Principles of Software Construction: Objects, Design, and Concurrency

The Last One: Locking Back & Looking Forward

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Looking Back at the Semester:
194 slides from 23 lectures in 40 min

Principles of Software Construction: Objects, Design, and Concurrency

Introduction, Overview, and Syllabus

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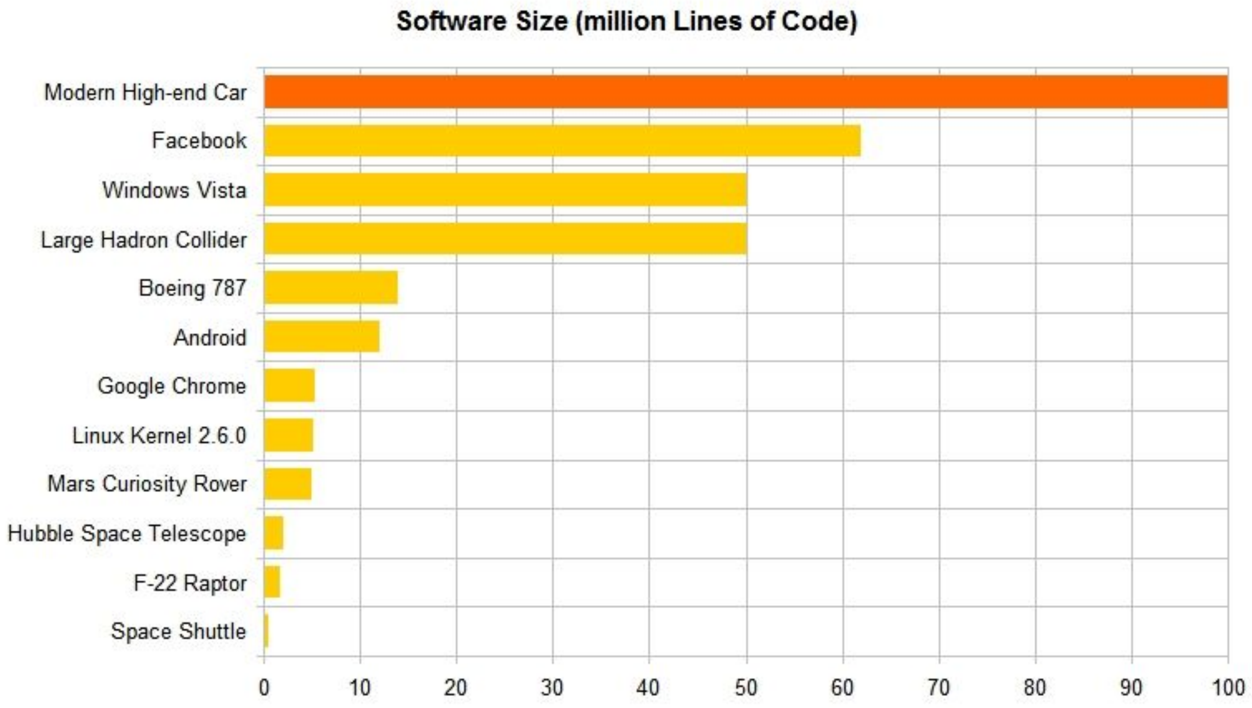
Welcome to the era of "big code"

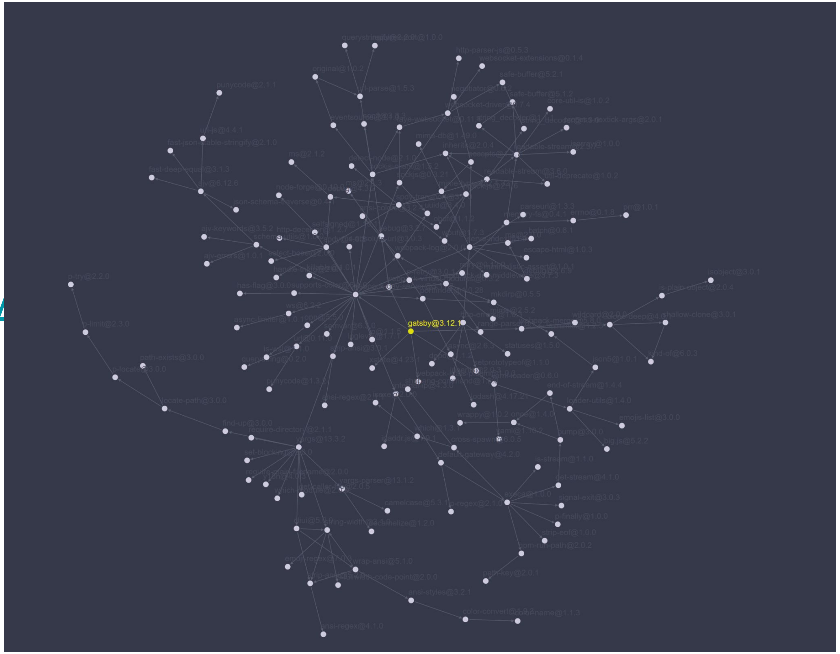


(informal reports)

Modern Software Engineering

Nobody wants to write a million lines of code.

- Instead, you use libraries
  - E.g., import Android => +12M LOC
  - You don’t write most of the code you use
    - And why would you want to?
- And your libraries use libraries
  - Et cetera
  - https://npm.anvaka.com/#/view/2d/gatsby



From Programs to Applications and Systems

Writing algorithms, data structures from scratch

Functions with inputs and outputs

Sequential and local computation

Full functional specifications

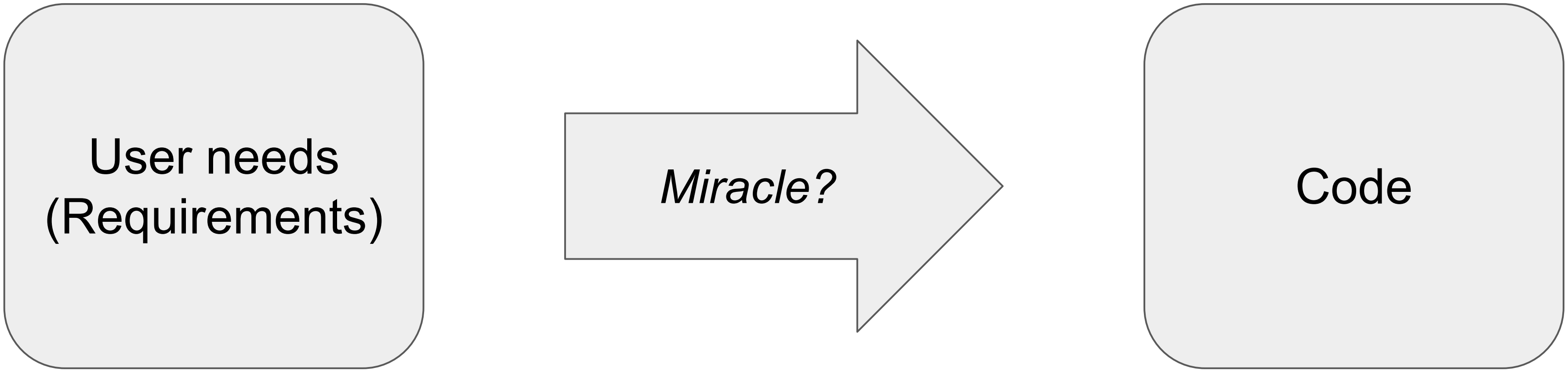
Reuse of libraries, frameworks

Asynchronous and reactive designs

Parallel and distributed computation

Partial, composable, targeted models

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



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

Semester overview

- Introduction to Object-Oriented Programming
- Introduction to **design**
  - **Design** goals, principles, patterns
- **Design**ing objects/classes
  - **Design** for change
  - **Design** for reuse
- **Design**ing (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

Which version is better?

Version A:

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

```
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

Trying to get back to normal with …
gestures widely everything

Talk to us about concerns and accommodations

Disclaimer:
This semester, we are changing a lot in this course.
Some things will go wrong.
Have patience with us.
Give us feedback.

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

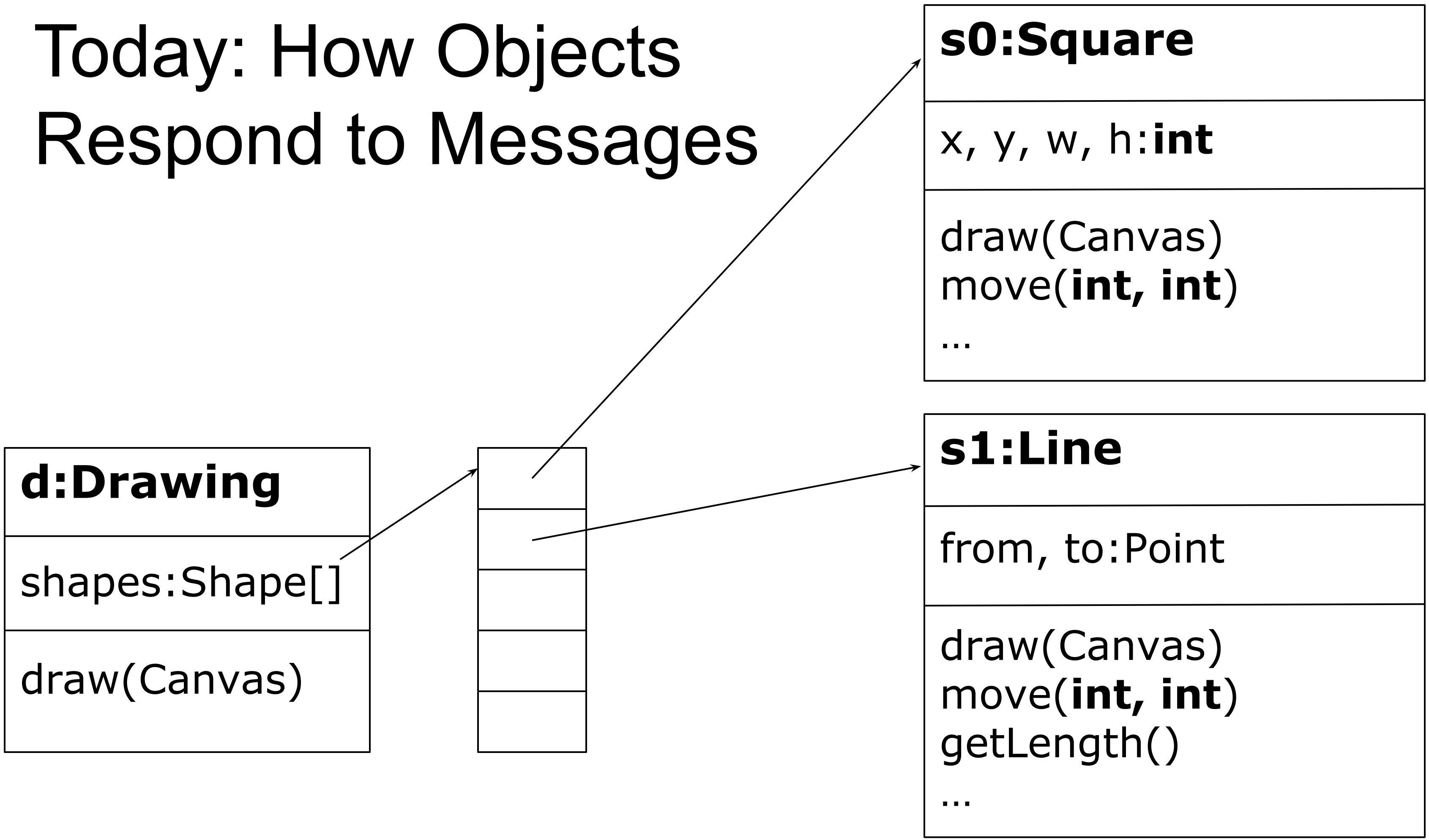
Starting with Objects
(dynamic dispatch, encapsulation)

Christian Kästner Vincent Hellendoorn

Where we are

	Small scale: One/few objects	*Mid scale:* Many objects	*Large scale:* Subsystems
Design for understanding change/ext. reuse robustness ...	**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

Today: How Objects Respond to Messages



Interface declared explicitly with TypeScript

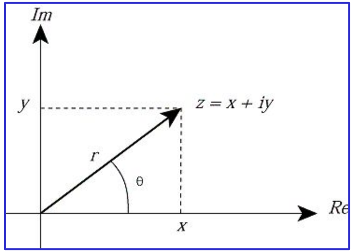
```
interface Counter {
    v: number;
    inc(): void;
    get(): number;
    add(y: number): number;
}
const obj: Counter = {
    v: 1,
    inc: function() { this.v++; },
    get: function() { return this.v; },
    add: function(y) { return this.v + y; }
}
obj.foo();
// Compile-time error: Property 'foo' does not exist
```

v must be part of the interface in TypeScript. Ways to avoid this later.

The object assigned to *obj* must have all the same methods as the interface.

Multiple Implementations of Interface

