Subsuming Methods: Finding New Optimisation Opportunities in OO Software

David Maplesden
John Hosking
Ewan Tempero
John Grundy

The University of Auckland
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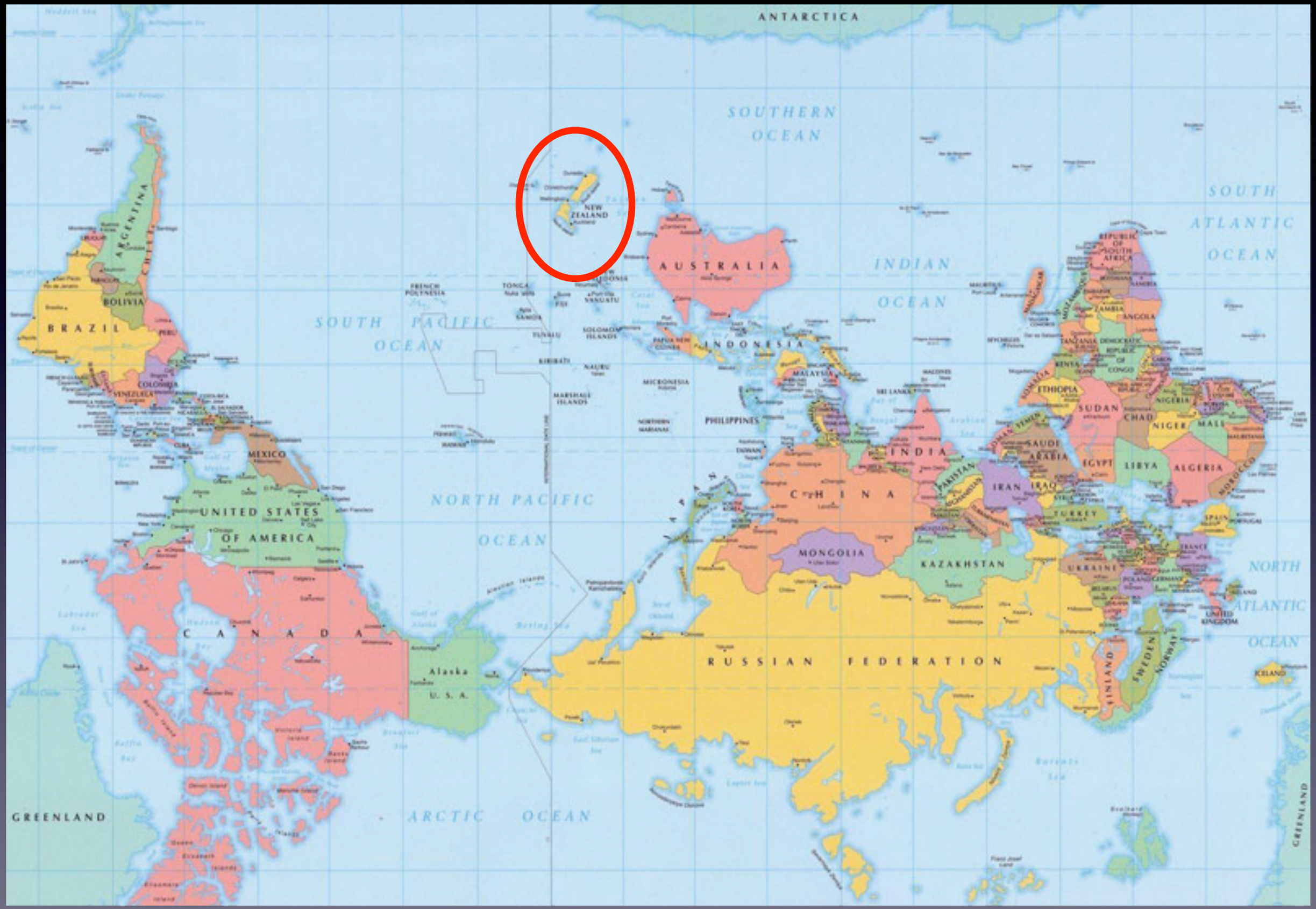
Performance is Important

- Cloud computing costs
- Resource constrained environments
    - Mobile applications
- Lost business - Amazon 100ms delay = 1% sales
- Failed projects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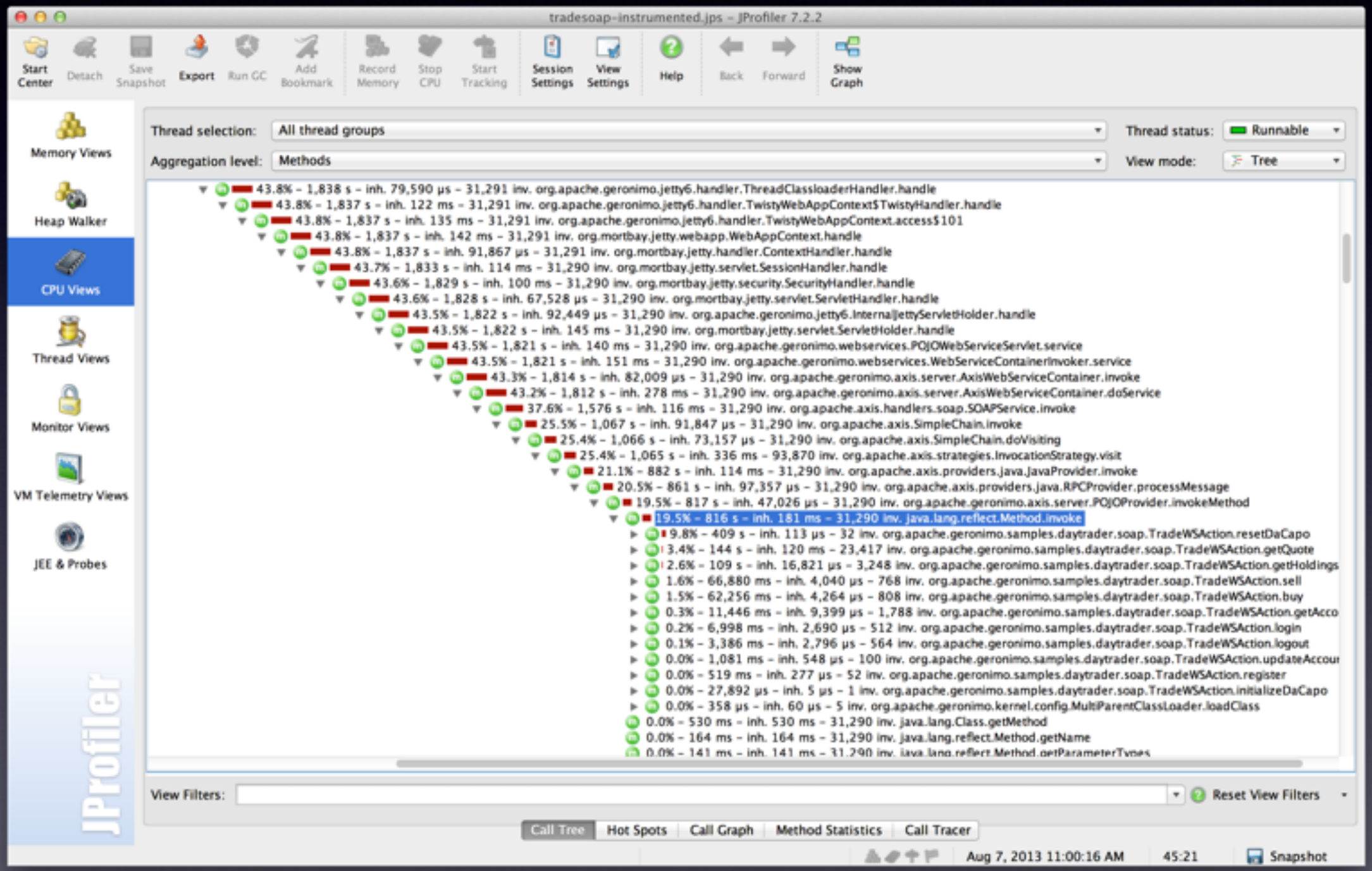
Focus

