Scalable Learning of One-Counter Automata via State-Merging Algorithms

Prince Mathew

Postdoctoral Researcher

Université Libre de Bruxelles, Belgium

prince.mathew@ulb.be

Joint work with Shibashis Guha (TIFR), Anirban Majumdar (TIFR) and Sreejith A.V (IIT Palakkad)

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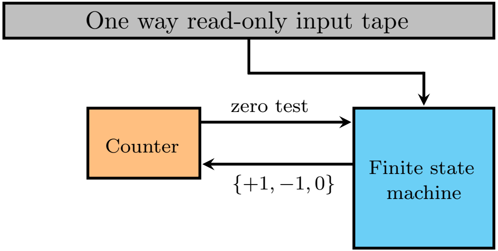
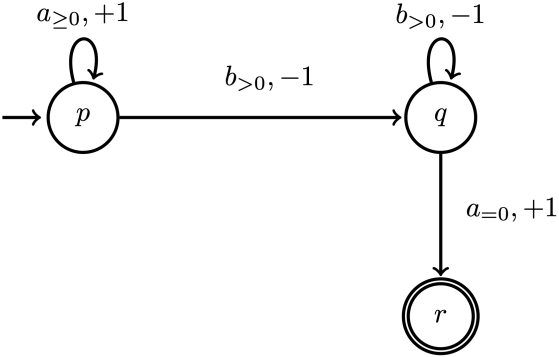
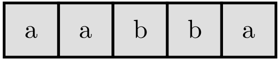
Deterministic real-time one-counter automata



- Write to counter: Increment (+1), No change (0), Decrement (-1).
- Read from counter: zero (0) or positive (+).
- Counter-value is always non-negative.
- Transitions of the finite-state machine are deterministic.
- There are no ϵ- transitions.

Example: DROCA





Input tape

$$\mathscr{L} = \{a^n b^n a \mid n > 0\}$$

Short history: Learning one-counter automata

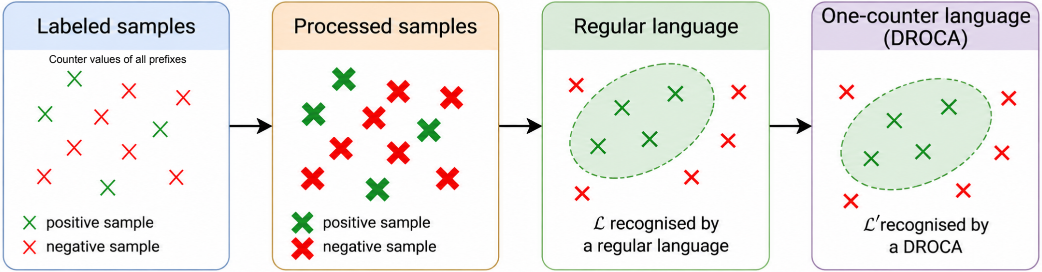
- (Gold, 1978) → Passive learning minimal DFA is NP-complete.
- (Angluin, 1987) → Active learning of DFA in polynomial time.
- (Fahmy & Roos, 1995) → Efficient learning of real-time OCA.
- (Neider & Löding, 2010) → Learning visibly OCA in EXPTIME.
- (Bruyère et. al, 2022) → Learning DROCA with an additional counter-value query in EXPTIME.
- (Mathew et. al, 2025a) → Learning DROCA using polynomially many queries.
- (Mathew et. al, 2025b) → Learning DOCA in polynomial time.

This talk

- `OPNI` : A passive learning algorithm for DROCA.
- `OCA-L*` : A semi-algorithm for learning DROCA that uses `OPNI`.
- The proposed active learning method outperforms existing techniques on randomly generated samples.

OPNI : Passive learning of DROCA

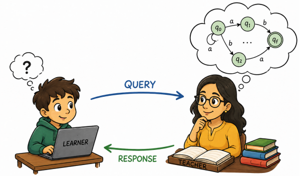
- Input:
  - Set of accepted words S^+ and set of rejected words S^-.
  - Counter values for all prefixes in S^+ and S^-.



