Ohua as STM Alternative for Shared State Applications

Master Defense

Felix Wittwer

25th of August, 2020

Motivation

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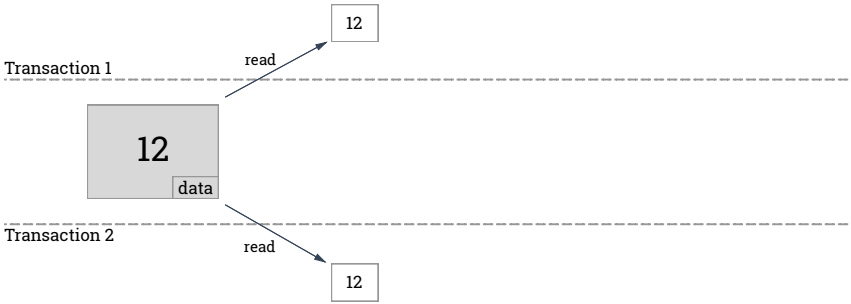

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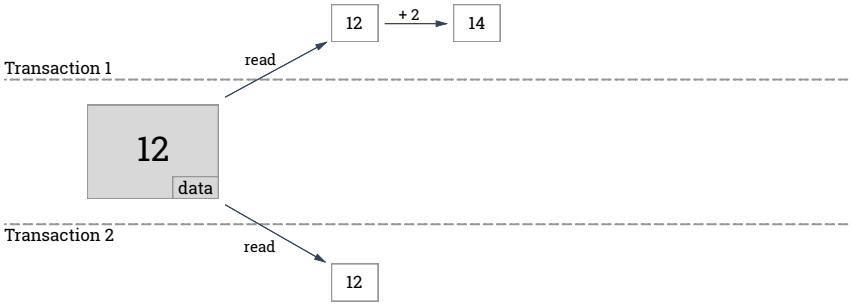

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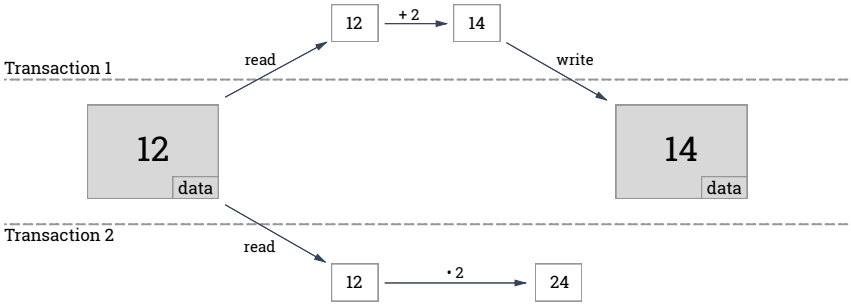

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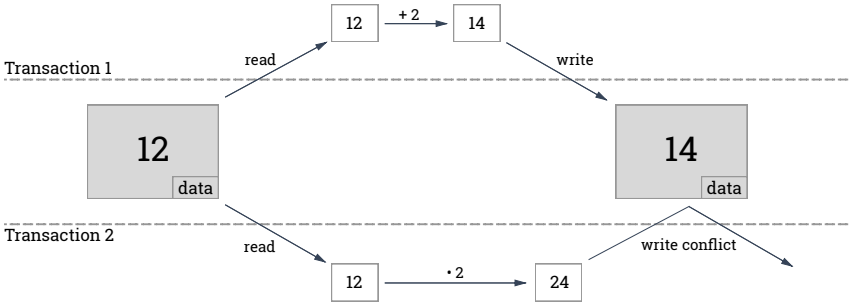

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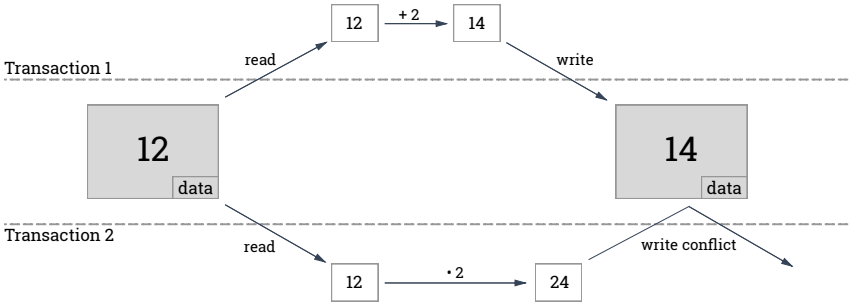

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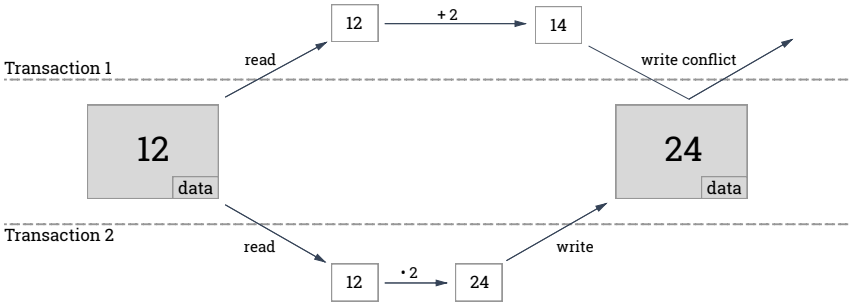

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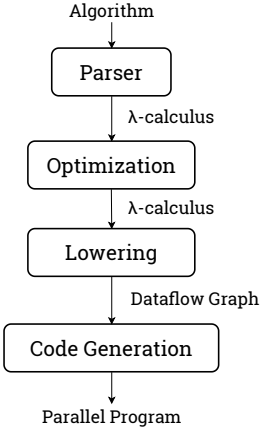
  - programs are still non-deterministic