- Large-scale object-oriented software
  - Ubiquitous in industry
- Late-cycle empirical performance analysis
  - a.k.a. profiling and tuning
  - Complementary to model-based predictive methods
- *Analysis* - the neglected backward path

A ‘modern’ profiler



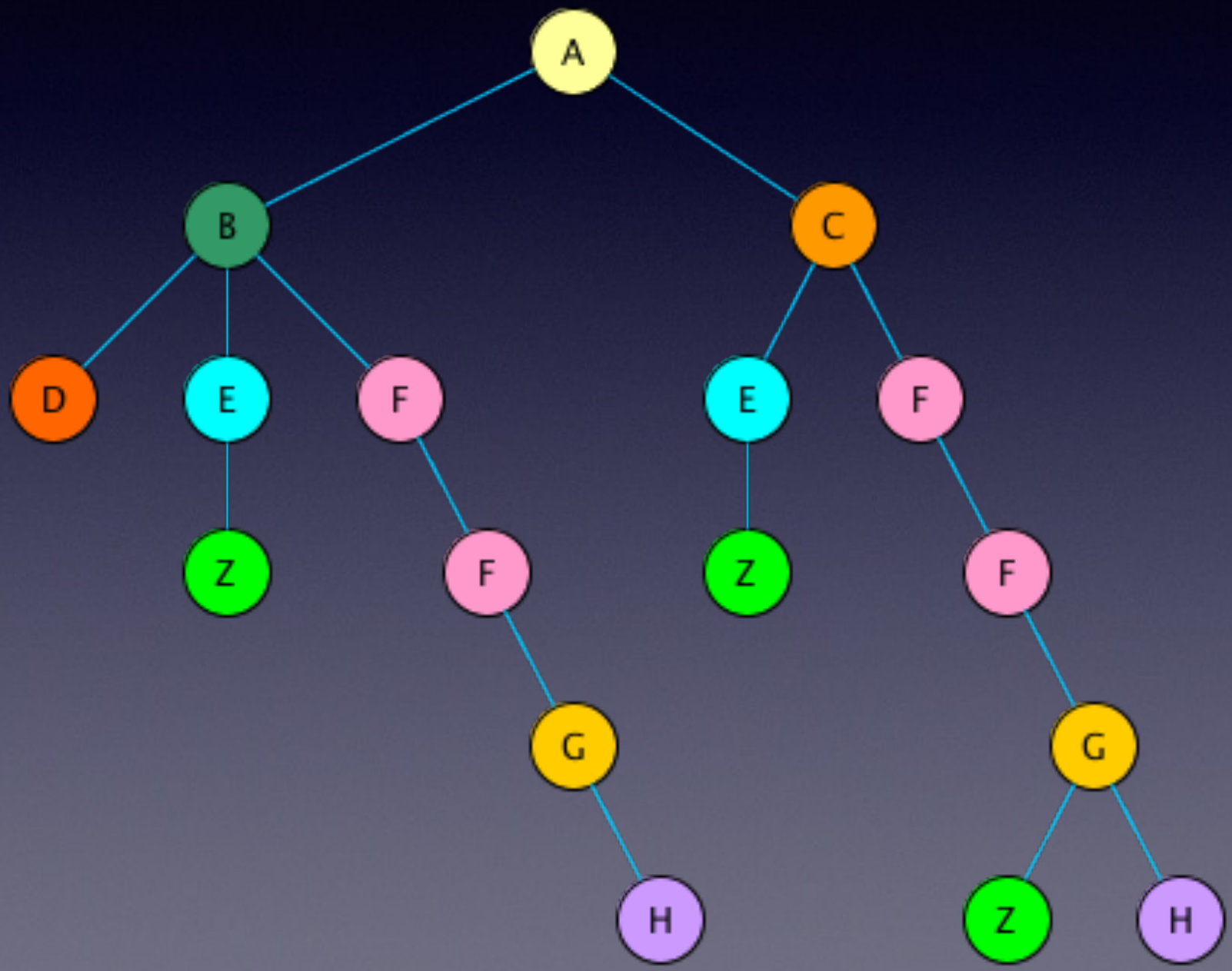
Challenges of OO software

- Numerous small methods
- Heavily layered architecture
    - Engineered for maintainability and reuse
    - Reusable frameworks, more abstractions
    - *Runtime bloat*
- Complex, thinly distributed, runtime behaviour
- Challenging to identify optimisation opportunities

