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ParaFormance: An Advanced Refactoring Tool for Parallelising C++ Programs

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C++ Meetup Edinburgh – November 2015

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RePhrase Project: Refactoring Parallel Heterogeneous Software – a Software Engineering Approach (ICT-644235), 2015-2018, €3.6M budget

8 Partners, 6 European countries
UK, Spain, Italy, Austria, Hungary, Israel

IBM

evopro it's possible!

PRQA Programming Research

scch software competence center hagenberg

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ALMA UNIVERSITAS TAURINENSIS

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The ParaFormance Project

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- Seed Funding from Scottish Enterprise
  - 1-3 years pre-commercialisation funding
  - Develop work from EU/UK publicly-funded projects
- Start Date
  - 1st June 2015
- Led by: Kevin Hammond and Chris Brown, University of St Andrews

The Dawn of a New Age

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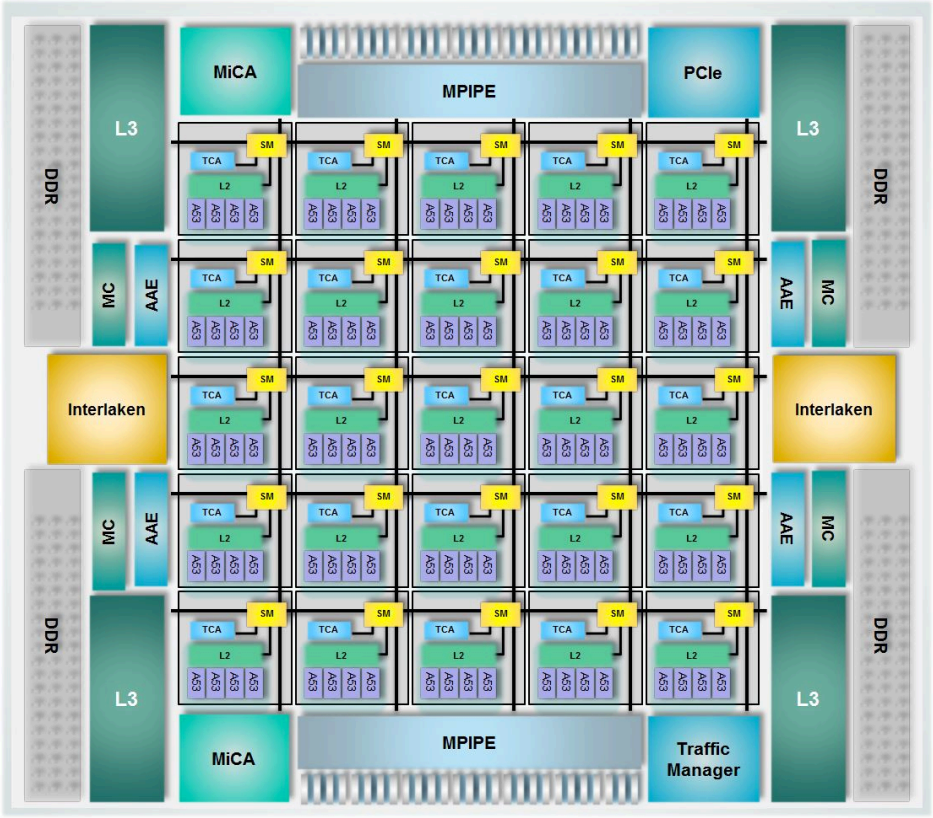

- EZCHIP – TILE-MX100
- 100 64-bit AMD x86 Cores
- 3-level cache with > 40 Mbytes on-chip cache
- Multitude of network accelerators
- Over 200Gbps integrated I/O including Ethernet,
- DDR supports up to 1 TB RAM

It's not just about large systems

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- Even mobile phones are multicore
  - Samsung Exynos 5 Octa has 8 cores, 4 of which are "dark"
- Performance/energy tradeoffs mean systems will be increasingly parallel
- If we don't solve the multicore challenge, then no other advances will matter!

ALL Future Programming will be Parallel!

