

# Principles of Software Construction: Objects, Design, and Concurrency

## The Last One: Locking Back & Looking Forward

Claire Le Goues

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# Looking Back at the Semester

# Principles of Software Construction: Objects, Design, and Concurrency

## Introduction, Overview, and Syllabus

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# How Modern Software Gets Built

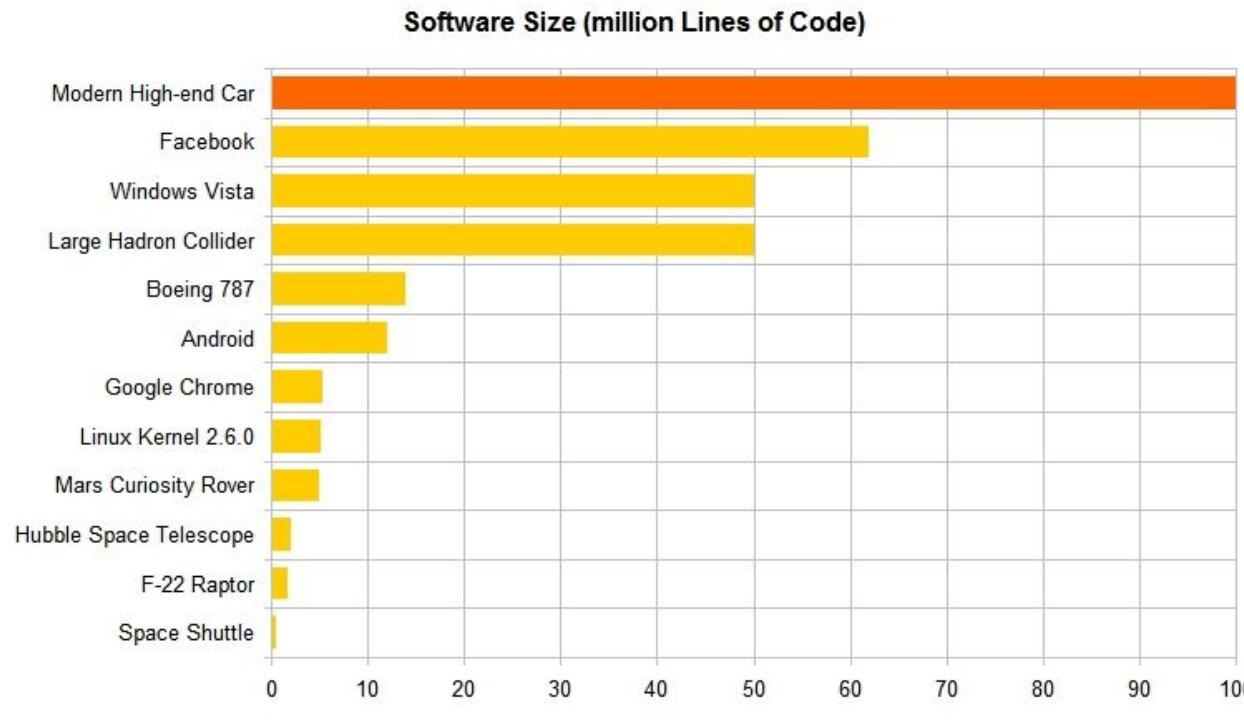
## Roads and Bridges:

The Unseen Labor Behind  
Our Digital Infrastructure

WRITTEN BY  
Nadia Eghbal

“Building software is like constructing a building. A construction company wouldn’t build its hammers and drills from scratch, or source and chop all of the lumber themselves.”

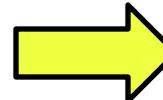
# Welcome to the era of “big code”



(informal reports)

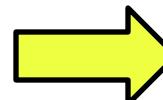
# From Programs to Applications and Systems

Writing algorithms, data structures from scratch



Reuse of libraries, frameworks

Functions with inputs and outputs



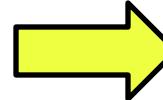
Asynchronous and reactive designs

Sequential and local computation



Parallel and distributed computation

Full functional specifications

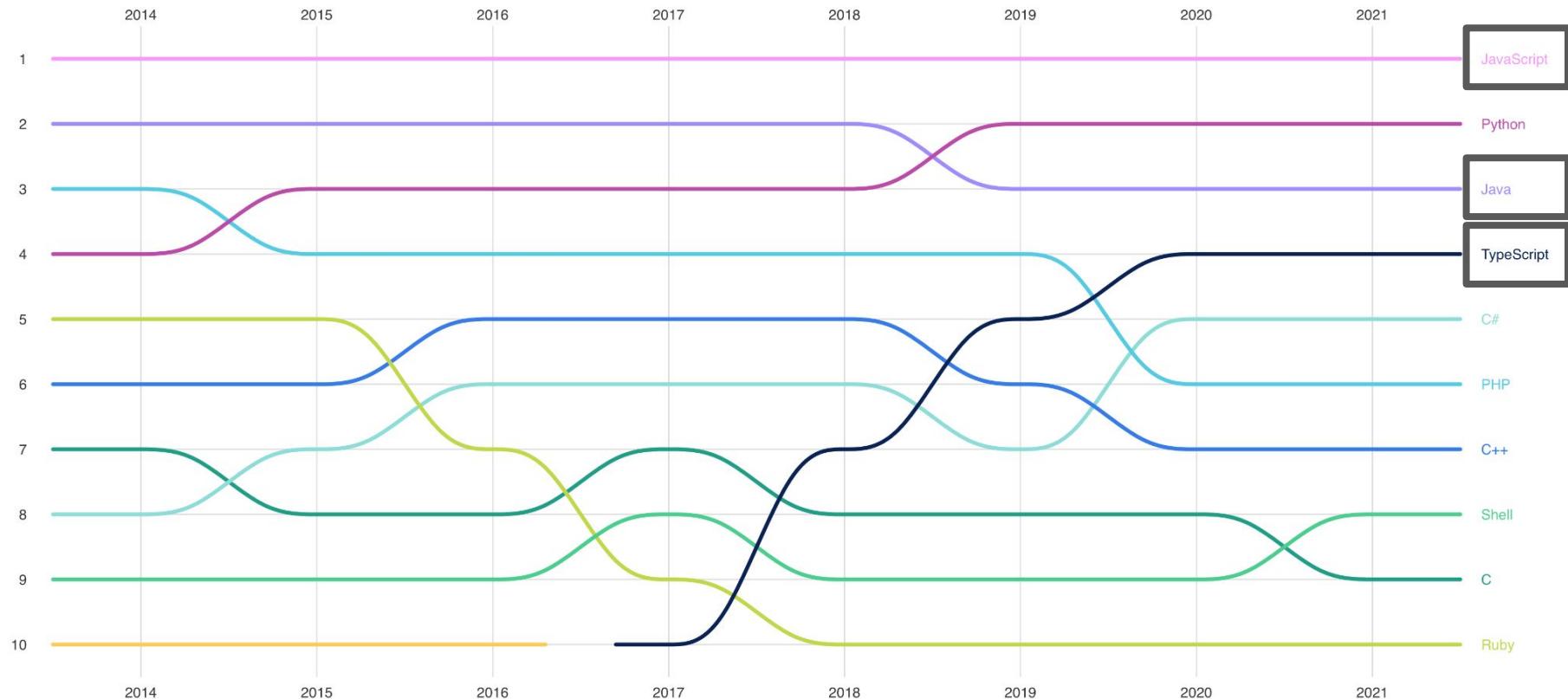


Partial, composable, targeted models

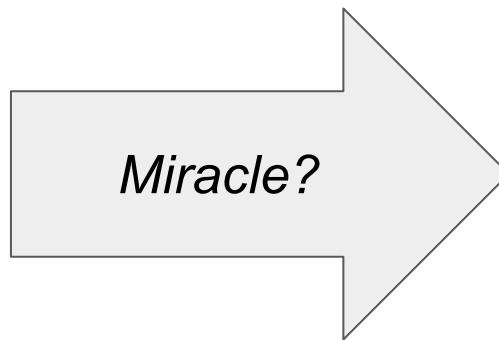
Our goal: understanding both the **building blocks** and also the **design principles** for construction of software systems at scale

# Top languages over the years

2021 GitHub State of the Octoverse report



User needs  
(Requirements)



Code

Maintainable?  
Testable?  
Extensible?  
Scalable?  
Robust? ...

# Which version is better?

Version A:

```
static void sort(int[] list, boolean ascending) {  
    ...  
    boolean mustSwap;  
    if (ascending) {  
        mustSwap = list[i] > list[j];  
    } else {  
        mustSwap = list[i] < list[j];  
    }  
    ...  
}
```

```
interface Order {  
    boolean lessThan(int i, int j);  
}  
class AscendingOrder implements Order {  
    public boolean lessThan(int i, int j) { return i < j; }  
}  
class DescendingOrder implements Order {  
    public boolean lessThan(int i, int j) { return i > j; }  
}
```

```
static void sort(int[] list, Order order) {  
    ...  
    boolean mustSwap =  
        order.lessThan(list[j], list[i]);  
    ...
```

Version B':

# **it depends**

**Depends on what?  
What are scenarios?  
What are tradeoffs?**

**In this specific case, what  
would you recommend?  
(Engineering judgement)**

# Some qualities of interest, i.e., *design goals*

Functional correctness	Adherence of implementation to the specifications
Robustness	Ability to handle anomalous events
Flexibility	Ability to accommodate changes in specifications
Reusability	Ability to be reused in another application
Efficiency	Satisfaction of speed and storage requirements
Scalability	Ability to serve as the basis of a larger version of the application
Security	Level of consideration of application security

**Source: Braude, Bernstein,  
Software Engineering. Wiley  
2011**

# Semester overview

- Introduction to Object-Oriented Programming
- Introduction to **design**
  - **Design** goals, principles, patterns
- **Designing** objects/classes
  - **Design** for change
  - **Design** for reuse
- **Designing** (sub)systems
  - **Design** for robustness
  - **Design** for change (cont.)
- **Design** for large-scale reuse

## Crosscutting topics:

- Building on libraries and frameworks
- Building libraries and frameworks
- Modern development tools: IDEs, version control, refactoring, build and test automation, static analysis
- Testing, testing, testing
- Concurrency basics

# Principles of Software Construction (Design for change, class level)

## Starting with Objects (dynamic dispatch, encapsulation, entry points)

Claire Le Goues

Vincent Hellendoorn



# Where we are

*Design for  
understanding  
change/ext.  
reuse  
robustness  
...*

	<i>Small scale: One/few objects</i>	<i>Mid scale: Many objects</i>	<i>Large scale: Subsystems</i>
	<b>Subtype Polymorphism ✓</b> <b>Information Hiding, Contracts ✓</b> Immutability ✓ Types ✓ Static Analysis ✓ Unit Testing ✓	Domain Analysis ✓ Inheritance & Del. ✓ Responsibility Assignment, Design Patterns, Antipattern ✓ Promises/ Reactive P. ✓ Integration Testing ✓	GUI vs Core ✓ Frameworks and Libraries ✓, APIs ✓ Module systems, microservices ✓ Testing for Robustness ✓ CI ✓, DevOps ✓, Teams

*This is C code!*

# Data structures and procedures

```
struct point {  
    int x;  
    int y;  
};  
  
void movePoint(struct point p, int deltax, int deltay) { p.x = ...; }  
  
int main() {  
    struct point p = { 1, 3 };  
    int deltaX = 5;  
    movePoint(p, 0, deltaX);  
    ...  
}
```

# Interfaces and Objects

```
interface Counter {  
    int get();  
    int add(int y);  
    void inc();  
}  
Counter obj = new Counter() {  
    int v = 1;  
    public int get() { return this.v; }  
    public int add(int y) { return this.v + y; }  
    public void inc() { this.v++; }  
};  
  
System.out.println(obj.add(obj.get()));  
// 2
```

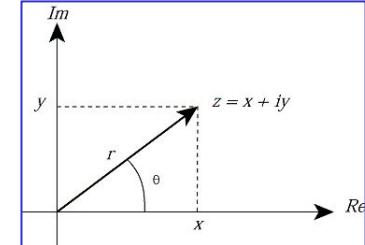
```
interface Counter {  
    v: number;  
    inc(): void;  
    get(): number;  
    add(y: number): number;  
}  
const obj: Counter = {  
    v: 1,  
    inc: function() { this.v++; },  
    get: function() { return this.v; },  
    add: function(y) { return this.v + y; }  
}
```

This uses anonymous classes to create an object without a class. This isn't very common, it just looks a lot like the TS.

# Multiple Implementations of Interface

*This is Java code!*

```
interface Point {  
    int getX();  
    int getY();  
}  
  
class PolarPoint implements Point {  
    double len, angle;  
    PolarPoint(double len, double angle)  
        {this.len=len; this.angle=angle;}  
    int getX() { return this.len * cos(this.angle); }  
    int getY() { return this.len * sin(this.angle); }  
    double getAngle() {...}  
}  
  
Point p = new PolarPoint(5, .245);
```



# Check your Understanding

```
interface Animal {  
    void makeSound();  
}  
  
class Dog implements Animal {  
    public void makeSound() { System.out.println("bark!"); } }  
  
class Cow implements Animal {  
    public void makeSound() { moo(); }  
    public void moo() {System.out.println("moo!"); } }  
  
Animal x = new Animal() {  
    public void makeSound() { System.out.println("chirp!"); } }  
x.makeSound(); // "chirp"  
  
Animal d = new Dog();  
d.makeSound(); // "bark!"  
  
Animal b = new Cow();  
b.makeSound(); // "moo!"  
b.moo(); // compile-time error
```

```
Animal a = new Animal();  
a.makeSound(); // compile-time error
```

# JavaScript Closures for Hiding

All methods and fields are public, no language constructs for access control

TypeScript added them, so it's quite similar to Java!

In JS: Encoding hiding with closures

```
function createPolarPoint(len, angle) {  
    let xcache = -1;  
    let internalLen=len;  
    function computeX() {...}  
    return {  
        getX: function() {  
            computeX(); return xcache; },  
        getY: function() {  
            return len * sin(angle); }  
    };  
}  
const pp = createPolarPoint(1, 0);  
pp.getX(); // works  
pp.computeX(); // runtime error  
pp.xcache // undefined  
pp.len // undefined
```

# How to hide information?

```
class CartesianPoint {  
    int x,y;  
    Point(int x, int y) {  
        this.x=x;  
        this.y=y;  
    }  
    int getX() { return this.x; }  
    int getY() { return this.y; }  
    int helper_getAngle();  
}
```

```
const point = {  
    x: 1, y: 0,  
    getX: function() {...}  
    helper_getAngle:  
        function() {...}  
}
```

# Principles of Software Construction: Objects, Design, and Concurrency

## IDEs, Build system, Continuous Integration, Libraries

Vincent Hellendoorn **Claire Le Goues**



# Productivity Requires Automation Requires Abstraction



# Quick overview of today's toolchain: Build Systems

How does this happen?

The image shows a software interface with two main panes. The left pane is titled "C++ source #1" and contains the following C++ code:

```
1 // Type your code here, or load an example.
2 int square(int num) {
3     return num * num;
4 }
```

The right pane is titled "#1 with MSP430 gcc 4.5.3" and displays the generated assembly code for the MSP430 processor using the Intel hex dump format. The assembly code is:

```
11010 LXO: text // Intel A A A +
1
2 *****
3 * Function `square(int)'
4 *****
5 square(int):
6     push    r10
7     push    r4
8     mov     r1, r4
9     add    #4, r4
10    sub    #2, r1
11    mov    r15, -6(r4)
12    mov    -6(r4), r10
13    mov    -6(r4), r12
14    call   #__mulhi3
15    mov    r14, r15
16    add    #2, r1
```

*This is Java code!*

# Starting a program: Java

All Java code is in classes, so how to create an object and call a method?

```
// start with: java Printer  
class Printer {  
    void print() {  
        System.out.println("hi");  
    }  
    public static void main(String[] args) {  
        Printer obj = new Printer();  
        obj.print();  
    }  
}
```

in Java,  
everything is  
a class

main must be  
public and  
static

is (java X calls

Main method to be  
executed, here used to  
create object and invoke  
method

Static methods belong to  
class not the object,  
generally avoid them

*This is Typescript code!*

# Starting a Program

TypeScript compiles to  
JavaScript, by the way. There  
are several ways to run it.

Objects do not do anything on their own, they wait for  
method calls

```
// start with: node file.js
function createPrinter() {
    return {
        print: function() { console.log("hi"); }
    }
}
const printer = createPrinter();
printer.print()
// hi
```

or waits for events

Defining interfaces,  
functions, classes

Starting:  
Creating objects and  
calling methods



```
m pom.xml (FlashCards) ×  
F 1 <?xml version="1.0" encoding="UTF-8"?>  
2 <project xmlns="http://maven.apache.org/POM/4.0.0"  
3   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"  
4   xsi:schemaLocation="http://maven.apache.org/POM/4.0.0 http://maven.apache.org/xsd/maven-4.0.0.xsd">  
5     <modelVersion>4.0.0</modelVersion>
```

## Maven Phases

Although hardly a comprehensive list, these are the most common *default* lifecycle phases executed.

- **validate:** validate the project is correct and all necessary information is available
- **compile:** compile the source code of the project
- **test:** test the compiled source code using a suitable unit testing framework. These tests should not require the code be modified.
- **package:** take the compiled code and package it in its distributable format, such as a JAR.
- **integration-test:** process and deploy the package if necessary into an environment where integration tests can be run.
- **verify:** run any checks to verify the package is valid and meets quality criteria
- **install:** install the package into the local repository, for use as a dependency in other projects locally
- **deploy:** done in an integration or release environment, copies the final package to the remote repository for sharing

There are two other Maven lifecycles of note beyond the *default* list above. They are

- **clean:** cleans up artifacts created by prior builds
- **site:** generates site documentation for this project

<https://maven.apache.org/guides/getting-started/maven-in-five-minutes.html>

```
31           <version>RELEASE</version>  
32           <scope>test</scope>  
33       </dependency>  
       project > dependencies > dependency  
final  Build  Dependencies
```



- Node.js is a JS runtime. npm is its package manager.

```
package.json — claire-hw1-js
```

```
{} package.json 1, M X
```

```
{ } package.json > {} dependencies
```

```
1 {  
2   "name": "hw1-flashcards",  
3   "version": "1.0.0",  
4   "description": "",  
5   "main": "index.js",  
6   "scripts": {  
7     "compile": "tsc",  
8     "lint": "ts-standard",  
9     "start": "node dist/index.js"  
10    },  
11    "author": "",  
12    "license": "ISC",  
13    "devDependencies": {  
14      "@types/node": "^17.0.8",  
15      "@types/readline-sync": "^1.4.4",  
16      "ts-standard": "^10.0.0",  
17      "typescript": "^4.4.2"  
18    },  
19    "dependencies": {  
20      "readline-sync": "^1.4.10"  
21    }  
22 }  
23
```

# Abstraction, Reuse, and Programming Tools

- For each in {IDE, Build systems, libraries, CI}:
  - What is it today?
  - **What is under the hood?**
- What is next?

# Under the Hood: IDEs

Combine build systems + IDEs + plugins (checkstyle example/demo!)

The screenshot shows a Java project named "FlashCards" with the package path "src > main > java > edu > cmu > cs214 > hw1 > Main.java". The code editor displays the Main.java file:

```
Main.java — java
src > main > java > edu > cmu > cs214 > hw1 > Main.java > Main > main(String[])
11
12 public final class Main {
13
14     private Main() {
15         // Disable instantiating this class.
16         throw new UnsupportedOperationException();
17     }
18
19     public static void main(String[] args) throws IOException {
20         // TODO: set up options, extract command line arguments, fill in the relevant
21         CardStore cards = new CardLoader().loadCardsFromFile(new File(pathname: "c
22         CardDeck cardDeck = new CardDeck(cards.getAllCards(), new CardShuffler());
23         new UI().studyCards(cardDeck);
24
25     }
26
27 }
```

The left sidebar shows the project structure with the "site" option highlighted with a red box.

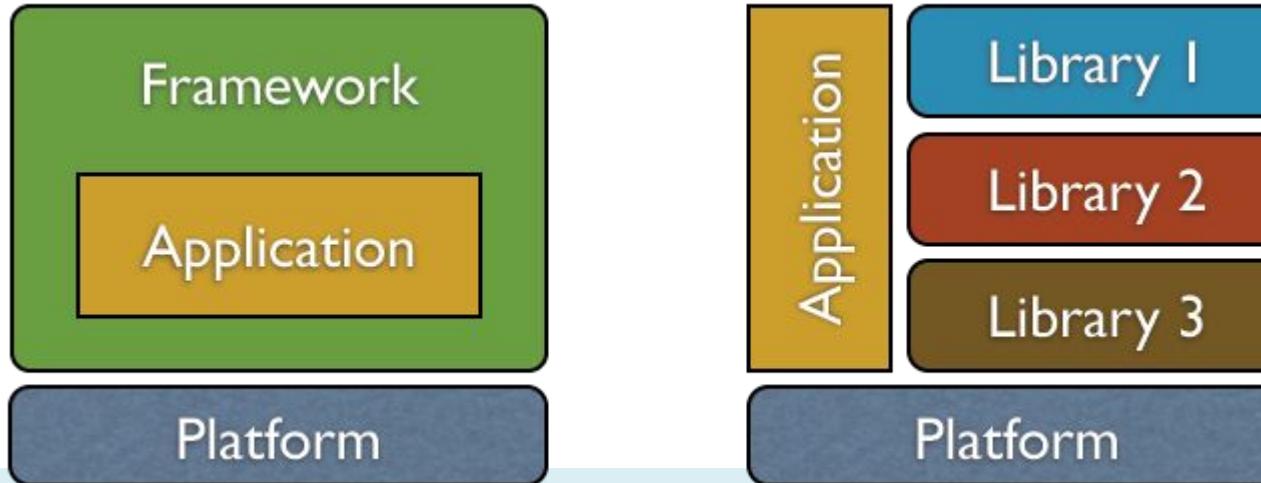
- EXPLORER
- > JAVA
- > OUTLINE
- > TIMELINE
- > JAVA PROJECTS
- > MAVEN
  - M FlashCards org.example:Flas...
  - Lifecycle
    - clean
    - validate
    - compile
    - test
    - test-compile
    - package
    - verify
    - install
    - site
    - deploy
- > Plugins
- > Dependencies
  - junit:junit:4.13.2 (test)

# Under the Hood: Libraries & Frameworks

Which kind is a command-line parsing package?

Which kind is Android?

How about a tool that runs tests based on annotations you add in your code?



# Under the Hood: Continuous Integration

Automatically builds, tests, and displays the result

We – and everyone else – used to use Travis CI.

- Until they randomly stopped supporting OSS.

GitHub has native CI support, and it's pretty good: GitHub Actions.

- Sidebar on how our GH Actions are configured for HW1

The screenshot shows a browser window displaying the Travis CI build log for repository `wyvernlang/wyvern`, build #17. The log indicates 17 passed tests. The log output includes commands like `git clone`, `jdk_switcher`, `java`, `javac`, and `cd tools`, along with their execution times.

```
1 Using worker: worker-linux-027f0490-1.bb.travis-ci.org:travis-linux-2
2
3 Build system information
67
68 $ git clone --depth=50 -branch=SimpleWyvern-devel
69 $ jdk_switcher use oraclejdk8
70 Switching to Oracle JDK8 (java-8-oracle), JAVA_HOME will be set to /usr/lib/jvm/java-8-oracle
71 $ java -Xmx32m -version
72 java version "1.8.0_31"
73 Java(TM) SE Runtime Environment (build 1.8.0_31-b13)
74 Java HotSpot(TM) 64-Bit Server VM (build 25.31-b07, mixed mode)
75 $ javac -J-Xmx32m -version
76 javac 1.8.0_31
77 $ cd tools
78
79
80 $ The command "cd tools" exited with 0.
81 $ ant test
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
```

# HW1: Extending the Flash Card System

# Principles of Software Construction: Objects, Design, and Concurrency

## Specifications and unit testing, exceptions

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Vincent Hellendoorn



# Where we are

	<i>Small scale:</i> One/few objects	<i>Mid scale:</i> Many objects	<i>Large scale:</i> Subsystems
<i>Design for understanding change/ext. reuse robustness ...</i>	Subtype Polymorphism ✓  Information Hiding, <b>Contracts</b> ✓  Immutability ✓  Types ✓ Static Analysis ✓  <b>Unit Testing</b> ✓	Domain Analysis ✓  Inheritance & Del. ✓  Responsibility Assignment, Design Patterns, Antipattern ✓  Promises/ Reactive P. ✓  Integration Testing ✓	GUI vs Core ✓  Frameworks and Libraries ✓ , APIs ✓  Module systems, microservices ✓  Testing for Robustness ✓  CI ✓ , DevOps ✓ , Teams

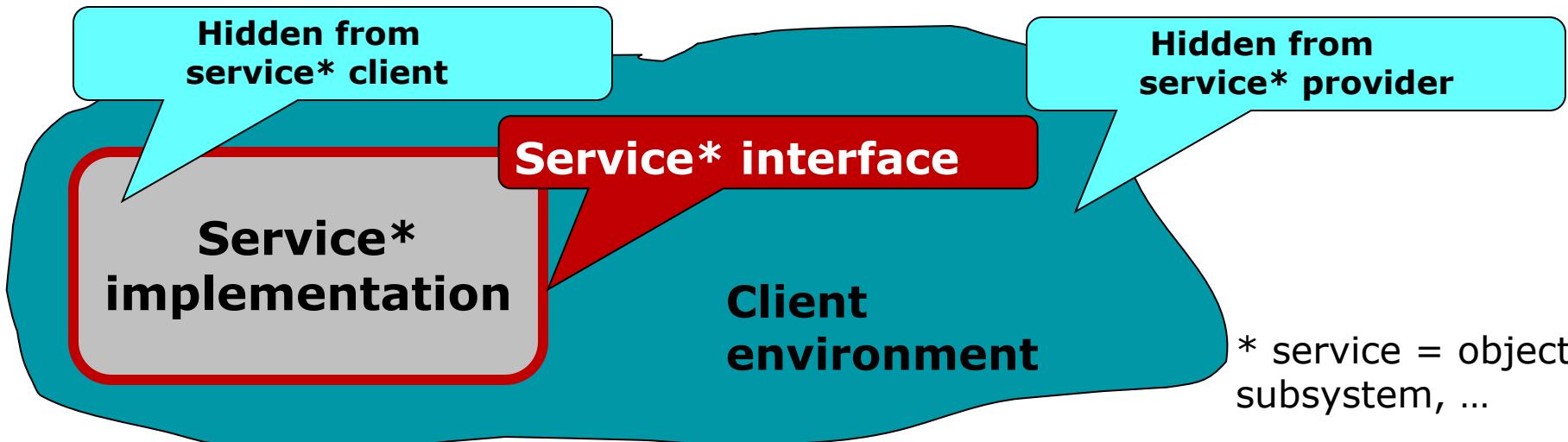
# Who's to blame?

```
Algorithms.shortestDistance(g, "Tom", "Anne");
```

> ArrayOutOfBoundsException

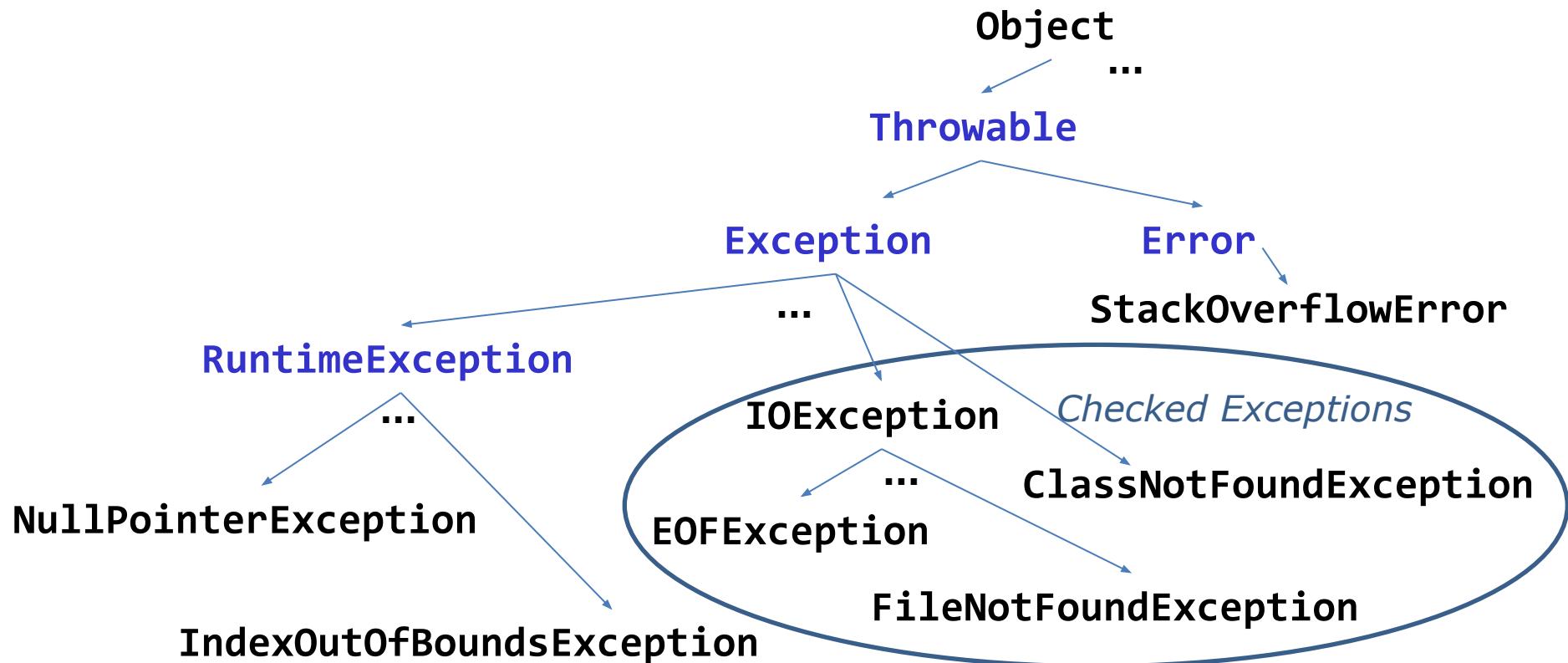
# Most real-world code has a contract

- Imperative to build systems that scale!
- This is why we:
  - Encode specifications
  - Test



\* service = object,  
subsystem, ...

# Java's exception hierarchy (messy)



# Testing

This is Java code

How do we know  
this works?

Testing

Are we done?

```
int isPos(int x) {  
    return x >= 1;  
}  
  
@Test  
void testIsPos() {  
    assertTrue(isPos(1));  
}  
  
@Test  
void testNotPos() {  
    assertFalse(isPos(-1));  
}
```

# Docstring Specification

```
class RepeatingCardOrganizer {  
    ...  
    /**  
     * Checks if the provided card has been answered correctly the required  
     * number of times.  
     * @param card The {@link CardStatus} object to check.  
     * @return {@code true} if this card has been answered correctly at least  
     * {@code this.repetitions} times.  
     */  
    public boolean isComplete(CardStatus card) {  
        // IGNORE THIS WHEN SPECIFICATION TESTING!  
    }  
}
```

# Specification vs. Structural Testing

This is Java code

```
/**  
 * Checks if the provided card has been answered correctly the required  
 * number of times.  
 * @param card The {@link CardStatus} object to check.  
 * @return {@code true} if this card has been answered correctly at least  
 * {@code this.repetitions} times.  
 */  
public boolean isComplete(CardStatus card) {  
    return card.getSuccesses.get(0); // <-- Bad, but passes both tests  
}
```

# Principles of Software Construction: Objects, Design, and Concurrency

## Test case design

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# CreditWallet.pay()

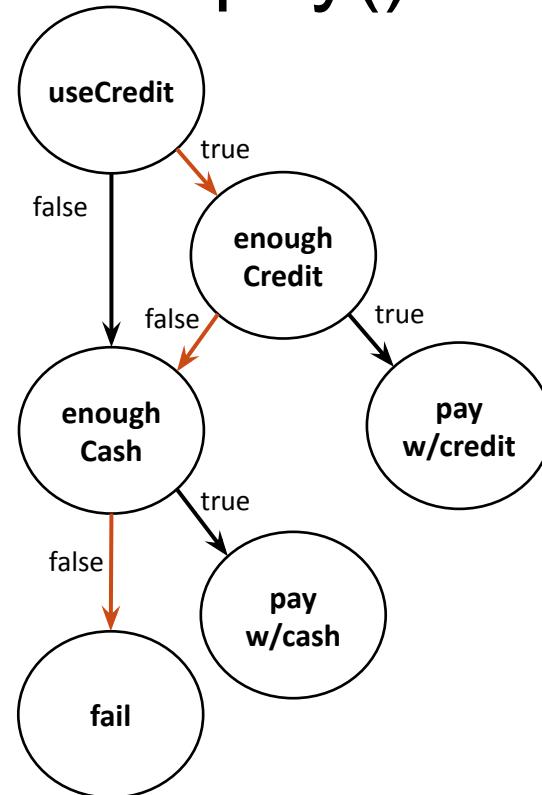
```
public boolean pay(int cost, boolean useCredit) {  
    if (useCredit) {  
        if (enoughCredit) {  
            return true;  
        }  
    }  
    if (enoughCash) {  
        return true;  
    }  
    return false;  
}
```

Test case	useCredit	Enough Credit	Enough Cash	Result	Coverage
1	T	T	-	Pass	--
2	F	-	T	Pass	--
3	F	-	F	Fails	Statement

# Control-Flow of CreditCard.pay()

Paths:

- {true, true}: pay w/credit
- {false, true}: pay w/cash
- {false, false}: fail
- {true, false, true}: pay w/cash after failing credit
- {true, false, false}: try credit, but fail, **and** no cash



# Writing Testable Code

What is the problem with this?

```
public boolean hasHeader(String path) throws IOException {
    List<String> lines = Files.readAllLines(Path.of(path));
    return !lines.get(0).isEmpty()
}

// to achieve a 'false' output without having a test input file:
try {
    Path tempFile = Files.createTempFile(null, null);
    Files.write(tempFile, "\n".getBytes(StandardCharsets.UTF_8));
    hasHeader(tempFile.toFile().getAbsolutePath()); // false
} catch (IOException e) {
    e.printStackTrace();
}
```

# Back to Specification Testing

What would you test differently in this situation?

- “if `useCredit` is set and enough credit is available”:
  - Test both true, either/both false
- “pays with cash if enough cash is available; otherwise”:
  - Test true, false
- Could do this with as few as three test cases

```
/** Pays with credit if useCredit is set and enough
 * credit is available; otherwise, pays with cash if
 * enough cash is available; otherwise, returns false.
 */
public boolean pay(int cost, boolean useCredit);
```

# Structural Testing vs. Specification Testing

You will *typically have both* code & (prose) specification

- Test specification, but know that it can be underspecified
- Test implementation, but not to the point that it cannot change
- Use testing strategies that leverage both
  - There is a fair bit of overlap; e.g., BVA yields useful branch coverage

# HW 2: Testing the Flash Card System

# Principles of Software Construction: Objects, Design, and Concurrency

## Object-oriented Analysis

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# Where we are

	<i>Small scale:</i> One/few objects	<i>Mid scale:</i> Many objects	<i>Large scale:</i> Subsystems
<i>Design for understanding change/ext. reuse robustness ...</i>	Subtype Polymorphism ✓ Information Hiding, Contracts ✓ Immutability ✓ Types ✓ Static Analysis ✓ Unit Testing ✓	<b>Domain Analysis</b> ✓ Inheritance & Del. ✓ Responsibility Assignment, Design Patterns, Antipattern ✓ Promises/ Reactive P. ✓ Integration Testing ✓	GUI vs Core ✓ Frameworks and Libraries ✓ , APIs ✓ Module systems, microservices ✓ Testing for Robustness ✓ CI ✓ , DevOps ✓ , Teams

# Problem Space (Domain Model)



# Solution Space (Object Model)

- Real-world concepts
  - Requirements, Concepts
  - Relationships among concepts
  - Solving a problem
  - Building a vocabulary
- System implementation
  - Classes, objects
  - References among objects and inheritance hierarchies
  - Computing a result
  - Finding a solution

# An object-oriented design process

Model / diagram the problem, define concepts

- **Domain model** (a.k.a. conceptual model), **glossary**

Define system behaviors

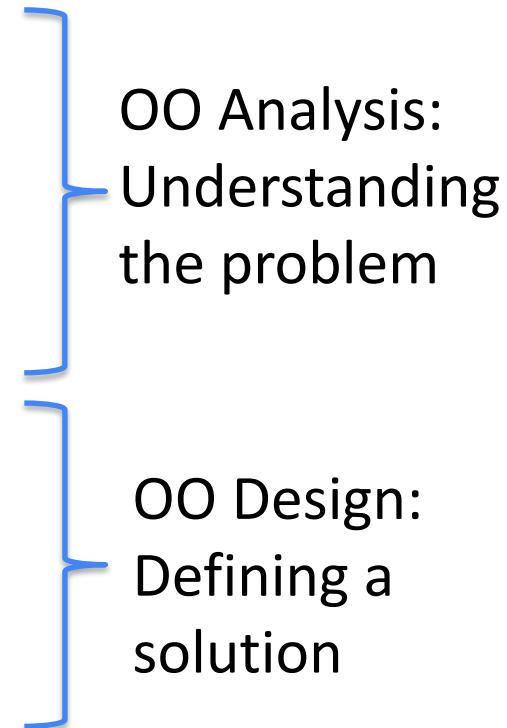
- **System sequence diagram**
- **System behavioral contracts**

Assign object responsibilities, define interactions

- **Object interaction diagrams**

Model / diagram a potential solution

- **Object model**

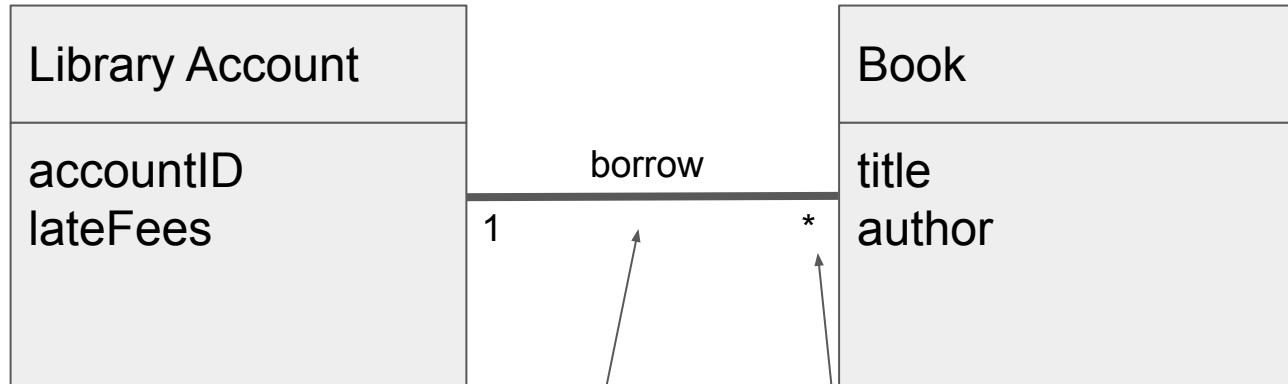


# Visual notation: UML

Name of  
real-world  
concept  
(not software class)



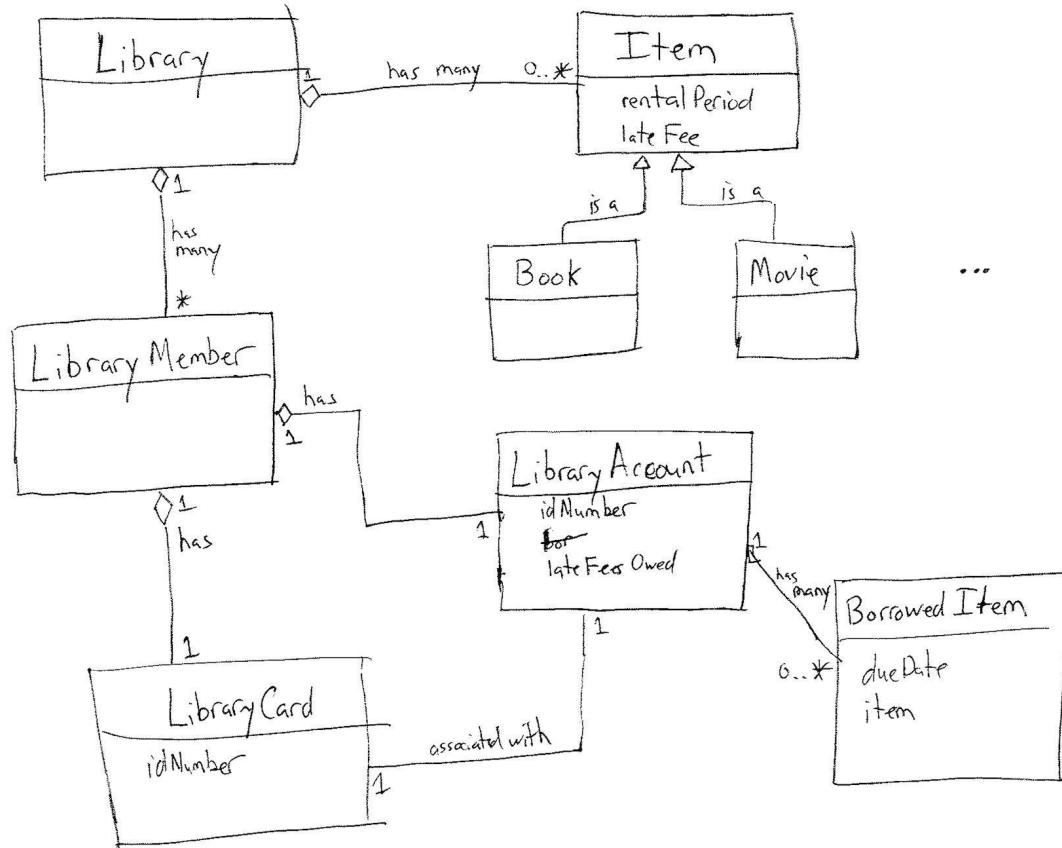
Properties  
of concept



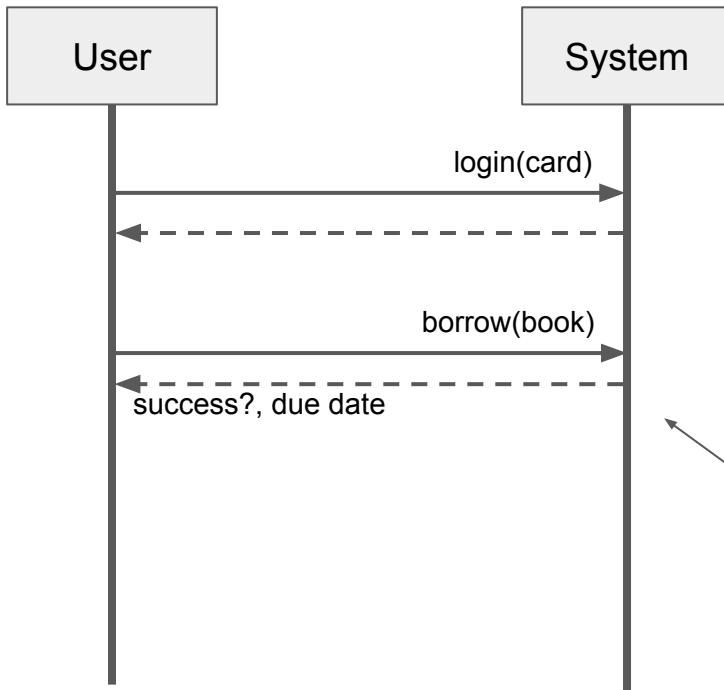
Associations  
between  
concepts

Multiplicities/cardinalities  
indicate “how many”

# One domain model for the library system



# UML Sequence Diagram Notation



Actors in this use case (systems and real-world objects/people)

Time proceeds from top to bottom

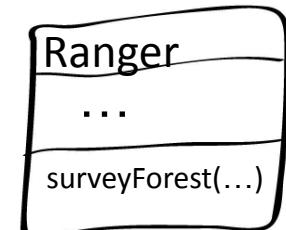
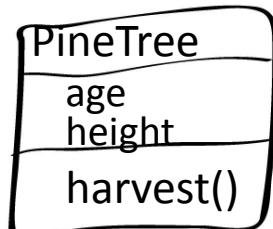
Messages and responses for interactions, text describes what happens conceptually

# Representational gap

- Real-world concepts:



- Software concepts:



# Principles of Software Construction: Objects, Design, and Concurrency

## Responsibility Assignment

Claire Le Goues

Vincent Hellendoorn

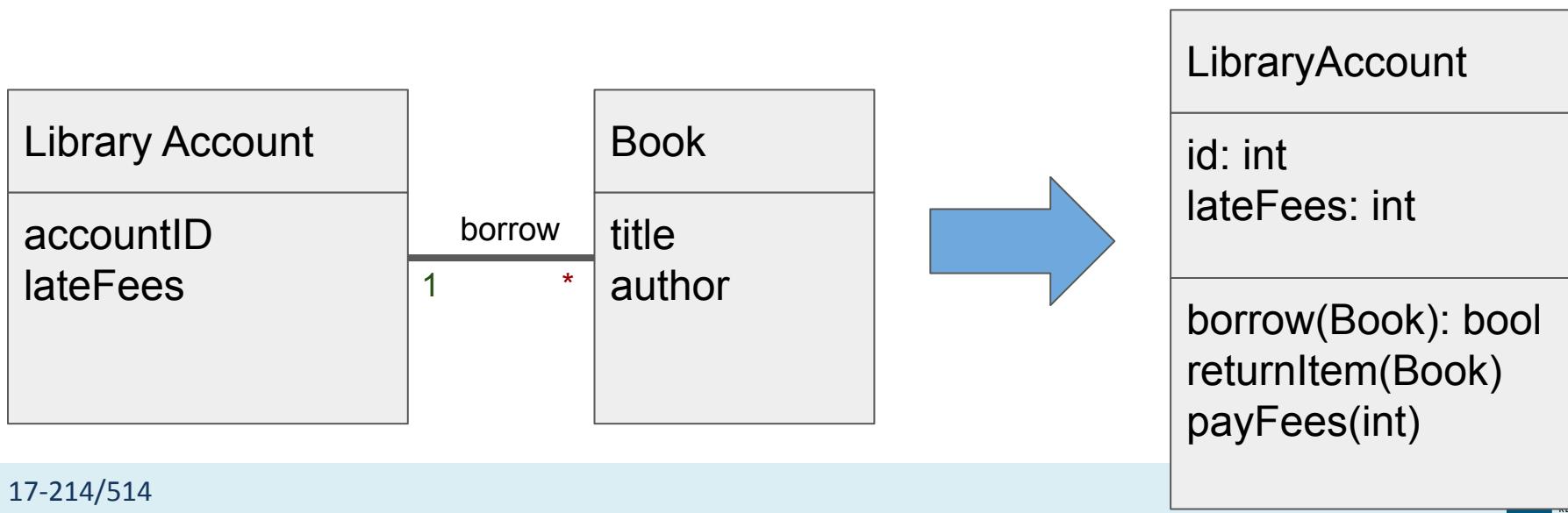


# Where we are

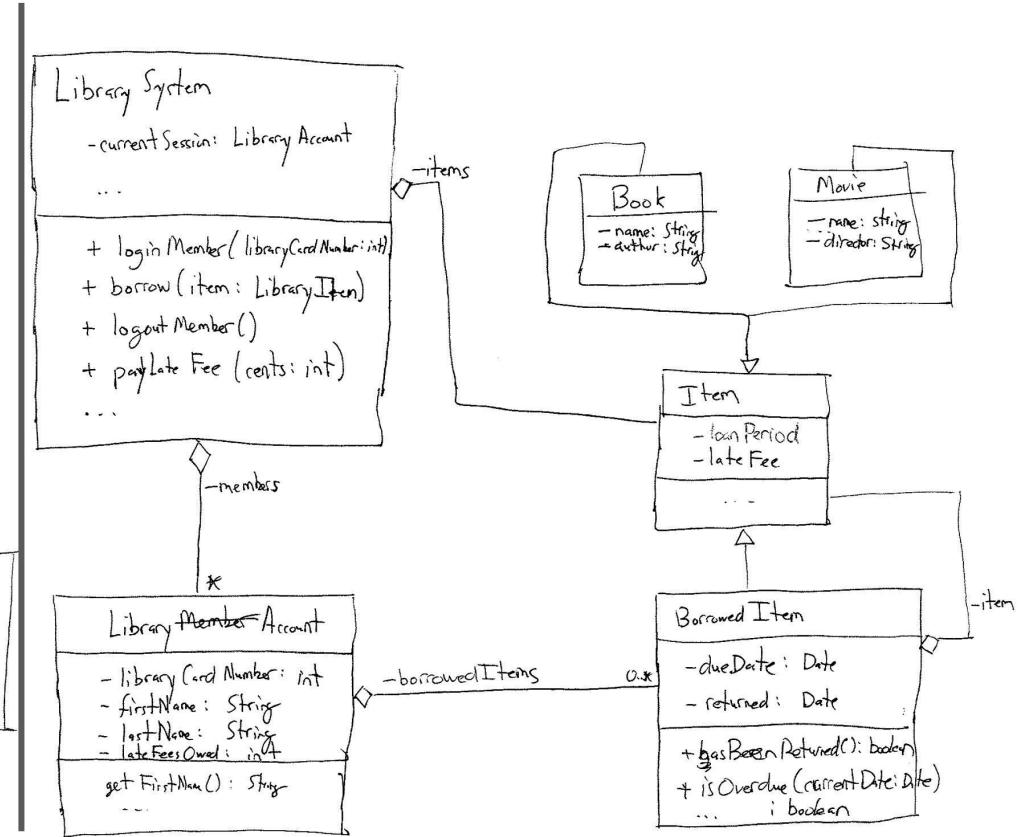
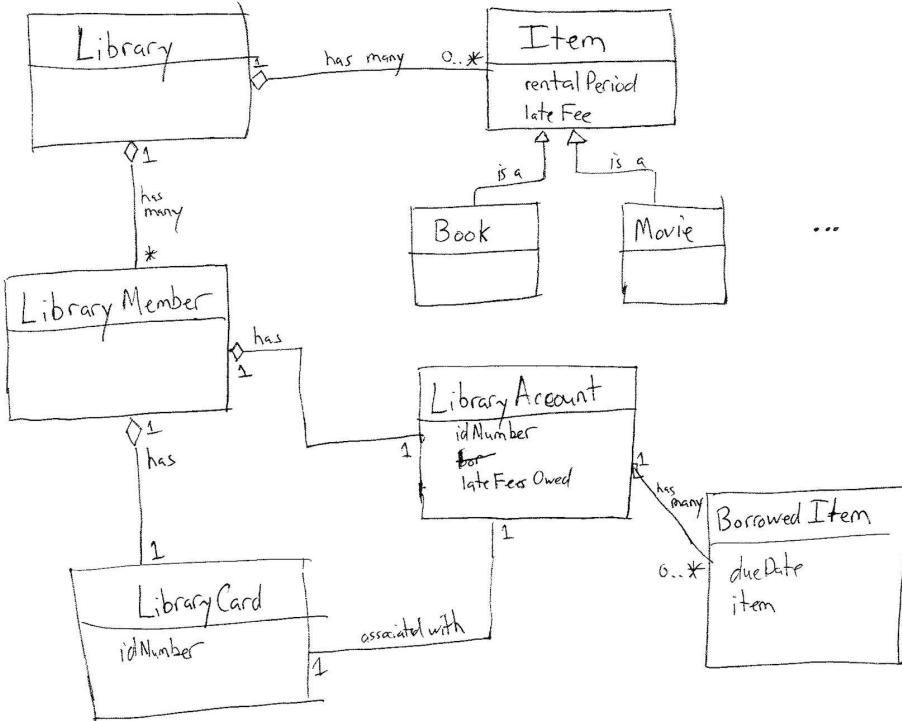
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# From concepts to objects

- How are domain concepts different from classes?
  - Should every concept become a class?
  - Does every class need to represent a concept?



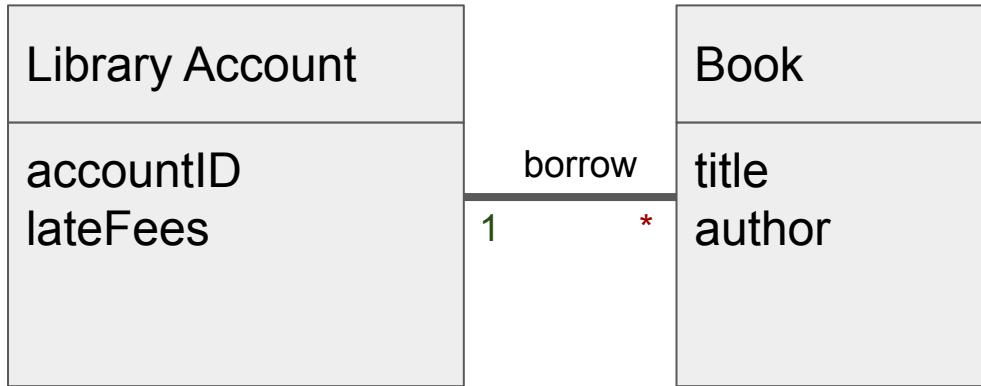
# Domain model (left) vs object model (right)



# Low Representational Gap

Identified concepts provide inspiration for classes in the implementation

Classes mirroring domain concepts often  
intuitive to understand, rarely change  
(low representational gap)

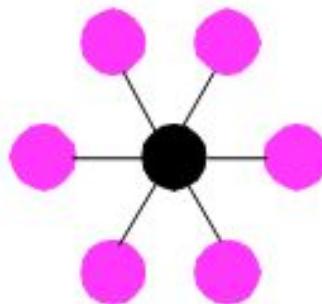


```
class Account {
    id: Int;
    lateFees: Int;
    borrowed: List<Book>;
    boolean borrow(Book) { ... }
    void save();
}

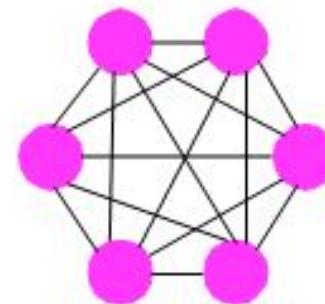
class Book { ... }
```

# Topologies with different coupling

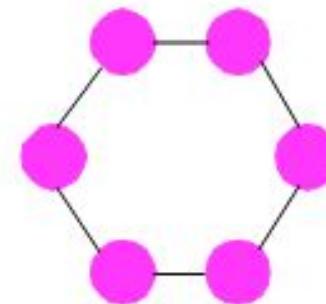
*Types of module interconnection structures*



(A)



(B)



(C)

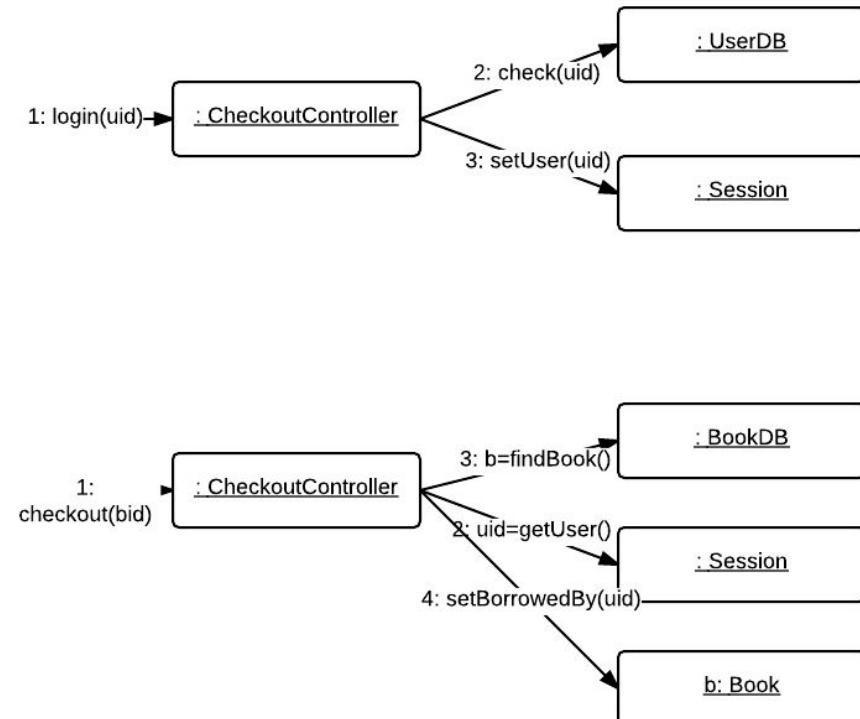
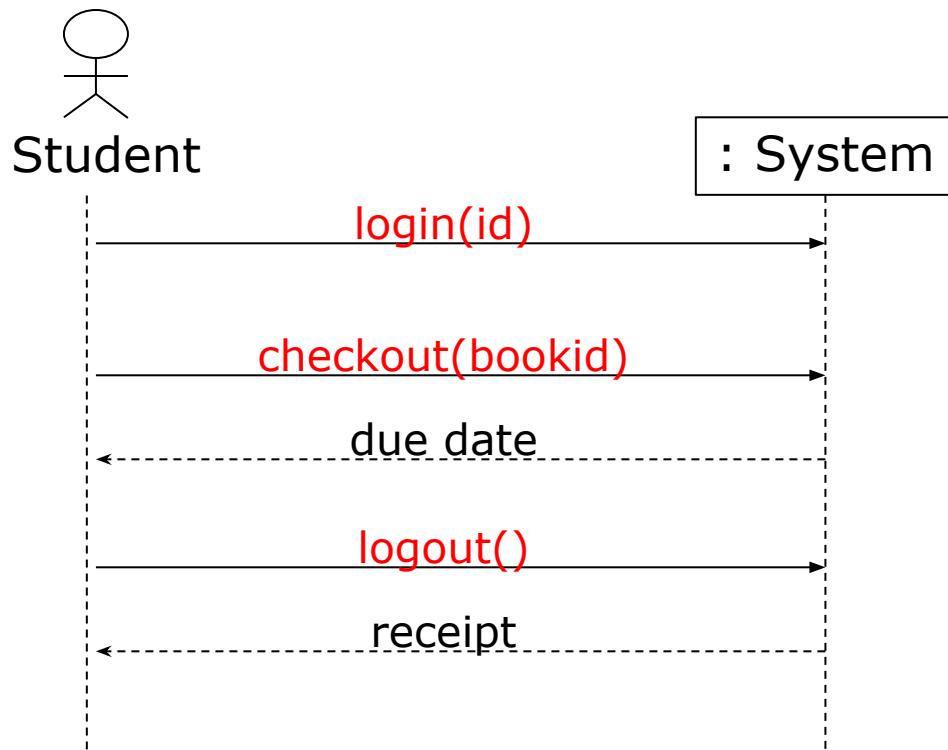
# Design Heuristic: Law of Demeter

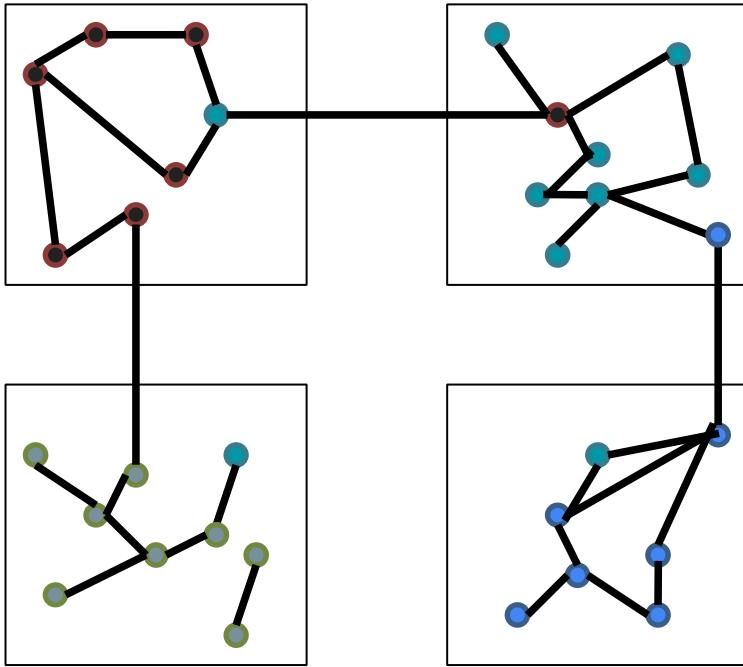
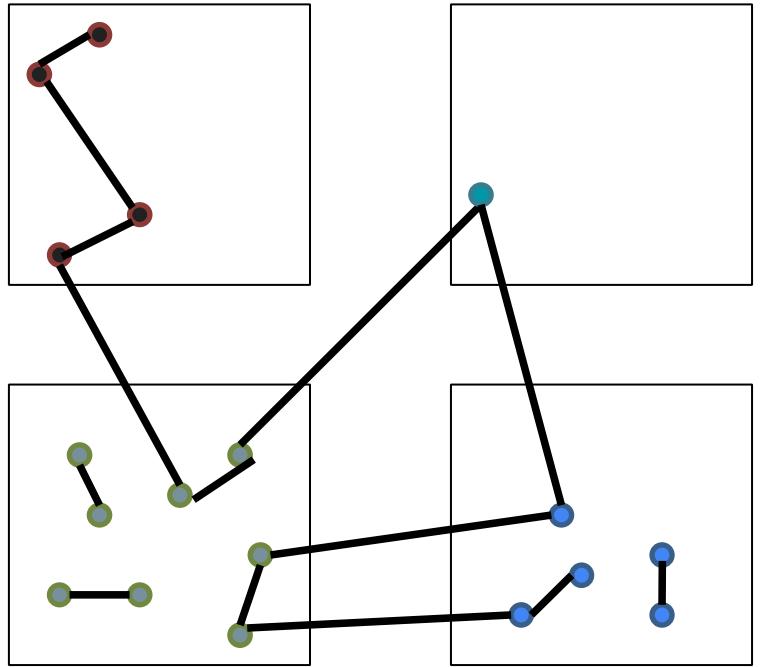
- *Each module should have only limited knowledge about other units: only units "closely" related to the current unit*
- In particular: Don't talk to strangers!
- For instance, no `a.getB().getC().foo()`

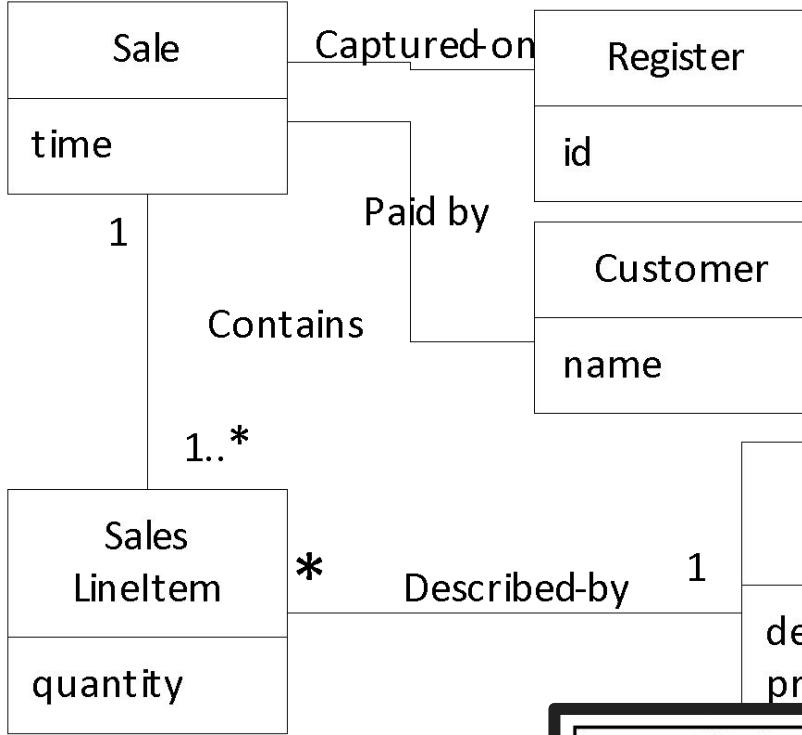
```
for (let i of shipment.getBox().getItems())
    shipmentWeight += i.getWeight() ...
So
```

# Requirements Analysis

# Object-Level Design







## Who should be responsible for knowing the grand total of a sale?



Design Class	Responsibility
Sale	knows sale total
SalesLineItem	knows line item subtotal
ProductSpecification	knows product price

# Anti-Pattern: God Object

```
class Chat {  
    Content content;  
    AccountMgr accounts;  
    File logFile;  
    ConnectionMgr conns;  
}  
  
class ChatUI {  
    Chat chat;  
    Widget sendButton, ...;  
}  
  
class AccountMgr {  
    ... accounts, bannedUsr...  
}
```

```
class Chat {  
    List<String> channels;  
    Map<String, List<Msg>> messages;  
    Map<String, String> accounts;  
    Set<String> bannedUsers;  
    File logFile;  
    File bannedWords;  
    URL serverAddress;  
    Map<String, Int> globalSettings;  
    Map<String, Int> userSettings;  
    Map<String, Graphic> smileys;  
    CryptStrategy encryption;  
    Widget sendButton, messageList;
```

# Information Expert (Design Heuristic)

- Heuristic: **Assign a responsibility to the class that has the information necessary to fulfill the responsibility**
- Typically follows common intuition
- Software classes instead of Domain Model classes
  - If software classes do not yet exist, look in Domain Model for fitting abstractions (-> correspondence)
- Design process: Derive from domain model (key principles: Low representational gap and low coupling)

# HW3: Santorini (Base game)

## Need Help?

**Video Tutorials** More of a visual learner? We've got you covered! Head over to [roxley.com/santorini-video](http://roxley.com/santorini-video) for video tutorials on how to play, as well as complete visual demonstrations of all God Powers!

**Santorini App** Can't decide which God Powers to match up? Head over to Google Play Store or the Apple App Store and download the Santorini App absolutely free. Complete with video tutorials, match randomizer and much more!

## Setup

- 1 Place the smaller side of the Cliff Pedestal  on the Ocean Board , using the long and short tabs on the Cliff Pedestal to guide assembly.
- 2 Place the Island Board  on top of the Cliff Pedestal , again using the long and short tabs to guide assembly.
- 3 The youngest player is the Start Player, who begins by placing 2 Workers  of their chosen color into any unoccupied spaces on the board. The other player(s) then places their Workers .



## How To Play

Players take turns, starting with the Start Player, who first placed their Workers. On your turn, select one of your Workers. You must move and then build with the selected Worker.

**Move** your selected Worker into one of the (up to) eight neighboring spaces .

A Worker may move up a maximum of one level higher, move down any number of levels lower, or move along the same level. A Worker may not move up more than one level .



The space your Worker moves into must be unoccupied (not containing a Worker or Dome).

**Build** a block  or dome  on an unoccupied space neighboring the moved Worker.

## Winning the Game

1 If one of your Workers moves up on top of level 3 during your turn, you instantly win!

2 You must always perform a move then build on your turn. If you are unable to, you lose.



## Components

18 X Dome	22 X Level 1	18 X Level 2	14 X Level 3
			
Blocks			
1 X Cliff Pedestal			
			

17-214

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SOFTWARE  
RESEARCH

# Principles of Software Construction: Objects, Design, and Concurrency

## Inheritance and delegation

Claire Le Goues

Vincent Hellendoorn

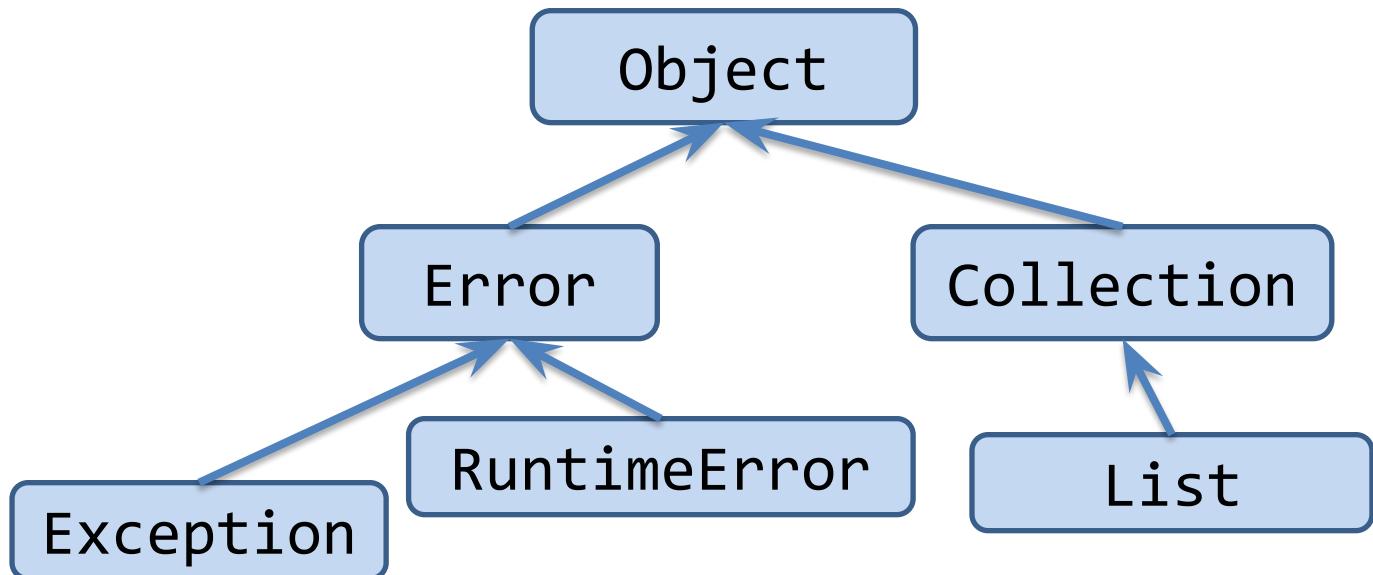


# Where we are

	<i>Small scale:</i> One/few objects	<i>Mid scale:</i> Many objects	<i>Large scale:</i> Subsystems
<i>Design for understanding change/ext. reuse robustness ...</i>	Subtype Polymorphism ✓  Information Hiding, Contracts ✓  Immutability ✓  Types ✓ Static Analysis ✓  Unit Testing ✓	Domain Analysis ✓  <b>Inheritance &amp; Del.</b> ✓  Responsibility Assignment, Design Patterns, Antipattern ✓  Promises/ Reactive P. ✓	GUI vs Core ✓  Frameworks and Libraries ✓ , APIs ✓  Module systems, microservices ✓  Testing for Robustness ✓  CI ✓ , DevOps ✓ , Teams

# All object types exist in a *class hierarchy*

In Java:



# Inheritance enables Extension & Reuse

```
class Animal {  
    final String name;  
  
    public Animal(String name) {  
        this.name = name;  
    }  
  
    public String identify() {  
        return this.name;  
    }  
}
```

```
class Dog extends Animal {  
    public Dog() {  
        super("dog");  
    }  
}
```

```
Animal animal = new Dog();  
animal.identify(); // "dog"
```

Declared Type

Compile-time  
Check (Java)

Instantiated Type

# Is Square a behavioral subtype of Rectangle?

```
class Rectangle {  
  
    int width;  
    int height;  
  
    public Rectangle(int width,  
                    int height) {  
        this.width = width;  
        this.height = height;  
    }  
    public void scale(int factor) {  
        width=width*factor;  
        height=height*factor;  
    }  
}
```

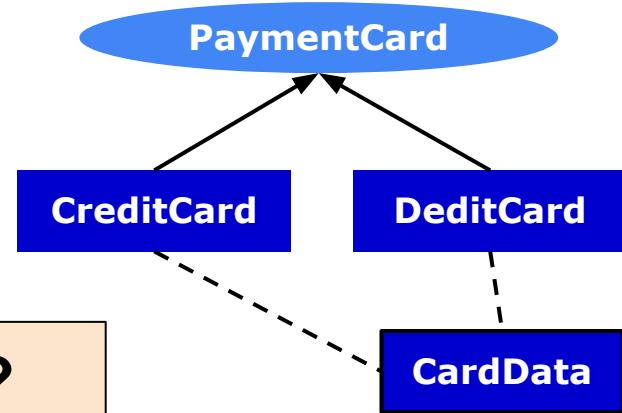
```
public class Square extends Rectangle {  
  
    public Square(int width) {  
        super(width, width);  
    }  
}
```

# Design option 3

```
class CardData {  
    private final String cardHolderName;  
    private final BigInteger digits;  
    private final Date expirationDate;
```

```
public CardData(...) {...}  
public String getCardHolderName() {...}  
public BigInteger getDigits() {...}  
public Date getExpiration() {...}  
}
```

Is this better?



```
class CreditCard implements PaymentCard {  
    private CardData cardData = new(...);  
    public BigInteger getDigits() {  
        return cardData.getDigits();  
    }  
    ...  
}  
class DebitCard implements PaymentCard {  
    ...  
}
```

You can still achieve good reuse  
with composition+delegation!

# This is the Template Method Design Pattern!

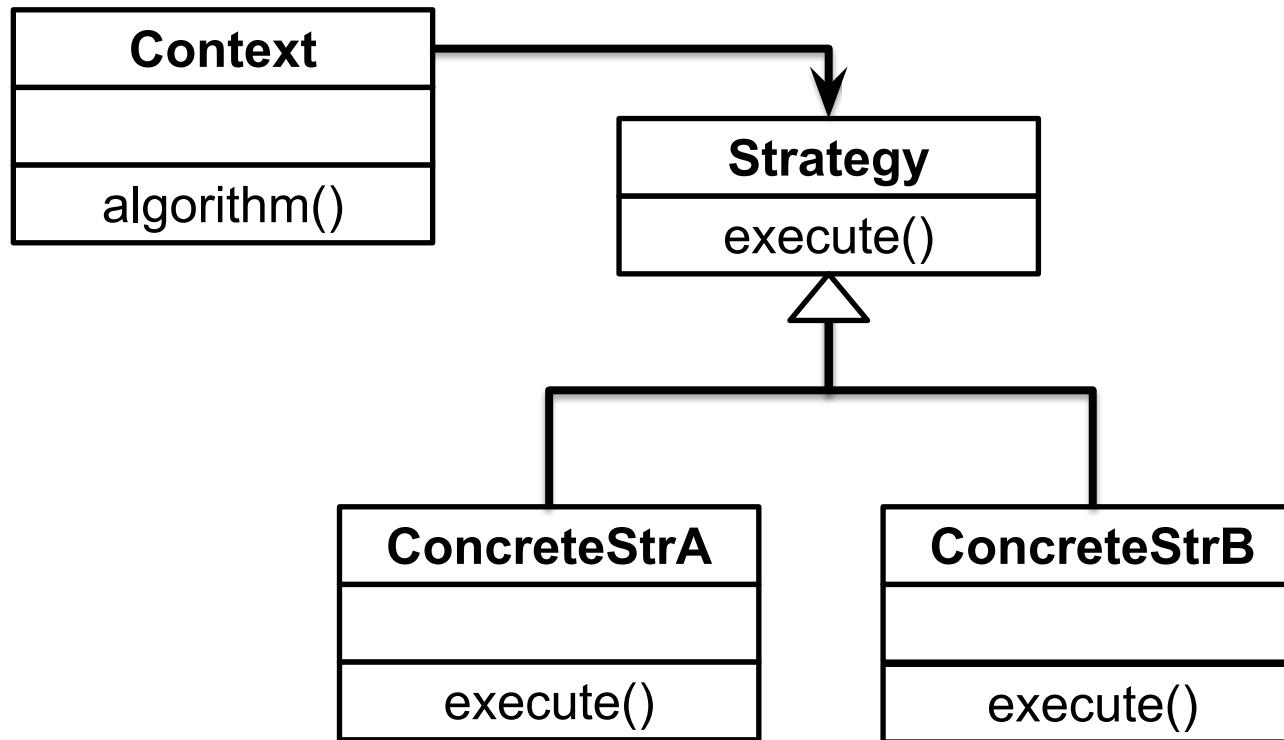
```
abstract class AbstractCashCard
    implements PaymentCard {
private int balance;
public AbstractCashCard(int balance) {
    this.balance = balance;
}
public boolean pay(int amount) {
    if (amount <= this.balance) {
        this.balance -= amount;
        chargeFee();
        return true;
    }
    return false;
}
abstract void chargeFee();
}
```

```
class GiftCard extends AbstractCashCard {
@Override
void chargeFee() {
    return; // Do nothing.
}
}
```

```
class DebitCard extends AbstractCashCard {
@Override
void chargeFee() {
    this.balance -= this.fee;
}
}
```

**Design Tradeoffs?**

# Strategy Pattern in UML.



# Principles of Software Construction: Objects, Design, and Concurrency

## Design Patterns

Claire Le Goues

Vincent Hellendoorn

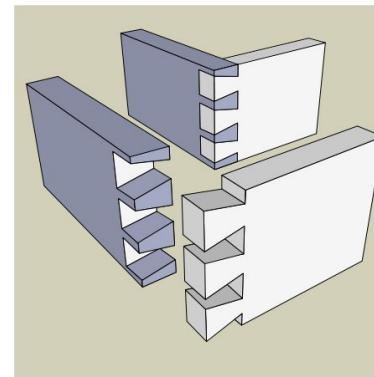


# Where we are

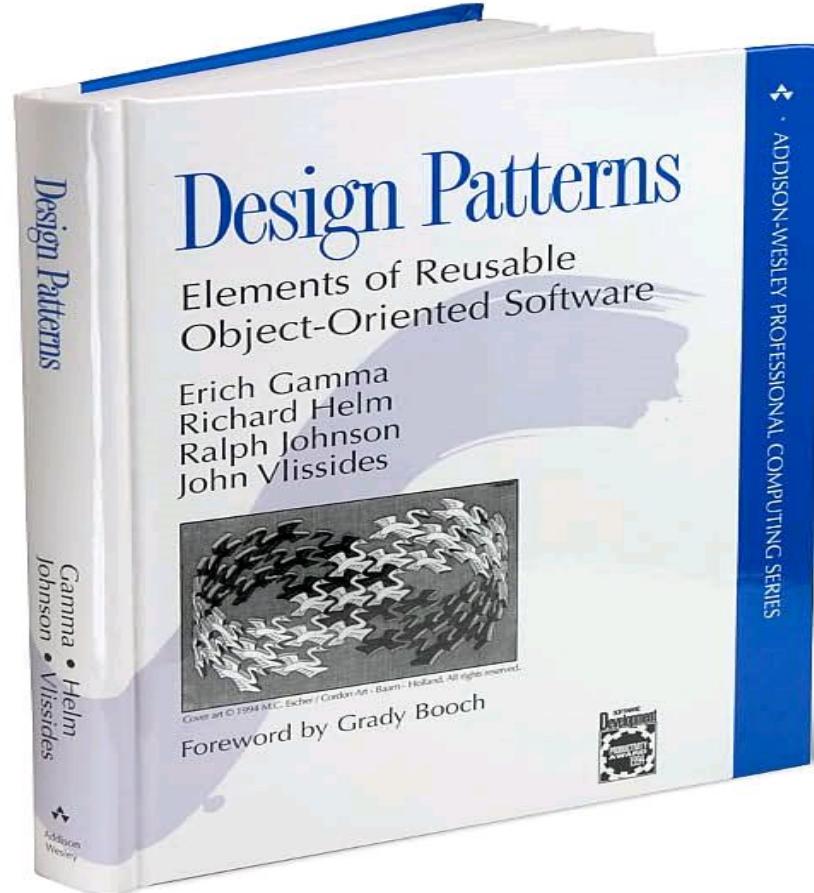
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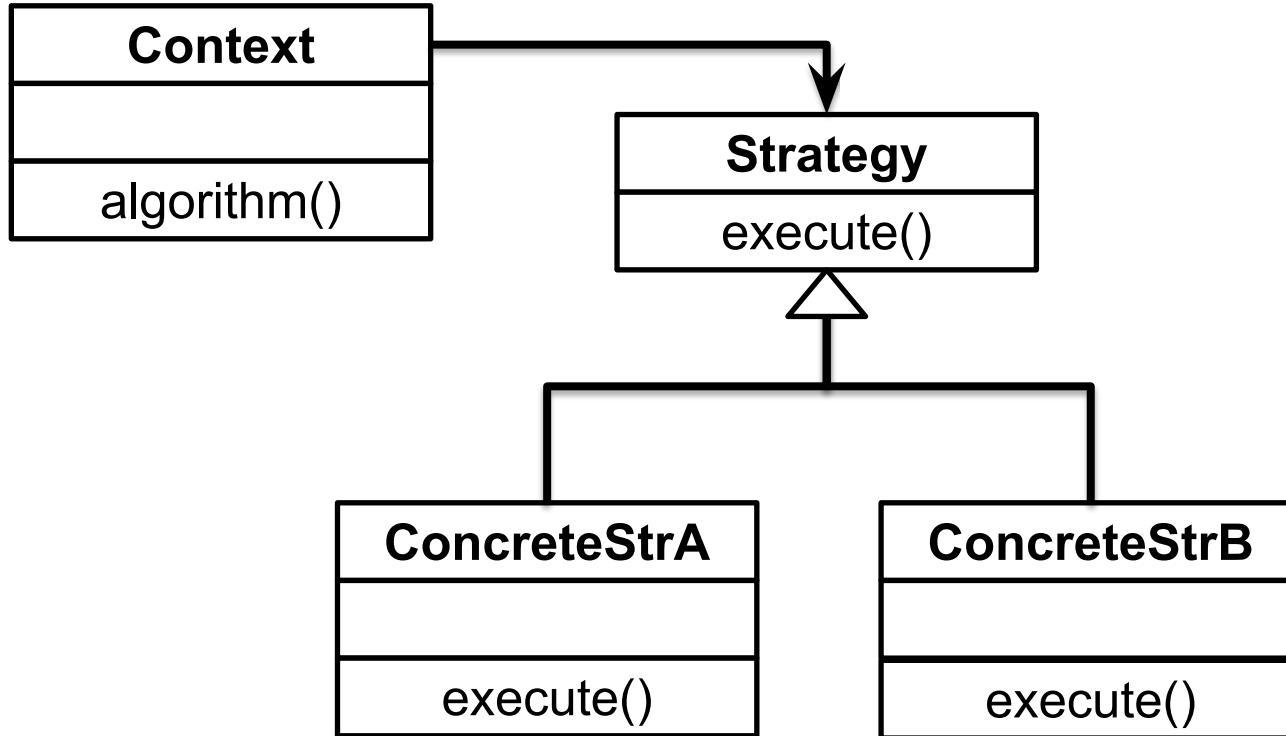
# Discussion with design patterns

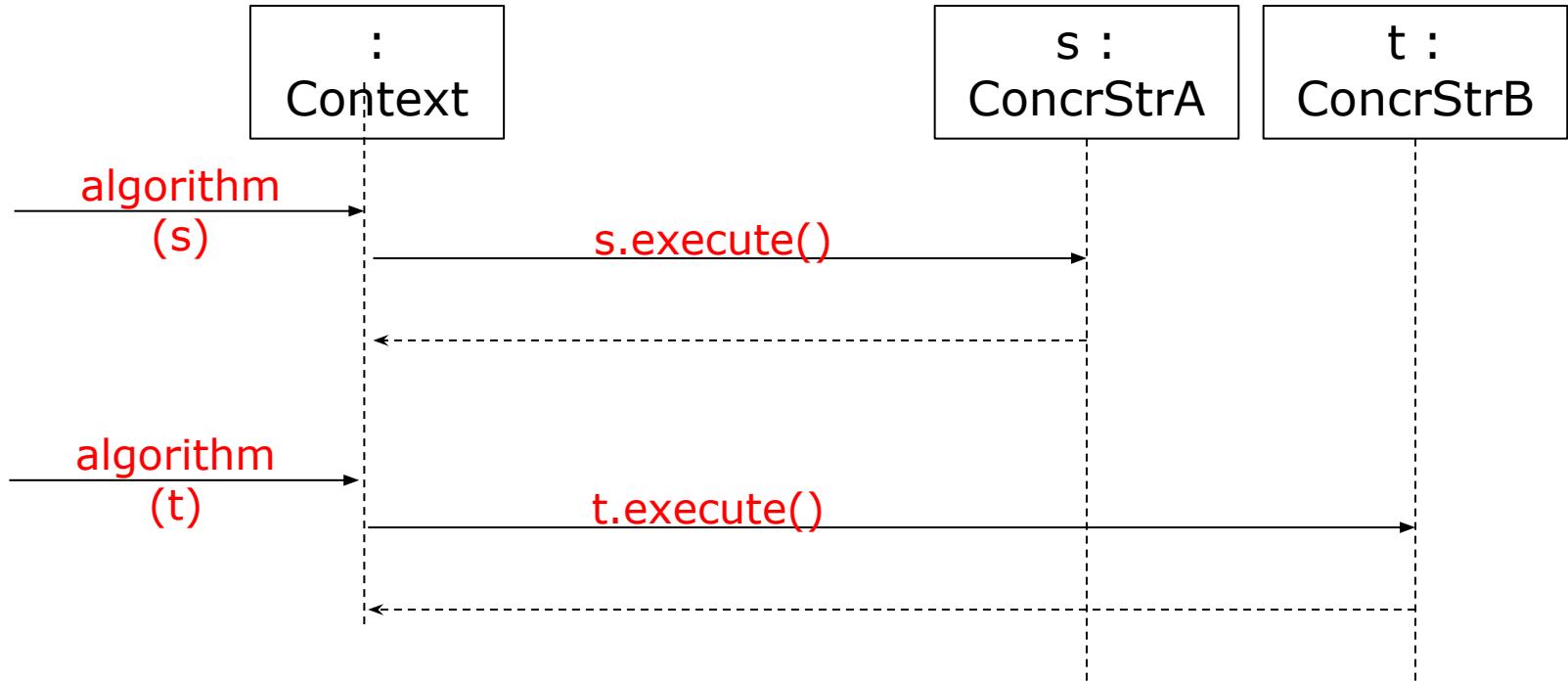
- Carpentry:
  - "Is a dovetail joint or a miter joint better here?"
- Software Engineering:
  - "Is a strategy pattern or a template method better here?"



# History: *Design Patterns* (1994)







*Strategy can be provided in method call or in any other way to context*

# One design scenario

- Amazon.com processes millions of orders each year, selling in 75 countries, all 50 states, and thousands of cities worldwide. These countries, states, and cities have hundreds of distinct sales tax policies and, for any order and destination, Amazon.com must be able to compute the correct sales tax for the order and destination.

