abc - the AspectBench Compiler for AspectJ

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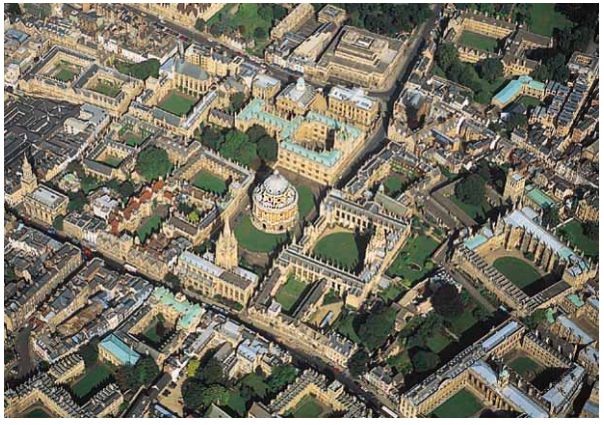

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Outline

- AspectJ introduction for compiler writers
- Challenges of building a compiler for AspectJ
- **abc** as an extensible and optimizing compiler
- How **abc** tackles performance issues
- Future Work

AspectJ Programming Language

- a seamless *aspect-oriented* extension to Java
- originally developed at Xerox PARC
- tools for AspectJ now developed and supported by the Eclipse AspectJ project
  - **ajc** compiler for the AspectJ language

(**`http://eclipse.org/aspectj`**)

AspectJ Programming Language

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  (**`http://eclipse.org/aspectj`**)

- **abc**, the **AspectBench Compiler**, is a new, alternative compiler for the AspectJ language, designed for *extensibility* and *optimization* (**`http://aspectbench.org`**)

AspectJ Introduction

- introduce a small Java program, a little expression interpreter
- illustrate three main uses of AspectJ by applying it to this small example
  - aspects for additional static checking at compile time
  - adding fields/classes/constructors to classes via aspects
  - dynamic aspects for applying advice (code) at specified run-time events

Example Java Program - expression interpreter

Consider a small interpreter for an expression language, consisting of:

- SableCC-generated files for scanner, parser and tree utilities in four packages: **`parser`**, **`lexer`**, **`node`** and **`analysis`**.
- main driver class, **`tiny/Main.java`**, which reads the input, invokes parser, evaluates resulting expression tree, prints input expression and result.
- expression evaluator class, **`tiny/Evaluator.java`**

```
> java tiny.Main
Type in a tiny exp followed by Ctrl-d :
3 + 4 * 6 - 7
The result of evaluating: 3 + 4 * 6 - 7
is: 20
```

AspectJ for Static (compile-time) Checking

- Programmer specifies a pattern describing a static program property to look for and a string with the warning text.
- An AspectJ compiler must check where the pattern matches in the program, and issue a compile-time warning (string) for each match.

```
public aspect StyleChecker {
  declare warning :
    set(!final !private * *) &&
    !withincode(void set*(..) ) :
    "Recommend use of a set method.";
}
```

Using the `StyleChecker` aspect

The compilation:

```
abc StyleChecker.java */*.java
```

produces the compile-time output:

```
  parser/TokenIndex.java:34:
  Warning -- Recommend use of a set method.
    index = 4;
    ^-------^
...
```

AspectJ for Intertype Declarations

- Programmer specifies, in a separate aspect, new fields/methods/constructors to be added to existing classes/interfaces.
- An AspectJ compiler must weave in code to implement these additions.
- Other classes in the application can use the added fields/members/constructors.
- In our example, we can use an aspect to add fields and accessors to the code generated by SableCC, without touching the generated classes.

Intertype Declarations - example

All AST nodes generated by SableCC are subclasses of **`node.Node`**.
We must **not** directly modify the code generated by SableCC.

```
public aspect AddValue {
  int node.Node.value; // a new field

  public void node.Node.setValue(int v)
     { value = v; }

  public int node.Node.getValue()
     { return value; }
}
```

Using the AddValue aspect

```
abc AddValue.java */*.java
```

where, the evaluator visitor can be now written using the **value** field to store intermediate values.

```
public void outAMinusExp(AMinusExp n)
  { n.setValue(n.getExp().getValue() -
                  n.getFactor().getValue());
  }
```

instead of the “old" way of storing intermediate values in a hash table. The aspect-oriented method is more efficient because fewer objects are created during the evaluation.