Programing Multicore Systems…

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Thinking in Parallel

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- Fundamentally, programmers must learn to ***"think parallel"***
  - this requires new *high-level* programming constructs
  - you cannot program effectively while worrying about deadlocks etc.
    - they must be eliminated from the design!
  - you cannot program effectively while fiddling with communication etc.
    - this needs to be packaged/abstracted!
  - you cannot program effectively without performance information
    - this needs to be included!
- **We use two key technologies:**
  - **Refactoring (changing the source code structure)**
  - **Parallel Patterns (high-level functions of parallel algorithms)**

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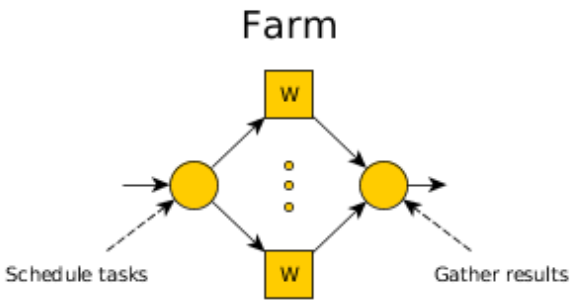
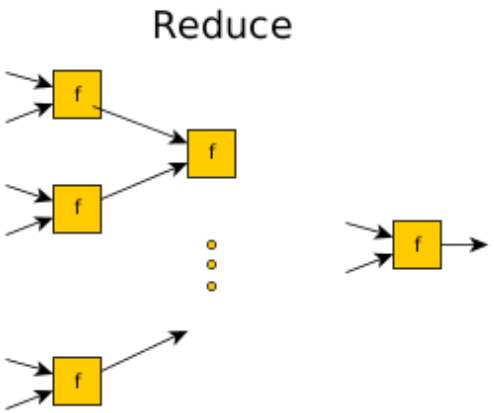
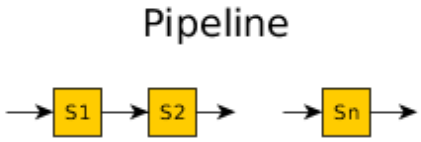
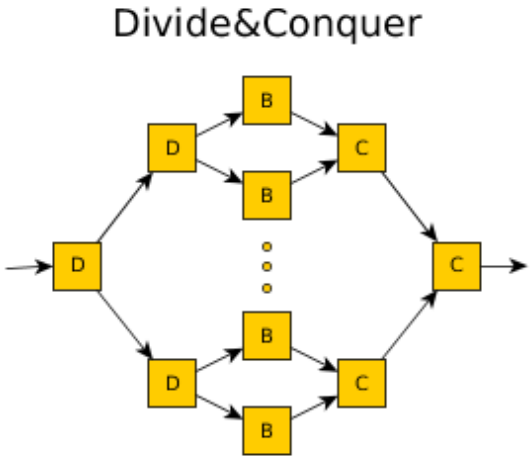
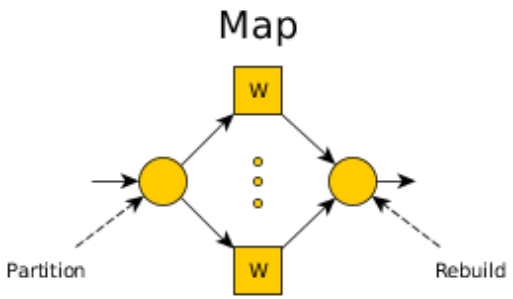
Parallel Patterns











Our Approach

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- Start bottom-up
  - Identify components (side-effect free functions that correspond to parallel computations)
  - *using semi-automated refactoring*
- Think about the **PATTERN** of parallelism
  - e.g. map(reduce), task farm, parallel search, parallel completion, …
- Structure the components into a parallel program
  - *turn the patterns into concrete (skeleton) code*
  - Take performance, energy etc. into account (multi-objective optimisation)
  - also using refactoring
- Restructure if necessary!
  - *also using refactoring*

