

Parallel Fringe Search

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Design of Parallel and High-Performance Computing

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Overview

1 Fringe Search

2 What we have done

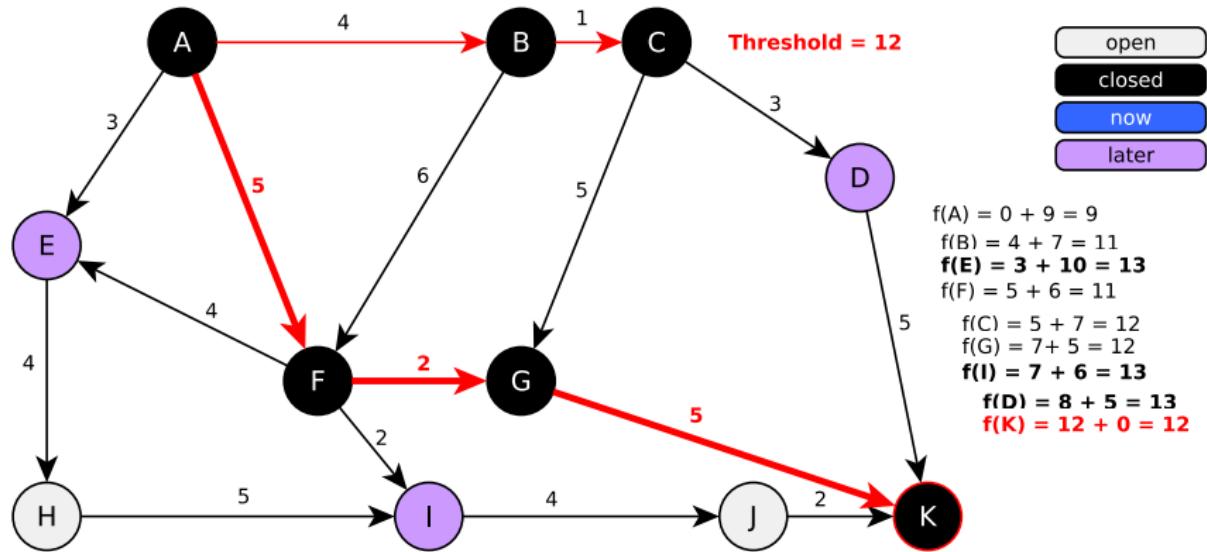
3 Locking concepts

4 Benchmarks

- Locks
- Strong scaling
- Weak scaling
- Path length
- Threshold handling

5 Conclusions

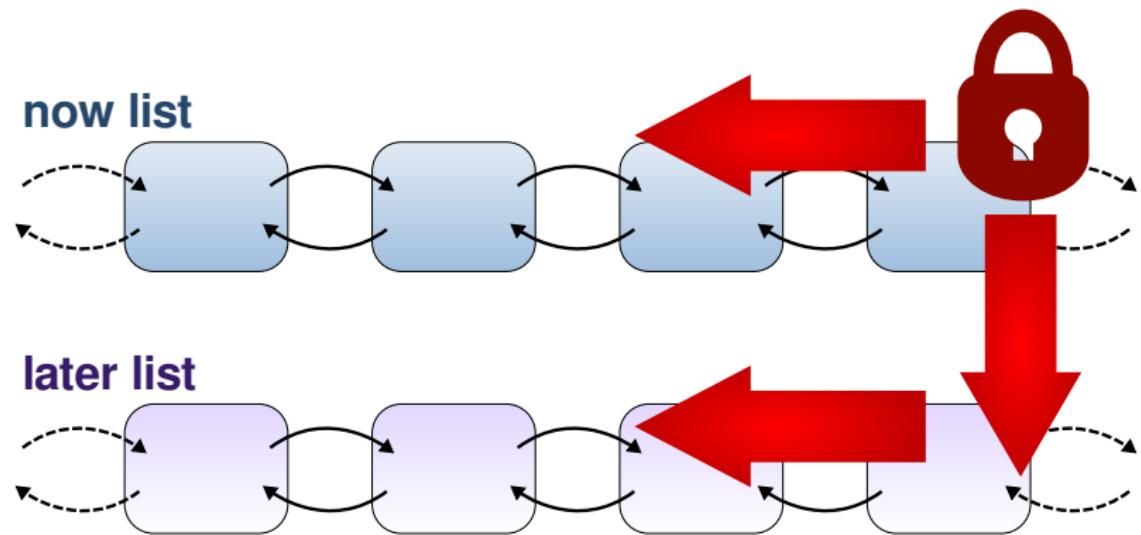
Fringe Search



What we have done

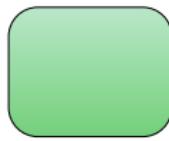
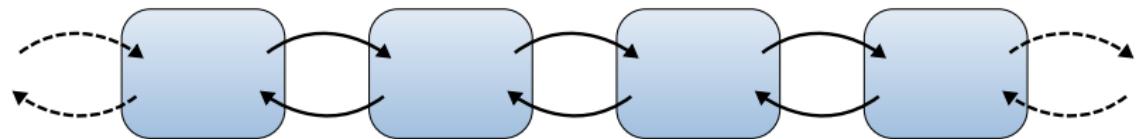
- Serial implementation of fringe search (much faster than Boost A*)
- Parallel implementation with Open MP
 - 2 different locking concepts
 - Locks implemented using inline assembly (faster than Open MP locks)
- Benchmarking
 - Strong scaling
 - Weak scaling
 - Path quality
 - Threshold handling

