ADVANCED SOFTWARE ENGINEERING

CS561
TUE/THU @4PM,

Danny Dig

QUIZ #1

- **Write down your name**
- **Grad Program (e.g., EECS PhD, EECS MS) and year of study**
- **What are your expectations from the class?**

Software Engineering as Done Today

Change is the heart of software development:

- **add features, fix bugs, support new hardware/UI/OS**

Today's program development is very crude

- **change carried manually, through low-level edits**
- **changes are almost never reused**
- **versioning tools focus on changes to lines of code**

Change is too ad-hoc making software development error-prone, time-consuming, and $$$

- **2/3rd of software costs due to software evolution, some industrial surveys claiming 90%**

OSU Oregon State University

My View of Tomorrow: Programming is Program Transformation

Change needs to move to a higher-level of abstraction

Program transformations as first-class:

- **most changes carried through automated program transformations**
- **even manual edits become transformations**
- **programs as sequence of program transformations**

Q1: Analyze what software changes occur in practice?

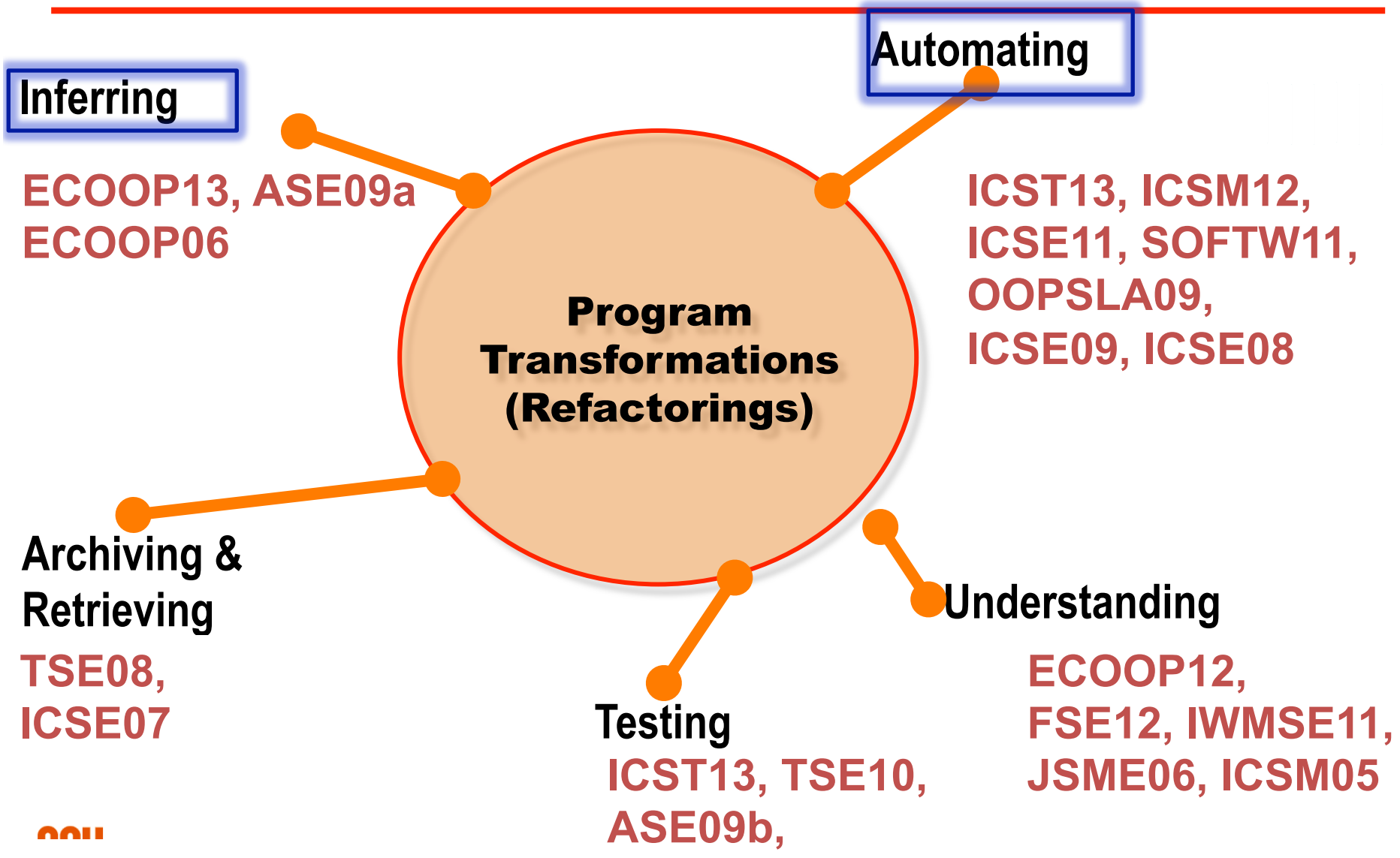
Q2: How can we automate them?