Ohua[2]

Framework for implicit parallel programming:



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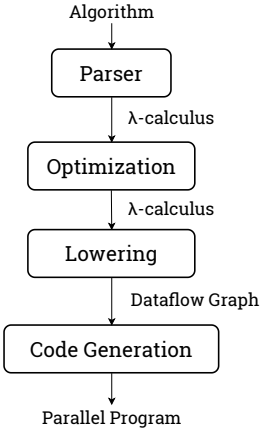

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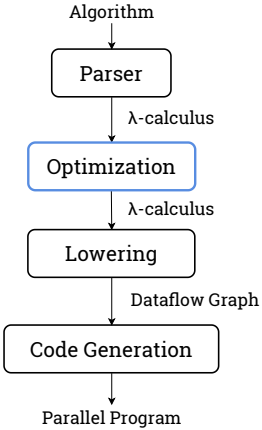

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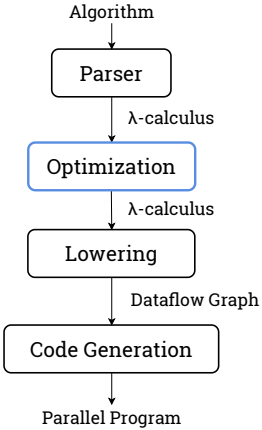

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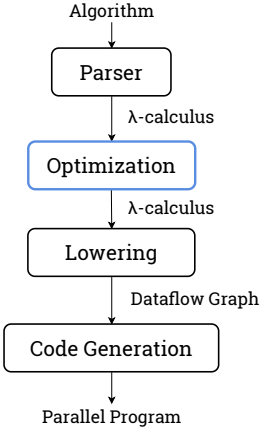

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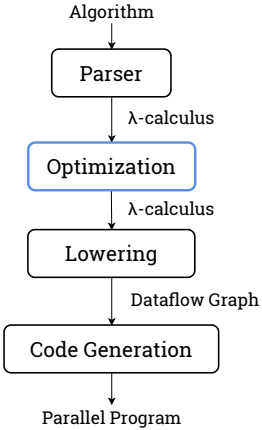

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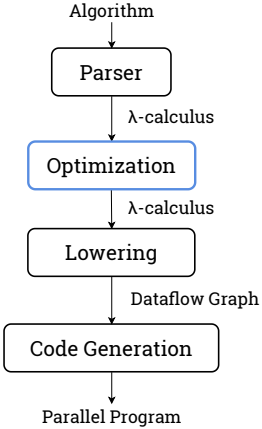
- Problem: Ohua only fosters local state



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Compiler Transformations

- Transformation 1: Map parallelization

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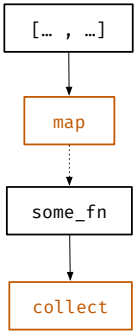

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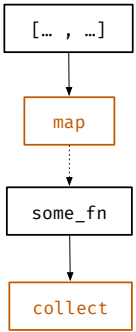

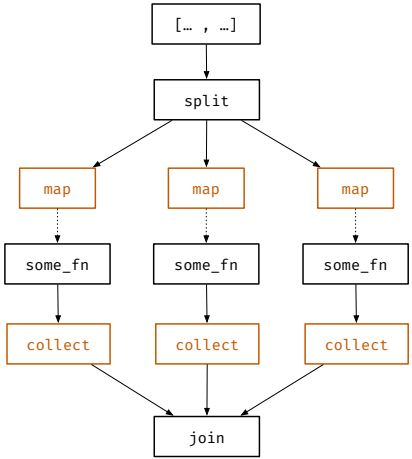

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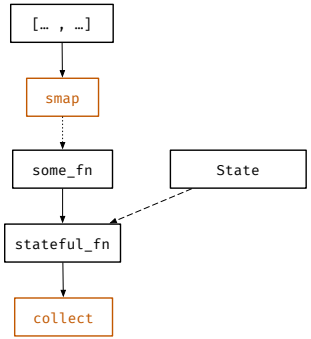

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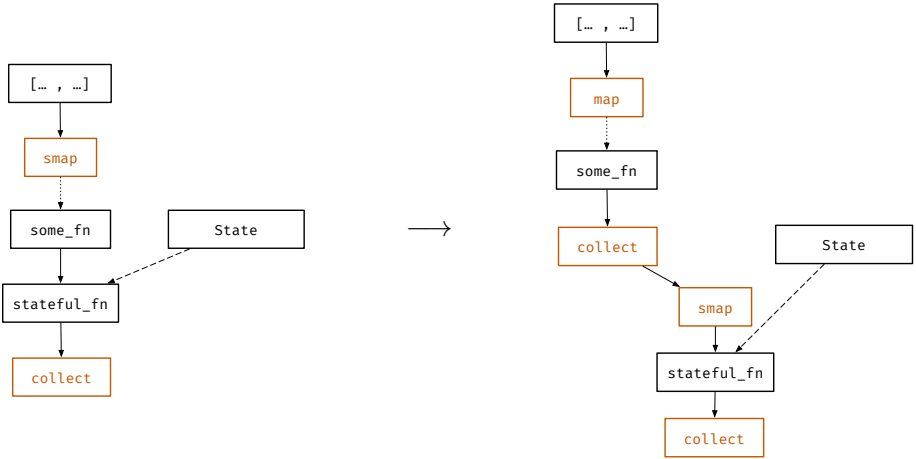

