*ng*AP: Non-blocking Large-scale Automata Processing on GPUs

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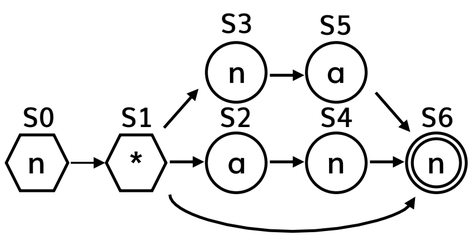
Background

Finite automata serve as compute kernels for various applications that require high throughput.

The structure of automata

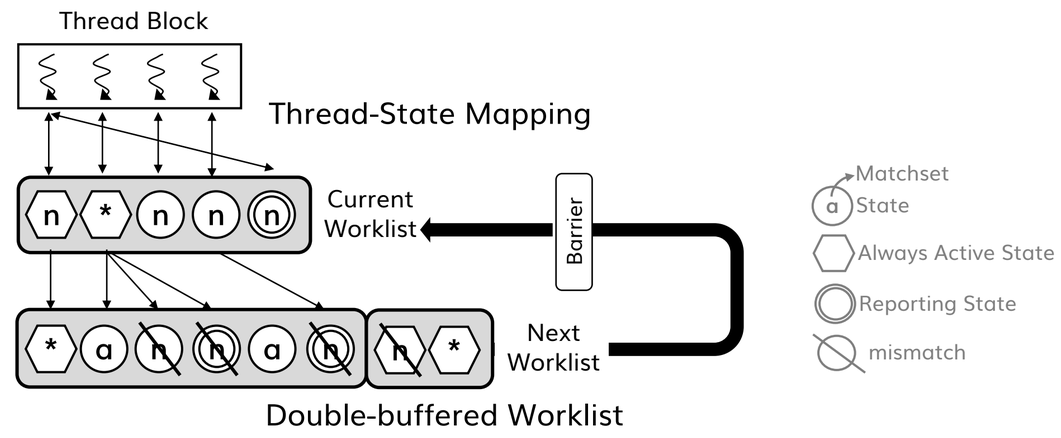


An example of matching process

Iter	Sym	Active states	Matched States	Report
0	b	S0, S1	S1	
1	a	S0, S1, S2, S3, S6	S1, S2	
2	n	S0, S1, S2, S3, S4, S6	S0, S1, S3, S4, S6	S6
3	a	S0, S1, S2, S3, S5, S6	S1, S2, S5	
4	n	S0, S1, S2, S3, S4, S6	S0, S1, S3, S4, S6	S6
5	a	S0, S1, S2, S3, S5, S6	S1, S2, S5	

GPU provides high throughput, making it an attractive option for processing large-scale automata applications.

Blocking Automata Processing on GPUs



Previous GPU-based approaches utilized a data-driven approach to enhance GPU utilization, incorporating:

1. A **double-buffered worklist** to store active states.
2. **Dynamic mapping** between threads and states.

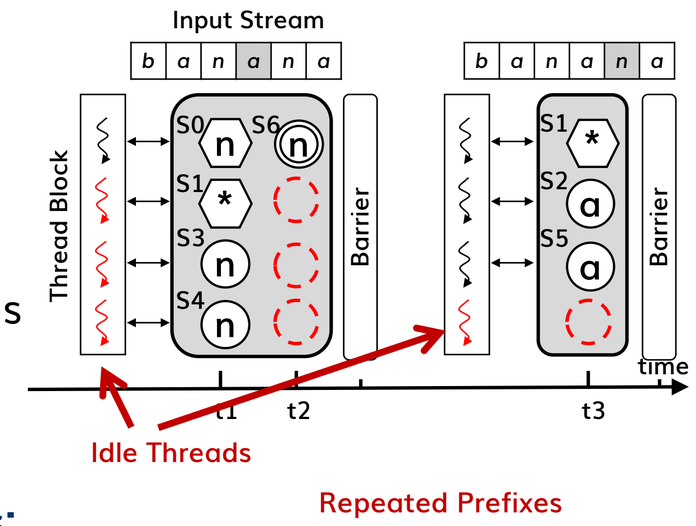
However, each state had to wait at a barrier until all states in the worklist were processed, resulting in a "**blocking**" **process.**

Motivation

Our detailed characterization reveals that **three challenges** have not been systematically addressed:

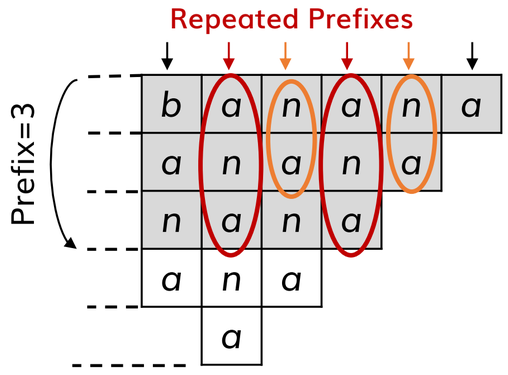
Threads Underutilization:

- Threads only work on states matched **in one iteration.**
- Utilization only achieves average **32.6%.**



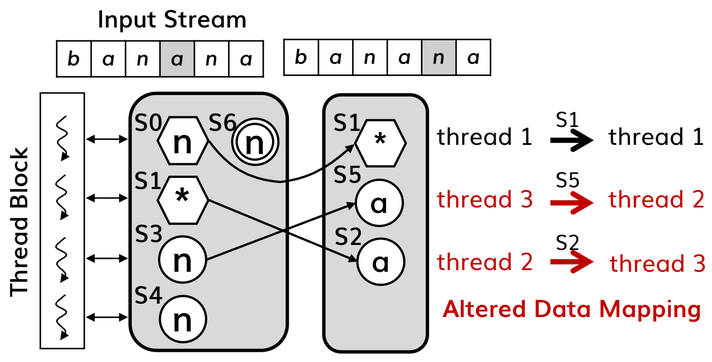
Redundant Computations:

- The always-active states match with some symbols repeatedly in every iteration.
- **93%** work can be reduced if eliminating the redundant matches.



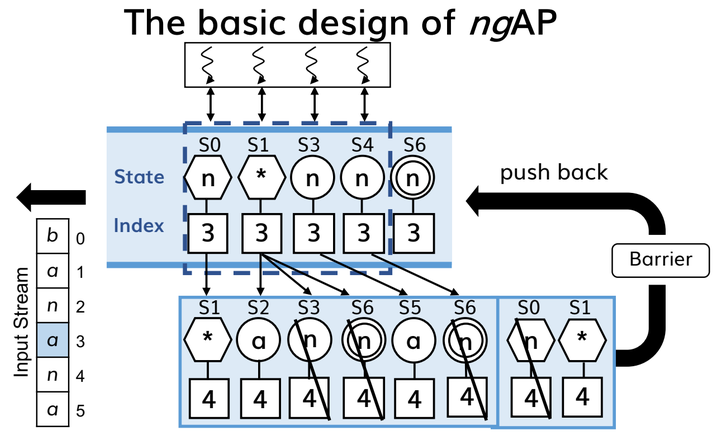
Poor Data Locality:

- Threads and states mapping **switches** frequently.
- L1 cache hit rate only achieves **23%.**



*ng*AP

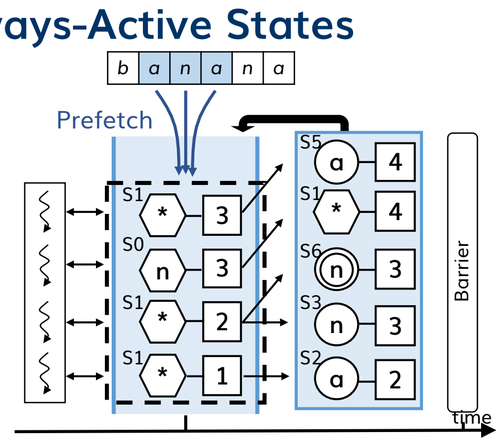
The basic design of *ng*AP



*ng*AP uses (1) **State-Index Pairs** (2) **Sliding Window,** to allow parallel processing of different symbols in the input stream and enable further **3 optimizations.**

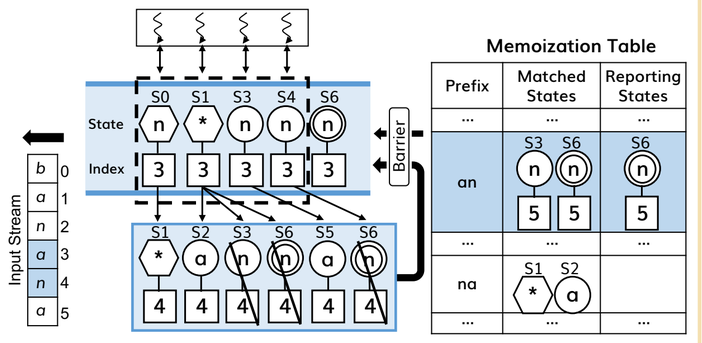
Optimization #1: Prefetching Always-Active States

✓ By prefetching the matches between always-active states and symbols to the worklist, the number of indices coexisting in the worklist increases.