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General Technique

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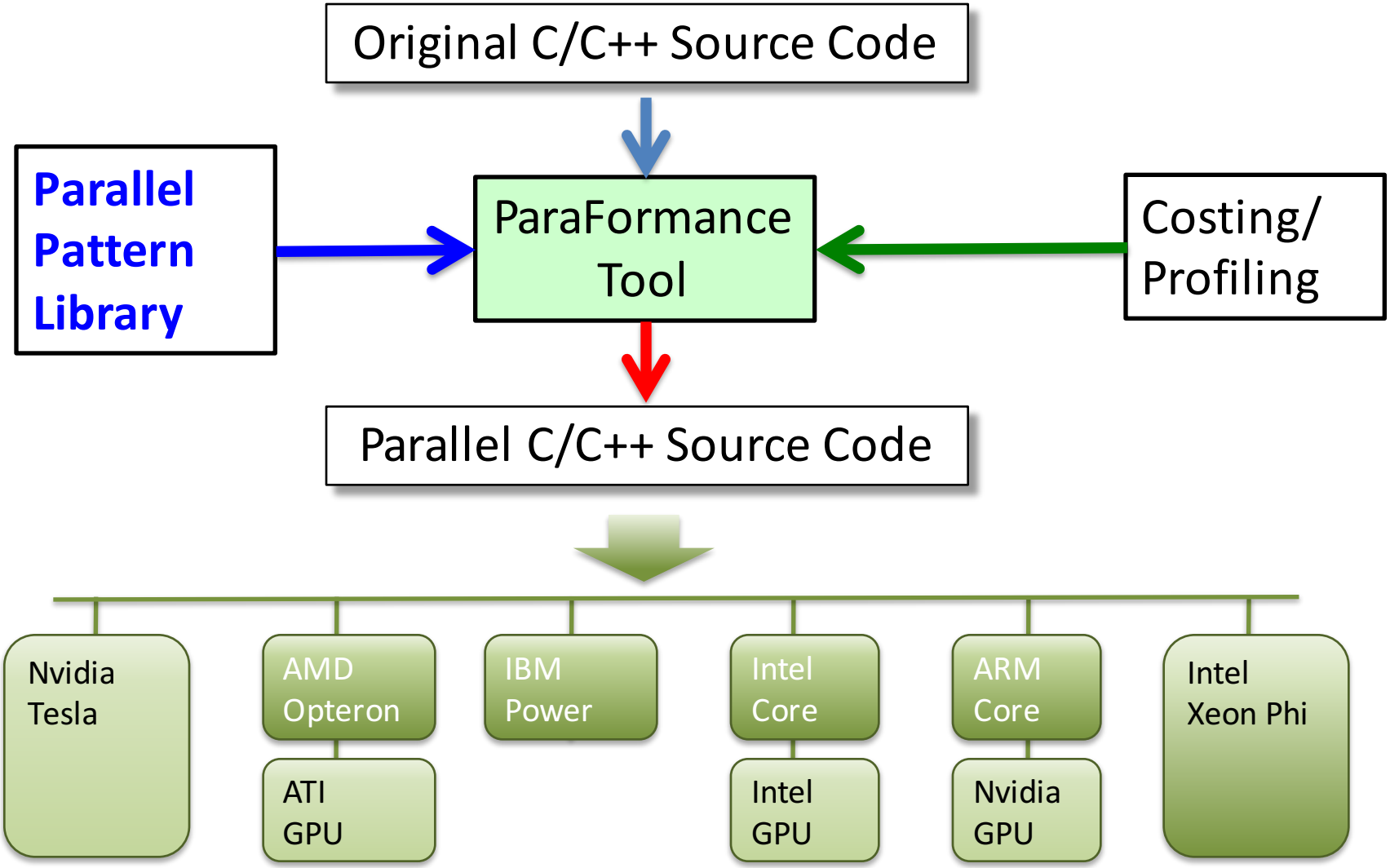

Sequential Refactoring

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Semi-automated (user-driven)

1. Renaming
2. Inlining
3. Changing scope
4. Adding arguments
5. Generalising Definitions
6. Type Changes

Examples include refactoring Linux kernels using Cocinelle, refactoring Java/C++ in Eclipse, etc.

Refactoring = Condition + Transformation

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Transformation

- Ensure change at all points needed.
- Ensure change at only those points needed.

Condition

- Is the refactoring applicable?
- Will it preserve the “semantics” of the program?
- The module? The File?

Both pre- and post- conditions

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Refactoring can help parallel thinking!

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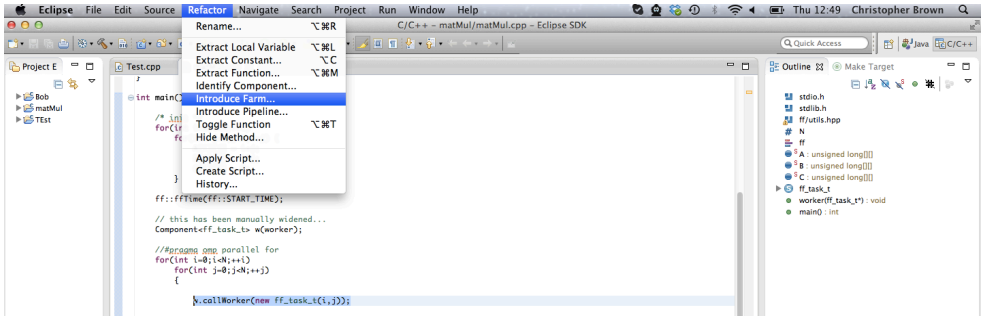
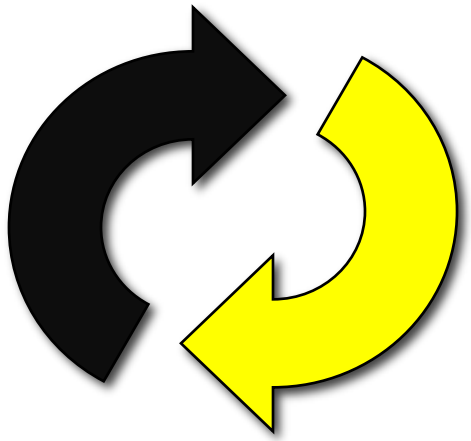
- can be used to introduce parallelism, and help choose the right abstraction
- parallel programs can be refactored for new parallel architectures
- can check the conditions for applying parallel skeletons
- performance information can be integrated
- Programmer 'in the loop'