```
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);
```



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

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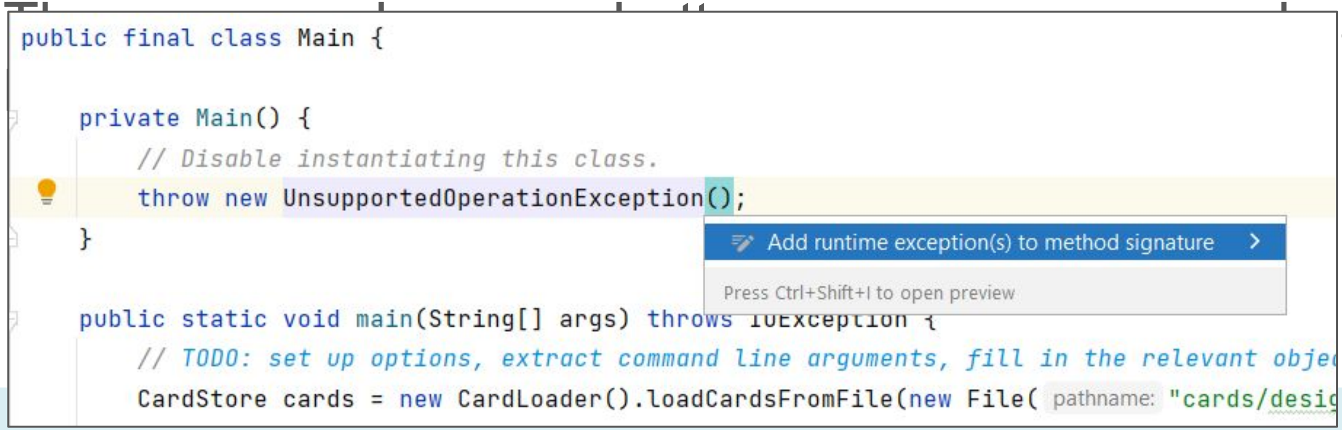
IDEs

Automate common programming actions:

- Handy refactorings, suggestions
  - E.g., just press `alt+enter` in IntelliJ while highlighting nearly any code
    - Keyboard shortcuts are super useful: explore your IDE!
  - a lot of



Build Systems

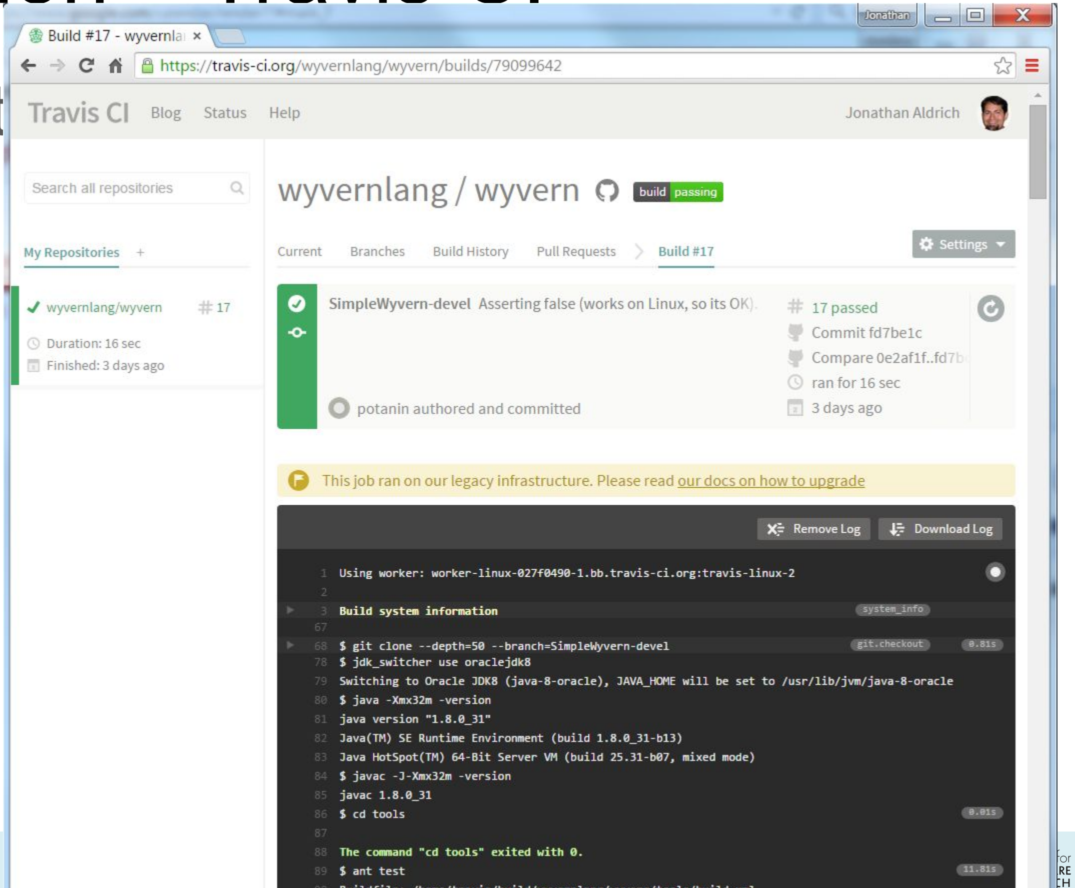
- These days: intricately tied with IDEs, package managers
- Projects often come with a build config file or two
  - 'pom.xml' for Maven
  - 'tsconfig.json' + 'package.json' for TypeScript+NPM -- the second deals with packages
  - These can be nested, one per (sub-)directory, to co
    - On GitHub, you can create links across repositories
  - Specifies:
    - Compilation source and target version
    - High-level configuration options
    - Targets for various phases in development
      - "lifecycle" in Maven; e.g. 'compile', 'test', 'deploy'
    - Often involving plugins
    - Dependencies with versions
      - Not shown: in package.json

```
{
    "compilerOptions": {
      "target": "es2016",
      "module": "commonjs",
      "sourceMap": true,
      "strict": true,
      "esModuleInterop": true,
      "moduleResolution": "node",
      "outDir": "dist"
    }
}
```

Continuous integration – Travis CI

Automatically builds, test

and displays the result



HW1: Extending the Flash Card System

Principles of Software Construction: Objects, Design, and Concurrency

Specifications and unit testing, exceptions

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Handling Exceptions

```
String read(String path) {
  try {
     return Files.lines(Path.of(path))
              .collect(Collectors.joining("\n"));
  }
  catch (IOException e) {
    // implement fall-back behavior.
  }
}
```

Testing

How do we know this works?

Testing

Are we done?

```
int isPos(int x) {
  return x >= 0;  // What if?
}

@Test
void test1IsPos() {
  assertTrue(isPos(1));
}

@Test
void test0IsNotPos() {
  assertFalse(isPos(0)); // Fails
}
```

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!
  }
}
```

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Test case design

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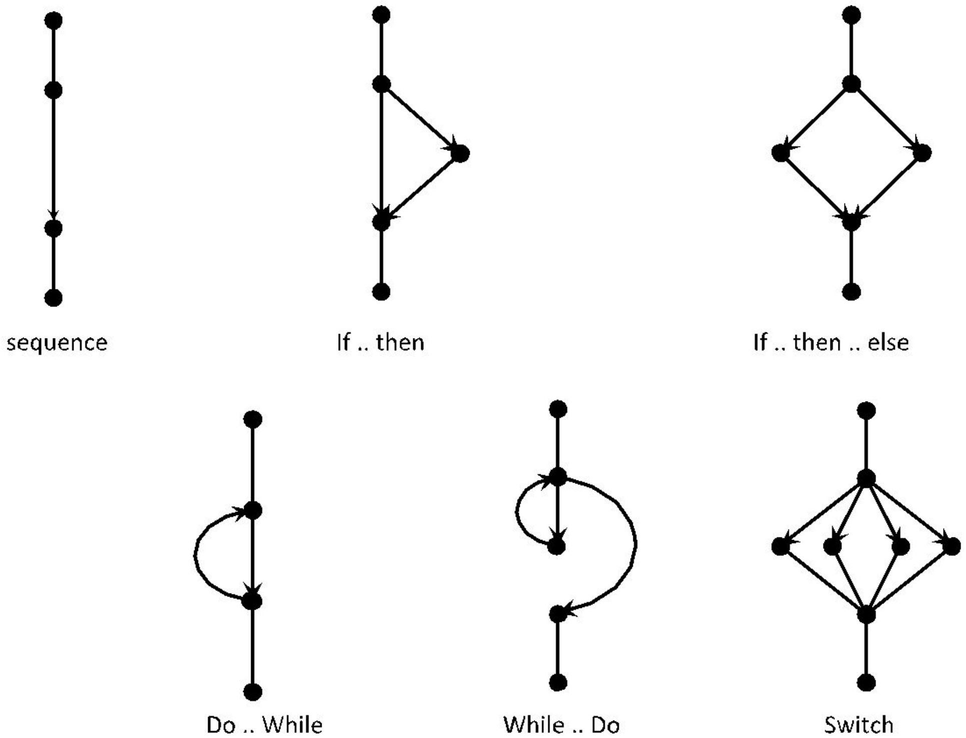
CreditWallet.pay()

```
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

Structures in Code



Writing Testable Code

Aim to write easily testable code

- Which is almost by definition more modular

```
public List<String> getLines(String path) throws IOException {
   return Files.readAllLines(Path.of(path));
}

public boolean hasHeader(List<String> lines) {
   return !lines.get(0).isEmpty()
}

// Test:
// - hasHeader with empty, non-empty first line
// - getLines (if you must) with null, real path
```

Boundary Value Testing

We need a *strategy* to identify plausible mistakes

- Boundary Value Testing: errors often occur at boundary conditions
  - Select: a nominal/normal case, a boundary value, and an abnormal case
  - Useful for few *categories* of behavior (e.g., null/not-null) per value
- Test: `cost < credit, cost == credit, cost > credit,`
  `cost < cash, cost == cash, cost > cash`