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  - reduce stragglers by implementing work stealing into the runtime

Performance Comparison

- selected 4 representative benchmarks from STAMP[3] suite

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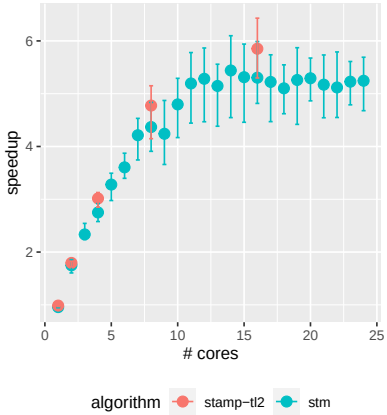
- compared speedups & CPU use for STM and Ohua

Results: Labyrinth



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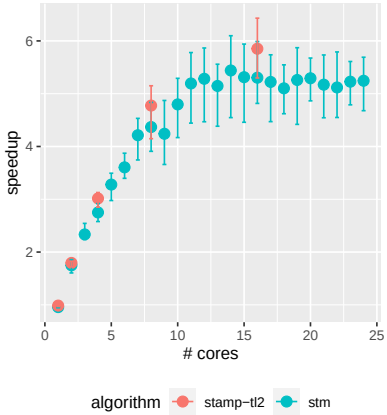

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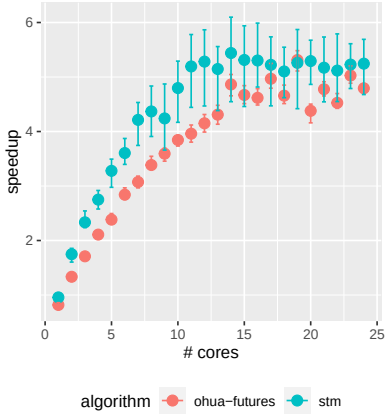

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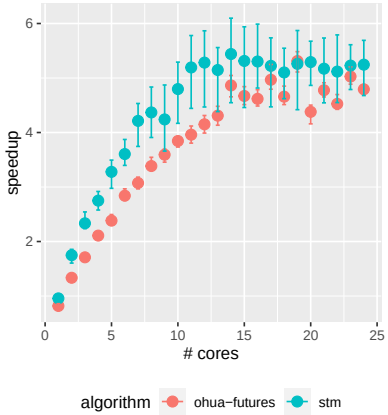

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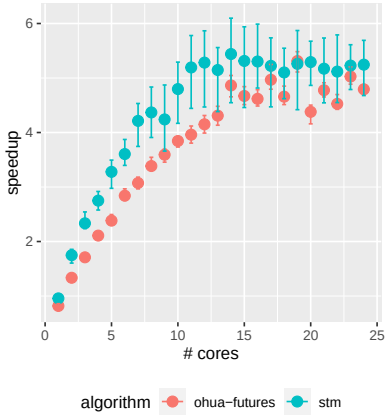

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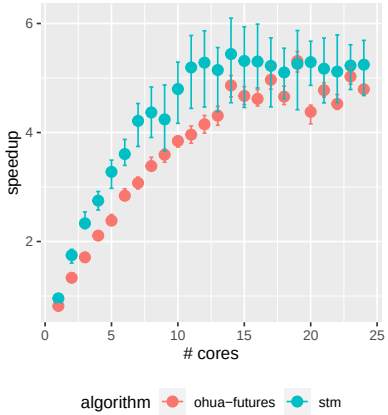

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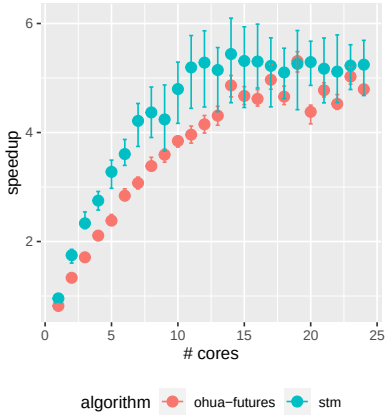

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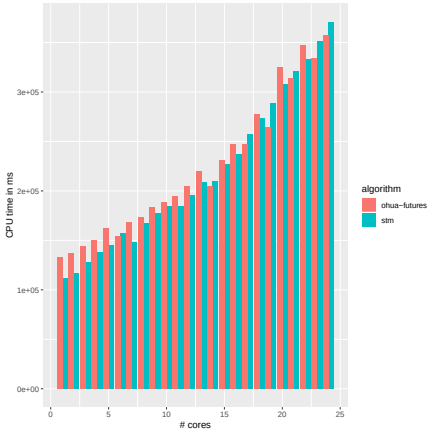

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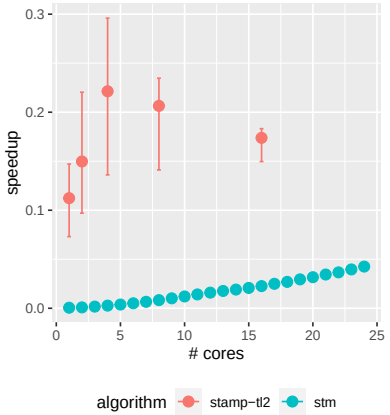

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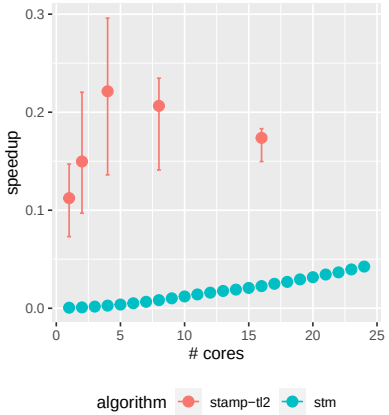