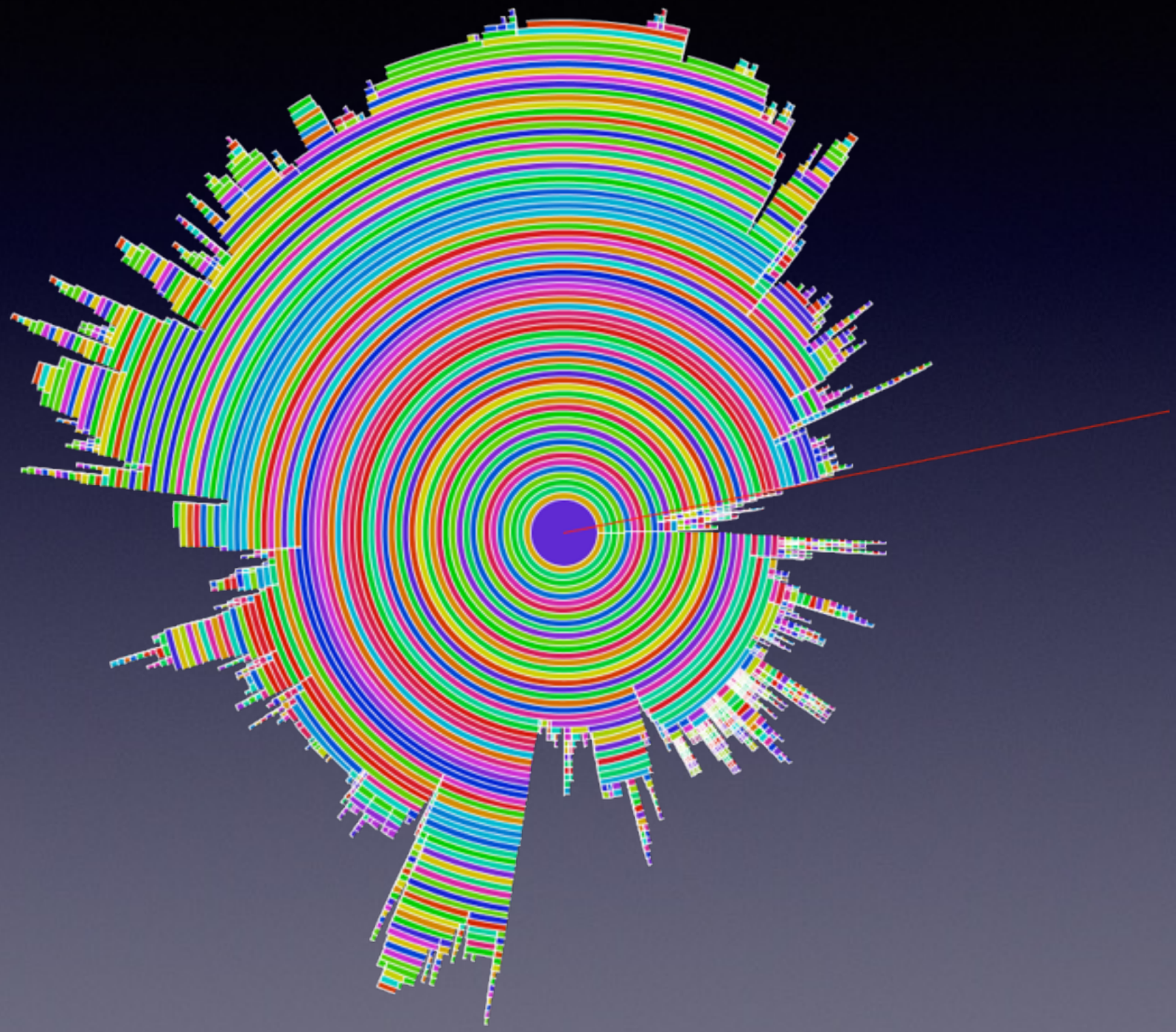
Hot methods - DaCapo fop benchmark

Method	Occurrences in CCT	% Exclusive Time
sun.misc.FloatingDecimal.dtoa	348	6.876
java.text.DigitList.set	374	5.245
java.text.DecimalFormat.subformat	374	3.110
org.apache.fop.fo.properties.PropertyMaker.findProperty	1501	2.461
java.lang.String.equals	4666	1.853
sun.nio.cs.US_ASCII$Encoder.encode	568	1.788
sun.misc.FloatingDecimal.countBits	348	1.556
java.util.HashMap.hash	10663	1.506
java.util.HashMap.getEntry	6081	1.342
java.lang.String.indexOf	3343	1.295