```java
/** 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);
```

HW 2: Testing the Flash Card System

Principles of Software Construction: Objects, Design, and Concurrency

Object-oriented analysis

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Lufthansa Flight 2904

- The Airbus A320-200 airplane has a software-based braking system
- Engaging reverse thrusters while in the air is very dangerous: **Only allow breaking when on the ground**

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**

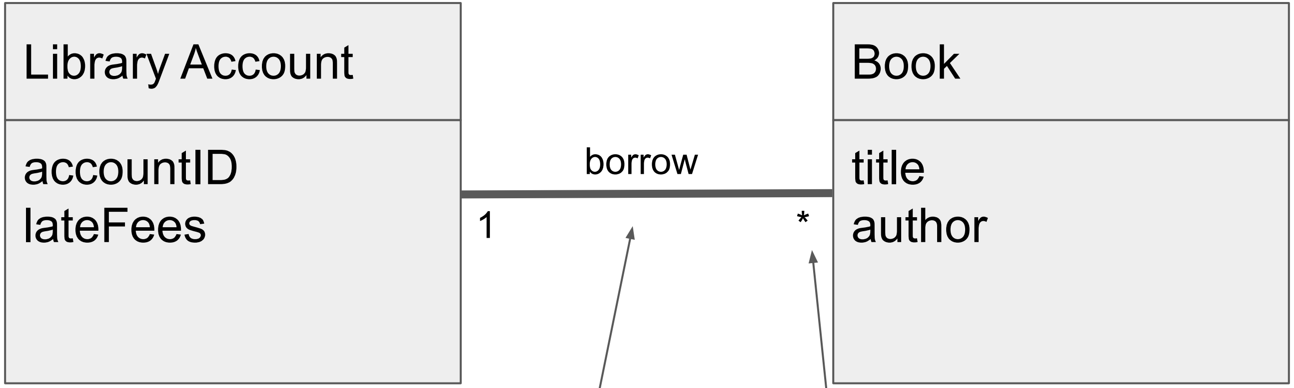
OO Analysis: Understanding the problem

OO Design: Defining a solution

Visual notation: UML

Name of real-world concept
(not software class)

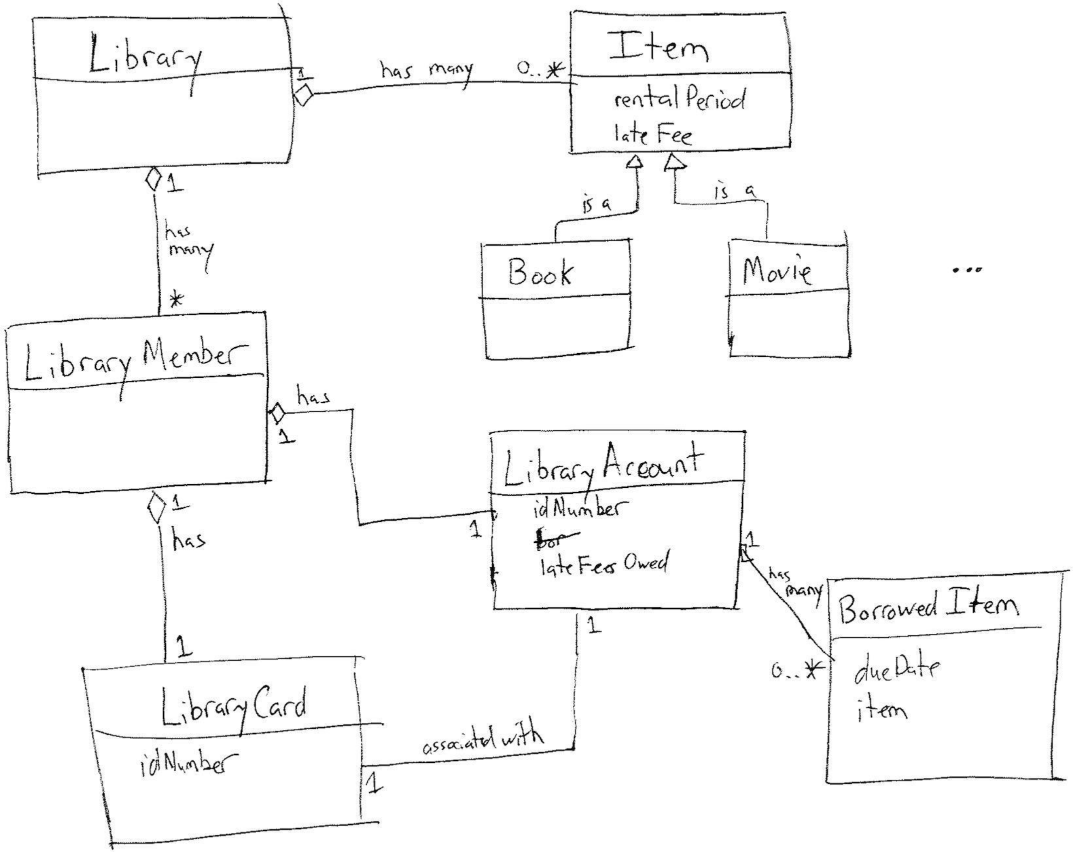
Properties of concept



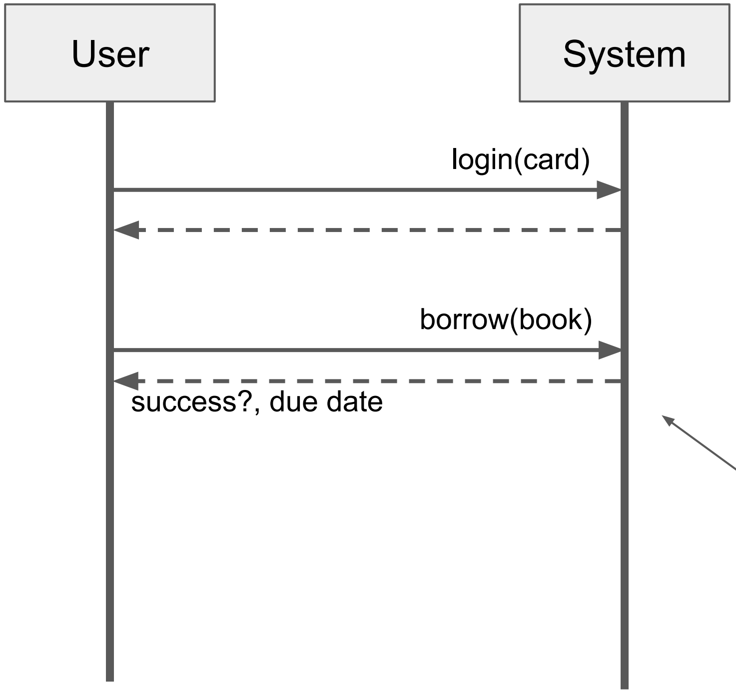
Associations between concepts

Multiplicities/cardinalities indicate “how many”

One domain model for the library system



UML Sequence Diagram Notation

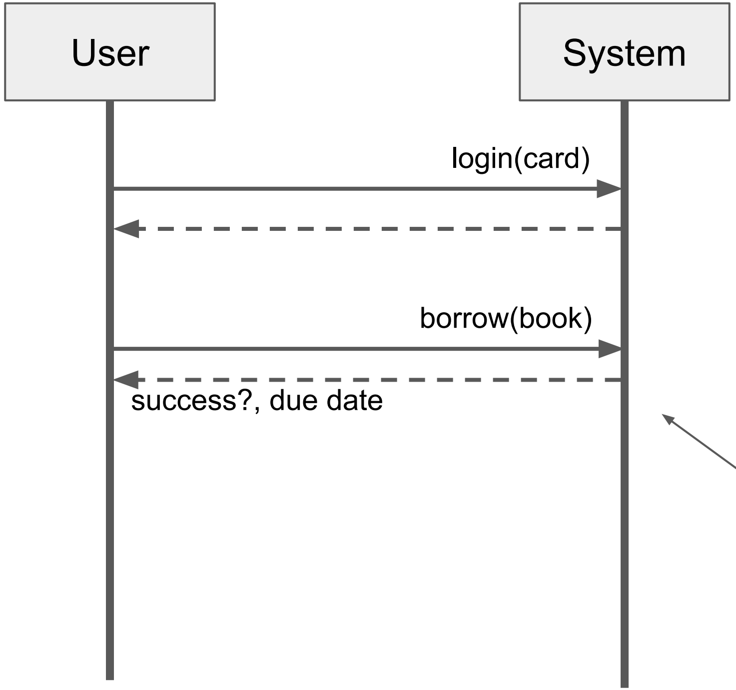


Actors in this use case (systems and real-world objects/people)

Time proceeds from top to bottom

Messages and responses for interactions,
text describes what happens conceptually

UML Sequence Diagram Notation



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

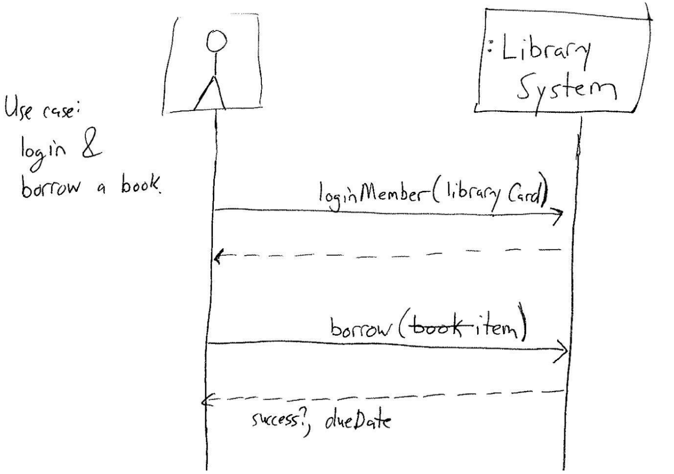
Time proceeds from top to bottom

Messages and responses for interactions,
text describes what happens conceptually

Formalize system at boundary

A *system behavioral contract* describes the pre-conditions and post-conditions for some operation identified in the system sequence diagrams

- System-level textual specifications, like software specifications



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Assigning Responsibilities

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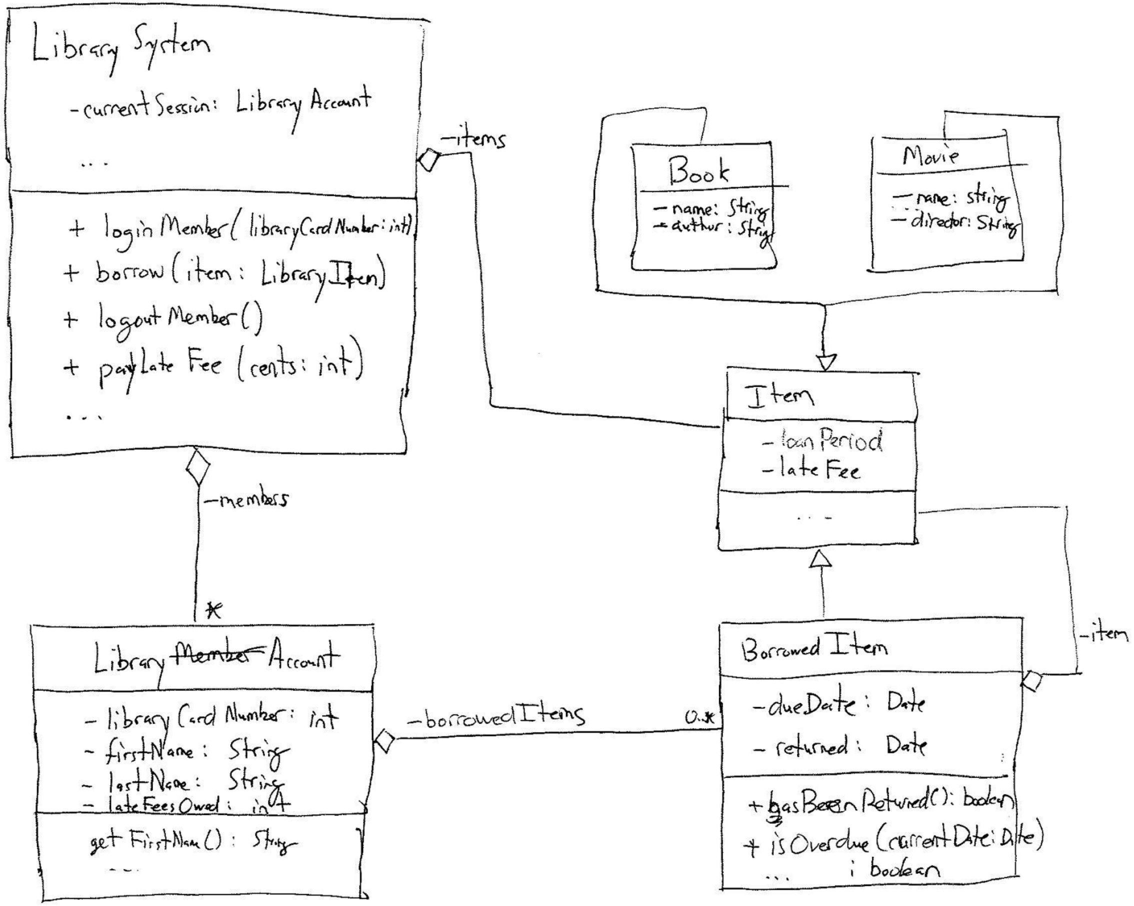
Object Diagrams

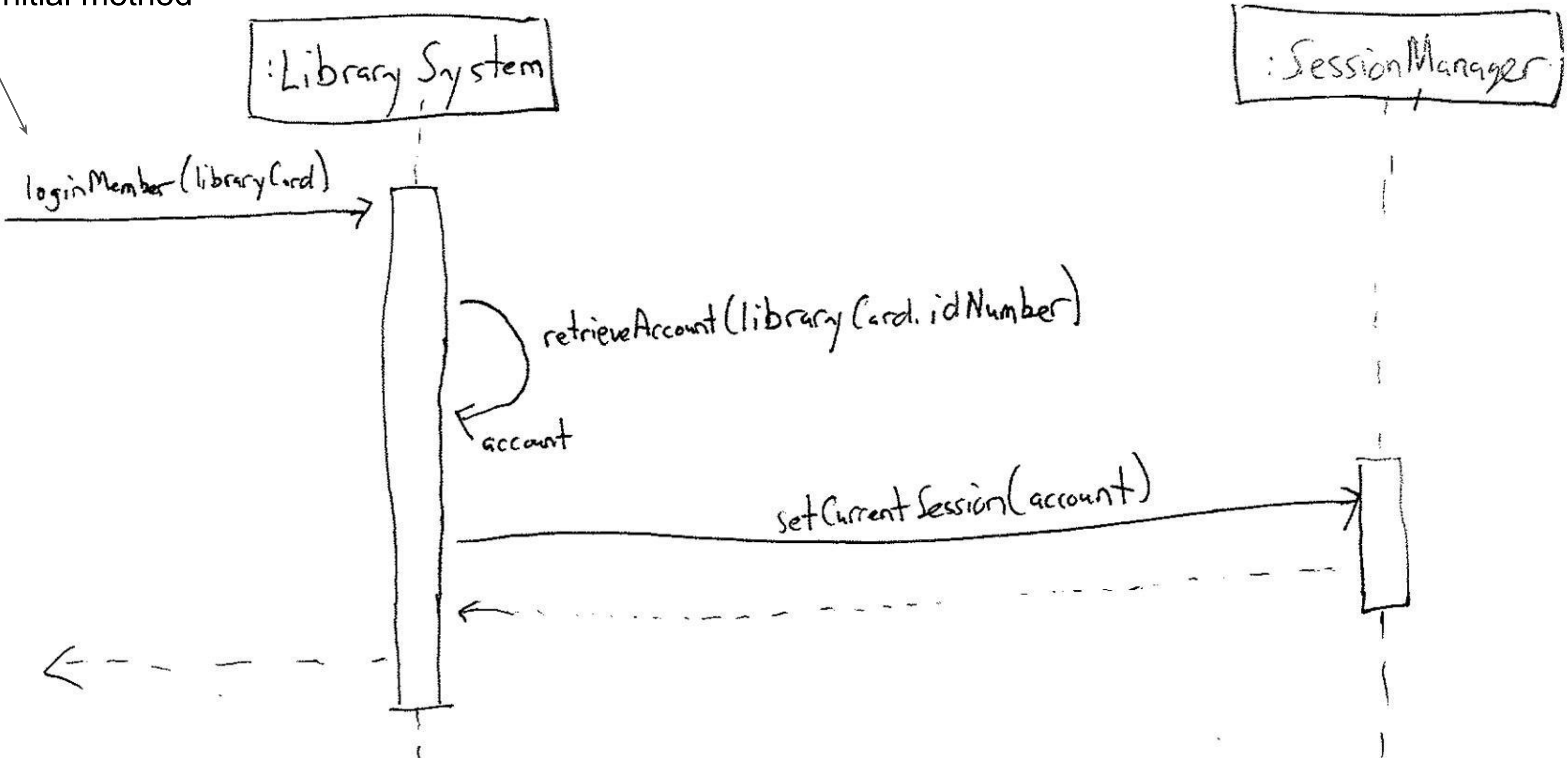
Objects/classes with fields and methods

Interfaces with methods

Associations, visibility, types



always start with
an initial method



Doing and Knowing *Responsibilities*

Responsibilities are related to the obligations of an object in terms of its behavior.

Doing responsibilities of an object include:

- doing something itself, such as creating an object or doing a calculation
- initiating action in other objects
- controlling and coordinating activities in other objects

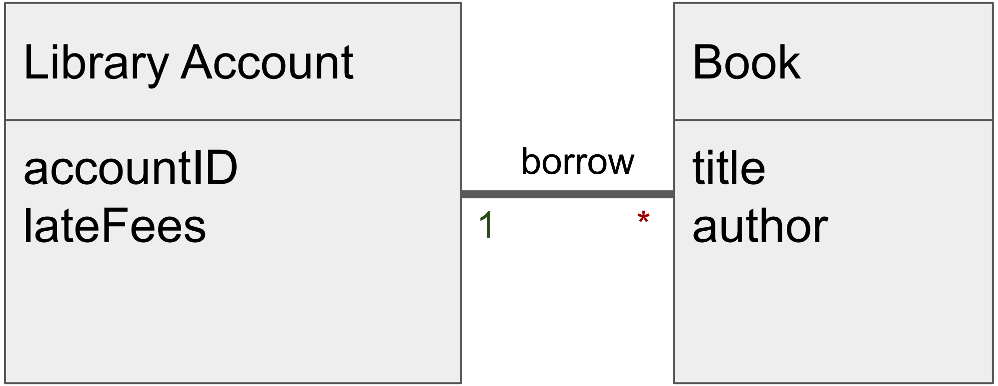
Knowing responsibilities of an object include:

- knowing about private encapsulated data
- knowing about related objects
- knowing about things it can derive or calculate

Low Representational Gap

Identified concepts provide inspiration for classes in the implementation

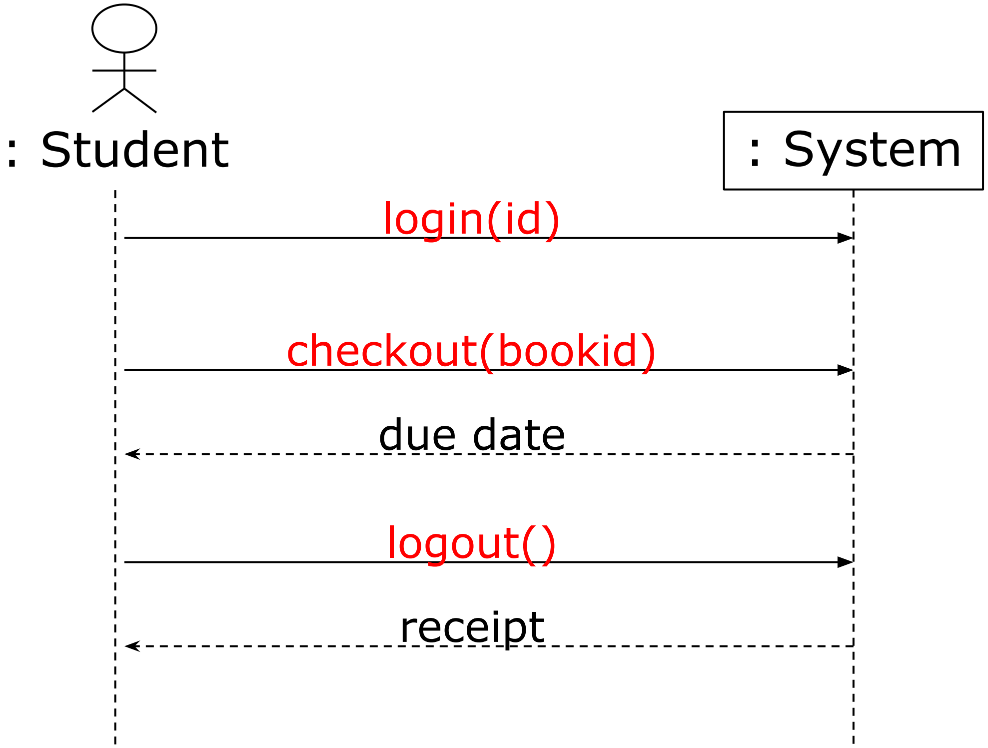
Classes mirroring domain concepts often intuitive to understand, rarely change (low representational gap)

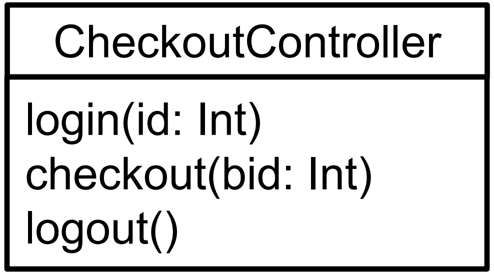



```
class LibraryDatabase {
    Map<Int, List<Int>>
        borrowedBookIds;
    Map<Int, Int> lateFees;
    Map<Int, String>
        bookTitles;
}
class DatabaseRow { … }
```

```java
class Shipment {
    private List<Box> boxes;
    int getWeight() {
        int w=0;
        for (Box box: boxes)
            for (Item item: box.getItems())
                w += item.weight;
        return w;
}
class Box {
    private List<Item> items;
    Iterable<Item> getItems() { return items;}
}
class Item {
    Box containedIn;
    int weight;
}
```

Which classes are coupled?
How can coupling be improved?


: Student
: System
login(id)
checkout(bookid)
due date
logout()
receipt


CheckoutController
login(id: Int)
checkout(bid: Int)
logout()

Anti-Pattern: God Object

