

Divide-and-Conquer Determinization of Büchi automata

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Büchi determinization

Büchi automata are **not closed** under determinization

**Nondeterministic
Büchi automata (NBA)**



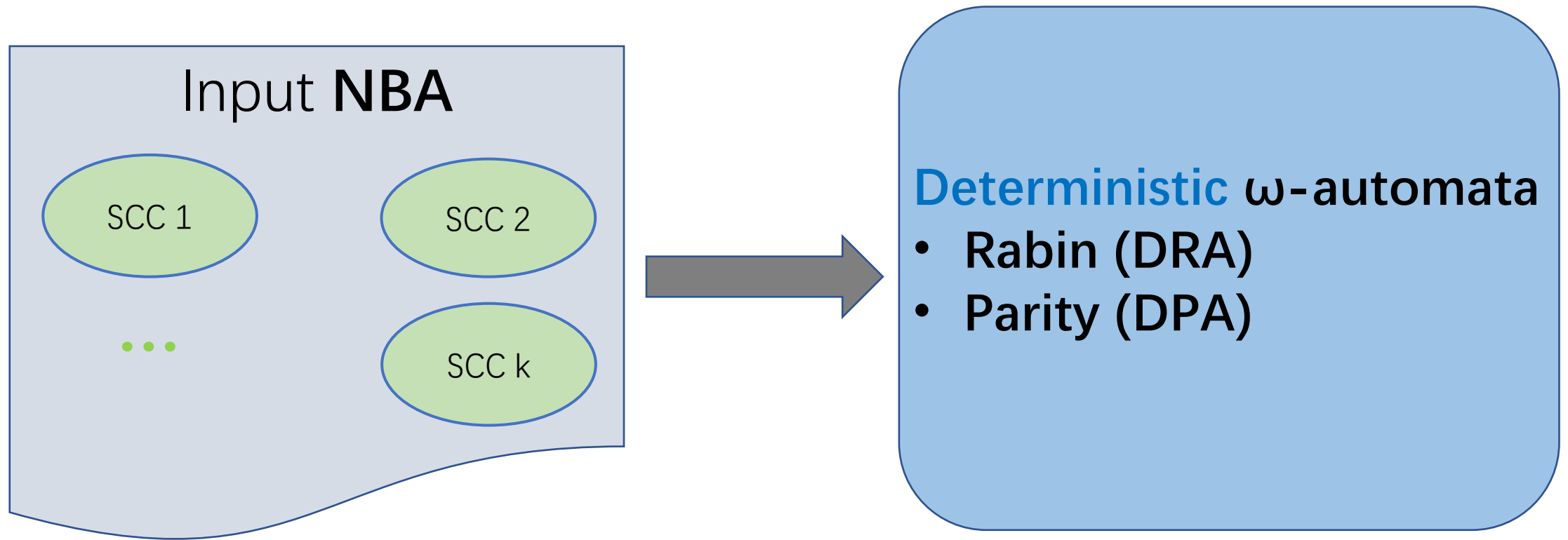
Deterministic ω -automata

- Rabin (DRA)
- Parity (DPA)
- **Emerson-Lei (DELA)**

Why Büchi determinization is important

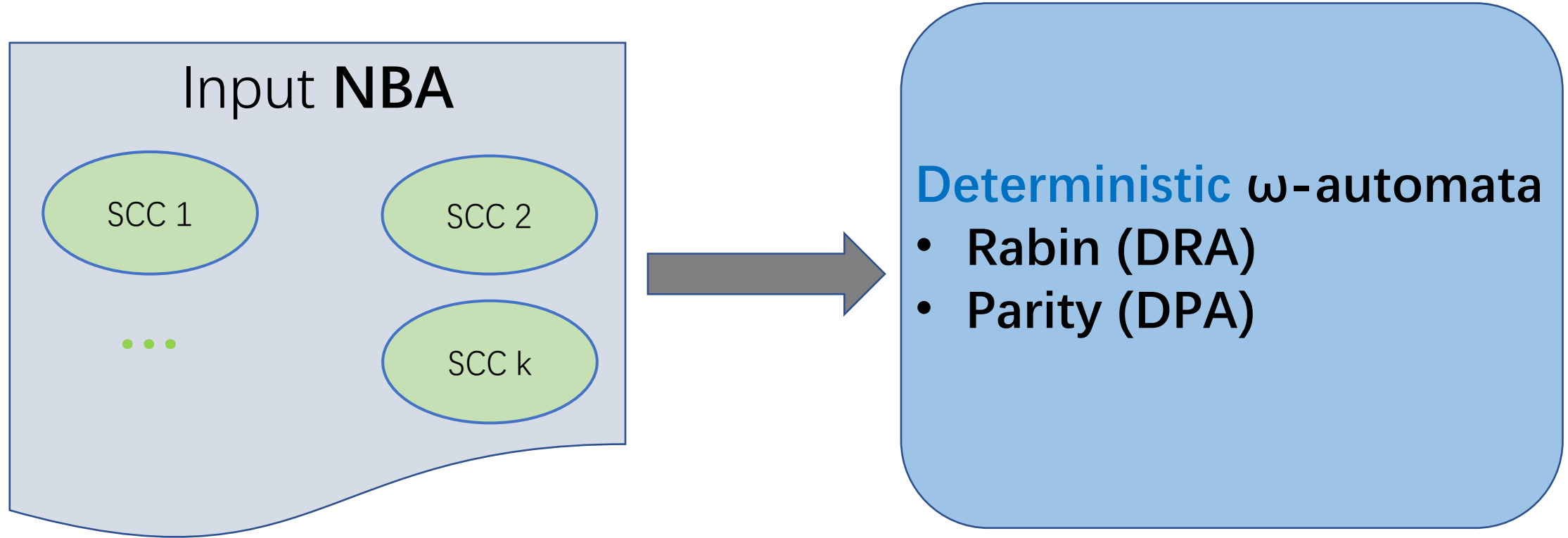
- **Reactive synthesis**
- **Probabilistic verification**
- **Complementing NBA**
- **Checking language inclusion of NBAs**