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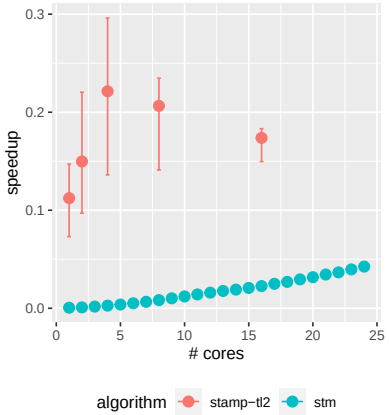

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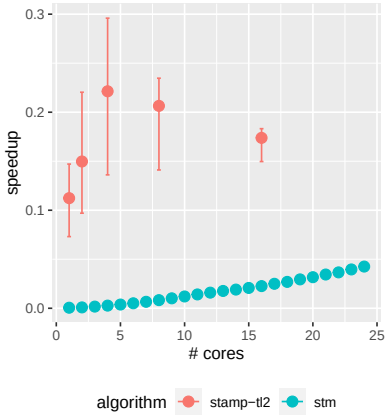

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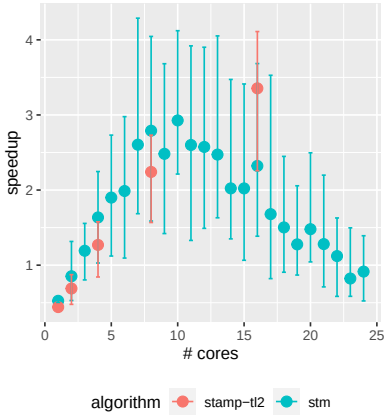

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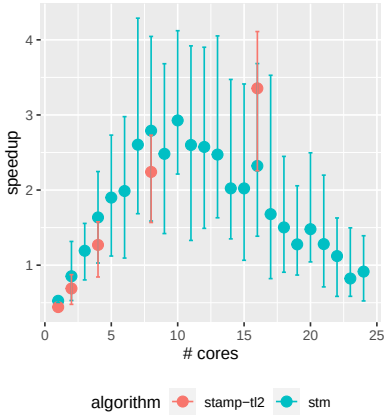

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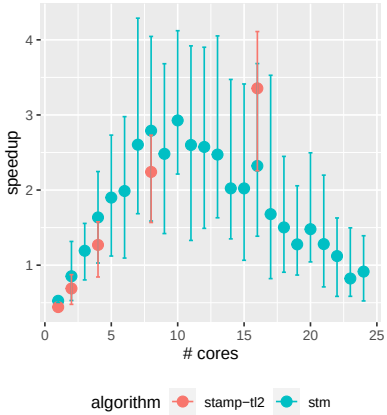

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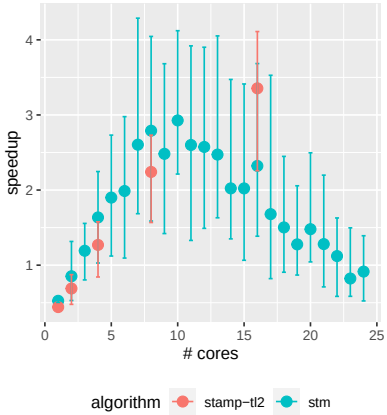

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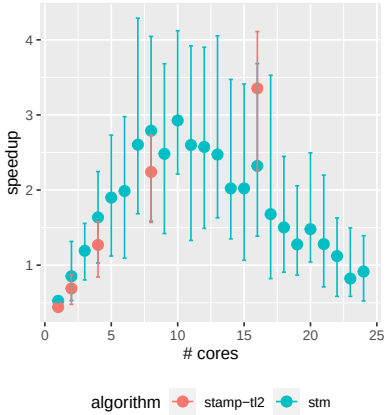

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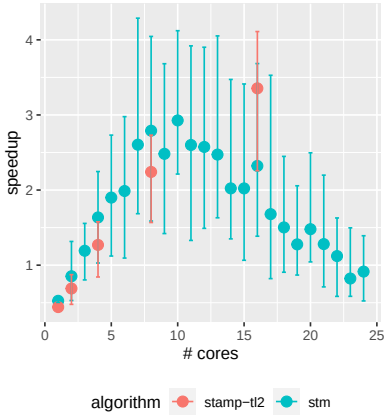

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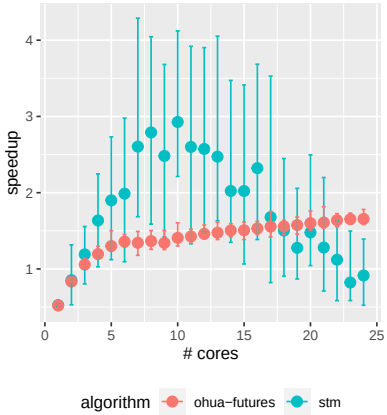

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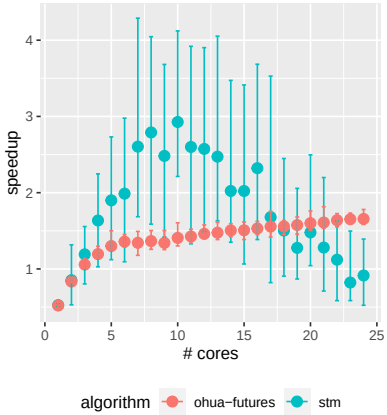