Locking concept: Deadlock prevention

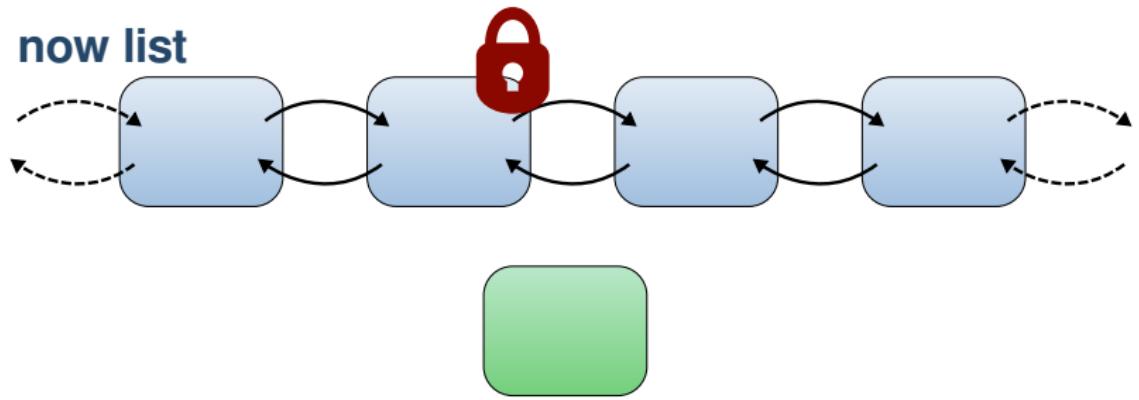


Locking concept: Insert node

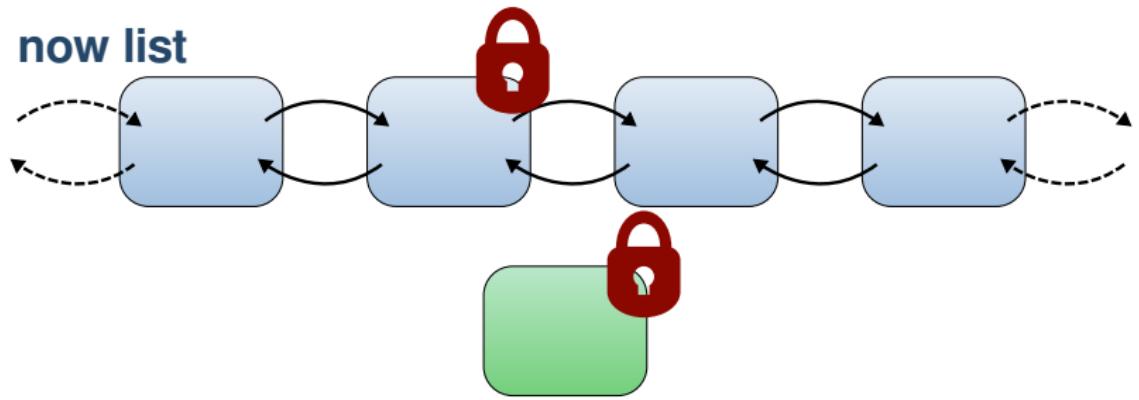
now list



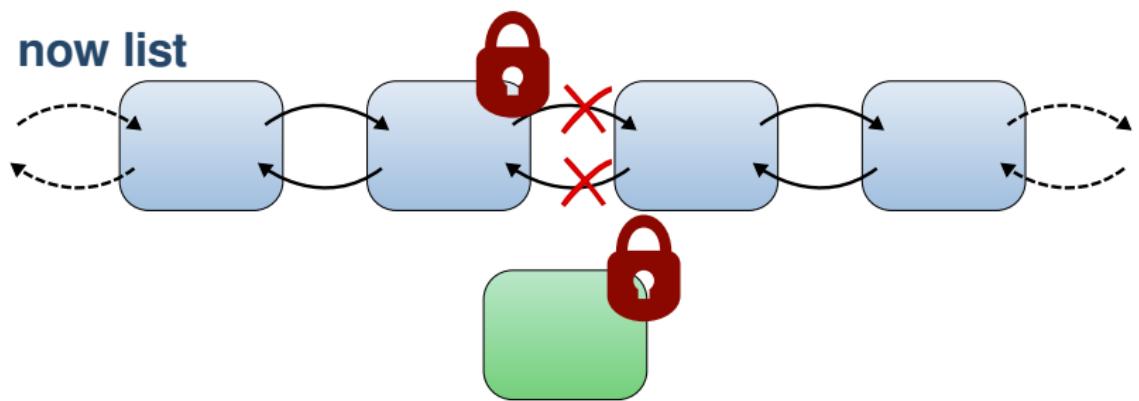
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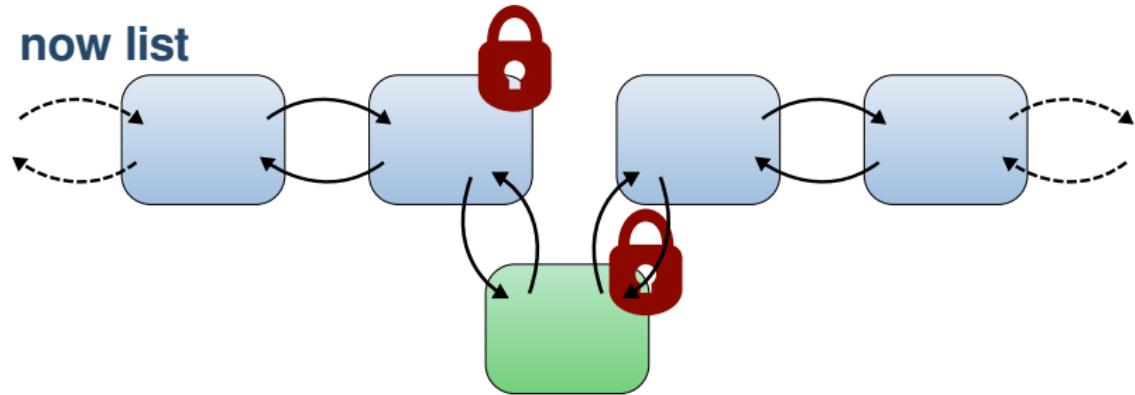
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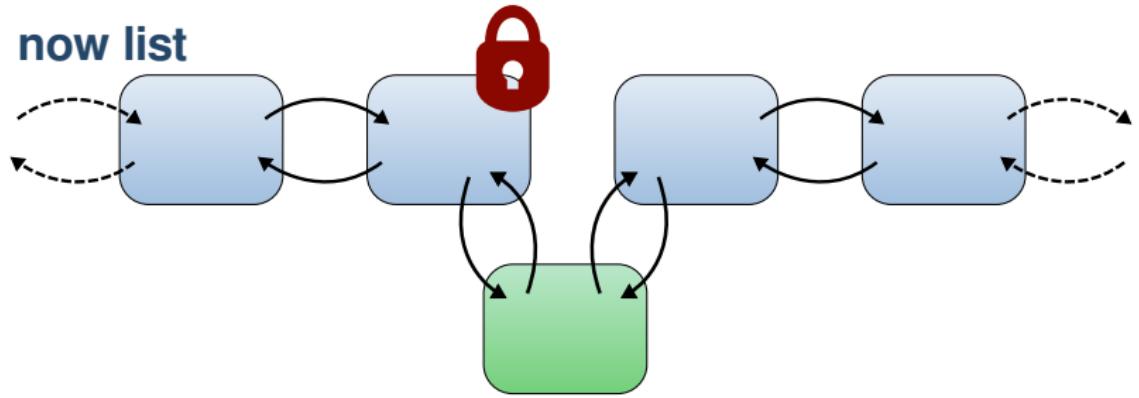
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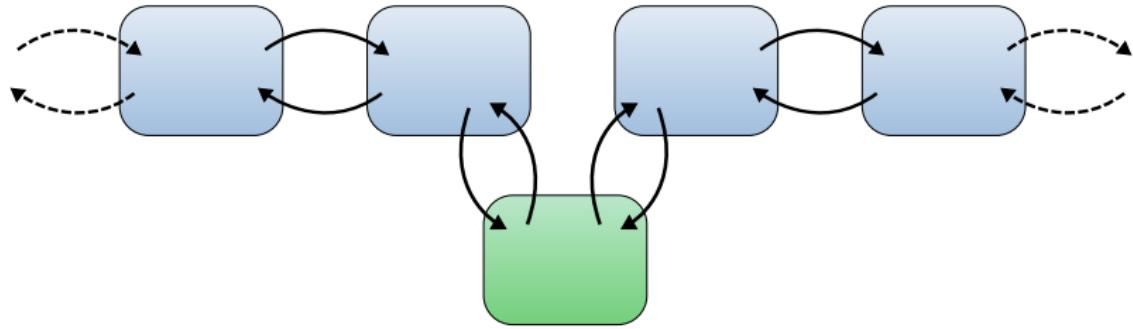