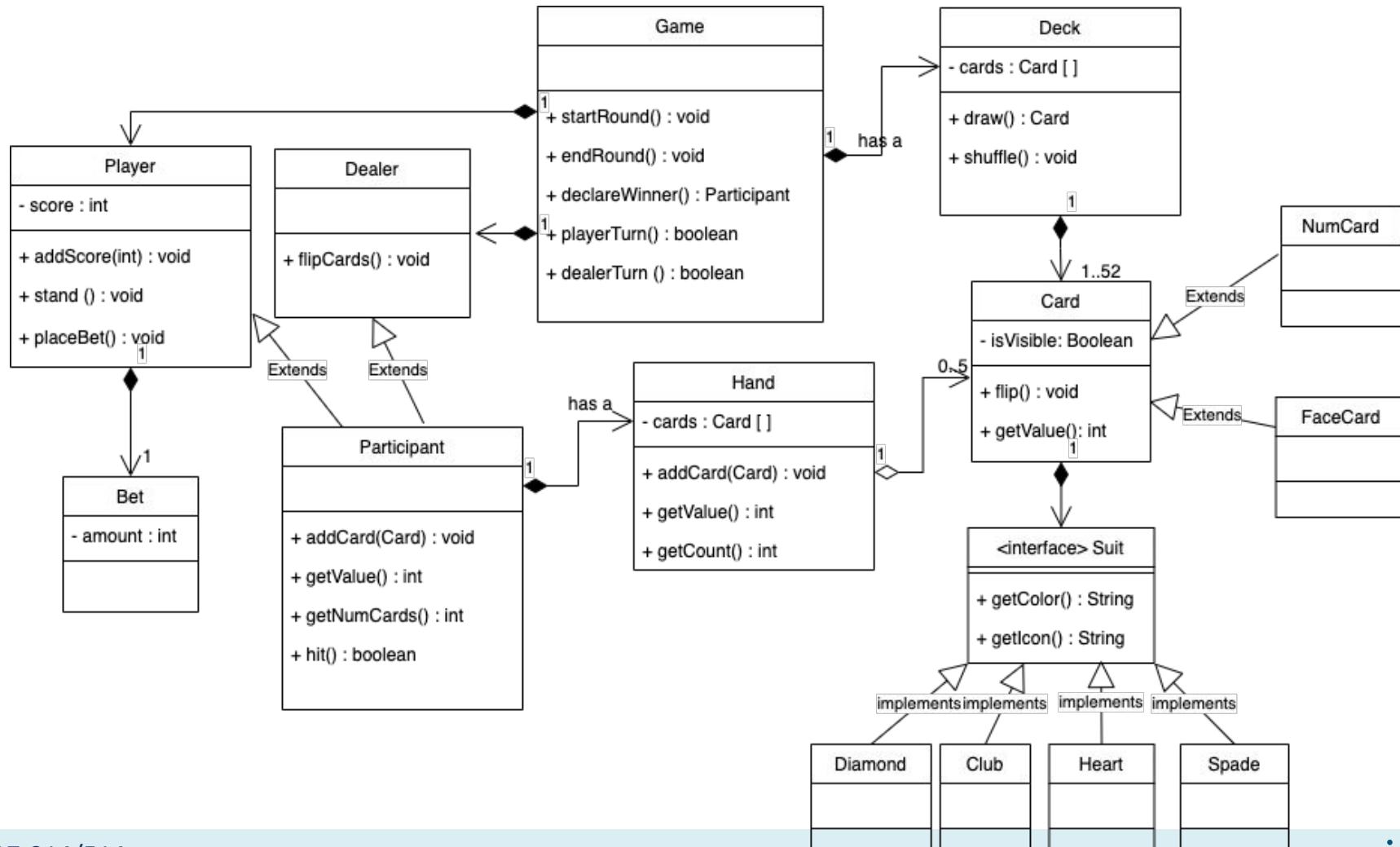
# Design Patterns and Programming Languages

Design patterns address general design challenges

Some patterns address problems with built-in solutions

Example: Strategy pattern vs higher-order functions

```
const ASC = function(i: number, j: number): boolean {
    return i < j;
}
const DESC = function(i: number, j: number): boolean {
    return i > j;
}
```



# Module pattern: Hide internals in closure

```
(function () {  
    // ... all vars and functions are in this scope only  
    // still maintains access to all globals  
}());
```

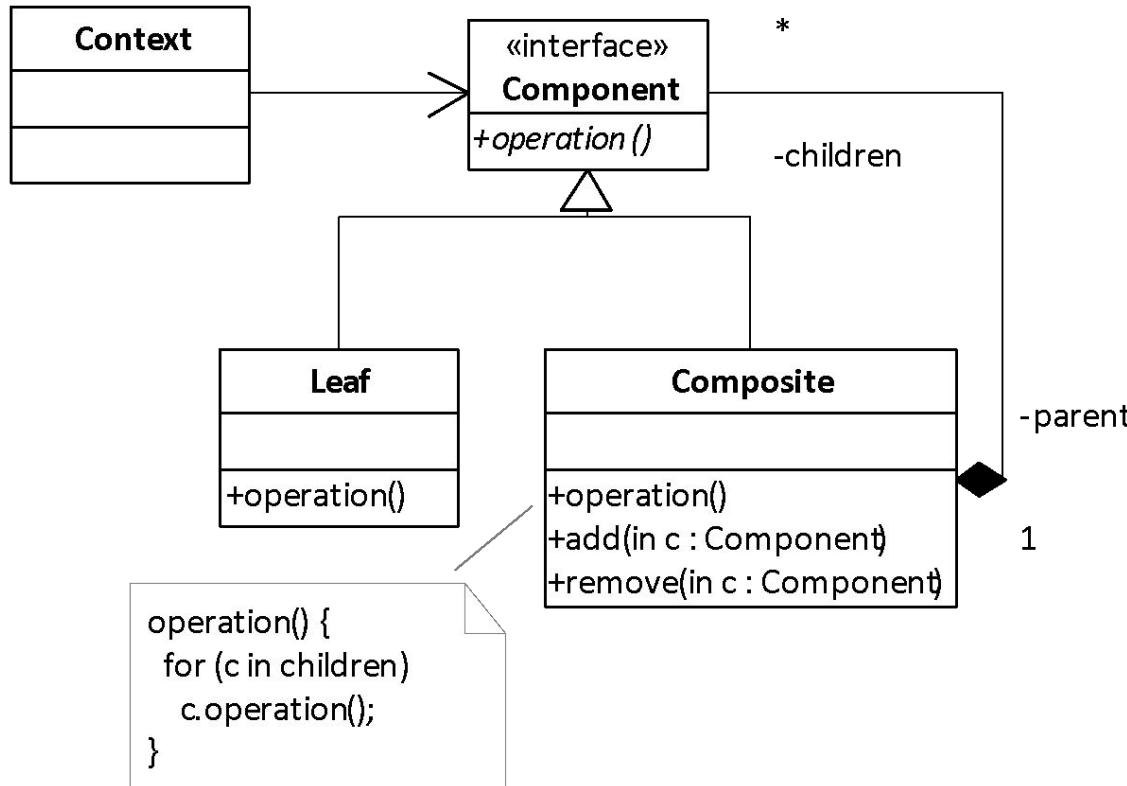
Function provides local scope, internals not accessible

Function directly invoked to execute it once

Wrapped in parentheses to make it expression

Discovered around 2007, became very popular, part of Node

# The Composite Design Pattern



# Principles of Software Construction: Objects, Design, and Concurrency

## Refactoring & Anti-patterns

Claire Le Goues

Vincent Hellendoorn



# Where we are

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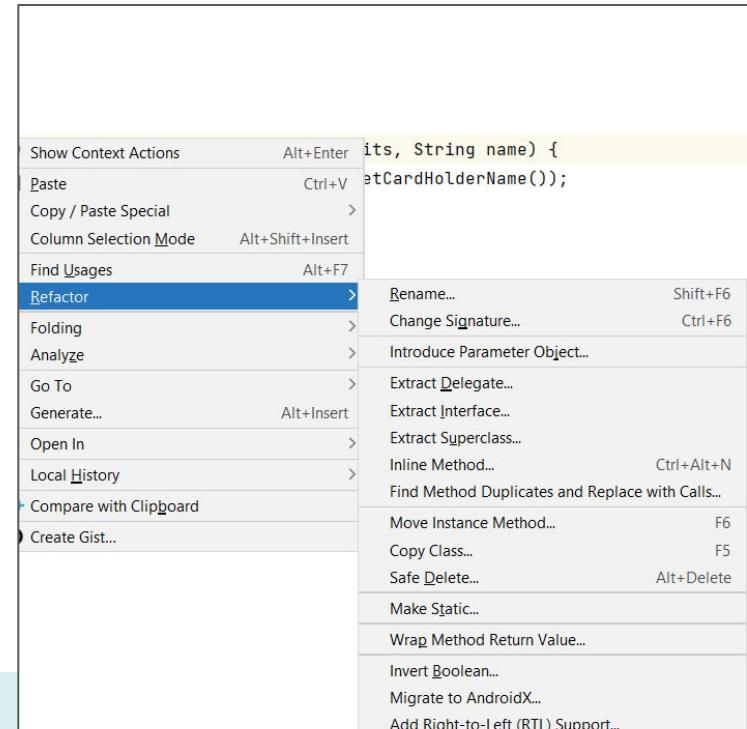
# Refactoring

- Any functionality-preserving restructuring
  - That is, the semantics of the program do not change, but the syntax does

```
○ class Player {  
    Board board;  
    /* in code somewhere... */ this.getSquare(n);  
    Square getSquare(String name) { // named monopoly squares  
        for (Square s: board.getSquares())  
            if (s.getName().equals(name))  
                return s;  
        return null;  
    }  
}
```

# Refactoring: IDE support

- Rename class, method, variable to something not in-scope
- Extract method/inline method
- Extract interface
- Move method (up, down, laterally)
- Replace duplicates



# True or false?

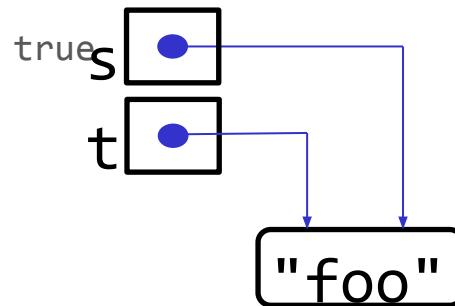
```
int i = 5;  
int j = 5;  
System.out.println(i == j);
```

---

true i 5  
j 5

```
String s = "foo";  
String t = s;  
System.out.println(s == t);
```

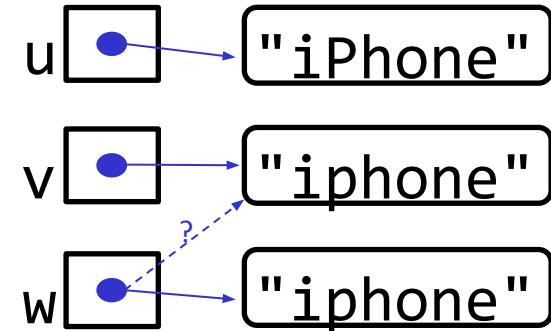
---



```
String u = "iPhone";  
String v = u.toLowerCase();  
String w = "iphone";  
System.out.println(v == w);
```

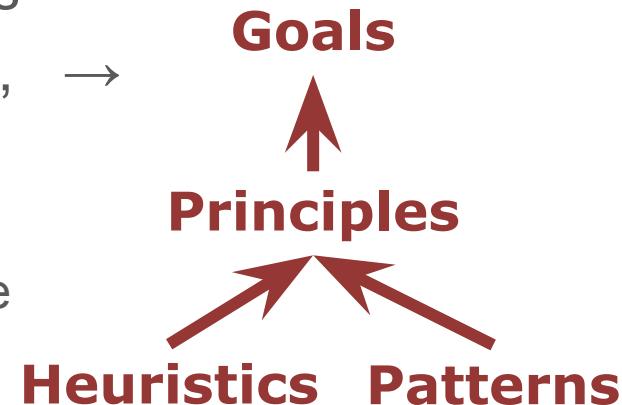
---

**false (in practice)**



# Anti-patterns

- Kind of like the evil twins of design patterns
- Similar to the design hierarchy on the right, → we want to think of both:
  - The design principles they run against
  - The low-level “heuristics” to detect them in code
    - Including many “code smells”
- As before, a pattern language helps
  - Many of these can be (re)paired with a correct pattern



# Liquid APIs

Each method changes state,  
then returns **this**

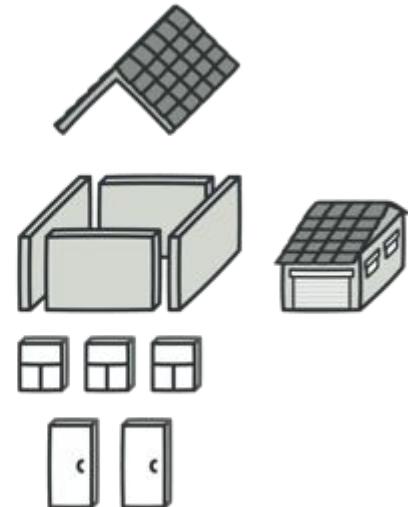
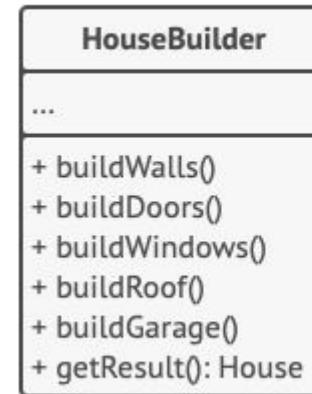
(Immutable version:  
Return modified copy)

```
class OptBuilder {  
    private String argName = "";  
    private boolean hasArg = false;  
    ...  
    OptBuilder withArgName(String n) {  
        this.argName = n;  
        return this;  
    }  
    OptBuilder hasArg() {  
        this.hasArg = true;  
        return this;  
    }  
    ...  
    Option create() {  
        return new Option(argName,  
                          hasArgs, ...)  
    }  
}
```

# Under the Hood: Builder Pattern

When creating many variations of a complex object:

- Assign assembling work to a Builder object
  - When cascading, the builder returns itself, modified on every update
  - Offers a method that generates the resulting object
- Direct clients to *only* use the Builder
  - E.g., hide the constructor



<https://refactoring.guru/design-patterns/builder>

# Traversing a collection

- Since Java 1.0:

```
Vector arguments = ...;
for (int i = 0; i < arguments.size(); ++i) {
    System.out.println(arguments.get(i));
}
```

- Java 1.5: enhanced for loop

```
List<String> arguments = ...;
for (String s : arguments) {
    System.out.println(s);
}
```

- Works for every implementation of `Iterable`

```
public interface Iterable<E> {
    public Iterator<E> iterator();
}

public interface Iterator<E> {
    boolean hasNext();
    E next();
    void remove();
}
```

- In JavaScript (ES6)

```
let arguments = ...
for (const s of arguments) {
    console.log(s)
}
```

- Works for every implementation with a “magic” function `[Symbol.iterator]` providing an iterator

```
interface Iterator<T> {
    next(value?: any): IteratorResult<T>;
    return?(value?: any): IteratorResult<T>;
    throw?(e?: any): IteratorResult<T>;
}

interface IteratorReturnResult<TReturn> {
    done: true;
    value: TReturn;
}
```

# HW4: Refactoring of Static Website Generator

# Principles of Software Construction: Objects, Design, and Concurrency

## Introduction to GUIs

Claire Le Goues

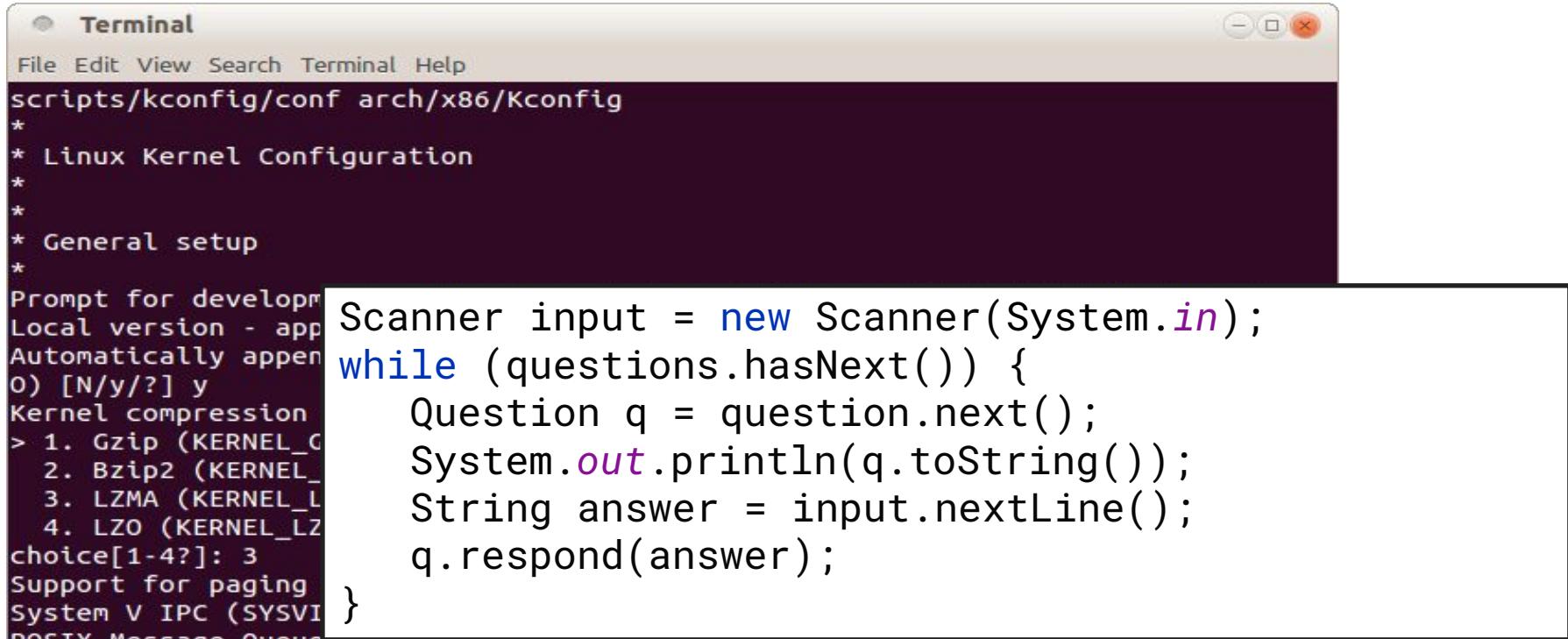
Vincent Hellendoorn



# Where we are

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# Interaction with CLI



```
Terminal
File Edit View Search Terminal Help
scripts/kconfig/conf arch/x86/Kconfig
*
* Linux Kernel Configuration
*
*
* General setup
*
Prompt for developer options (def
Local version - appname (def
Automatically append -def
0) [N/y/?] y
Kernel compression (def
> 1. Gzip (KERNEL_GZIP)
  2. Bzip2 (KERNEL_BZIP2)
  3. LZMA (KERNEL_LZMA)
  4. LZO (KERNEL_LZO)
choice[1-4?]: 3
Support for paging model (def
System V IPC (SYSVIPC)
POSIX Message Queues (POSIX_MQUEUE) [Y/n/?] n
BSD Process Accounting (BSD_PROCESS_ACCT) [Y/n/?] n
Export task/process statistics through netlink (EXPERIMENTAL) (TASKSTATS) [Y/n/?] n
1) y
Enable per-task delay accounting (EXPERIMENTAL) (TASK_DELAY_ACCT) [Y/n/?] n
```

```
Scanner input = new Scanner(System.in);
while (questions.hasNext()) {
    Question q = question.next();
    System.out.println(q.toString());
    String answer = input.nextLine();
    q.respond(answer);
}
```

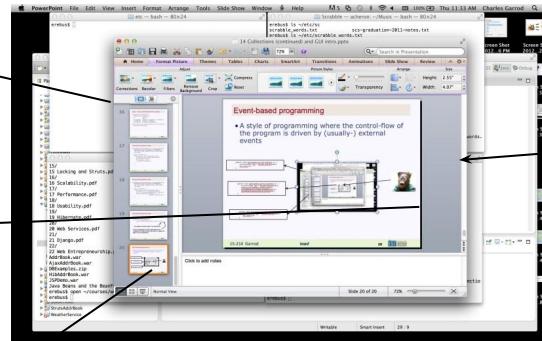
# Event-based programming

- Style of programming where control-flow is driven by (usually external) events

```
public void performAction(ActionEvent e) {  
    List<String> lst = Arrays.asList(bar);  
    foo.peek(42)  
}
```

```
public void performAction(ActionEvent e) {  
    bigBloatedPowerPointFunction(e);  
    withANameSoLongIMadeItTwoMethods(e);  
    yesIKnowJavaDoesntWorkLikeThat(e);  
}
```

```
public void performAction(ActionEvent e) {  
    List<String> lst = Arrays.asList(bar);  
    foo.peek(40)  
}
```



# Anatomy of an HTML Page

## Nested elements

- Sizing
- Attributes
- Text

You can write these out directly, or compose and modify them programmatically!

- Or, both! (we'll see in a minute).

The screenshot shows a browser window with developer tools open. The left pane displays the page content: a header with the text "Principles of Software Construction" and "Objects, Design, and Concurrency", followed by a section titled "Overview" with a detailed description of the course's focus on software engineering concepts and system construction at scale. The right pane shows the "Elements" tab of the developer tools, listing the DOM structure of the page. The "body" element contains nested components like "navigation", "header", "main", and "h2" for the overview section. Below the DOM tree, the "Computed" styles tab is selected, showing a visual representation of the element's bounding box with various CSS properties like margin, border, padding, and width/height. The overall width of the main content area is noted as 355.200x14052.300.

17-214 Fall 2021

header#top.container 355.2 x 141.6

Principles of Software Construction  
Objects, Design, and Concurrency

## Overview

Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, program structures, and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object oriented programming, (3) static and dynamic analysis for

... ▼ <body> == \$0

- ▶ <nav id="navigation" class="hidden">...</nav>
- ▶ <header id="top" class="container">...</header>
- ▼ <div id="main" class="container">
  - ::before
  - <h2 id="overview">Overview</h2>
  - ▶ <p>...</p>
  - ▶ <p style="color: red;">...</p>
  - ▶ <p>After completing this course, students will:</p>
  - ▶ <ul>...</ul>
  - ▶ <n> </n>

html body

Styles Computed Layout Event Listeners DOM Breakpoints

margin -  
border -  
padding 50  
355.200x14052.300  
50 -

# Interactivity: A GUI is more than just a document

- How do we make it “work”?
- This is a two-part answer: (1) we can attach scripts to elements, but (2) ...how? [Design question!]

The screenshot shows a browser's developer tools open to the "Elements" tab. The page content includes the text "Hi there!" and "Hello again!", with "Hello again!" being bolded. Below the text is a button labeled "Click me". The developer tools interface shows the following details:

- DOM Structure:** The page has a single `<div>` element containing a `<br>`, a regular `<span>`, and a bolded `<span>` with the text "Hello again!".
- Styles:** The bolded `<span>` is styled with `font-weight:bold`.
- Event Listeners:** The "Click me" button has an event listener attached to it.
- Network:** The Network tab is visible at the top but contains no data.
- Properties and Accessibility:** These tabs are also visible at the bottom of the developer tools.

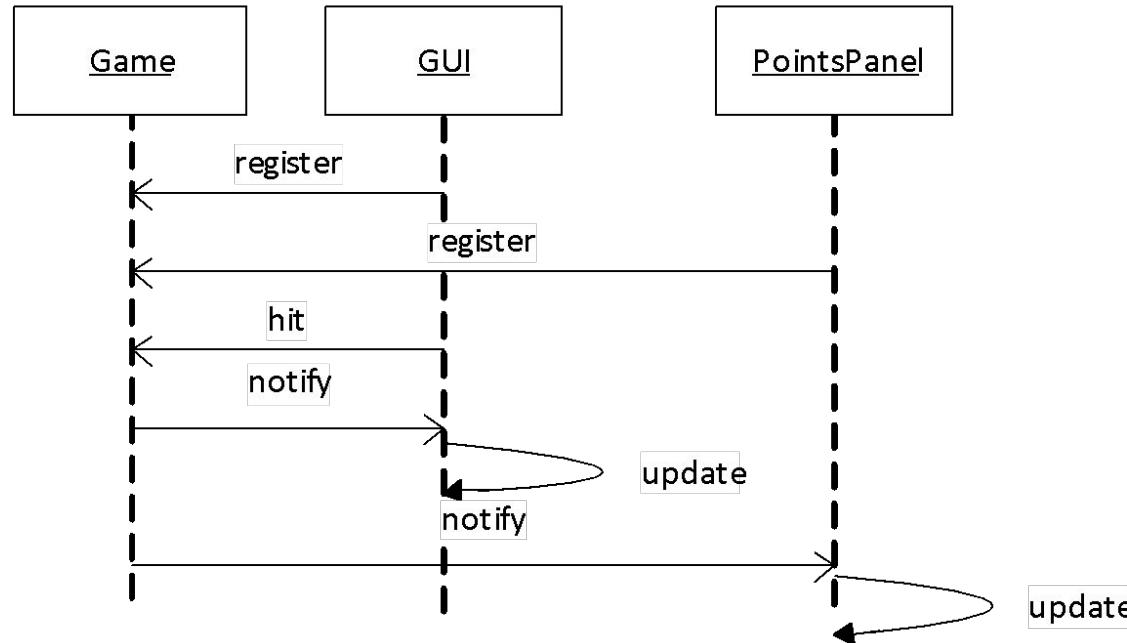
That's extremely simple, let's try something  
*slightly* more complicated.

## Consider: TicTacToe

(note that this is NOT the same code you'll see in recitation next week,  
but the game itself will look basically the same.)

# Decoupling with the Observer pattern

- Let the Game tell *all* interested components about updates



# Principles of Software Construction: Objects, Design, and Concurrency

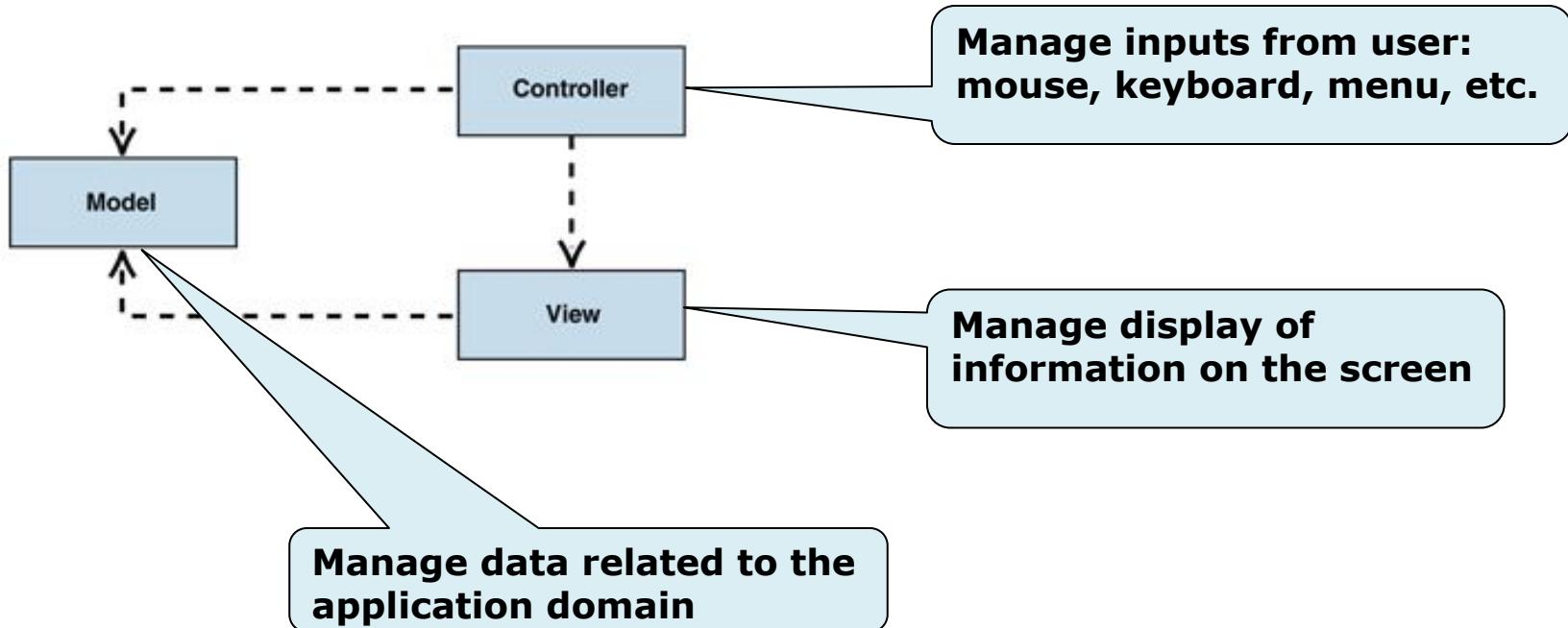
## (Towards) Building Web-Apps

Claire Le Goues

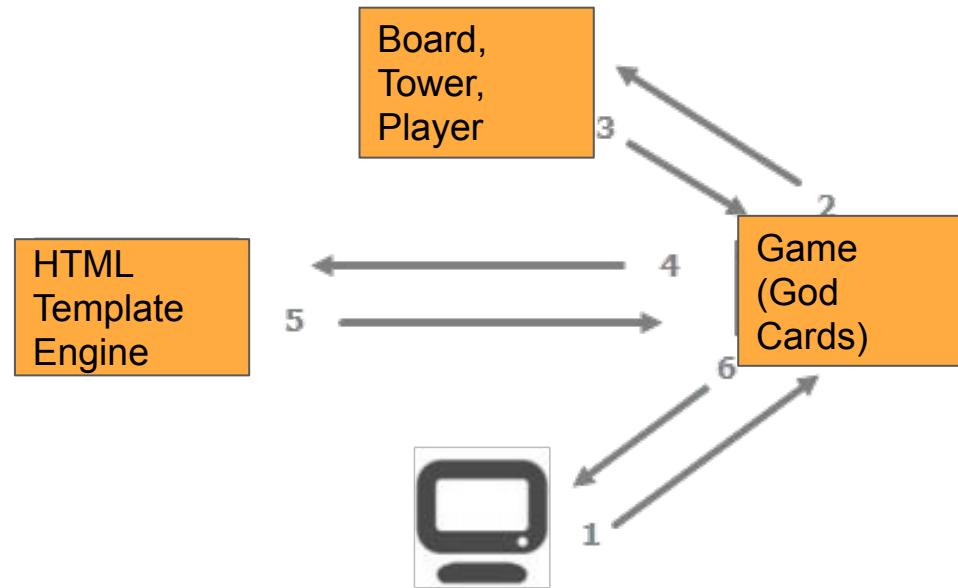
Vincent Hellendoorn



# An architectural pattern: Model-View-Controller (MVC)



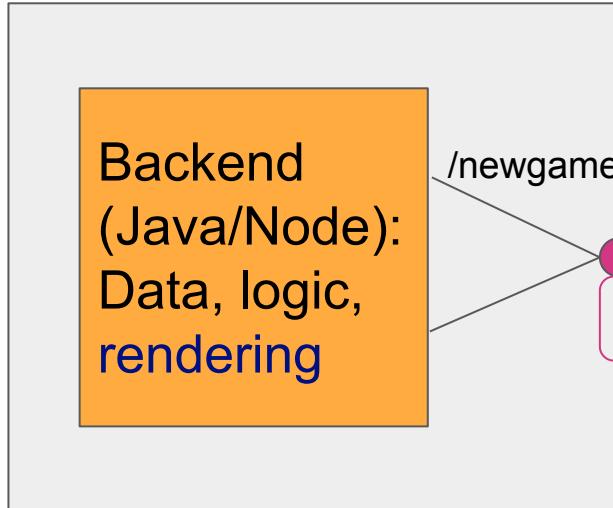
# Model View Controller in Santorini



<https://overiq.com/django-1-10/mvc-pattern-and-django/>

# TicTacToe

NanoHTTPd



ReactJS (+ HandleBars)



# Connecting React to Some Core

Use observer pattern to let react component observe changes

Encapsulate in *useEffect()* hook

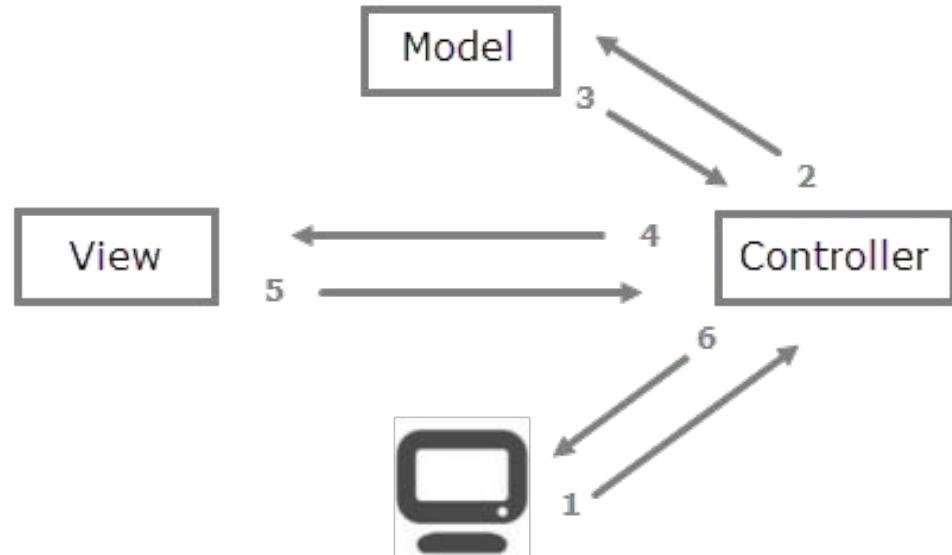
Further discussion:  
<https://reactjs.org/docs/hooks-custom.html>

```
function App() {
  const [data, setData] =
    React.useState(null);
  React.useEffect(() => {
    function handleStatChange(e) {
      setData(e.updatedData);
    }
    CoreAPI.subscribe(handleStatChange);
    return () => {
      CoreAPI.unsubscribe(handleStatChange);
    };
  });
  return (
    <div>/* using state in data */</div>
  );
}
```

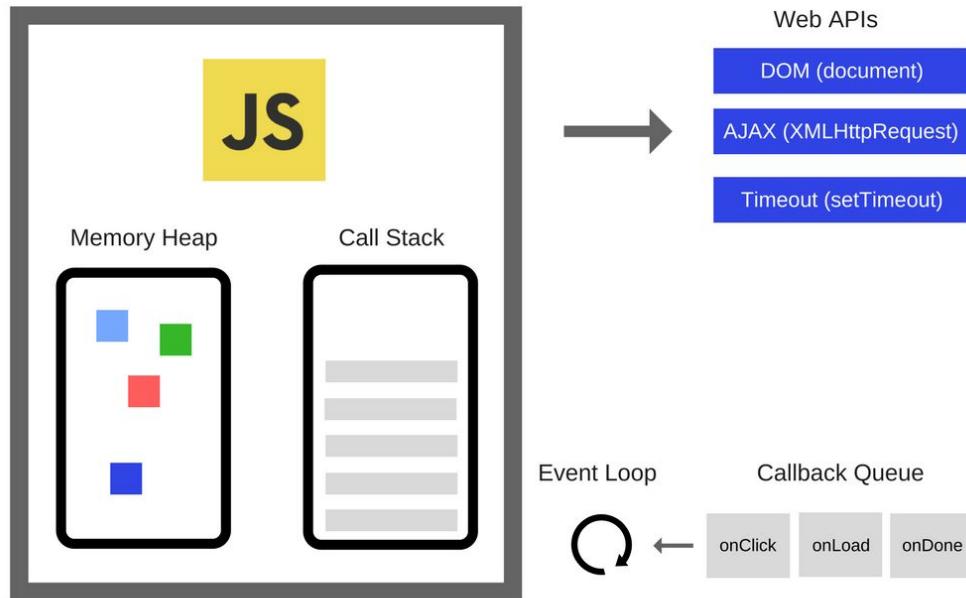
# How Do We Talk?

Talking to another computer is *hard*

- Why? We already covered HTTP (GET/POST), right?



# The JavaScript Runtime



Engine plus:

- Web APIs — provided by browsers, like the DOM, AJAX, setTimeout and more.
- Event loop
- Callback queue

# Solution: Callbacks

By far the most common way to express and manage asynchronicity in JavaScript programs.

```
Start script...
Done!
Download a file.
```



```
function task(message) {
    // emulate time consuming task
    let n = 100000000000;
    while (n > 0){
        n--;
    }
    console.log(message);
}

console.log('Start script...');
setTimeout(() => {
    task('Download a file.');
}, 1000);
console.log('Done!');
```

# “Callback Hell”?

- Issue caused by coding with complex nested callbacks.
- Every callback takes an argument that is a result of the previous callbacks.

If asynchronous:

```
const makeBurger = nextStep => {
  getBeef(function (beef) {
    cookBeef(beef, function (cookedBeef) {
      getBuns(function (buns) {
        putBeefBetweenBuns(buns, beef, function(burger) {
          nextStep(burger)
        })
      })
    })
  })
}

// Make and serve the burger
makeBurger(function (burger) => {
  serve(burger)
})
```

# Principles of Software Construction: Objects, Design, and Concurrency

## Asynchrony and Concurrency

Claire Le Goues

Vincent Hellendoorn



# Basic concurrency in Java

- An interface representing a task

```
public interface Runnable {  
    void run();  
}
```

- A class to execute a task in a thread

```
public class Thread {  
    public Thread(Runnable task);  
    public void start();  
    public void join();  
    ...  
}
```

makes sure that thread is terminated  
before the next instruction is executed  
by the program

# Solving “Callback Hell” with Promises

- You can chain promises.
  - ‘then’ returns a promise (remember cascade?)
- Promises can be resolved in parallel
- No more deep nesting
- Easy to follow control-flow

If asynchronous:

```
let bunPromise = getBuns();
let cookedBeefPromise = getBeef()
  .then(beef => cookBeef(beef));
// Resolve both promises in parallel
Promise.all([bunPromise, cookedBeefPromise])
  .then(([buns, beef]) => putBeefBetweenBuns(buns, beef))
  .then(burger => serve(burger))
```

# Next Step: Async/Await

- Async functions return a promise
  - And are allowed to ‘await’ synchronously
  - May wrap concrete values
  - May return rejected promises on exceptions

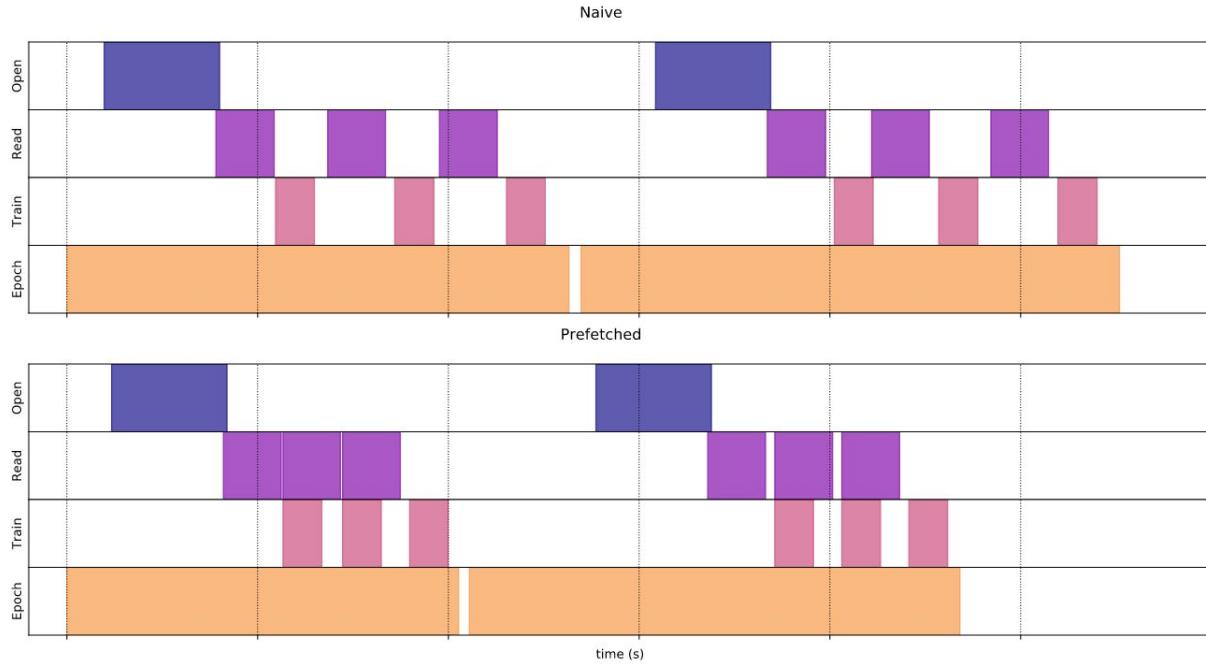
```
async function copyAsyncAwait(source: string, dest: string) {
  let statPromise = promisify(fs.stat)

  // Stat dest.
  try {
    await statPromise(dest)
  } catch (_) {
    console.log("Destination already exists")
    return
  }
}
```

# Concurrency with file I/O

An example from Machine Learning

Different devices:



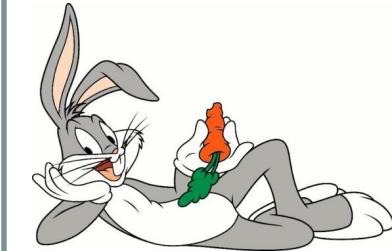
# Threading Example: Money-grab (2)

```
public static void main(String[] args) throws InterruptedException {
    BankAccount bugs = new BankAccount(1_000_000);
    BankAccount daffy = new BankAccount(1_000_000);

    Thread bugsThread = new Thread(()-> {
        for (int i = 0; i < 1_000_000; i++)
            transferFrom(daffy, bugs, 1);
    });

    Thread daffyThread = new Thread(()-> {
        for (int i = 0; i < 1_000_000; i++)
            transferFrom(bugs, daffy, 1);
    });

    bugsThread.start(); daffyThread.start();
    bugsThread.join(); daffyThread.join();
    System.out.println(bugs.balance() - daffy.balance());
}
```



# Deadlock example

Two threads:

A does transfer(a, b, 10)

B does transfer(b, a, 10)

```
class Account {  
    double balance;  
  
    void withdraw(double amount){ balance -= amount; }  
    void deposit(double amount){ balance += amount; }  
    void transfer(Account from, Account to, double amount){  
        synchronized(from) {  
            from.withdraw(amount);  
            synchronized(to) {  
                to.deposit(amount);  
            }  
        }  
    }  
}
```

Execution trace:

A: lock a (v)

B: lock b (v)

A: lock b (x)

B: lock a (x)

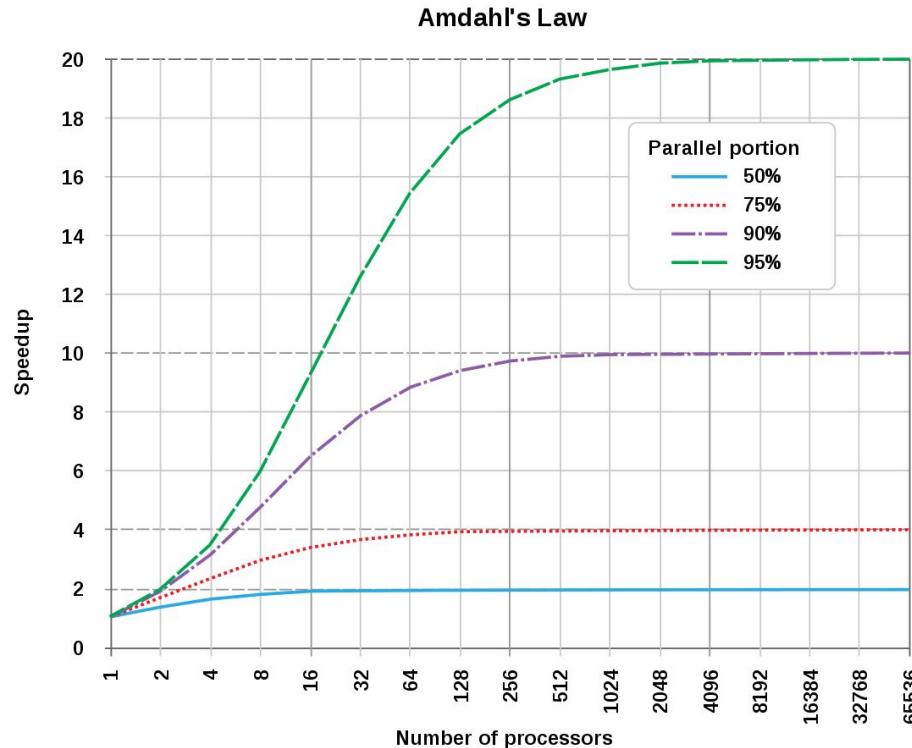
A: wait

B: wait

Deadlock!

# Amdahl's law

- The speedup is limited by the serial part of the program.



# Principles of Software Construction: Objects, Design, and Concurrency

## Concurrency: Safety & Immutability

Claire Le Goues

Vincent Hellendoorn



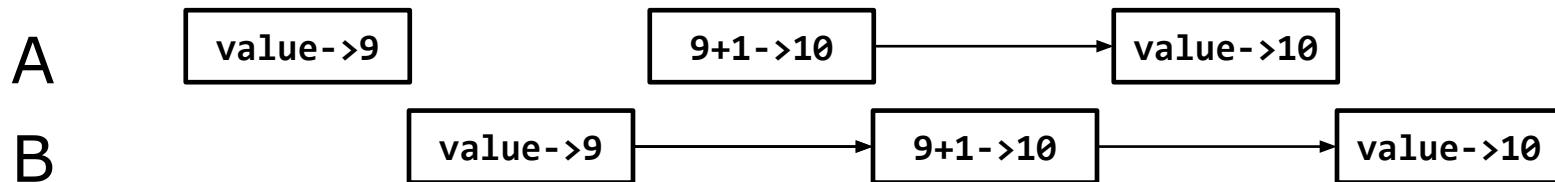
# Making a Class Immutable

```
public class Complex {  
    double re, im;  
  
    public Complex(double re, double im) {  
        this.re = re;  
        this.im = im;  
    }  
  
    public double getRealPart() { return re; }  
    public double getImaginaryPart() { return im; }  
  
    public double setRealPart(double re) { this.re = re; }  
    public double setImaginaryPart(double im) { this.im = im; }  
  
    ...
```

# Fixed

```
class Stack {  
    readonly #inner: any[]  
    constructor (inner: any[]) {  
        this.#inner=inner.slice()  
    }  
    push(o: any): Stack {  
        const newInner = this.#inner.slice()  
        newInner.push(o)  
        return new Stack(newInner)  
    }  
    peek(): any {  
        return this.#inner[this.#inner.length-1]  
    }  
    getInner(): any[] {  
        return this.#inner.slice()  
        // Java: return new ArrayList(inner)  
    }  
}
```

# Non atomicity and thread (un)safety



```
@NotThreadSafe
public class UnsafeCountingFactorizer implements Servlet {
    private long count = 0;

    public long getCount() { return count; }

    public void service(ServletRequest req, ServletResponse resp) {
        BigInteger i = extractFromRequest(req);
        BigInteger[] factors = factor(i);
        ++count;
        encodeIntoResponse(resp, factors);
    }
}
```

# You can do better (?)

## *volatile is synchronization without mutual exclusion*

```
public class StopThread {  
    private static volatile boolean stopRequested;  
  
    public static void main(String[] args) throws Exception {  
        Thread backgroundThread = new Thread(() -> {  
            while (!stopRequested)  
                /* Do something */ ;  
        });  
        backgroundThread.start();  
  
        TimeUnit.SECONDS.sleep(1);  
        stopRequested = true;  
    }  
}
```

forces all accesses (read or write) to the volatile variable to occur in main memory, effectively keeping the volatile variable out of CPU caches.