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The ParaFormance Tool Prototype

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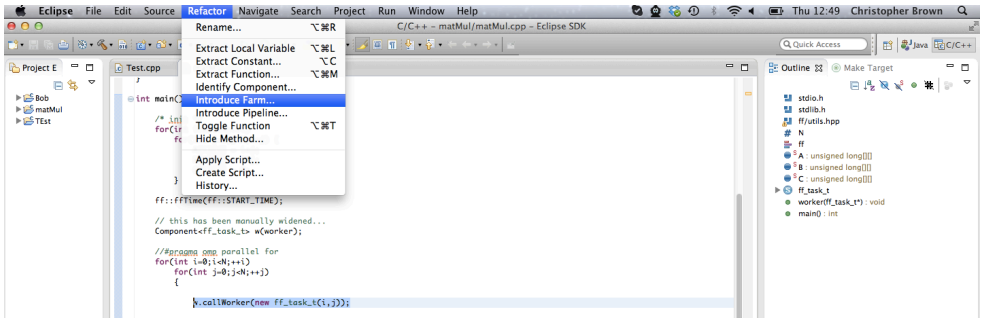
- Integrated into Eclipse (CDT)
- Supports full C++(11) standard
- Layout and comment preserving
- Undoable
- Preview feature



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Our Refactorings

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- Refactorings to Introduce:
  - Farm/Map, Parallel-For and Pipeline patterns
  - FastFlow
    - Components
    - Farm
    - Pipeline
  - TBB
    - Lambda
    - Function Class
    - Parallel For/Pipeline
  - OpenMP
    - Parallel-For

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The ParaFormance Toolkit

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1. Prediction/Estimation
   - Accurate and advance performance modelling
2. Discovery
   - Automatic discovery of (instances of) parallel patterns
3. Insertion
   - Automatically insert the parallel “Business Logic”
4. Elimination
   - Remove exisiting/legacy parallelism
5. Validity
   - Fundamental condition checks
6. Profile
7. Shaping

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Image Convolution

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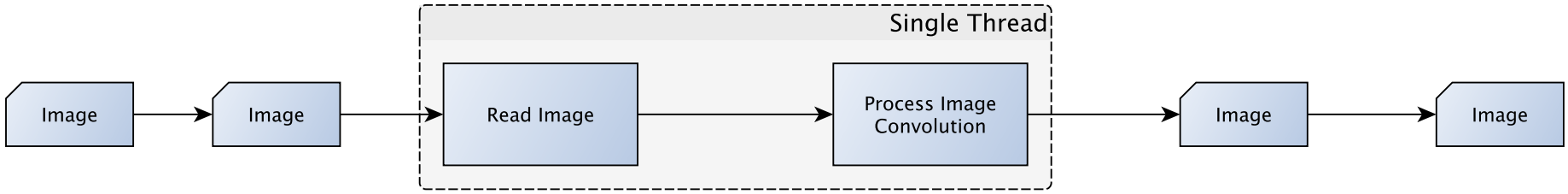

