The Use of Traces for Inlining in Java Programs

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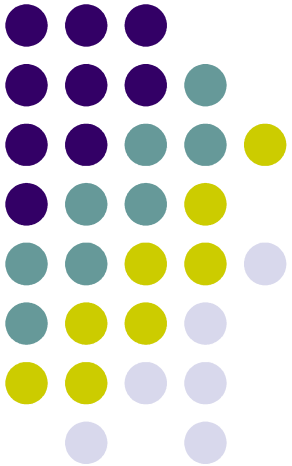
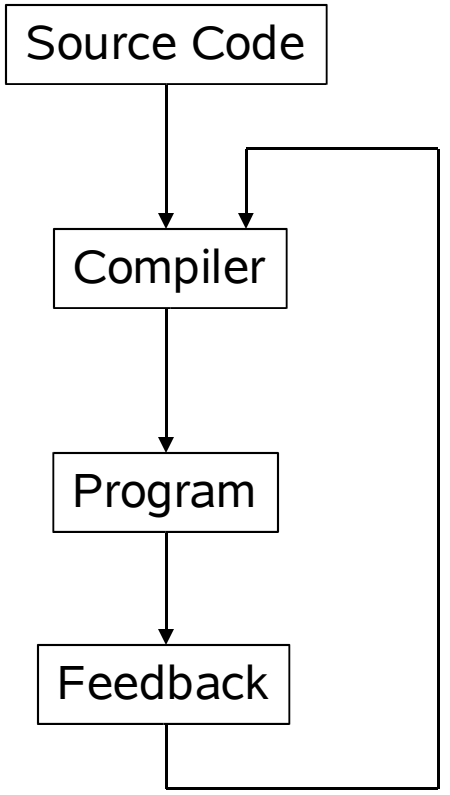


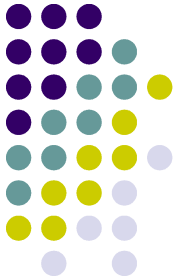
Introduction

- Feedback-directed systems provide information to a compiler regarding program behaviour

- Examples:
  - Jikes RVM [AFG+00]
  - Open Runtime Platform [Mic03]



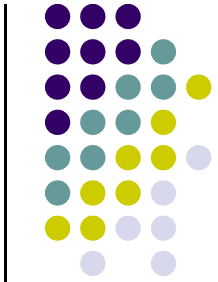
Work Overview



- Explore whether traces are useful in offline feedback directed systems

- Create trace collection system for Jikes
- Use traces to guide Jikes's built in optimizing compiler
  - Help with a single optimization, inlining
  - Improves execution time

Outline

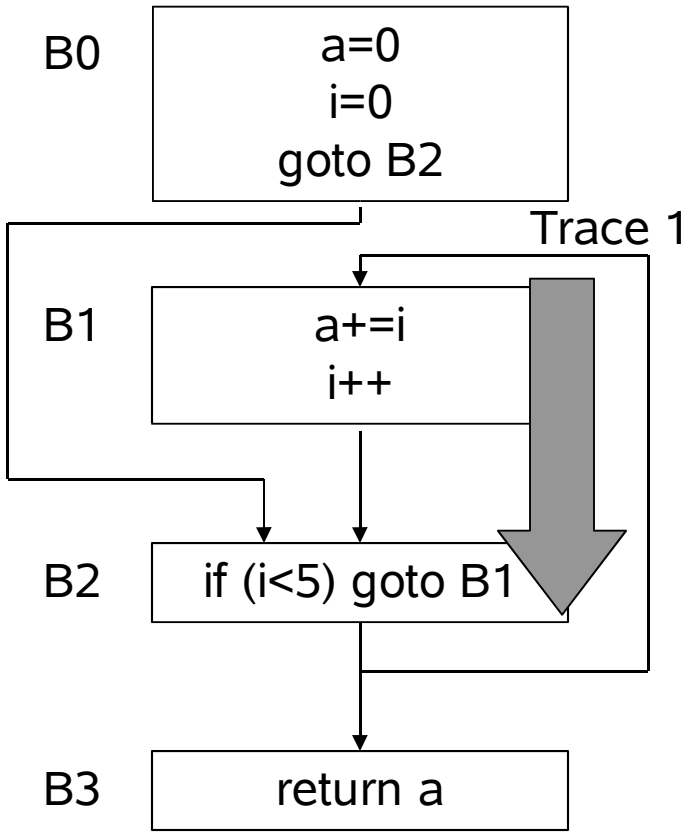


- Background
- Implementation
- Results
- Related work
- Conclusion

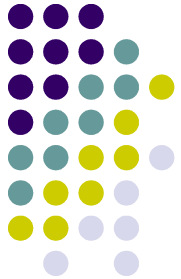
Trace Definition

- A trace is a frequently executed sequence of unique basic blocks or instructions

```
public static int foo() {
  int a=0;
  for (int i=0;i<5;i++)
    a++;
  return a;
}
```