Q3: Can we represent programs as transformations? Archive, retrieve, and visualize them?

Q4: Can we infer higher-level transformations?

Oregon State University

Overview of my Approach to Software Evolution Research



Our Refactorings for Parallelism

Refactorings for thread-safety
- make class immutable [ICSE'11]
- convert to Atomic* classes [ICSE'09]
- use concurrent collections [ICSE'09]
- infer region annotations [ASE'09]
- atomic check-then-act operations [ICST'13]

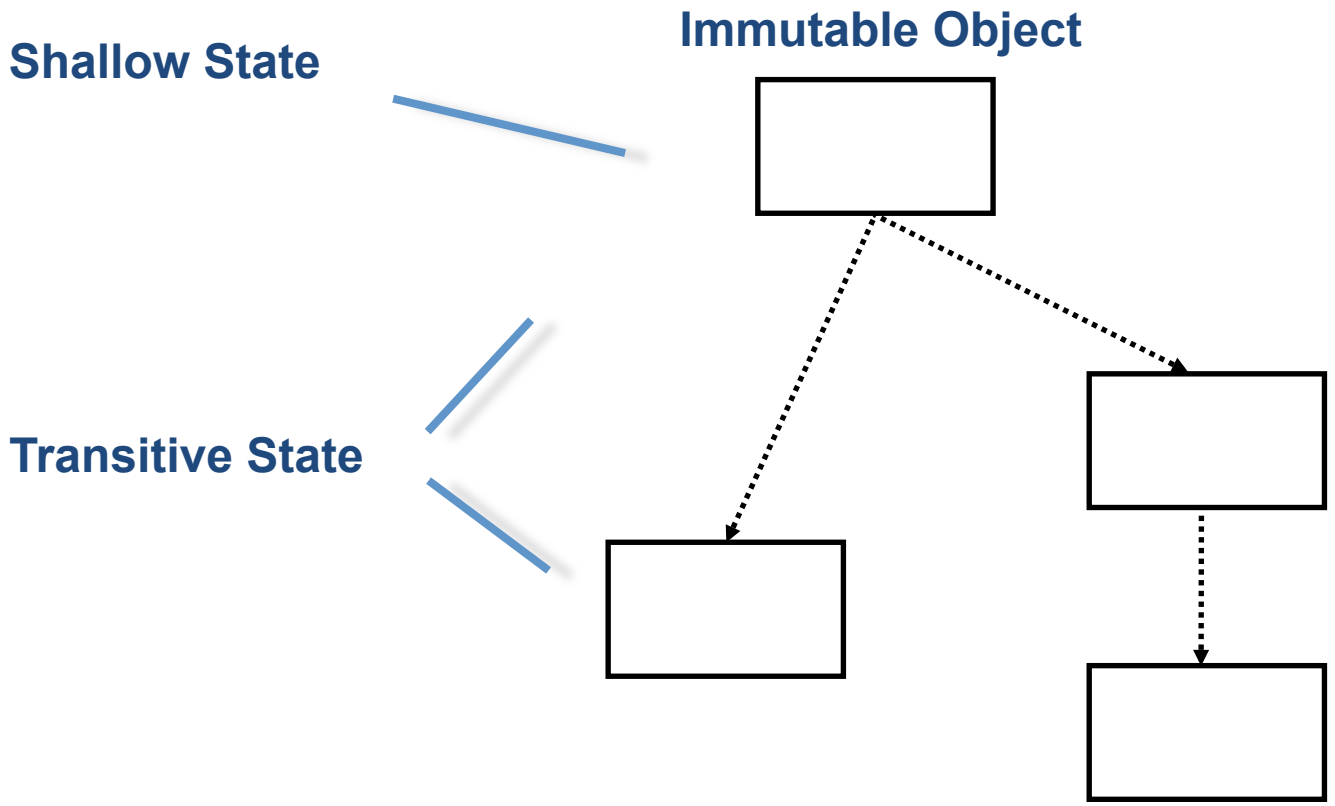
Interprocedural analyses:
- control, data-flow
- points-to
- constraint-based