Image Convolution, Refactored

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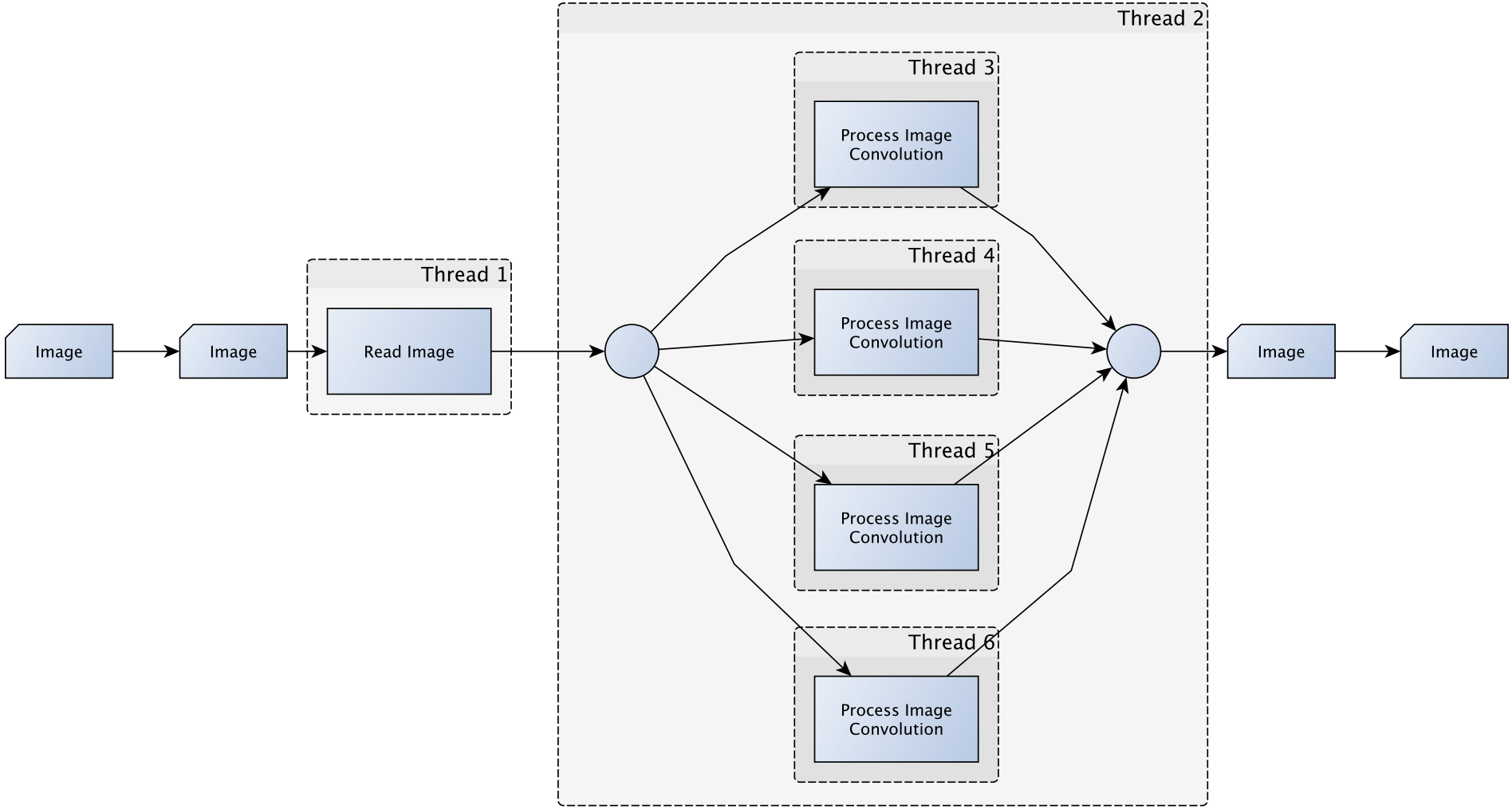