Existing constructions



Safra-Piterman's construction

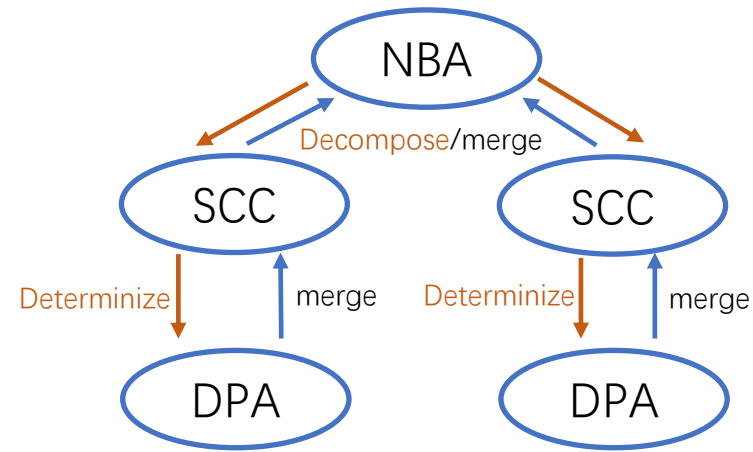
Existing constructions



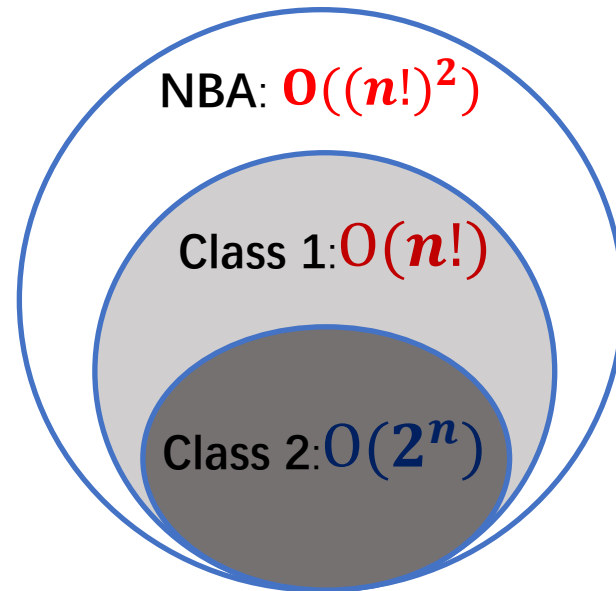
Work on **all SCCs at once**