```
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;
```

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

Information Expert -> "Do It Myself Strategy"

Expert usually leads to designs where a software object does those operations that are normally done to the inanimate real-world thing it represents

- a sale does not tell you its total; it is an inanimate thing

In OO design, all software objects are "alive" or "animated," and they can take on responsibilities and do things.

They do things related to the information they know.

Creator: Discussion of Design Goals/Principles

Promotes **low coupling**, **high cohesion**

- class responsible for creating objects it needs to reference
- creating the objects themselves avoids depending on another class to create the object

Promotes **evolvability** (design for change)

- Object creation is hidden, can be replaced locally

Contra: sometimes objects must be created in special ways

- complex initialization
- instantiate different classes in different circumstances
- *then **cohesion** suggests putting creation in a different object*: see *design patterns* such as builder, factory method

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

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

I Win!

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

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Design Patterns

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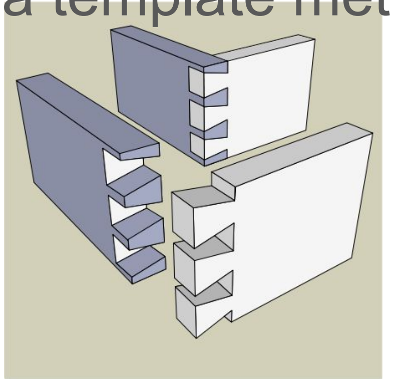
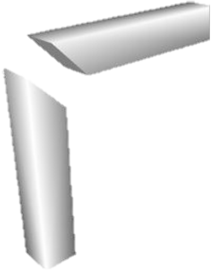
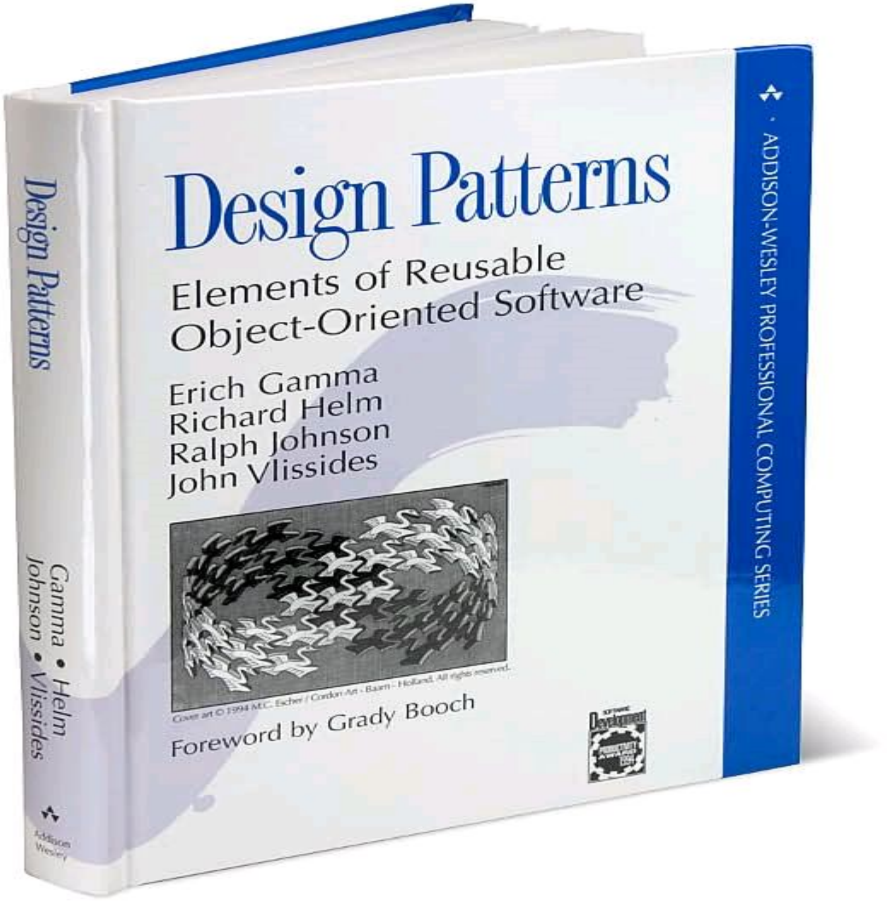
Discussion with design patterns

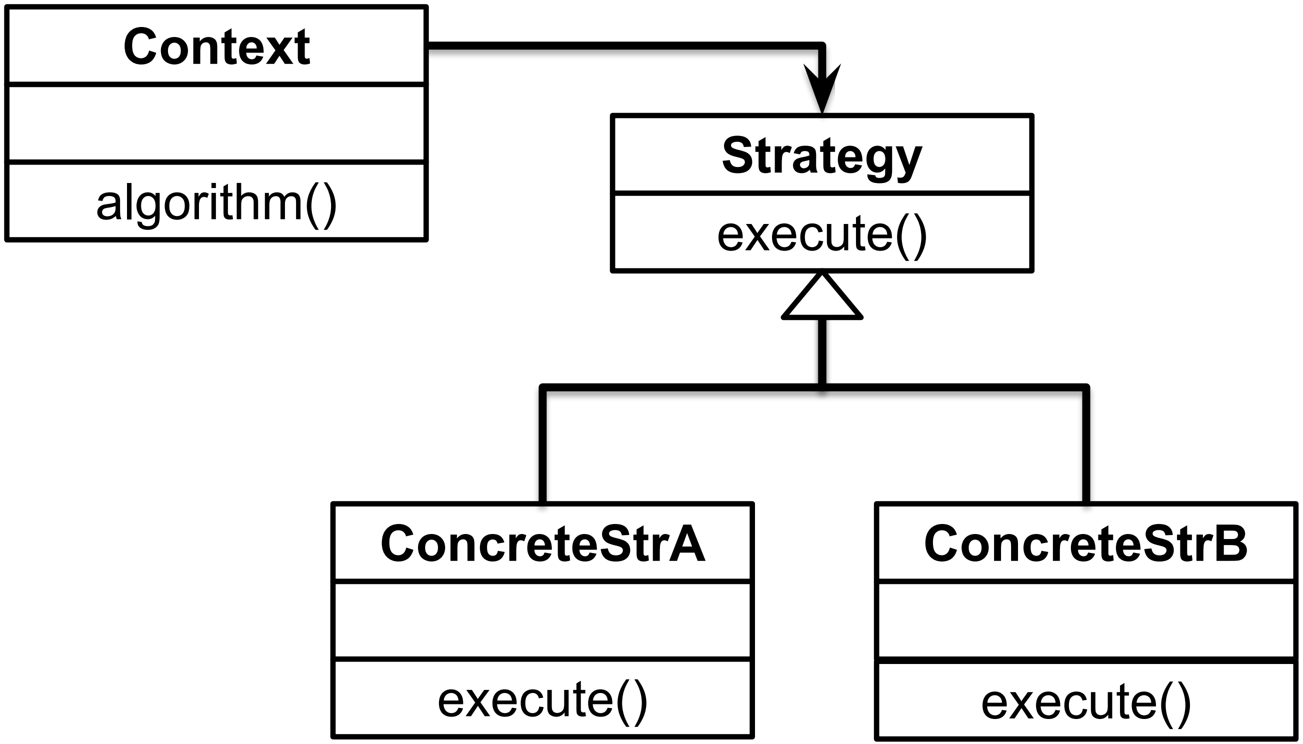
- Carpentry:
  - "Is a dovetail joint or a miter joint better here?"
- Software Engineering:
  - "Is a strategy pattern or a template method better here?"





History: *Design Patterns* (1994)




Context
algorithm()
Strategy
execute()
ConcreteStrA
execute()
ConcreteStrB
execute()

Module pattern: Decide what to export

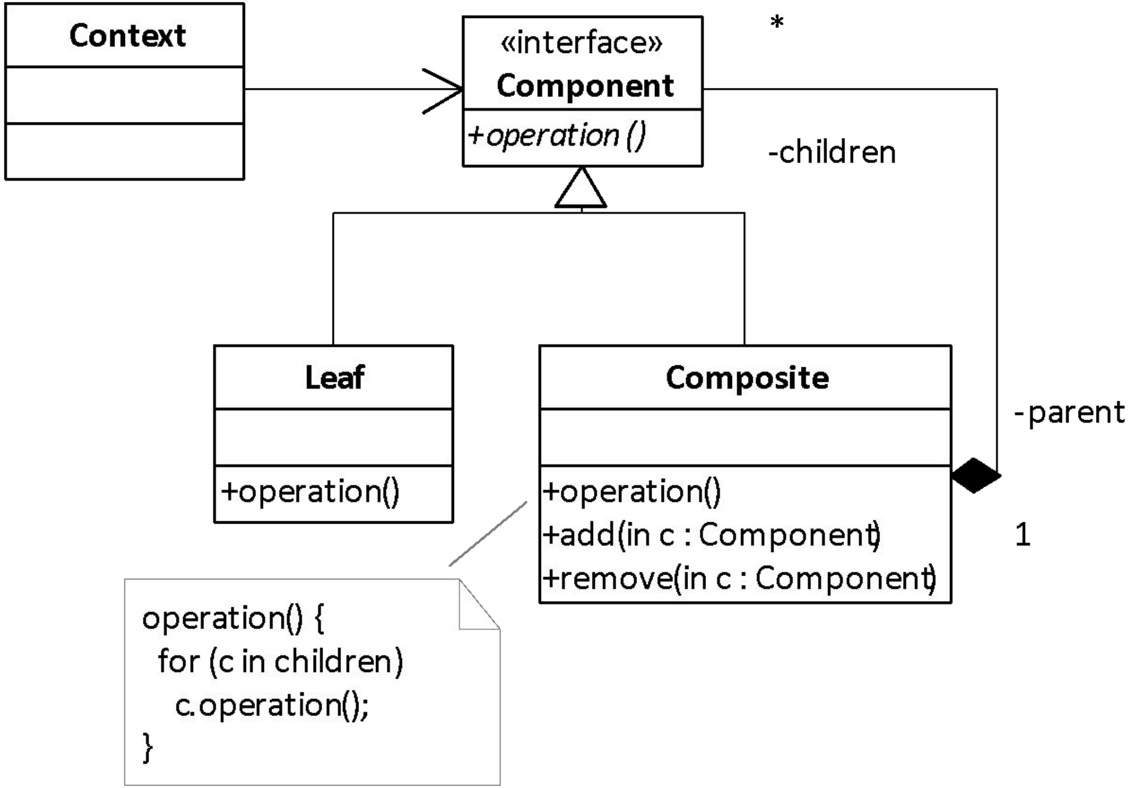
```
var MODULE = (function () {
    var my = {},
    privateVariable = 1;

    function privateMethod() {
        // ...
    }

    my.moduleProperty = 1;
    my.moduleMethod = function () {
        // ...
    };

    return my;
}());
```

The Composite Design Pattern



Principles of Software Construction: Objects, Design, and Concurrency

Inheritance and delegation

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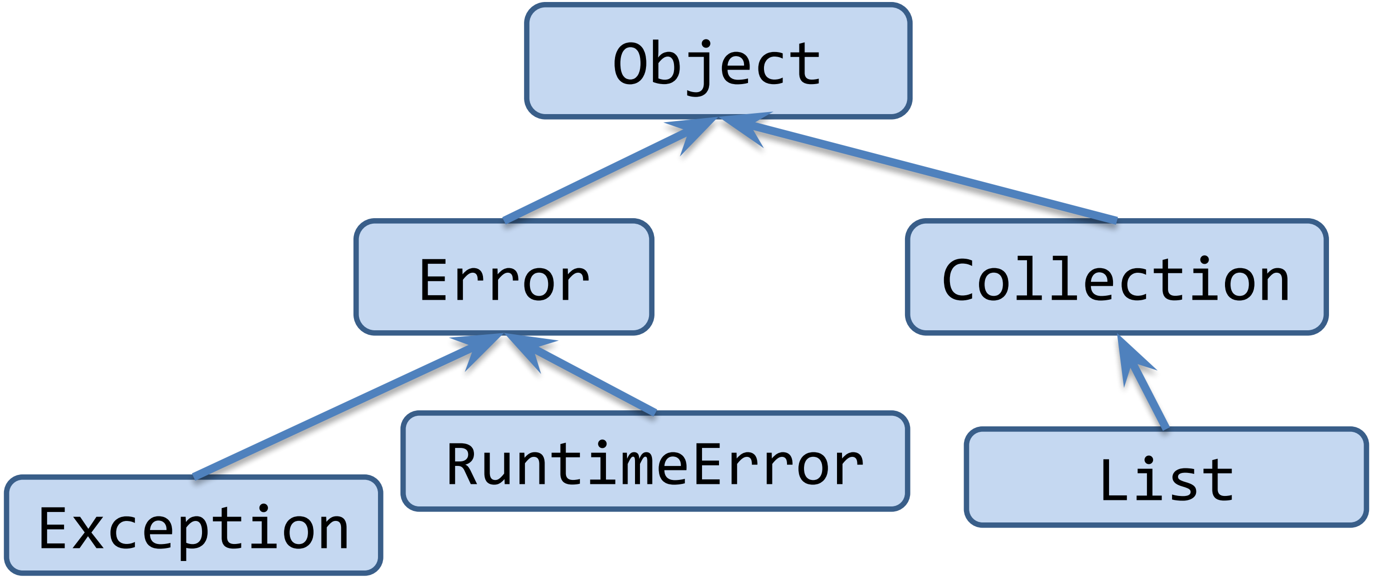
Class Hierarchy

In Java:



Behavioral Subtyping

- Formalizes notion of extension

```java
Animal dog = new Dog();
```

  - Roughly: anything an Animal does, a Dog should do
  - You should be able to use a subtype as if it was its parent
  - But, dog may be more specific

The **Liskov substitution principle:**
“Let q(x) be a property provable about objects x of type T. Then q(y) should be provable for objects y of type S where S is a subtype of T.”
Barbara Liskov

So why inheritance?