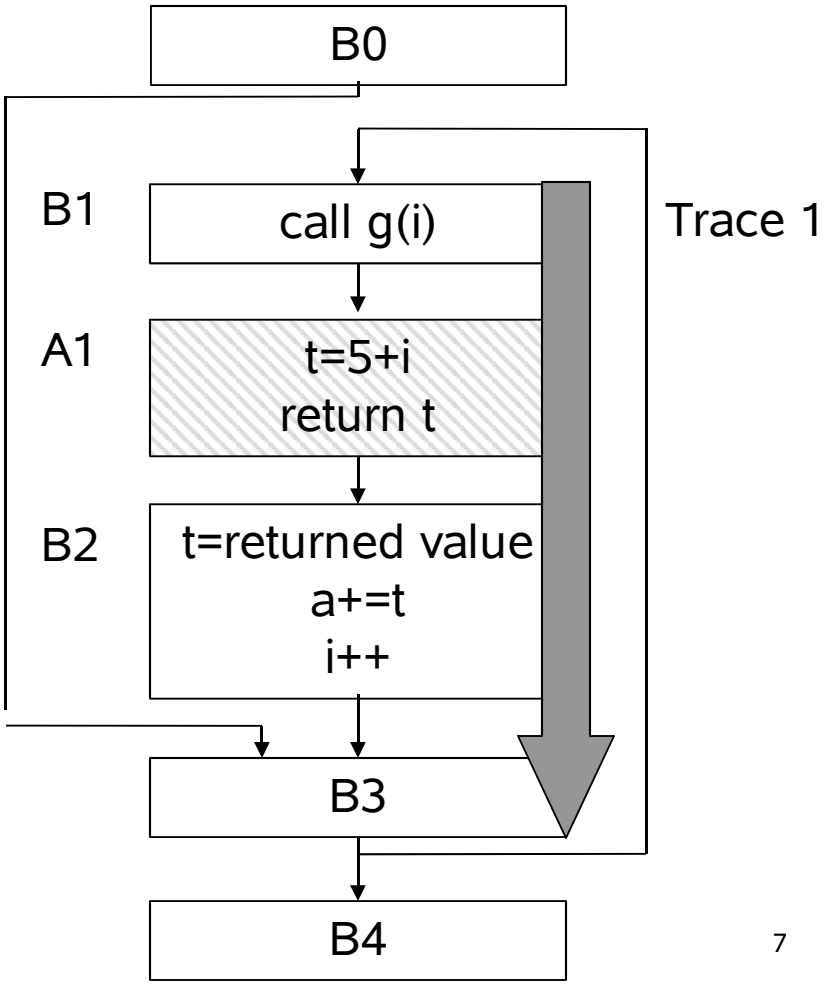
Traces and Optimization



- Traces may offer a better opportunity for optimization:
  - Enable inter-procedural analysis
  - Reduce the amount of instructions optimized
  - Simplify the control flow graph, allowing for more optimization

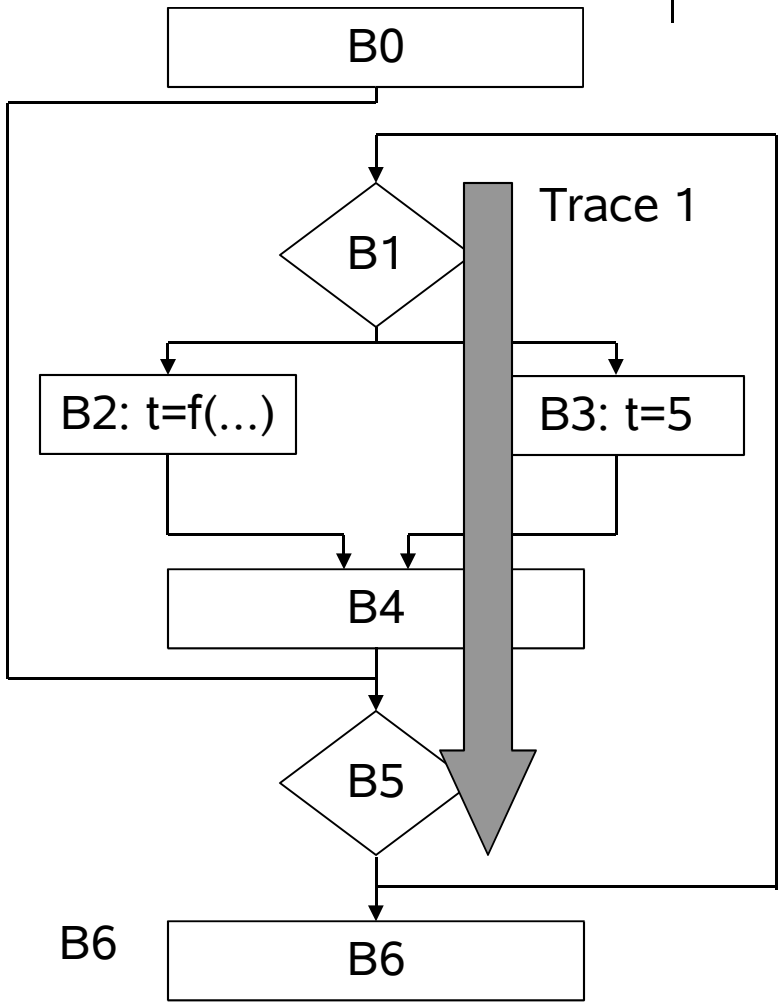
Multiple Methods

- Inter-procedural analysis without an additional framework
- Increase possibility of optimization
  - B1,A1,B2 can be simplified to two instructions
    - a+=(5+i)
    - i++



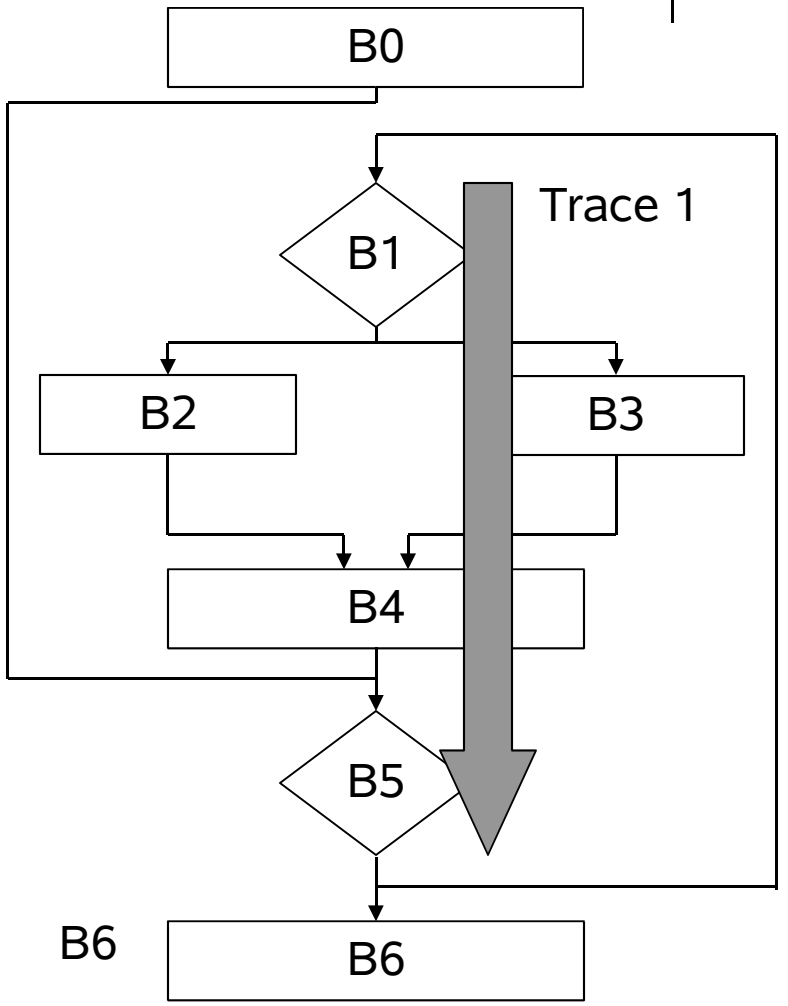
Fewer Instructions

- Fewer instructions to optimize
- May allow for extra optimization
  - If know that B3 is executed then know that t=5