Our contributions

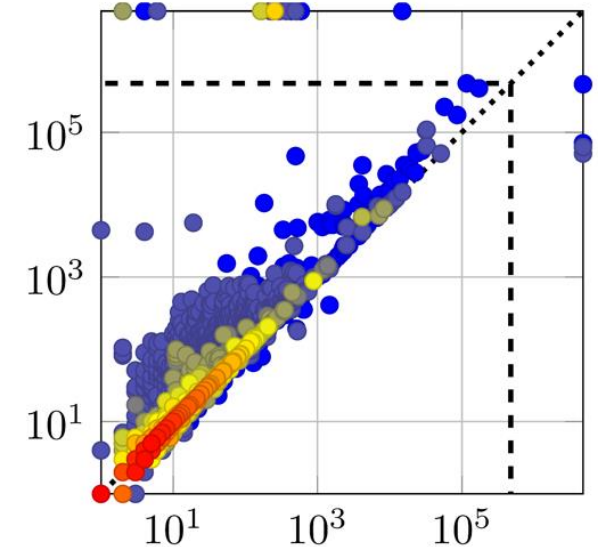
1. Divide-and-conquer methodology



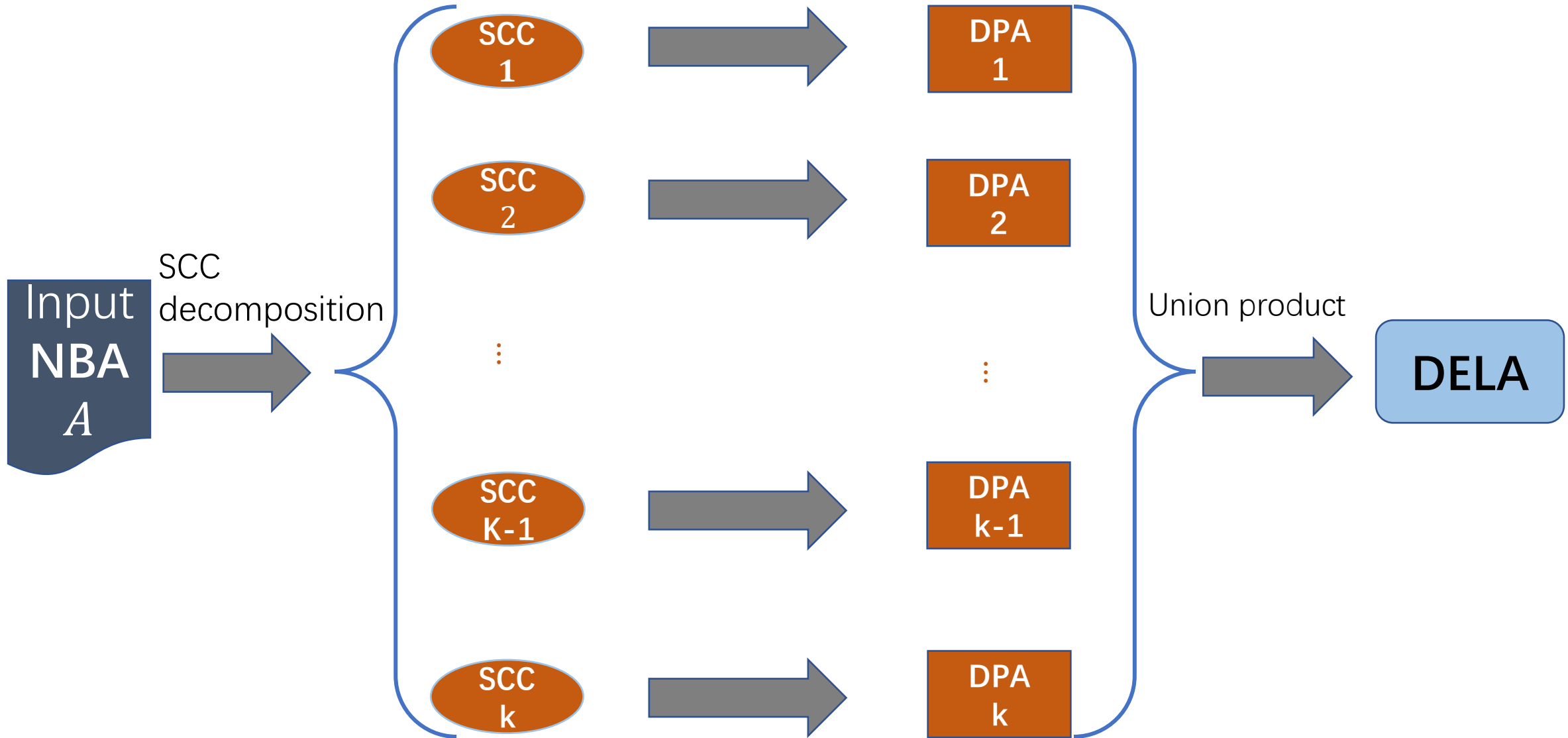
2. Two subclasses with better upper bounds



