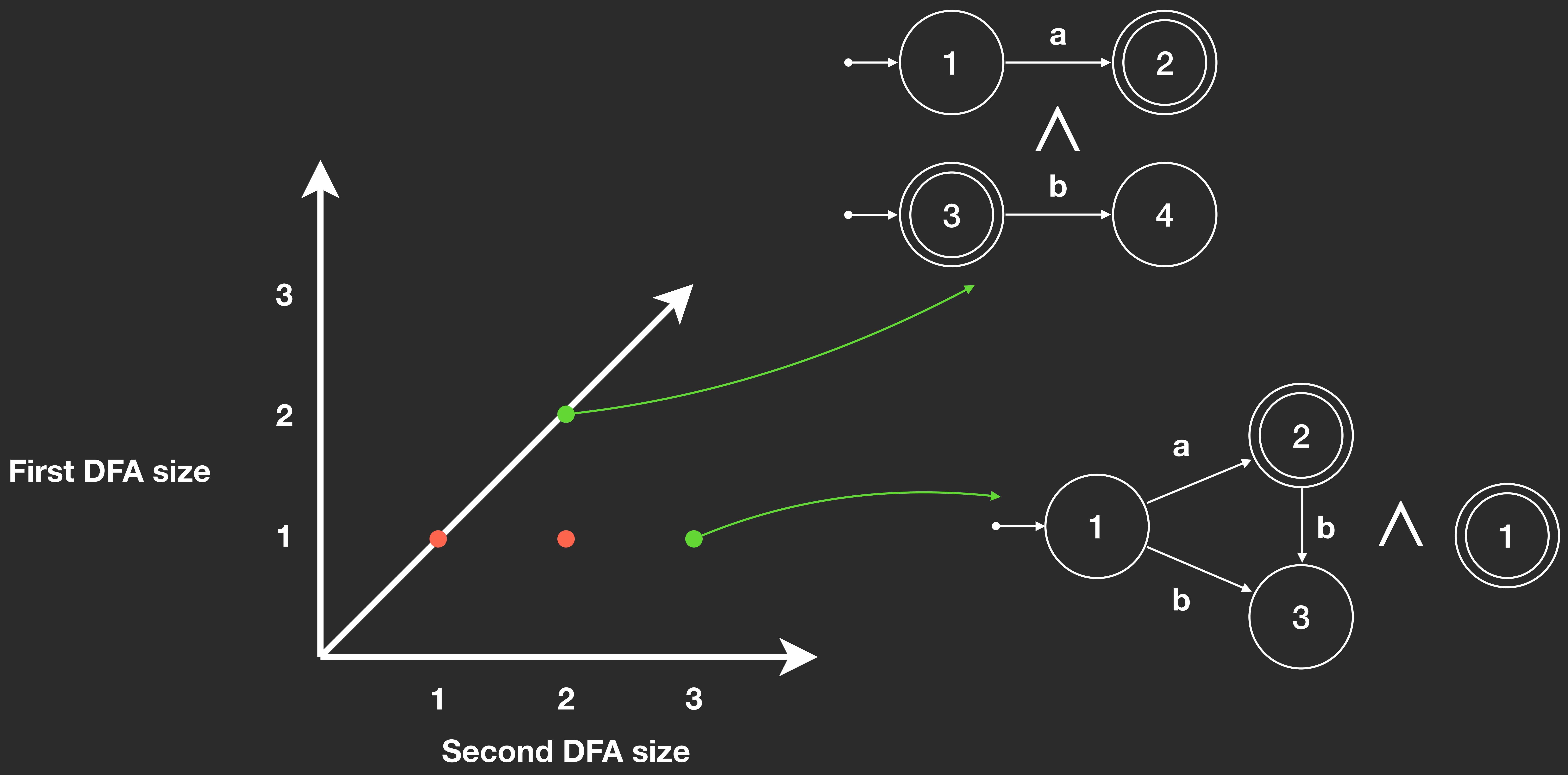

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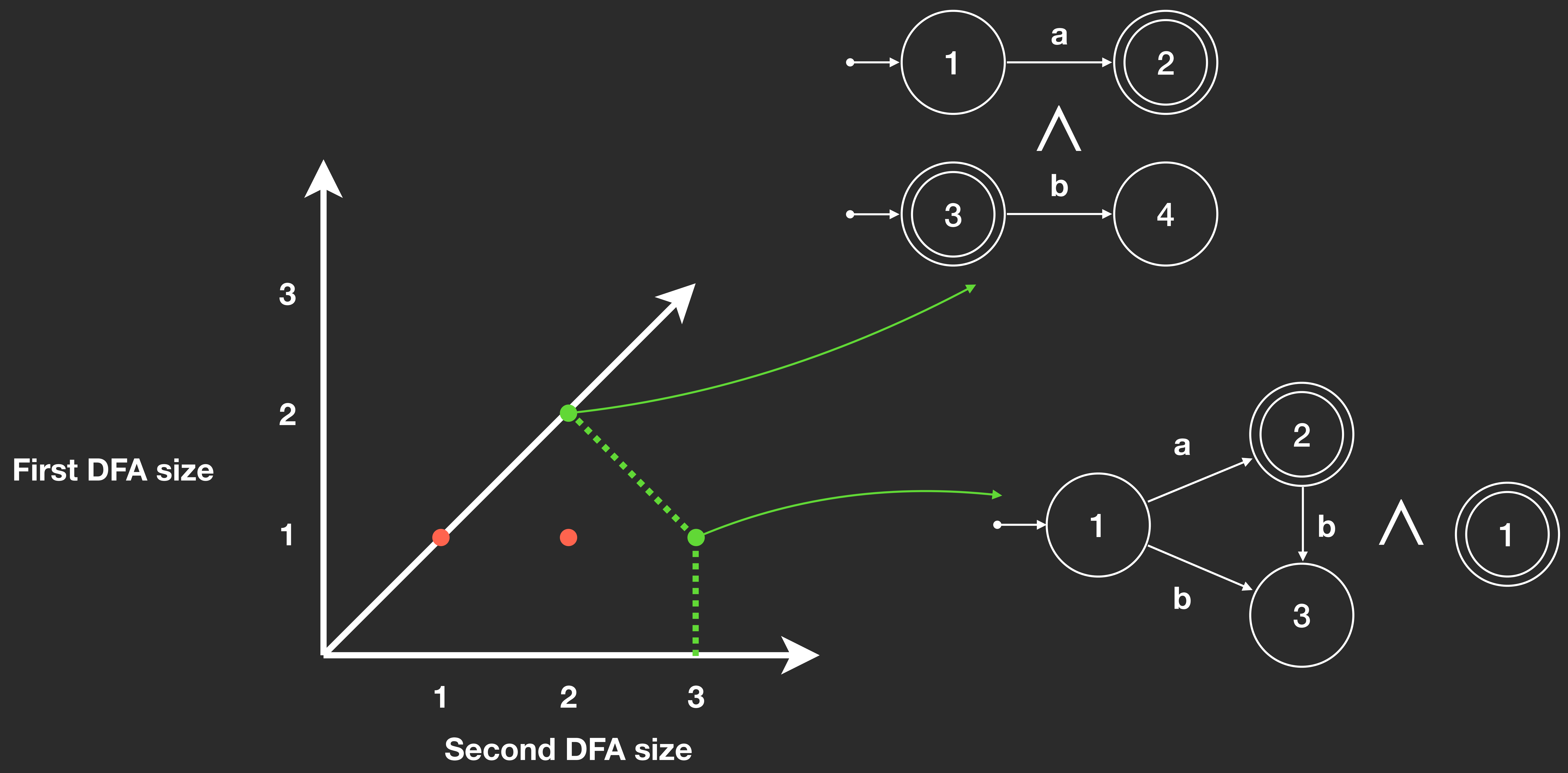