Background - Calling Context Trees



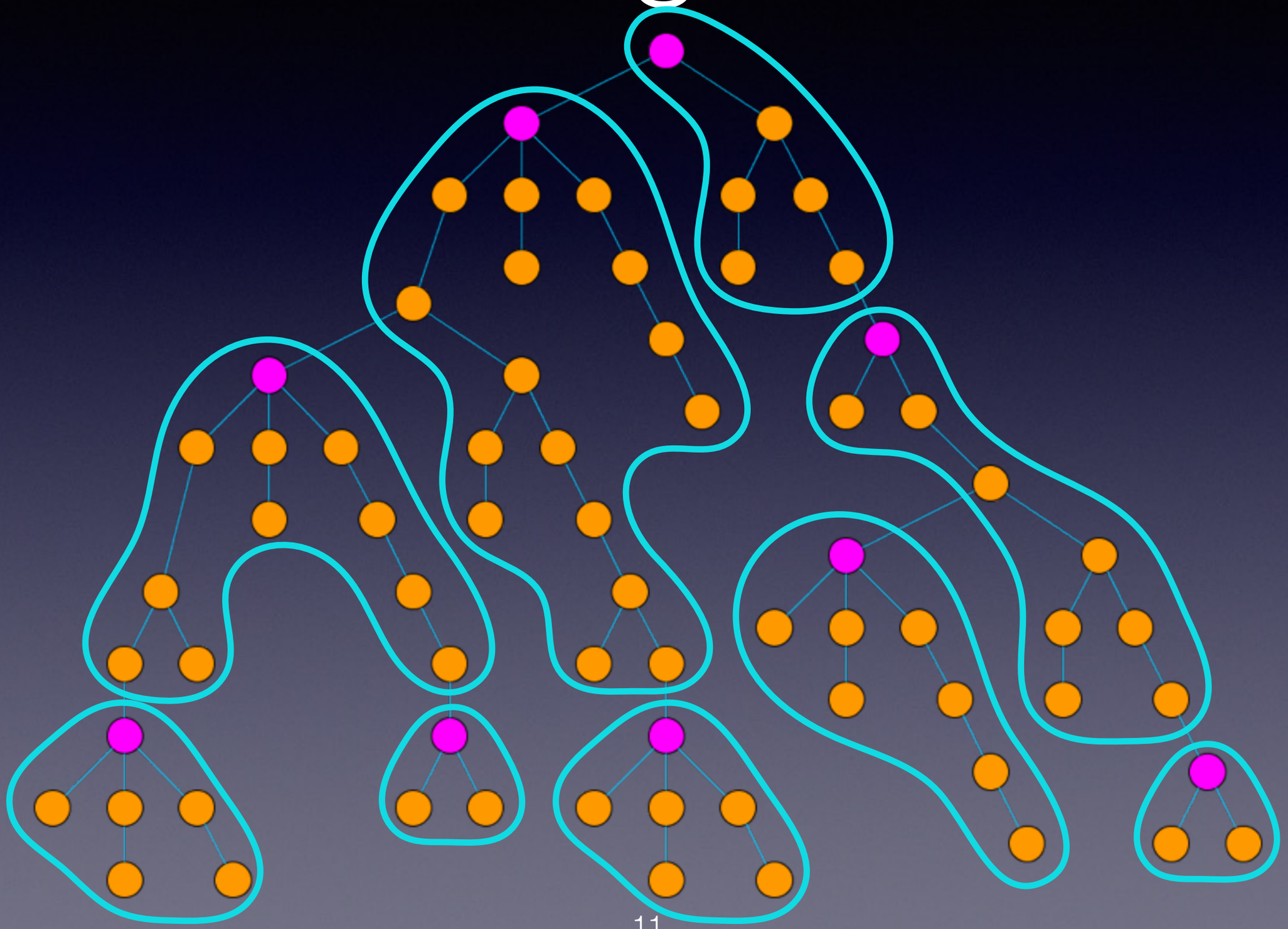
Calling Context Ring Chart



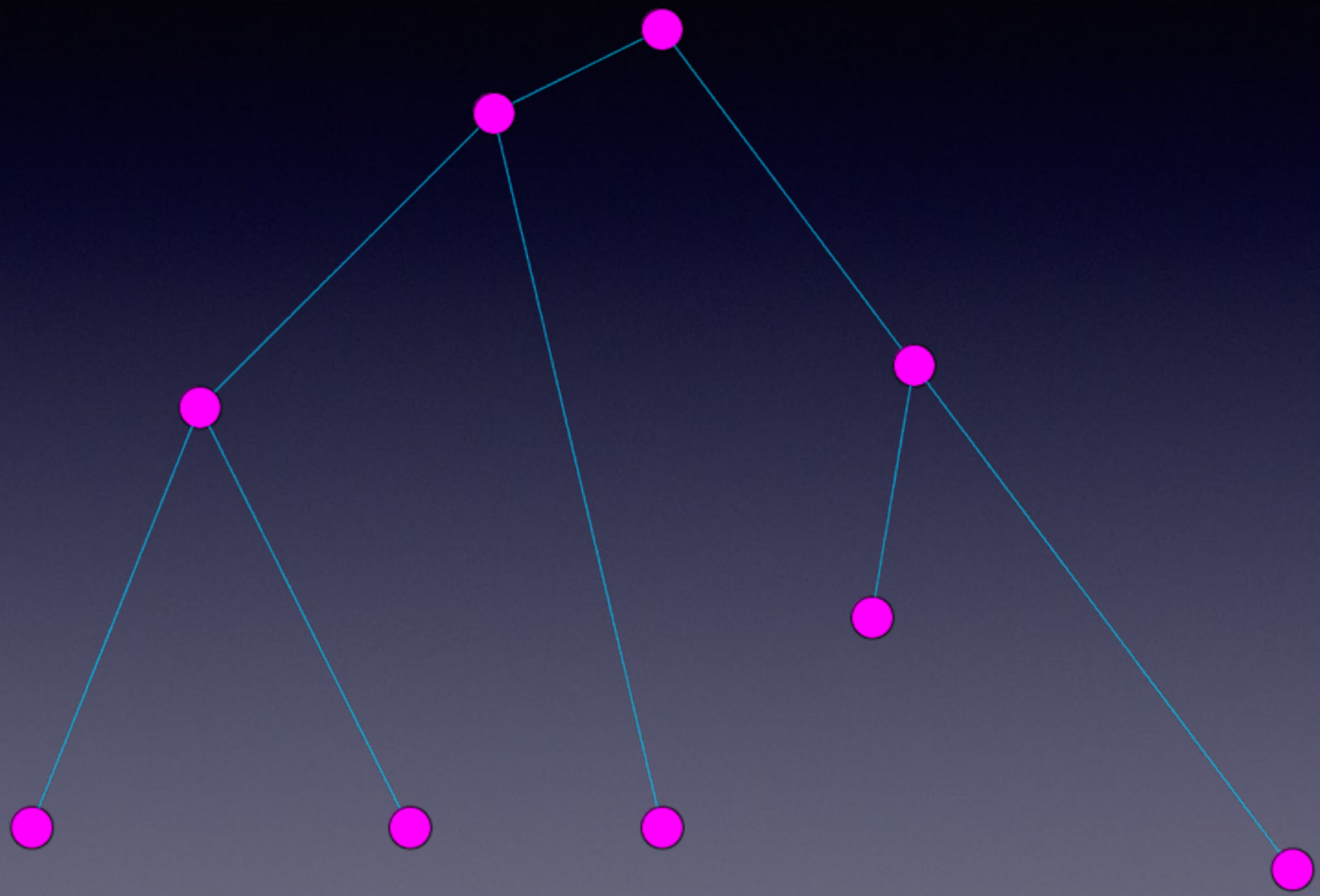
Key Idea

- CCTs aren’t just random data
- There are patterns within the calling context tree
  - induced by the design of the software
  - compact
  - repeated in multiple locations
  - expensive when aggregated