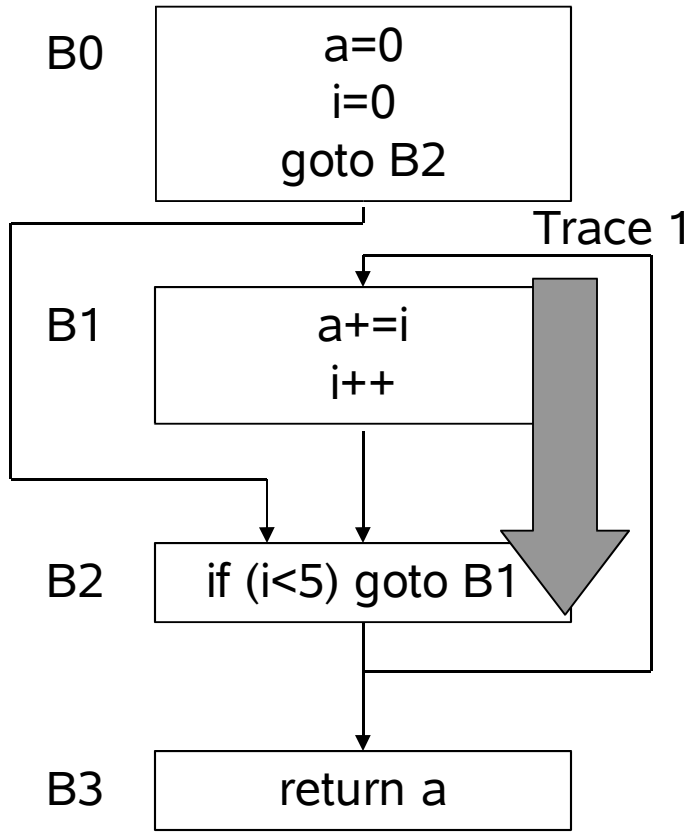
Trace Exits

- Traces usually contain many basic blocks
- Traces may not execute completely
  - Unlike basic blocks