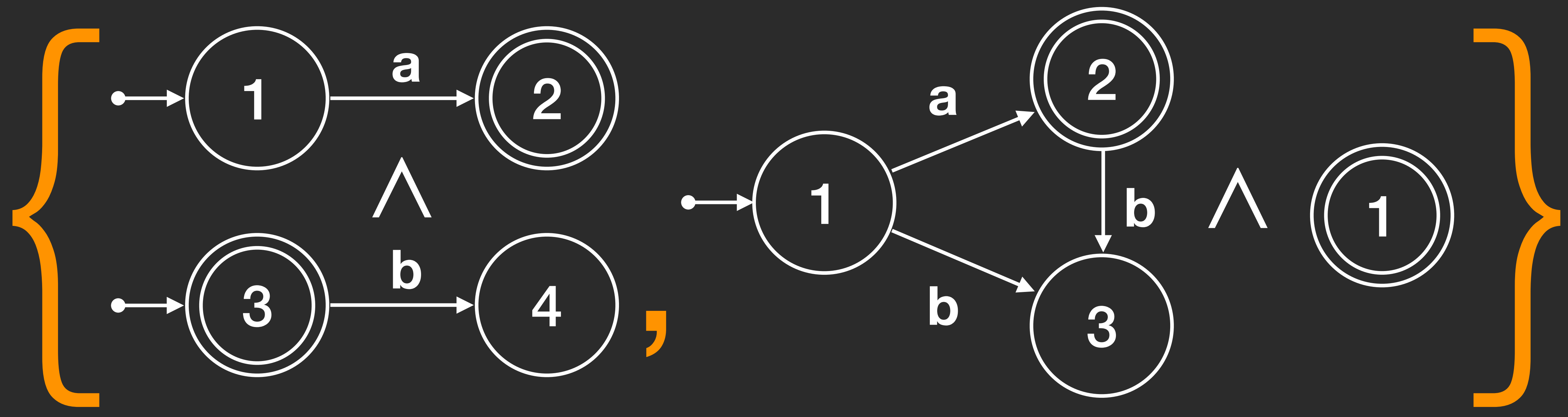
Structure of the talk

1. Technical details

Examples

Positive	**Negative**
a	∅
	b
	ba
	ab
	aab

Our algorithm



Pareto front of DFA decompositions

2. Scalability analysis

3. Learning from demonstrations

Structure of the talk

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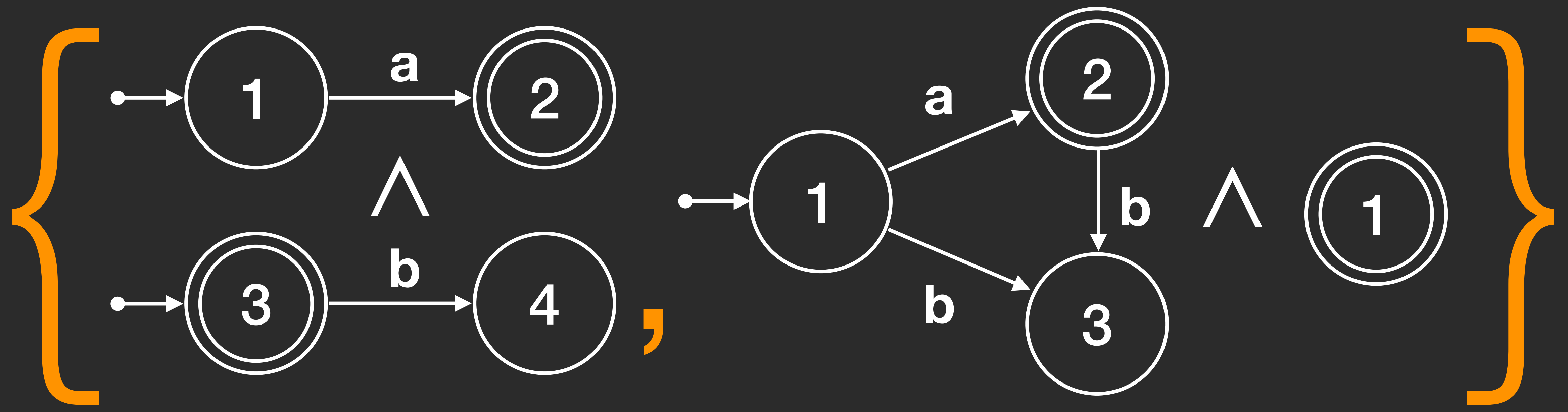