Refactorings for throughput
- parallel recursive divide-and-conquer [ICSE'09]
- loop parallelism via ParallelArray [OOPSLA'10:demo]
- loop parallelism via lambda-enabled functional operators [FSE'13]

Refactorings for scalability
- Atomic*, concurrent collections [ICSE'09]

OSU Oregon State University

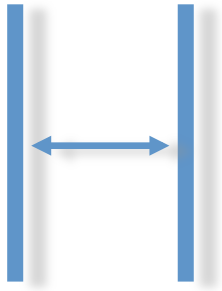
An immutable object is one whose state can not be changed after it has been constructed



The transitive state of a deeply immutable object can not be mutated

OSU Oregon State University

Motivation: immutable classes make applications simpler

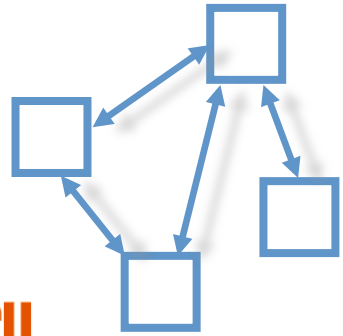


Simpler parallel applications

- **No interference with other threads through immutable objects**
- **No races → no locks → no deadlocks**
- **Embarrassingly thread-safe**

Simpler sequential applications

- **No side effects from method calls**
- **Efficient comparison based on identity**
- **Reduced memory footprint through interning**
- **Secure applications**