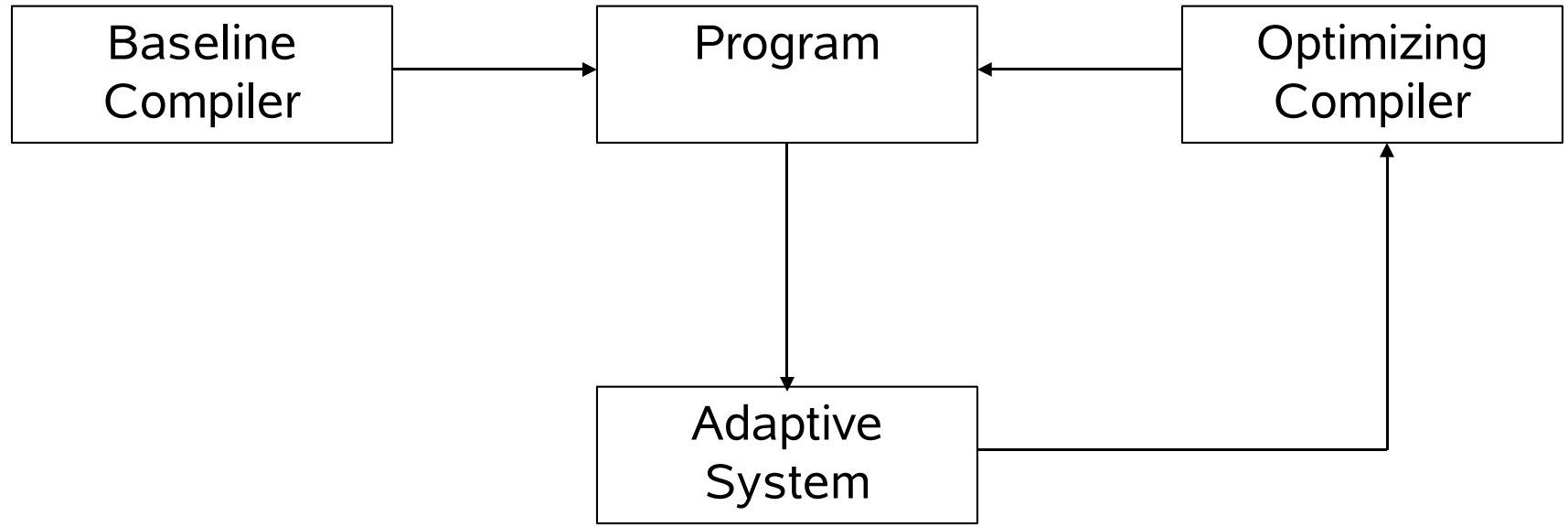


Trace Collection System

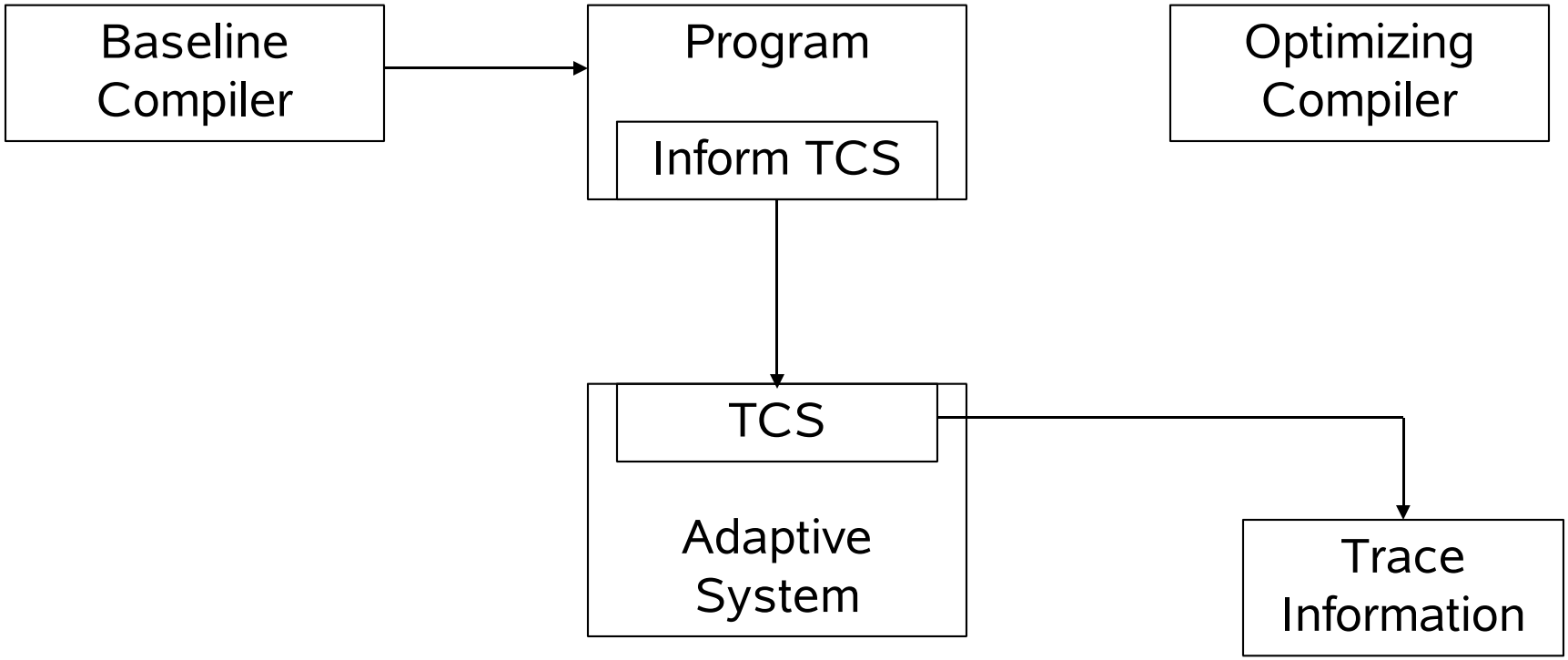
- Monitor program execution
- Record traces
- Start traces at frequently occurring events
  - Backward branches
  - Trace exits
  - Returns
- Stop at backward branches and trace starts
- Captures frequently executed loops and functions