```
public interface PaymentCard {
   String getCardHolderName();
   BigInteger getDigits();
   Date getExpiration();
   int getValue();
   boolean pay(int amount);
}
```

```
class CreditCard implements PaymentCard {
   private final String cardHolderName;
   private final BigInteger digits;
   private final Date expirationDate;
   private final int creditLimit;
   private int currentCredit;

   public CreditCard(String cardHolderName,
         BigInteger digits, Date expirationDate,
         int creditLimit, int credit) {
      this.cardHolderName = cardHolderName;
      this.digits = digits;
      this.expirationDate = expirationDate;
      this.creditLimit = creditLimit;
      this.currentCredit = credit;
   }
```

Template Method 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.
   }
}
```

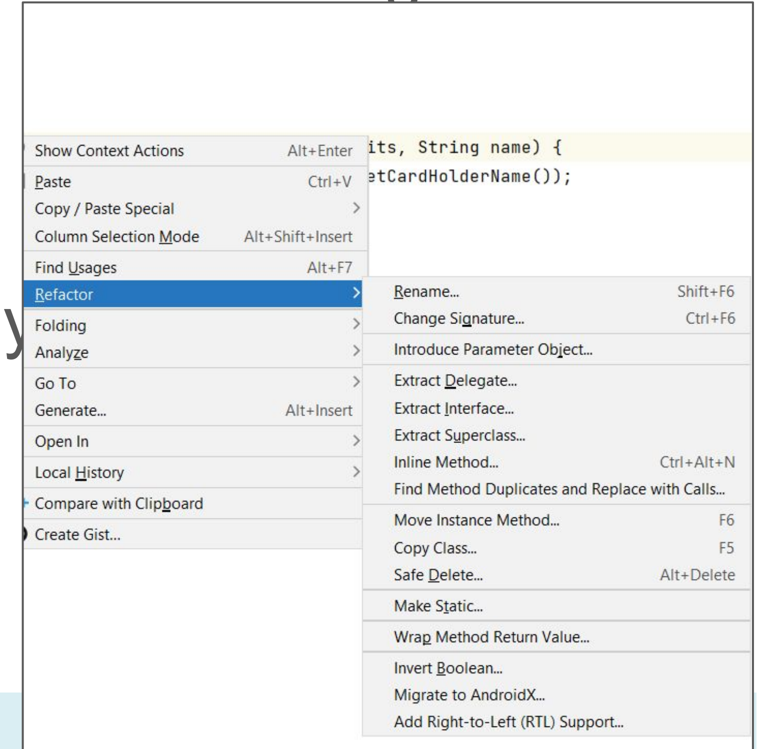
'Pay' is already implemented

Template Method vs. Strategy Pattern

- Template method uses inheritance to vary part of an algorithm
  - Template method implemented in supertype, primitive operations implemented in subtypes
- Strategy pattern uses delegation to vary the entire algorithm
  - Strategy objects are reusable across multiple classes
  - Multiple strategy objects are possible per class

Refactoring

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



Principles of Software Construction: Objects, Design, and Concurrency

Refactoring & Anti-patterns

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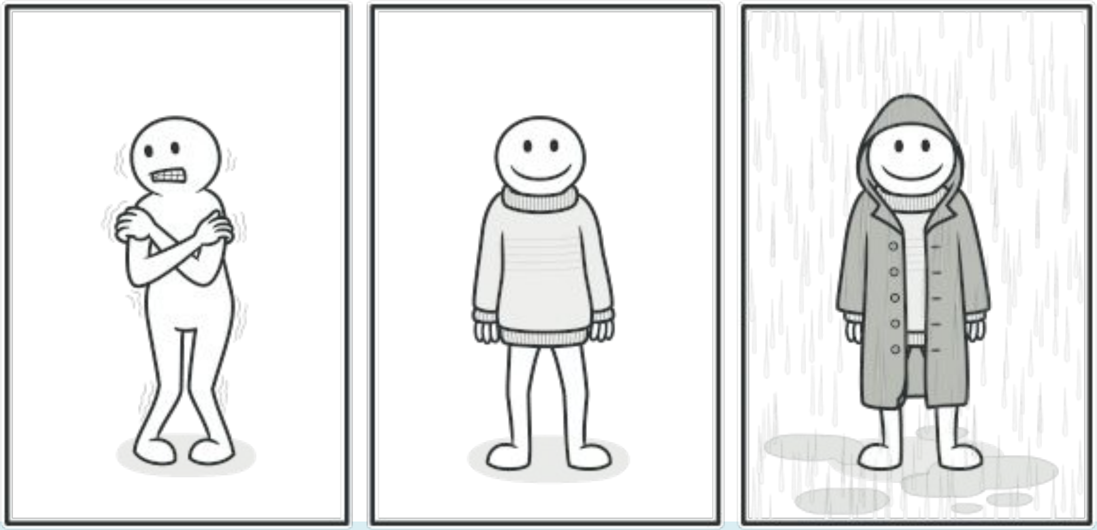
The Decorator Pattern

You have a complex drawing that consists of many shapes and want to save it. Some logic of the saving functionality is always the same (e.g., going through all shapes, reducing them to drawable lines), but others you want to vary to support saving in different file formats (e.g., as png, as svg, as pdf). You want to support different file formats later.

Why is this not:



https://refactoring.guru/design-patterns/decorator

This binding

```
class Parent {
   private int i;
   public Parent() {
       this.i = 5;
   }

   void print() {
       System.out.println(this.i);
   }
}

class Child extends Parent {
   private int i;
   public Child() {
       this.i = 7;
   }
}
```

```
Child m = new Child();

System.out.println(m.i);

m.print();
```

Details: type-casting

- Sometimes you want a different type than you have
  - e.g., `double pi = 3.14;`
    `int indianaPi = (int) pi;`

In TS:
```
(dog as Animal).identify()
```

- Useful if you know you have a more specific subtype:

```
Account acct = …;
CheckingAccount checkingAcct = (CheckingAccount) acct;
long fee = checkingAcct.getFee();
```

  - Will get a `ClassCastException` if types are incompatible
- Advice: avoid downcasting types
  - Never(?) downcast within superclass to a subclass

Anti-patterns

- Zooming in: common code smells
  - Not necessarily bad, but worthwhile indicators to check
    - When problematic, often point to design problems
  - Long methods, large classes, and the likes. Suggests bad abstraction
    - Tend to evolve over time; requires restructuring
  - Inheritance despite low coupling (“refused bequest”)
    - Replace with delegation, or rebalance hierarchy
  - ‘instanceof’ (or ‘switch’) instead of polymorphism
  - Overly similar classes, hierarchies
  - Any change requires lots of edits
    - High coupling across classes (“shotgun surgery”), or heavily entangled implementation (intra-class)

HW4: Refactoring of Static Website Generator

Principles of Software Construction: Objects, Design, and Concurrency

Asynchrony and Concurrency

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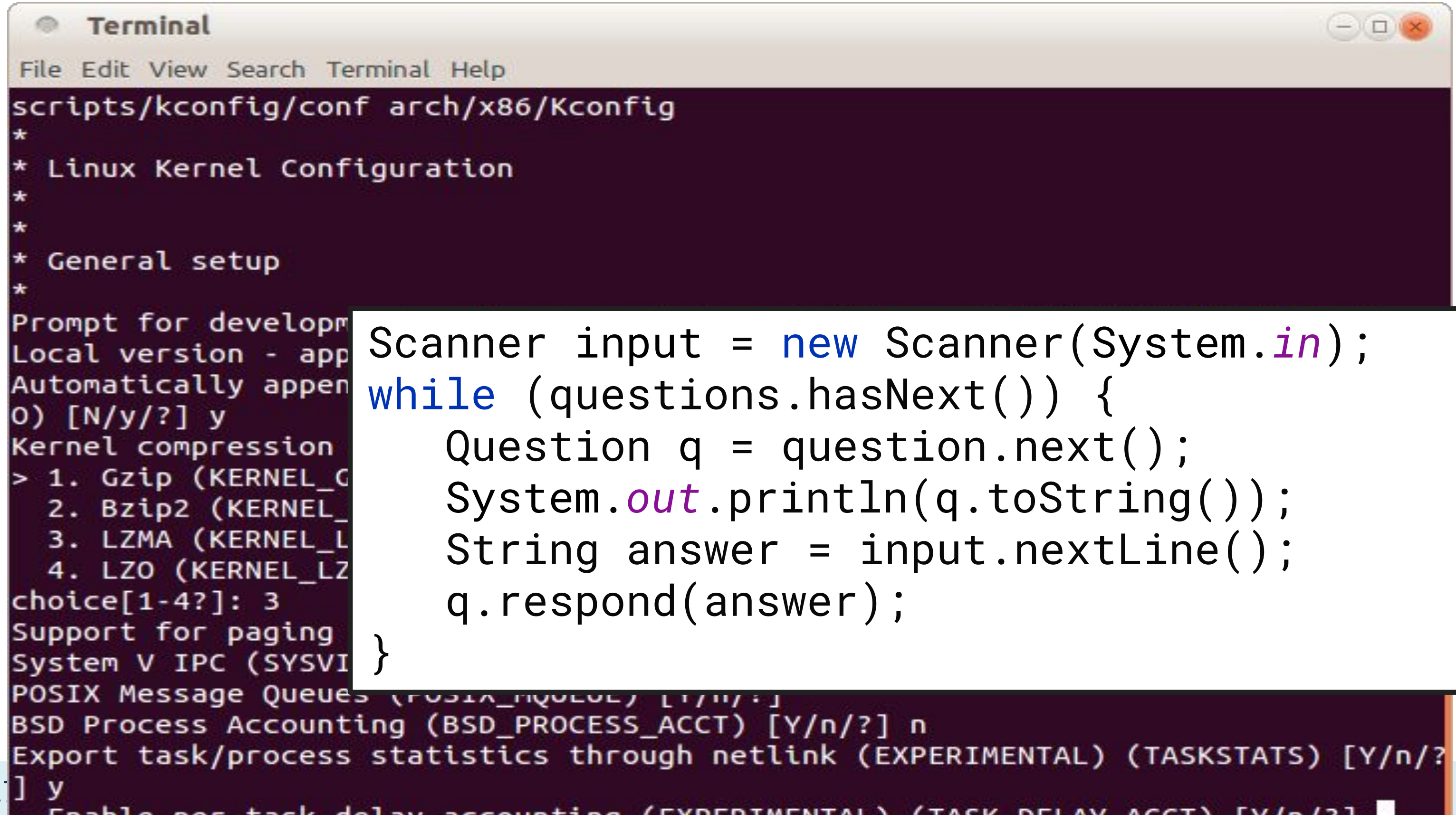
Interaction with CLI




```java
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);
}
```

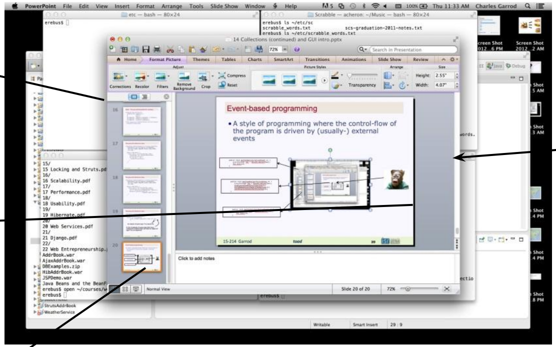
Event-based programming

- 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)
}
```



Concurrency with file I/O

Asynchronous code requires Promises

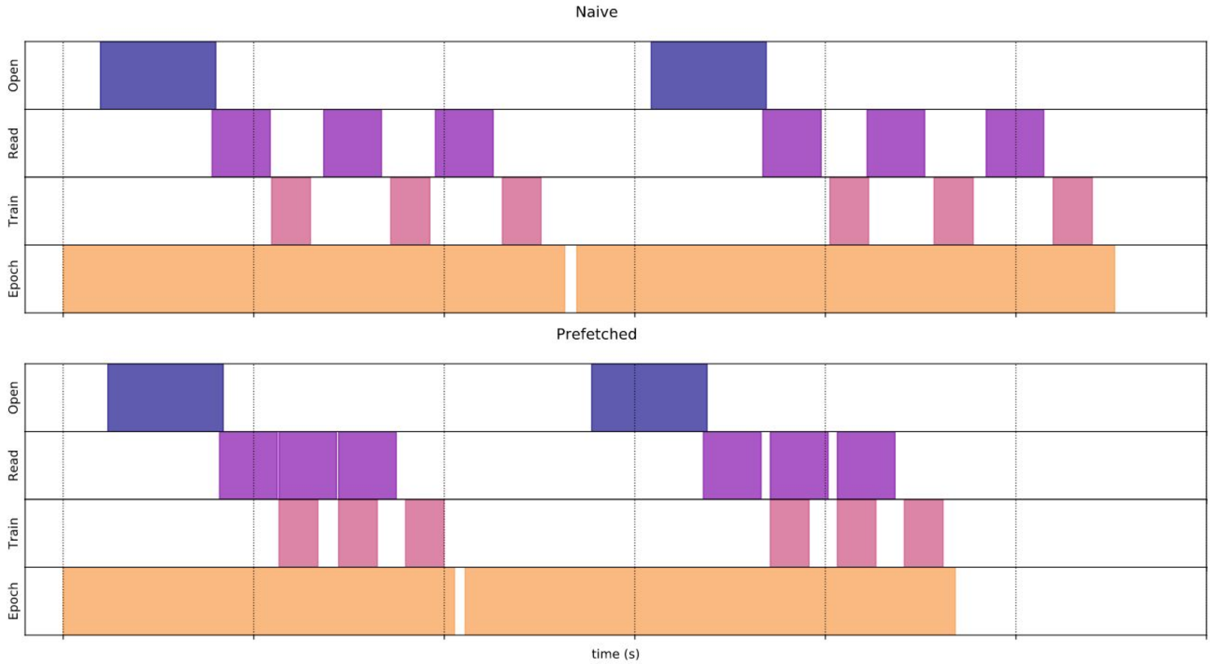
- Captures an intermediate state
  - Neither fetched, nor failed: we'll find out eventually

