Using AOP for Detailed Runtime Monitoring Instrumentation

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Runtime Monitoring

- The act of observing an executing system in order to learn something about its dynamic behavior

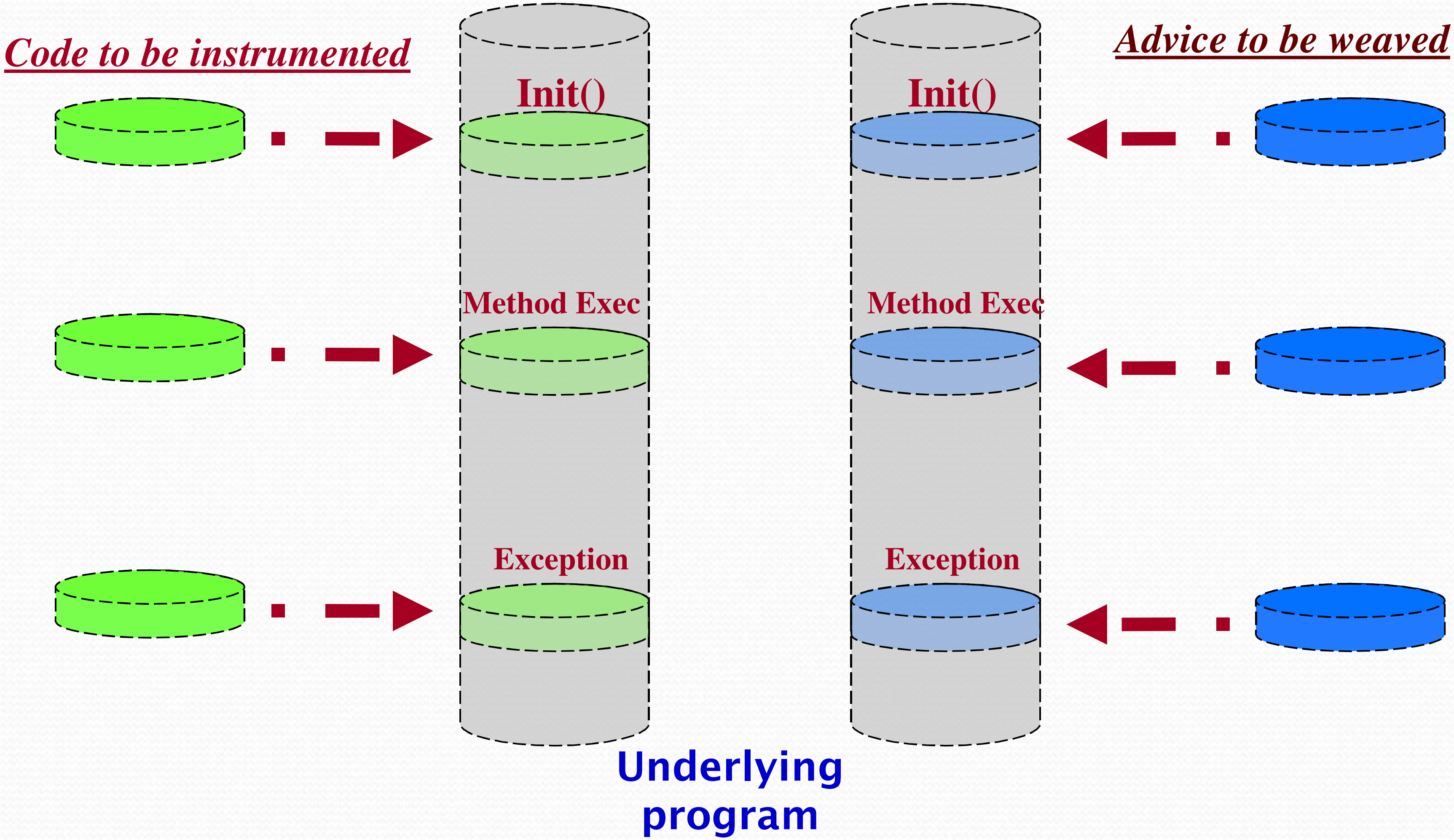
- RM needs an extremely wide variety of instrumentation mechanisms

Aspect Oriented Programming

- An elegant framework for constructing program behaviour that is orthogonal to the underlying program code base