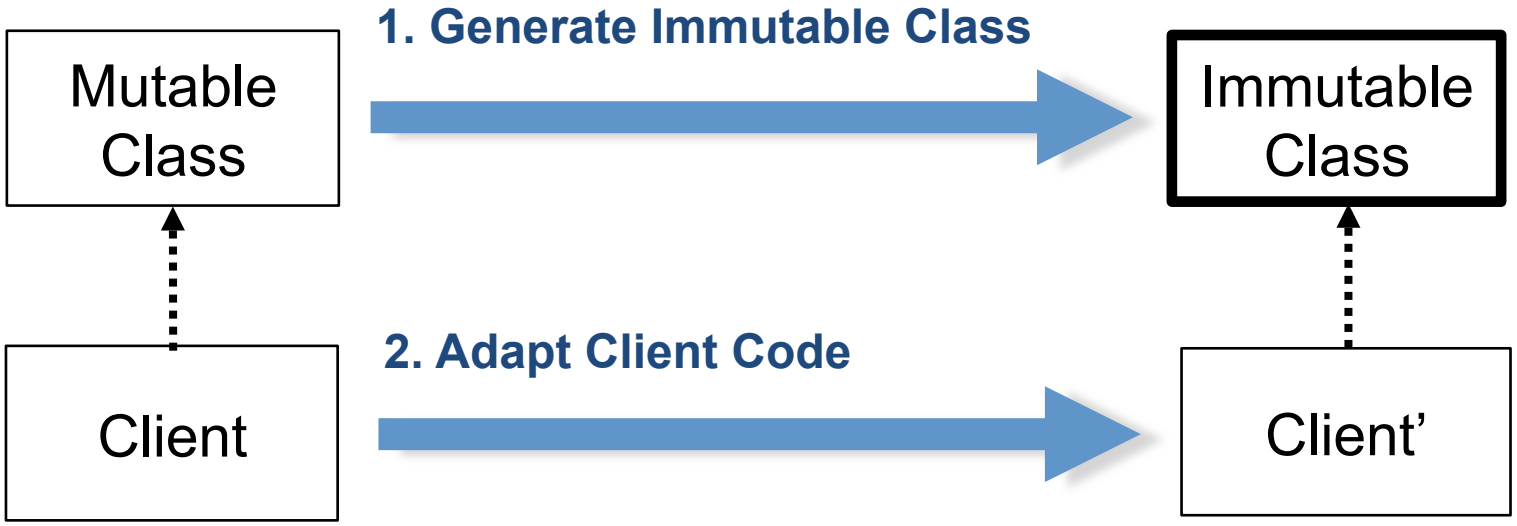


Simpler distributed applications

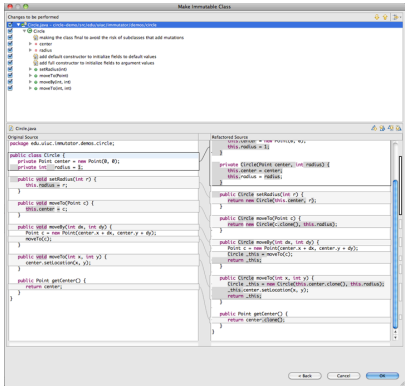
- **Reduced need for complex proxy update protocols**

OSU Oregon State University

Mutable classes can be refactored to immutable classes in two steps



I will talk about Immutator, a technique and a tool that *Generates Immutable Classes*



Challenges: finding mutator methods and entering/escaping objects

```
public class Circle {
   private Point center = new Point(0, 0);
   private int   radius = 1;

   public void setRadius(int r) {
      radius = r;
   }

   public void moveTo(Point c) {
      center = c;
   }

   public void moveBy(int dx, int dy) {
      Point c = new Point(center.x + dx, center.y + dy);
      moveTo(c);
   }

   public void moveTo(int x, int y) {
      center.setLocation(x, y);
   }

   public Point getCenter() {
      return center;
   }
```

Mutation

Mutation

Enter

Indirect Mutation

Transitive Mutation

Escape

Find mutator methods that change the state of the instances

Mutation

Mutation

```
public class Circle {
   private Point center = new Point(0, 0);
   private int   radius = 1;

   public void setRadius(int r) {
      radius = r;
   }

   public void moveTo(Point c) {
      center = c;
   }

   public void moveBy(int dx, int dy) {
      Point c = new Point(center.x + dx, center.y + dy);
      moveTo(c);
   }

   public void moveTo(int x, int y) {
      center.setLocation(x, y);
   }

   public Point getCenter() {
      return center;
   }
```

Find transitive mutators that change the state of objects reachable through fields

```
public class Circle {
   private Point center = new Point(0, 0);
   private int   radius = 1;

   public void setRadius(int r) {
      radius = r;
   }

   public void moveTo(Point c) {
      center = c;
   }

   public void moveBy(int dx, int dy) {
      Point c = new Point(center.x + dx, center.y + dy);
      moveTo(c);
   }
```

library code, aliases, long call chains, polymorphism

Transitive Mutation →

```
   public void moveTo(int x, int y) {
      center.setLocation(x, y);
   }

   public Point getCenter() {
      return center;
   }
```