# Monitor Example

```
class SimpleBoundedCounter {  
    protected long count = MIN;  
    public synchronized long count() { return count; }  
    public synchronized void inc() throws InterruptedException {  
        awaitUnderMax(); setCount(count + 1);  
    }  
    public synchronized void dec() throws InterruptedException {  
        awaitOverMin(); setCount(count - 1);  
    }  
    protected void setCount(long newValue) { // PRE: lock held  
        count = newValue;  
        notifyAll(); // wake up any thread depending on new value  
    }  
    protected void awaitUnderMax() throws InterruptedException {  
        while (count == MAX) wait();  
    }  
    protected void awaitOverMin() throws InterruptedException {  
        while (count == MIN) wait();  
    }  
}
```

# Principles of Software Construction: Objects, Design, and Concurrency

## Distributed Systems – Events Everywhere!

Claire Le Goues



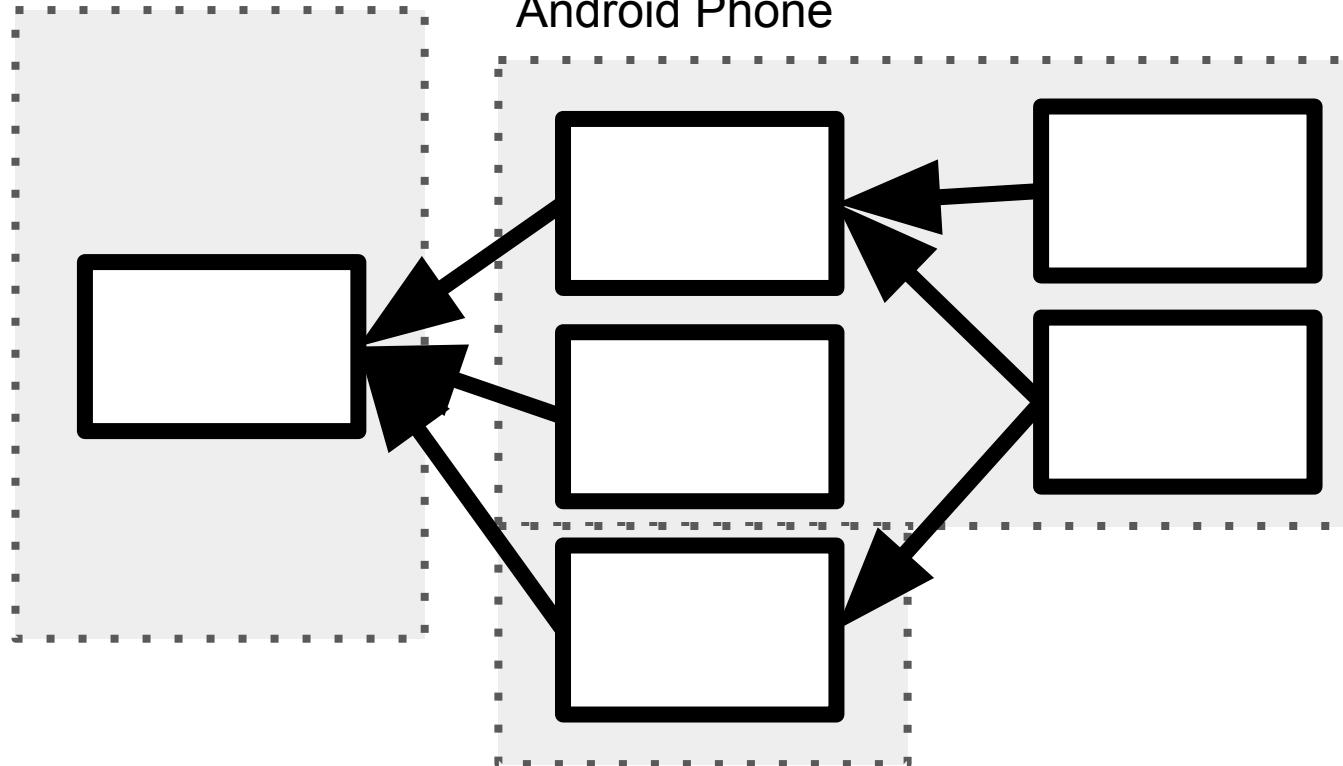
Vincent Hellendoorn



# Recapping Concurrency

Database Server

Android Phone



Credit card server





# NETFLIX

# Retry!

- Still need an exit-strategy
  - Learn [HTTP response codes](#)
    - Don't bother retrying on a 403 (go find out why)
  - Use the API response, if any
    - Errors are often documented -- e.g., GitHub will send a “rate limit exceeded” message

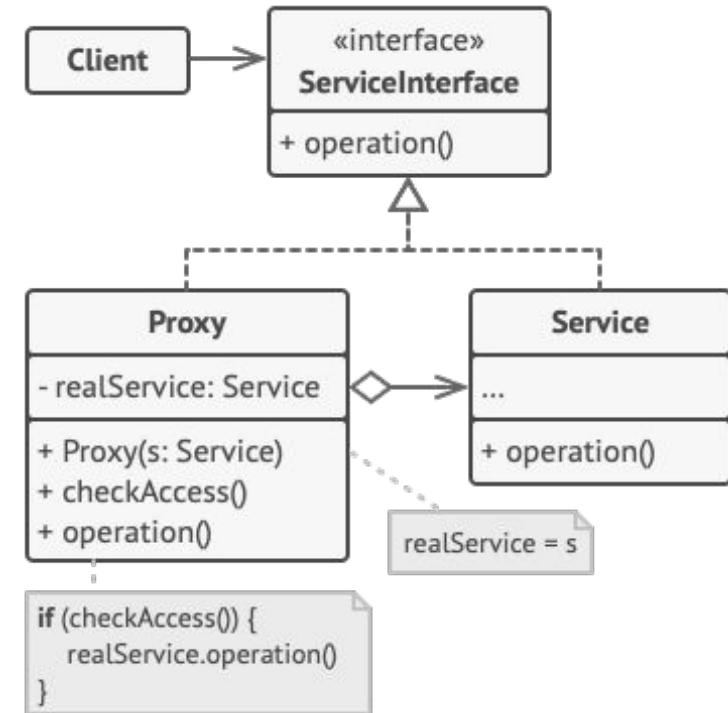
```
const delay = retryCount => new Promise(resolve =>
    setTimeout(resolve, 10 ** retryCount));

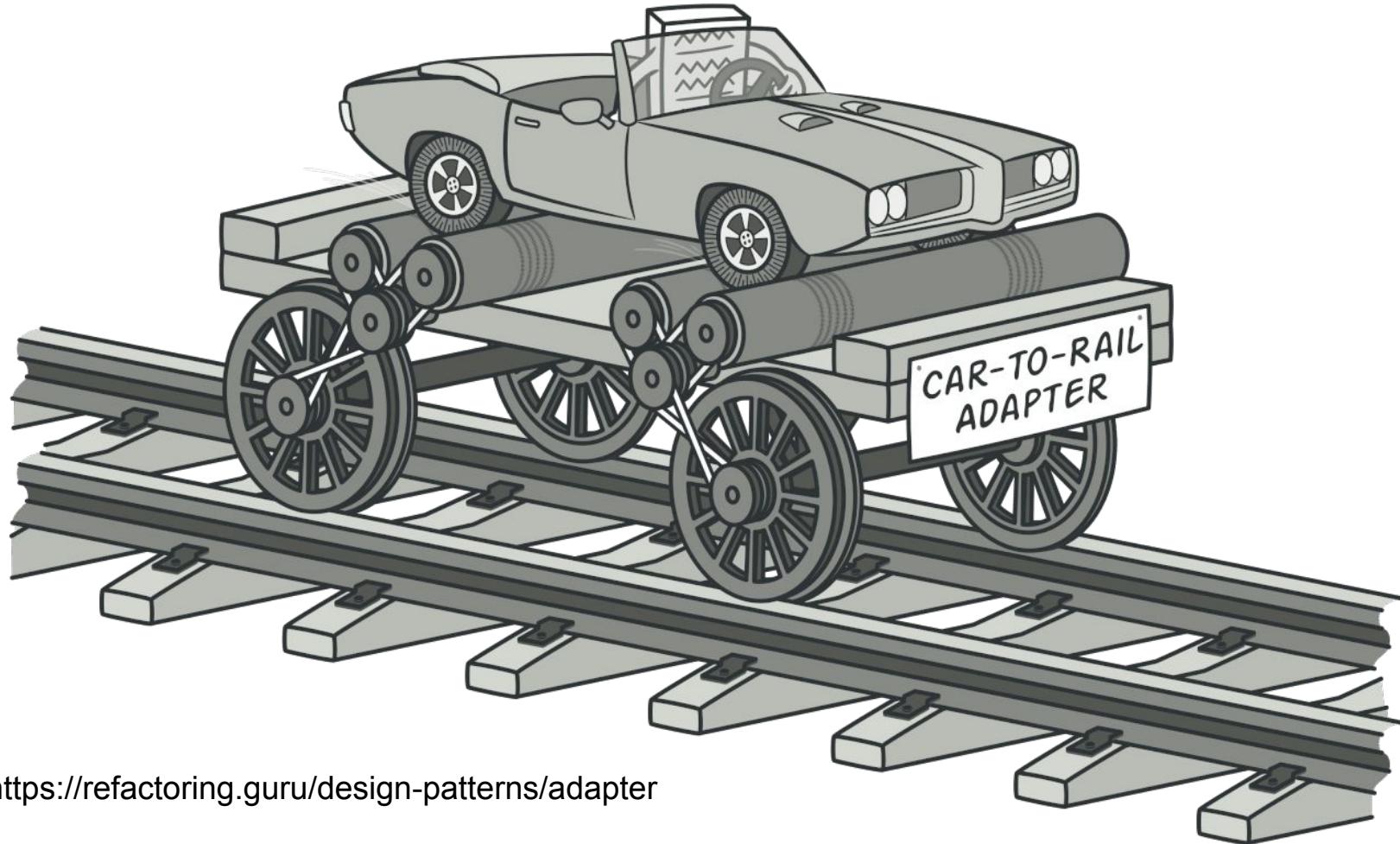
const getResource = async (retryCount = 0, lastError = null) => {
    if (retryCount > 5) throw new Error(lastError);
    try {
        return apiCall();
    } catch (e) {
        await delay(retryCount);
        return getResource(retryCount + 1, e);
    }
}
```

17- } https://www.bayanbennett.com/posts/retrying-and-exponential-backoff-with-promises/

# Proxy Design Pattern

- Local representative for remote object
  - Create expensive obj on-demand
  - Control access to an object
- Hides extra “work” from client
  - Add extra error handling, caching
  - Uses *indirection*





<https://refactoring.guru/design-patterns/adapter>

# HW5: Santorini with God Cards and GUI

# Principles of Software Construction: Objects, Design, and Concurrency

## Libraries and Frameworks

(Design for large-scale reuse)

Claire Le Goues

Vincent Hellendoorn



# Where we are

	<i>Small scale:</i> One/few objects	<i>Mid scale:</i> Many objects	<i>Large scale:</i> Subsystems
<i>Design for understanding change/ext. reuse robustness ...</i>	Subtype Polymorphism ✓ Information Hiding, Contracts ✓ Immutability ✓ Types ✓ Static Analysis ✓ Unit Testing ✓	Domain Analysis ✓ Inheritance & Del. ✓ Responsibility Assignment, Design Patterns, Antipattern ✓ Promises/ Reactive P. ✓ Integration Testing ✓	GUI vs Core ✓ <b>Frameworks and Libraries ✓ , APIs ✓</b> Module systems, microservices ✓ Testing for Robustness ✓ CI ✓ , DevOps ✓ , Teams

# Earlier in this course: Class-level reuse

Language mechanisms supporting reuse

- Inheritance
- Subtype polymorphism (dynamic dispatch)
- Parametric polymorphism (generics)\*

Design principles supporting reuse

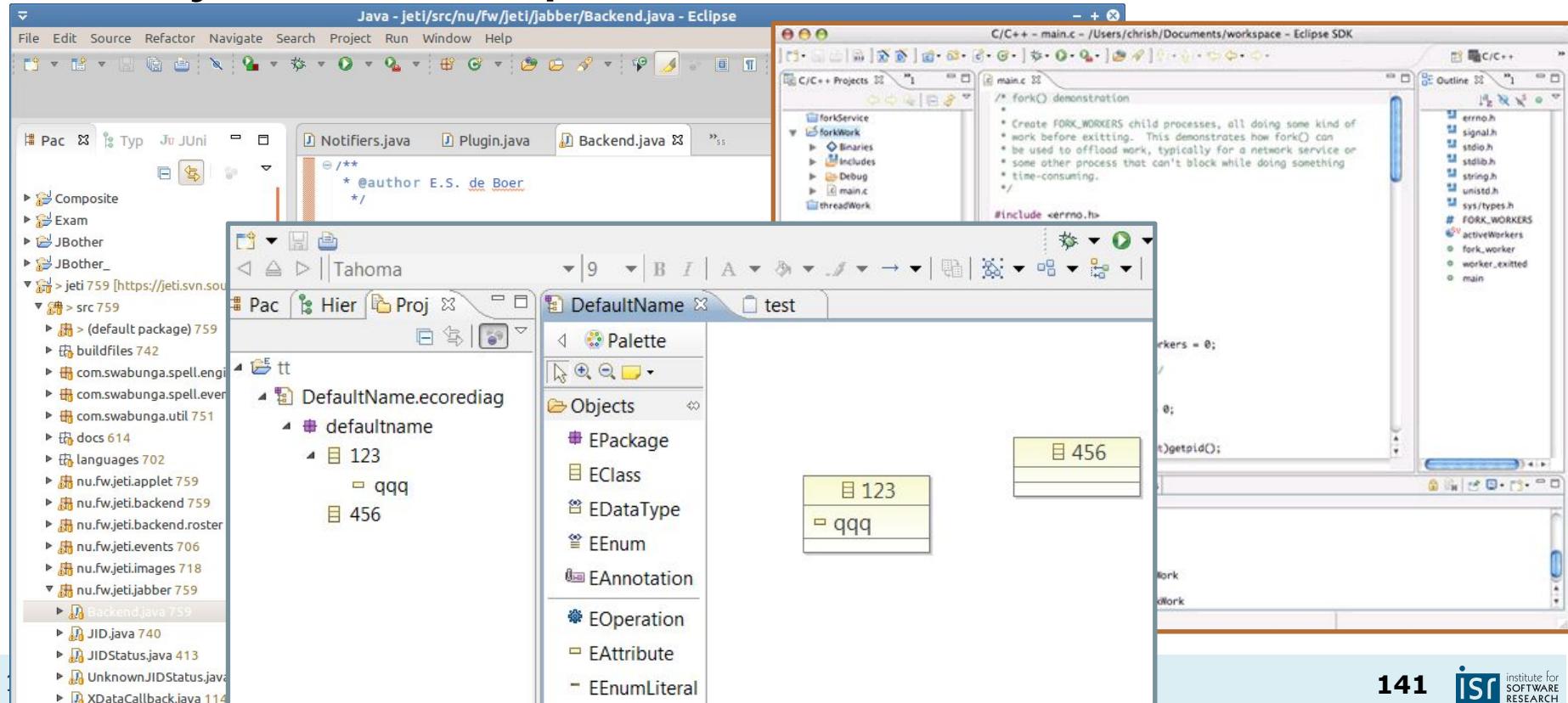
- Small interfaces
- Information hiding
- Low coupling
- High cohesion

Design patterns supporting reuse

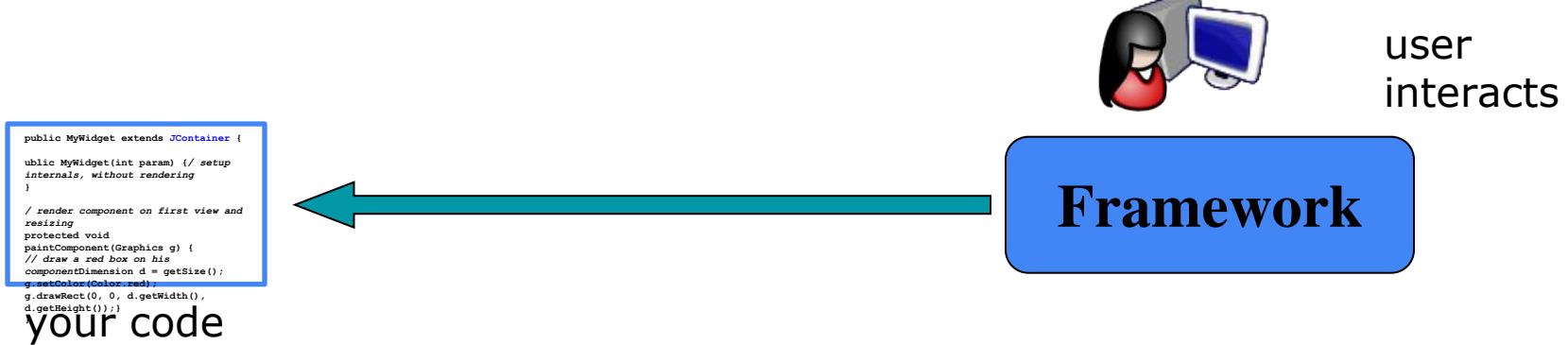
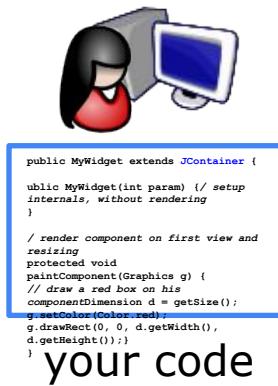
- Template method, decorator, strategy, composite, adapter, ...

\* Effective Java items 26, 29, 30, and 31

# Reuse and variation: Family of development tools



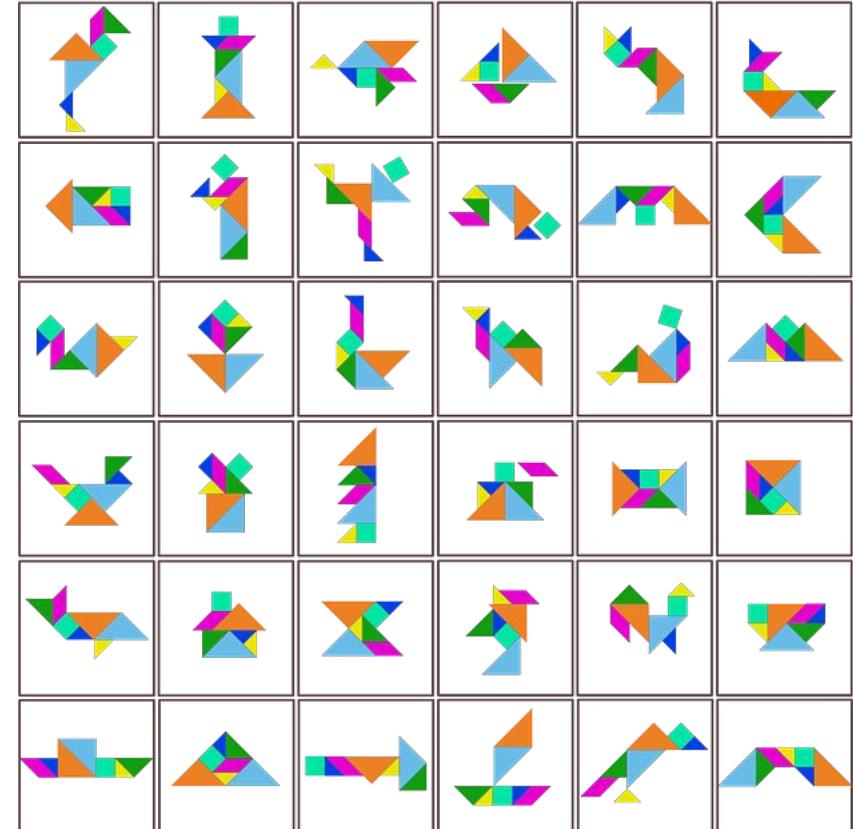
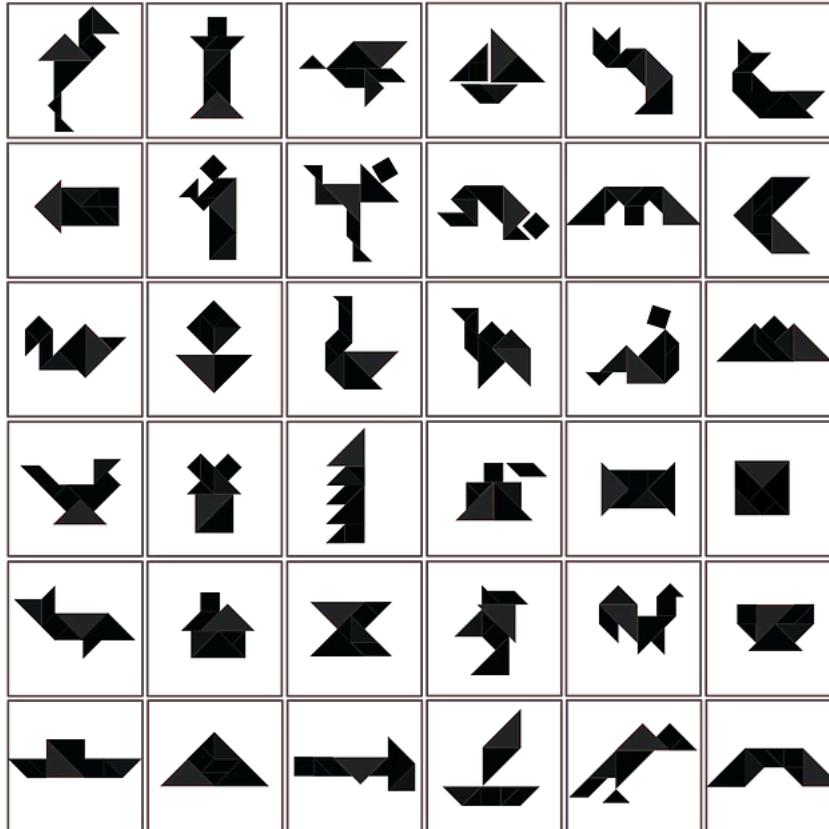
# General distinction: Library vs. framework



# Is this a whitebox or blackbox framework?

```
public abstract class Application extends JFrame {  
    protected String getApplicationTitle() { return ""; }  
    protected String getButtonText() { return ""; }  
    protected String getInitialText() { return ""; }  
  
    public class Calculator extends Application {  
        protected String getApplicationTitle() { return "My Great Calculator"; }  
        protected String getButtonText() { return "calculate"; }  
        protected String getInitialText() { return "(10 - 3) * 6"; }  
        protected void buttonClicked() {  
            JOptionPane.showMessageDialog(this, "The result of " + getInput() +  
                " is " + calculate(getInput()));  
        }  
    }  
    . . .  
    public class Ping extends Application {  
        protected String getApplicationTitle() { return "Ping"; }  
        protected String getButtonText() { return "ping"; }  
        protected String getInitialText() { return "127.0.0.1"; }  
        protected void buttonClicked() { ... }  
    }
```

# Tangrams



# The use vs. reuse dilemma

- Large rich components are very useful, but rarely fit a specific need
- Small or extremely generic components often fit a specific need, but provide little benefit

**“maximizing reuse minimizes use”**

**C. Szyperski**

# The cost of changing a framework

```
public class Application extends JFrame {  
    private JTextField textfield;  
    private Plugin plugin;  
    public Application(Plugin p) { this.plugin=p; p.setApplication(this); init(); }  
    protected void init() {  
        JPanel contentPane = new JPanel(new BorderLayout());  
        contentPane.setBorder(new BevelBorder(BevelBorder.LOWERED));  
        JButton button = new JButton();  
        if (plugin != null)  
            button.setText(plugin.getButtonText());  
        else  
            button.setText("Calculate");  
        contentPane.add(button, "Center");  
        textfield = new JTextField("0");  
        if (plugin != null)  
            textfield.addActionListener(plugin);  
        contentPane.add(textfield, "South");  
        this.setContentPane(contentPane);  
        this.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);  
        this.setVisible(true);  
    }  
}
```

Consider adding an extra method.  
Requires changes to *all* plugins!

```
public interface Plugin {  
    String getApplicationTitle();  
    String getButtonText();  
    String getInitialText();  
    void buttonClicked();  
    void setApplication(Application app);  
}  
  
public class CalcPlugin implements Plugin {  
    private Application application;  
    public void setApplication(Application app) { this.application = app; }  
    public String getButtonText() { return "calculate"; }  
    public String getInitialText() { return "10 / 2 + 6"; }  
    public void buttonClicked() {  
        JOptionPane.showMessageDialog(null, "The result of "  
            + application.getText());  
    }  
    String getApplicationTitle() { return "My Great Calculator"; }  
}
```

```
class CalcStarter { public static void main(String[] args) {  
    new Application(new CalcPlugin()).setVisible(true); }}  
    this.setContentPane(contentPane);  
    this.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);  
    this.setVisible(true);  
}
```

# An example plugin loader in Node.js

```
const args = process.argv
if (args.length < 3)
    console.log("Plugin name not specified");
else {
    const plugin = require("plugins/"+args[2]+".js")()
    startApplication(plugin)
}
```

# Principles of Software Construction

## API Design

**Claire Le Goues**      Vincent Hellendoorn  
(Many slides originally from Josh Bloch, some from Christian Kaestner)



# Where we are

	<i>Small scale:</i> One/few objects	<i>Mid scale:</i> Many objects	<i>Large scale:</i> Subsystems
<i>Design for understanding change/ext. reuse robustness ...</i>	Subtype Polymorphism  Information Hiding, Contracts  Immutability  Types  Unit Testing	Domain Analysis  Inheritance & Deleg.  Responsibility Assignment, Design Patterns, Antipattern  Promises/Reactive P.  Integration Testing	GUI vs Core  <b>Frameworks and Libraries, APIs</b>  Module systems, microservices  Testing for Robustness  CI, DevOps, Teams

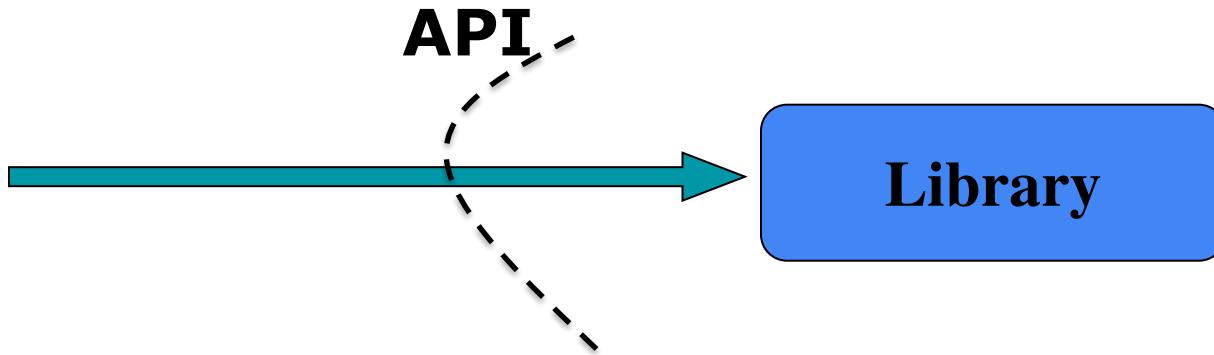
# API: Application Programming Interface

- An API defines the boundary between components/modules in a programmatic system

# Libraries and frameworks (and protocols!) define APIs

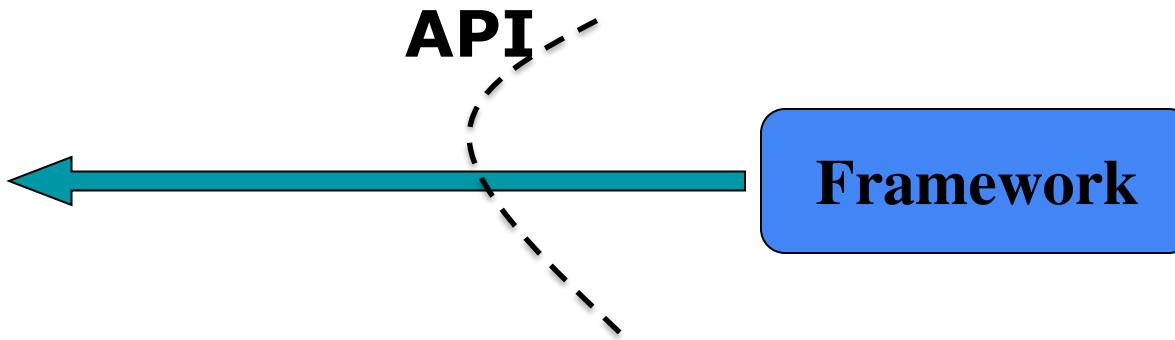
```
public MyWidget extends JPanel {  
    public MyWidget(int param) { /* setup  
        internals, without rendering  
    */  
  
        /* render component on first view and  
        resizing  
        protected void  
        paintComponent(Graphics g) {  
            // draw a red box on his  
            componentDimension d = getSize();  
            g.setColor(Color.red);  
            g.drawRect(0, 0, d.getWidth(),  
            d.getHeight());  
        }  
    }  
}
```

your code



```
public MyWidget extends JPanel {  
    public MyWidget(int param) { /* setup  
        internals, without rendering  
    */  
  
        /* render component on first view and  
        resizing  
        protected void  
        paintComponent(Graphics g) {  
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            componentDimension d = getSize();  
            g.setColor(Color.red);  
            g.drawRect(0, 0, d.getWidth(),  
            d.getHeight());  
        }  
    }  
}
```

your code



# An API design process: plan with use cases

- Similar to our framework discussion!
- Define the scope of the API
  - Collect use-case stories, define requirements
  - Be skeptical: Distinguish true requirements from so-called solutions, "When in doubt, leave it out."
  - Be explicit about *non-goals*
- Draft a specification, gather feedback, revise, and repeat. Keep it simple, short!
- Code early, code often: Write *client code* before you implement the API

# Sample Early API Draft

```
// A collection of elements (root of the collection hierarchy)
public interface Collection<E> {

    // Ensures that collection contains o
    boolean add(E o);

    // Removes an instance of o from collection, if present
    boolean remove(Object o);

    // Returns true iff collection contains o
    boolean contains(Object o);

    // Returns number of elements in collection
    int size();

    // Returns true if collection is empty
    boolean isEmpty();

    ... // Remainder omitted
}
```

# Hyrum's Law

*“With a sufficient number of users of an API, it does not matter what you promise in the contract: all observable behaviors of your system will be depended on by somebody.”*

<https://www.hyrumslaw.com/>

CHANGES IN VERSION 10.17:  
THE CPU NO LONGER OVERHEATS  
WHEN YOU HOLD DOWN SPACEBAR.

## COMMENTS:

LONGTIMEUSER4 WRITES:

THIS UPDATE BROKE MY WORKFLOW!  
MY CONTROL KEY IS HARD TO REACH,  
SO I HOLD SPACEBAR INSTEAD, AND I  
CONFIGURED EMACS TO INTERPRET A  
RAPID TEMPERATURE RISE AS "CONTROL".

ADMIN WRITES:

THAT'S HORRIFYING.

LONGTIMEUSER4 WRITES:

LOOK, MY SETUP WORKS FOR ME.  
JUST ADD AN OPTION TO REENABLE  
SPACEBAR HEATING.

EVERY CHANGE BREAKS SOMEONE'S WORKFLOW.

<https://xkcd.com/1172/>

# Applying Information hiding: Factories

```
public class Rectangle {  
    public Rectangle(Point e, Point f) ...  
}  
// ...  
Point p1 = PointFactory.Construct(...);  
// new PolarPoint(...); inside  
Point p2 = PointFactory.Construct(...);  
// new PolarPoint(...); inside  
Rectangle r = new Rectangle(p1, p2);
```

# Don't let your output become your de facto API

- Document the fact that output formats may evolve in the future
- Provide programmatic access to all data available in string form

```
public class Throwable {  
    public void printStackTrace(PrintStream s);  
}
```

```
org.omg.CORBA.MARSHAL: com.ibm.ws.pmi.server.DataDescriptor; IllegalAccessException minor code: 4942F23E comp  
at com.ibm.rmi.io.ValueHandlerImpl.readValue(ValueHandlerImpl.java:199)  
at com.ibm.rmi.iiop.CDRInputStream.read_value(CDRInputStream.java:1429)  
at com.ibm.rmi.io.ValueHandlerImpl.read_Array(ValueHandlerImpl.java:625)  
at com.ibm.rmi.io.ValueHandlerImpl.readValueInternal(ValueHandlerImpl.java:273)  
at com.ibm.rmi.io.ValueHandlerImpl.readValue(ValueHandlerImpl.java:189)  
at com.ibm.rmi.iiop.CDRInputStream.read_value(CDRInputStream.java:1429)  
at com.ibm.ejs.sm.beans._EJSRemoteStatelessPmiService_Tie._invoke(_EJSRemoteStatelessPmiService_Tie.ja  
at com.ibm.CORBA.iiop.ExtendedServerDelegate.dispatch(ExtendedServerDelegate.java:515)  
at com.ibm.CORBA.iiop.ORB.process(ORB.java:2377)  
at com.ibm.CORBA.iiop.OrbWorker.run(OrbWorker.java:186)  
at com.ibm.ejs.oa.pool.ThreadPool$PooledWorker.run(ThreadPool.java:104)  
at com.ibm.ws.util.CachedThread.run(ThreadPool.java:137)
```

# Principle: Minimize conceptual weight

- API should be as small as possible but no smaller
  - When in doubt, leave it out
- Conceptual weight: How many concepts must a programmer learn to use your API?
  - APIs should have a "high power-to-weight ratio"

# Boilerplate Code

```
import org.w3c.dom.*;
import java.io.*;
import javax.xml.transform.*;
import javax.xml.transform.dom.*;
import javax.xml.transform.stream.*;

/** DOM code to write an XML document to a specified output stream. */
static final void writeDoc(Document doc, OutputStream out) throws IOException{
    try {
        Transformer t = TransformerFactory.newInstance().newTransformer();
        t.setOutputProperty(OutputKeys.DOCTYPE_SYSTEM, doc.getDoctype().getSystemId());
        t.transform(new DOMSource(doc), new StreamResult(out)); // Does actual writing
    } catch(TransformerException e) {
        throw new AssertionError(e); // Can't happen!
    }
}
```

- Generally done via cut-and-paste
- Ugly, annoying, and error-prone

N  
RE  
The  
matrix1d  
daliirhe(s  
[], float  
float \*hd1W  
float, flt  
x, float  
y1, float  
float br  
Thi  
Edi  
Art  
col  
res  
tex  
sel  
anc  
cor  
we  
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me  
cor

will always converge, provided that the initial guess is good enough. Indeed one can even determine in advance the rate of convergence of most algorithms.

It cannot be overemphasized, however, how crucially success depends on having a good first guess for the solution, especially for multidimensional problems. This crucial beginning usually depends on analysis rather than numerics. Carefully crafted initial estimates reward you not only with reduced computational effort, but also with understanding and increased self-esteem. Hamming's motto, "the purpose of computing is insight, not numbers," is particularly apt in the area of finding roots. You should repeat this motto aloud whenever your program converges, with ten-digit accuracy, to the wrong root of a problem, or whenever it fails to converge because there is actually no root, or because there is a root but your initial estimate was not sufficiently close to it.

... all very well, but what do I actually do? ...

```
int jz,j,i;
float ysml,ybig,x2,x1,x,dyj,dx,y[ISCR+1];
char scr[ISCR+1][JSCR+1];
```

## Starting points.

- Brent's algorithm in §9.3 is the method of choice to find a bracketed root of a general one-dimensional function, when you cannot easily compute the function's derivative. Ridders' method (§9.2) is concise, and a close competitor.
- When you can compute the function's derivative, the routine `rtsafe` in §9.4, which combines the Newton-Raphson method with some bookkeeping on bounds, is recommended. Again, you must first bracket your root.
- Roots of polynomials are a special case. Laguerre's method, in §9.5, is recommended as a starting point. Beware: Some polynomials are ill-conditioned!
- Finally, for multidimensional problems, the only elementary method is Newton-Raphson (§9.6), which works very well if you can supply a

```
if (ybig == ysml) ybig=ysml+1.0;
dyj=(JSCR-1)/(ybig-ysml);
jz=1-(int)(ysml*dyj);
for (i=1;i<=ISCR;i++) {
    scr[i][jz]=ZERO;
    jz+=1-(int)((y[i]-ysml)*dyj);
    scr[i][jz]=FP;
}
printf(" %10.3f ",ybig);
for (i=1;i<=ISCR;i++) printf("%c",scr[i][JSCR]);
printf("\n");
for (j=JSCR-1;j>=2;j--) {
    printf("%12s", " ");
    for (i=1;i<=ISCR;i++) printf("%c",scr[i][j]);
    printf("\n");
}
printf(" %10.3f ",ysml);
```

Be sure to separate top and bottom.  
Note which row corresponds to 0.  
Place an indicator at function height and  
0.

# HW6: Data Analytics Framework

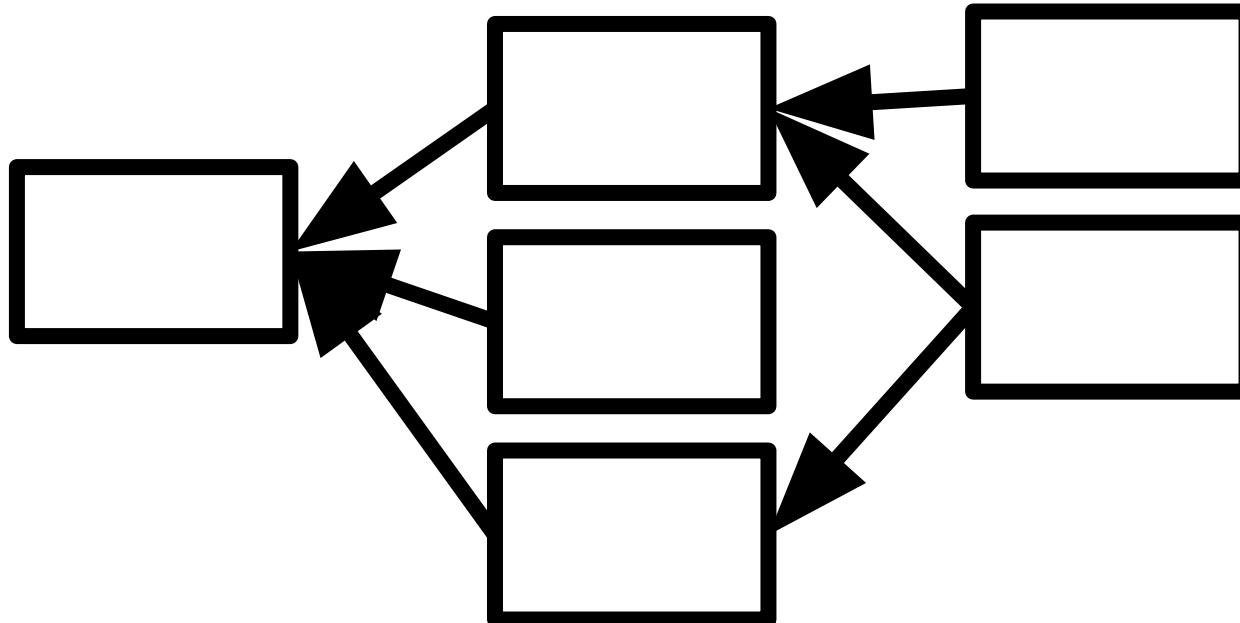
# Principles of Software Construction: Objects, Design, and Concurrency

## Organizing Systems at Scale: Modules, Services, Architectures

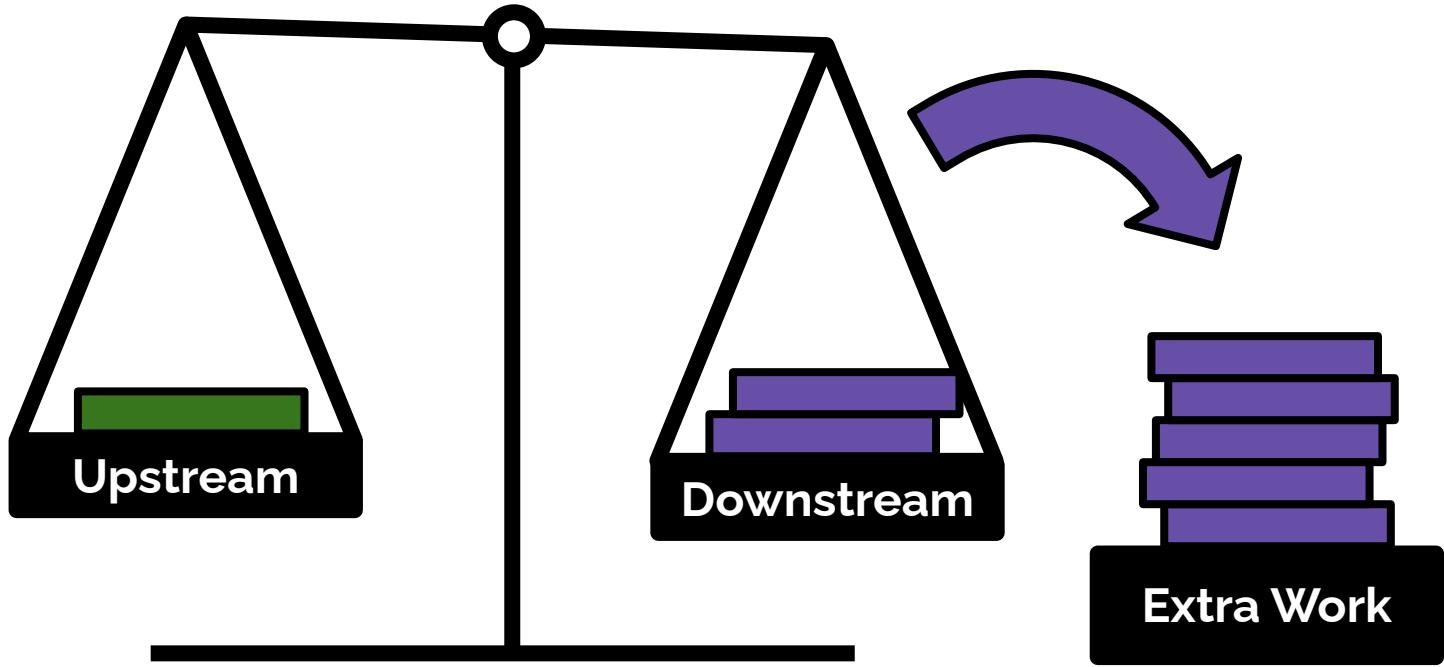
Claire Le Goues

Vincent Hellendoorn





# Software Ecosystem



Avoiding dependencies  
Encapsulating from change

# How to Break an API?

In Eclipse, you don't.

In CRAN, you reach out to affected downstream developers.

In Node.js, you increase the major version number.

# Java Platform Module System

Since Java 9 (2017); built-in alternative to OSGi

Modularized JDK libraries itself

Several technical differences to OSGi (e.g., visibility vs access protection, handling of diamond problem)

```
module A {  
    exports org.example.foo;  
    exports org.example.bar;  
}  
module B {  
    require A;  
}
```

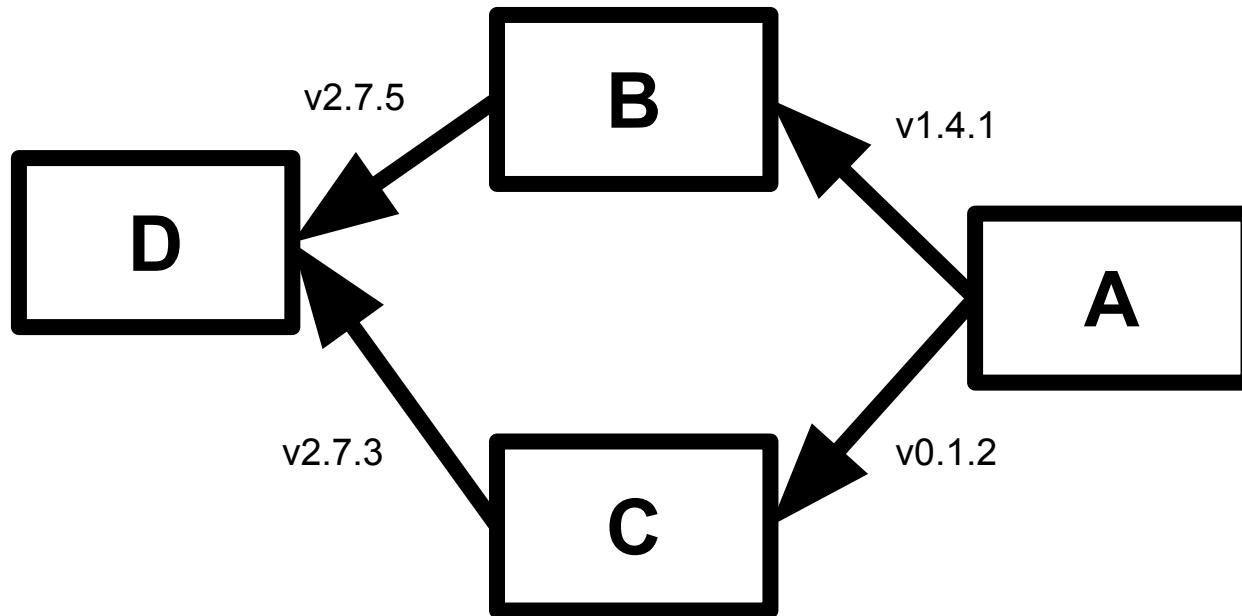
# Toward JavaScript Modules

Traditionally no module concept, import into flat namespace

Creating own namespaces with closures/module pattern

```
<html>
<header>
<script type="text/javascript" src="lib1.js"></script>
<script type="text/javascript">
    var x = 1;
</script>
<script type="text/javascript" src="lib2.js"></script>
```

# The Diamond Problem



What now?