- AOP is a natural fit for the domain of runtime monitoring

AOP Weaving vs Runtime monitoring instrumentation



Aspect Oriented Programming

- Weaving: the process of instrumentation
- Advice: code that will be weaved
- Jointpoint: points in the program where advice can be weaved
  - method call, object construction
- Aspect: an entity that holds all of the above

AOP for Runtime Monitoring

- Naturally captures the idea of scattered instrumentation in a base program
- Can be used on existing programs
- It is formal and uses normal programming concepts that programmers can readily grasp

AOP Deficiencies

- Not enough detail to cover all runtime monitoring needs
  - e.g., statement level weaving, basic blocks, loops, local variable access
- Limited to weaving based on the source code
  - Sampling-based profiling needs weaving based on execution time intervals rather than on places in the code

```
final double matgen(double a[][], final int n, double b[]) {
       .....
       for (i = 0; i < n; i++) {
           for (j = 0; j < n; j++) {
               init = 3125 * init % 65536;
               a[j][i] = (init - 32768.0) / 16384.0;
               norma = (a[j][i] > norma) ? a[j][i] : norma;
           }
       }

        for (j = kp1; j < n; j++) {
                   col_j = a[j];
                   if (l != k) {
                       col_j[l] = col_j[k];
                       col_j[k] = t;
                   }
                   daxpy(n - (kp1), t, col_k, kp1, 1, col_j, kp1, 1);
                   }
   .....
}
```

```
final double matgen(double a[][], final int n, double b[]) {
    .....
    for (i = 0; i < n; i++) {
        for (j = 0; j < n; j++) {
            init = 3125 * init % 65536;
            a[j][i] = (init - 32768.0) / 16384.0;
            norma = (a[j][i] > norma) ? a[j][i] : norma;
        }
    }

     for (j = kp1; j < n; j++) {
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                col_j[l] = col_j[k];
                col_j[k] = t;
            }
            daxpy(n - (kp1), t, col_k, kp1, 1, col_j, kp1,
            }
  .....
}
```