Detect objects that enter or escape. These can be mutated by client code.

```
public class Circle {
   private Point center = new Point(0, 0);
   private int   radius = 1;

   public void setRadius(int r) {
      radius = r;
   }

   public void moveTo(Point c) {
      center = c;
   }
```

Enter

Client Code

```
   Point point = new Point(2, 2);
   circle.moveTo(point);
   point.setLocation(3, 3);
```

Escape

```
   return center;
}
```

wrapped inside containers

Analysis and Transformations

Entering Objects

Transitive Mutations

Indirect Mutations

Mutations

Escaping Objects

Immutator converts direct mutator methods to factory methods

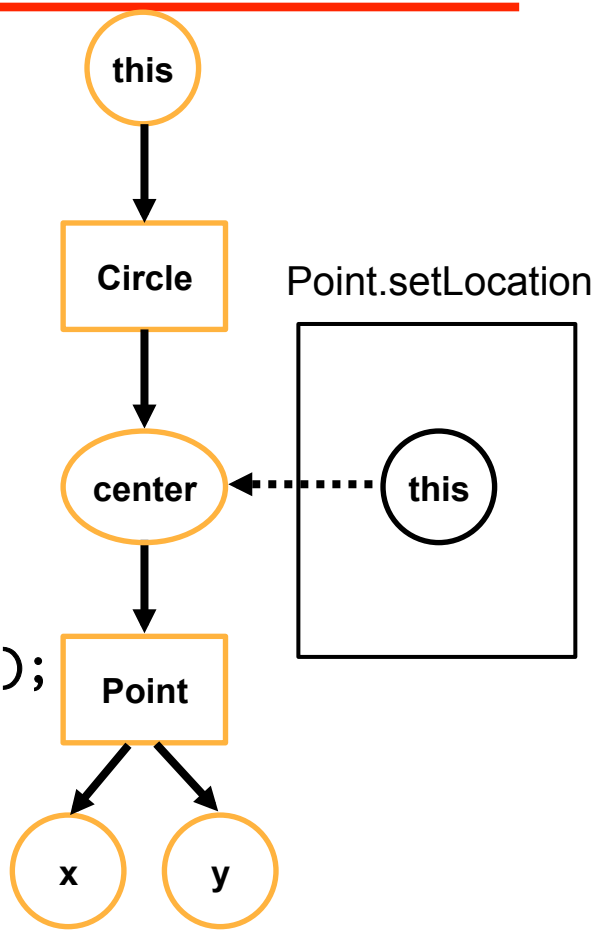
```
public void setRadius(int r) {
    radius = r;
}
```

```
public Circle setRadius(int r) {
    return new Circle(this.center, r);
}
```

Immutator detects methods that are mutating the transitive state of the class

```
public void moveTo(int x, int y) {
   this.center.setLocation(x, y);
}
```

```
public Circle moveTo(int x, int y) {
   Circle _this = new Circle(center.clone(),radius);
   _this.center.setLocation(x, y);
   return _this;
}
```