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C++ Refactoring Demo

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Image Convolution

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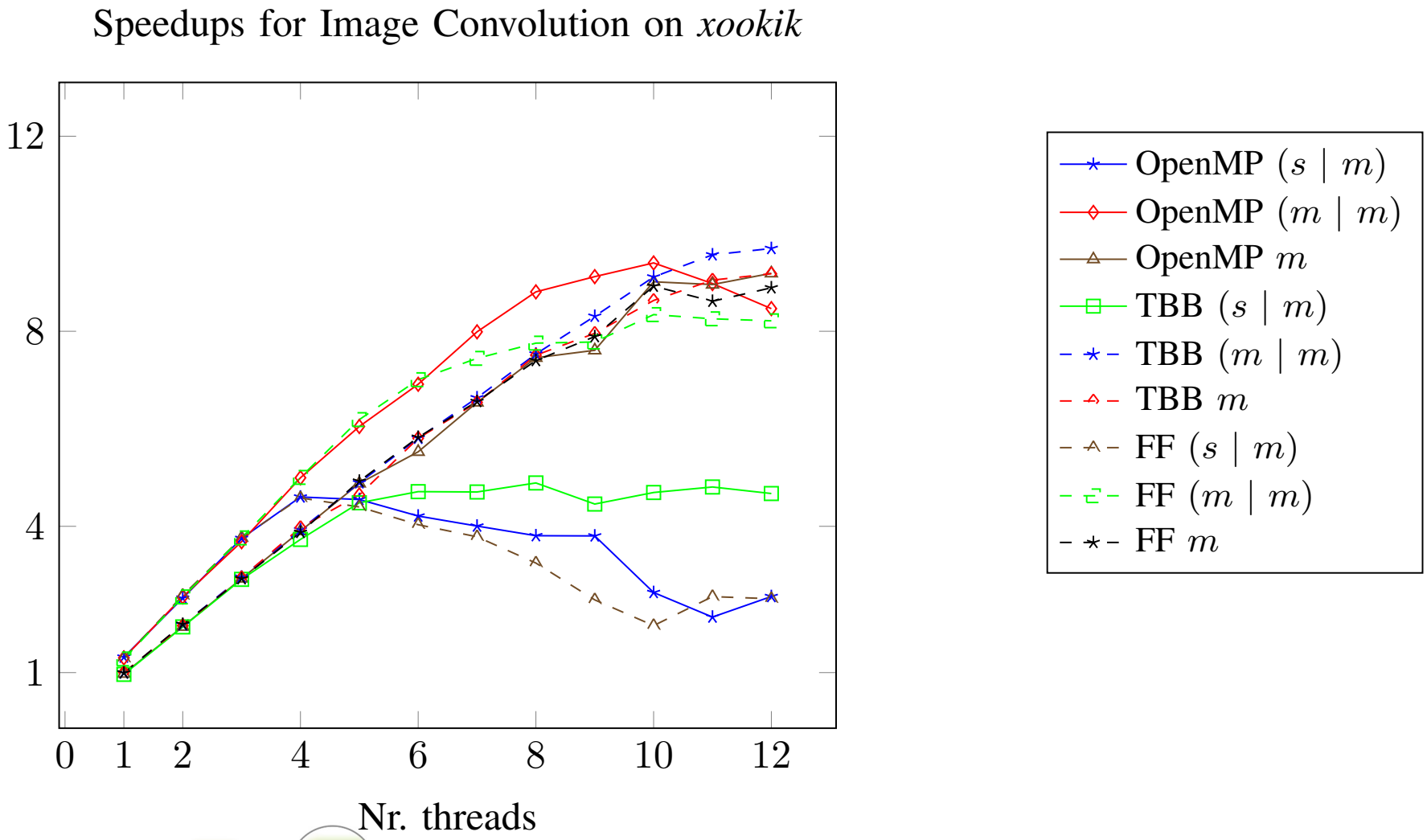

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Image Convolution

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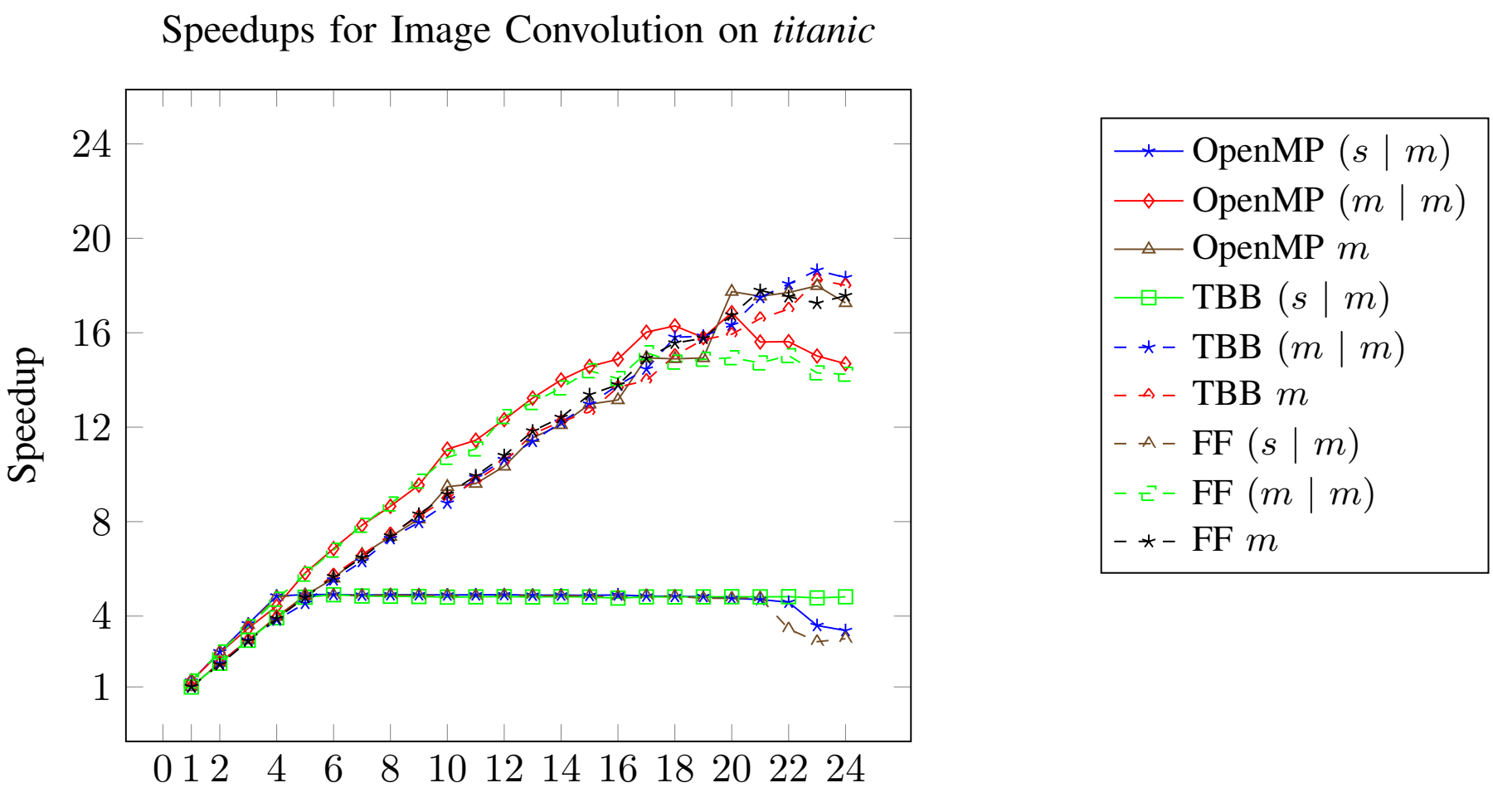