# Recall: Ever looked at NPM Install's output?

```
npm [WARN] deprecated babel-eslint@10.1.0: babel-eslint is now @babel/eslint-parser. This package will no longer receive updates.
npm [WARN] deprecated chokidar@2.1.8: Chokidar 2 will break on node v14+. Upgrade to chokidar 3 with 15x less dependencies.
npm [WARN] deprecated svgo@1.3.2: This SVGO version is no longer supported. Upgrade to v2.x.x.
npm [WARN] deprecated querystring@0.2.1: The querystring API is considered Legacy. new code should use the URLSearchParams API instead.
npm [WARN] deprecated @hapi/joi@15.1.1: Switch to 'npm install joi'
npm [WARN] deprecated rollup-plugin-babel@4.4.0: This package has been deprecated and is no longer maintained. Please use @rollup/plugin-babel.
npm [WARN] deprecated fsevents@1.2.13: fsevents 1 will break on node v14+ and could be using insecure binaries. Upgrade to fsevents 2.
npm [WARN] deprecated uuid@3.4.0: Please upgrade to version 7 or higher. Older versions may use Math.random() in certain circumstances, which is known to be problematic. See https://v8.dev/blog/math-random for details.
npm [WARN] deprecated querystring@0.2.0: The querystring API is considered Legacy. new code should use the URLSearchParams API instead.
npm [WARN] deprecated sane@4.1.0: some dependency vulnerabilities fixed, support for node < 10 dropped, and newer ECMAScript syntax/features added
npm [WARN] deprecated flatten@1.0.3: flatten is deprecated in favor of utility frameworks such as lodash.
npm [WARN] deprecated urix@0.1.0: Please see https://github.com/lydell/urix#deprecated
npm [WARN] deprecated @hapi/bourne@1.3.2: This version has been deprecated and is no longer supported or maintained
```

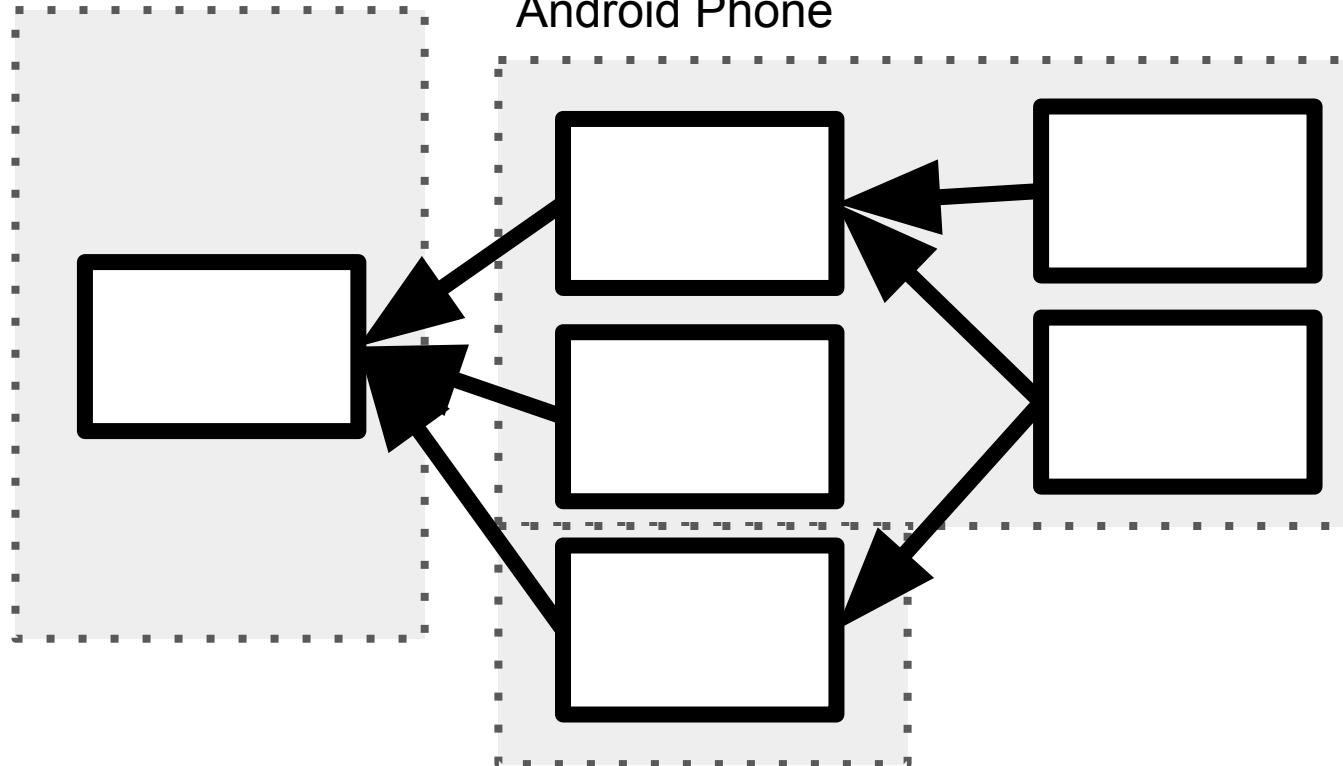


Recommended reading:

<https://republicans-oversight.house.gov/wp-content/uploads/2018/12/Equifax-Report.pdf>

Database Server

Android Phone



Credit card server

# CRUD Operations

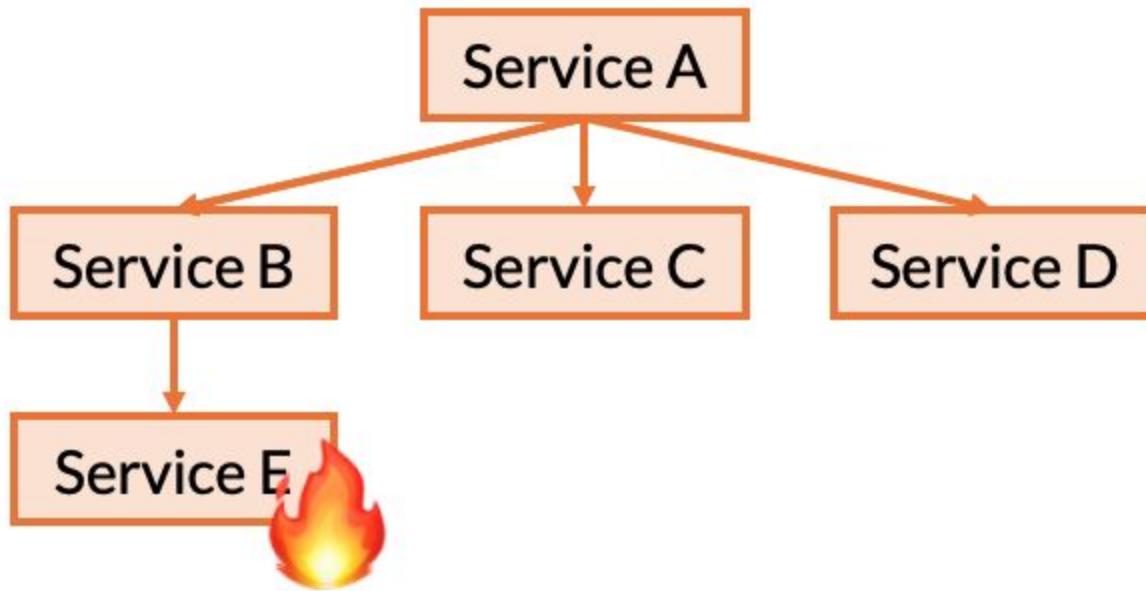
Path correspond to nouns, not verbs, nesting common:

- `/articles, /state, /game`  
`/articles/:id/comments`

GET (receive), POST (submit new),  
PUT (update), and DELETE  
requests sent to those paths

Parameters for filtering, searching,  
sorting, e.g., `/articles?sort=date`

```
const express = require('express');
const bodyParser = require('body-parser');
const app = express();
app.use(bodyParser.json()); // JSON input
app.get('/articles', (req, res) => {
  const articles = [];
  // code to retrieve an article...
  res.json(articles);
});
app.post('/articles', (req, res) => {
  // code to add a new article...
  res.json(req.body);
});
app.put('/articles/:id', (req, res) => {
  const { id } = req.params;
  // code to update an article...
  res.json(req.body);
});
app.delete('/articles/:id', (req, res) => {
  const { id } = req.params;
  // code to delete an article...
  res.json({ deleted: id });
});
app.listen(3000, () => console.log('server started'));
```



# Principles of Software Construction: Objects, Design, and Concurrency

## Designing for Robustness in Large & Distributed Systems

Claire Le Goues



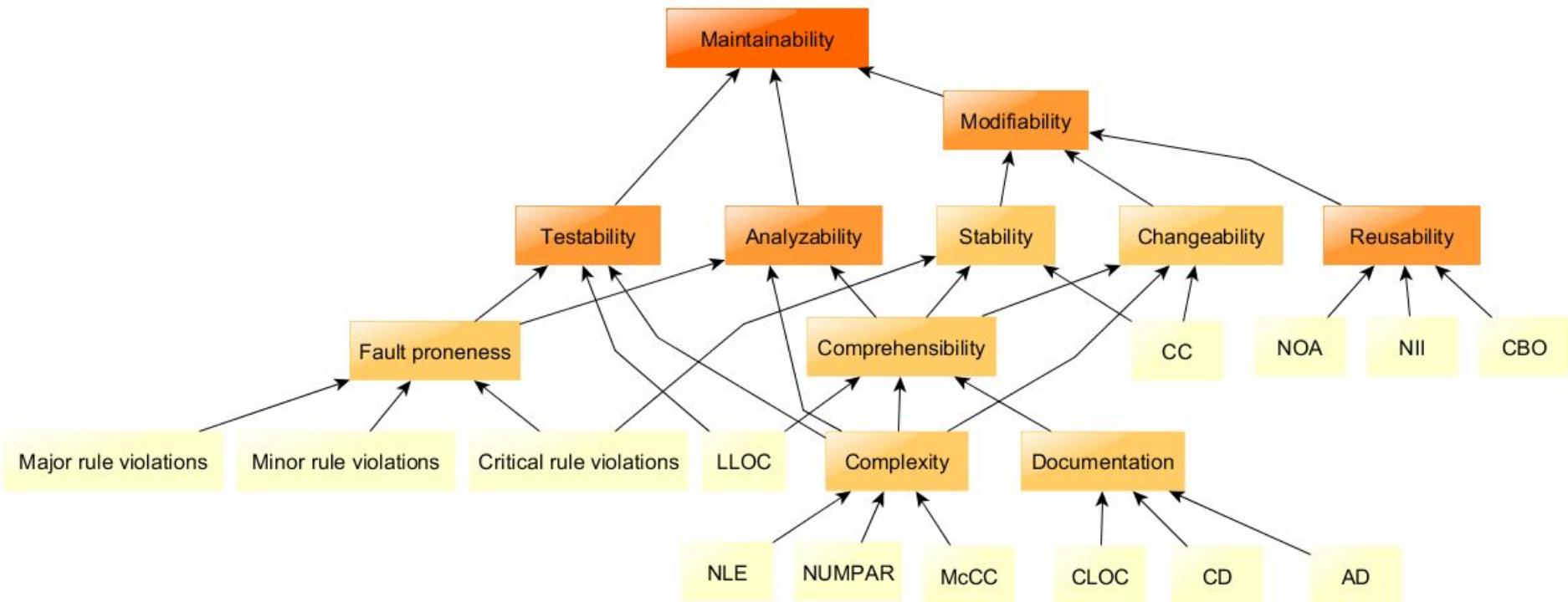
Vincent Hellendoorn



# Where we are

	<i>Small scale:</i> One/few objects	<i>Mid scale:</i> Many objects	<i>Large scale:</i> Subsystems
<i>Design for understanding change/ext. reuse robustness ...</i>	Subtype Polymorphism ✓  Information Hiding, Contracts ✓  Immutability ✓  Types  Unit Testing ✓	Domain Analysis ✓  Inheritance & Del. ✓  Responsibility Assignment, Design Patterns, Antipattern ✓  Promises/ Reactive P. ✓  Integration Testing ✓	GUI vs Core ✓  Frameworks and Libraries ✓ , APIs ✓  Module systems, microservices  <b>Designing for business</b>  CI ✓ , DevOps, Teams

# Excerpt of The ISO/EIC 9216 SQA Standard



[https://en.wikipedia.org/wiki/ISO/IEC\\_9126#Developments](https://en.wikipedia.org/wiki/ISO/IEC_9126#Developments)

# What Do We Test?



```
void buttonClicked() {  
    render(getFriends());  
}  
  
List<Friend> getFriends() {  
    Connection c = http.getConnection();  
    FacebookAPI api = new FacebookAPI(c);  
    return api.getFriends("john");  
}
```

A large rectangular callout box surrounds the central "Code" section. It contains the Java code for an "buttonClicked" method. The code uses the "http" class to get a connection, creates a "FacebookAPI" object, and then calls its "getFriends" method, passing the string "john" as an argument.

# Test Doubles

- Stand in for a real object under test
- Elements on which the unit testing depends (i.e. collaborators), but need to be approximated because they are
  - Unavailable
  - Expensive
  - Opaque
  - Non-deterministic
- Not just for distributed systems!



<http://www.kickvick.com/celebrities-stunt-doubles>

# Fault injection



```
class FacebookErrorStub implements FacebookAPI {  
    void connect() {}  
    int counter = 0;  
    List<Node> getFriends(String name) {  
        counter++;  
        if (counter % 3 == 0)  
            throw new SocketException("Network is unreachable");  
        else if (name.equals("john")) {  
            return List.of(...);  
        } //
```

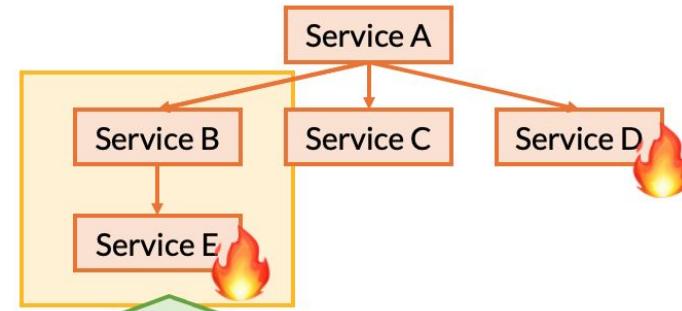
# Chaos Engineering

Experimenting on a distributed system in order to build confidence in the system's capability to withstand turbulent conditions in production



# Considerations in HW6

- What should the framework do when a plugin fails?
  - Recall this figure? Think of framework as Service A, plugin as B, and the API that B depends on ass as E



**Service encapsulation** hides failure Service E behind Service B such that it is not observable by Service A.  
(execution either the same as Service B, C success and D failure combo or Service C success and B and D failure combo, depending on B.)

# Principles of Software Construction: Objects, Design, and Concurrency

## A Tour of the 23 GoF Design Patterns

Claire Le Goues

Vincent Hellendoorn



# Principles of Software Construction: Objects, Design, and Concurrency

## A Quick Tour of all 23 GoF Design Patterns

Claire Le Goues

**Bogdan Vasilescu**



# Where we are

	<i>Small scale:</i> One/few objects	<i>Mid scale:</i> Many objects	<i>Large scale:</i> Subsystems
<i>Design for understanding change/ext. reuse robustness ...</i>	Subtype Polymorphism ✓  Information Hiding, Contracts ✓  Immutability ✓  Types  Unit Testing ✓	Domain Analysis ✓  Inheritance & Del. ✓  Responsibility Assignment, <b>Design Patterns</b> , Antipattern ✓  Promises/ Reactive P. ✓  Integration Testing ✓	GUI vs Core ✓  Frameworks and Libraries ✓ , APIs ✓  Module systems, microservices ✓  Testing for Robustness ✓  CI ✓ , DevOps, Teams

# Course so far...

## Creational:

- |                          |                     |
|--------------------------|---------------------|
| 1. Abstract factory      | 9. <b>Decorator</b> |
| 2. Builder               | 10. Façade          |
| 3. <b>Factory method</b> | 11. Flyweight       |
| 4. Prototype             | 12. <b>Proxy</b>    |
| 5. Singleton             |                     |

## Structural:

- |                     |  |
|---------------------|--|
| 6. <b>Adapter</b>   |  |
| 7. Bridge           |  |
| 8. <b>Composite</b> |  |

## Behavioral:

- |                             |                            |
|-----------------------------|----------------------------|
| 13. Chain of Responsibility | 20. State                  |
| 14. Command                 | 21. <b>Strategy</b>        |
| 15. Interpreter             | 22. <b>Template method</b> |
|                             | 23. Visitor                |

## Not in the book:

- Model view controller
- Promise
- Module (JS)

- 16. **Iterator**
- 17. Mediator
- 18. Memento
- 19. **Observer**

# Warm Up Scenario

You are developing a mobile application for cities where users can report potholes and similar problems (with photos) and city crews can investigate, prioritize, and address reports.

Design problem 1: You want to create monthly reports. However, different cities want this report slightly differently, with different text on top and sorted in different ways. You want to vary text and sorting in different ways.

# Singleton Illustration

```
public class Elvis {  
    private static final Elvis ELVIS = new Elvis();  
    public static Elvis getInstance() { return ELVIS; }  
    private Elvis() { }  
    ...  
}
```

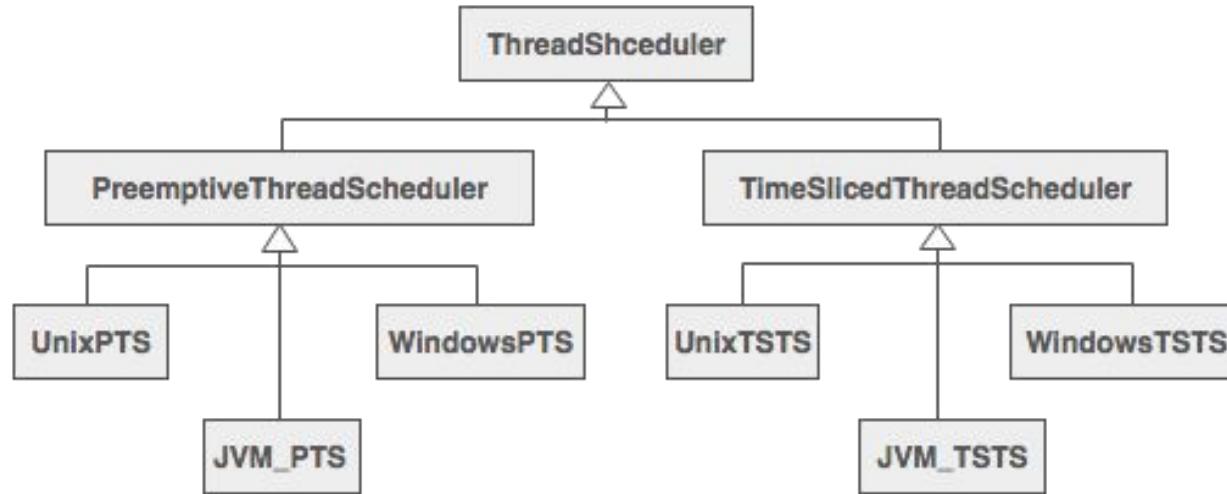
```
const elvis = { ... }  
function getElvis() {  
  
export { getElvis }
```

# Decorator vs Strategy?

```
interface GameLogic {  
    isValidMove(w, x, y)  
    move(w, x, y)  
}  
  
class BasicGameLogic  
    implements GameLogic { ... }  
  
class AbstractGodCardDecorator  
    implements GameLogic { ... }  
  
class PanDecorator  
    extends AbstractGodCardDecorator  
    implements GameLogic { ... }
```

```
interface GameLogic {  
    isValidMove(w, x, y)  
    move(w, x, y)  
}  
  
class BasicGameLogic  
    implements GameLogic {  
    constructor(board) { ... }  
    isValidMove(w, x, y) { ... }  
    move(w, x, y) { ... }  
}  
  
class PanDecorator  
    extends BasicGameLogic {  
    move(w, x, y} { /* super.move(w,  
x, y) + checkWinner */ }  
}
```

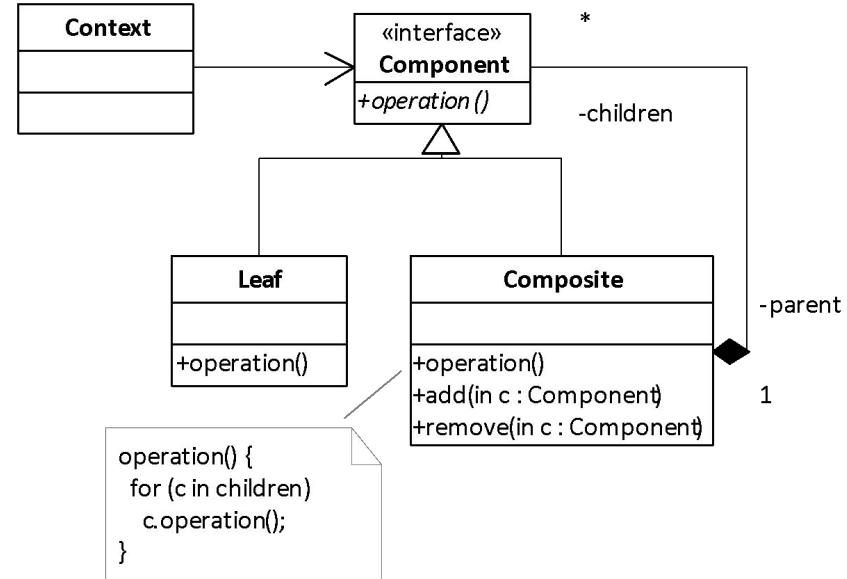
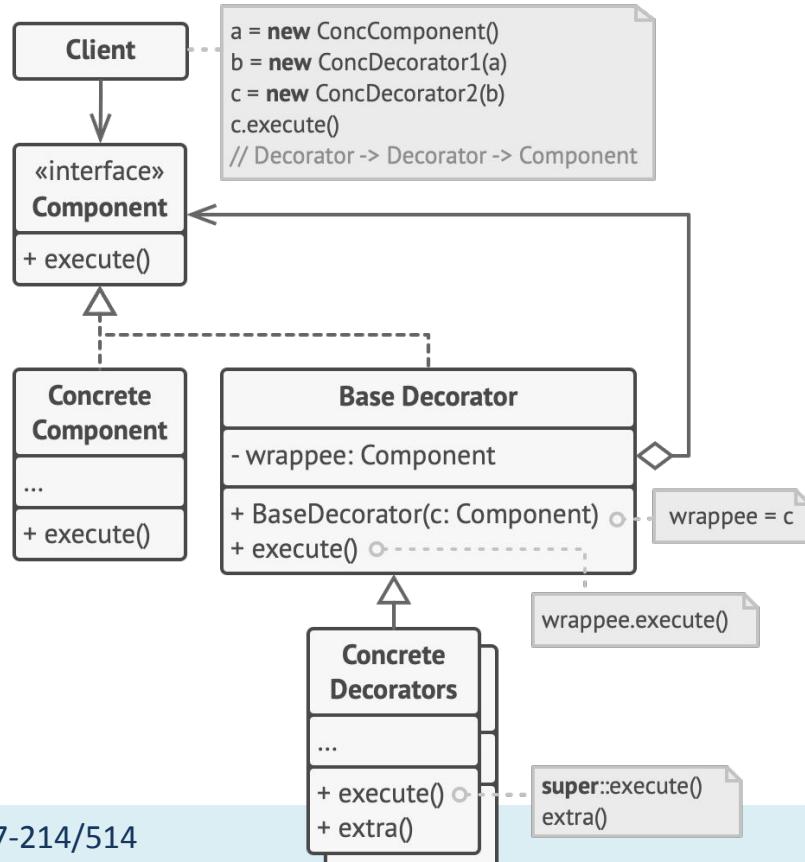
(New) Problem: we have to define a class for each permutation of these two dimensions



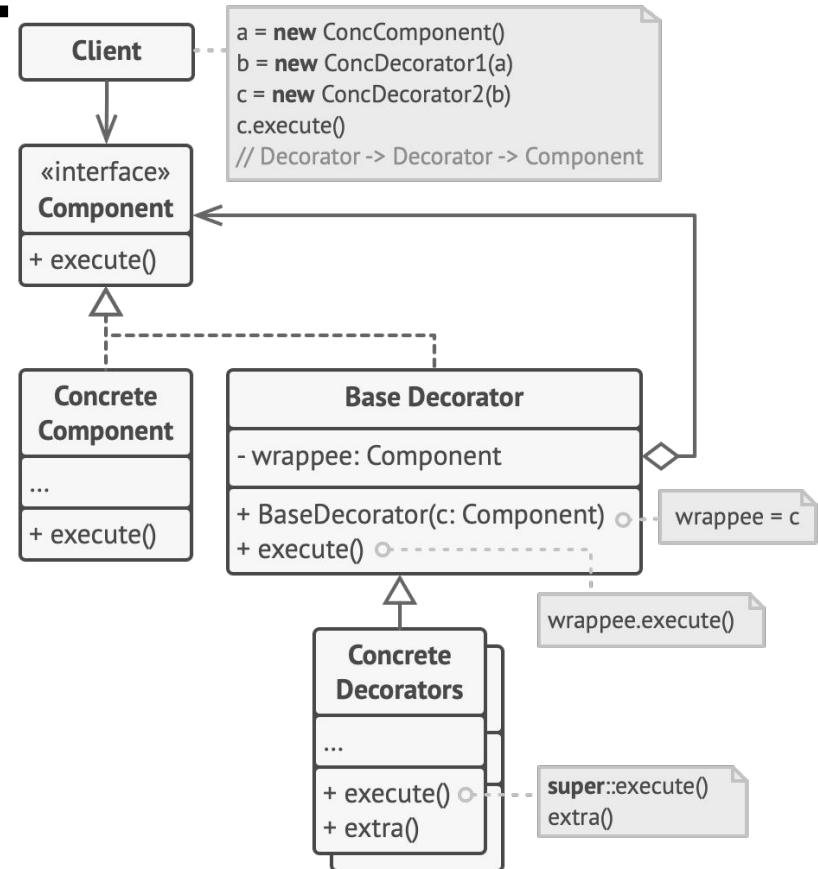
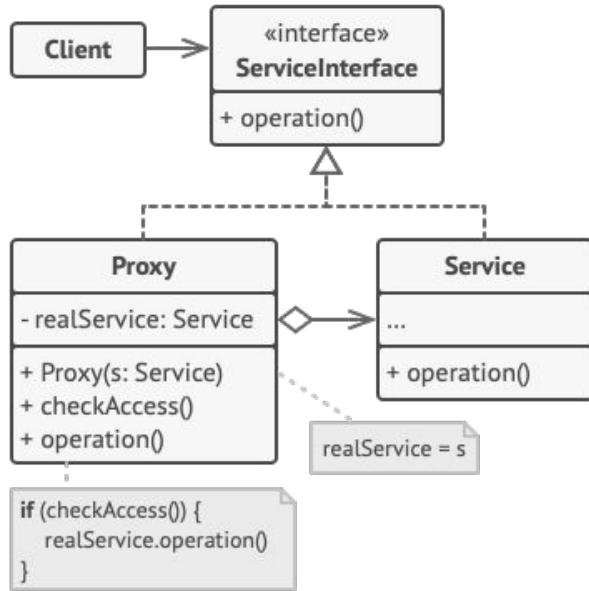
How would you redesign this?

image source: <https://sourcemaking.com>

# Decorator vs Composite?



# Proxy vs Decorator?



# Principles of Software Construction: Objects, Design, and Concurrency

## Git Workflows in Practice

Claire Le Goues

Vincent Hellendoorn



# Agree/Disagree

Total tangent, interested in  
your opinions!



Mario Fusco @mariofusco

...

Unpopular opinion: this book is almost 30 years old and in all honesty didn't age very well. If you own a copy do yourself a favor: bury it deeply in your bookshelf and forget about it forever.

The image shows the front cover of the book "Design Patterns: Elements of Reusable Object-Oriented Software". The title is at the top in large blue serif font. Below it is the subtitle "Elements of Reusable Object-Oriented Software". The authors' names are listed below the subtitle. The background features a stylized profile of a person's head in blue and white. At the bottom is a black and white abstract graphic of interlocking shapes. A small note at the bottom right says "Cover art © 1994 M.C. Escher / Cordon Art - Baarn - Holland. All rights reserved." To the right of the book cover is a vertical blue sidebar with the text "ADDISON-WESLEY PROFESSIONAL COMPUTING SERIES" and a small arrow pointing left.

Design Patterns

Elements of Reusable Object-Oriented Software

Erich Gamma  
Richard Helm  
Ralph Johnson  
John Vlissides

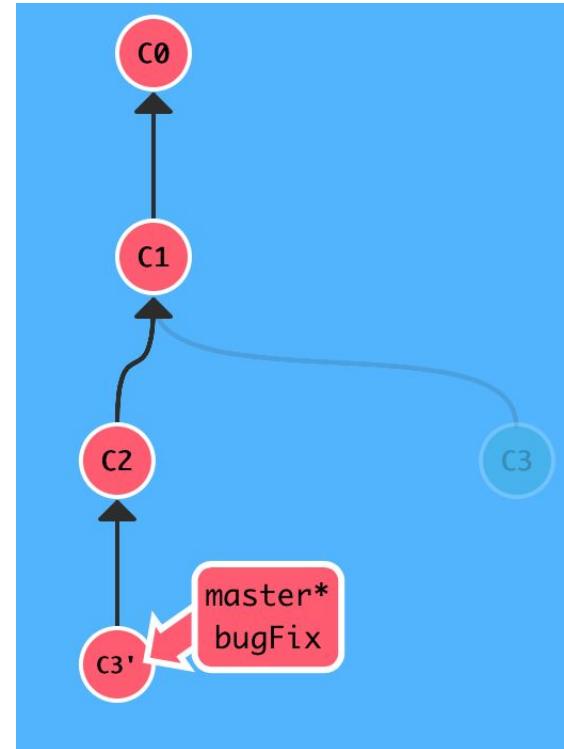
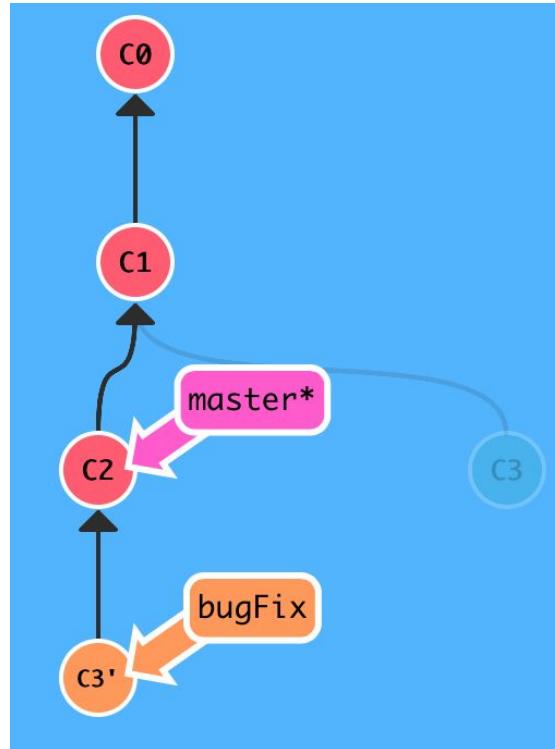
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Foreword by Grady Booch

ADDISON-WESLEY PROFESSIONAL COMPUTING SERIES

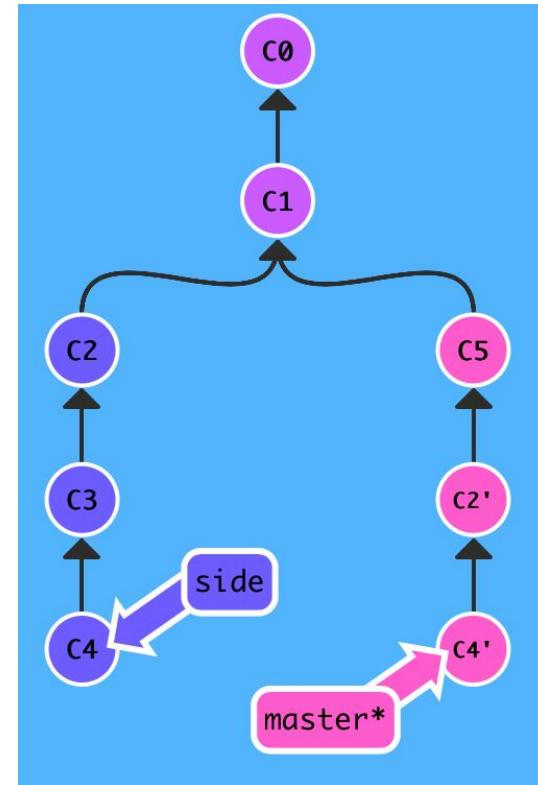
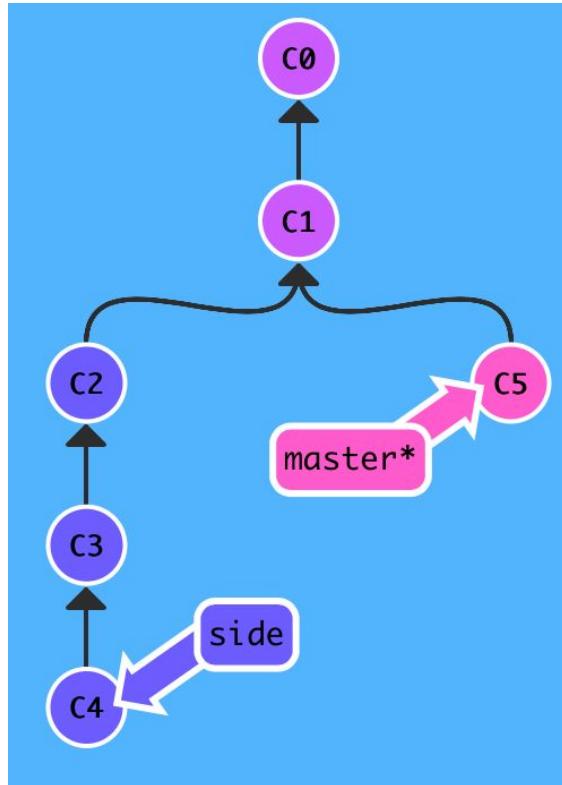
But master hasn't been updated, so:

```
git checkout master; git rebase bugFix
```



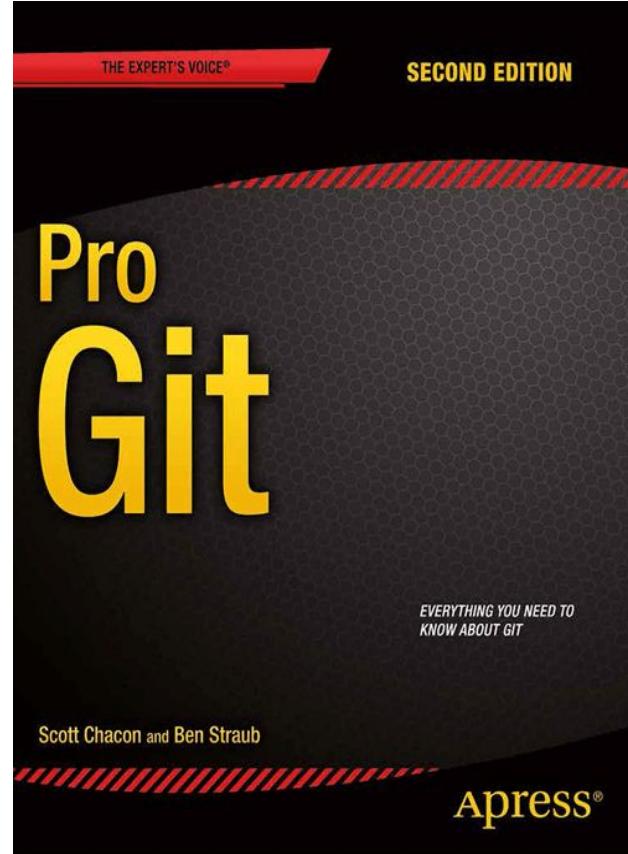
Copy a series of commits below current location

3) git cherry-pick C2 C4



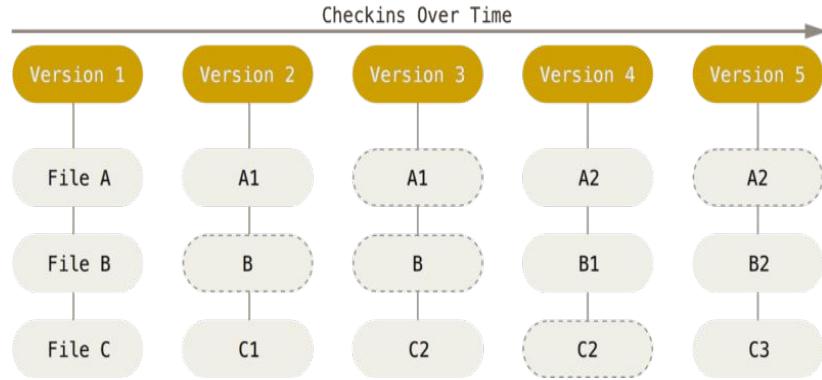
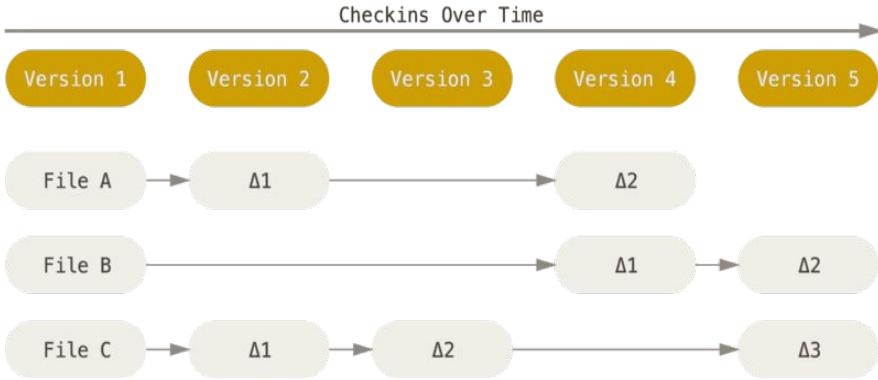
# Highly Recommended

- Courtesy of Prof. Bogdan Vasilescu  
(teaches this course last & next Spring)
- (second) most useful life skill you will have learned in 214/514



<https://git-scm.com/book/en/v2>

# SVN (left) vs. Git (right)



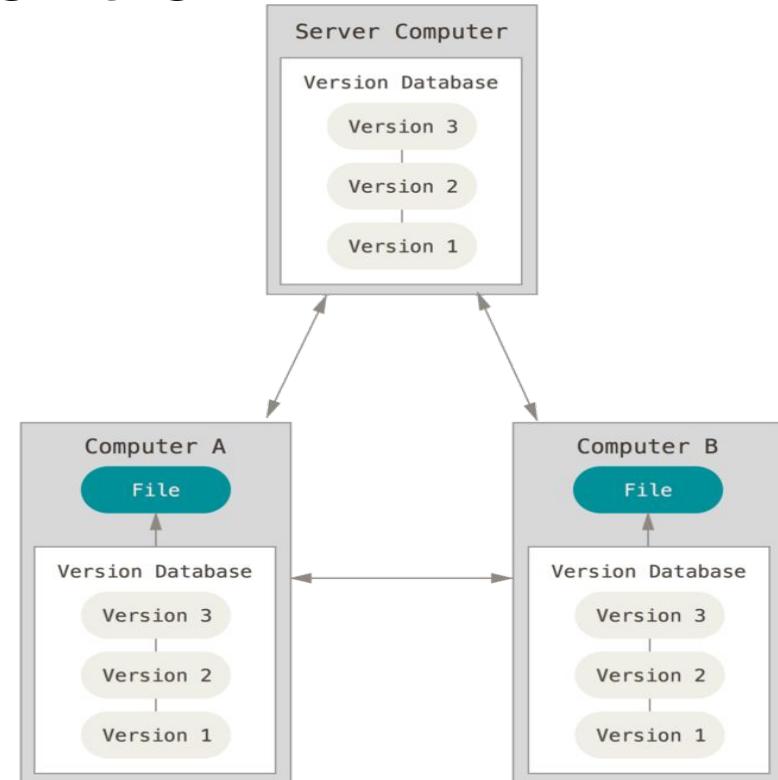
- SVN stores changes to a base version of each file
- Version numbers (1, 2, 3, ...) are increased by one after each commit

- Git stores each version as a snapshot
- If files have not changed, only a link to the previous file is stored
- Each version is referred by the SHA-1 hash of the contents

<https://git-scm.com/book/en/v2/Getting-Started-About-Version-Control>

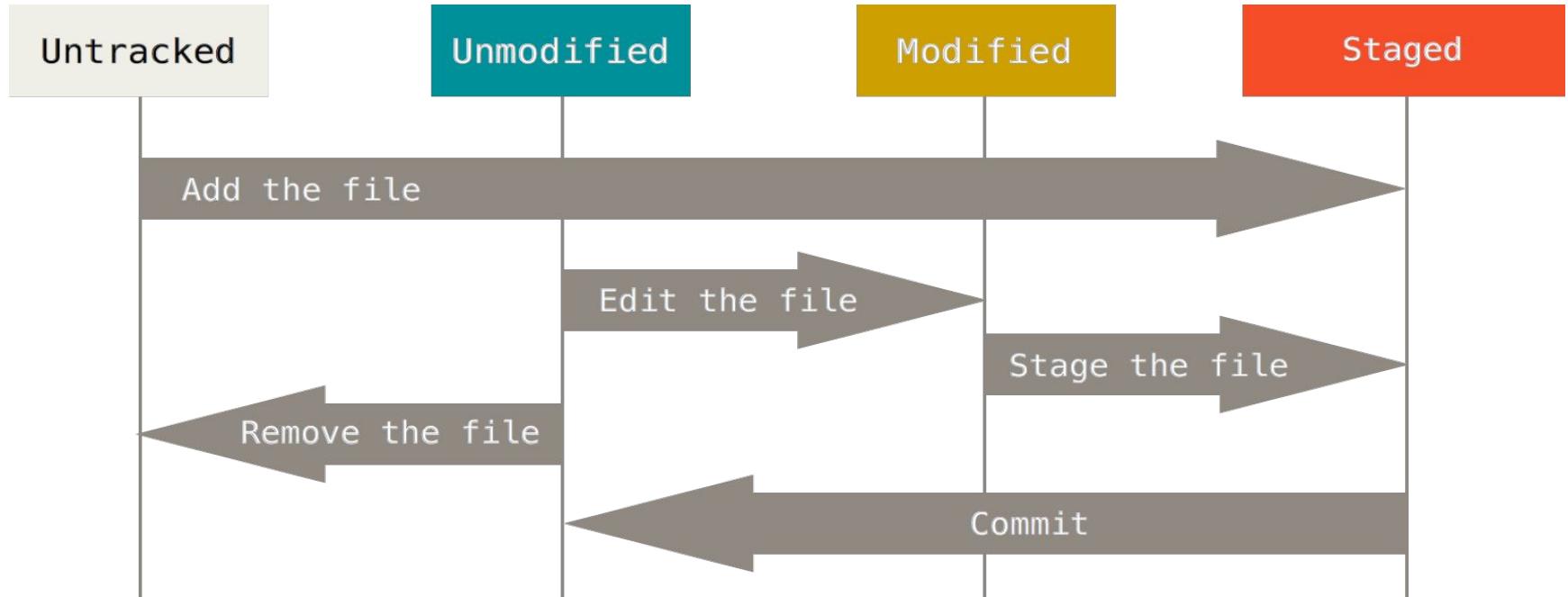
# Distributed version control

- Clients fully mirror the repository
  - Every clone is a full backup of *all* the data
- E.g., Git, Mercurial, Bazaar



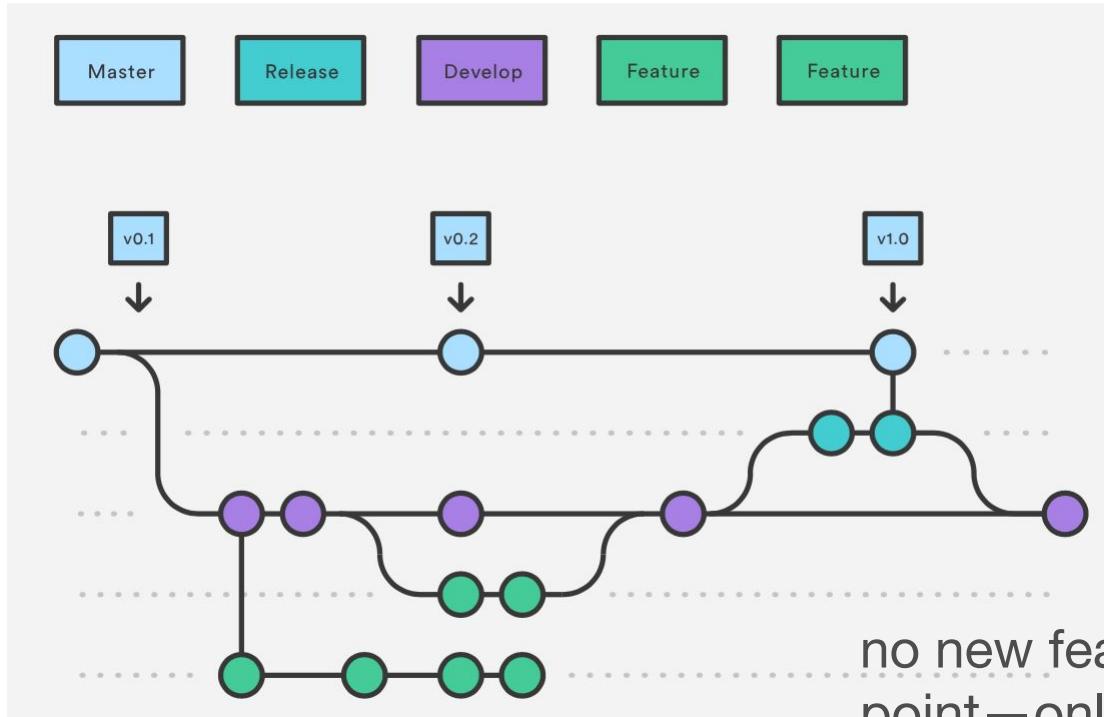
<https://git-scm.com/book/en/v2/Getting-Started-About-Version-Control>

# Aside: Git process



© Scott Chacon "Pro Git"

# GitFlow release branches (eventually into master)



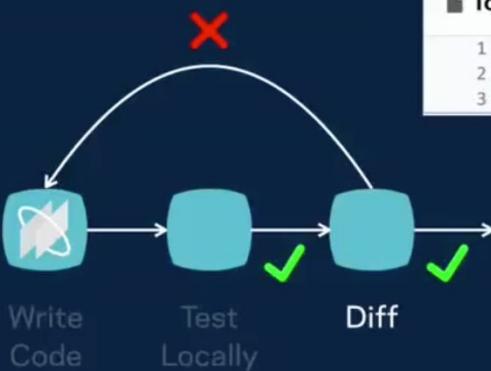
no new features after this point—only bug fixes, docs, and other release tasks

# Semantic Versioning

Given a version number MAJOR.MINOR.PATCH,  
increment the:

1. MAJOR version when you make incompatible API changes,
2. MINOR version when you add functionality in a backwards compatible manner, and
3. PATCH version when you make backwards compatible bug fixes.