Locking concept: Insert node



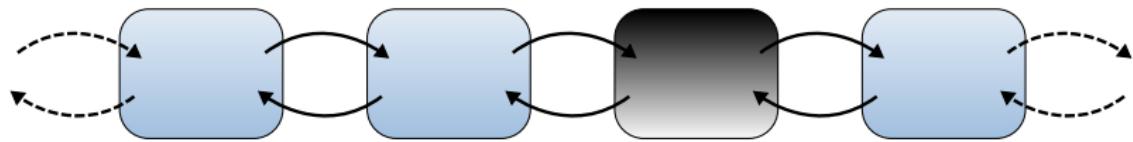
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now list

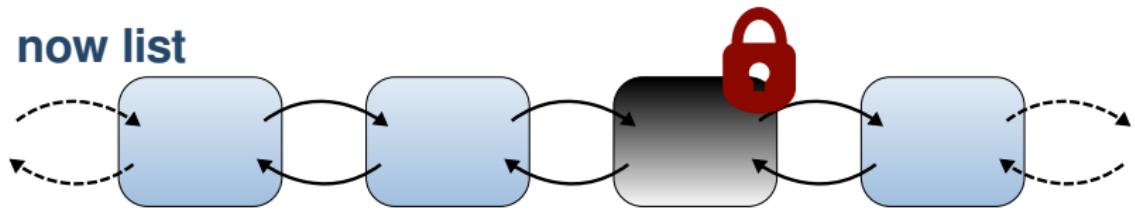


Locking concept: Remove node

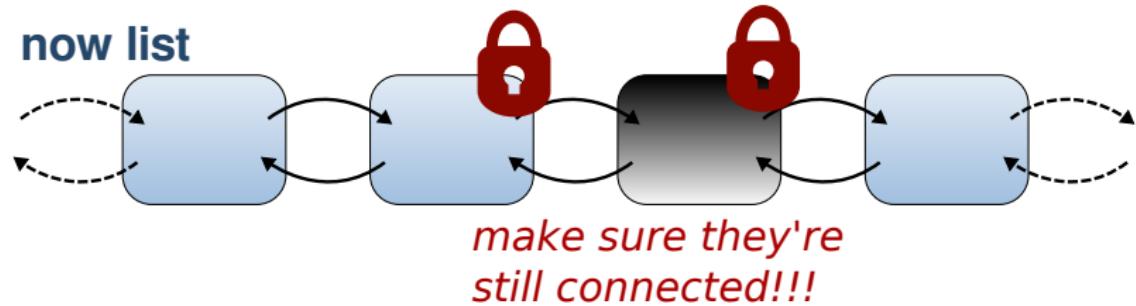
now list



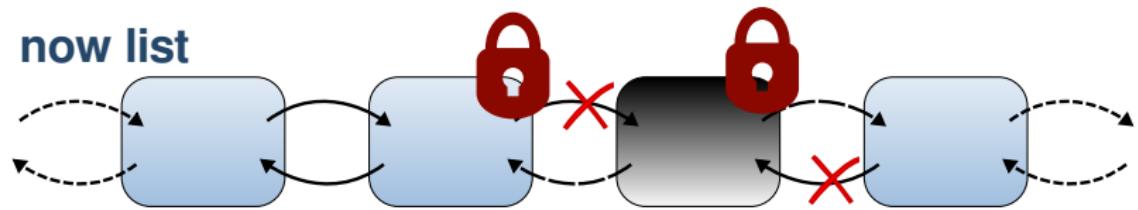
Locking concept: Remove node



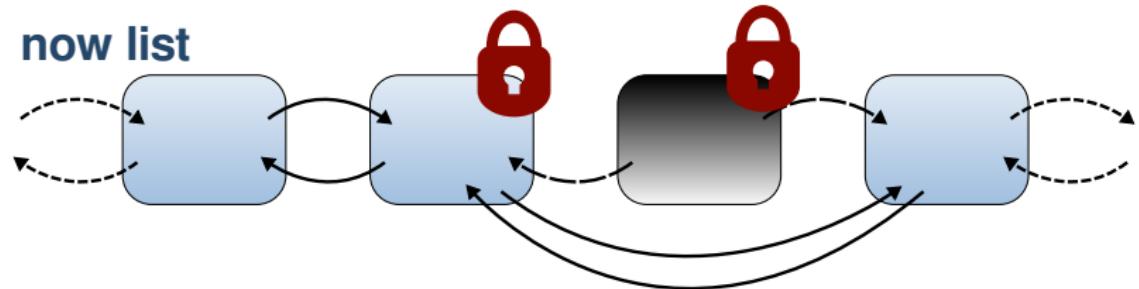
Locking concept: Remove node



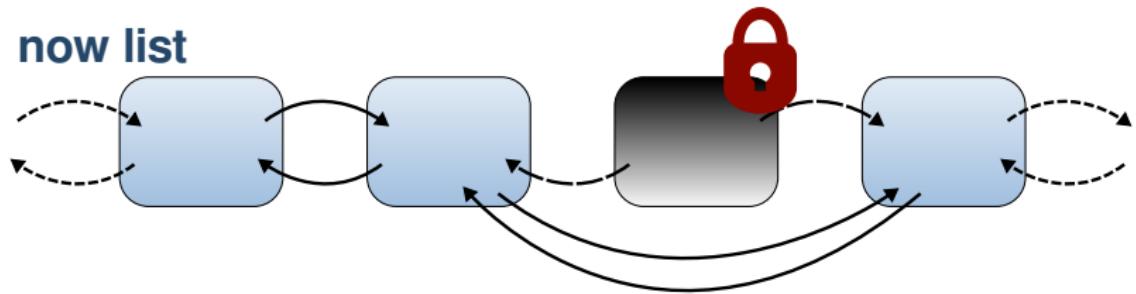
Locking concept: Remove node



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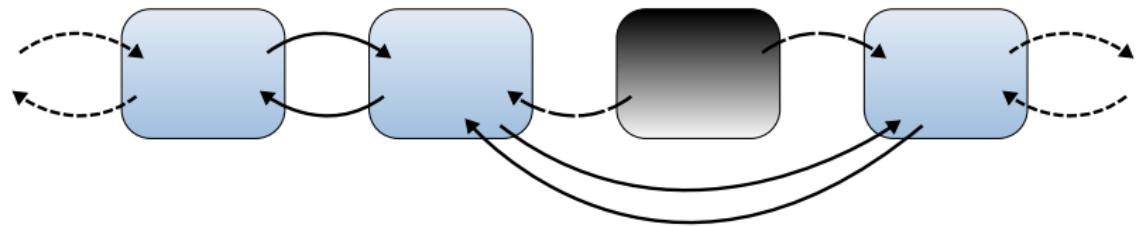


Locking concept: Remove node



Locking concept: Remove node

now list



Locking concept: 2 concepts for removing nodes

Both concepts use optimistic locking for acquiring the locks.

Normal:

- Lock node and predecessor as shown before and remove it right away

Lazy locking:

- Don't lock anything and just mark the node as removed