Pareto front of DFA decompositions

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Structure of the talk

1. Technical details

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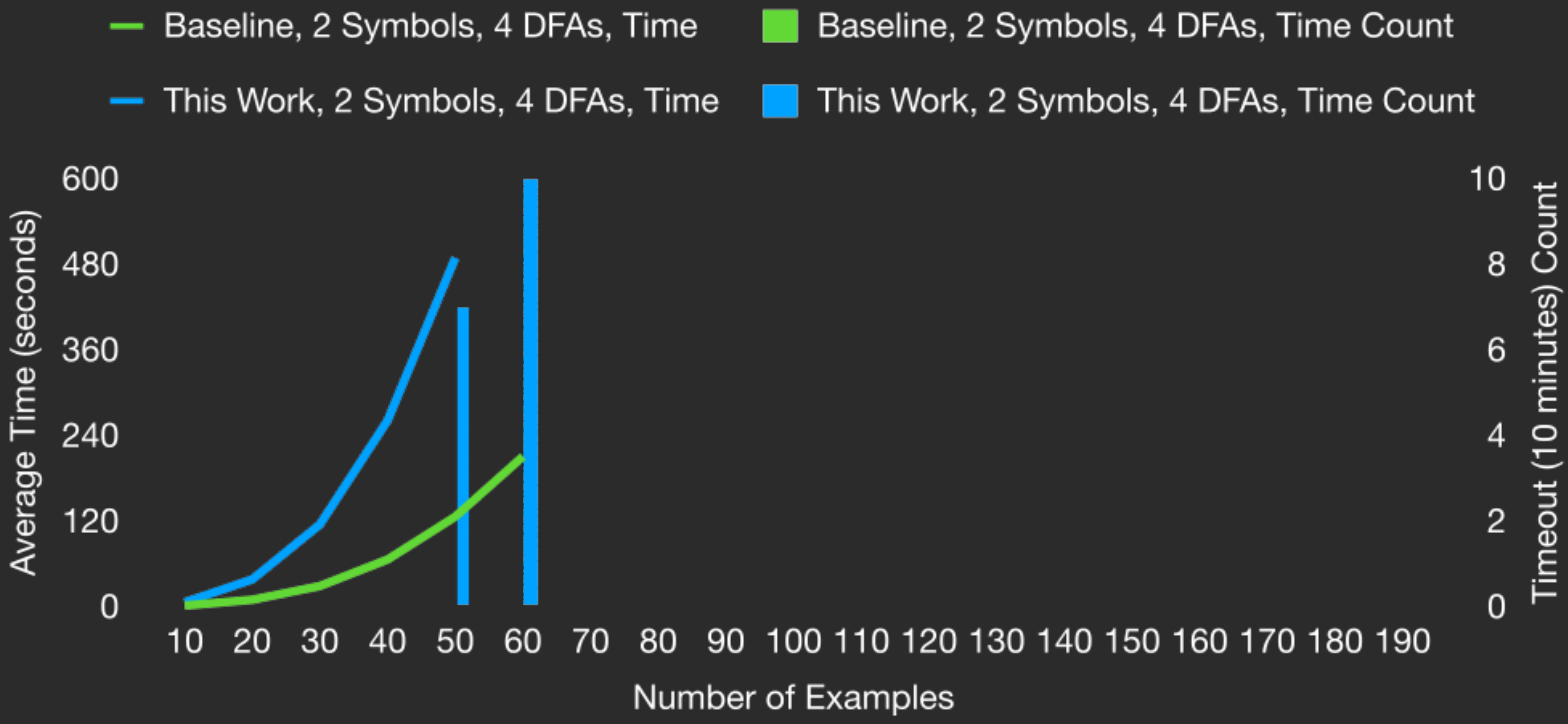
Overhead comparable to the monolithic baseline



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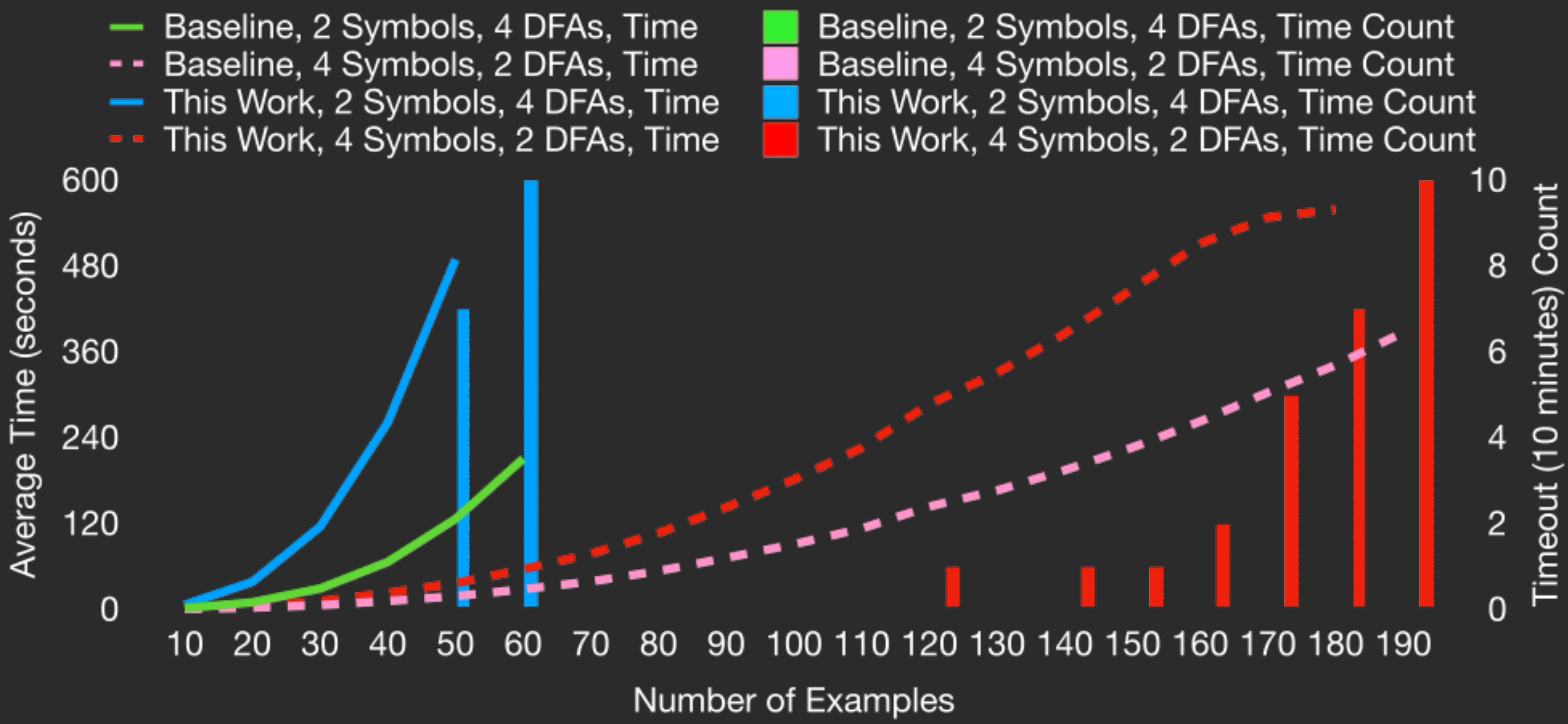