AspectJ for Dynamic Advice

- Programmer specifies a pattern describing run time events, and some extra code (advice) to execute before/after/around those events.
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- Programmer specifies a pattern describing run time events, and some extra code (advice) to execute before/after/around those events.
- An AspectJ Compiler must weave the advice into the base program for all potentially matching events.
- Since events can depend on dynamic information:
  - some execution state may need to be tracked, and
  - some advice may be conditional on the result of a *dynamic residue test*.

Dynamic Advice - counting runtime events

```
public aspect CountEvalAllocs {
  int allocs;  // counter

  before () : call(* *.eval(..)) &&
              within(*.Main)
    { allocs = 0; }

  after () : call(* *.eval(..)) &&
             within(*.Main)
    { System.out.println(
        "*** Eval allocs: " + allocs); }

  before () : call(*.new(..)) &&
              cflow(call(* *.eval(..)))
    { allocs ++; }
}
```

Using the `CountEvalAllocs` aspect

- Using the interpreter with the **`CountEvalAllocs`** aspect included.

```
The result of evaluating:
3 + 4 * 6 + 9 / 3
*** Eval allocations: 17
is: 30
```

- Using the interpreter with the **`CountEvalAllocs`** aspect, and the improved evaluator enabled by the **`addValue`** aspect.

```
The result of evaluating:
3 + 4 * 6 + 9 / 3
*** Eval allocations: 2
is: 30
```

Dynamic Advice - example 2

```
public aspect ExtraParens {
String around() :
 execution(String node.AMultFactor.toString()) ||
 execution(String node.ADivFactor.toString())
 { String normal = proceed();
   return "(" + normal + ")";
 }
}
```

Compile: **abc ExtraParens.java */*.java**
Run: **java tiny.Main**

```
The result of evaluating:
3 + (4 * 6) + (9 / 3)
is: 30
```

Recap: uses of AspectJ for example

- **Static (compile-time) check:** Check that accessor methods are always used to set non-private non-final fields.
- **Intertype declaration:** Add a new field and associated accessor methods to the SableCC-generated **`node.Node`** class.
- **Dynamic advice:**
  - Count the number of allocations peformed during a an expression evaluation.
  - Intercept calls to **`toString()`** for factors and add surrounding parentheses, if they are not already there.

Challenges: front-end

- AspectJ-specific language features, including relatively complex pointcut (patterns) language.
- Intertype declarations, need to be able to extend the type system in non-trivial ways.

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- AspectJ-specific language features, including relatively complex pointcut (patterns) language.
- Intertype declarations, need to be able to extend the type system in non-trivial ways.
- **abc**'s solution:
  - use Polyglot, an extensible framework for Java compilers (Cornell)
  - express AspectJ language via LALR(1) grammar: base Java grammar + additional grammar rules for AspectJ
  - use Polyglot's extension mechanisms to override key points in type system to handle intertype declarations.

Challenges: back-end

- Need to handle input from .java and .class files.
- AspectJ compilers need additional modules: matcher, weaver
- need to produce **efficient** woven code (.class files)

Challenges: back-end

- Need to handle input from .java and .class files.
- AspectJ compilers need additional modules: matcher, weaver
- need to produce **efficient** woven code (.class files)
- **abc**'s solution:
  - clean design of matcher and weaver using a simplified and factored pointcut language
  - use Soot, which provides Jimple IR (typed 3-addr), standard optimizations, and an optimization framework

The abc approach

abc has been designed to be an:

- **extensible compiler:**
  - easy to implement language extensions
  - build on two extensible frameworks, Polyglot and Soot
  - see AOSD 2005 submission at **`http://aspectbench.org/techreports`**

The abc approach

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- **extensible compiler:**
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  - build on two extensible frameworks, Polyglot and Soot
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- **optimizing compiler:**
  - convenient IR
  - good weaving strategies
  - standard compiler optimizations
  - AspectJ-specific optimizations

Does the weaving strategy matter?