- Other threads will clean up and remove it later

Benchmarking

Setup:

Each of the following boxplots was generated from data from **50 runs** on **1 node** of kanifushi.inf.ethz.ch.

Specifications of kanifushi.inf.ethz.ch:

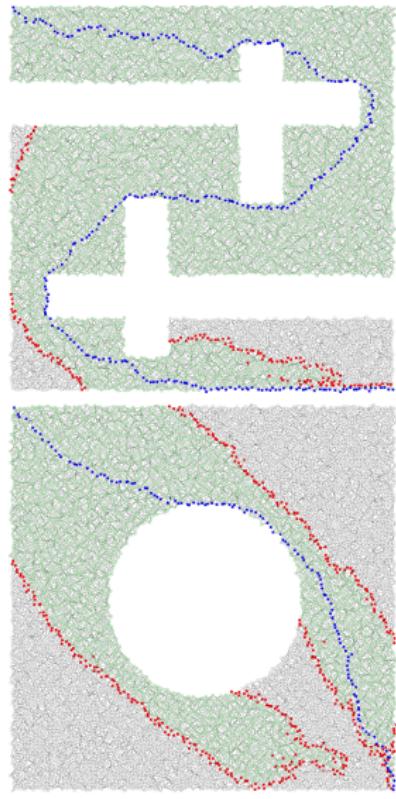
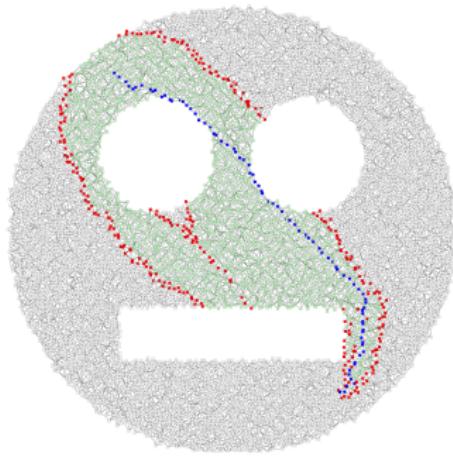
- NUMA model with 32 CPUs on 4 nodes
- 8 CPUs per node
- Intel(R) Xeon(R) CPU E7- 4830 @ 2.13GHz
- per CPU: 32KB L1 cache, 256KB L2 cache
- per node: 24MB L3 cache, 16GB memory

The code is written in C++ / Open MP and it has been compiled with g++ v. 4.6.1 using O1 optimization.

Benchmarking

Graphs

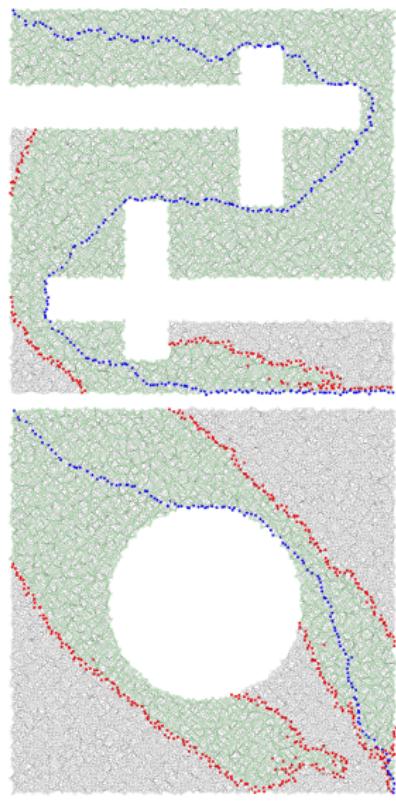
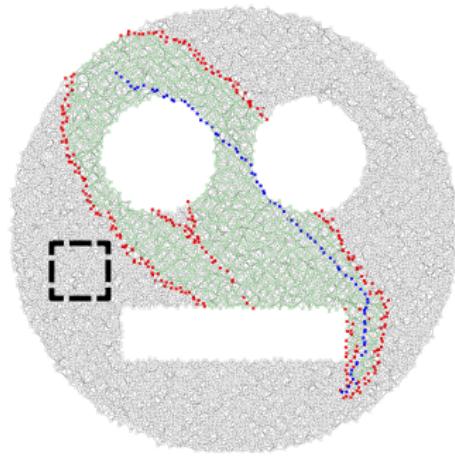
- based on a regular grid with distance 1 and 8 edges per node
- each node is moved randomly (normal distribution, $\sigma = 0.3$)
- different obstacles (circle, crosses, etc.)