Subsuming Methods

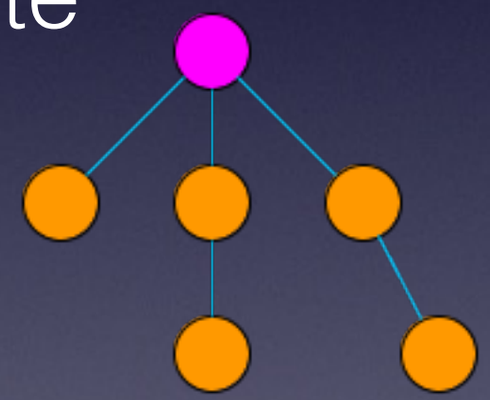


Consolidated Tree



Subsuming Methods

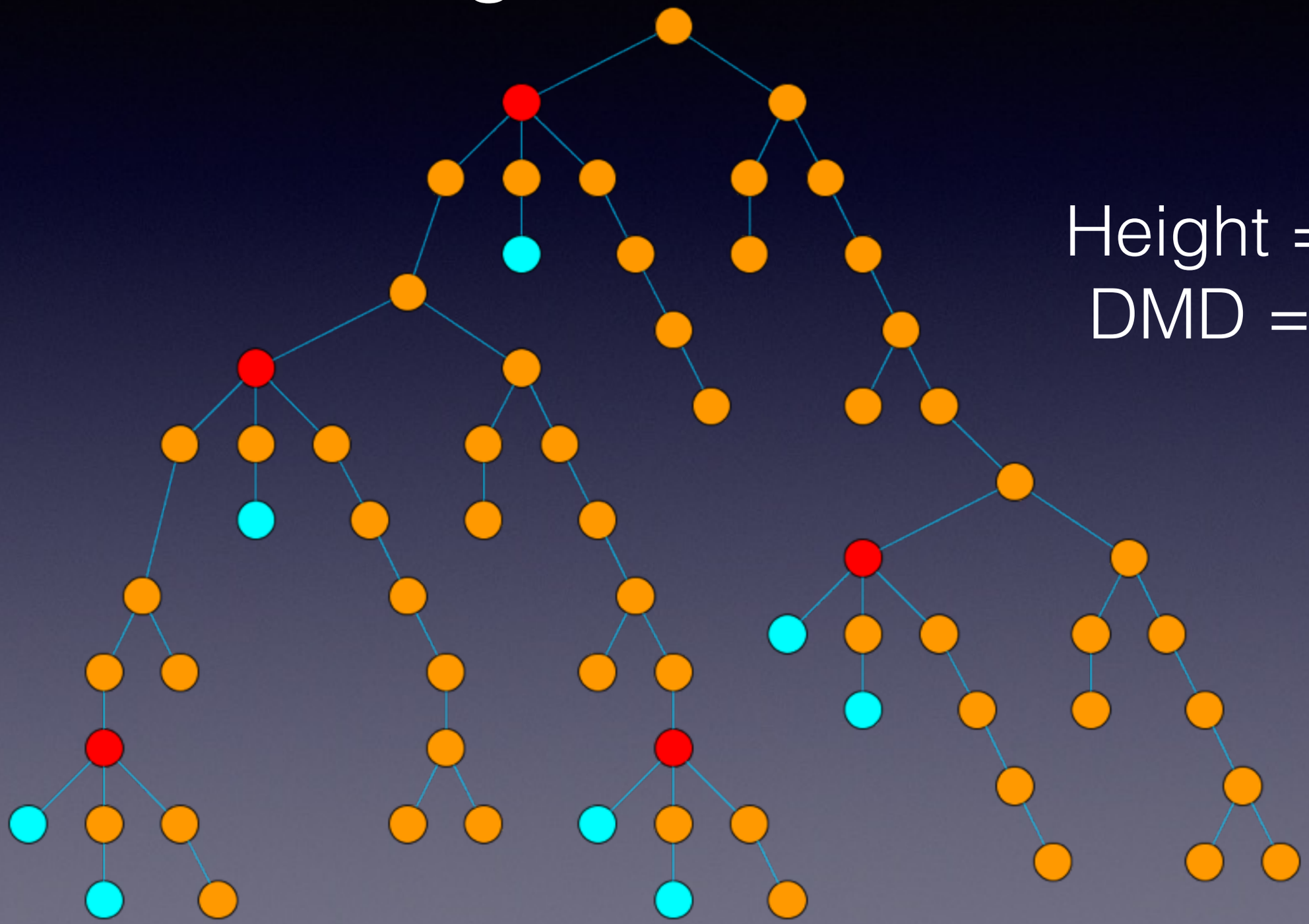
- Partition the CCT into areas of related functionality
- Induced time is very efficient to calculate
- Each subsuming method represents a repeated pattern
- How do we choose our subsuming methods?



Subsuming Attributes

- ‘Elementary’ methods - induce a limited range of behaviour
  - Approximated using height of method in CCT
  - Trivial case (height = 0) - makes no method calls - a leaf method
  - getters, setters, hashCode(), equals()
  - ~30% of all methods are leafs ~70% have height <= 4
- ‘Subordinate’ methods - called in a predictable manner
  - Every call to the method can be attributed to a (nearby) dominating method which is responsible for the invocation
  - Measured using novel metric - dominating method distance
  - Trivial case is when a method is only ever called from a single call site
  - ~70% of all methods have a single parent ~77% have DMD <= 4