- Studied the code produced by **ajc** by tagging instructions that are introduced by the **ajc** weaver and using *J tool to measure dynamic metrics. (OOPSLA 2004)
- When there is **not** a lot of overhead:
  - very simple **before** and **after** advice
  - when the aspect only applies to a small, cold, part of the program
  - when the aspect body is a large computation
- When there can be overhead:
  - frequent (hot) aspects with small bodies
  - frequent (hot) use of cflow and/or around advice

How abc reduces overhead

- use Soot in back-end, so can optimize generated code
- new around weaving strategy
- new cflow implementation

Reducing overhead by using Soot

- the **abc** backend uses Jimple, a typed 3-address IR (**ajc** use stack-based Java bytecode)
  - **abc** weaver does not need to save implicit values on the stack, leads to fewer locals in generated code
  - **abc** weaver can use def-use and variable types to generate better code
- **abc** uses the Soot basic optimizations to clean up generated code
- **abc** can use Soots intra- and inter-procedural analysis frameworks to implement AspectJ-specific optimizations.

Weaving in bytecode (ajc)

```
public int foo(int x, int y, int z)
0:    aload_0
1:    iload_1
2:    iload_2
3:    iload_3
4:    istore          %4
6:    istore          %5
8:    istore          %6
10:   astore          %7
12:   invokestatic    A.aspectOf ()LA; (52)
15:   aload           %7
17:   invokevirtual   A.ajc$before$A$124 (LFoo;)
20:   aload           %7
22:   iload           %6
24:   iload           %5
26:   iload           %4
28:   invokevirtual   Foo.bar (III)I (37)
31:   ireturn
```

Weaving in Jimple (abc)

```
public int foo(int, int, int)
{ Foo this;
    int x, y, z, $i0;
    A theAspect;

    this := @this;
    x := @parameter0;
    y := @parameter1;
    z := @parameter2;
    theAspect = A.aspectOf();
    theAspect.before$0(this);
    $i0 = this.bar(x, y, z);
    return $i0;
}
```

Sascha's strategy for around weaving

- **ajc** has two strategies, inlining around advice, and using closures
  - the inlining method will work well for small advice bodies, or advice the applies in few places
  - the closure strategy is very inefficient, but must be used in some situations (i.e. when an advice applies to itself)
- **abc** has another strategy (**`http://aspectbench.org/theses`**):
  - doesn't inline (no code bloat), but uses generic advice methods
  - replaces polymorphism with lookup tables
  - avoids object creation
  - no closures in the general case
  - uses closures only at specific points, degrades gracefully