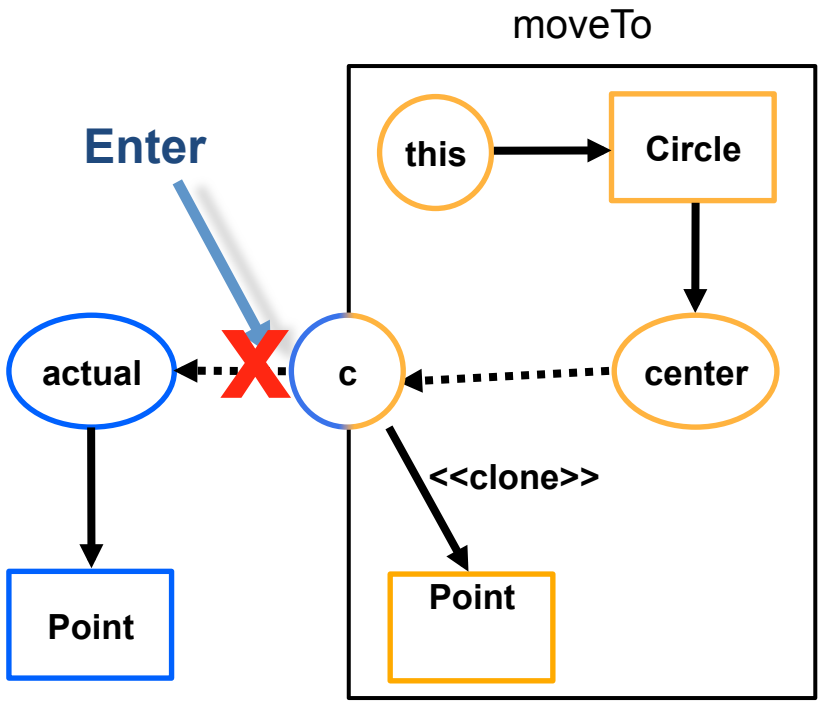


Algorithm creates a summary of variables and fields in the class' transitive state

Immutator detects objects that enter or escape from methods of the class

```
public void moveTo(Point c) {
    this.center = c;
}
```

```
public Circle moveTo(Point c) {
    return new Circle(c.clone(),this.r);
}
```



Static program analysis

Supporting data-structures:

- **call graph, control-flow graph**
- **points-to graph (model objects as allocation sites)**

Two novel interprocedural analyses determine safety w.r.t. to *transitive state of target* class:

1. **purity analysis detects side effects**
   - **reachability problem: mutated state reachable from `this`**
   - **summarization algorithm propagates mutation in reversed topological order through call graph**

2. **class escape analysis detects entering/escaping objects**
   - **transitive closure of `this` and outside nodes**
   - **reachability between the `in` and `out` sets**

Evaluation Setup

RQ1: Is Immutator safer than manual transformations?
RQ2: How applicable is Immutator?
RQ3: Does it make the programmer more productive?

CaseStudy1: Ran Immutator on all 346 classes from 3 open-source projects

CaseStudy2: Compared Immutator with 11 manual refactorings performed by developers from 6 open-source projects

Controlled Experiment: Asked 6 experienced programmers to refactor by hand

OSU Oregon State University

Immutator is safer

Open-source refactorings contained 2.1 errors/class (confirmed by developers)

Developers of JDigraph applied our patch

Other developers updated the documentation with warnings about entering/escaping objects