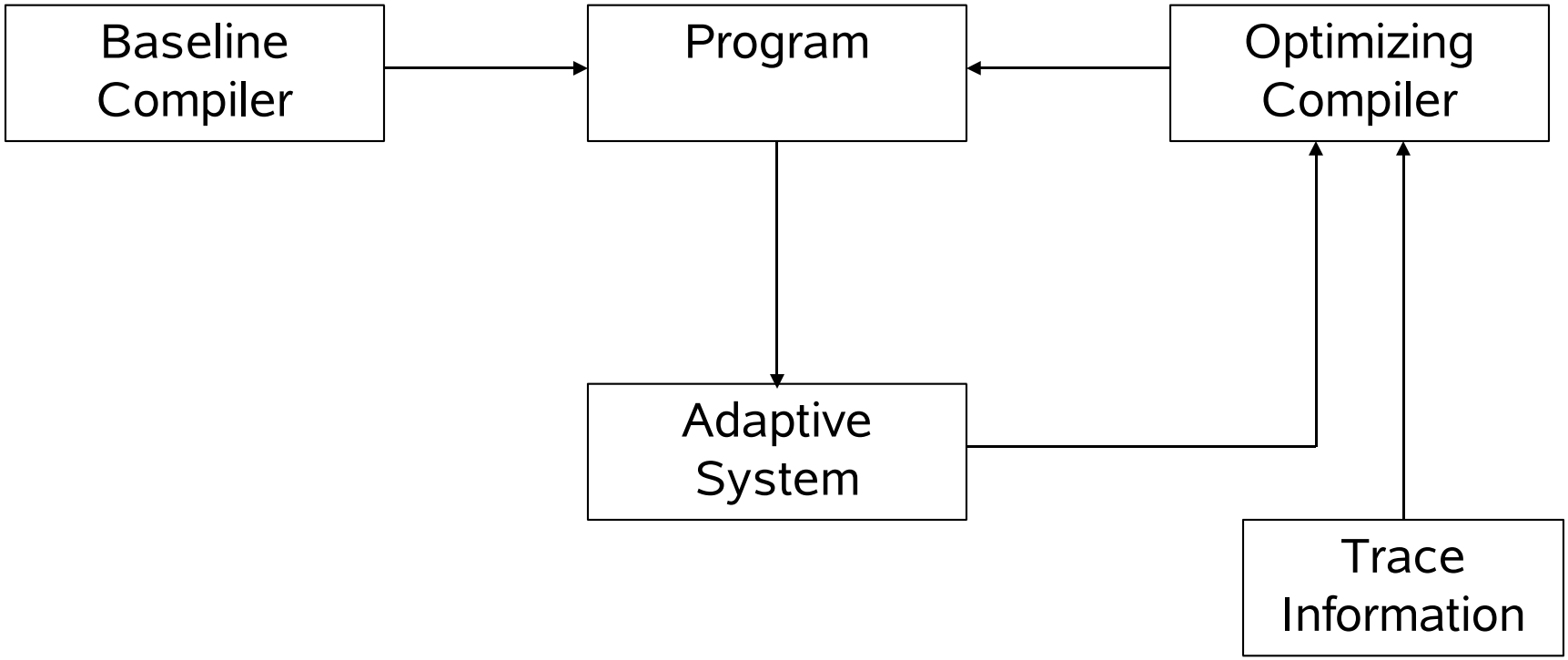
Jikes


Baseline Compiler
Program
Optimizing Compiler
Adaptive System

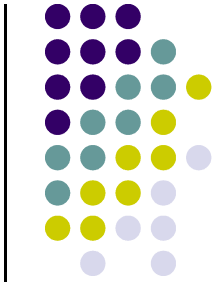
Jikes and our TCS



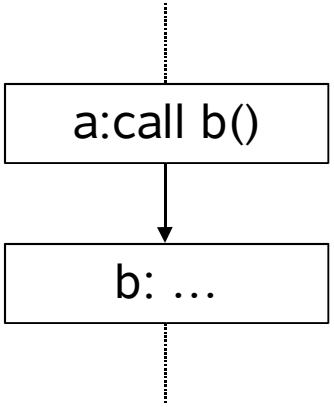
Jikes – Second Phase

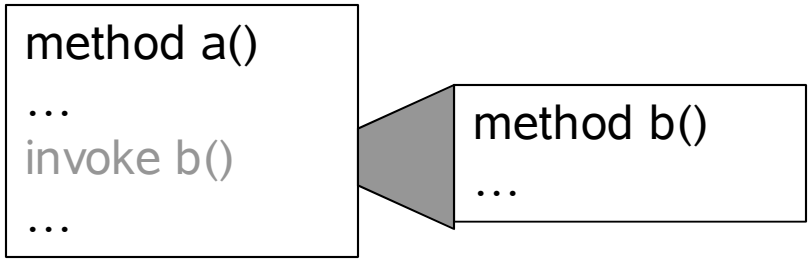


Inlining and Traces



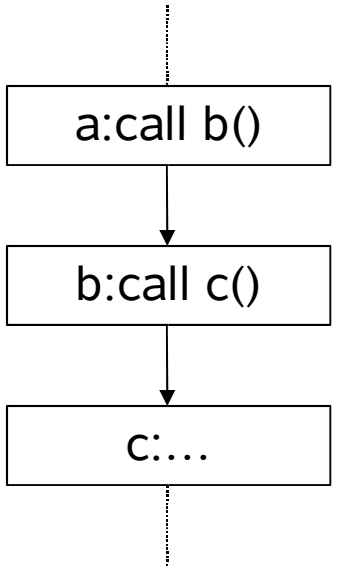
- Traces are executed frequently
- Therefore invocations on traces should be inlined
  - Reduce invocation overhead
  - Allow for more opportunities for optimization
- May lead to large code expansion



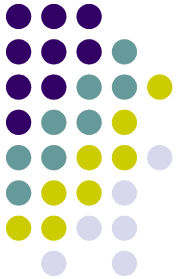


Code Expansion Control

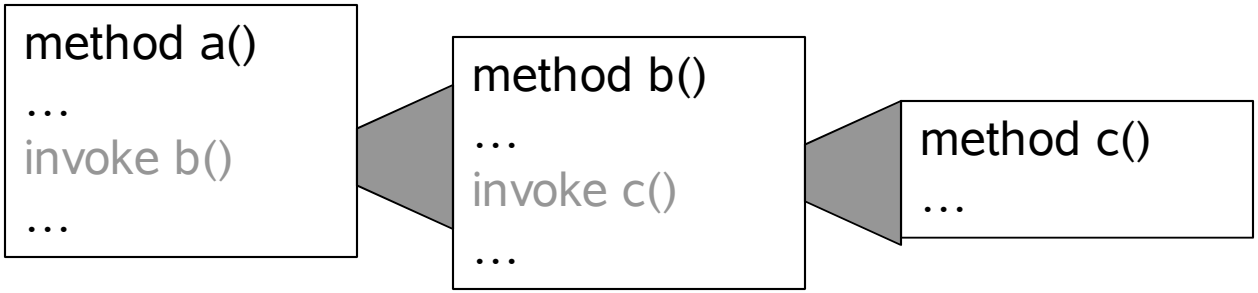
- There are ways to control inline expansion
- Inline sequences [HG03,BB04]
- Selectively inlining:
  - What if compile method a()?
  - What if compile method b()?



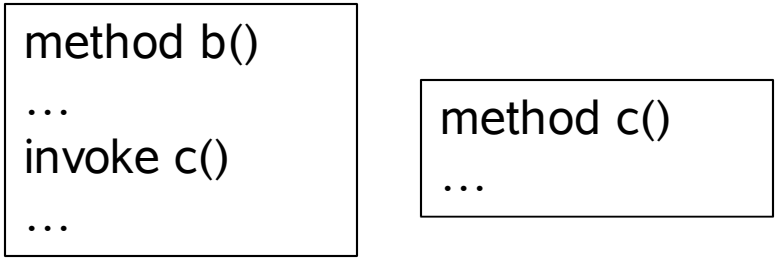
Code Expansion Control



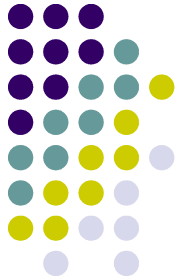
- Compile method a()
  - Inline methods b() and c()