```
let imageToBe: Promise<Image> = fetch('myImage.png');
imageToBe.then((image) => display(image))
         .catch((err) => console.log('aw: ' + err));
```

Concurrency with file I/O

An example from Machine Learning

Different devices:



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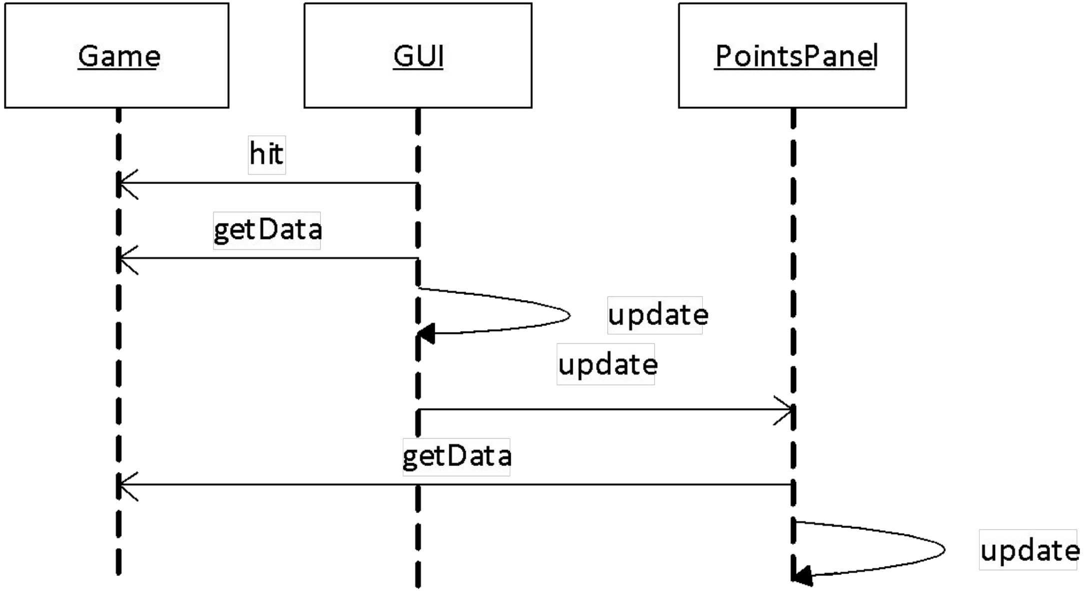
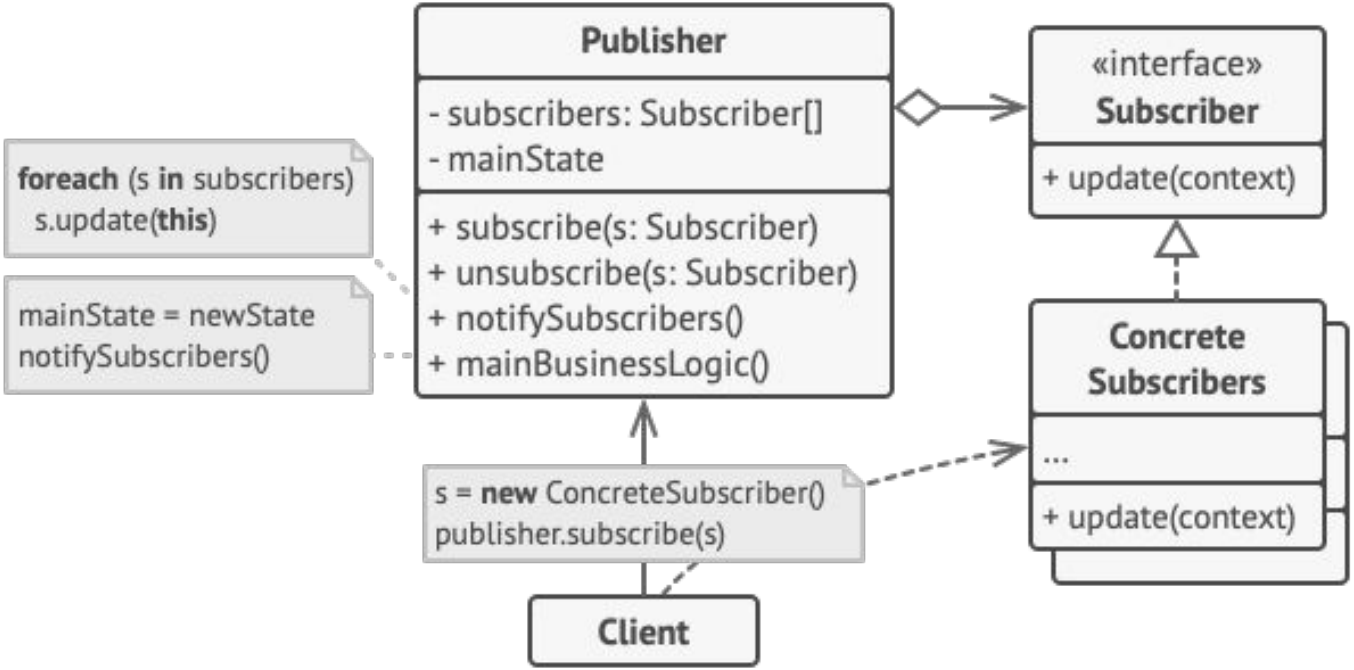
A GUI design challenge, extended

- What if we want to show the points won?

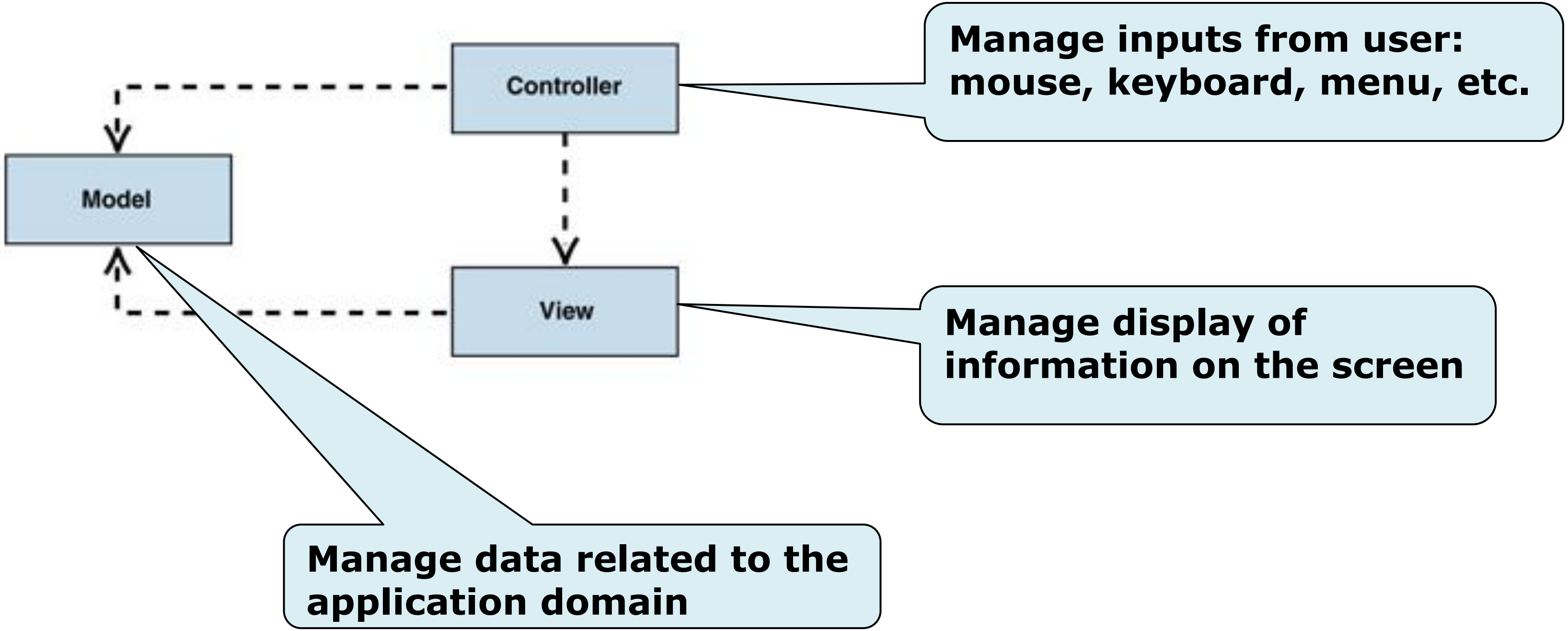


Recall the Observer



https://refactoring.guru/design-patterns/observer

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



Principles of Software Construction: Objects, Design, and Concurrency

Basic GUI concepts, HTML

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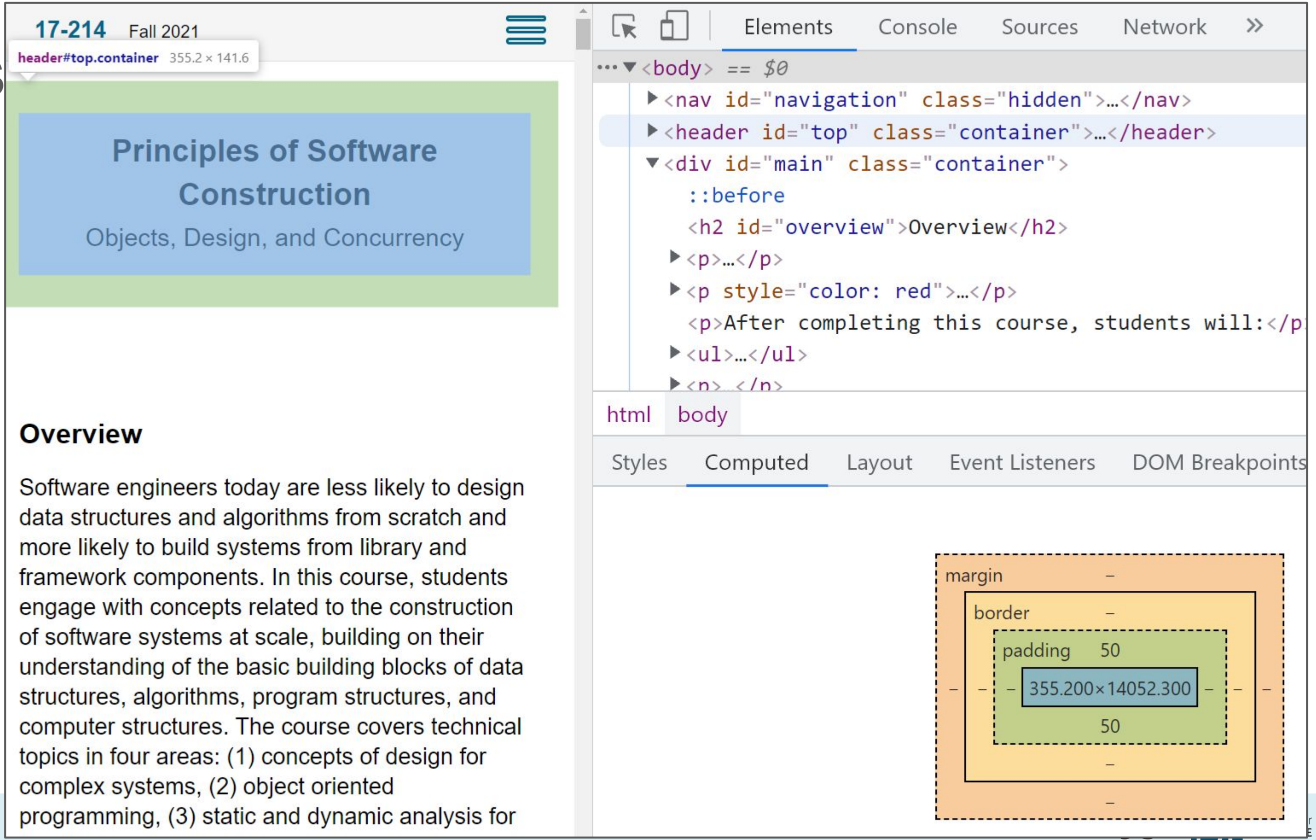
Anatomy of an HTML Page

Nested elements

- Sizing
- Attributes
- Text



The composite pattern

- Problem: Collection of objects has behavior similar to the individual objects
- Solution: Have collection of objects and individual objects implement the same interface
- Consequences:
  - Client code can treat collection as if it were an individual object
  - Easier to add new object types
  - Design might become too general, interface insufficiently useful

A few Tags

- <html>
  - The root of the visible page
- <head>
  - Stores metadata, imports
- <p>
  - A paragraph
- [<button>]
  - Attributes include `name`, `type`, `value`
- <div>
  - Generic section -- very useful
- <table>
  - The obvious
- Many more; dig into a real page!

Style: CSS

- Cascading Style Sheets
  - Reuse: styling rules for tags, classes, types
  - Reuse: not just at the leafs!

```
<span style="font-weight:bold">Hello again!</span>
```

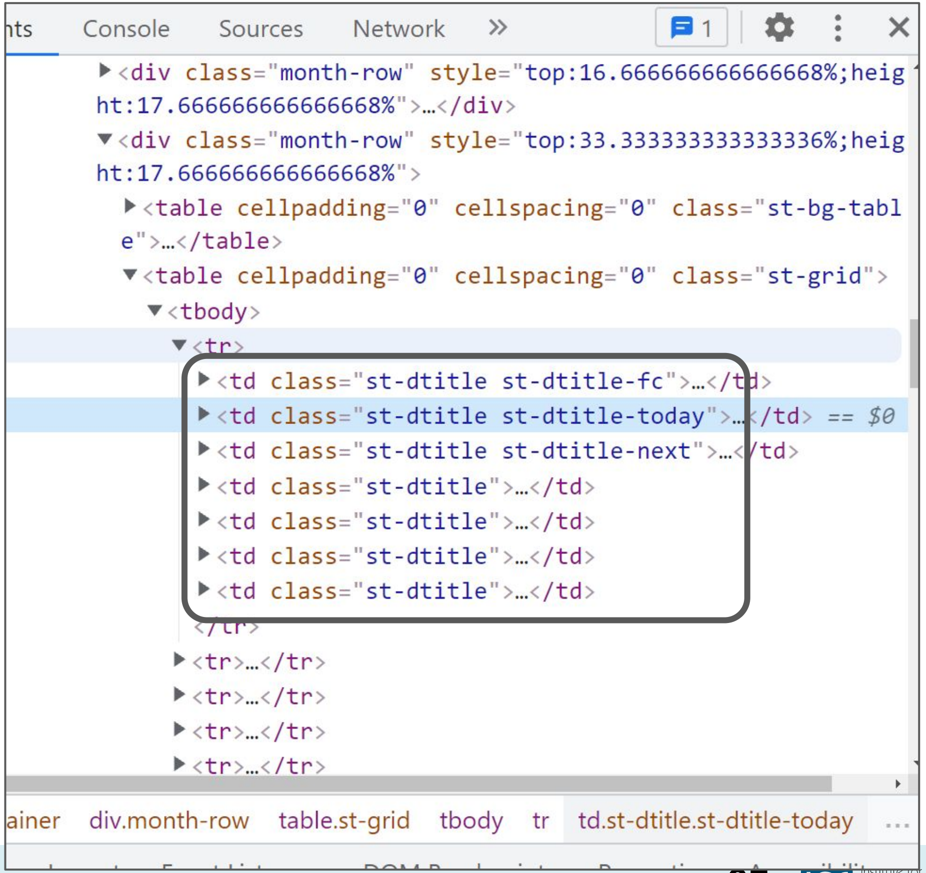
vs.