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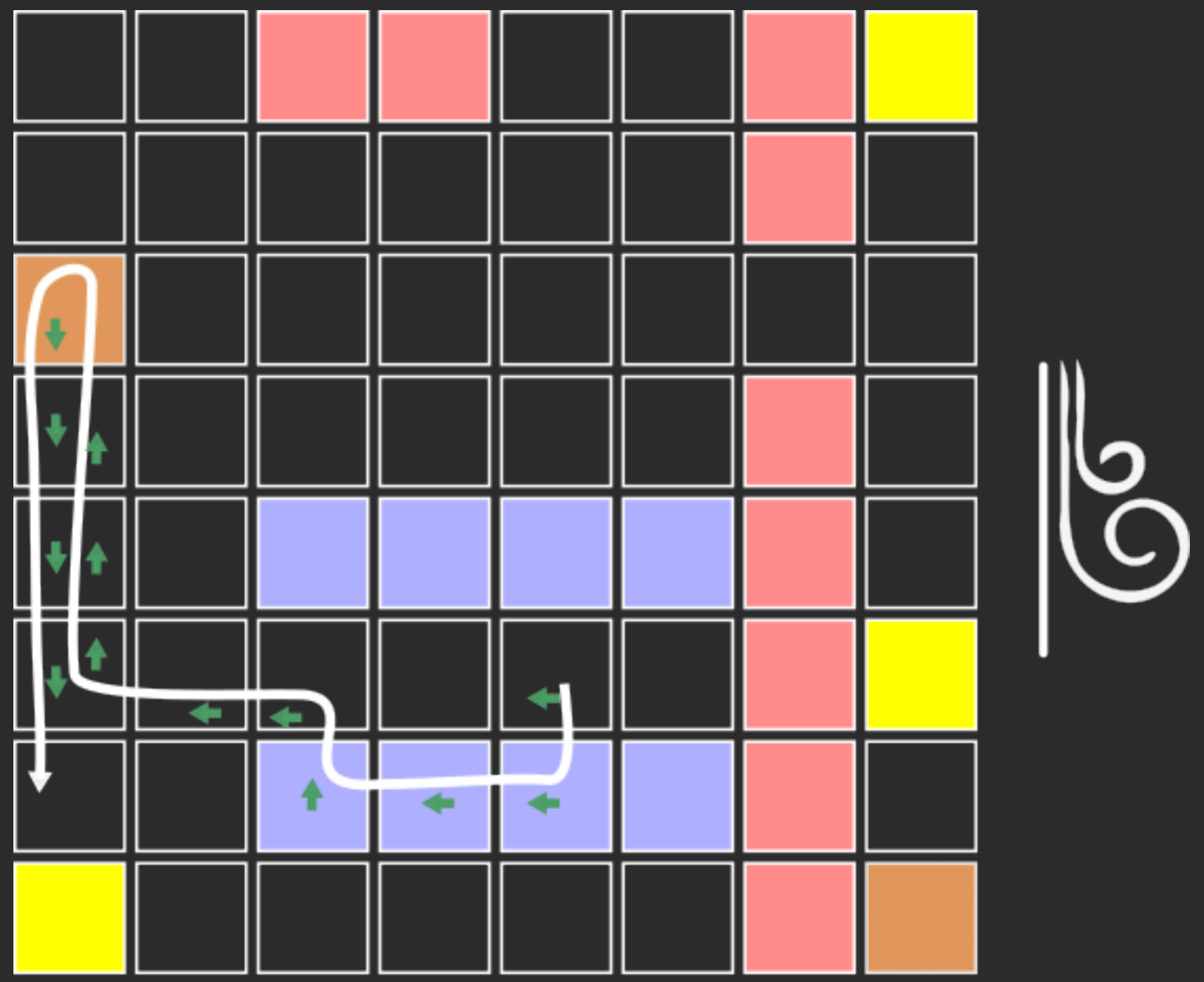

Actions = {↑ ↓ ← →}

Pr(slip ↓) = 1/32

Demonstration Informed Specification Search (DISS)

Learning from Demonstrations

*Vazquez-Chanlatte, Marcell Jose. Specifications from Demonstrations: Learning, Teaching, and Control. Diss. UC Berkeley, 2022.

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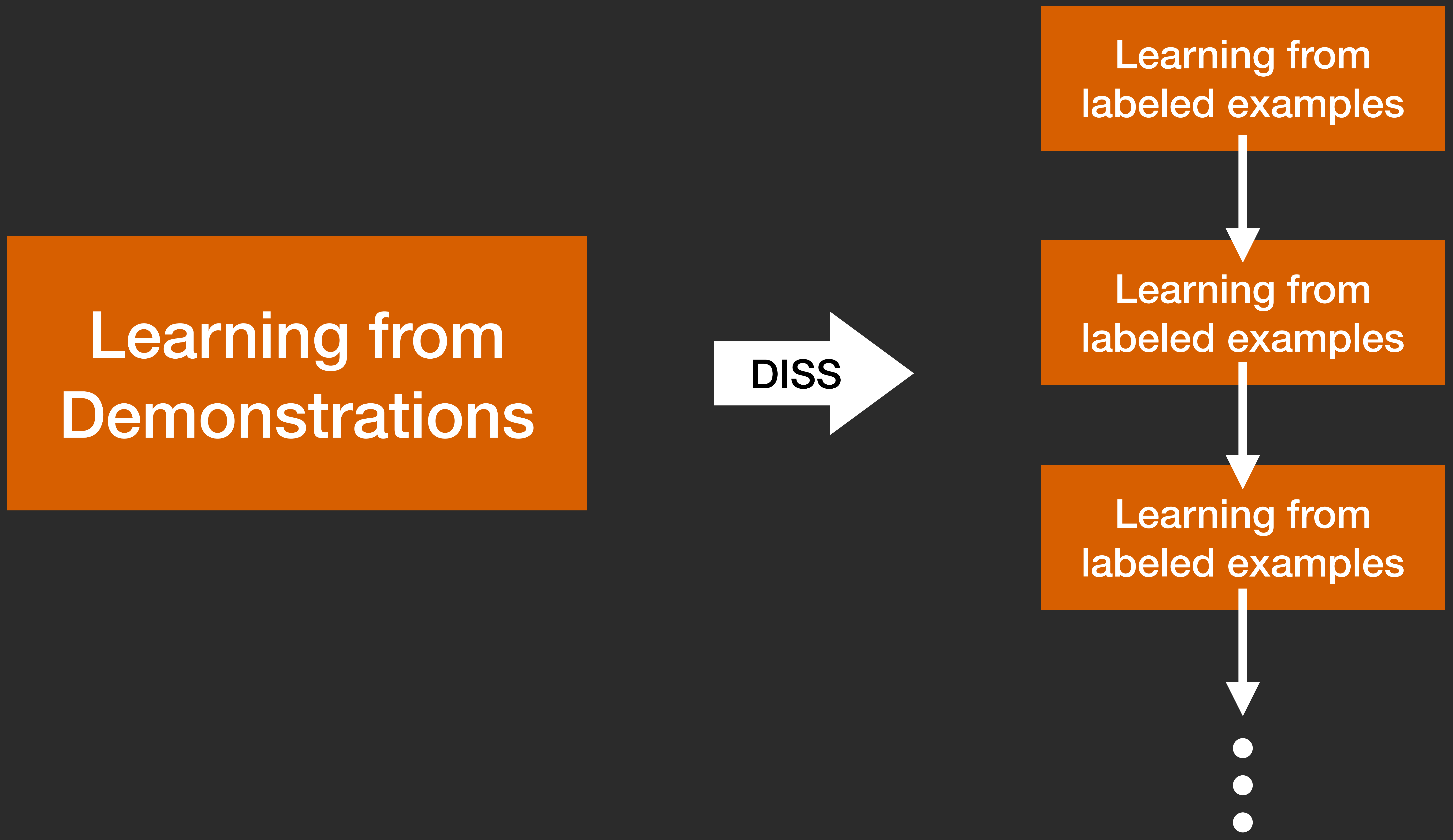