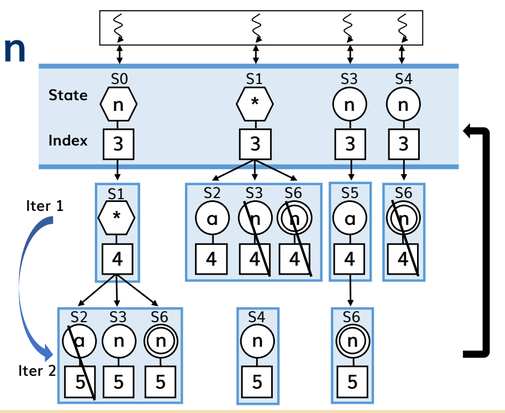
Optimization #2: Prefix Memoization

✓ Prefix Memoization substitutes matches between always-active states and pattern prefixes with table look-ups.



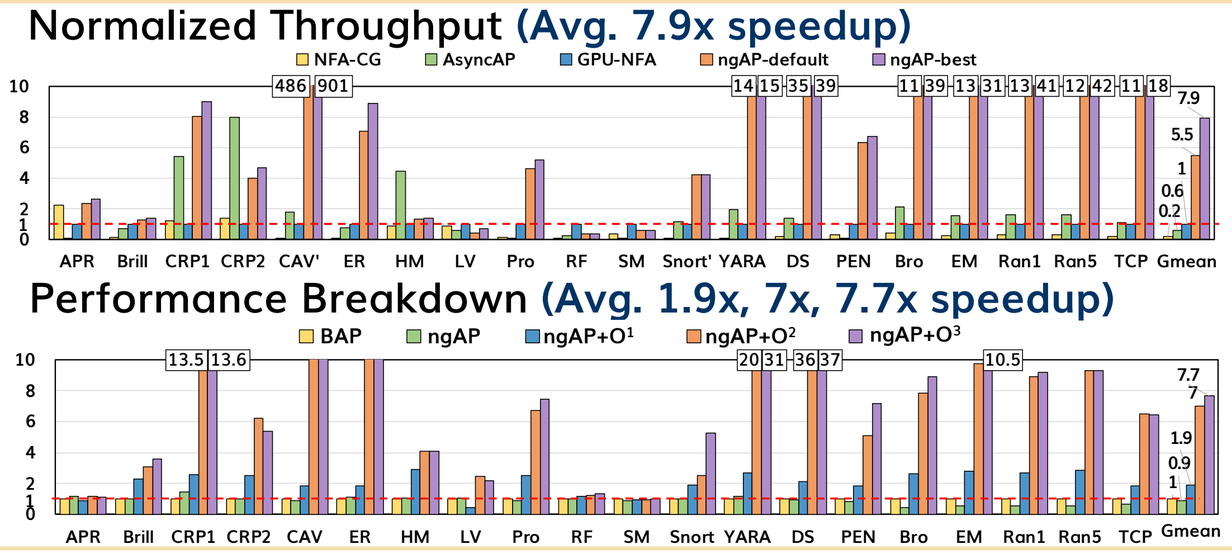
Optimization #3: Work Privatization

✓ Each thread can decide whether it privatizes the extended neighbors without writing them back to the shared worklist.



Results

Normalized Throughput **(Avg. 7.9x speedup)**



Performance Breakdown **(Avg. 1.9x, 7x, 7.7x speedup)**

Conclusion

- We present Non-blocking Automata Processing (***ng*AP**) which allows multiple symbols to be processed on GPUs.
- On top of *ng*AP, we propose **3 optimizations** to address identified challenges.
- Evaluation shows *ng*AP outperforms SOTA by an average of **7.9×** and up to **901×** across 20 applications.

***ng*AP GitHub Repository**
https://github.com/getianao/ngAP

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