```
<style type="text/css">
    span {
        font-family: arial
    }
</style>
```

Strategy or Observer?

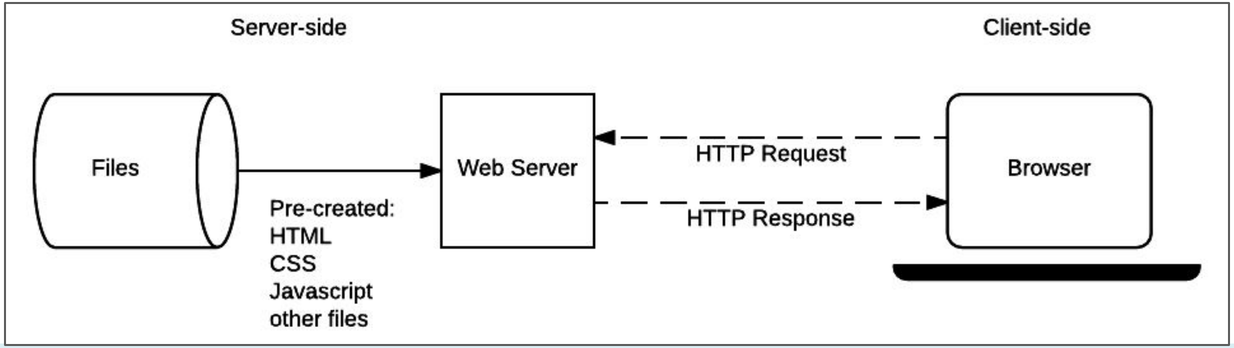
Either could apply

- Both involve callback
- Strategy:
  - Typically single
  - Often involves a return
- Observer:
  - Arbitrarily many
  - Involves external updates



Static Web Pages

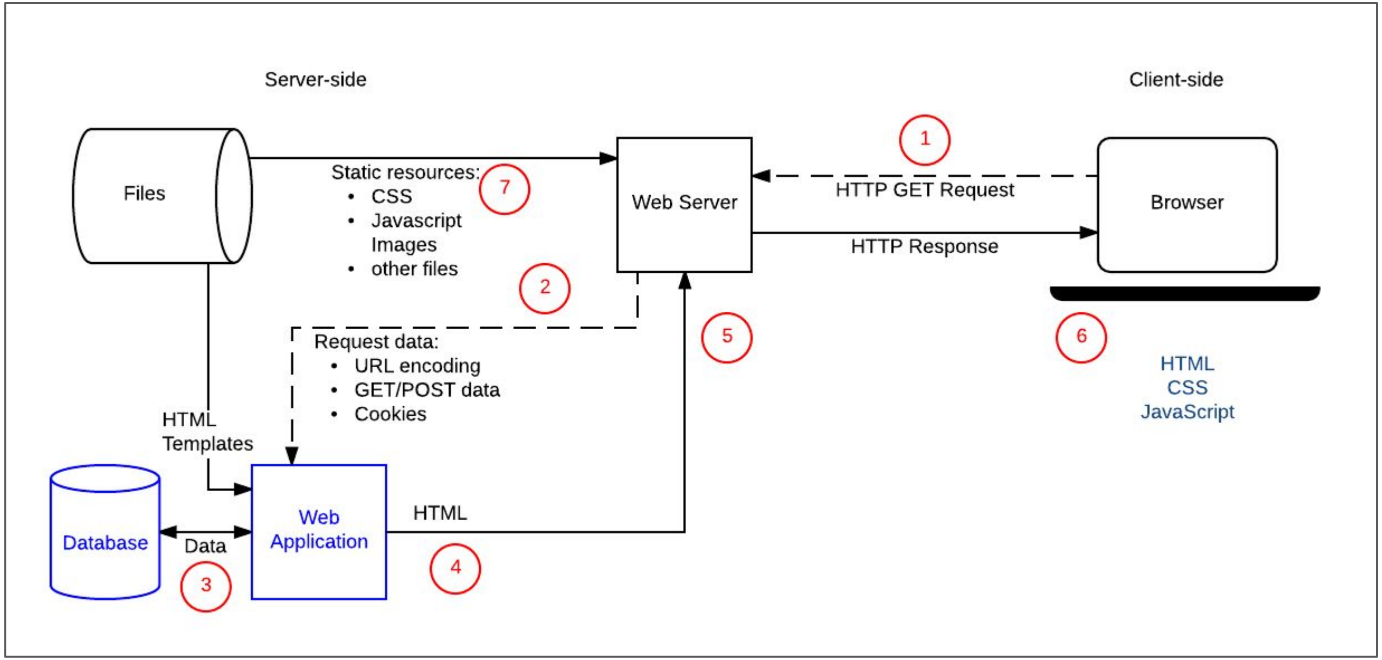
- Delivered as-is, final
  - Consistent, often fast
  - Cheap, only storage needed
- “Static” a tad murky with JavaScript
  - We can still have buttons, interaction
  - But it won’t “go” anywhere -- the server is mum



https://developer.mozilla.org/en-US/docs/Learn/Server-side/First_steps/Client-Server_overview#anatomy_of_a_dynamic_request

Web Servers

Dynamic sites can do more *work*



https://developer.mozilla.org/en-US/docs/Learn/Server-side/First_steps/Client-Server_overview#anatomy_of_a_dynamic_request

Principles of Software Construction: Objects, Design, and Concurrency

Concurrency: Safety & Immutability

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Components of a Swing application

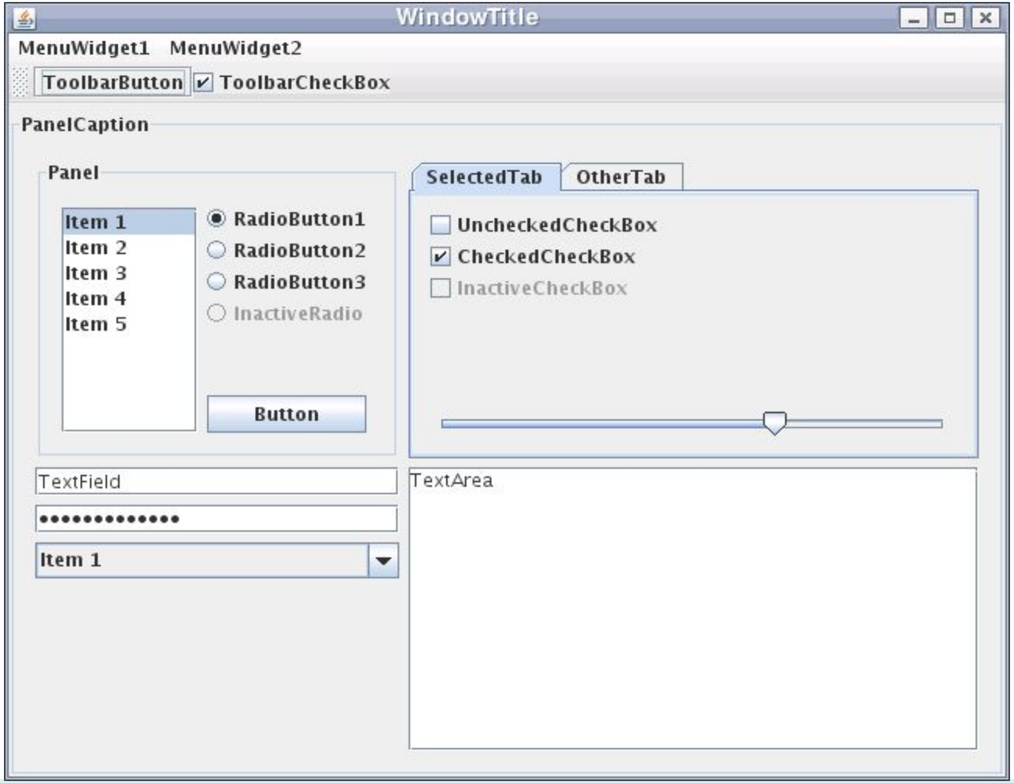
JFrame

JPanel

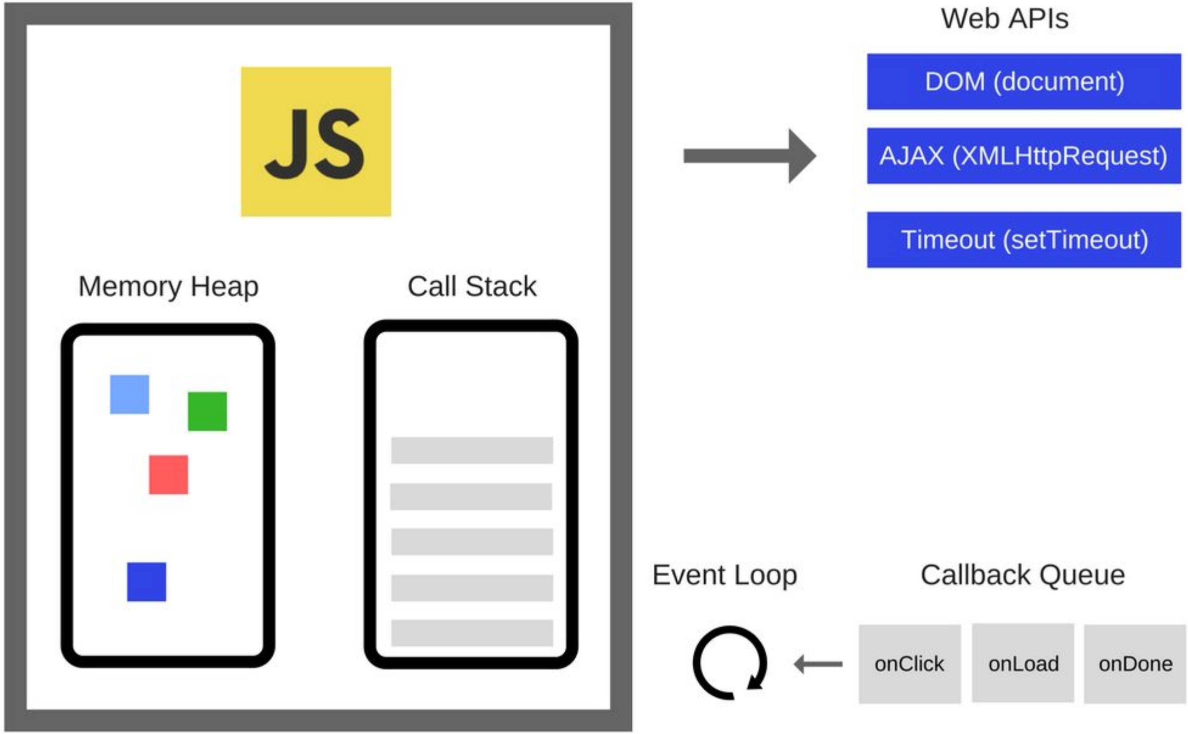
JButton

JTextField

…



Event Loop in JS



https://blog.sessionstack.com/how-javascript-works-event-loop-and-the-rise-of-async-programming-5-ways-to-better-coding-with-2f077c4438b5

What will Happen:

Where does this fail?

What if single threaded?

Could we make it work with 2 threads?

```java
public class Synchronization {
    static long balance1 = 100;
    static long balance2 = 100;

    public static void main(String[] args) throws InterruptedException {
        Thread thread1 = new Thread(Synchronization::from1To2);
        Thread thread2 = new Thread(Synchronization::from2To1);

        thread1.start(); thread2.start();
        thread1.join(); thread2.join();
        System.out.println(balance1 + ", " + balance2);
    }

    private static void from1To2() {
        for (int i = 0; i < 10000; i++) {
            balance1 -= 100;
            balance2 += 100;
        }
    }

    private static void from2To1() {
        for (int i = 0; i < 10000; i++) {
            balance2 -= 100;
            balance1 += 100;
        }
    }
}
```

Ensuring Immutability

- Don’t provide any mutators
- Ensure that no methods may be overridden
- Make all fields final
- Make all fields private
- Ensure security of any mutable components

Making a Class Immutable

```
public final class Complex {
    private final double re, im;

    public Complex(double re, double im) {
        this.re = re;
        this.im = im;
    }

    // Getters without corresponding setters
    public double getRealPart()      { return re; }
    public double getImaginaryPart() { return im; }

    // subtract, multiply, divide similar to add
    public Complex add(Complex c) {
        return new Complex(re + c.re, im + c.im);
    }
```

Shared State

- *Volatile* fields always return the most recently written value
  - Does <u>not</u> guarantee atomicity
  - Useful if only one thread writes
- Are atomicity + coordinated communication sufficient for thread safety?

Principles of Software Construction: Objects, Design, and Concurrency

Concurrency: Patterns & Promises

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Design Goals

- What are we looking for in design?
  - Reuse
  - Readability
  - Robustness
  - Extensibility
  - Performance
  - ...

A simple function

...in sync world

How to make this asynchronous?

- What needs to “happen first”?
- What is the control-flow in callback world?

```
function copyFileSync(source: string, dest: string) {
    // Stat dest.
    try {
        fs.statSync(dest);
    } catch {
        console.log("Destination already exists")
        return;
    }

    // Open source.
    let fd;
    try {
        fd = fs.openSync(source, 'r');
    } catch {
        console.log("Destination already exists")
        return;
    }

    // Read source.
    let buff = Buffer.alloc(1000)
    try {
        fs.readSync(fd, buff, 0, 0, 1000);
    } catch (_) {
        console.log("Could not read source file")
        return;
    }

    // Write to dest.
    try {
        fs.writeFileSync(dest, buff)
    } catch (_) {
        console.log("Failed to write to dest")
    }
```

Next Step: Async/Await

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

```
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
    }
```

The Promise Pattern

- Problem: one or more values we will need will arrive later
  - At some point we must wait
- Solution: an abstraction for *expected values*
- Consequences:
  - Declarative behavior for when results become available (*conf.* callbacks)
  - Need to provide paths for normal and abnormal execution
    - E.g., then() and catch()
  - May want to allow combinators
  - Debugging requires some rethinking

Generator Pattern

- Problem: process a collection of indeterminate size
- Solution: provide data points on request when available
- Consequences:
  - Each call to ‘next’ is like awaiting a promise
  - A generator can be infinite, and can announce if it is complete.
  - Generators can be *lazy*, only producing values on demand
    - Or producing promises
- Where might this be useful?

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;
}
```

```java
List<String>results = stream.map(Object::toString)
                .filter(s -> pattern.matcher(s).matches())
                .collect(Collectors.toList());
```

```java
int sum = numbers.parallelStream().reduce(0, Integer::sum);
```

```javascript
for (let [odd, even] in numbers.split(n => n % 2, n => !(n % 2)).zip()) {
    console.log(`odd = ${odd}, even = ${even}`);  // [1, 2], [3, 4], ...
 }
```

```javascript
Stream(people).filter({age: 23}).flatMap("children").map("firstName")
   .distinct().filter(/a.*/i).join(", ");
```

HW5: Santorini with God Cards and GUI

Principles of Software Construction: Objects, Design, and Concurrency

Events Everywhere

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Travis CI

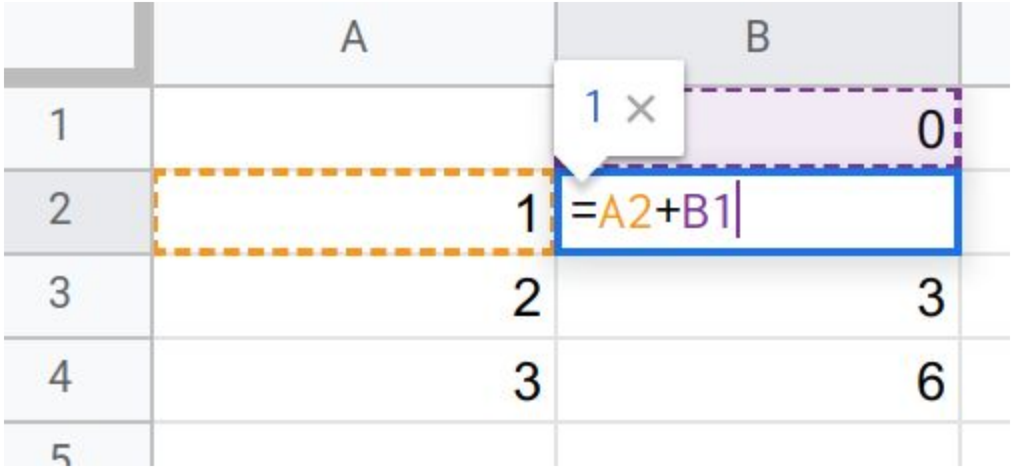
Immutable?

```
class Stack {
    readonly #inner: any[]
    constructor (inner: any[]) {
        this.#inner=inner
    }
    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
    }
}
```