Benchmarking

Graphs

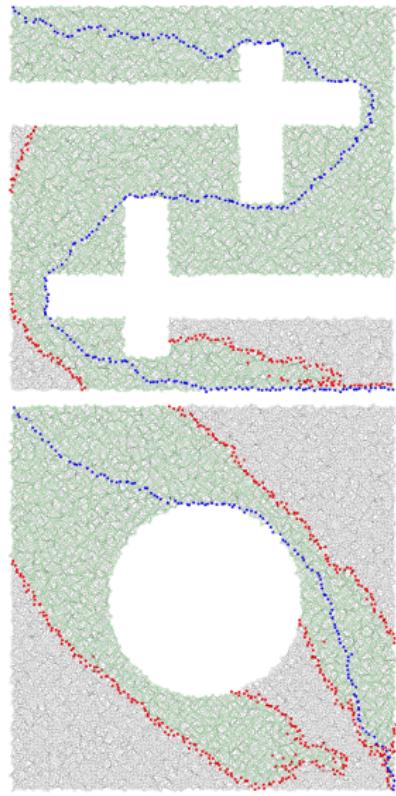
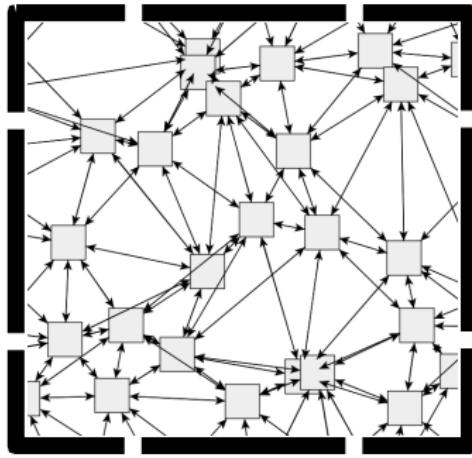
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Benchmarking

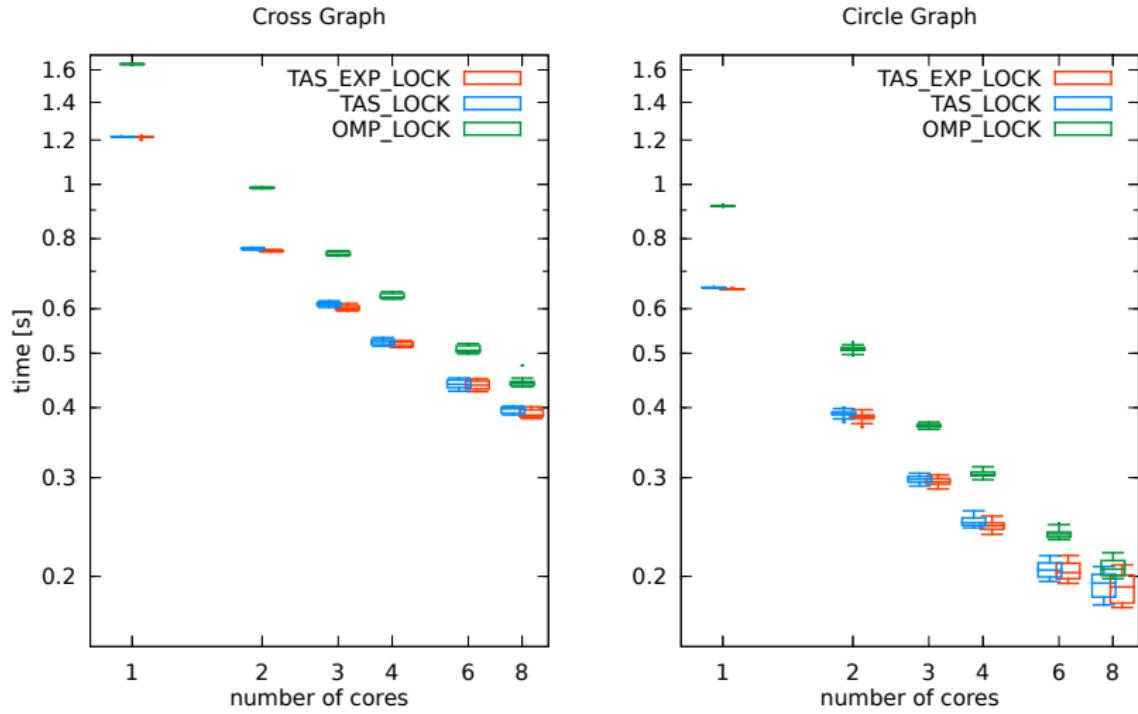
Graphs

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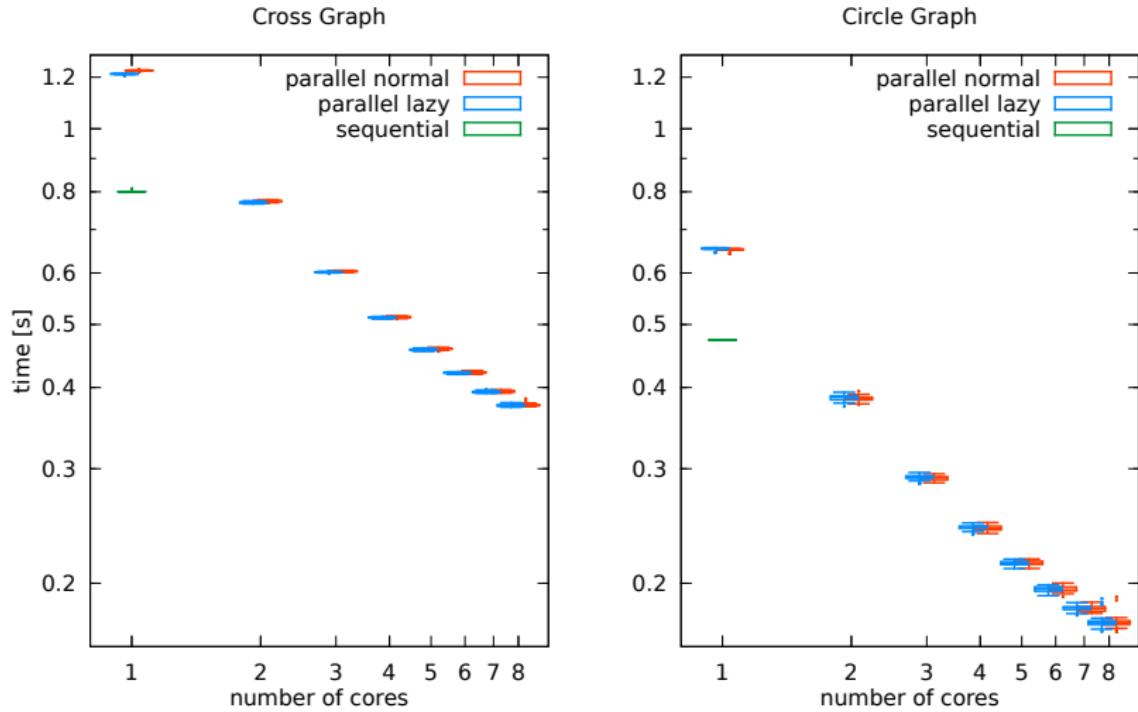
Benchmarking: Locks