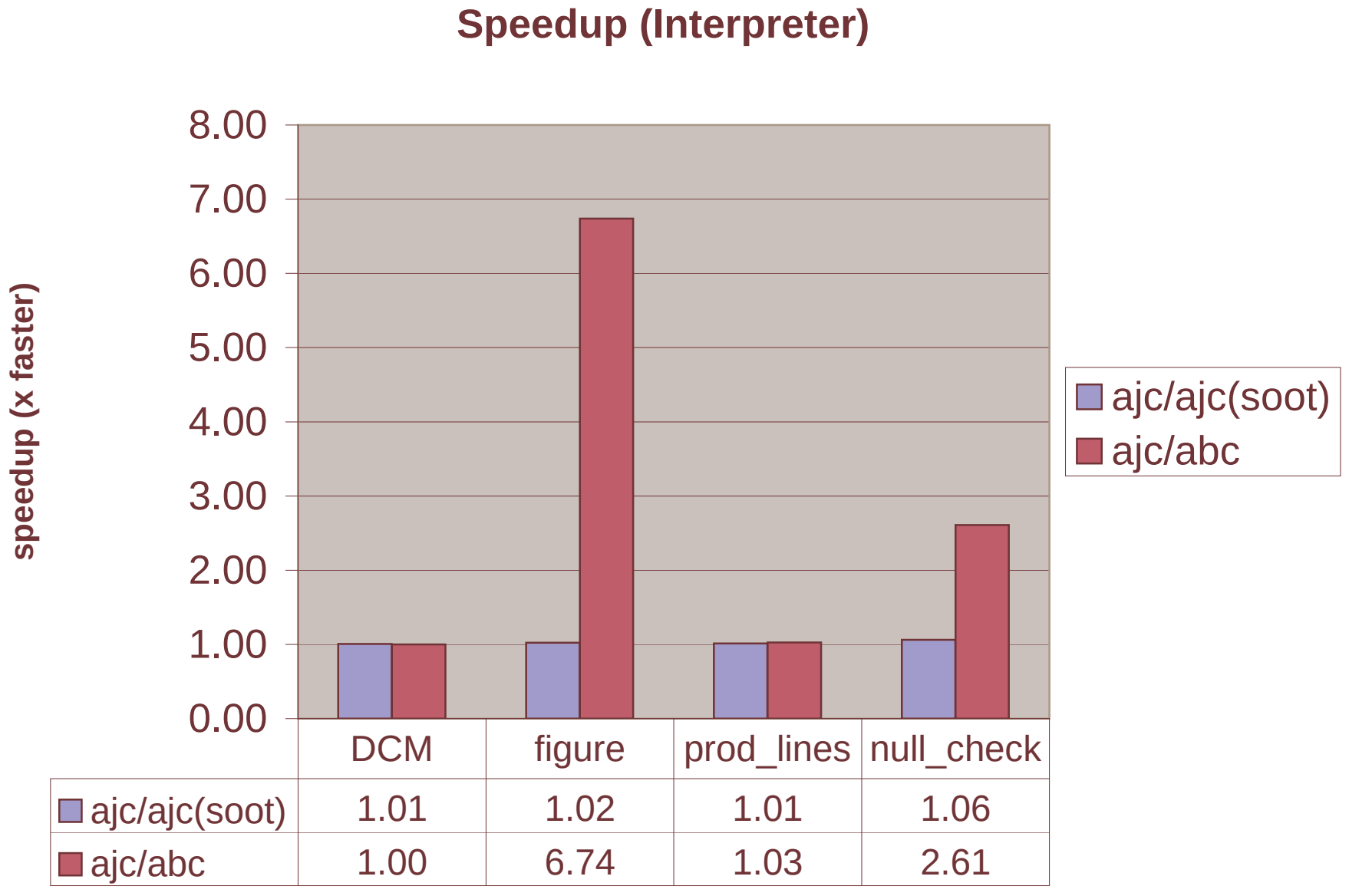
Improving the implementation of cflow

- to track if a runtime computation is within the cflow of some event, the compiler has to generate code to track when that event begins and when it ends
- in general the event may have some state, but most often it does not
- **ajc** uses a stack of states that must be thread-safe
- **abc** improves upon this by:
  - recognizing when there is no state and using a counter instead of a stack of empty states
  - recognizing when counters (or stacks) are equivalent and can be shared
  - only peforming thread-specific operations once per method body
  - will soon use interprocedural analysis to determine if the cflow can be decided statically (and thus no runtime book-keeping is necessary)

Peformance Improvement(1)