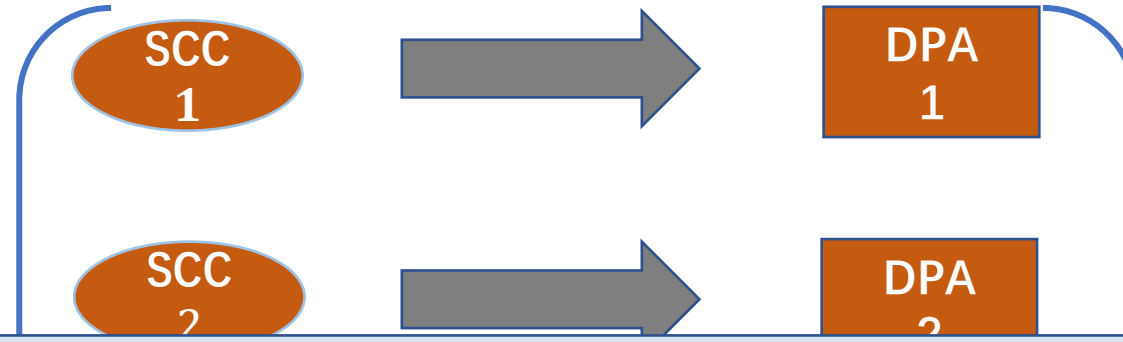
3. Comprehensive evaluation



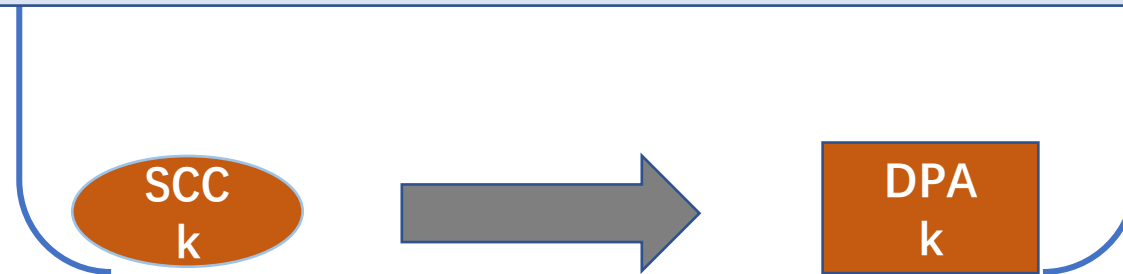
Our determinization construction



Our determinization construction



Insight 1:
Determinize each SCC independently