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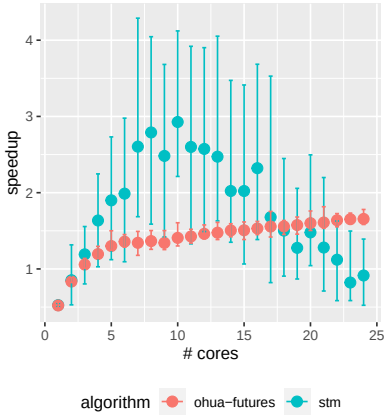

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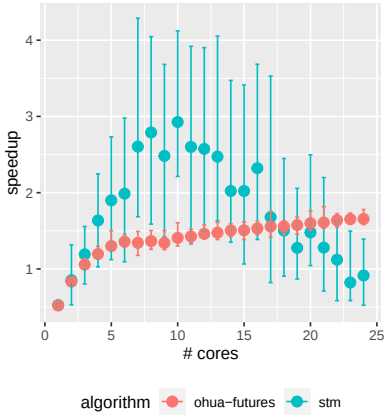

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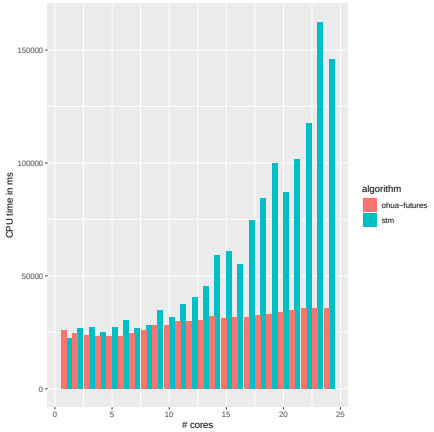
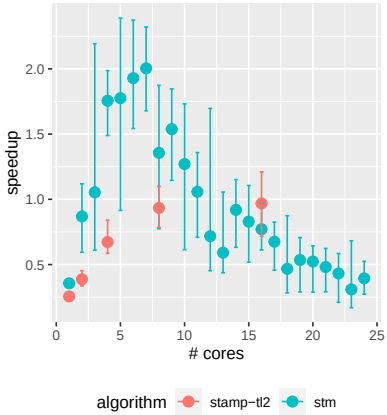


- Ohua does not perform as good as STM
- performance reaches ceiling
  - indicates that not all available parallelism has been exploited
- uses nearly constant, relatively low amount of CPU time

Results: k-means (high contention)



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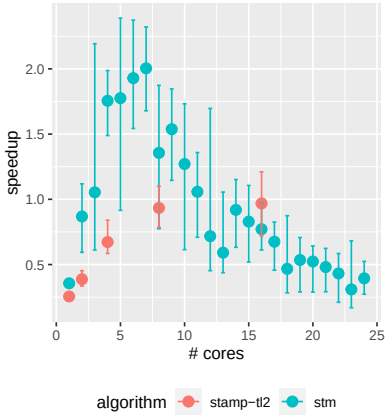
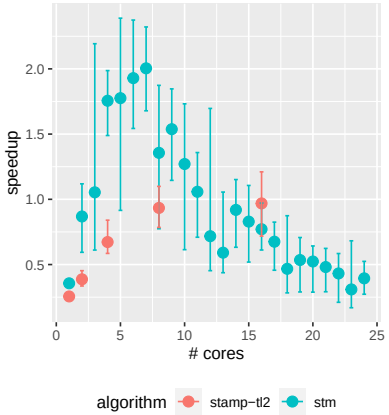


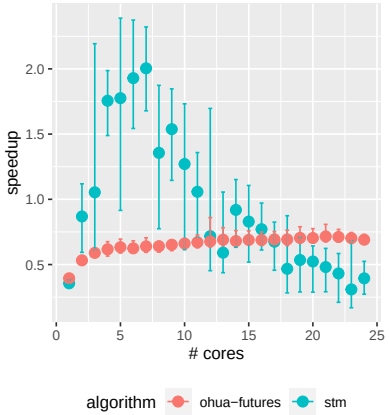
☑ Rust version outperforms STAMP

Results: k-means (high contention)



- ☑ Rust version outperforms STAMP
- ☐ same behavior as in low contention run

Results: k-means (high contention)



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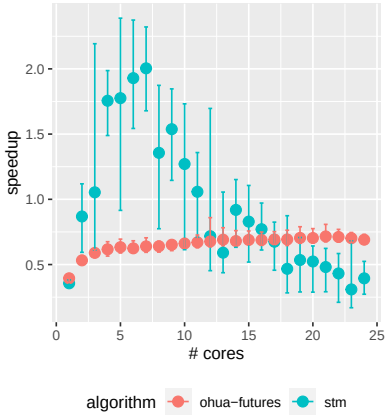
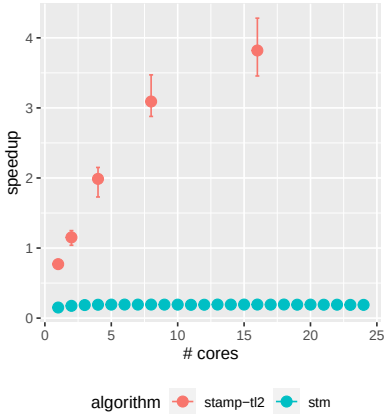