Controlled experiment participants refactorings contained 6.3 errors/class

All 13,000 tests pass before/after our refactoring

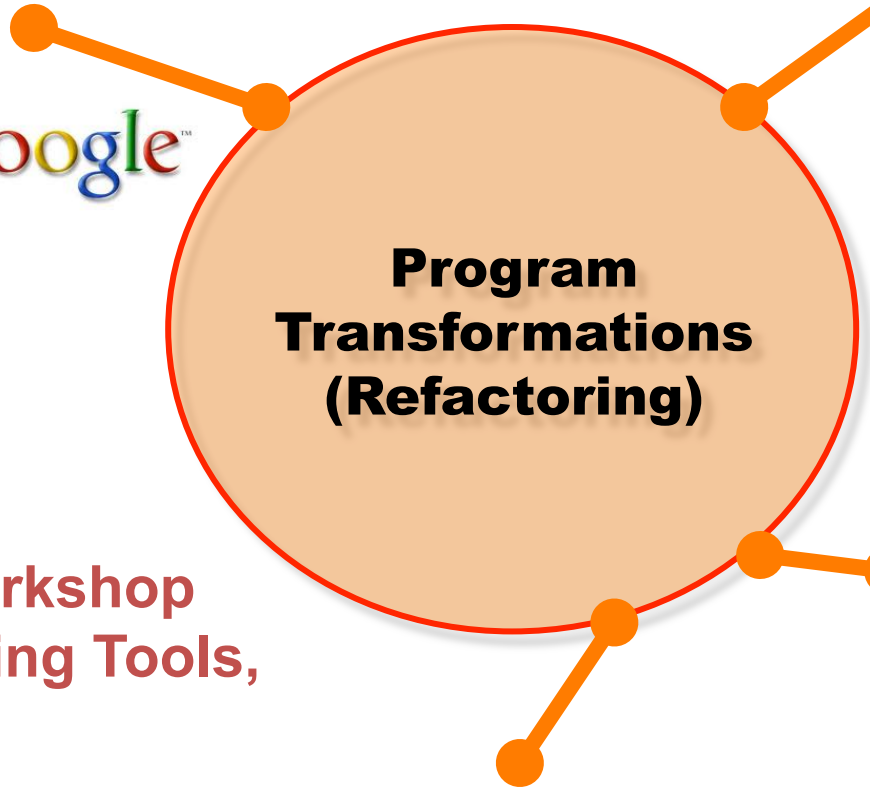
project	immutable class	programmer errors		
		mutator	enter	escape
JDigraph	ImmutableBag	-	1	-
	FastDigraph	-	2	-
	HashDigraph	-	2	-
	ArrayGrid2D	-	2	-
	MapGrid2D	-	2	-
WALA	ImmutableByteArray	-	1	-
	ImmutableStack	-	2	3
j.u.c.	ImmutableEntry	-	2	2
Guava	ImmutableEntry	-	-	2
peaberry	ImmutableAttribute	-	-	1
Spring	ImmutableFlow-AttributeMapper	2	2	-

Immutator dramatically improves productivity

Saves analyzing 57 methods/refactoring and rewriting 45 lines per refactored class

Immutator is fast: 2 sec/refactoring compared with 27 min/manual refactoring

Practical Impact of My Research



Inferring

- used at Google
  IBM
- dozen labs

Automating

- ship
- ship/ongoing

NetBeans IDE

eclipse

Understanding

- influenced Java and .NET official concurency libraries
-learnparallelism.net
30,000 visitors in 6 mo

Testing

testing infra at ORACLE

founded Workshop on Refactoring Tools, HotSwUp

first open-source refactoring
17,000 downloads

Course Administration

Check Wiki:

http://classes.engr.oregonstate.edu/eecs/fall2014/cs561/index.php

2 work items due today:

- **sign up on Piazza (all communications through Piazza, no email)**
- **Read one paper about how to read Soft Eng papers**

Prereqs: took at least two classes of undergrad coursework in Software Engineering (e.g., CS361/CS362)

Course Administration

Research-based course:

- **Participate in class discussion and activities.**

- **Read two research papers for every class meeting (around 10 pages, double column => total of 800 research pages during the term)**
- **For each class meeting submit a one-page critique of one paper before class (at 12pm)**
- **Prepare and deliver presentations of the selected research papers**

- Homework

- Complete a term project (teams of 2 students)

OSU Oregon State University

Projects Focus on Mobile & Cloud Applications

New converging forces that reshape computing

- end users spend most time on mobile apps

- by 2016, more than 300B applications downloaded [Gartner]

Technological shifts/opportunities:

- mobile devices are all going multicore

- constraints on memory/CPU/bandwidth/battery usage

- connectivity with the cloud

Encouraging good (old) software engineering practices

OSU Oregon State University

Transformations for Mobile Applications

What are the new transformations we need to automate?

- inspiration from explorative studies

Examples of transformations:

- adding concurrency in apps to improve responsiveness

- candidate programs with trade-offs between performance & power consumption

- adaptation to different display technologies

- split functionality between the device and cloud

OSU Oregon State University

Science and Tools for Change

“Change is the only guaranteed constant”

To foster a revolution in software technology, we need to raise the level of abstraction for changes

Interactive, automated transformation more effective than manual

Many of our tools ship with official release

- YOU can make a difference too

Today's brand new programs are tomorrow's legacy programs

- software evolution becomes the primary paradigm of software development

OSU Oregon State University