Three different types of SCCs

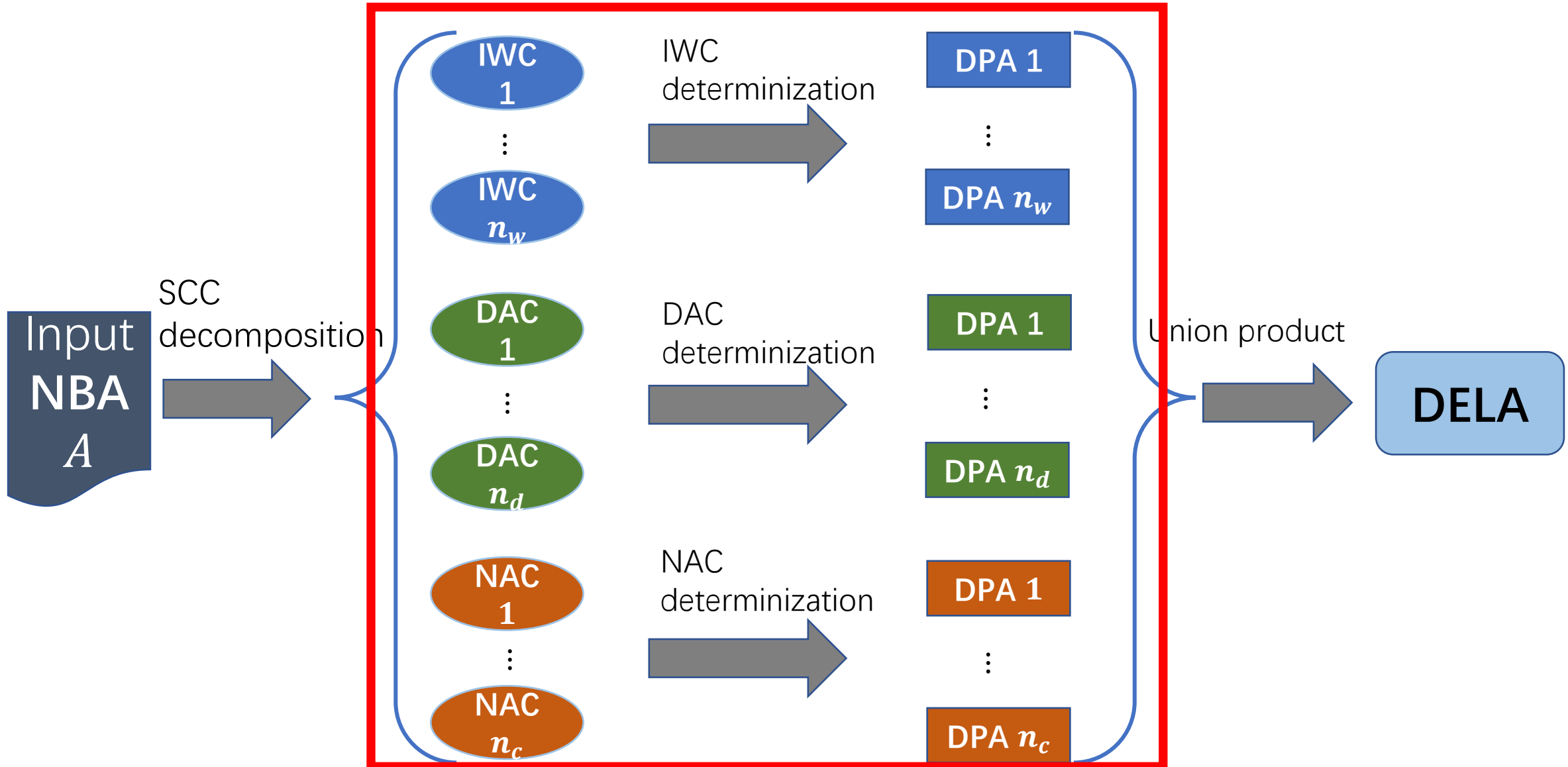
1. Inherently Weak SCC (IWC): 3^n
2. Deterministic Accepting SCC (DAC): $O(n!)$
3. Nondeterministic Accepting SCC (NAC): $O((n!)^2)$