Strong scaling 2048 x 2048, threshold=1



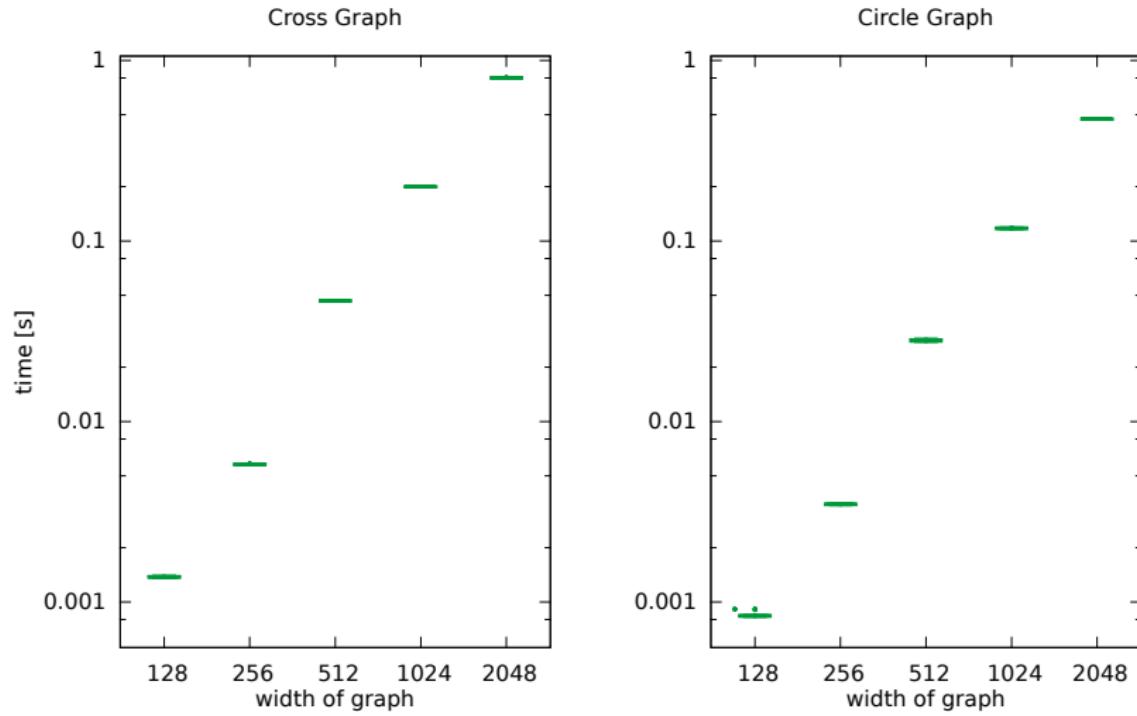
Benchmarking: Strong scaling

Strong scaling 2048 x 2048, threshold=1



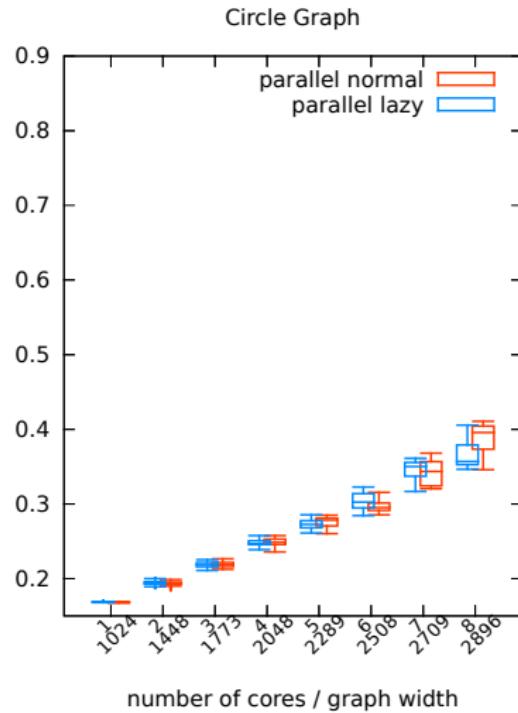
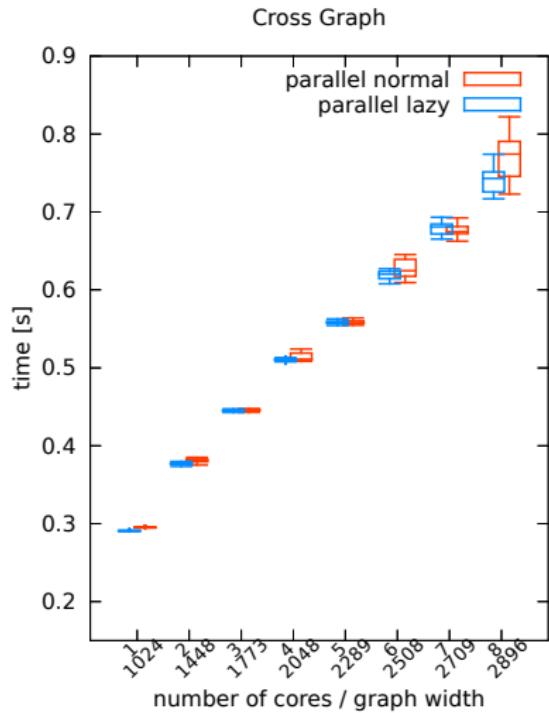
Benchmarking: Sequential scaling

Scaling sequential, threshold=1



Benchmarking: Weak scaling

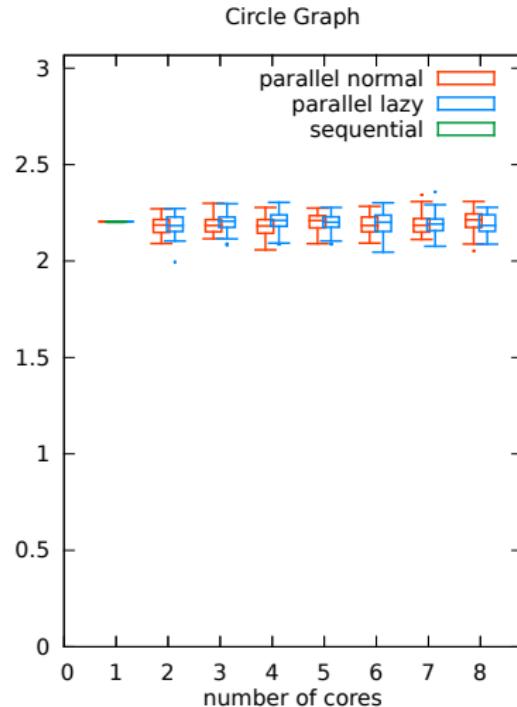
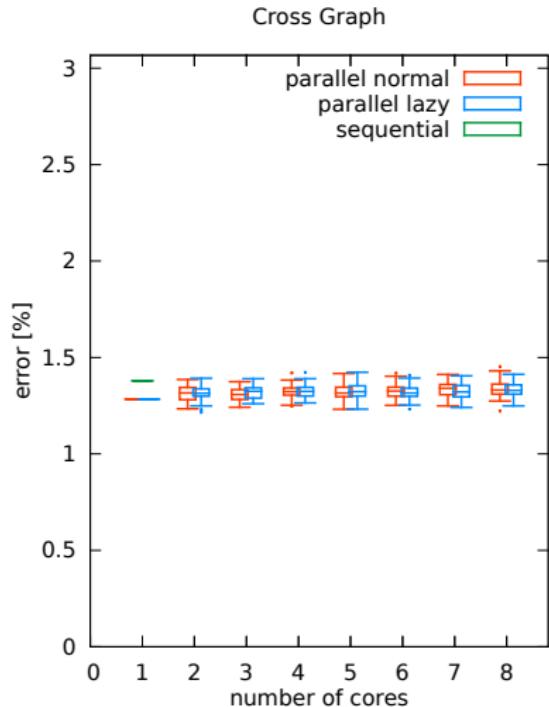
Weak scaling, threshold=1