# Diff lifecycle: local testing



Tools/xctool/xctool/xctool/Version.m

```
1 #import "Version.h"
2
3 NSString * const XCToolVersionString = @"0.2.1";
```

View Options ▾

```
1 #import "Version.h"
2
3 NSString * const XCToolVersionString = @"0.2.2";
```

PASS ExampleTest (0.050s)

.

OK (1 test, 4 assertions)

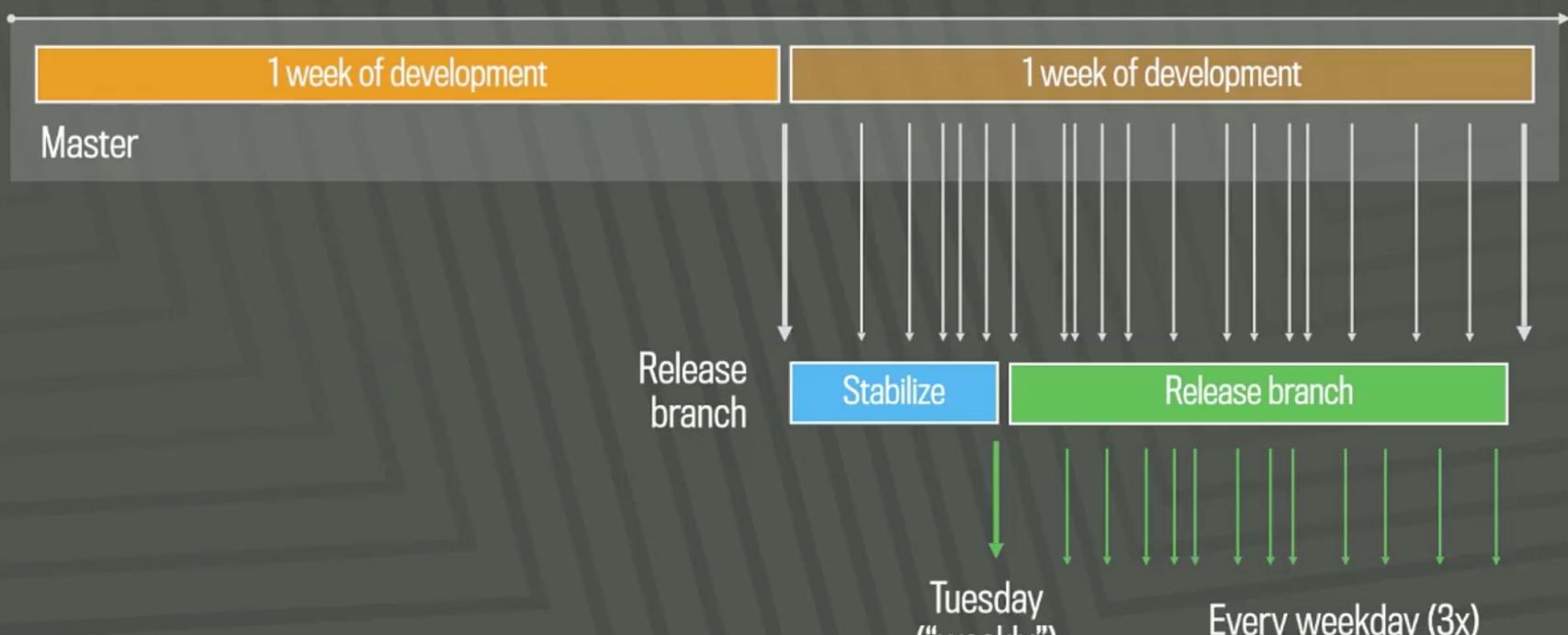
OK

(1 tests, 4 assertions, 0 incomplete, 0 failures)

Test and lint locally

# Release every two weeks

**www.facebook.com**



# You've Probably Seen These

Status

Build Pipeline



Release Pipeline

Dev	Test	Prod
deployment succeeded	deployment succeeded	deployment succeeded
NuGet 0.6.0	NuGet 0.6.0	NuGet 0.4.0

<https://blog.devops4me.com/status-badges-in-azure-devops-pipelines/>

# Google code base vs Linux kernel code base

## Some perspective

### Linux kernel

- 15 million lines of code in 40 thousand files (total)

### Google repository

- 15 million lines of code in 250 thousand files *changed per week, by humans*
- 2 billion lines of code, in 9 million source files (total)

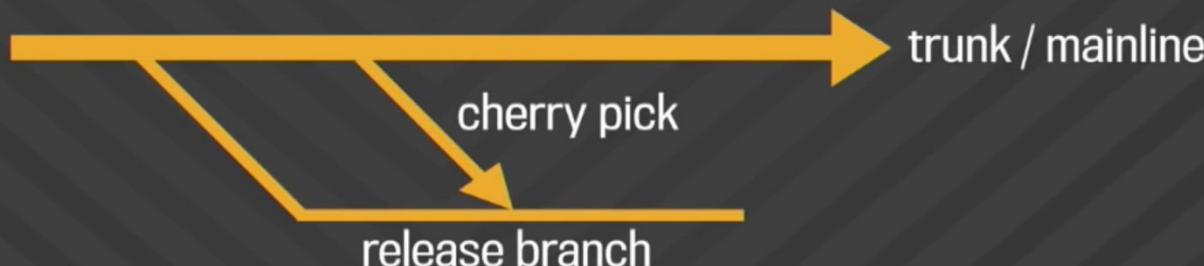
Google Continuous Integration Display

# Monolithic repository – no major use of branches for development

## Trunk-based development

Combined with a centralized repository, this defines the monolithic model

- Piper users work at “head”, a consistent view of the codebase
- All changes are made to the repository in a single, serial ordering
- There is no significant use of branching for development
- Release branches are cut from a specific revision of the repository



# Principles of Software Construction: Objects, Design, and Concurrency

{Static & Dynamic} x {Typing & Analysis}

Claire Le Goues

Vincent Hellendoorn



# How Do You Find Bugs?

- Run it?

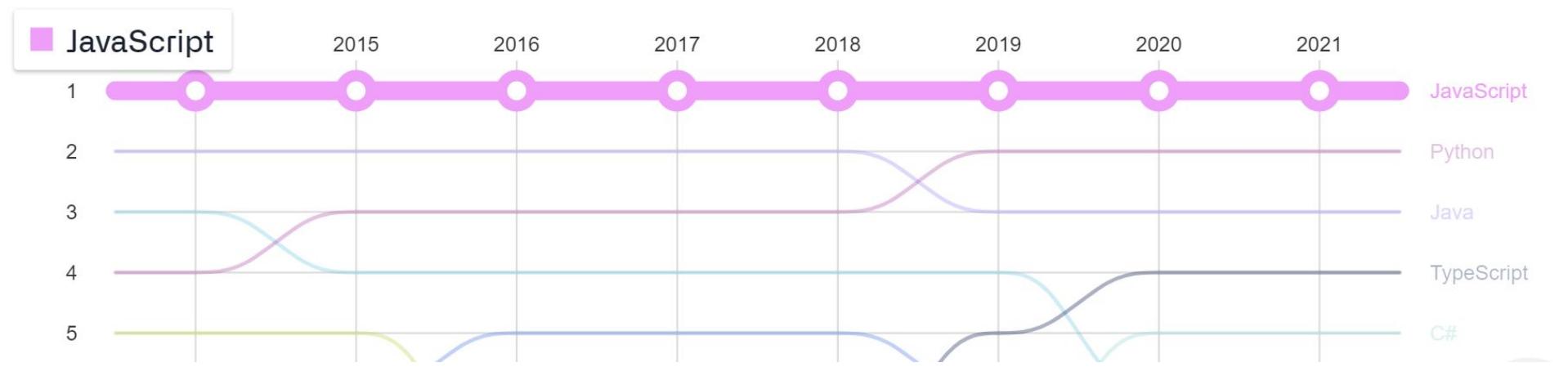
```
public class Fails {  
    public static void main(String[] args) {  
        getValue( i: null);  
    }  
  
    private static int getValue(Integer i) {  
        return i.intValue();  
    }  
}
```

```
Exception in thread "main" java.lang.NullPointerException Create breakpoint : Cannot invoke "java.lang.Integer.intValue()" because "i" is null  
at misc.Fails.getValue(Fails.java:9)  
at misc.Fails.main(Fails.java:5)
```

# Static vs. Dynamic Typing

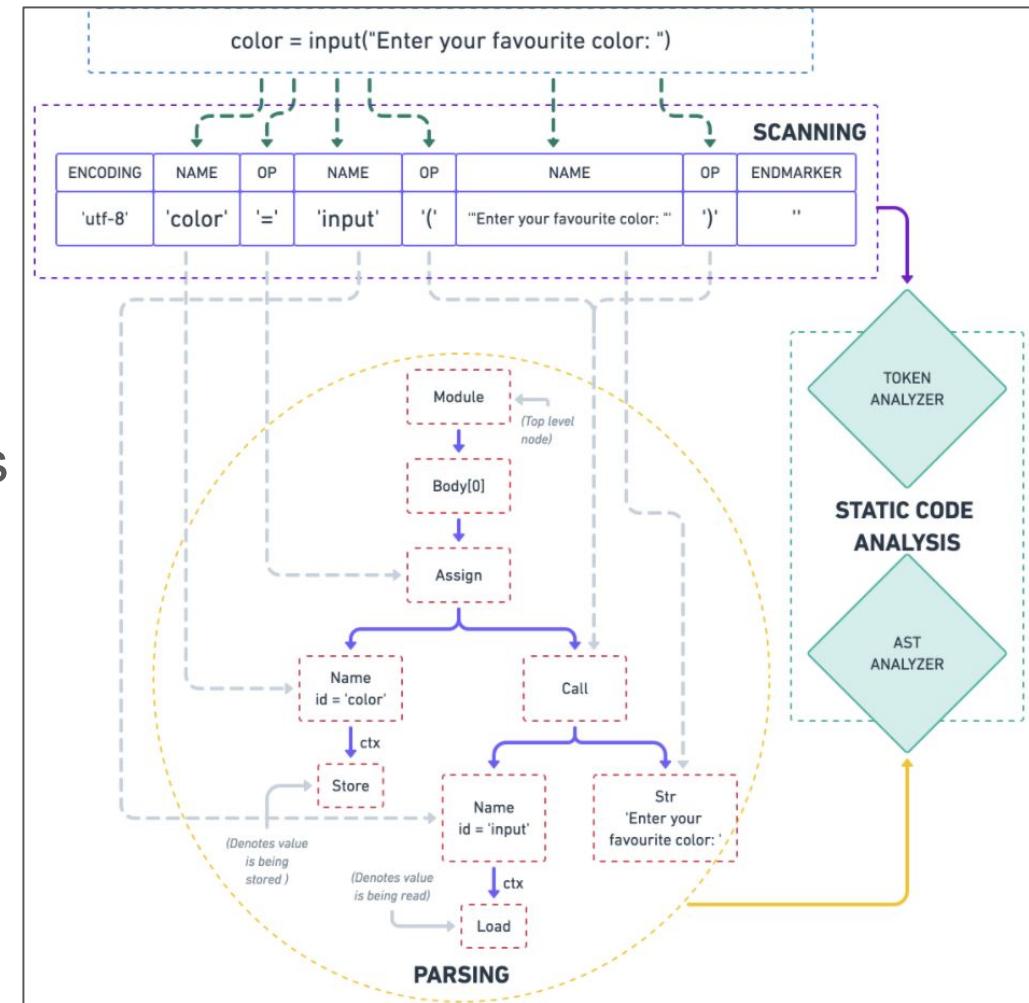
Okay, but:

Top languages over the years



# Static Analysis

- How?
  - Program analysis + Vocabulary of patterns



<https://deepsource.io/blog/introduction-static-code-analysis/>

# Soundness & Precision

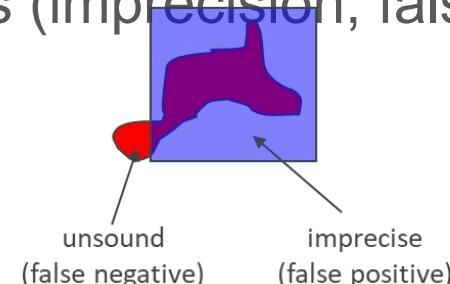
- Since we can't perfectly analyze behavior statically
  - We may miss things by being cautious (unsound; false negative)
  - We might identify non-problems (imprecision, false positive)



Program state covered in actual execution



Program state covered by abstract execution with analysis



# TriCorder

```
package com.google.devtools.staticanalysis;

public class Test {
```

▼ Lint Missing a Javadoc comment.

Java

1:02 AM, Aug 21

[Please fix](#)

[Not useful](#)

```
    public boolean foo() {
        return getString() == "foo".toString();
```

▼ ErrorProne String comparison using reference equality instead of value equality  
(see <http://code.google.com/p/error-prone/wiki/StringEquality>)

StringEquality  
1:03 AM, Aug 21

[Please fix](#)

```
//depot/google3/java/com/google/devtools/staticanalysis/Test.java

package com.google.devtools.staticanalysis;

public class Test {
    public boolean foo() {
        return getString() == "foo".toString();
    }

    public String getString() {
        return new String("foo");
    }
}
```

```
package com.google.devtools.staticanalysis;

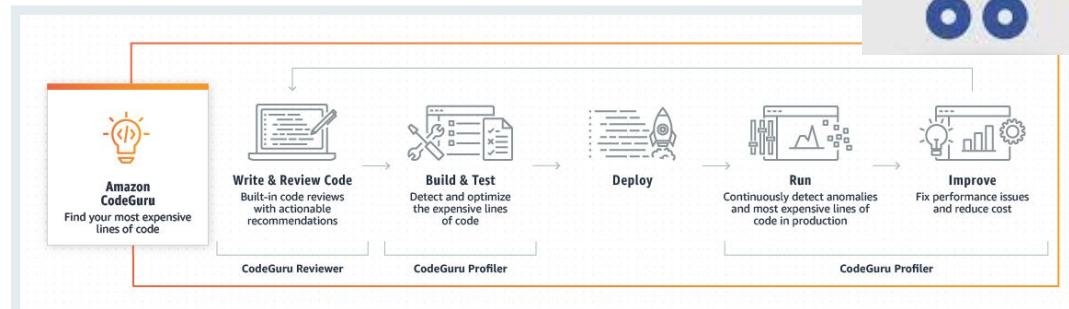
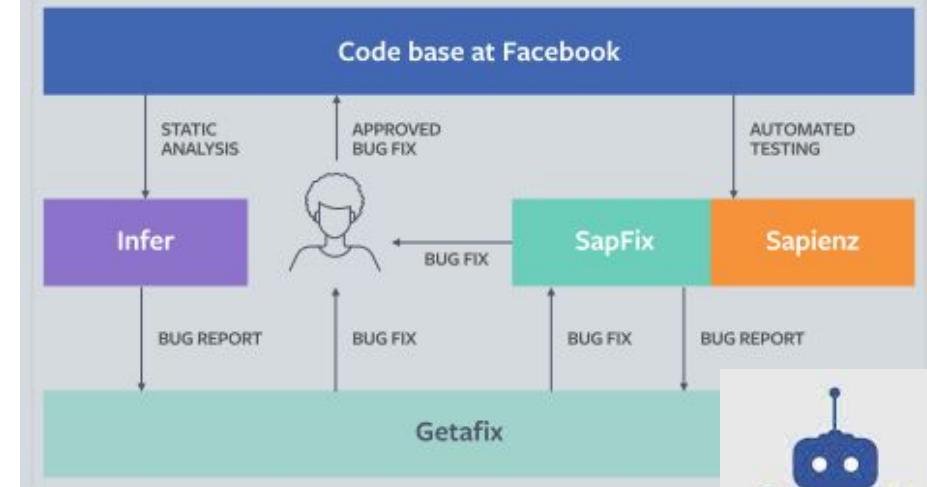
import java.util.Objects;

public class Test {
    public boolean foo() {
        return Objects.equals(getString(), "foo".toString());
    }

    public String getString() {
        return new String("foo");
    }
}
```

# What else could we do?

- Use more complicated logic
  - One example: Infer, at Facebook  
(Google claims this won't (easily) scale to their mono-repo.)
- Use AI?
  - Facebook: Getafix, also integrates with SapFix
  - Amazon: CodeGuru
  - Microsoft: IntelliSense in VSCode, mostly refactoring/code completion, trained on large volumes of code
  - Mostly fairly simple ML (details limited)



# Principles of Software Construction: Objects, Design, and Concurrency

## DevOps

Claire Le Goues

**Vincent Hellendoorn**

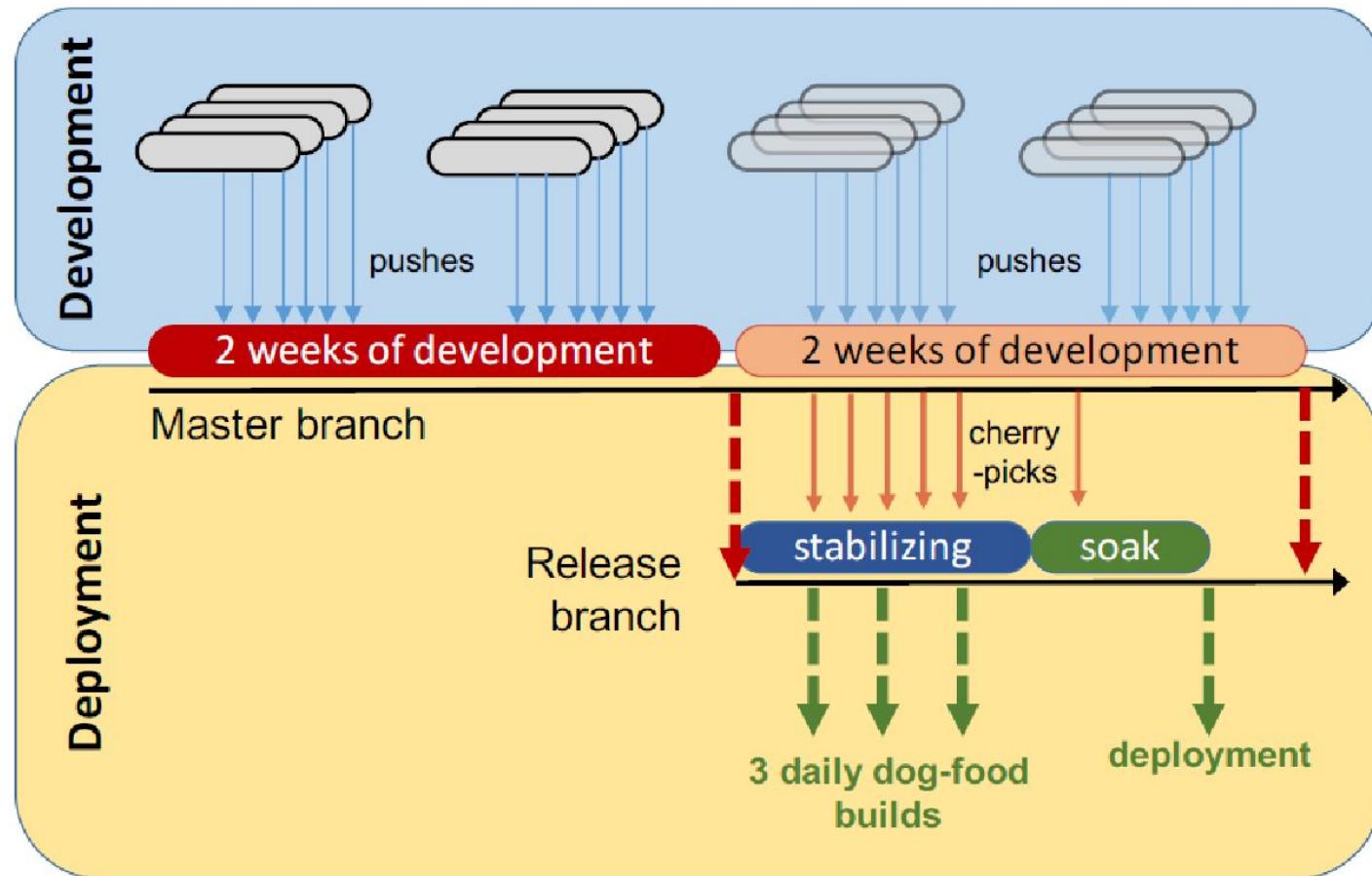


# Where we are

	<i>Small scale:</i> One/few objects	<i>Mid scale:</i> Many objects	<i>Large scale:</i> Subsystems
<i>Design for understanding change/ext. reuse robustness ...</i>	Subtype Polymorphism ✓  Information Hiding, Contracts ✓  Immutability ✓  Types ✓ Static Analysis ✓  Unit Testing ✓	Domain Analysis ✓  Inheritance & Del. ✓  Responsibility Assignment, Design Patterns, Antipattern ✓  Promises/ Reactive P. ✓  Integration Testing ✓	GUI vs Core ✓  Frameworks and Libraries ✓ , APIs ✓  Module systems, microservices ✓  Testing for Robustness ✓  CI ✓ , DevOps, Teams

# So you want to build a cathedral





- [Back to Dashboard](#)
- [Status](#)
- [Changes](#)
- [Workspace](#)
- [Build Now](#)
- [Delete Project](#)
- [Configure](#)
- [Set Next Build Number](#)
- [Duplicate Code](#)
- [Coverage Report](#)
- [SLOCCount](#)
- [Git Polling Log](#)

## Project Stop-tabac dev

CI build

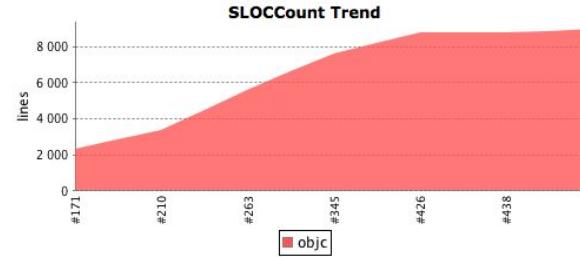
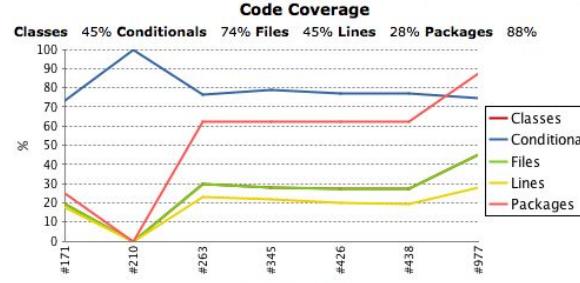
- [!\[\]\(507d652760fa676fdb3e0c63e71b2324\_img.jpg\) Coverage Report](#)
- [!\[\]\(ebd8270efb3991722f7c9469efa58ae0\_img.jpg\) Workspace](#)
- [!\[\]\(3672e1e33fd8a46502e9ccd5b06c659c\_img.jpg\) Recent Changes](#)
- [!\[\]\(2fdddca2d9def3dc11f1f48c149ef2e4\_img.jpg\) Latest Test Result \(no failures\)](#)

Build History <small>(trend)</small>	
	#977 Aug 27, 2012 4:37:27 PM
	#438 Jun 28, 2012 8:47:42 AM
	#426 Jun 26, 2012 1:39:39 PM
	#345 Jun 19, 2012 9:02:20 AM
	#263 Jun 6, 2012 9:14:42 PM
	#210 May 31, 2012 8:42:29 AM
	#171 May 23, 2012 9:58:18 PM
	#90 May 15, 2012 11:49:41 AM

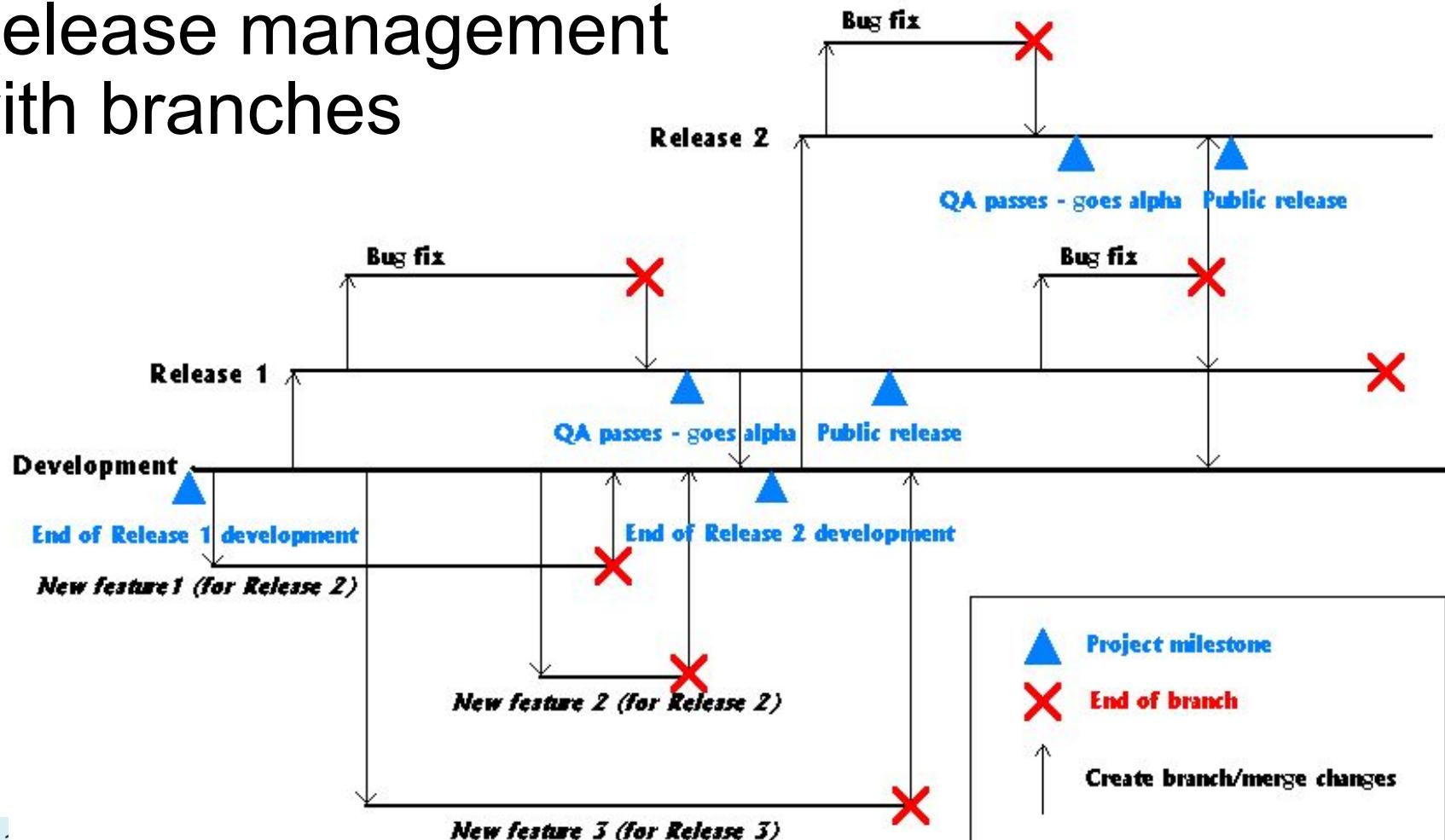
[RSS for all](#) [RSS for failures](#)

### Permalinks

- [Last build \(#977\), 3 min 17 sec ago](#)
- [Last stable build \(#977\), 3 min 17 sec ago](#)
- [Last successful build \(#977\), 3 min 17 sec ago](#)



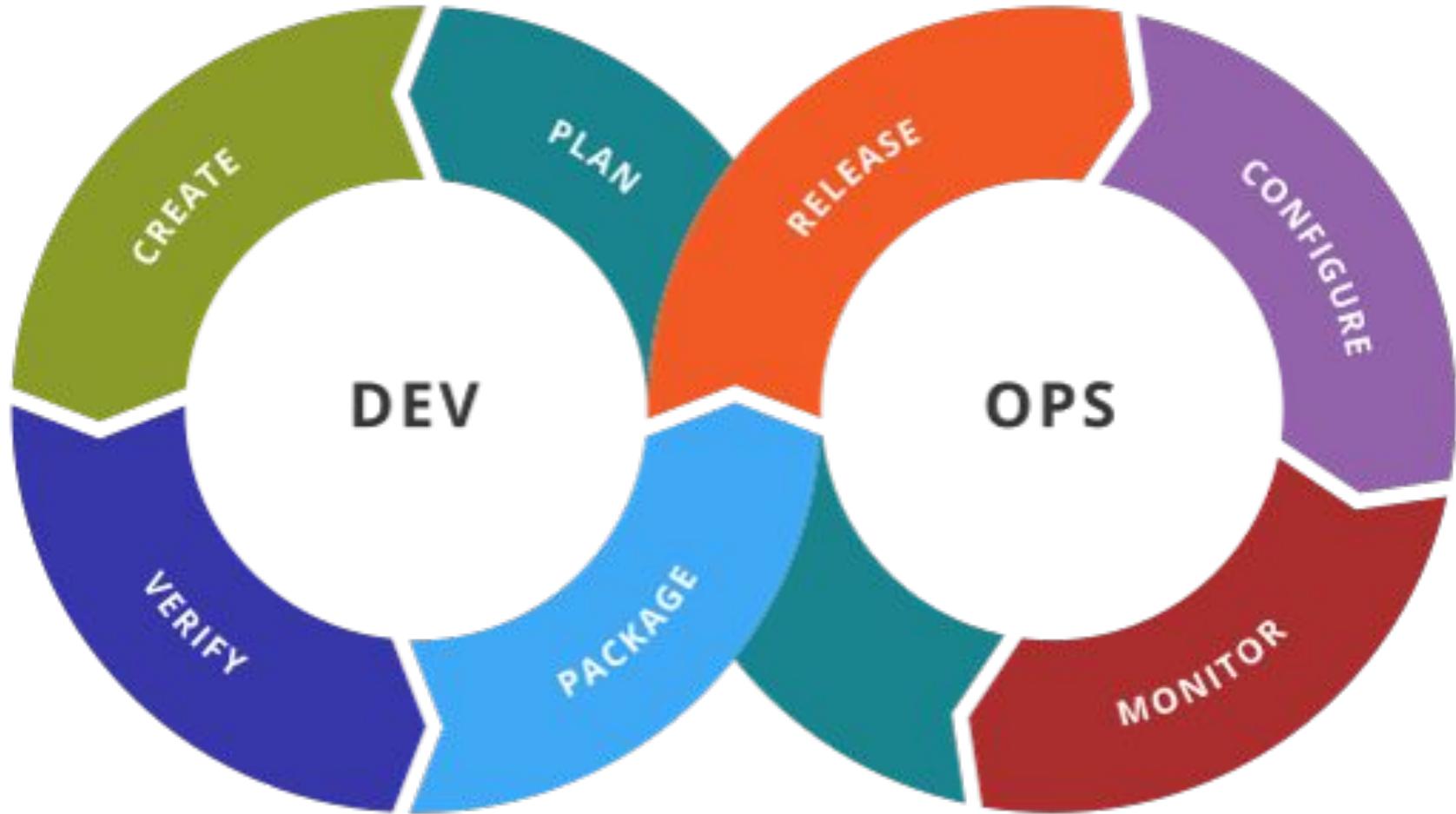
# Release management with branches



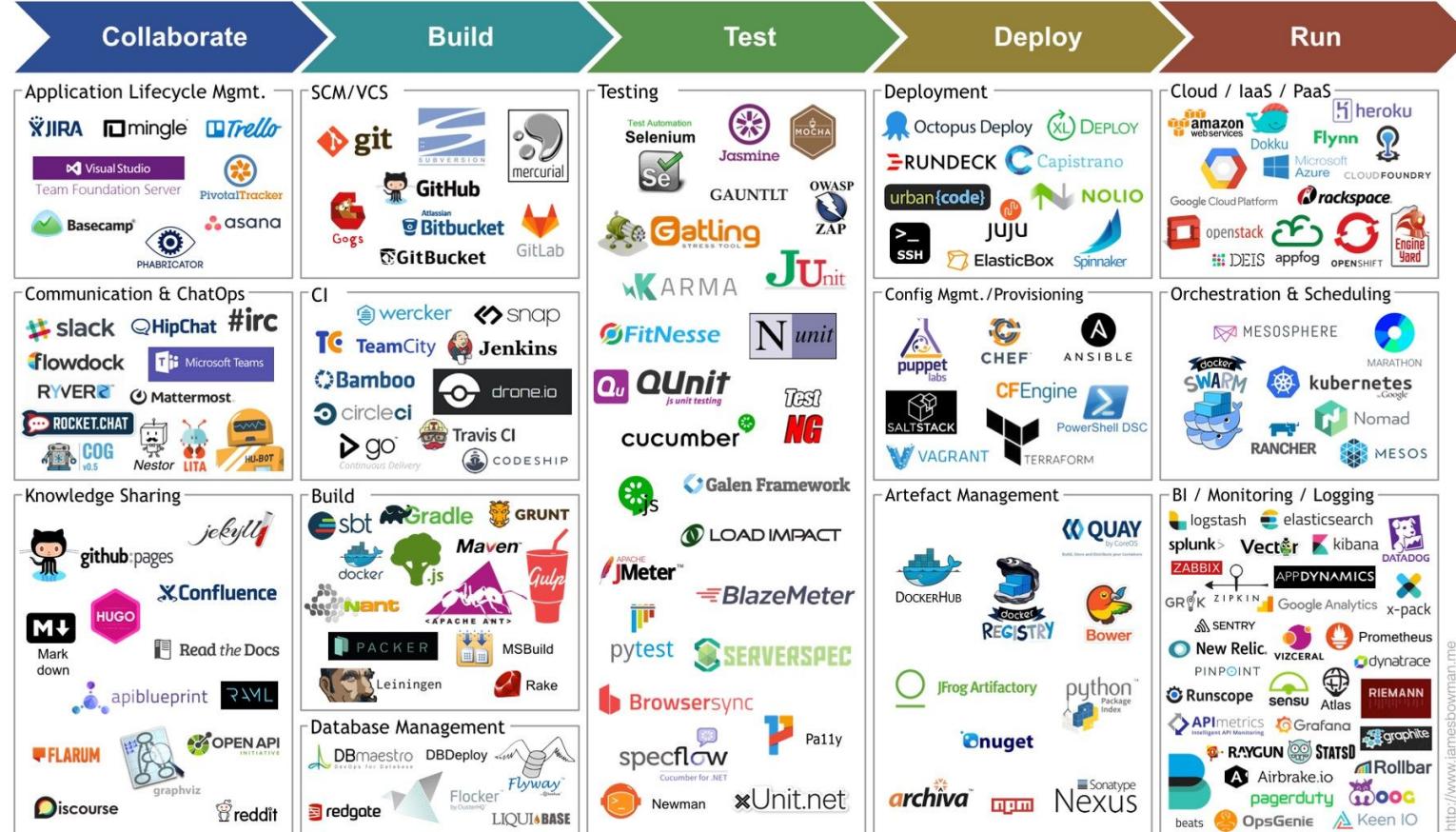
**WORKED FINE IN  
DEV**

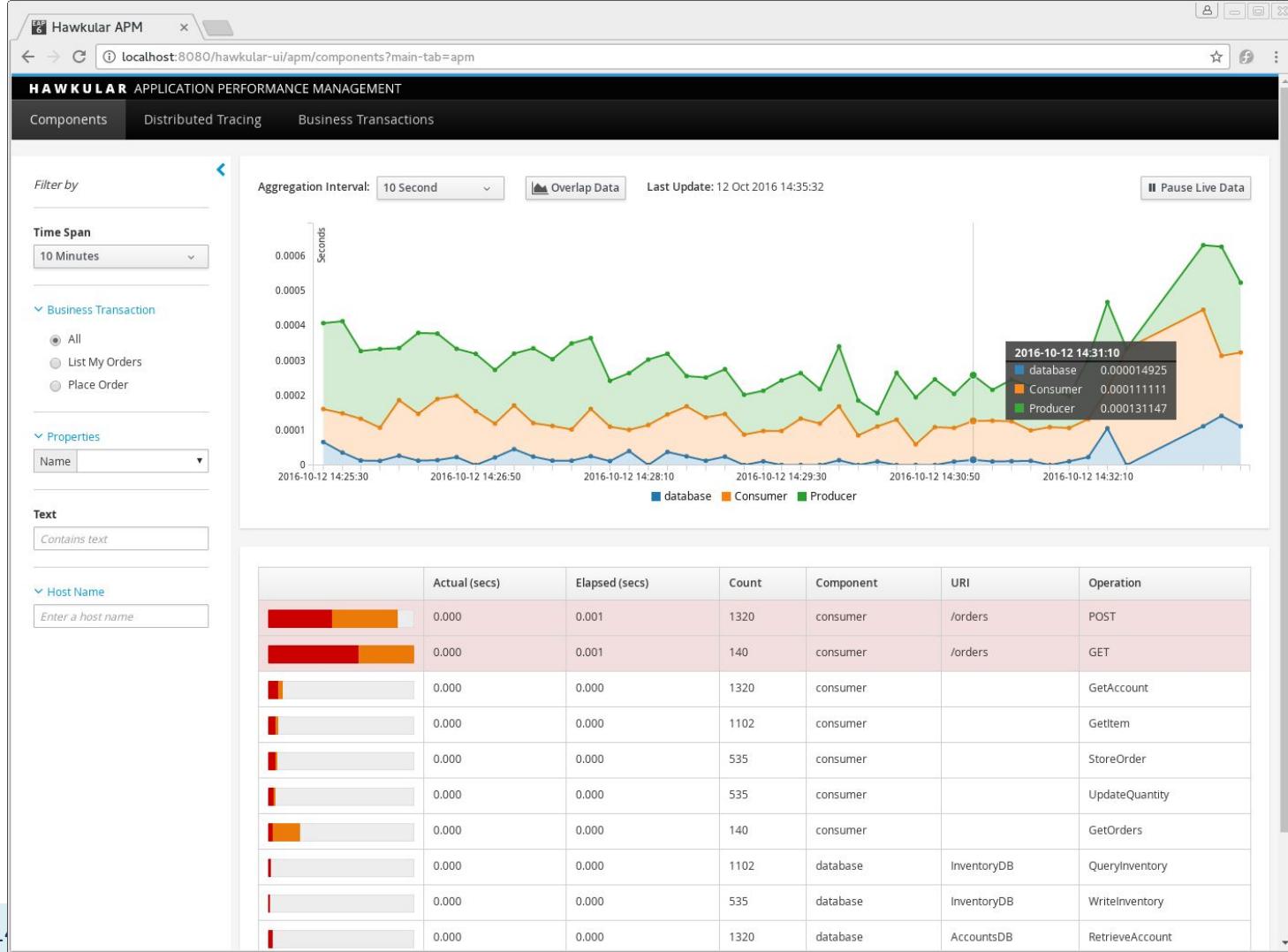
**OPS PROBLEM NOW**

memegenerator.net



# Heavy Tooling and Automation





# A/B Testing

Original: 2.3%



The original landing page for Groove features a large image of a smiling man in a plaid shirt. To his left, the text reads: "SaaS & eCommerce Customer Support." Below this, a quote from "Griffin, Customer Champion at Allocacoo" says: "Managing customer support requests in Groove is so easy. Way better than trying to use Gmail or a more complicated help desk." A testimonial bar at the bottom states: "97% of customers recommend Groove." A green "Learn More" button is located at the bottom right of the main image area.

You'll be up and running in less than a minute.

Long Form: 4.3%



The long-form landing page for Groove includes a larger headline: "Everything you need to deliver awesome, personal support to every customer." Below the headline is a subtext: "Assign support emails to the right people, feel confident that customers are being followed up with and always know what's going on." A video player shows a man speaking, with the caption "ALLAN USES GROOVE TO GROW HIS BUSINESS. HERE'S HOW". To the right, a sidebar lists "WHAT YOU'LL DISCOVER ON THIS PAGE" with five bullet points: "Three reasons pricing teams choose Groove", "How Groove makes your whole team more productive", "Delivering a personal support experience every time", "Take a screencast tour", and "A personal note from our CEO". At the bottom, social media icons for BuySellAds, Hootsuite, and StatusPage.io are displayed.