Determinizing different types of SCCs

Three different types of SCCs

Insight 2:
Specific construction for each type of SCCs

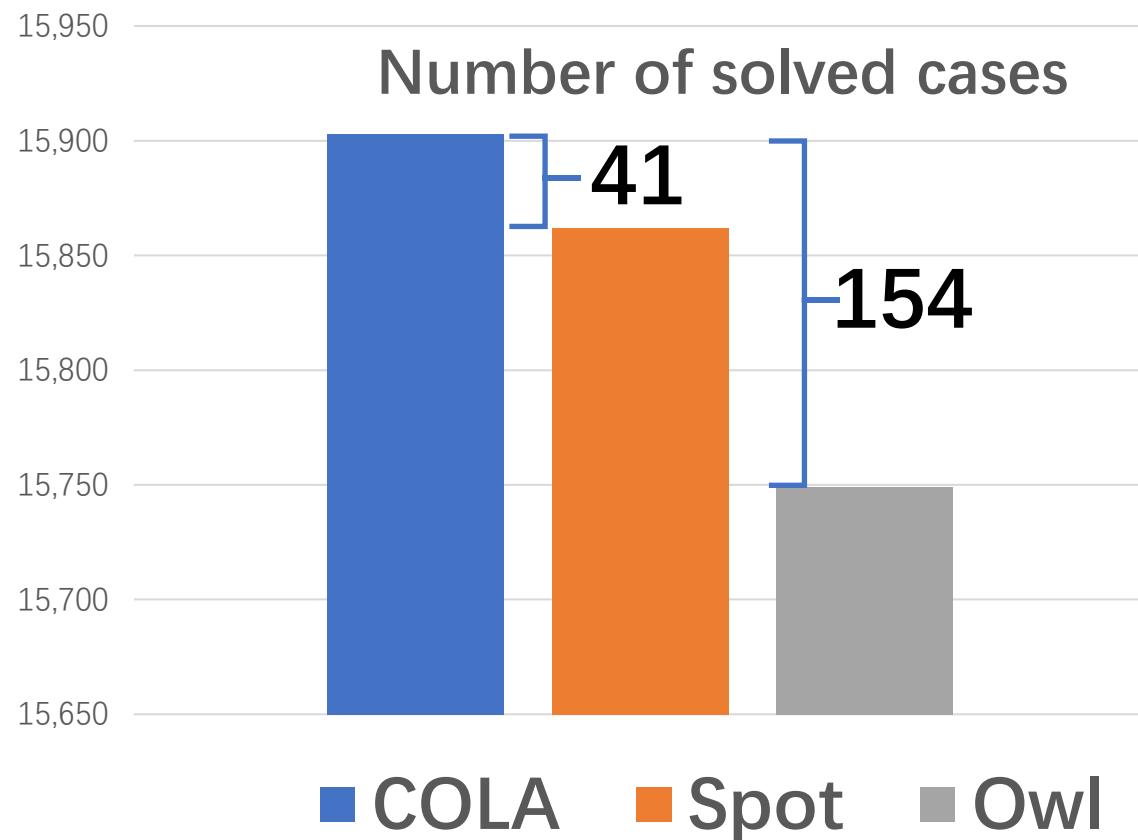
Final determinization construction



Perform union product **on-the-fly**

Empirical evaluation

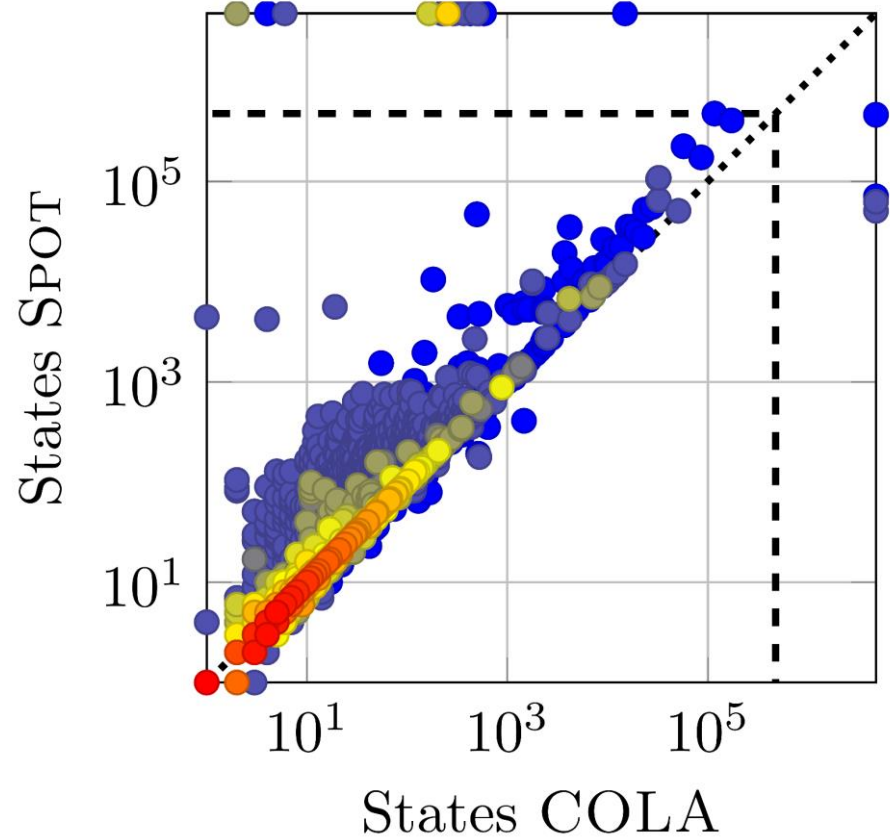
COLA solves **more instances** in **shorter** time