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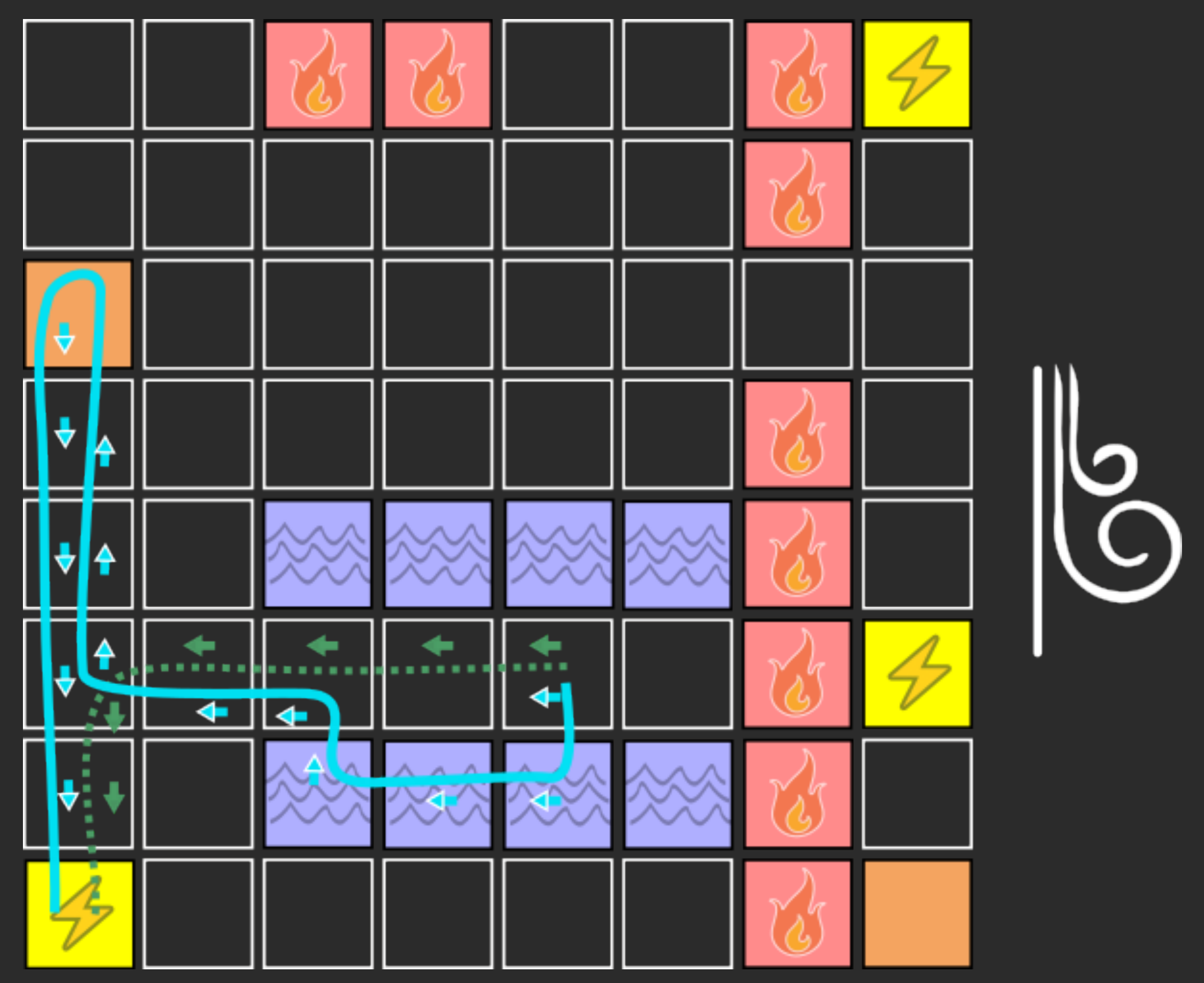
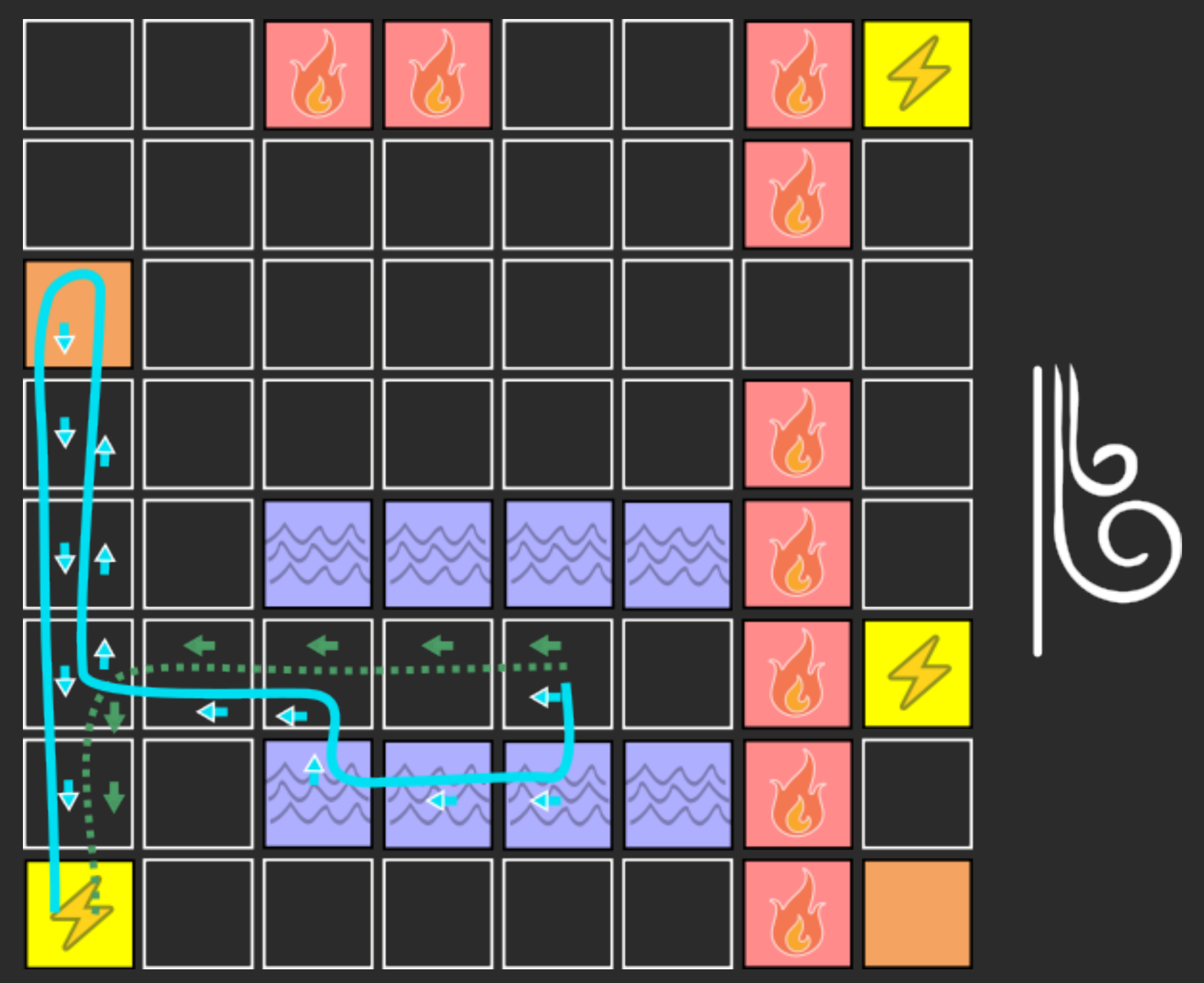
A helpful inductive bias from decompositions