Height and Dominating Method Distance



Height = 0
DMD = 2

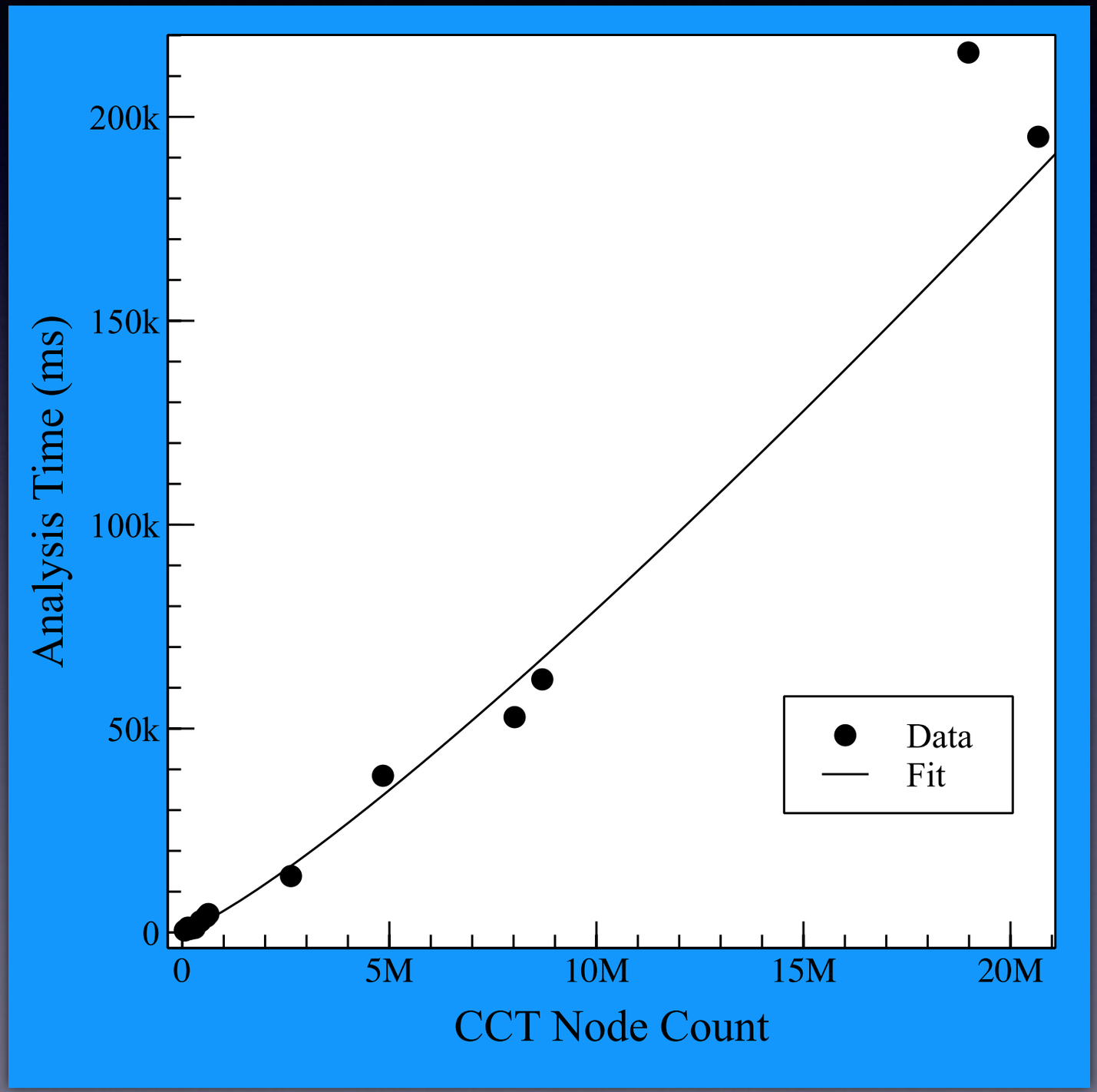
Experimental Evaluation

- DaCapo-9.12-bach (2009) benchmark suite
  - 14 different Java benchmark applications
- JP2 profiler to capture CCT profiles
  - Very consistent, reproducible results
- Apply our subsuming methods analysis
- 5 runs for each benchmark
- Constraints: height > 4 and DMD > 4

Results Summary

- Across the 14 benchmarks:
  - 6.12% of all methods were subsuming
  - 11.82% of nodes in the CCT were subsuming
    - => subsuming methods aggregation greatly simplifies profile information
  - 15 of the top 20 subsuming methods were not in the top 20 inclusive or exclusive cost methods
    - => new optimisation opportunities are identified
- https://www.cs.auckland.ac.nz/~dmap001/subsuming/