- Compile method b()
  - No inlining



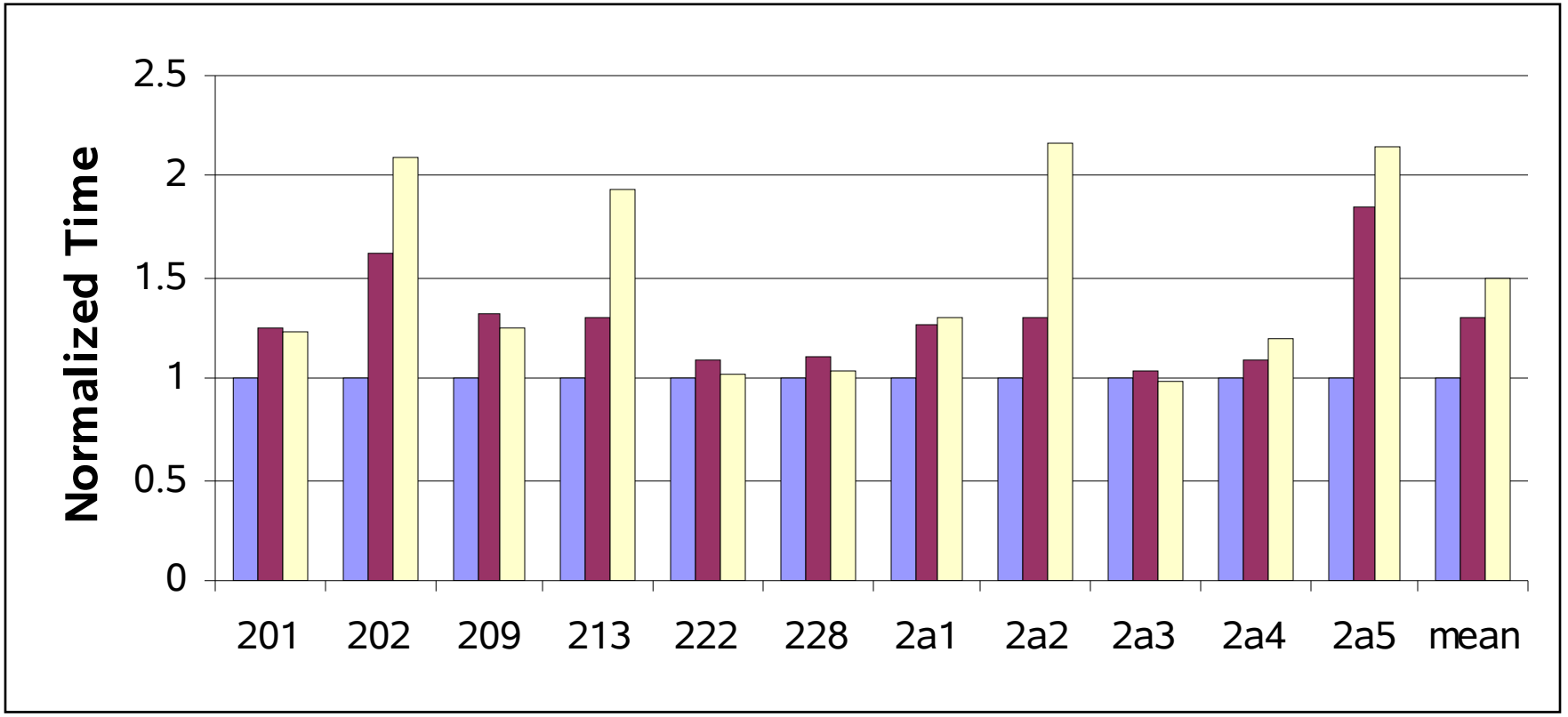
Results



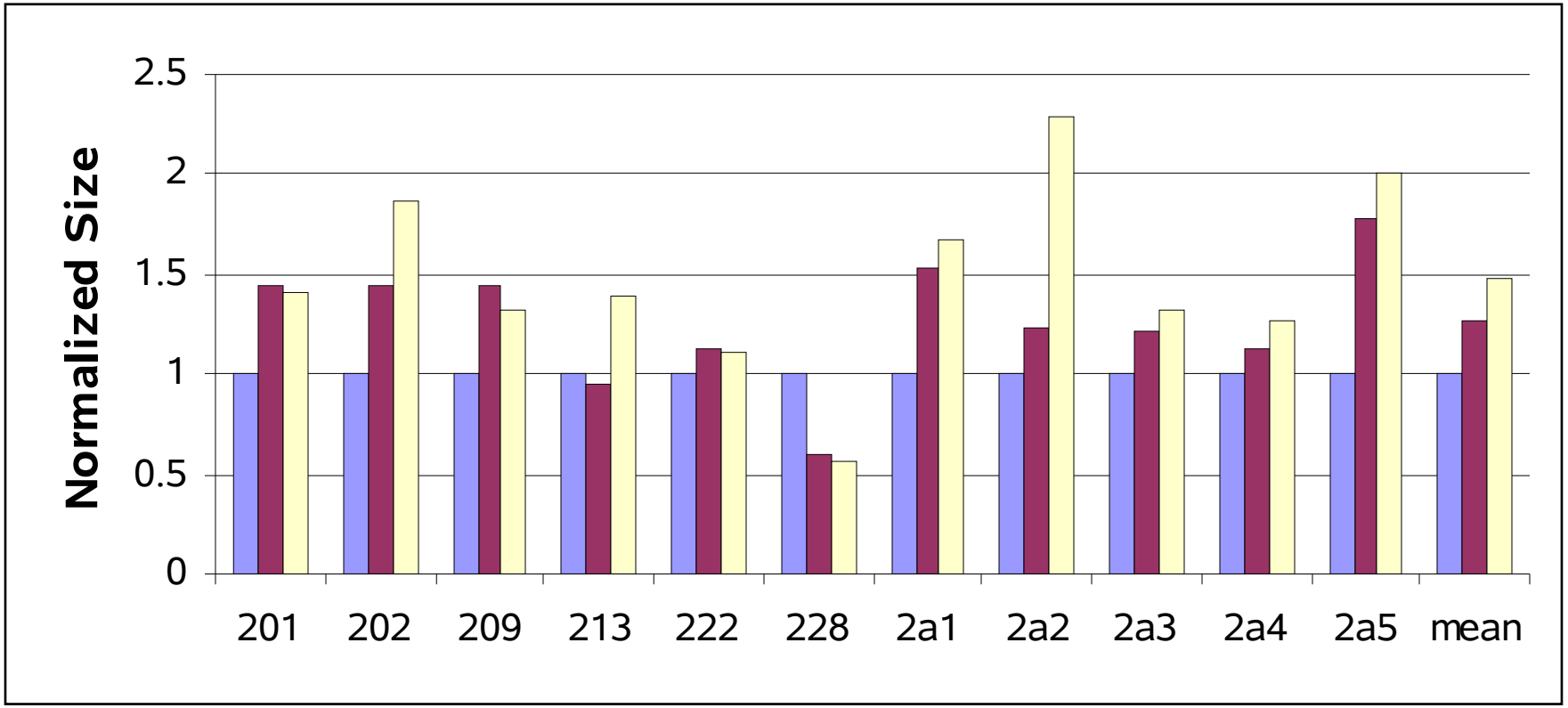
- Provide inline information to Jikes based on previous executions
- Compare our approach to two others:
  - Inline information provided by the Adaptive system of Jikes
  - A greedy algorithm based on work by Arnold et al. [Arn00]
- Evaluate two approaches: Just in Time and Ahead of Time
- Measure overhead of system