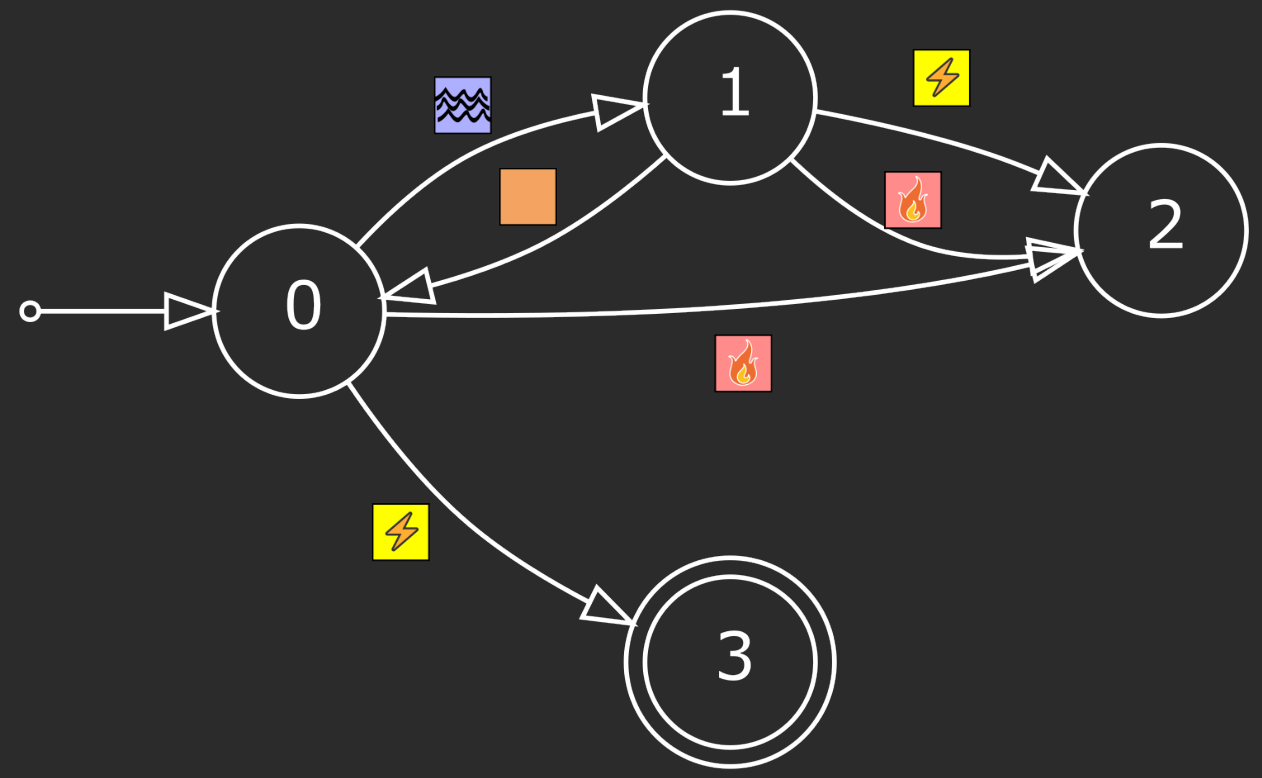


Reach while avoiding . If you ever touch , you must then touch before reaching .