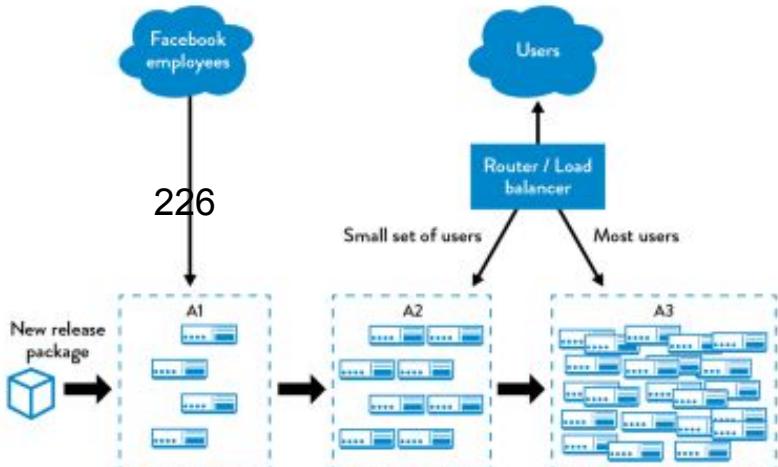
# Canary Releases



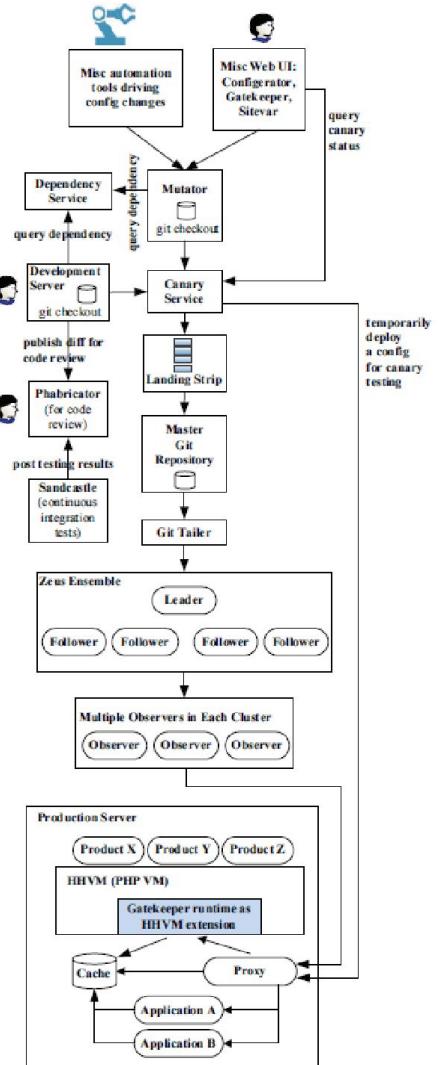
foto Javier Baño

# Real DevOps Pipelines are Complex

- Incremental rollout, reconfiguring routers
- Canary testing
- Automatic rolling back changes



Chunqiang Tang,  
Thawan Kooburat,  
Pradeep  
Venkatachalam, Akshay  
Chander, Zhe Wen,  
Aravind Narayanan,  
Patrick Dowell, and  
Robert Karl. [Holistic Configuration Management at Facebook](#). Proc. of SOSP: 328–343 (2015).



# Principles of Software Construction: Objects, Design, and Concurrency

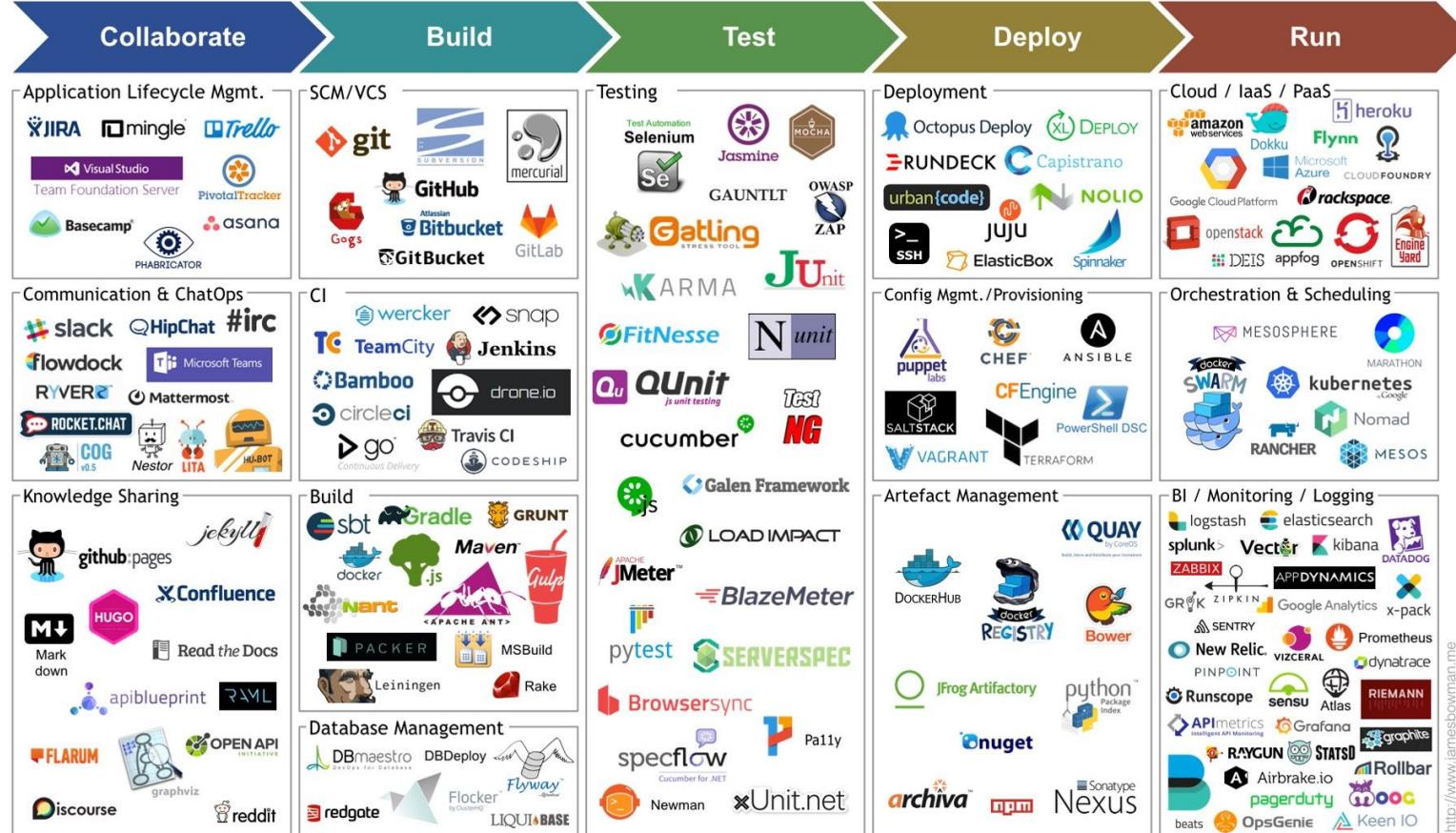
## Containers & Cloud

Claire Le Goues

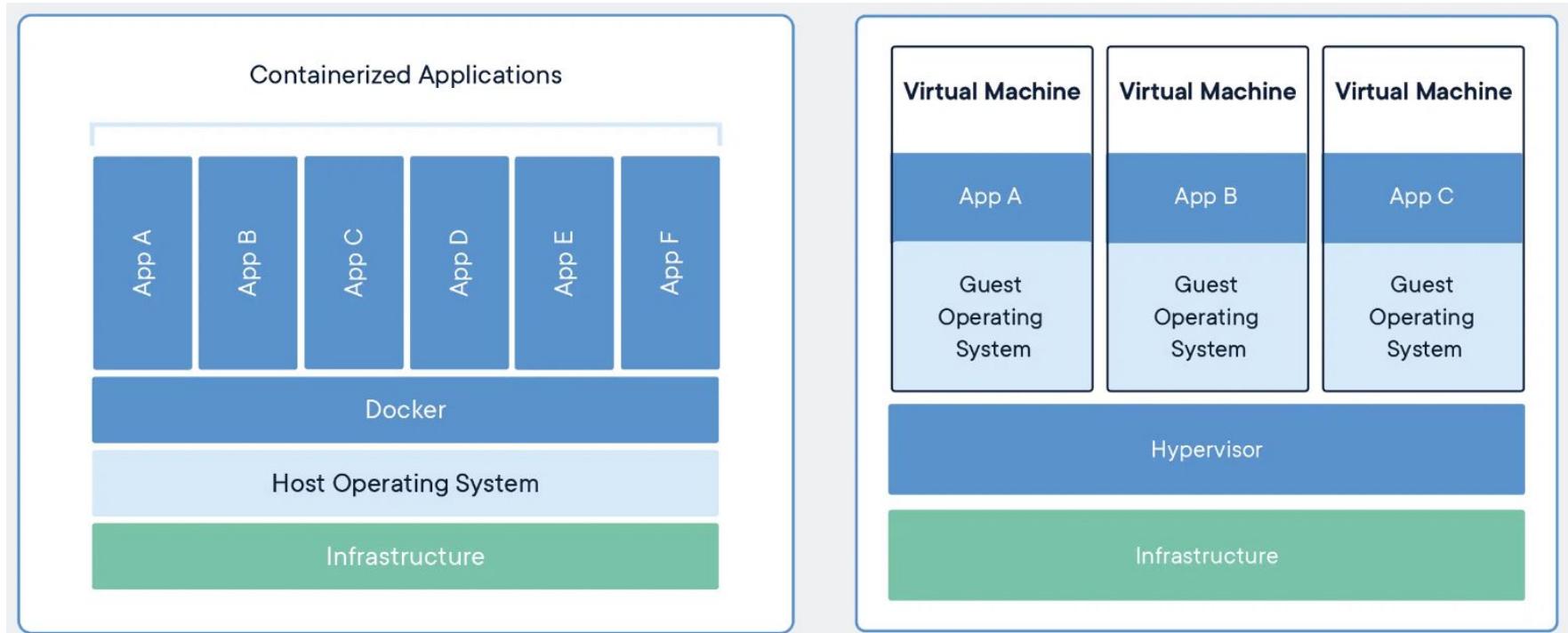
**Vincent Hellendoorn**



# Recall Programming Reality



# Containers offer Virtualization on the OS



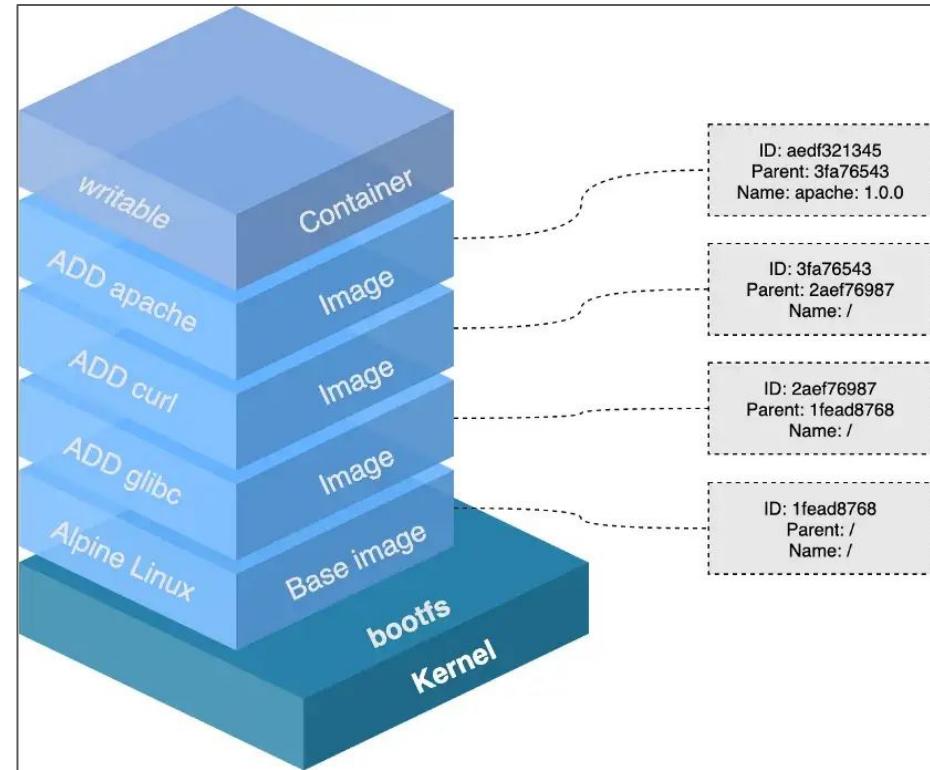
<https://www.docker.com/resources/what-container/>

# Docker images are *layers*

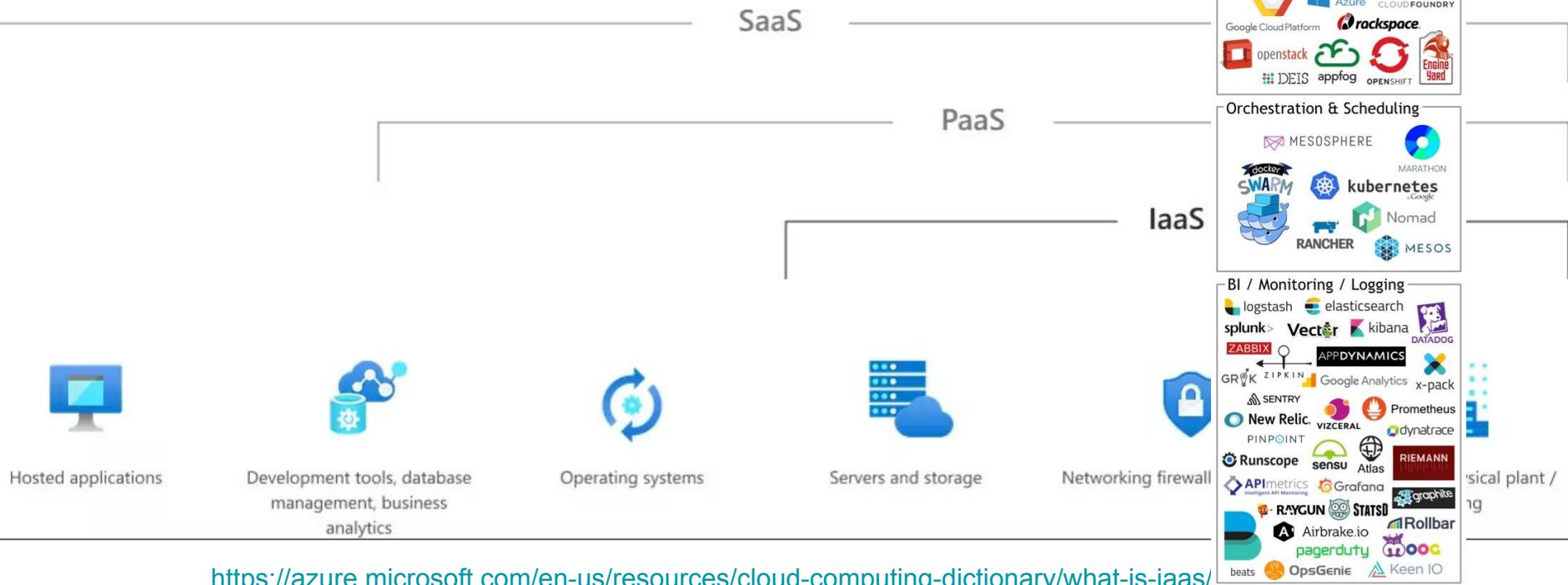
- Each action yields a new layer
- The base layer is typically an OS
  - E.g., “ubuntu:20.04”
- Data from previous layers is “copy-on-write”

Consequences:

- Layer-stacks are easily reused making images very light
- Security via IO permissions

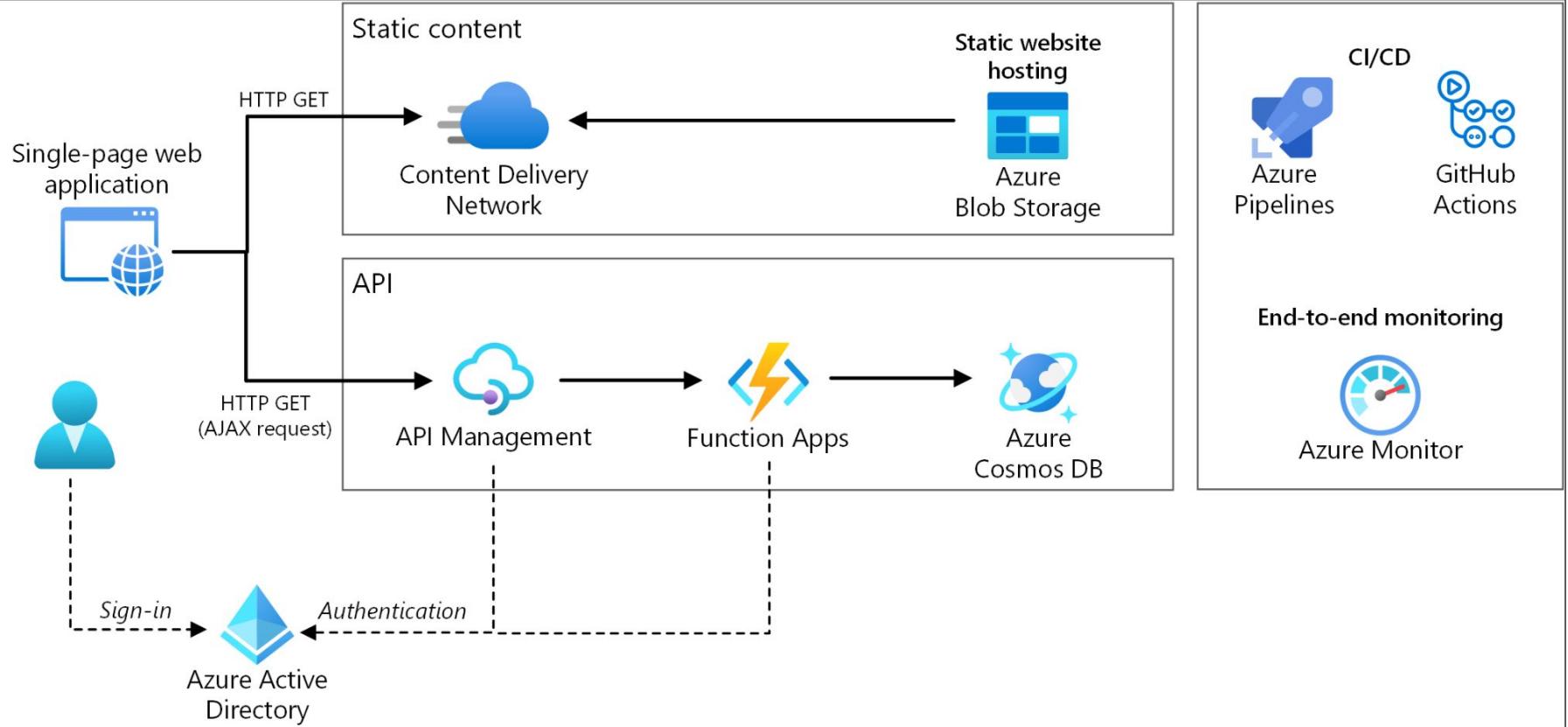


# There's more in the cloud



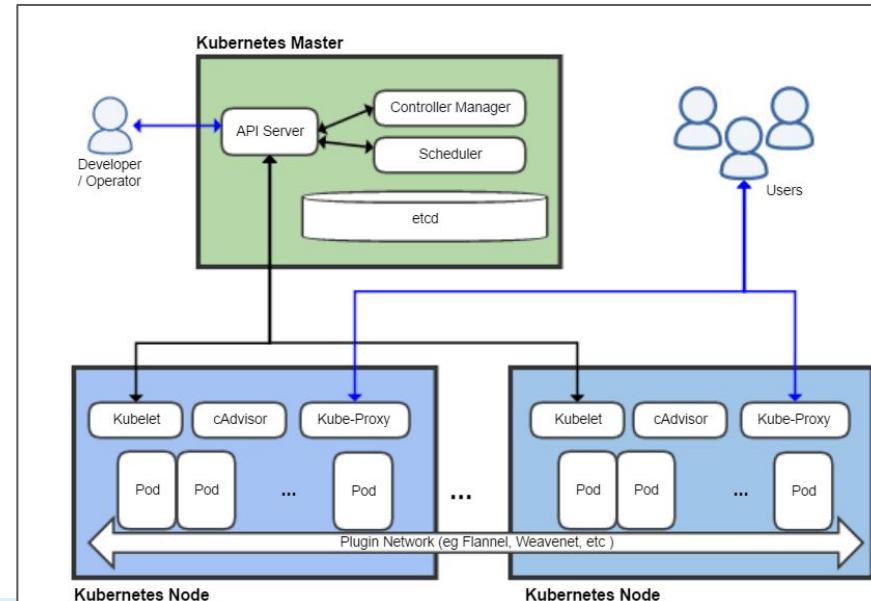
<https://azure.microsoft.com/en-us/resources/cloud-computing-dictionary/what-is-iaas/>

Note: not everyone thinks of these as nested categories



# Managing Systems with Kubernetes

- Note how much this decouples the client from the code
  - In our previous systems, the client talked directly to the frontend
  - Now, to a data center, which talks to a proxy, to a pod, to a container, to code



# Finally, is the Cloud right for you?

- You're borrowing someone else's computer
  - That comes at a big premium
    - Hosting on-prem can be many times cheaper
    - I recall a thread where a Twitter engineer said their AWS bill would be \$100M+/month if they went that way
  - Also fewer guarantees
    - Some VMs are rarely available
    - Allocating large nrs of any kind almost certainly requires discussion
- Still worth it if you:
  - Are a small team, can't spare cycles for system ops
  - Are growing quickly, won't know your computing needs far out

# Looking Forward: Beyond Code-Level Concerns

# Where we are

	<i>Small scale:</i> One/few objects	<i>Mid scale:</i> Many objects	<i>Large scale:</i> Subsystems
<i>Design for understanding change/ext. reuse robustness ...</i>	Subtype Polymorphism ✓  Information Hiding, Contracts ✓  Immutability ✓  Types ✓ Static Analysis ✓  Unit Testing ✓	Domain Analysis ✓  Inheritance & Del. ✓  Responsibility Assignment, Design Patterns, Antipattern ✓  Promises/ Reactive P. ✓  Integration Testing ✓	GUI vs Core ✓  Frameworks and Libraries ✓ , APIs ✓  Module systems, microservices ✓  Testing for Robustness ✓  CI ✓ , DevOps ✓ , <b>Teams</b>

# This Course

We focused on code-level concerns

Writing maintainable, extensible, robust, and correct  
code

Design from classes to subsystems

Testing, concurrency, basic user interfaces

## Toyota Case: Single Bit Flip That Killed

Junko Yoshida

10/25/2013 03:35 PM EDT

During the trial, embedded systems experts who reviewed Toyota's electronic throttle source code testified that they found Toyota's source code defective, and that it contains bugs -- including bugs that can cause unintended acceleration.

"We did a few things that NASA apparently did not have time to do," Barr said. For one thing, by looking within the real-time operating system, the experts identified "unprotected critical variables." They obtained and reviewed the source code for the "sub-CPU," and they uncovered gaps and defects in the throttle fail safes."

The experts demonstrated that "the defects we found were linked to unintended acceleration through vehicle testing," Barr said. "We also obtained and reviewed the source code for the black box and found that it can record false information about the driver's actions in the final seconds before a crash."

Stack overflow and software bugs led to memory corruption, he said. And it turns out that the crux of the issue was these memory corruptions, which acted "like ricocheting bullets."

Barr also said more than half the dozens of tasks' deaths studied by the experts in their experiments "were not detected by any fail safe."

© Copyright 2014, Philip Koopman. CC Attribution 4.0 International license.

## Bookout Trial Reporting

[http://www.eetimes.com/document.asp?doc\\_id=1319903&page\\_number=1](http://www.eetimes.com/document.asp?doc_id=1319903&page_number=1)  
(excerpts)

"Task X death  
in combination  
with other task  
deaths"

003 / 45 / 7844



ISAT GeoStar 45  
23:15 EST 14 Aug. 2003

# Healthcare.gov: Government IT Project Failure at its Finest

Posted: 10/18/2013 6:33 pm



Read more > [Project Management](#), [Government](#), [Healthcare](#), [IT Projects](#), [Open Source](#), [Business News](#)

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The *BusinessWeek* article on the Healthcare.gov failure is nothing if not instructive. From the piece:

Healthcare.gov isn't just a website; it's more like a platform for building health-care marketplaces. Visiting the site is like visiting a restaurant. You sit in the dining room, read the menu, and tell the waiter what you want, and off he goes to the kitchen with your order. The dining room is the front end, with all the buttons to click and forms to fill out. The kitchen is the back end, with all the databases and services. The contractor most responsible for the back end is CGI Federal. Apparently it's this company's part of the system that's burning up under the load of thousands of simultaneous users.

The restaurant analogy is a good one. Projects with scopes like these fail for all sorts of reasons. *Why New Systems Fail* details a bunch of culprits, most of which are people-related.

As I read the article, a few other things jumped out at me, as they virtually guarantee failure:

- The sheer number of vendors involved
- The unwillingness of key parties involved with the back-end to embrace transparency

**“But we’re CMU students and we  
are really, really smart!”**

What is engineering? And how is it different from  
hacking/programming?

# Software *Engineering*?

# 1968 NATO Conference on Software Engineering

“Software Engineering” was a provocative term



# Compare to other forms of engineering

- e.g., Producing a car or bridge
  - Estimable costs and risks
  - Well-defined expected results
  - High quality
- Separation between plan and production
- Simulation before construction
- Quality assurance through measurement
- Potential for automation



# From Programming to Software Engineering

# Healthcare.gov: Government IT Project Failure at its Finest

Posted: 10/18/2013 6:33 pm



Read more > [Project Management](#), [Government](#), [Healthcare](#), [IT Projects](#), [Open Source](#), [Business News](#)

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- The unwillingness of key parties involved with the back-end to embrace transparency

# What happened with HealthCare.gov?

- Poor team and process coordination.
- Changing requirements.
- Inadequate quality assurance infrastructure.
- Architecture unsuited to the ultimate system load.

But....*why*??

# Boeing 737 MAX



# Software is written by humans

*Sociotechnical system:* interlinked system of people, technology, and their environment

Key challenges in how to

- identify what to build (requirements)
- coordinate people building it (process)
- assure quality (speed, safety, fairness)
- contain risk, time and budget (management)
- sustain a community (open source, economics)

# Requirements

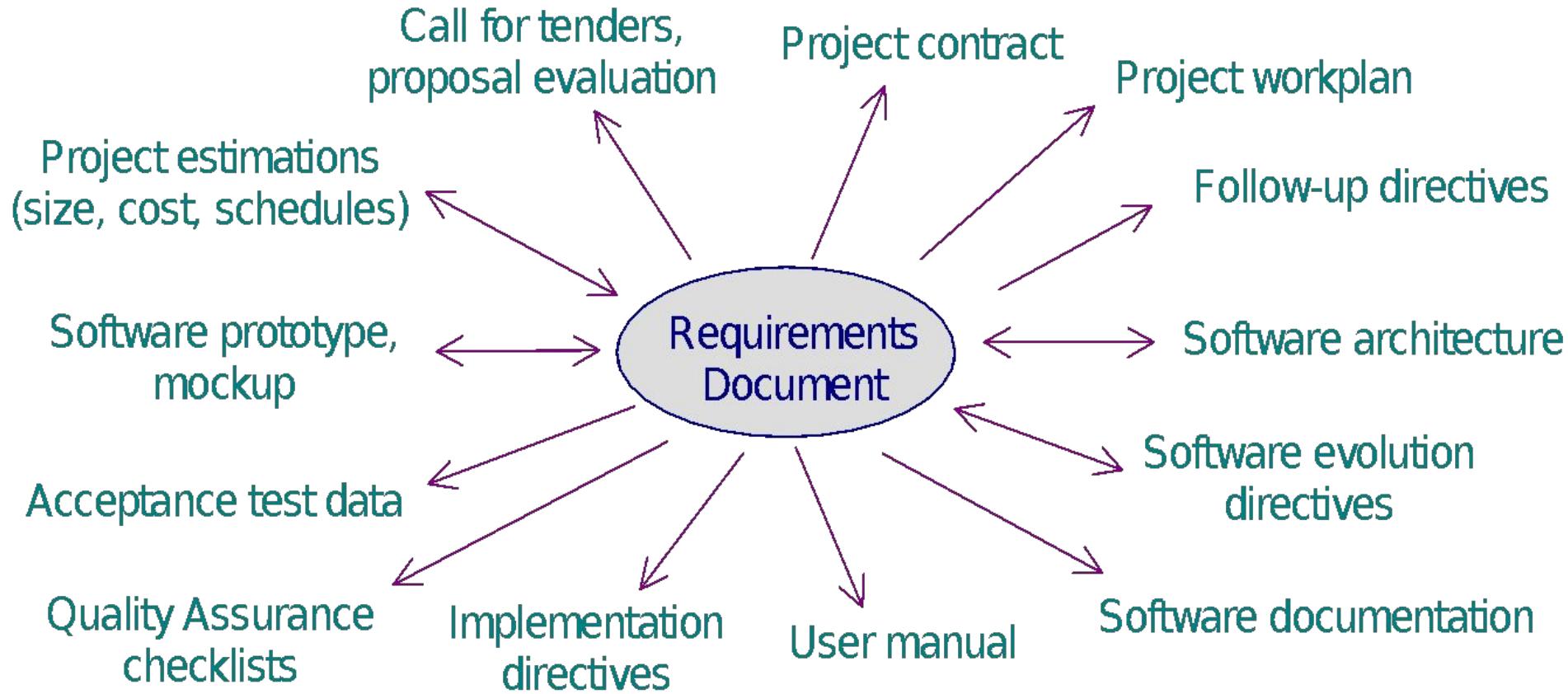
# Requirements

- What does the customer want?
- What is required, desired, not necessary? Legal, policy constraints?
- Customers often do not know what they really want; vague, biased by what they see; change their mind; get new ideas...
- Difficult to define requirements precisely
- (Are we building the right thing? Not: Are we building the thing right?)



17-214/5

2



# Interviews



# Abby Jones<sup>1</sup>



## You can edit anything in blue print

- 28 years old
- Employed as an Accountant
- Lives in Cardiff, Wales

Abby has always liked music. When she is on her way to work in the morning, she listens to music that spans a wide variety of styles. But when she arrives at work, she turns it off, and begins her day by scanning all her emails first to get an overall picture before answering any of them. (This extra pass takes time but seems worth it.) Some nights she exercises or stretches, and sometimes she likes to play computer puzzle games like Sudoku

## Background and skills

Abby works as an accountant. She is comfortable with the technologies she uses regularly, but she just moved to this employer 1 week ago, and their software systems are new to her.

Abby says she's a "numbers person", but she has never taken any computer programming or IT systems classes. She likes Math and knows how to think with numbers. She writes and edits spreadsheet formulas in her work.

In her free time, she also enjoys working with numbers and logic. She especially likes working out puzzles and puzzle games, either on paper or on the computer

## Motivations and Attitudes

▪ **Motivations:** Abby uses technologies to accomplish her tasks. She learns new technologies if and when she needs to, but prefers to use methods she is already familiar and comfortable with, to keep her focus on the tasks she cares about.

▪ **Computer Self-Efficacy:** Abby has low confidence about doing unfamiliar computing tasks. If problems arise with her technology, she often blames herself for these problems. This affects whether and how she will persevere with a task if technology problems have arisen.

▪ **Attitude toward Risk:** Abby's life is a little complicated and she rarely has spare time. So she is risk averse about using unfamiliar technologies that might need her to spend extra time on them, even if the new features might be relevant. She instead performs tasks using familiar features, because they're more predictable about what she will get from them and how much time they will take.

## How Abby Works with Information and Learns:

▪ **Information Processing Style:** Abby tends towards a comprehensive

▪ **Learning: by Process vs. by Tinkering:** When learning new technology,

# Process

# How to develop software?

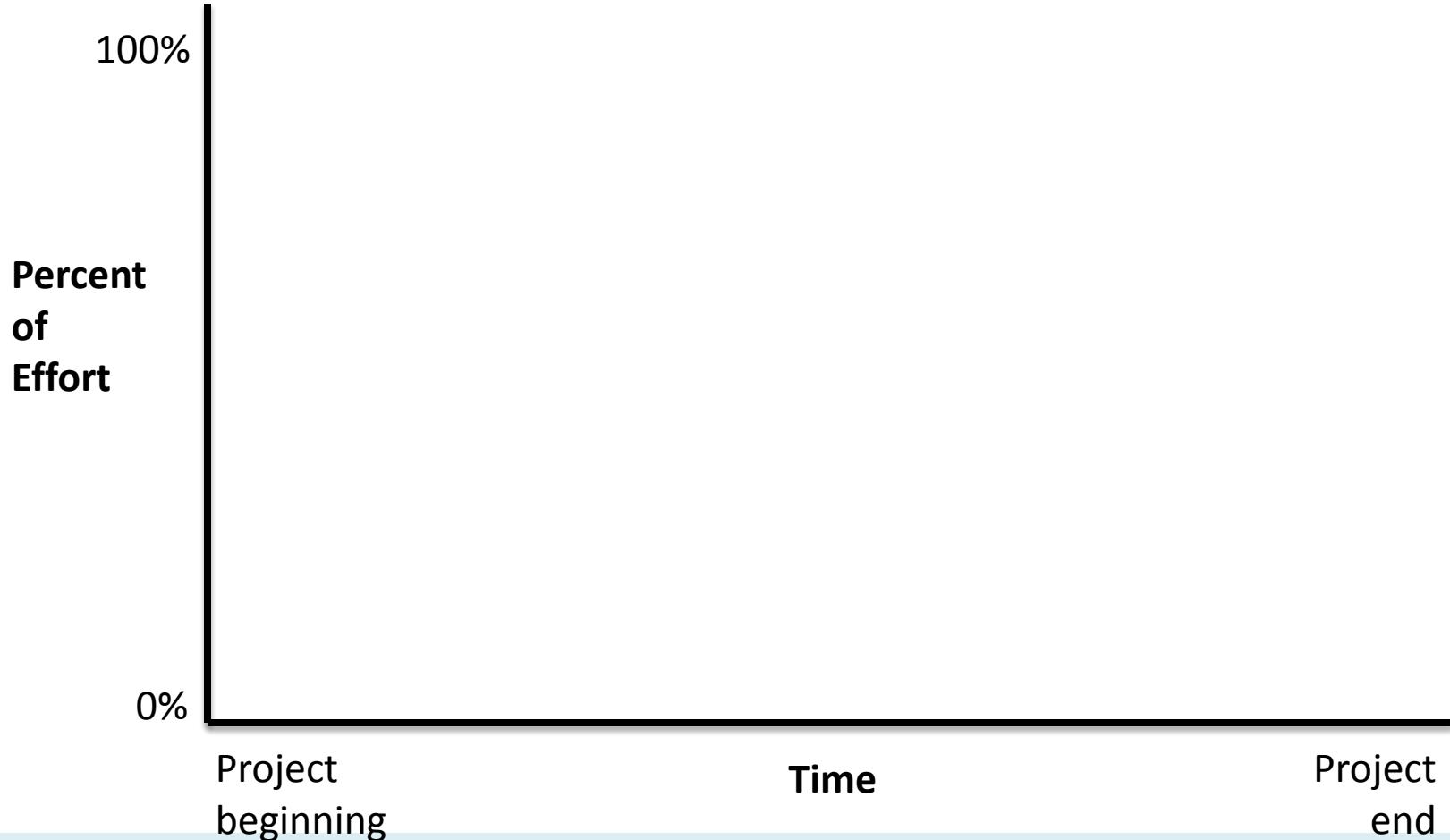
1. Discuss the software that needs to be written
2. Write some code
3. Test the code to identify the defects
4. Debug to find causes of defects
5. Fix the defects
6. If not done, return to step 1

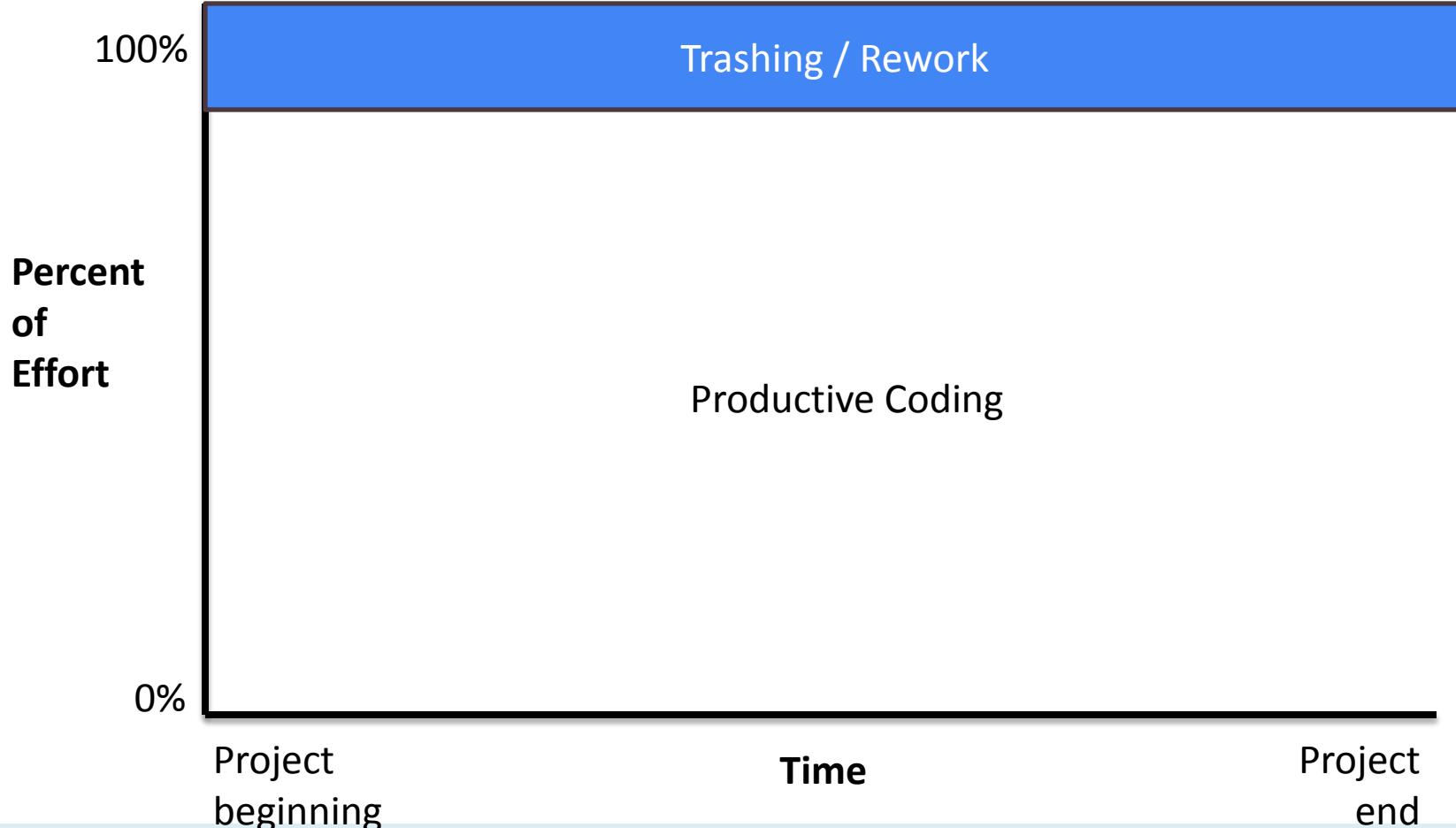
# Software Process

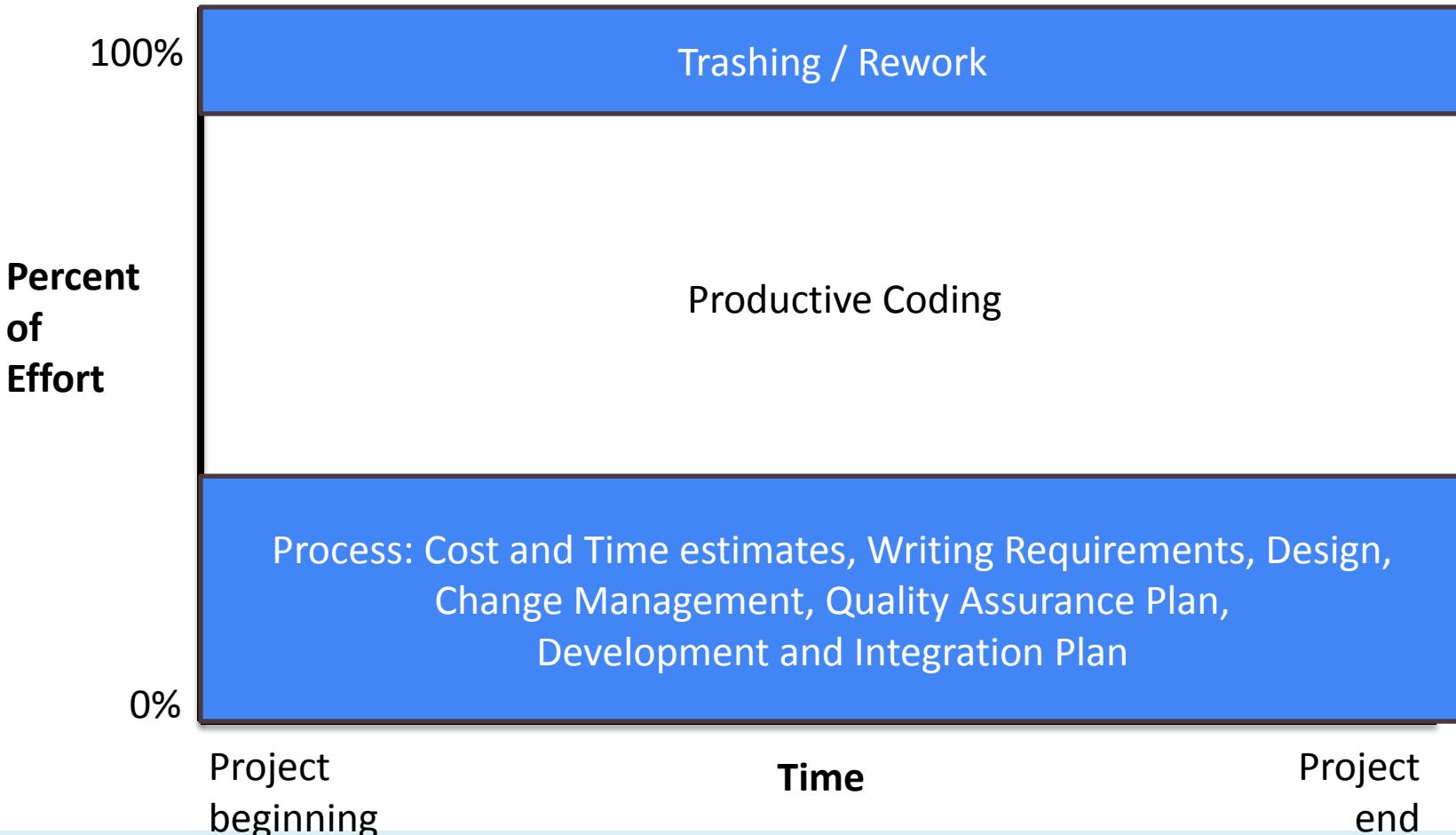
“The set of activities and associated results that produce a software product”

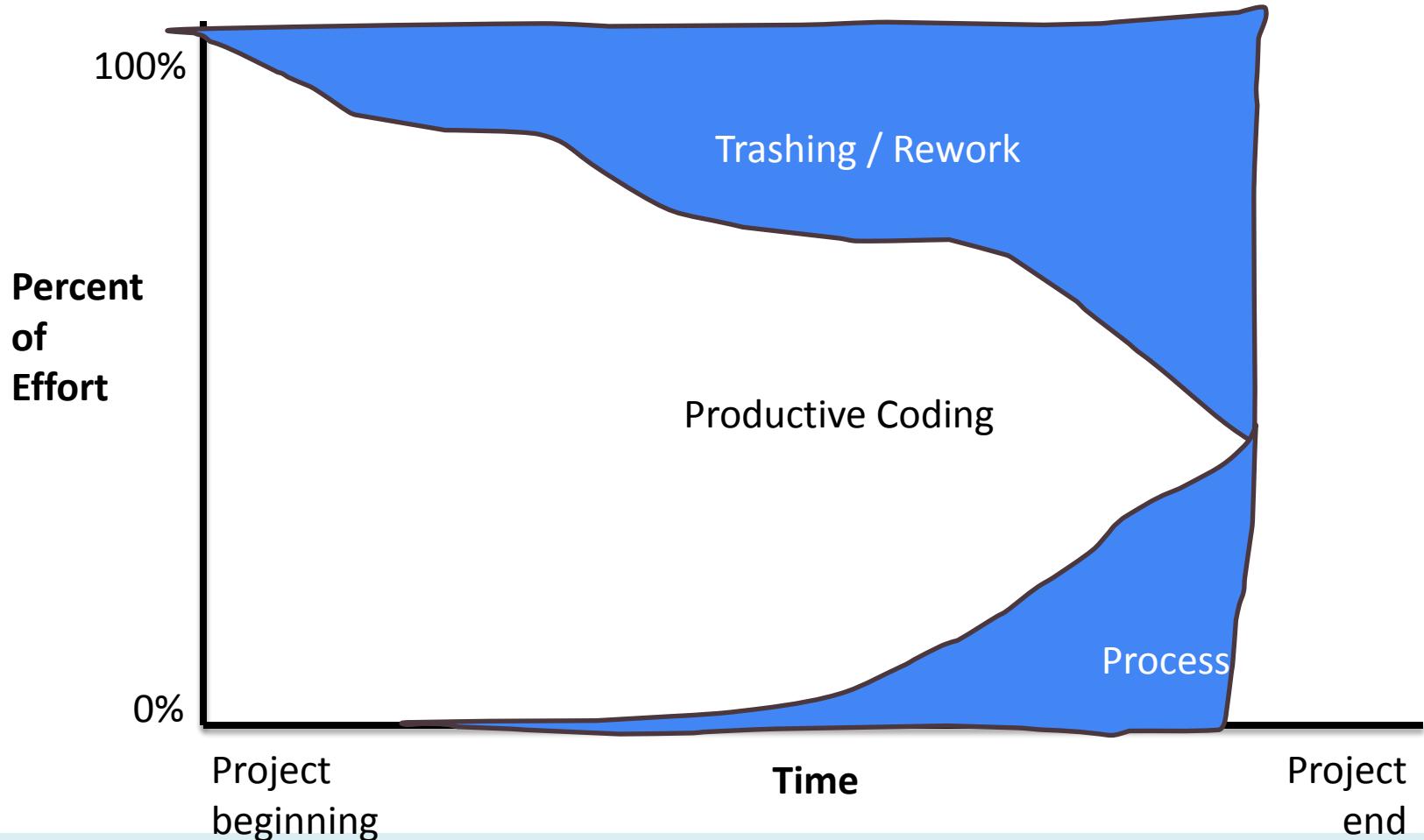
What makes a good process?