- Ohua again reaches performance ceiling

Results: Genome



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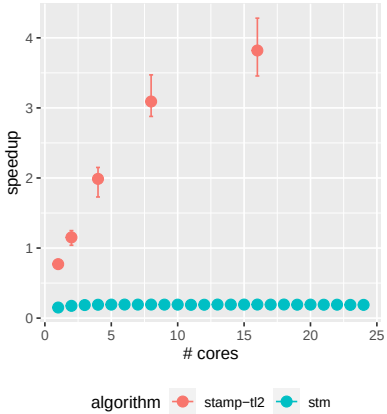

- completely different curve shapes

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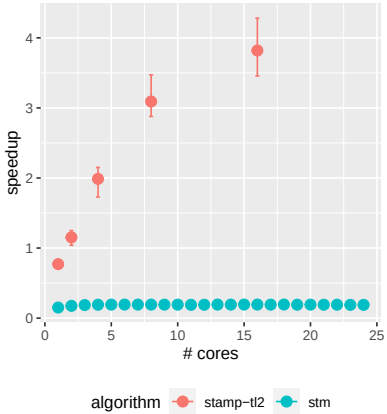

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Possible Reasons:

- ☐ STAMP is more optimized (e.g., own HashSet)

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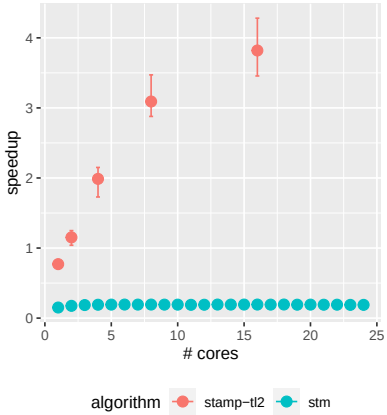

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Possible Reasons:

- ☐ STAMP is more optimized (e.g., own HashSet)
- ☐ high overhead for data duplication (24 % of total time used)

Results: Remarks

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- Transformations 2 & 3 proved useful for parallelization
  - used for `labyrinth`
  - only applicable for amorphous data parallel applications
- optimizing other applications requires deeper insight into shared state usage
- Ohua uses often less or equally as much CPU time as STM

Conclusions

Could Ohua be an alternative to STM for shared state applications?

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- yes, for *some* applications
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Future Work:

- understand, how shared data structures could be partitioned for parallel accesses
  - identifiable using certain functions defined on a type?
  - could a special data type be defined to allow better compiler insight?

Thank you for your attention.

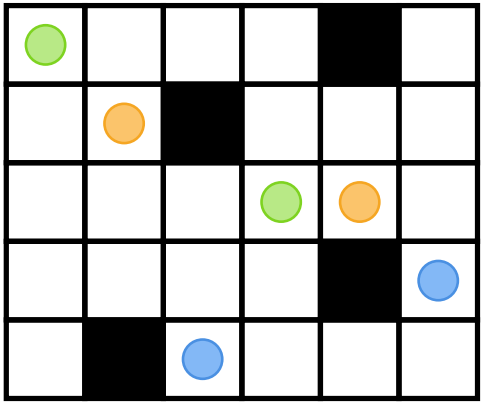
Backup

Backup: Representative Benchmark Selection

Application	tx length	r/w set	tx time	Contention
labyrinth	long	large	high	high
bayes	long	large	high	high
yada	long	large	high	medium
vacation	medium	medium	high	low/medium
genome	medium	medium	high	low
intruder	short	medium	medium	high
kmeans	short	small	low	low
ssca2	short	small	low	low

Backup: Labyrinth Benchmark

Given: 3D maze, pairs of points



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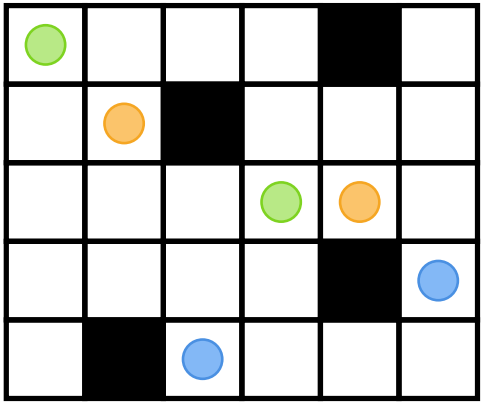
Given: 3D maze, pairs of points

Goal: Map a path between each pair of points



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Implementation:

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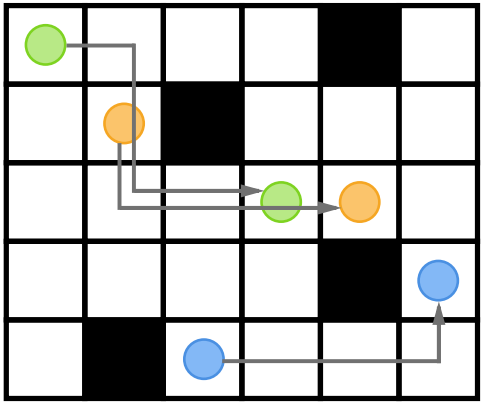

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- parallel search for new paths
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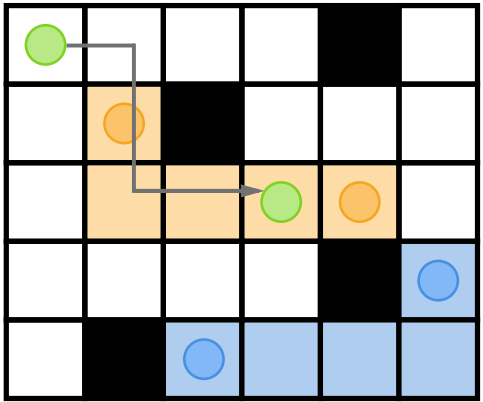