Benchmarking: Path length \leftrightarrow # cores

compared to A* from Boost Graph Library

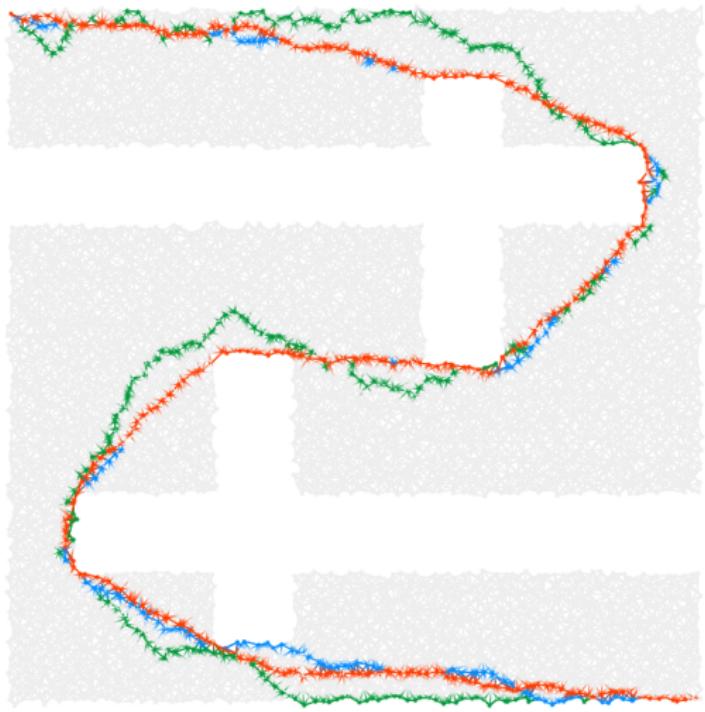
relative Error, 2048 x 2048, threshold=1



Benchmarking: Path length \leftrightarrow Threshold update

Threshold update

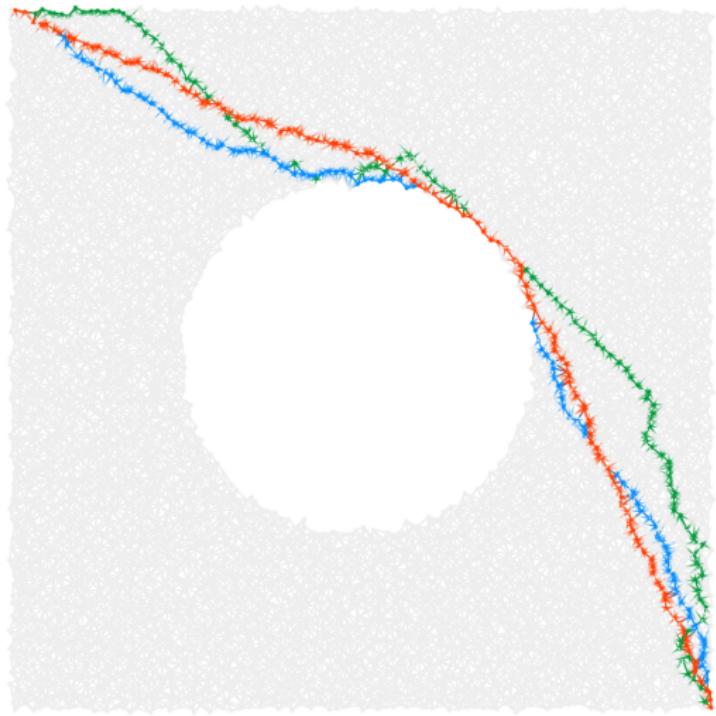
- threshold $+= 0.1$
- threshold $+= 1$
- threshold $+= 10$



Benchmarking: Path length \leftrightarrow Threshold update

Threshold update

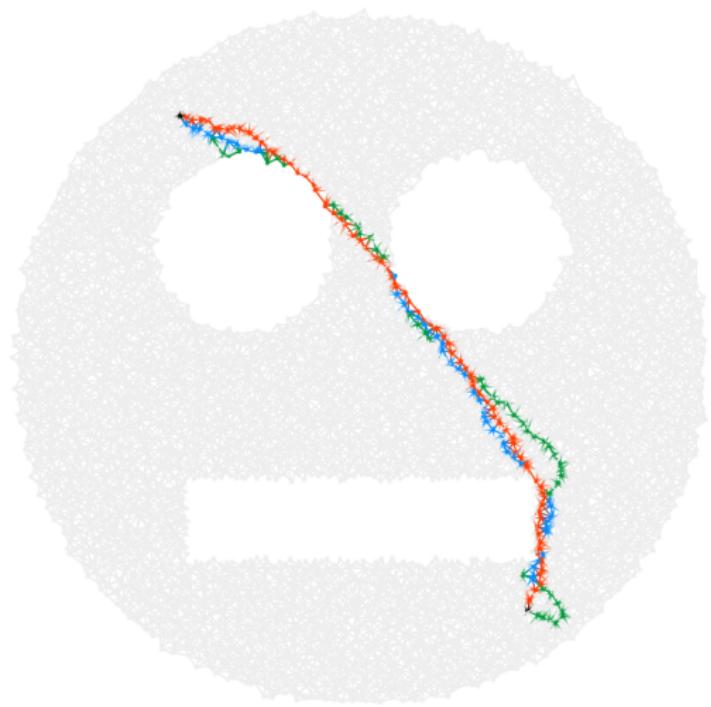
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Benchmarking: Path length \leftrightarrow Threshold update