JIT Inlining – Execution Time

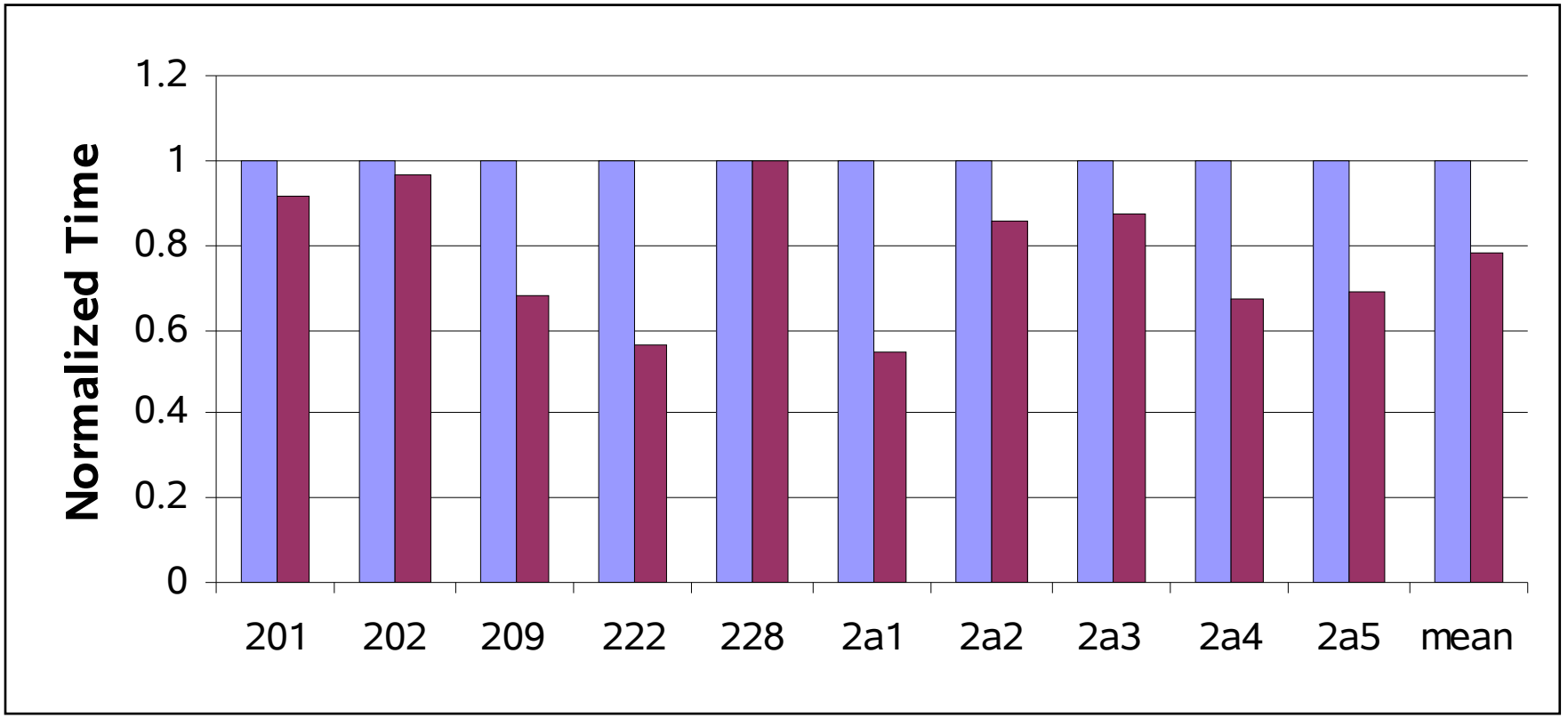
JIT Inlining – Compilation Time



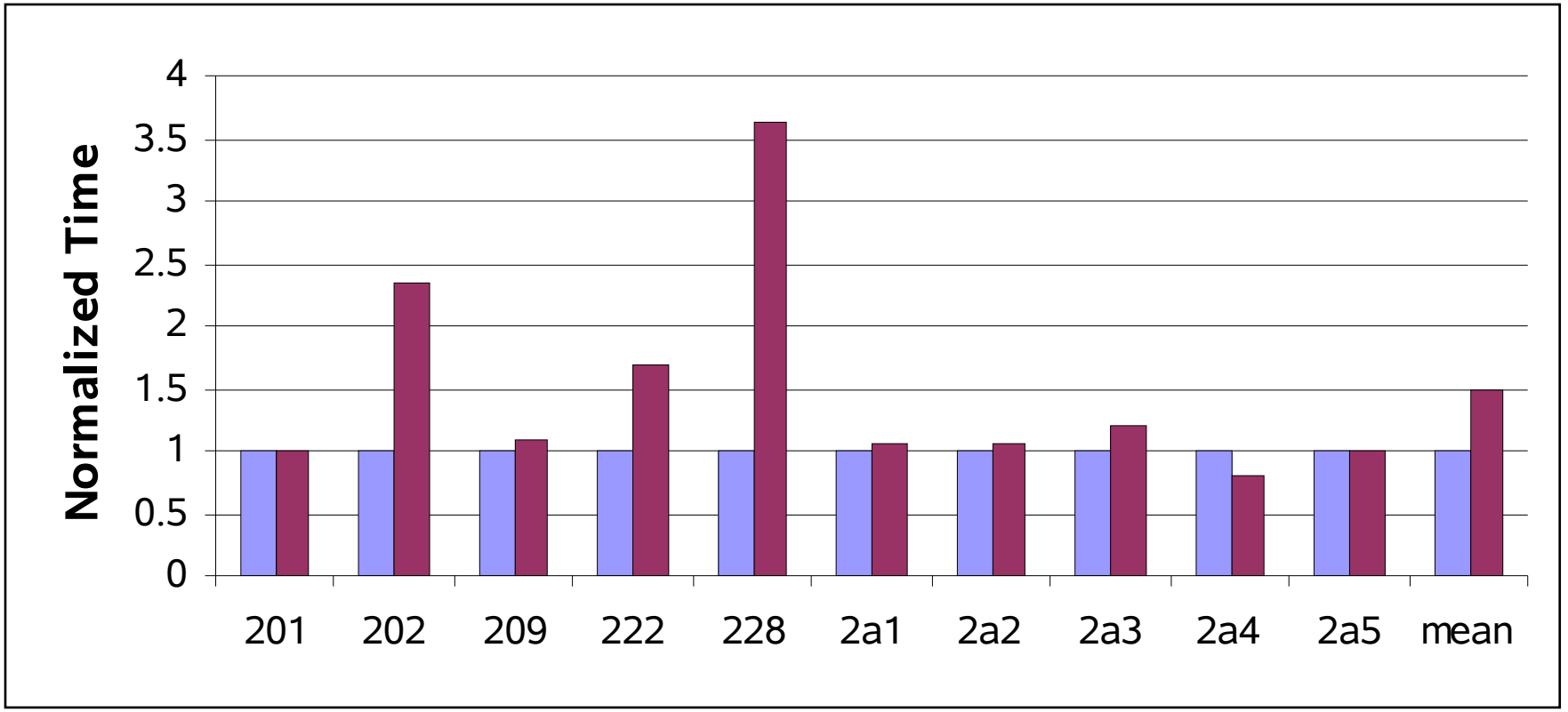
JIT Inlining – Code Expansion



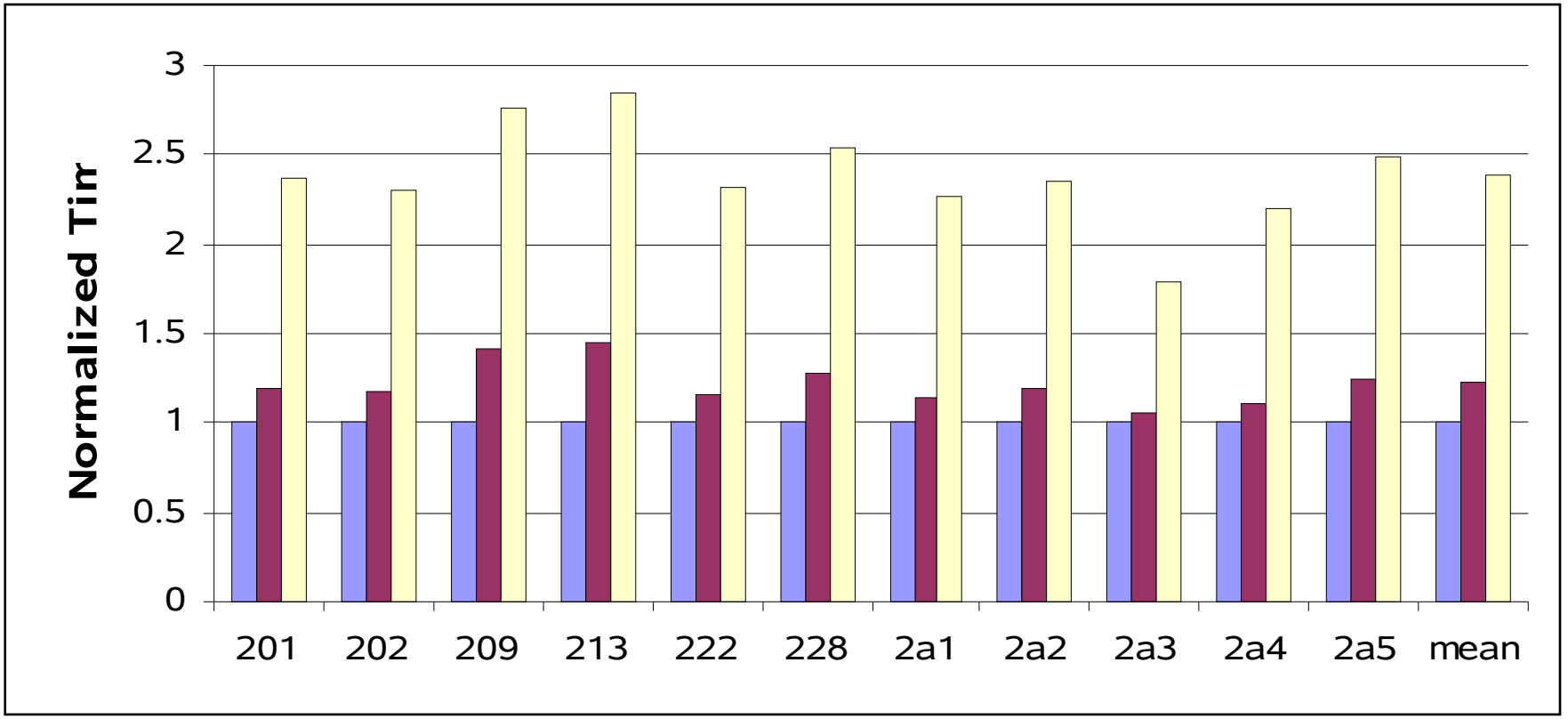
AOT Inlining – Execution Time



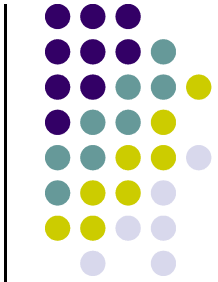
AOT Inlining – Compilation Time



Overhead

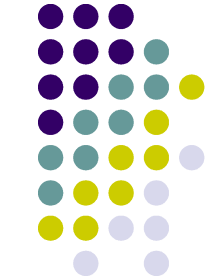

Normalized Tim
3
2.5
2
1.5
1
0.5
0
201
202
209
213
222
228
2a1
2a2
2a3
2a4
2a5
mean

Related Work



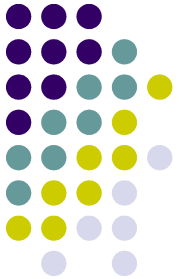
- Arnold et al. [Arn00]
  - Feedback-directed inlining in Java
  - Collected edge counts at method invocations
  - Used a greedy algorithm to select inlines that maximize invocations relative to code expansion
- Dynamo [BDB99]
  - Trace collection system
  - PA-RISC architecture
  - Assembly Instructions
  - Compiled traces

Conclusions



- Traces are beneficial for inlining:
  - Decreased execution time compared to one approach
  - Decrease competitive with another approach
  - Increases compilation time and code size
- A potential avenue of future research

Future Work



- Different trace collection strategies
- Trace based compilation and execution
- Reduction of code size
- Application of traces to other optimizations
- Usage of an online feedback directed system

References

- [MSD00] Matthew Arnold, Stephen Fink, David Grove, Michael Hind, and Peter F. Sweeney. Adaptive optimization in the Jalapeno JVM. ACM SIGPLAN Notices, 35(10):47-65, 2000.
- [Mic03] Michael Cierniak et al. The open runtime platform: A flexible high-performance managed runtime environment. Intel Technology Journal, February 2003.
- [HG03] Kim Hazelwood and David Grove. Adaptive online context-sensitive inlining. International Symposium on Code Generation and Optimization, p 253-264, 2003.
- [BB04] Bradel, B.J.: The use of traces in optimization. Master's thesis, University of Toronto (2004).
- [Arn00] Matthew Arnold et al: A comparative study of static and profile-based heuristics for inlining. SIGPLAN Workshop on Dynamic and Adaptive Compilation and Optimization. (2000) 52-64.
- [BDB99] Vasanth Bala, Evelyn Duesterwald, and Sanjeev Banerjia. Transparent dynamic optimization: The design and implementation of dynamo. HP Laboratories Technical Report HPL1999 –78.

AOT – Compilation Time (Wall Time)