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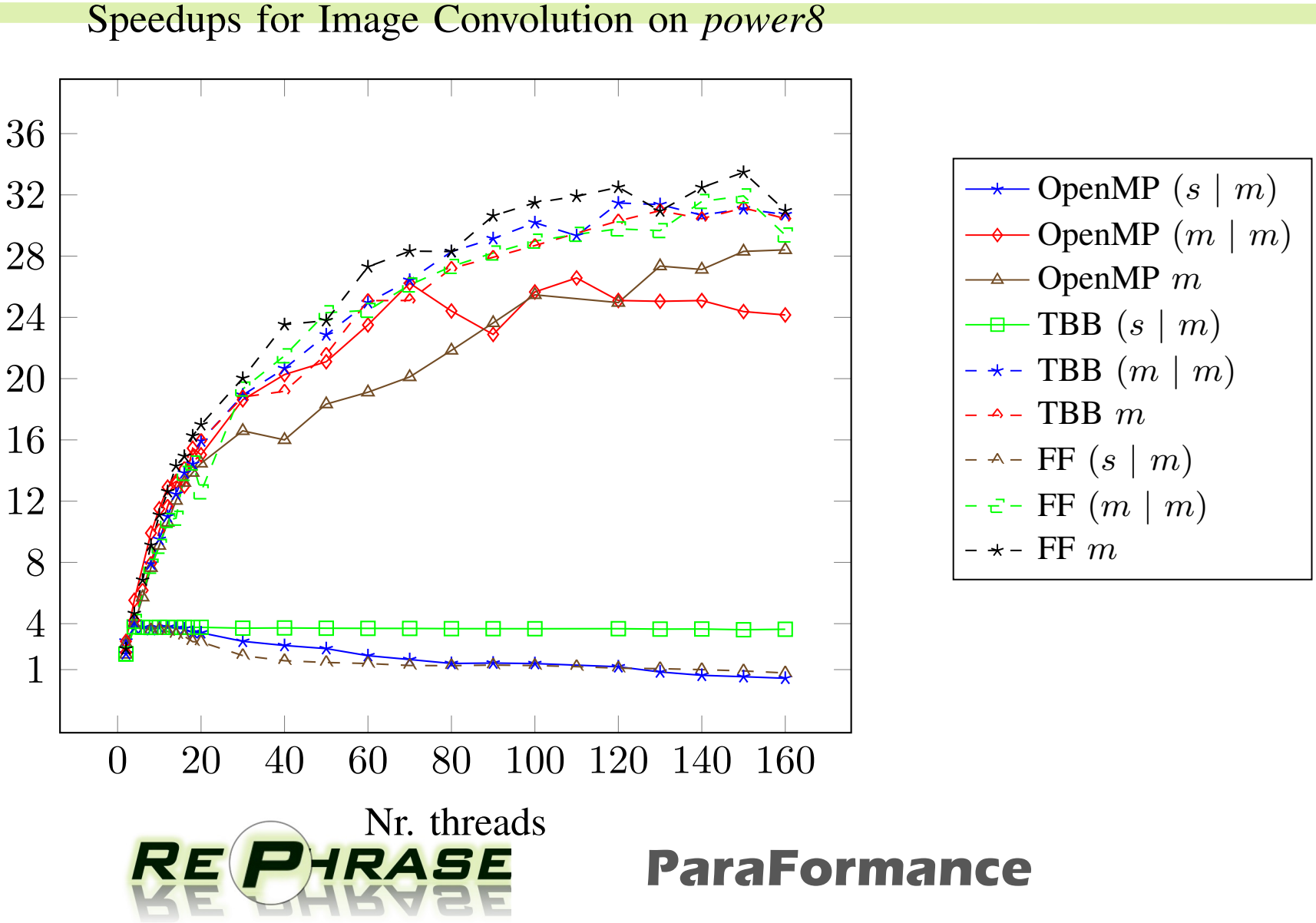
Image Convolution – 20 Cores!



