Retrofitted Parallelism Considered Grossly Sub-Optimal

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HotPar’12: Retrofitted Parallelism Considered Grossly Suboptimal

But Now We Use Computers To Solve Mazes
Goals
Goals (Why Was I Messing With Mazes???)
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- An example of near-perfect partitioning for “Is Parallel Programming Hard, And If So, What Can You Do About It?”

- Use case for RCU-protected union-find data structure
But First, A Sequential Maze Solver
Sequential Maze Solving (SEQ)
Sequential Maze Solving
Sequential Maze Solving
Sequential Maze Solving
Parallel Maze Solving: Work-Queue Approach
Parallel Work Queue (PWQ)
Parallel Work Queue

Start

End
Parallel Work Queue
Parallel Work Queue: Saved An Iteration!!!

But can you see the weak point?
Performance Comparison: PWQ vs. SEQ
Performance Comparison: PWQ vs. SEQ (Two Threads)
Everything I Need to Know, I Learned in Kindergarten
Everything I Need to Know, I Learned in Kindergarten

- In this case, when solving a maze, start at both ends!!!
Partitioned Parallel Solution (PART)
Partitioned Parallel Solution
Performance Comparison: SEQ vs. PWQ vs. PART
Performance Comparison: SEQ vs. PWQ vs. PART: Two Threads

Lots of overlap – are these really different???
Performance Comparison: SEQ vs. PWQ vs. PART

- The CDFs assume independence
- This is not true: data is highly correlated
  - Test script generates a maze, then runs all solvers on that same maze
  - CDFs lose the relationship between those solutions
Performance Comparison: SEQ vs. PWQ vs. PART

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  - Test script generates a maze, then runs all solvers on that same maze
  - CDFs lose the relationship between those solutions
- Preserve this relationship by taking CDF of ratios
  - SEQ/PWQ and SEQ/PART
Performance Comparison: SEQ/PWQ vs. PWQ/PART: Two Threads

Anything odd about this graph?
What is Going on Here???

- Median speedup of 4x on only two threads!!!
- Individual data points show speedups of up to 40x!!!
- This is not merely embarrassingly parallel
  - **Embarrassingly parallel:** Adding threads does not significantly increase the aggregate amount of work, resulting in linear scaling
What is Going on Here???

- Median speedup of 4x on only two threads!!!
- Individual data points show speedups of up to $40x$!!!
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  - Embarrassingly parallel: Adding threads does not significantly increase the aggregate amount of work, resulting in linear scaling
- This is humiliatingly parallel
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  - **Humiliatingly parallel:** Adding threads significantly decreases the aggregate amount of work, resulting in superlinear scaling
- Yeah, yeah, it is great to have a definition, but how is this happening???
What is Going on Here???

- First assumption: there is a bug in either the solver or the data-reduction scripts
  - There probably still is, but the solutions and times checked out
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  - SEQ and PWQ never visited fewer than 9% for 500x500 maze
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- The solver also prints the fraction of cells visited
  - SEQ and PWQ never visited fewer than 9% for 500x500 maze
  - But PART sometimes visited fewer than 2%!!!
Visit Fraction vs. Solution Time Correlation

But correlation is not causation, nor is it “why”...
Partitioned Parallel Solution
Partitioned Parallel Solution

The threads get in each others' way!
But Why The Separation Between PWQ and PART?
PWQ Has Many Potential Contention Points: Contention is Expensive
Does PART Always Achieve Humiliating Parallelism?
Does PART Always Achieve Humiliating Parallelism?
Partitioning is a Powerful Parallelization Tool
Partitioning is a Powerful Parallelization Tool
But Let's Not Forget Sequential Optimizations!!!
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But Let's Not Forget Sequential Optimizations!!!

-O3 much better than PWQ, almost as good as PART!
Compiler Optimizations Beat PWQ!!!

- Yes, PART is even better, but if all you need is a 2x improvement (rather than optimality), compiler optimization is an extremely attractive option.

- These results indicate that parallel-programming research making use of high-level/overhead languages is vulnerable to invalidation given improvements in optimization.
And The Threads Will Get In Each Other's Way Even If They Are Running on One CPU... (Coroutines!!!)
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Effect Of Maze Size

Back to merely modest speedups!
Effect Of Increasing Numbers of Threads

Larger, older, less tightly integrated HW: Smaller speedups
Summary and Conclusions
How Did I Do Against My Goals?
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- An example of near-perfect partitioning for “Is Parallel Programming Hard, And If So, What Can You Do About It”
  - Not so good!
  - From modestly scalable to humiliatingly parallel and back again

- Use case for RCU-protected union-find data structure
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  - No need for RCU in this problem
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- On the other hand, this problem turned out to be interesting in its own unexpected way!
  - And a nice change of pace from Linux kernel's RCU implementation
Open Questions

- Can other human-maze-solver techniques be applied?
  - Follow walls to exclude portions of maze
  - Choosing internal starting points based on traversal

- Do these results apply to unsolvable or cyclic mazes?

- Do other problems exhibit humiliating parallelism?

- Does humiliating parallelism always lead to a more-efficient sequential solution?

- How much current parallel-programming research can stand up to improved optimization?
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- Does humiliating parallelism always lead to a more-efficient sequential solution? (No, it does not.)

- How much current parallel-programming research can stand up to improved optimization?
Conjecture

- Conjecture (Due to Jon Walpole):
  - Thinking from a parallel perspective leads to a much more efficient search strategy.
  - It is not the parallelism of the implementation that is important, but rather the parallelism of the strategy.
Parting Words of Advice

▪ Apply parallelism as a first-class optimization technique
  – Apply at as high a level as possible, to full application
  – Often simplifies solution
  – Usually reduces synchronization overhead, thereby improving both performance and scalability

▪ In contrast, retrofitted parallelism is likely to be grossly suboptimal
  – Especially when applied as a low-level after-the-fact optimization
  – Might be OK in some situations, but we can do much better
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Questions?