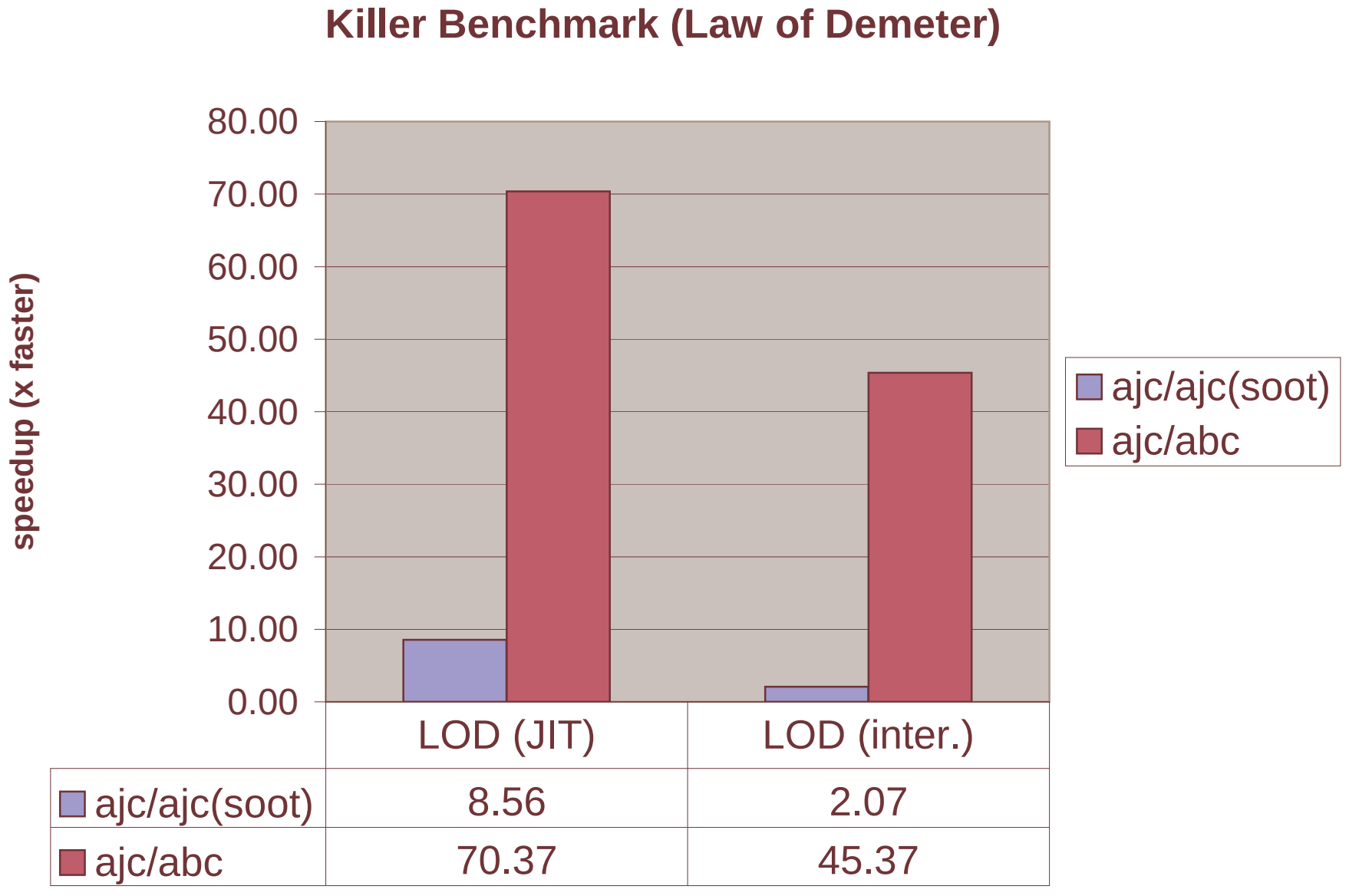
	DCM	figure	prod_lines	null_check
ajc/ajc(soot)	1.00	1.00	1.01	1.02
ajc/abc	1.00	7.45	1.04	4.65

Peformance Improvement(2)



	DCM	figure	prod_lines	null_check
ajc/ajc(soot)	1.01	1.02	1.01	1.06
ajc/abc	1.00	6.74	1.03	2.61

Peformance Improvement(3)



	LOD (JIT)	LOD (inter.)
ajc/ajc(soot)	8.56	2.07
ajc/abc	70.37	45.37

Conclusions

- AspectJ is very useful for many tasks - illustrated with tiny interpreter
- **abc** is a new compiler for AspectJ which is extensible and optimizing.
- You can use **abc** as an alternative AspectJ compiler, or you can use it for research into language extensions and new optimizations.
- It is worth thinking about AspectJ-specific optimizations, and **abc** has already implemented some of these.
- Lots more work by the **abc** team to come ... we welcome users!

`http://aspectbench.org`