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Comparable Performance

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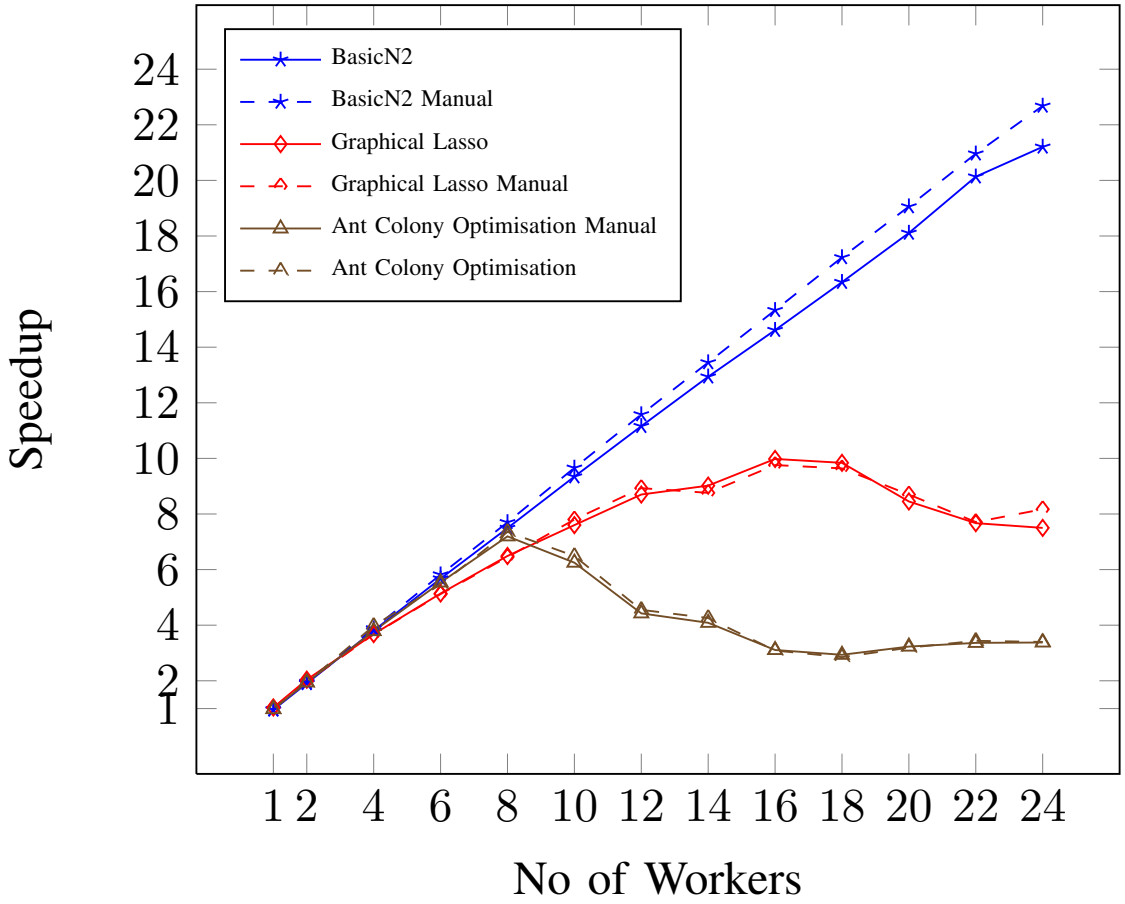
Speedups for Ant Colony, BasicN2 and Graphical Lasso



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Conclusions

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- Refactoring tool support:
  - Guides a programmer through steps to achieve parallelism
  - Warns the user if they are going wrong
  - Avoids common pitfalls
  - Helps with understanding and intuition
  - Reduces amount of boilerplate code
    - Allows programmer to concentrate on algorithm, rather than parallelism.

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  - access to free development software
  - chat to the developers
  - free developer workshops
  - bug tracking and fixing
  - Tools for both Erlang and C++
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