A helpful inductive bias from decompositions

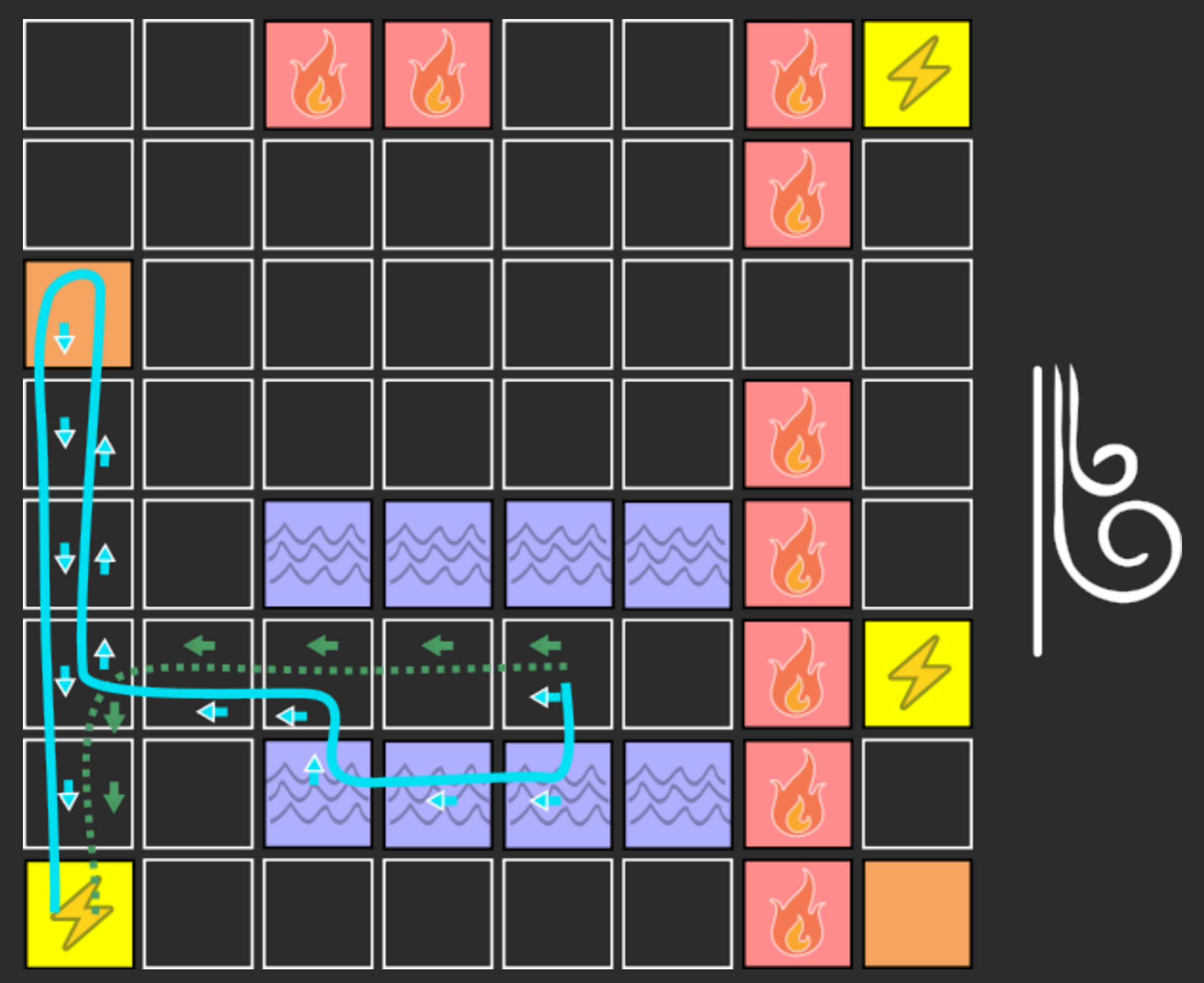


Reach ⚡ while avoiding 🔥. If you ever touch 〰, you must then touch ■ before reaching ⚡.



Identified monolithic DFA
(incorrect)

A helpful inductive bias from decompositions



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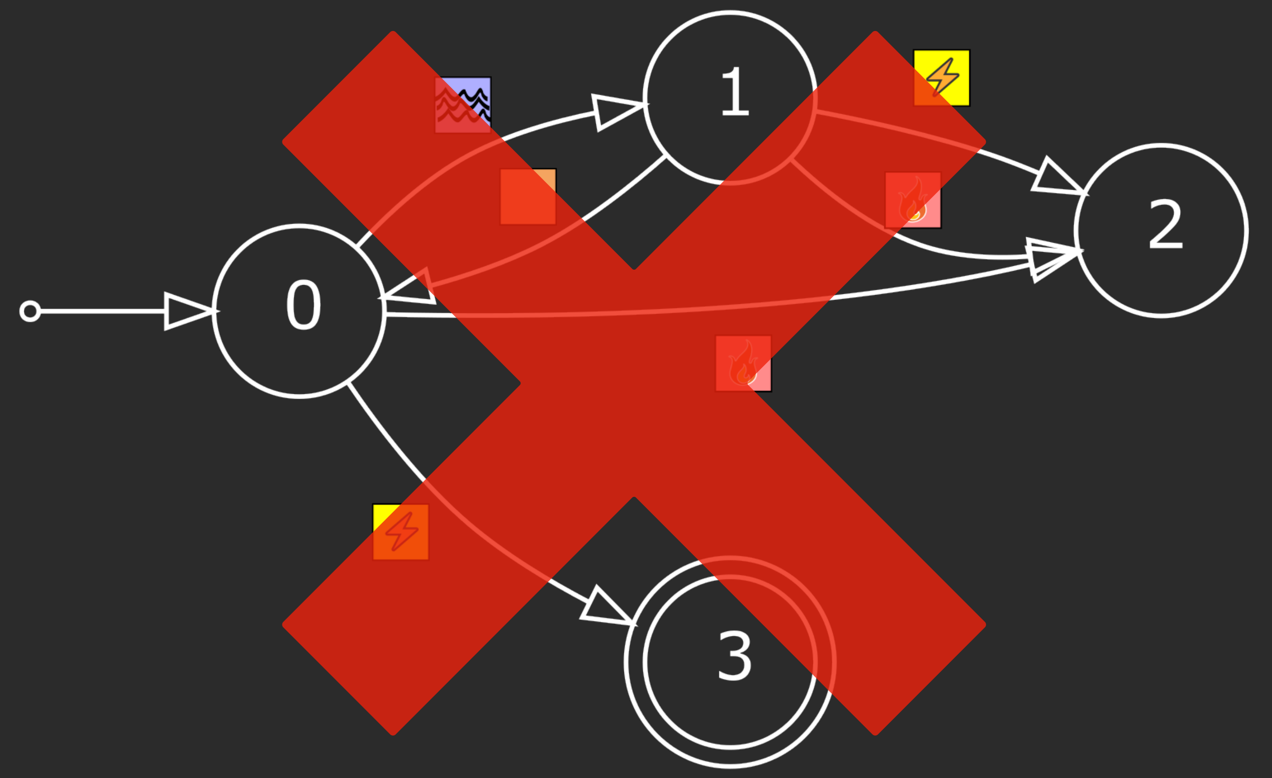