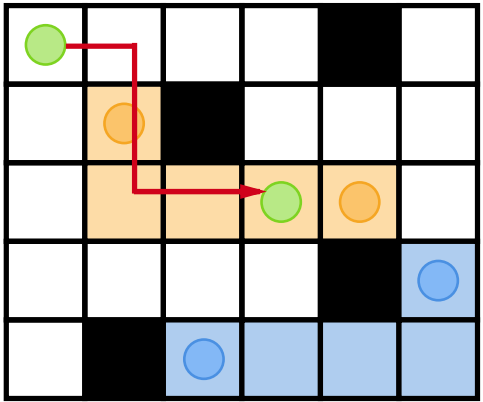
Backup: Labyrinth Benchmark

Given: 3D maze, pairs of points

Goal: Map a path between each pair of points

Implementation:

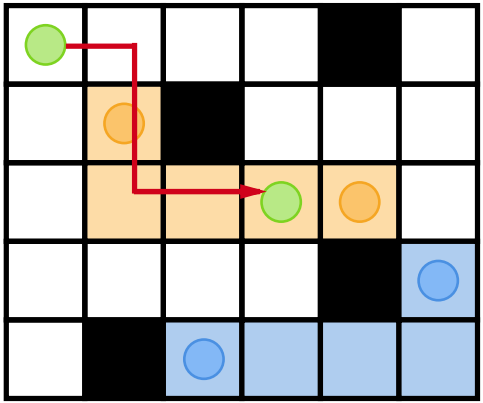
- parallel search for new paths
- merge paths into the maze
  → retry if path crosses other paths



Shared State Application: Labyrinth Benchmark

Irregular Applications

centered around the manipulation of pointer-based data structures



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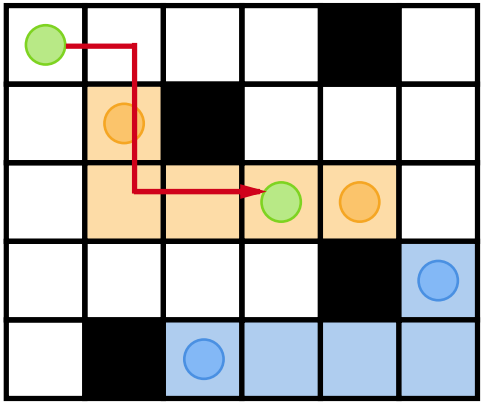
- structure makes identification of safe parallel accesses hard

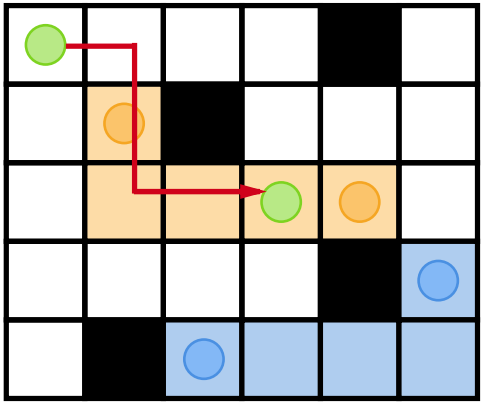


Shared State Application: Labyrinth Benchmark

Irregular Applications

centered around the manipulation of pointer-based data structures

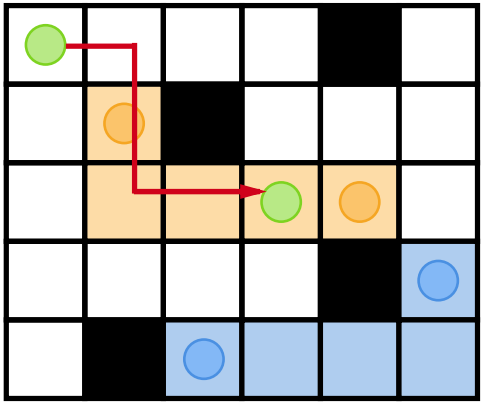
- structure makes identification of safe parallel accesses hard
- compiler analyses struggle to uncover meaningful parallelism



Shared State Application: Labyrinth Benchmark

Amorphous Data Parallelism

behaviour observed in some irregular applications



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Amorphous Data Parallelism

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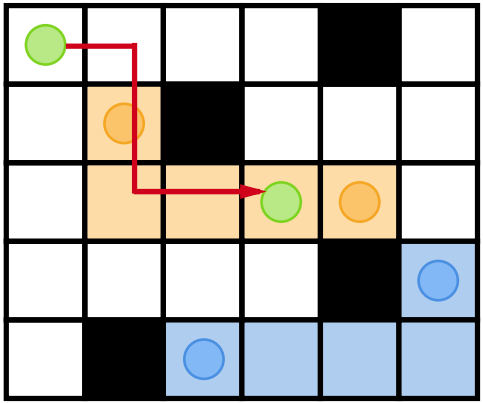
- processing one element may generate new work items or remove others



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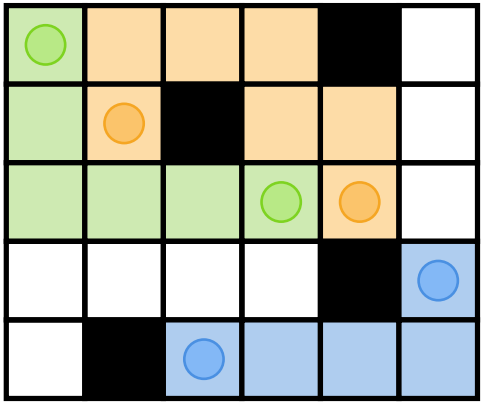