Encode counter values　　RPNI (Oncina, Garcia, 1992)　　Decode counter values

- The output DROCA accepts all words in S^+ and reject all words in S^-.
- For all prefixes in S^+ and S^- the counter value reached by the DROCA is same as that of the input.

Active learning framework



Membership queries:

Learner: "Is w in $\mathscr{L}(\mathscr{A})$?"
Teacher : "yes" or "no"

Counter-value queries:

Learner: "What is the counter-value reached on reading w?"
Teacher: "counter-value reached on w"

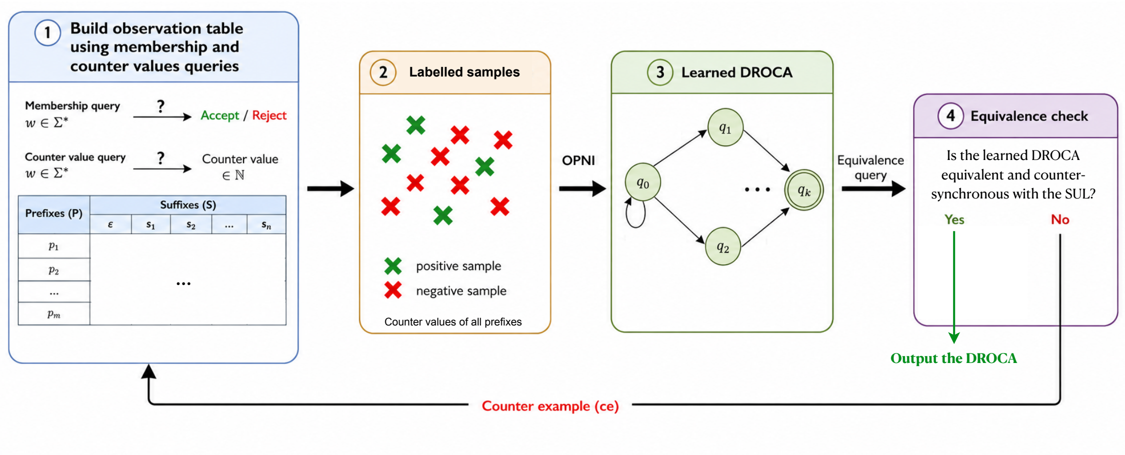
Minimal-equivalence queries:

Learner: "Does $\mathscr{B}$ and $\mathscr{A}$ recognise the same language?"
Teacher : "yes" or "no & the smallest counter-example"

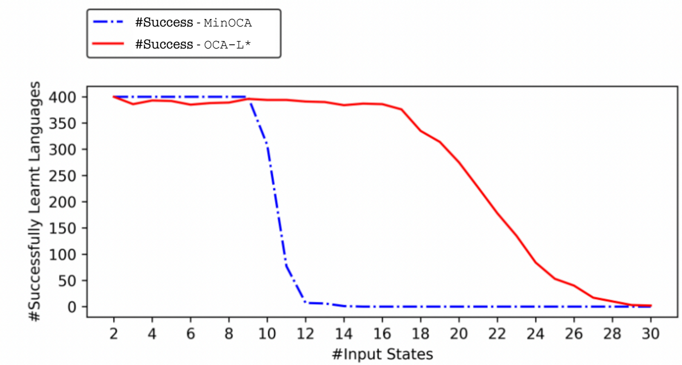
Membership different

Counter-value different

OCA-L* : Active learning of DROCA



Experimental evaluation



Number of successfully learnt DROCAs by `MinOCA` and `OCA-L*`

- Works in practice but **no** termination guarantees.

Conclusion and future work

- Passive learning algorithm (`OPNI`) for DROCA.
- Semi-algorithm (`OCA-L*`) for active learning of DROCA that works well in practice.
- The existing algorithm for learning DROCA in polynomial time is not suitable for practical use.
- Is there a faster polynomial time algorithm for learning DROCA that works in practice?

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Thank You !