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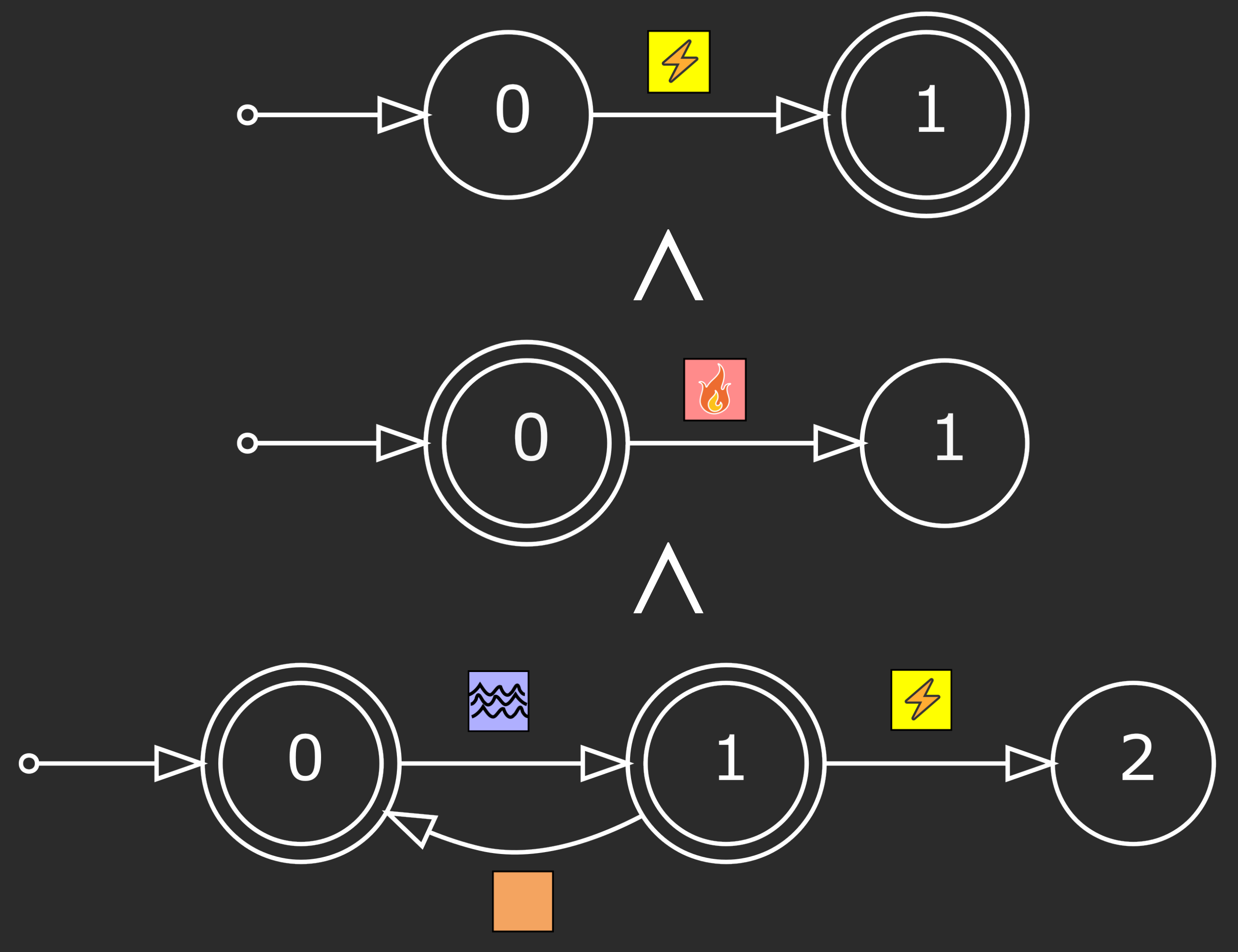
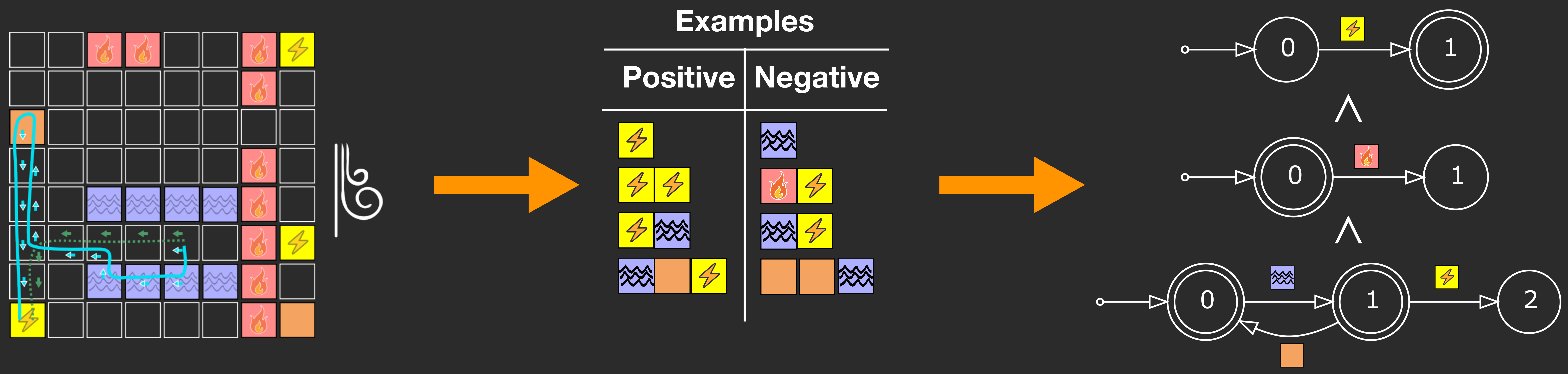


Identified DFA decomposition
(correct)

Conclusion



- Known symmetry-breaking optimization still missing from the encoding
- Easy to extend to disjunctions and boolean combinations of DFAs