Shared State Application: Labyrinth Benchmark

Amorphous Data Parallelism

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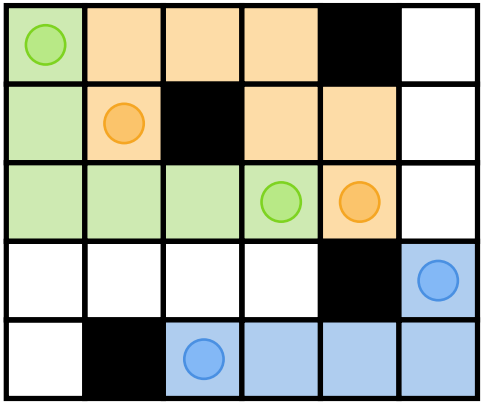
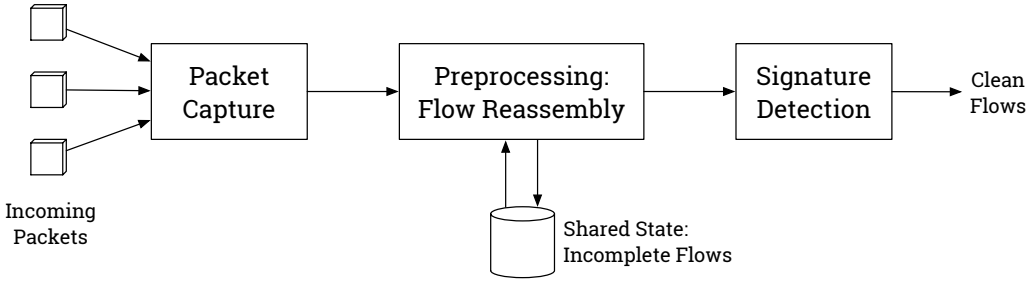
- processing one element may generate new work items or remove others
- some items cannot be processed in parallel due to conflicts



Backup: Intruder Benchmark

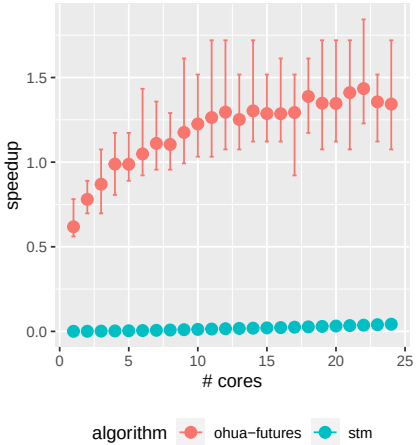


Backup: Intruder Benchmark

```
let mut flows = State::new();
for packet in input {
    flows.add(packet);
}

for flow in flows {
    analyze(flow);
}
```

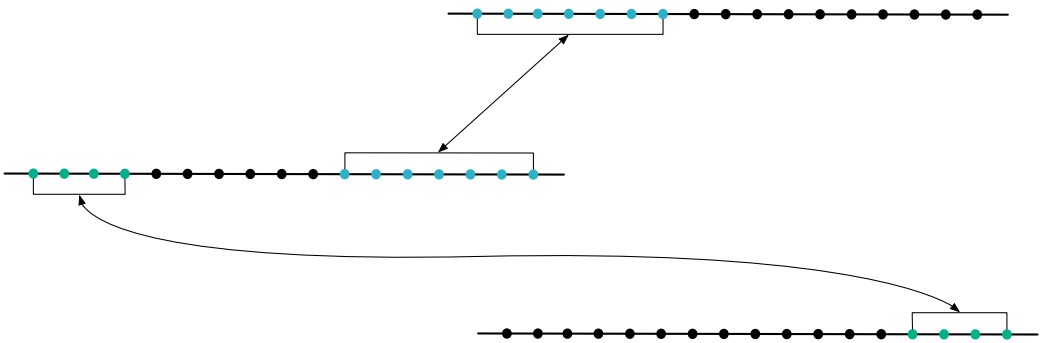
Backup: Intruder Benchmark



Backup: k-means Benchmark

```
let mut centers = initialize(input);
loop {
    // data parallelism
    for item in input {
        item.find_center(centers);
    }
    // fold
    centers = recompute(input);
}
```

Backup: Genome Benchmark - Overlap Matching

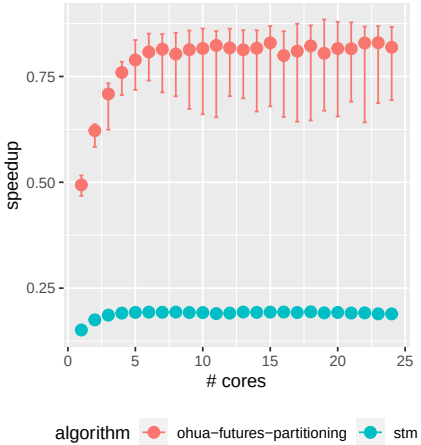


Backup: Genome Benchmark

```
let mut nucleotides = Hashset::new();
for segment in input {
    // deduplication
    nucleotides.insert(segment);
}

loop {
    for item in nucleotides {
        item.find_neighbor(nucleotides);
    }
}
```

Backup: Genome Benchmark



Backup: Differences in Memory Sharing

```
unsigned long data[] = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10};

pid_t pid = fork();
if (pid != 0) {
    int lower = 0;
    int upper = 4;
    // changes elements at indices 0 to 4
    modify_elements(data, lower, upper);
} else {
    int lower = 5;
    int upper = 9;
    // changes elements at indices 5 to 9
    modify_elements(data, lower, upper);
}
```