Tool	PAR-2 score: lower is better
COLA	17,351
Spot	67,258
Owl	206,431

Comparison with Spot

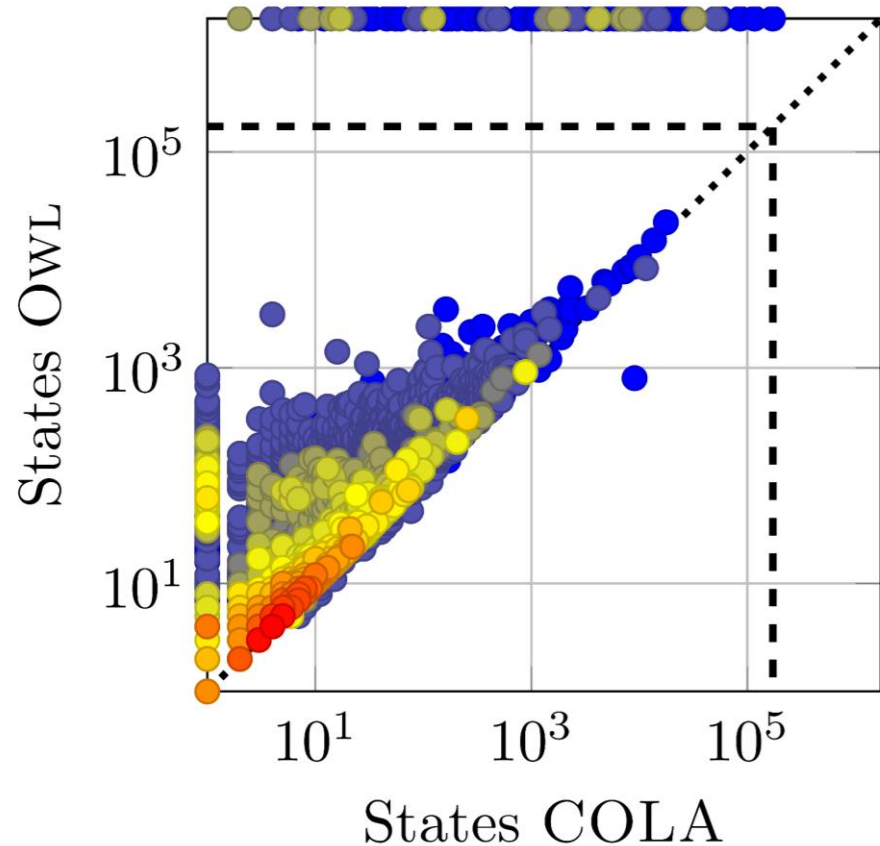
Heat map: **blue** color corresponds to fewer data points



COLA constructs
smaller
deterministic automata
than **Spot**

Comparison with Owl

Heat map: **blue** color corresponds to fewer data points



COLA constructs
smaller
deterministic automata
than **Owl**

1. **Divide-and-conquer** determinization
2. **Better upper bounds for two subclasses:**
 - $O(n!)$ vs. $O((n!)^2)$ and $O(2^n)$ vs. $O(n!)$
3. **COLA** outperforms **Spot** and **Owl**

Future work

- **Parallel** determinization for each SCC
- Applications to
 - **Reactive synthesis**
 - **Probabilistic** verification
 - **Büchi complementation** and **inclusion**