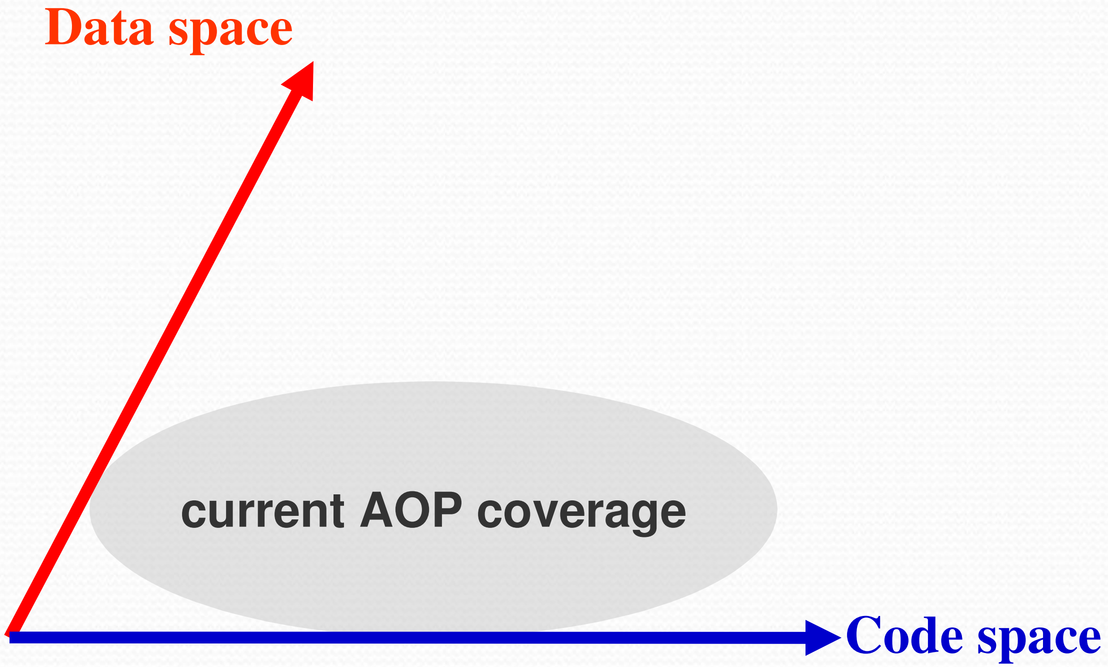
Existing joinpoints Method Execution

Non-existing joinpoints

Existing joinpoints Method Call

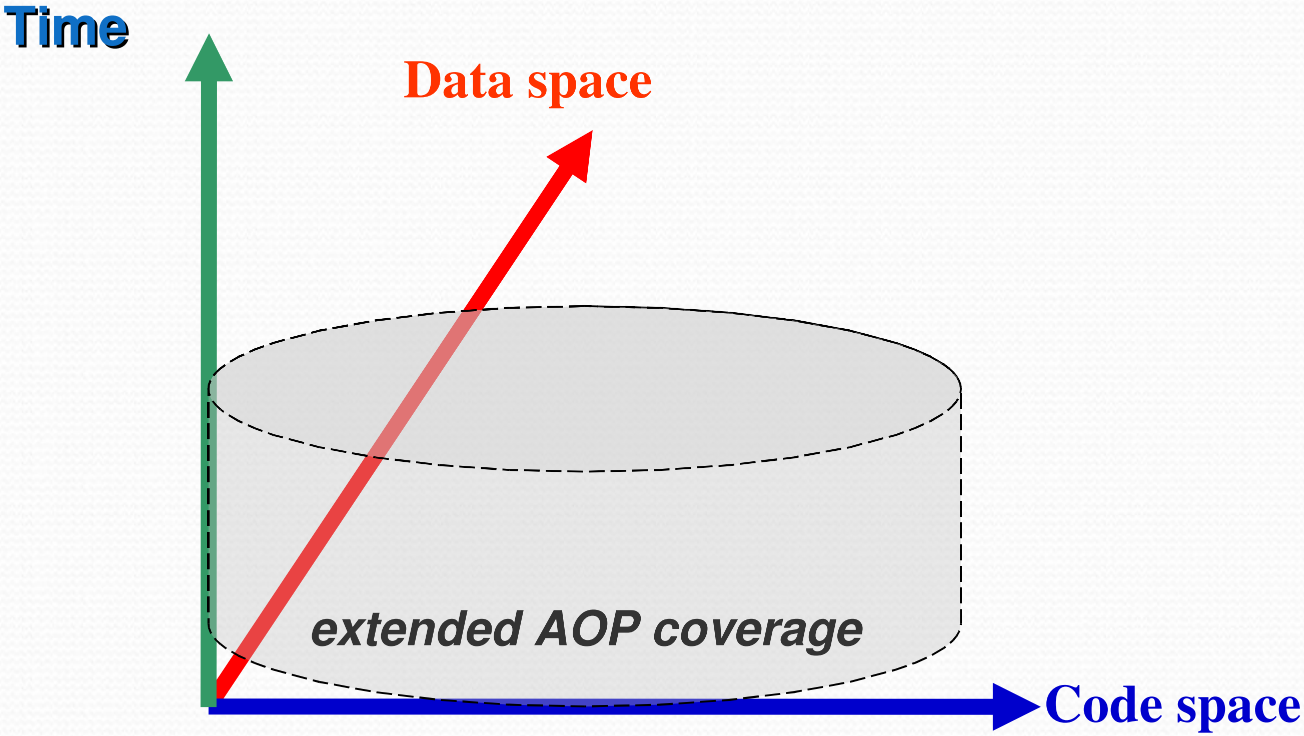
Axes of Weaving

Weaving in code and data space



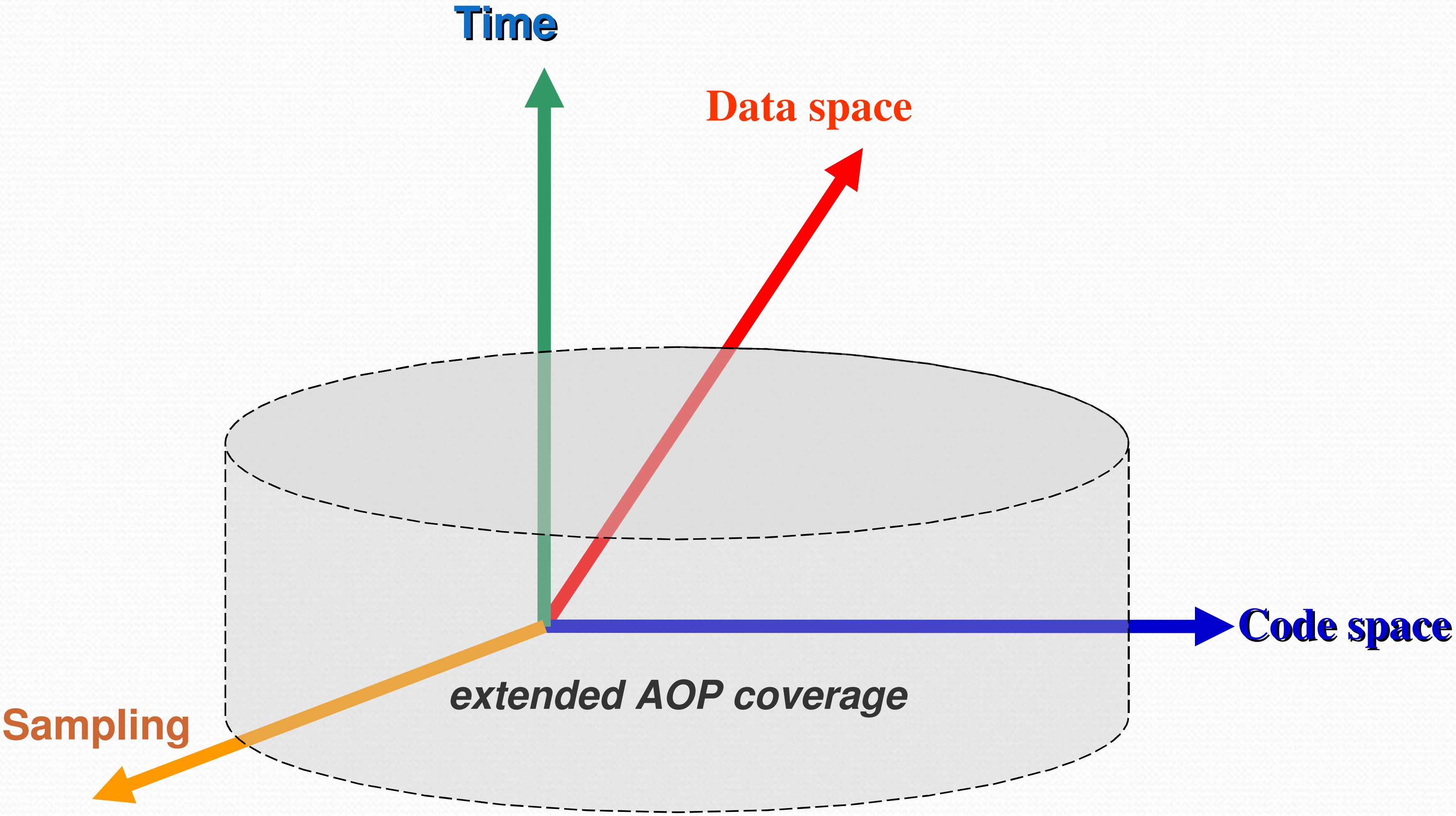
Weaving in two dimensions

Axes of Weaving



Extending the axes of weaving to a 3 dimensional view

Axes of Weaving



New Code PCDs

- An extension in abc (AspectJ)
- New *basicblock* pointcut designator enables advice on every basic block
- New *loopbackedge* pointcut designator enables advice on every loop
- Both give reflective information
  - Class and Method name (already existing)
  - In-method unique ID (additional)

Basic Block PCD

```
aspect TraceBasicBlocks {
     before(int blockID)  : basicblock()  && args(blockID)
    {
     System.err.println("Entering Block --> " + blockID
         + " at" + thisJoinPoint.getSourceLocation());

    }
    after(int blockID)  : basicblock() && args(blockID)
    {
     System.err.println("Exiting Block --> " + blockID ); }
    }
}
```

Loop Backedge PCD

```
aspect TraceLoops {
before(int id) : loopbackedge() && args(id)
{
    System.err.println("Loop body done, " +
     id + " at " +
     thisJoinPoint.getSourceLocation());
  }
}
```

AOP / RM Issues

- ABC was specifically created for extensibility, but is still limited
  - When we tried statement-level advice, we were told “we never intended *abc* for that!”
- For RM, we implement *before* and *after* advice, but not *around* advice
  - Would *around* be useful?