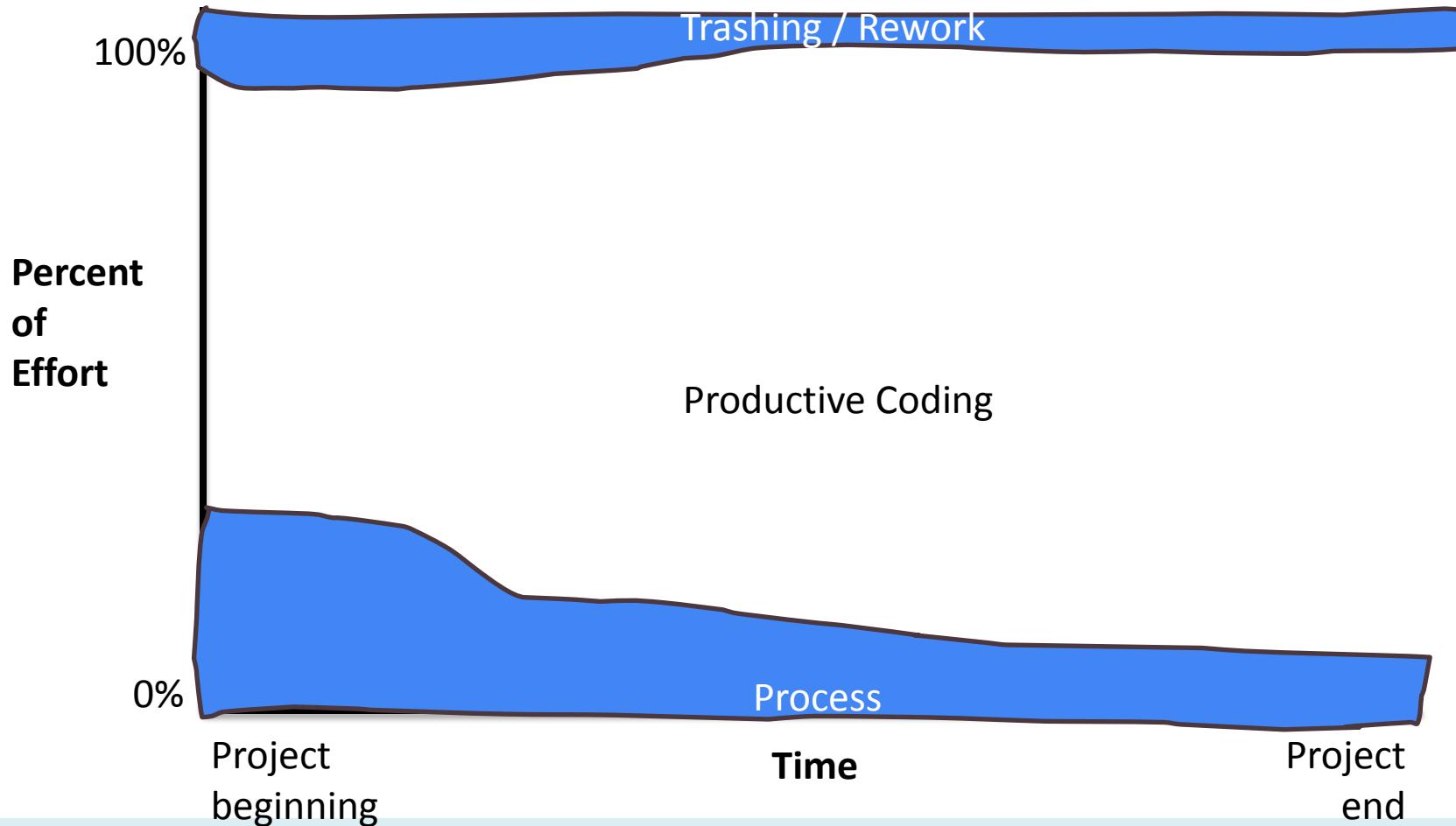
Sommerville, SE, ed. 8







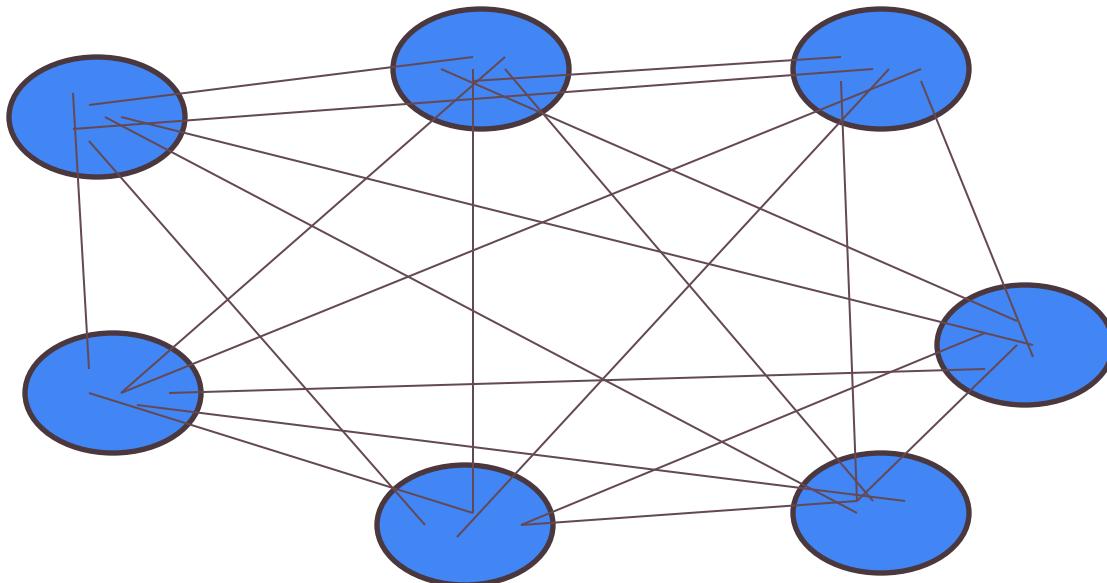




# Example process issues

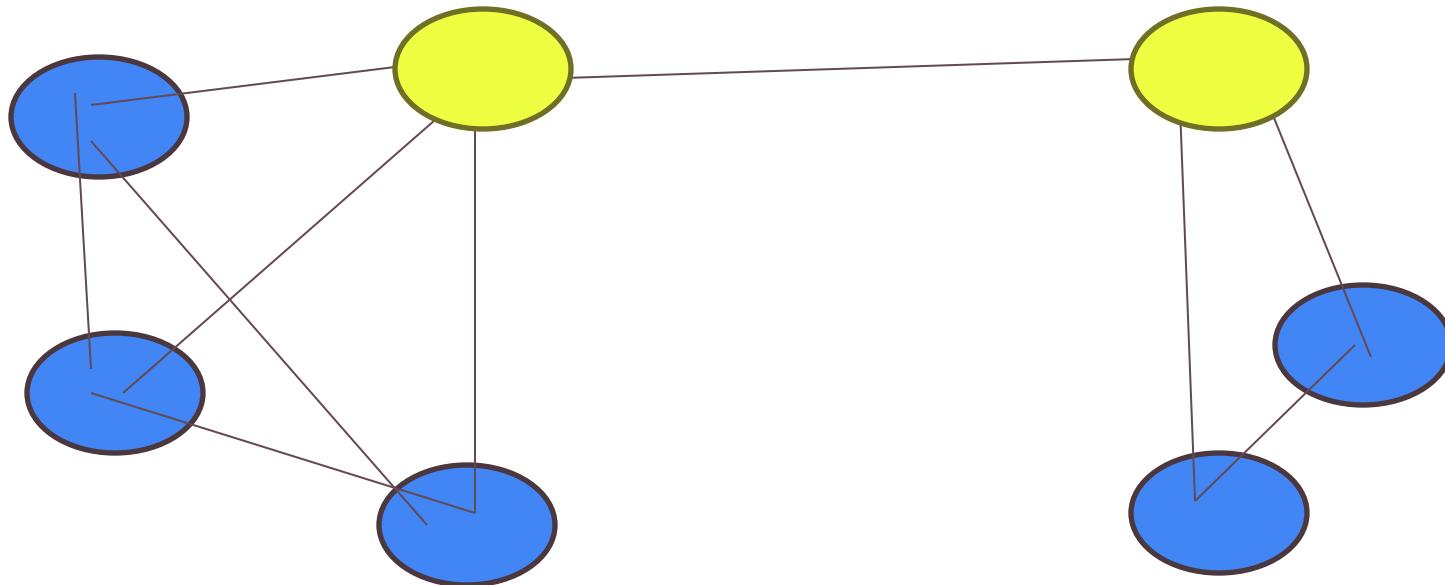
- Change Control: Mid-project informal agreement to changes suggested by customer or manager. Project scope expands 25-50%
- Quality Assurance: Late detection of requirements and design issues. Test-debug-reimplement cycle limits development of new features. Release with known defects.
- Defect Tracking: Bug reports collected informally, forgotten
- System Integration: Integration of independently developed components at the very end of the project. Interfaces out of sync.
- Source Code Control: Accidentally overwritten changes, lost work.
- Scheduling: When project is behind, developers are asked weekly for new estimates.

# Process Costs



$n(n - 1) / 2$   
communication links

# Process Costs



Large teams (29 people) create around six times as many defects as small teams (3 people) and obviously burn through a lot more money. Yet, the large team appears to produce about the same amount of output in only an average of 12 days' less time. This is a truly astonishing finding, though it fits with my personal experience on projects over 35 years.

- Phillip Amour, 2006, CACM 49:9

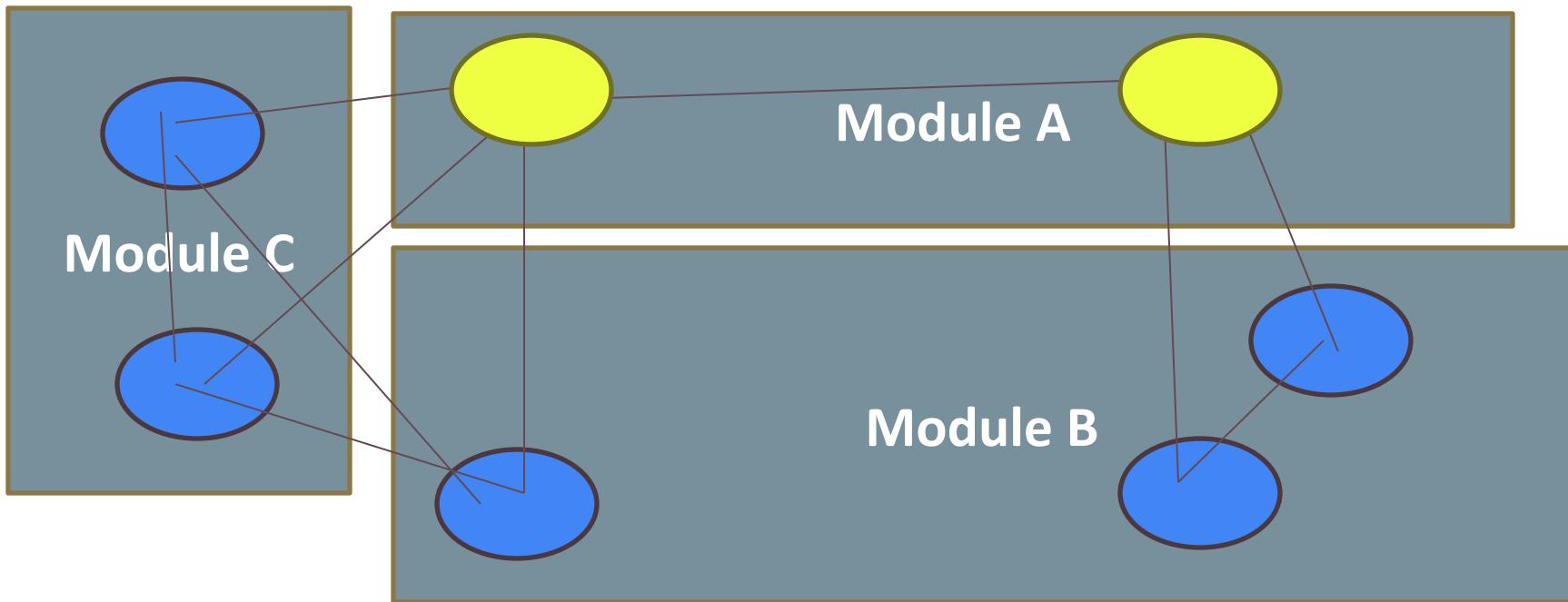
# Conway's Law

“Any organization that designs a system (defined broadly) will produce a design whose structure is a copy of the organization's communication structure.”

— *Mel Conway, 1967*

“If you have four groups working on a compiler, you'll get a 4-pass compiler.”

# Congruence



# The Manifesto for Agile Software Development (2001)

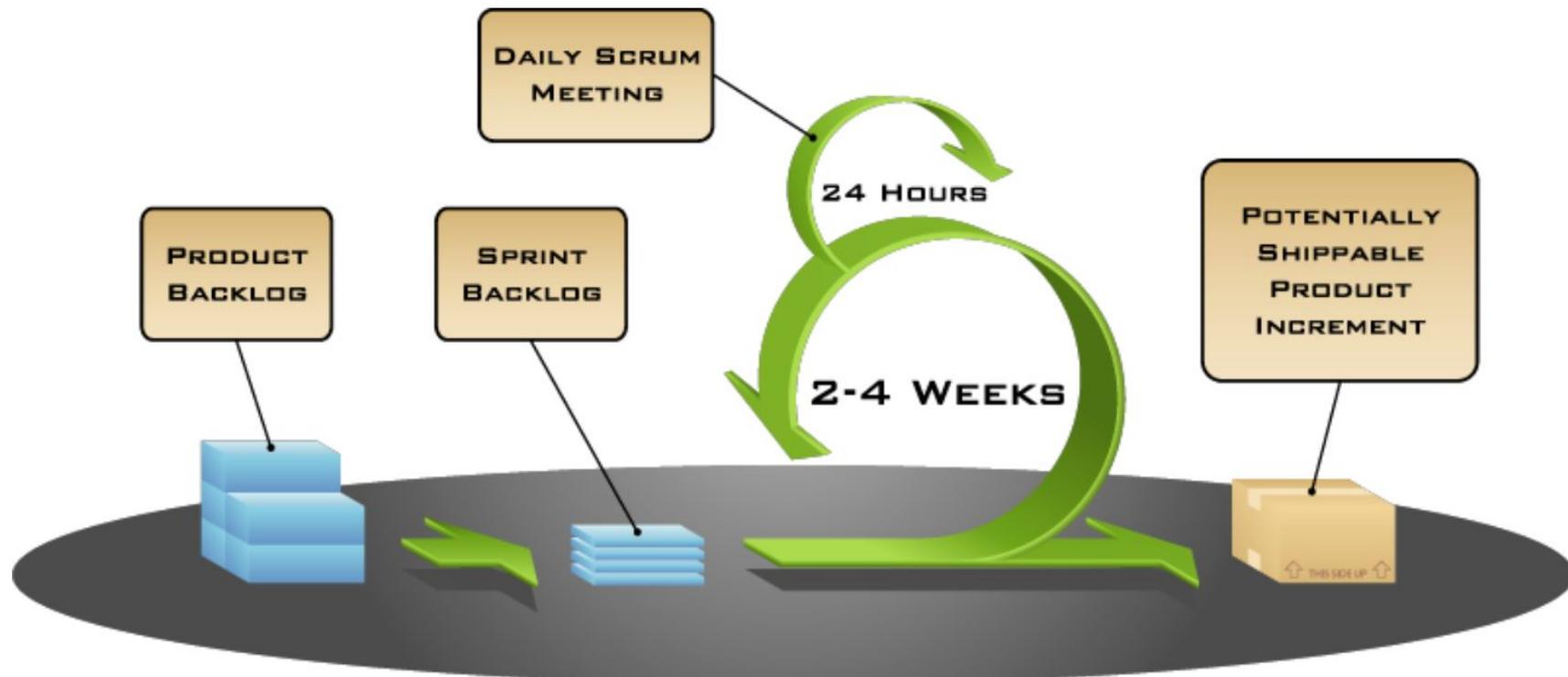
## ***Value***

Individuals and interactions	<i>over</i>	Processes and tools
Working software	<i>over</i>	Comprehensive documentation
Customer collaboration	<i>over</i>	Contract negotiation
Responding to change	<i>over</i>	Following a plan

# Pair Programming



# Scrum Process



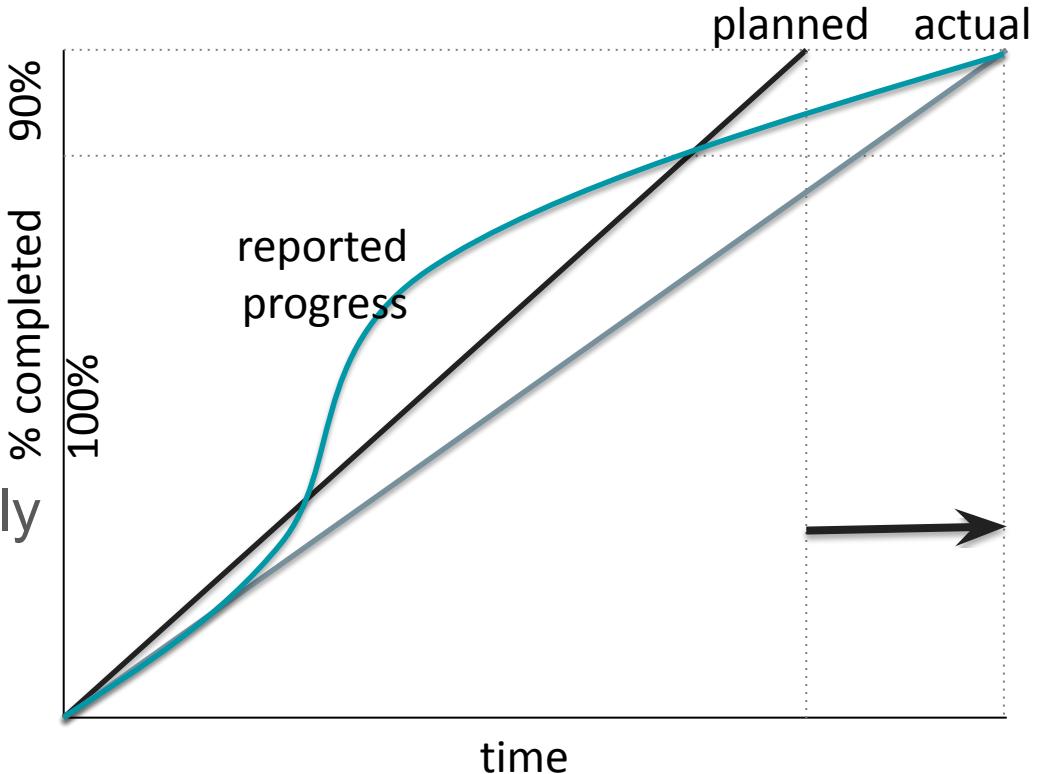
# Planning

# Measuring Progress?

“I’m almost done with the X. Component A is almost fully implemented. Component B is finished except for the one stupid bug that sometimes crashes the server. I only need to find the one stupid bug, but that can probably be done in an afternoon?”

# Almost Done Problem

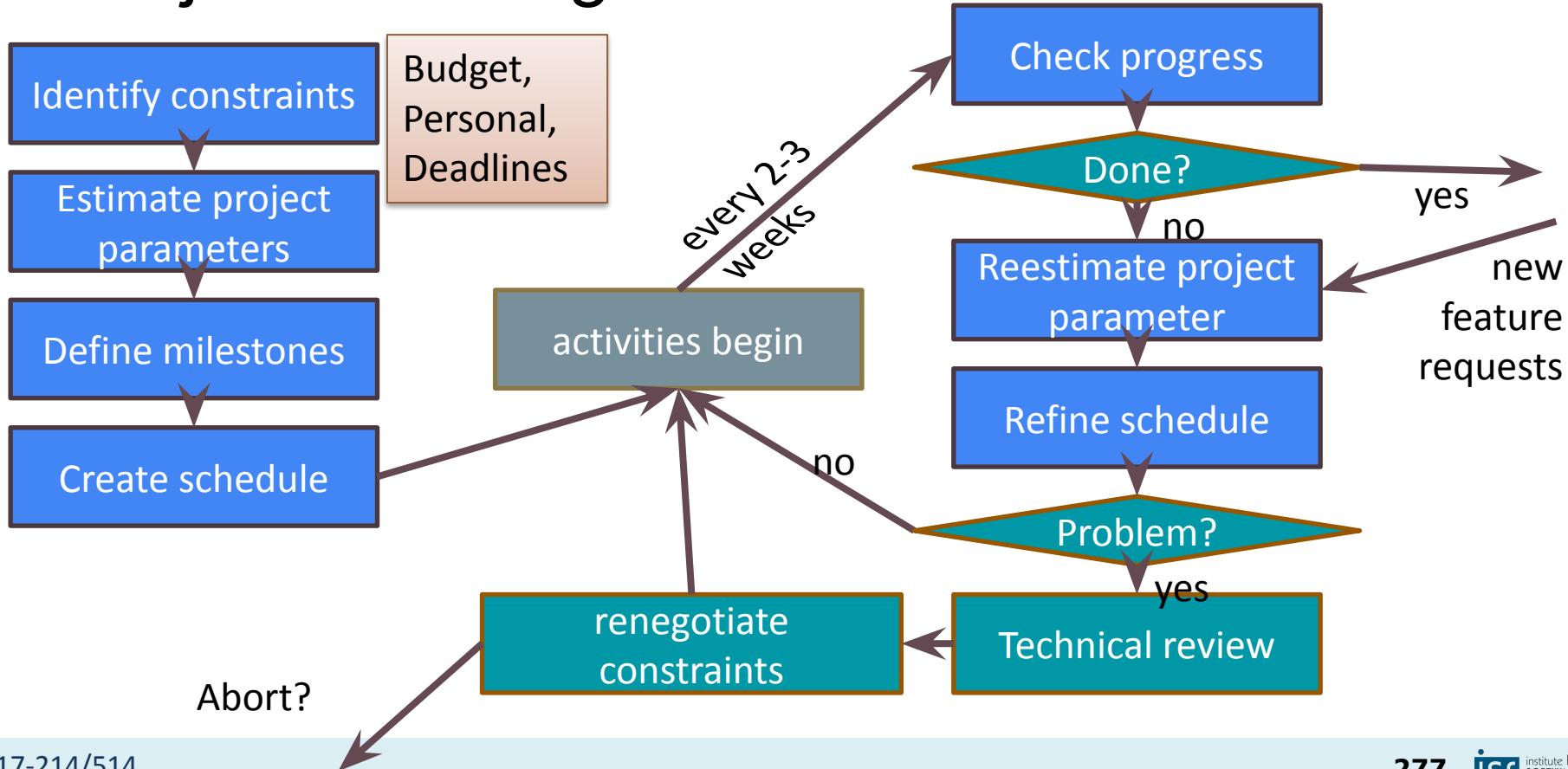
- Last 10% of work -> 40% of time (or 20/80)
- Make progress measurable
- Avoid depending entirely on developer estimations



# Measuring Progress?

- Developer judgment: x% done
- Lines of code?
- Functionality?
- Quality?

# Project Planning

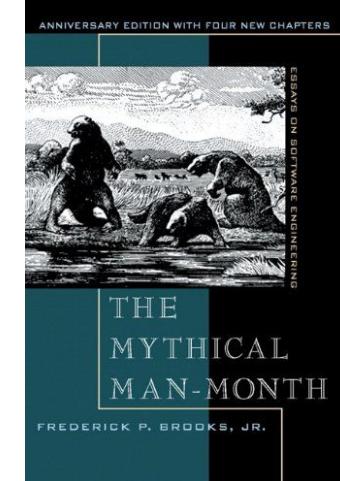
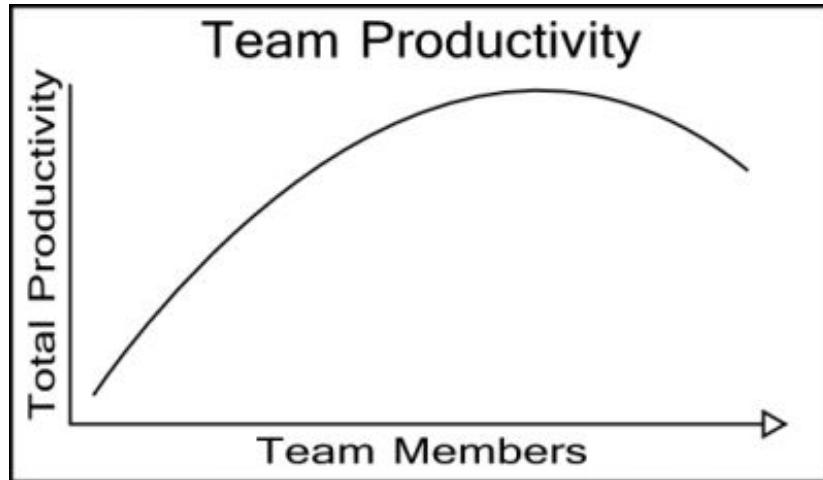


# Reasons for Missed Deadlines

- Insufficient staff (illnesses, staff turnover, ...)
- Insufficient qualification
- Unanticipated difficulties
- Unrealistic time estimations
- Unanticipated dependencies
- Changing requirements, additional requirements
- Especially in student projects
  - Underestimated time for learning technologies
  - Uneven work distribution
  - Last-minute panic.

# Team productivity

- Brook's law: Adding people to a late software project makes it later.



# Estimating effort



# Software Architecture

Requirements

Architecture

Implementation

# Software Architecture

*"The software architecture of a computing system is the set of structures needed to reason about the system, which comprise software elements, relations among them, and properties of both."*

*[Clements et al. 2010]*

# Design vs. Architecture

## Design Questions

- How do I add a menu item in Eclipse?
- How can I make it easy to add menu items in Eclipse?
- What lock protects this data?
- How does Google rank pages?
- What encoder should I use for secure communication?
- What is the interface between objects?

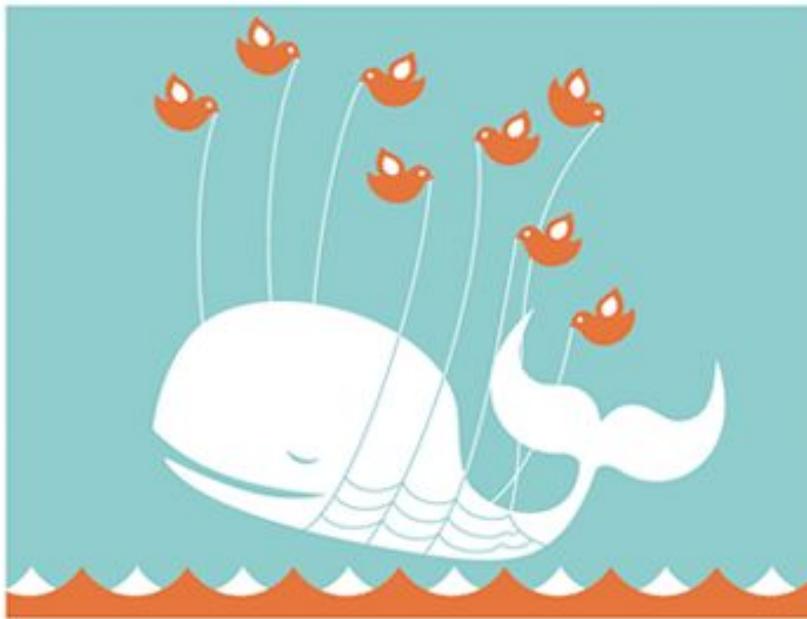
## Architectural Questions

- How do I extend Eclipse with a plugin?
- What threads exist and how do they coordinate?
- How does Google scale to billions of hits per day?
- Where should I put my firewalls?
- What is the interface between subsystems?

# Case Study: Architecture Changes at Twitter

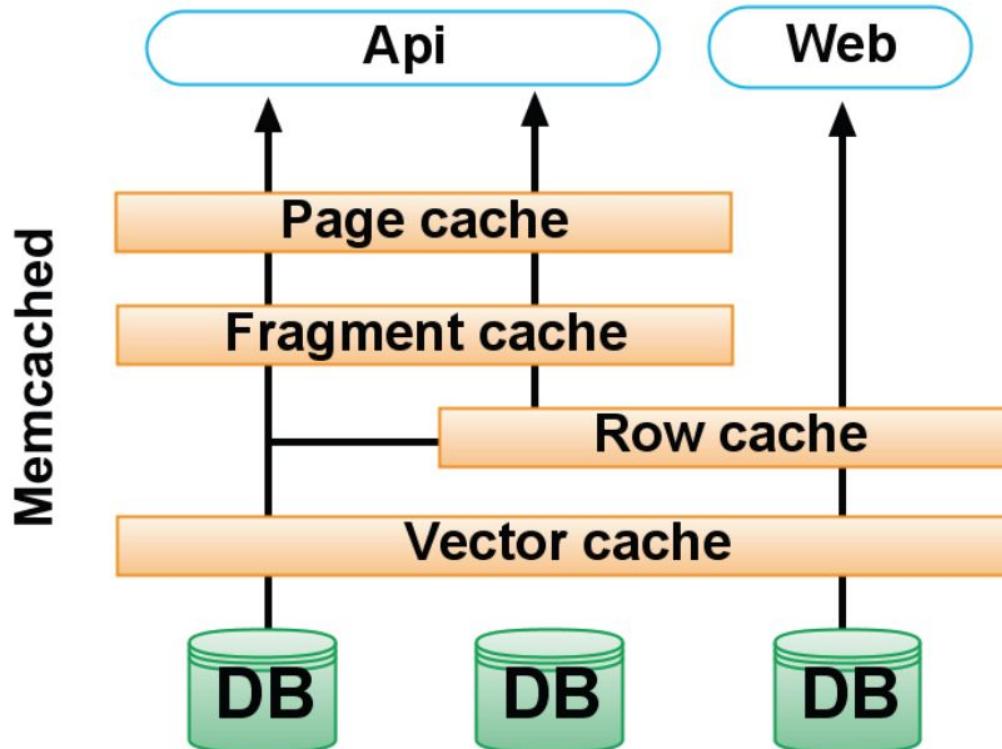
## Twitter is over capacity.

Too many tweets! Please wait a moment and try again.





# Caching



# Redesign Goals

- Improve median latency; lower outliers
- Reduce number of machines 10x
- Isolate failures
- "We wanted cleaner boundaries with “related” logic being in one place"
  - encapsulation and modularity at the systems level (rather than at the class, module, or package level)
- Quicker release of new features
  - "run small and empowered engineering teams that could make local decisions and ship user-facing changes, independent of other teams"

reliability

performance

maintainability

modifiability

# Outcome: Rearchitecting Twitter

"This re-architecture has not only made the service more **resilient when traffic spikes** to record highs, but also provides a more **flexible** platform on which to **build more features faster**, including synchronizing direct messages across devices, Twitter cards that allow Tweets to become richer and contain more content, and a rich search experience that includes stories and users."

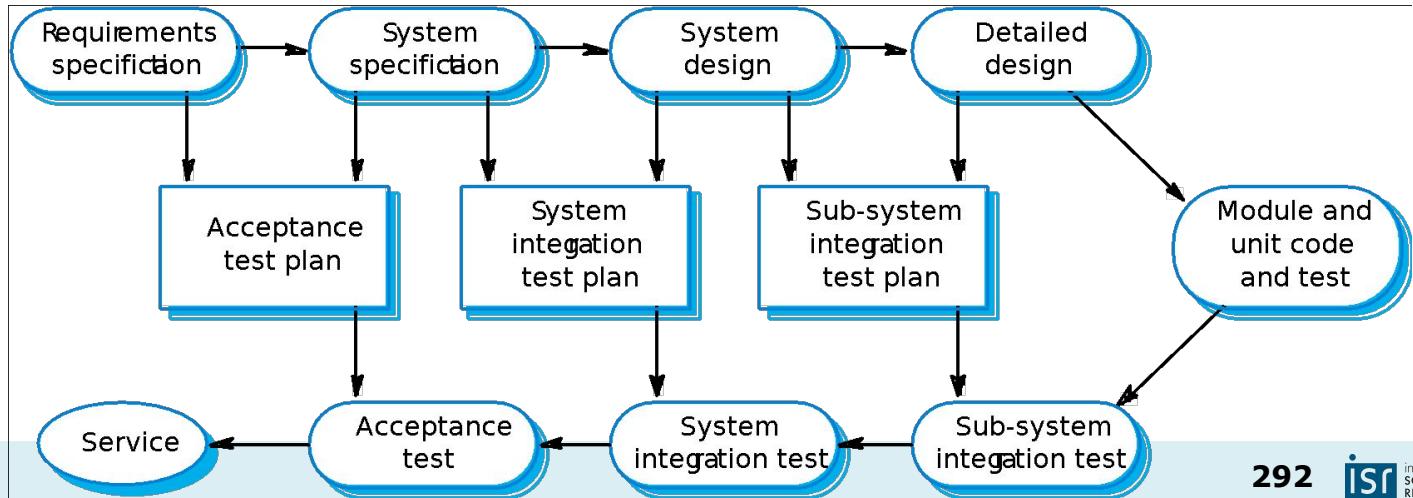
# *Was the original architect wrong?*

# Beyond testing: QA and Process

Many QA approaches

Code review, static analysis, formal verification, ...

Which to use when, how much?



# How to get students to write tests?

*“We had initially scheduled time to write tests for both front and back end systems, although this never happened.”*

*“Due to the lack of time, we could only conduct individual pages’ unit testing. Limited testing was done using use cases. Our team felt that this testing process was rushed and more time and effort should be allocated.”*

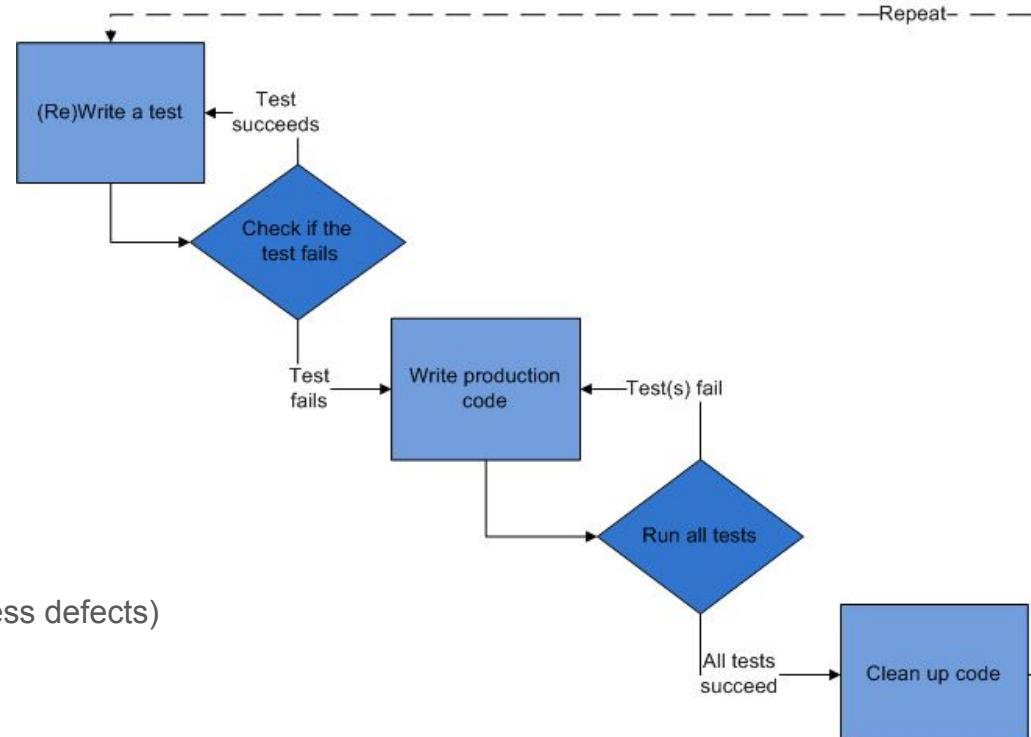
# Time estimates (in hours):

Activity	Estimated	Actual
testing plans	3	0
unit testing	3	1
validation testing	4	2
test data	1	1

# How to get developers to write tests?

# Test Driven Development

- Tests first!
- Popular agile technique
- Write tests as specifications before code
- Never write code without a failing test
- Claims:
  - Design approach toward testable design
  - Think about interfaces first
  - Avoid writing unneeded code
  - Higher product quality (e.g. better code, less defects)
  - Higher test suite quality
  - Higher overall productivity



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Excirial



Search all repositories



## My Repositories +

wyvernlang/wyvern

# 17

Duration: 16 sec

Finished: 3 days ago

## wyvernlang / wyvern build passing

Current

Branches

Build History

Pull Requests

Build #17

Settings ▾



SimpleWyvern-devel Asserting false (works on Linux, so its OK).



potanin authored and committed

# 17 passed

Commit fd7be1c

Compare 0e2af1f..fd7b

ran for 16 sec

3 days ago

This job ran on our legacy infrastructure. Please read [our docs](#) on how to upgrade

Remove Log

Download Log

```
1 Using worker: worker-linux-027f0490-1.bb.travis-ci.org:travis-linux-2
2
3 Build system information
67
68 $ git clone --depth=50 --branch=SimpleWyvern-devel
69 $ jdk_switcher use oraclejdk8
70 Switching to Oracle JDK8 (java-8-oracle), JAVA_HOME will be set to /usr/lib/jvm/java-8-oracle
71 $ java -Xmx32m -version
72 java version "1.8.0_31"
73 Java(TM) SE Runtime Environment (build 1.8.0_31-b13)
```

# How to get developers to use static analysis?



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## Refactorings #28

New issue

Merged joliebig merged 17 commits into liveness from CallGraph 9 months ago

Conversation 3

Commits 17

Files changed 97

+1,149 -10,129



ckaestne commented on Jan 29

Owner

@joliebig

Please have a look whether you agree with these refactorings in CRewrite

key changes: Moved ASTNavigation and related classes and turned EnforceTreeHelper into an object

Labels

None yet

Milestone

No milestone

Assignee

No one assigned

2 participants



ckaestne added some commits on Jan 29

remove obsolete test cases

e2dddb6

refactoring: move AST helper classes to CRewrite package where it is ...

f8fc311

improve readability of test code

7e61a34

removed unused fields

✓ f35b398

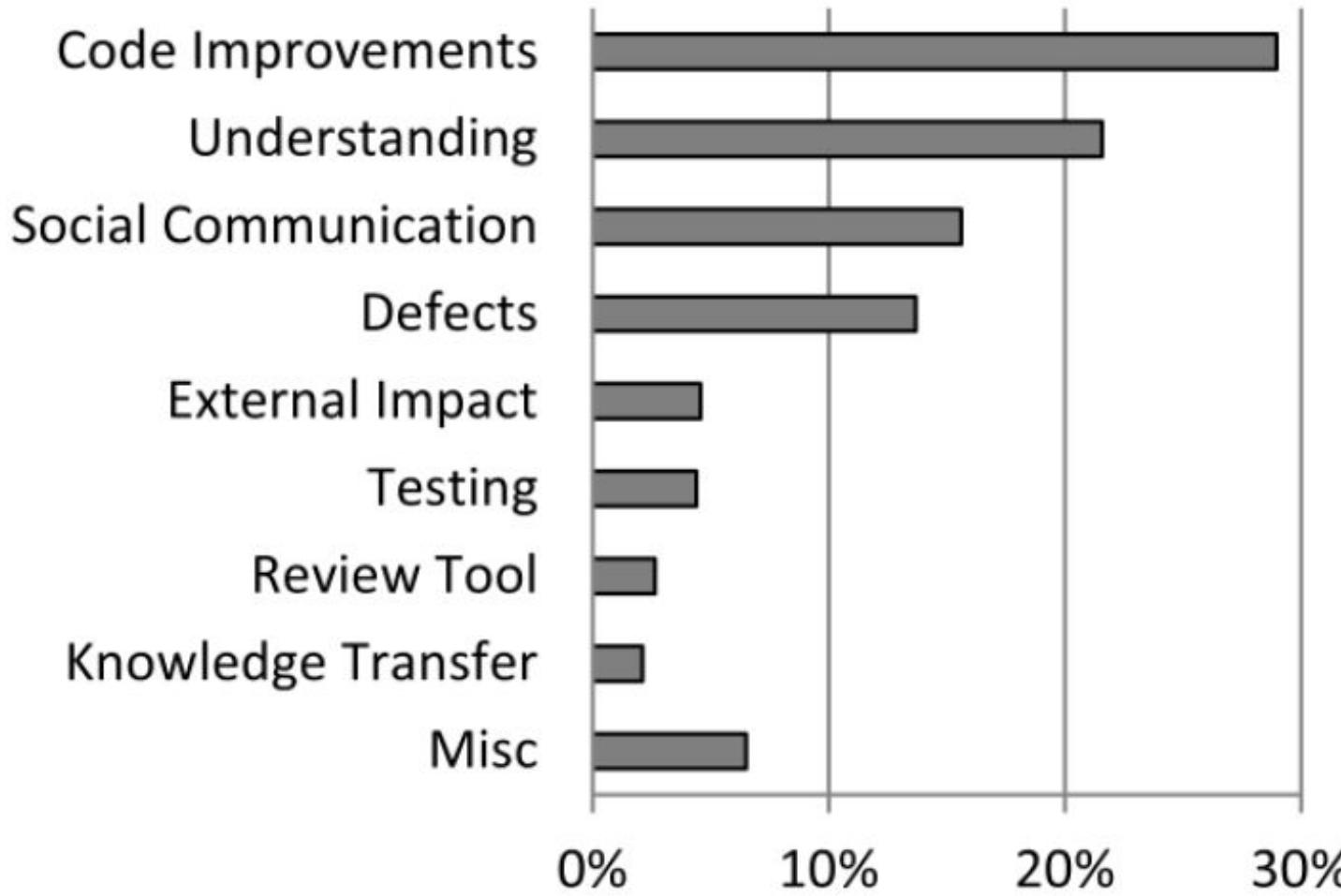


ckaestne commented on Jan 29

Owner

Can one of the admins merge this?

<https://help.github.com/articles/using-pull-requests/>



# How to get developers to use static analysis?

```
package com.google.devtools.staticanalysis;
```

```
public class Test {
```

▼ Lint            Missing a Javadoc comment.  
Java  
1:02 AM, Aug 21

[Please fix](#)

[Not useful](#)

```
public boolean foo() {  
    return getString() == "foo".toString();
```

▼ ErrorProne     String comparison using reference equality instead of value equality  
(see <http://code.google.com/p/error-prone/wiki/StringEquality>)  
StringEquality  
1:03 AM, Aug 21

[Please fix](#)

[Not useful](#)

Suggested fix attached: [show](#)

```
}
```

```
public String getString() {  
    return new String("foo");
```

# Are code reviews worth it?

# Summary

Looking back at one semester of code-level design,  
testing, and concurrency

Looking forward to human aspects of software  
engineering, including process and requirements

There are many other courses in SE at CMU, consider  
taking them!