Threshold update

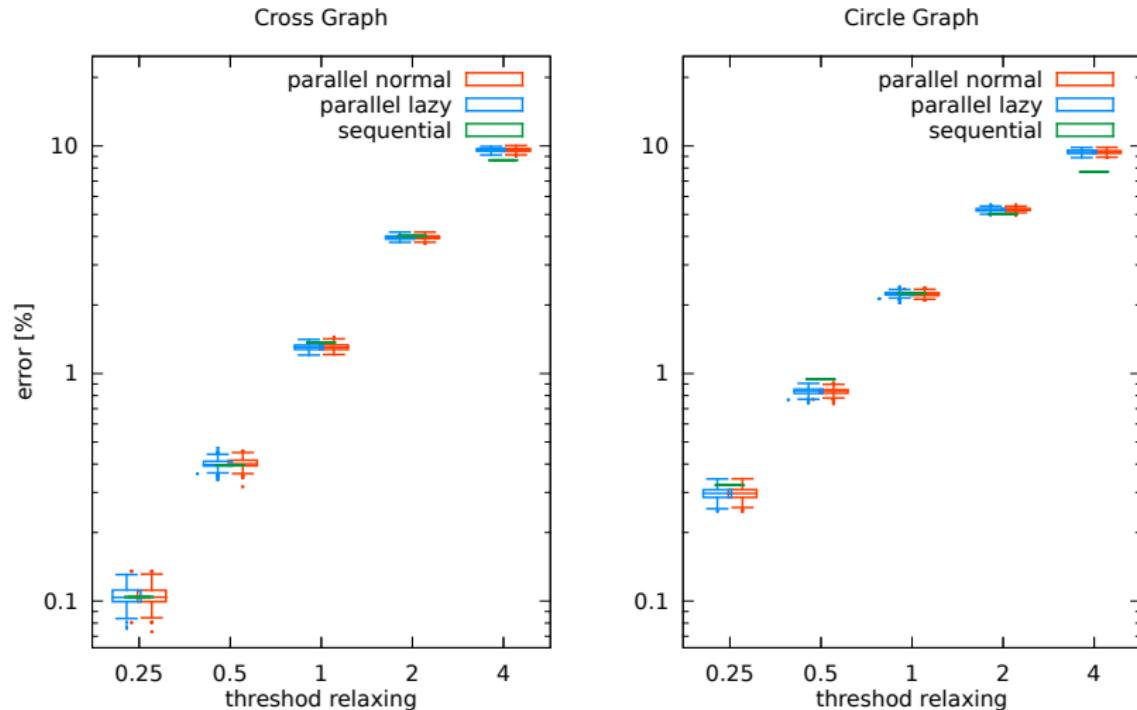
- threshold $+= 0.1$
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Benchmarking: Path length \leftrightarrow Threshold update

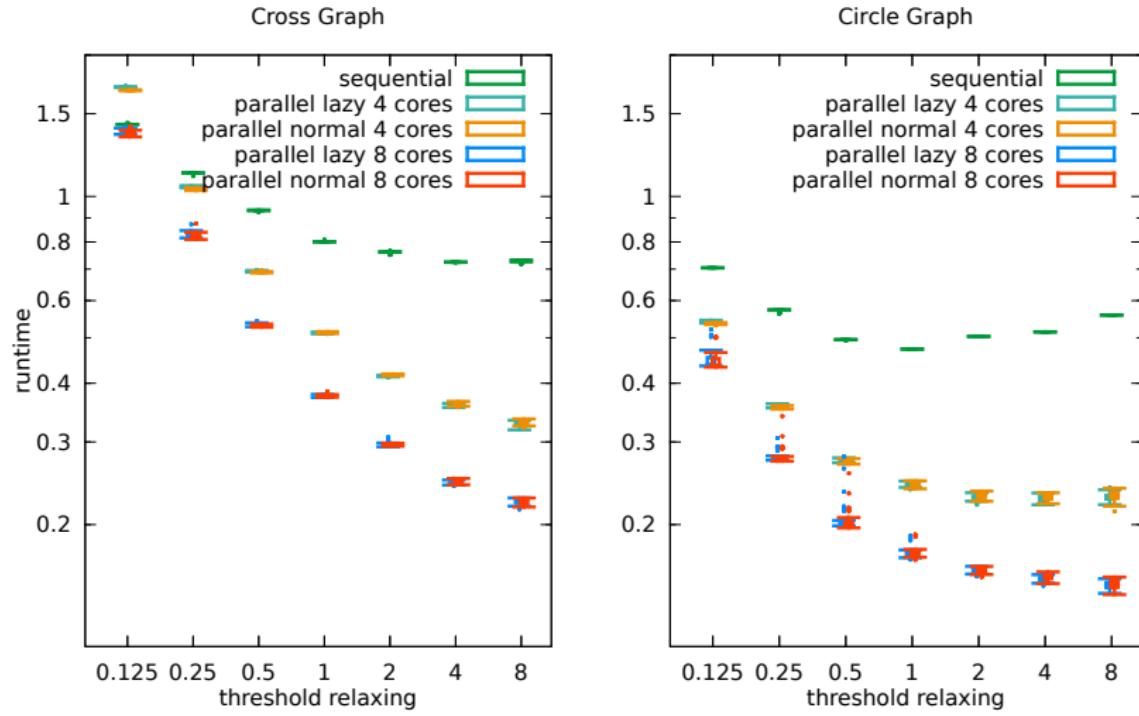
compared to A* from Boost Graph Library

relative Error, 2048 x 2048



Benchmarking: Run time \leftrightarrow Threshold update

runtime with different thresholds, 2048 x 2048



Conclusions

In general Fringe Search is a good single source shortest path algorithm, that can be well implemented in parallel.

- Path quality is not dependent of # cores
- Good strong scaling
- Weak scaling is not perfect
- quality \leftrightarrow runtime trade-off can be tuned for desired result

References / Related Work



Yngvi Björnsson, Markus Enzenberger, Robert C. Holte and Jonathan Schaeffer (2005)

Fringe Search: Beating A* at Pathfinding on Game Maps

Proceedings of the 2005 IEEE Symposium on Computational Intelligence and Games (CIG05), Essex University, Colchester, Essex, UK, 4-6 April, 2005



Sandy Brand (2009)

Efficient obstacle avoidance using autonomously generated navigation meshes

Master Thesis (Delft University of Technology)



Sandy Brand and Rafael Bidarra (2012)

Multi-core scalable and efficient pathfinding with Parallel Ripple Search

Computer Animation and Virtual Worlds, Volume 23, Issue 2 2012, pp 73 – 85.

The End