Results - Analysis Efficiency



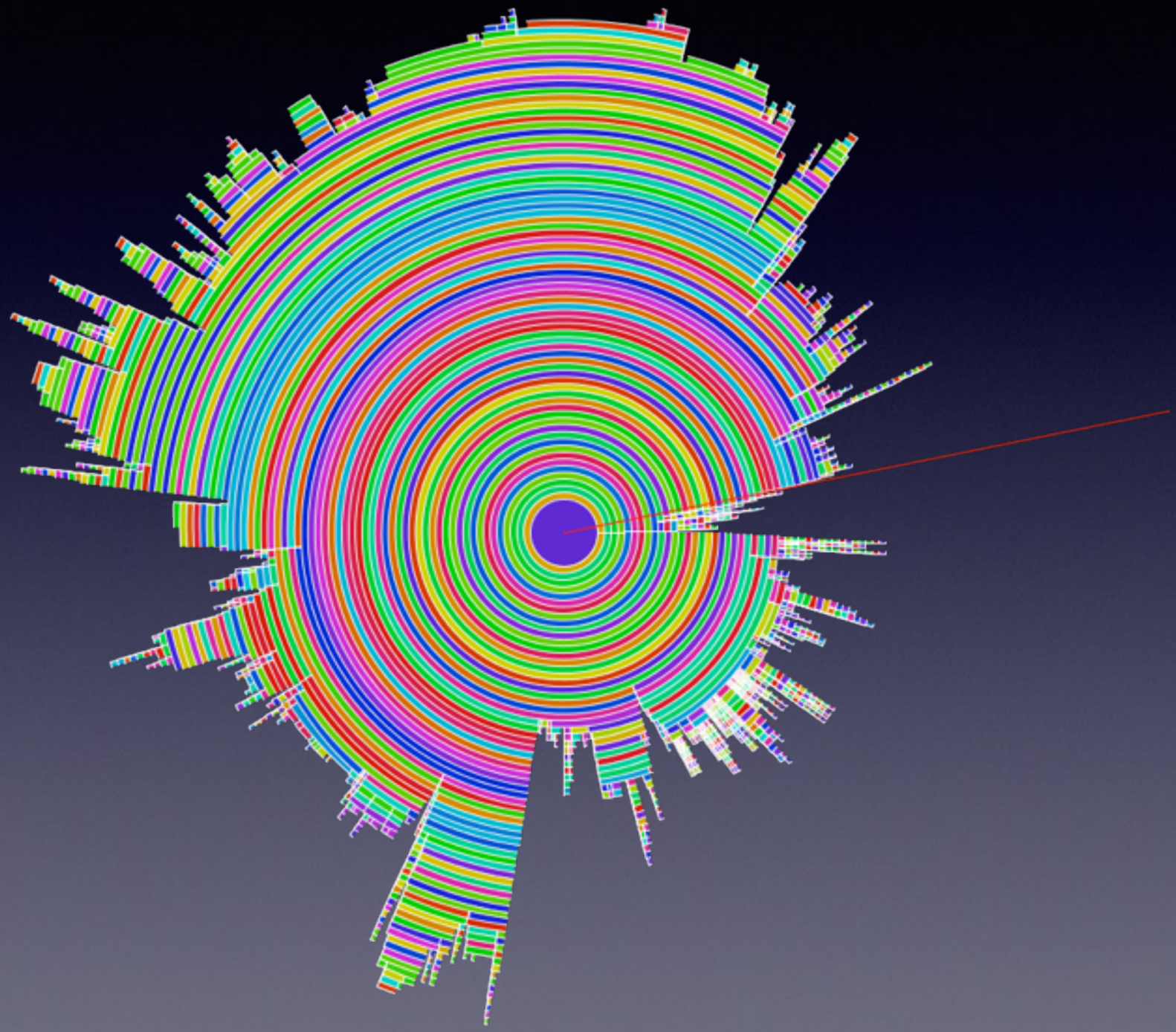
Results - DaCapo fop benchmark

	Full CCT	Subsuming CCT	Ratio
Nodes	628751	71430	11.36%
Height	111	25	22.52%
Unique Methods	6709	345	5.14%

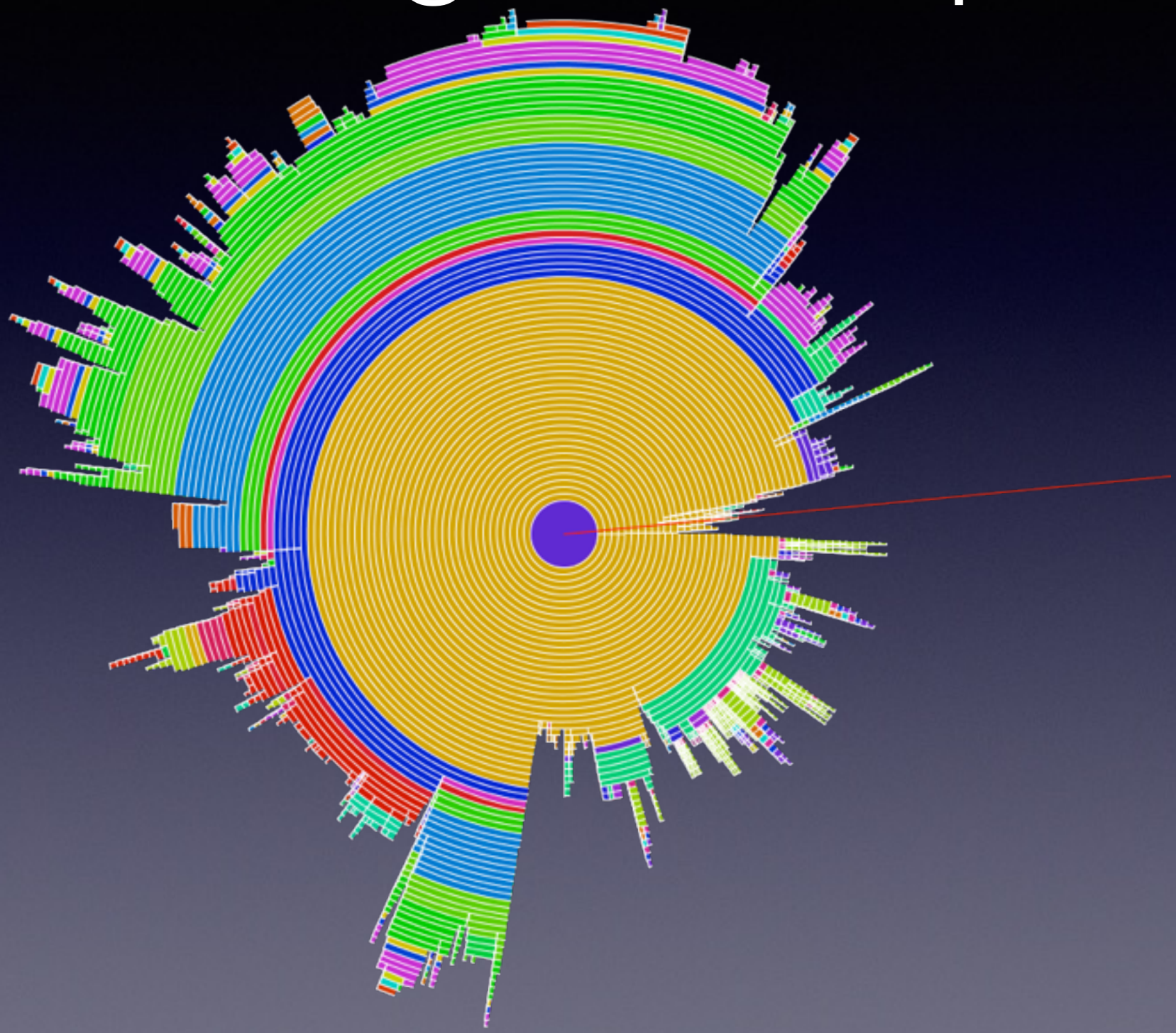
Top Subsuming Methods - DaCapo fop benchmark

Method	Occurrences in CCT	% Exclusive Time	% Induced Time
java.text.DecimalFormat.format	374	0.169	13.644
org.apache.fop.fo.StaticPropertyList.get	1691	1.228	8.884
sun.misc.FloatingDecimal.dtoa	348	6.876	8.871
org.apache.fop.layoutmgr.BlockStackingLayoutManager.getNextKnuthElements	12	0.068	6.381
org.apache.fop.render.AbstractRenderer.renderInlineArea	42	0.041	4.449
org.apache.fop.layoutmgr.BreakingAlgorithm.findBreakingPoints	16	0.002	4.340