AOP / RM Issues

- ABC weaving occurs on an intermediate representation
  - e.g., all loops translated to if-goto structures
  - can we ensure source code fidelity?
- After advice misses final logical compare
  - single JVM compare-branch instruction
  - can be fixed with code duplication

AOP / RM Issues

- Ultimate goal: performance
  - abc implements advice as method call
  - can we rely on optimizing JVMs?

Examples

- Benchmark suite
  - JTetris: Tetris game in Java
  - Image2Html: converts a bitmap image into HTML
  - Java Linpack, an implementation in Java of the FORTRAN Linpack routines
- Coverage analysis.
  - Full instrumentation and Key class instrumentation
- Profiling
  - Time
  - Probability

Results

Application	Total number of blocks	Number of methods and loops	Time no Instrumentation	Prob= .5 --------- – Time Block Instr	Prob= .5 --------- – Time Loop Instr	Prob= .05 --------- – Time Block Instr	Prob= .05 ---------- Time Loop Instr
Java linpack	156	38	0.0675	0.572	0.335	0.271	0.187
J-Tetris	240	84	0.3275	0.547	0.435	0.439	0.339
Image2Html	409	39	0.6611	2.311	0.819	0.967	0.735

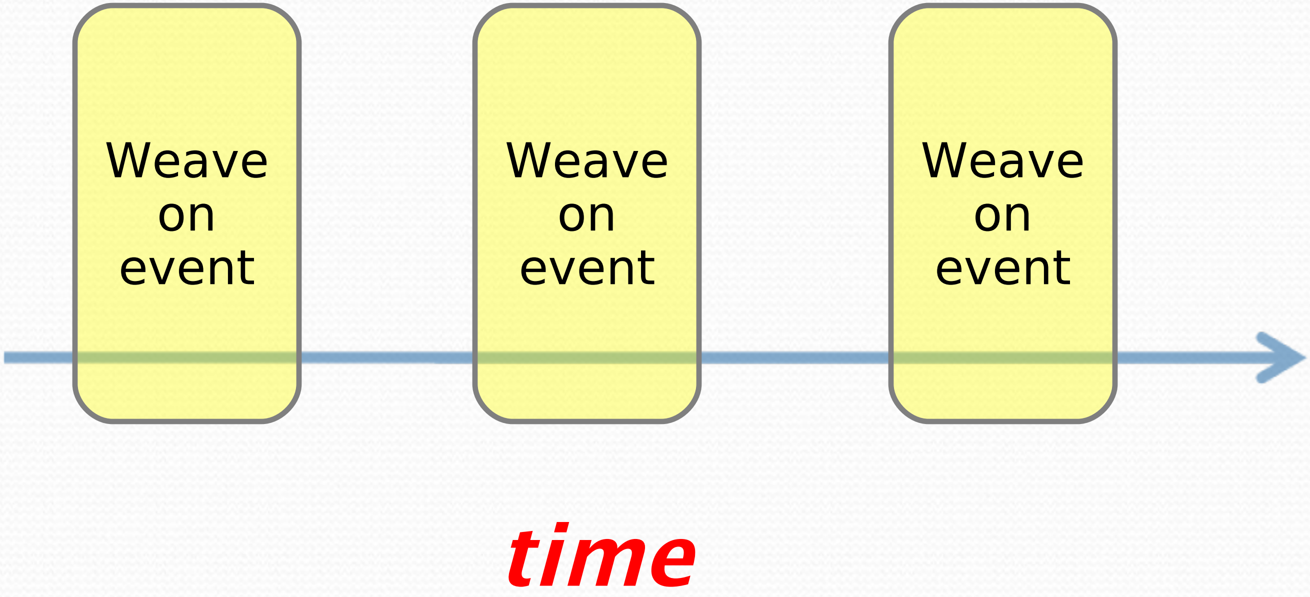
Future work.

- Continue to work new joinpoint types
  - loop body, if-else body, case body
  - time and probability dimensions
- Design, prototype, implement, test, and evaluate new pointcuts in the new dimensions
- Mechanisms for making reflective information easier and faster to obtain in the advice code will be needed

Thank you

Questions ?

Sampling based profiling


Weave on event
Weave on event
Weave on event
time