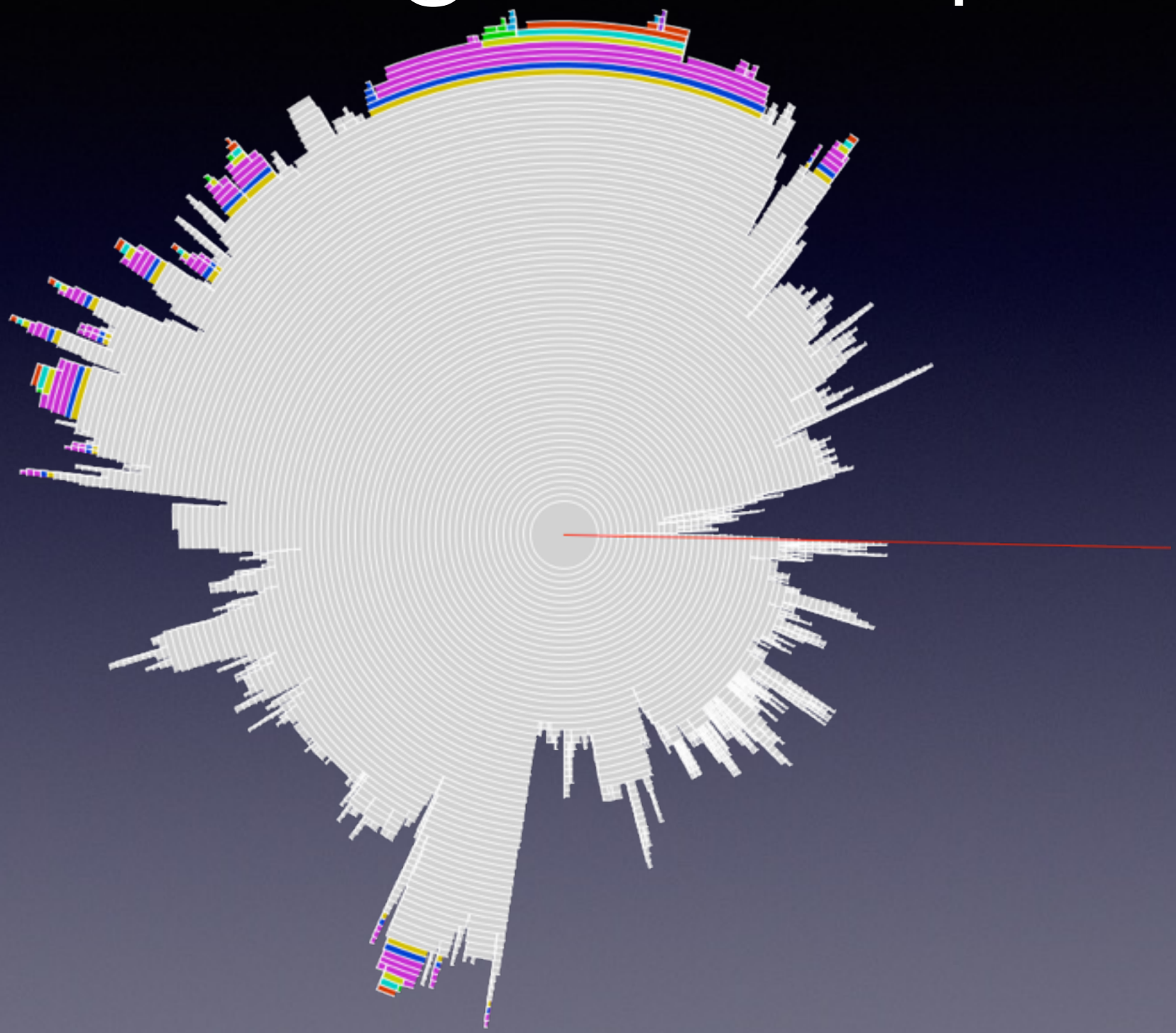
Calling Context Ring Chart



Subsuming - DaCapo fop



Subsuming - DaCapo fop



DaCapo fop - Improvements

- Top subsuming method - java.text.DecimalFormat.format
- Highly complex general purpose number formatter
- Called 98% of the time from one location to produce a very specific (and simple) 2 decimal place format
  - org.apache.xmlgraphics.ps.PSGenerator.formatDouble
- Accounts for 26% of the total benchmark cost
- Replace with a more specialised implementation
  - 22% reduction in benchmark cost

Summary

- Subsuming Methods
  - Empirical performance analysis approach
    - Helps identify repeated patterns within a CCT profile
    - Efficient offline analysis
    - Complementary to existing approaches
    - Applicable to a wide range of data
- Preliminary evaluation with DaCapo benchmark

Industry Case Study

- letterboxd.com
  - 125,700 registered members
  - 3.6 million requests per day
  - 54.8% reduction in CPU load
  - 49.6% reduction in response time
- Paper accepted at ICSE 2015 - SEIP track
  - “Performance Analysis using Subsuming Methods: An Industrial Case Study” - Maplesden et al

User Study

- Test the effectiveness of subsuming methods analysis in aiding software engineers
- Implemented as an on-line test and questionnaire
- Mid 2015
- If interested please volunteer!
  - Contact: david@maplesden.co.nz

Thank you!

Questions?

Related Work

- Very broad domain (100 venues in our SLR)
- Relevant work from HPC, Compiler, Programming Language domains
- Majority of approaches provide simple metrics
  - Lack of actionable feedback
- Very few approaches leverage static analysis
- Runtime bloat research focussed on data-flow

Systematic Mapping

- “Performance Analysis for Object-Oriented Software: A Systematic Mapping”
- Empirical methods focus
- Accepted for publication in TSE
- http://dx.doi.org/10.1109/TSE.2015.2396514

Runtime Bloat Research

- Tackle problem of excessive activity to achieve seeming simple functionality
- Data-flow centric approaches
- Efficiency of data structures
- Object pooling opportunities
- Copy profiling
- Reference propagation profiling

Existing Approaches

- Lin et al (2010). Towards Anomaly Comprehension: Using Structural Compression to Navigate Profiling Call-Trees.
  - Aggregation by package and class name
- Srinivas & Srinivasan (2005). Summarizing application performance from a components perspective.
  - Thresholding and filtering