Useful analogy: Spreadsheets

Cells contain data or formulas

Formula cells are computed automatically whenever input data changes

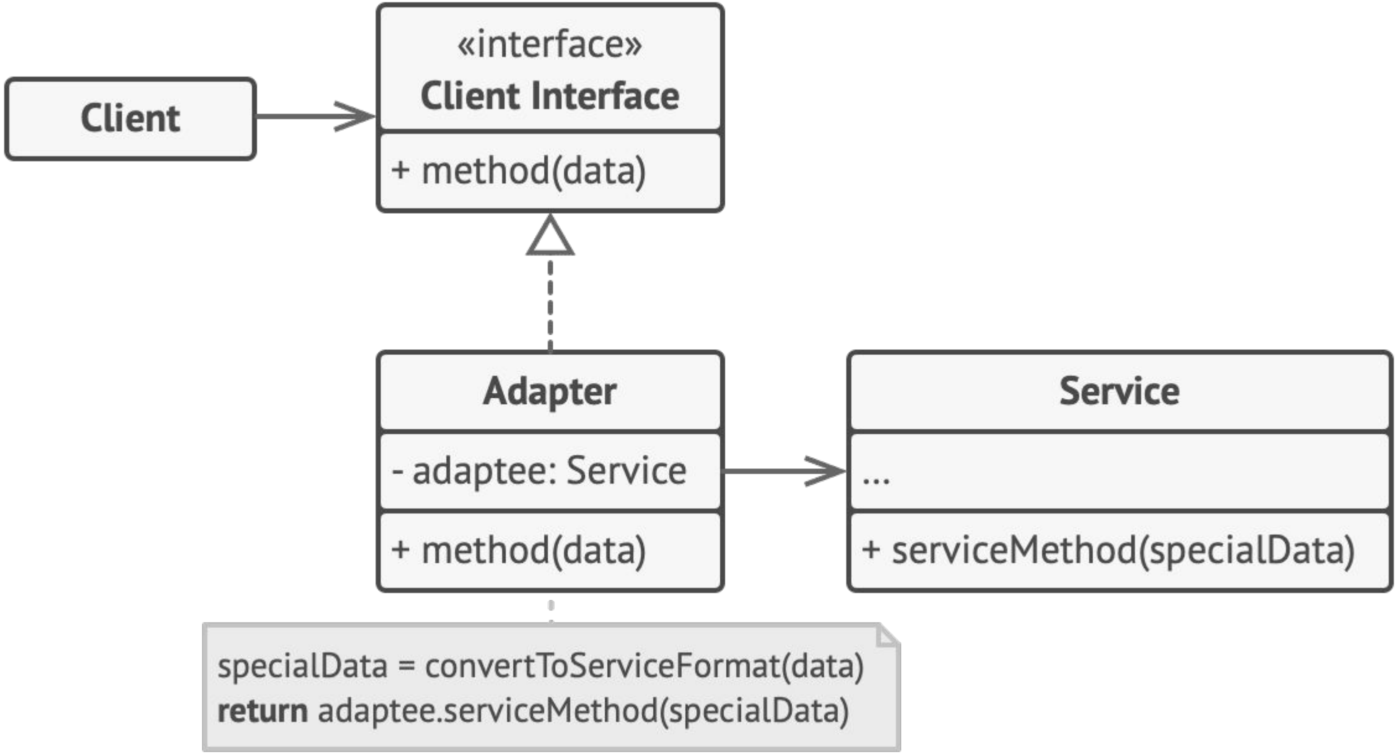


Beyond Spreadsheet Cells

	SINGLE	MULTIPLE
Pull	`Function`	`Iterator`
Push	`Promise`	`Observable`

https://rxjs.dev/guide/observable

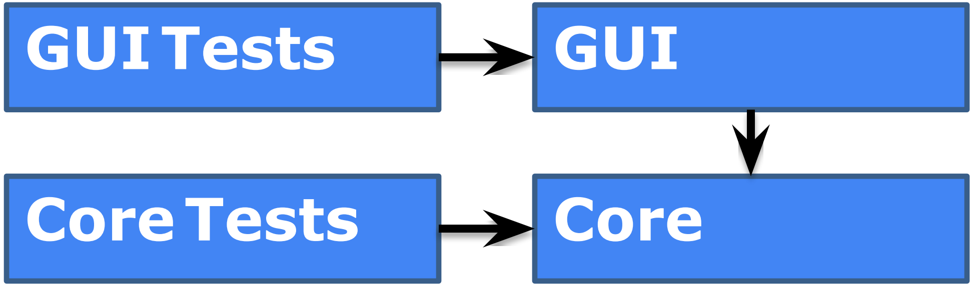
The *Adapter* Design Pattern



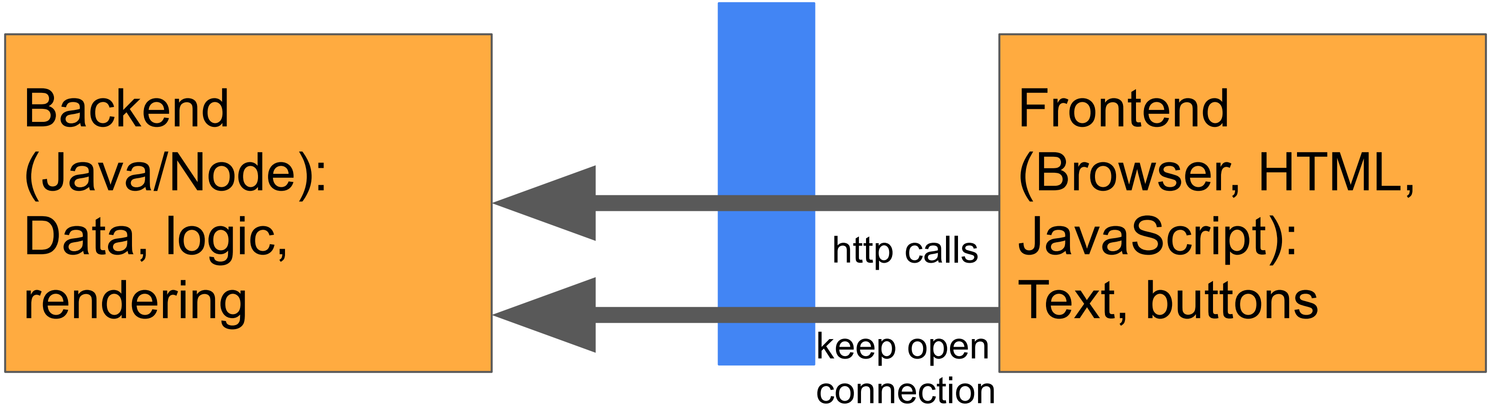
https://refactoring.guru/design-patterns/adapter

Recall: Separating application core and GUI

- Reduce coupling: do not allow core to depend on UI
- Create and test the core without a GUI
    - Use the Observer pattern to communicate information from the core (Model) to the GUI (View)



Client-Server Programming forces Frontend-Backend Separation



Trick to let backend push information to frontend: Keep http request open, append to page (compare to stream)
Alternative: regular pulling

Principles of Software Construction: Objects, Design, and Concurrency

Libraries and Frameworks

(Design for large-scale reuse)

~~Christian Kästner~~ ~~Vincent Hellendoorn~~
Michael Hilton

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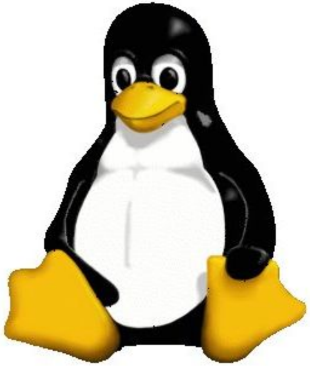
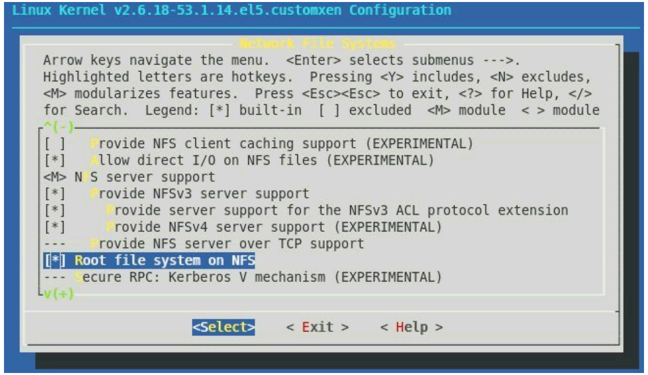
Where we are

	Small scale: One/few objects	*Mid scale:* Many objects	*Large scale:* Subsystems
Design for understanding change/ext. reuse robustness ...	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

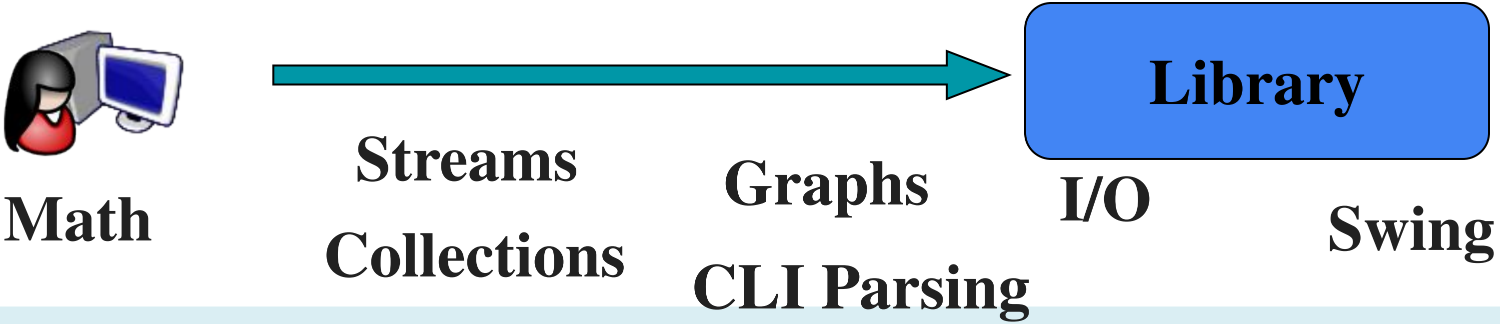
Reuse and variation: Flavors of Linux





Terminology: Libraries

- Library: A set of classes and methods that provide reusable functionality



Terminology: Frameworks

- Framework: Reusable skeleton code that can be customized into an application
- Framework calls back into client code
  - The Hollywood principle: “Don’t call us. We’ll call you.”

```
public MyWidget extends JContainer {

ublic 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

Framework

IntelliJ **Firefox** **Swing**

Express **NanoHttpd** **Spring**

An aside: Plugins could be reusable too…

```java
public class Application extends JFrame implements InputProvider {
  private JTextField textField;
  private Plugin plugin;
  public Application() { }
  protected void init(Plugin p) {
      p.setApplication(this);
      this.plugin = p;
```

```java
public interface Plugin {
    String getApplicationTitle();
    String getButtonText();
    String getInititalText();
    void buttonClicked() ;
    void setApplication(InputProvider app);
```

```java
public class CalcPlugin implements Plugin {
  private InputProvider app;
  public void setApplication(InputProvider app) 
  public String getButtonText() { return "calcul
  public String getInititalText() { return "10 / 2 + 6"; }
  public void buttonClicked() {
      JOptionPane.showMessageDialog(null, "The result of "
              + application.getInput() + " is "
              + calculate(application.getInput()));
  }
  public String getApplicationTitle() { return "My Great Calculator"; }
```

```java
public interface InputProvider {
    String getInput();
}
```

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

Principles of Software Construction

API Design

Christian Kästner Vincent Hellendoorn
(Many slides originally from Josh Bloch)

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Composing Templates

(Corresponds to Fragments in Handlebars)

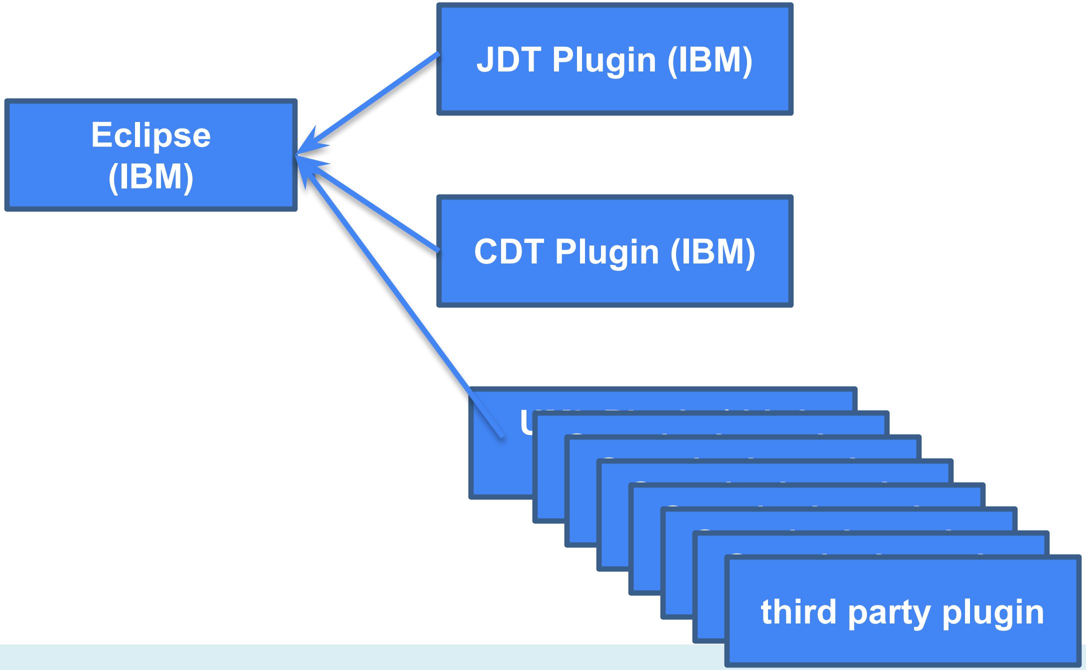
Nest templates

Pass arguments (properties) between templates

Try it:
https://reactjs.org/redirect-to-codepen/components-and-props/composing-components

```
function Welcome(props) {
  return <h1>Hello, {props.name}</h1>;
}
function App() { return (
    <div>
     <Welcome name="Sara" />
     <Welcome name="Edite" />
   </div>
  );}
ReactDOM.render(
  <App />,
  document.getElementById('root')
);
```

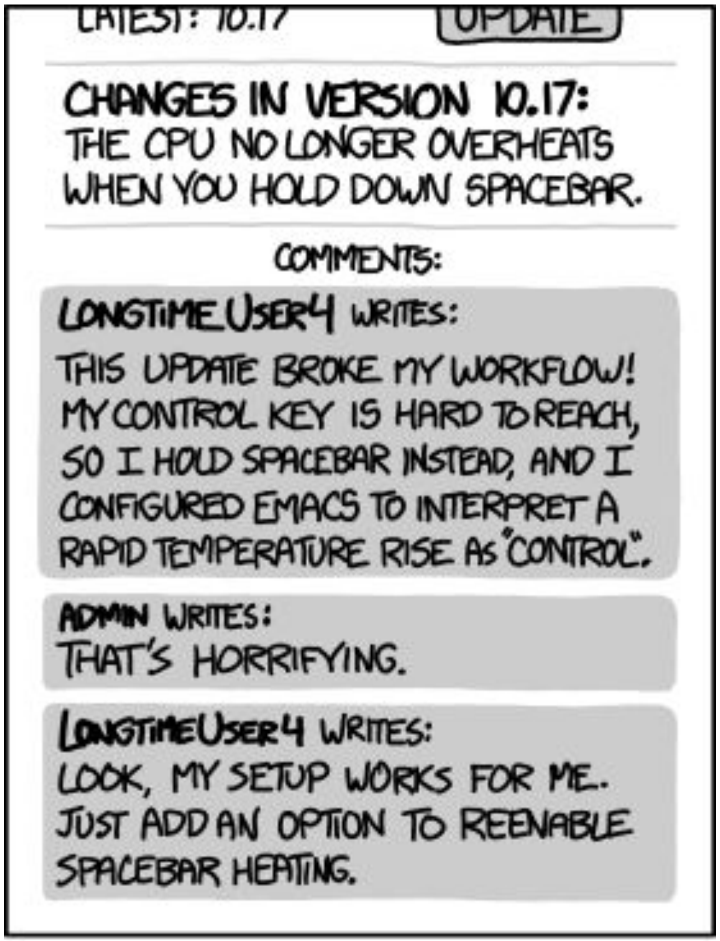
Public APIs are forever



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/



EVERY CHANGE BREAKS SOMEONE'S WORKFLOW.

https://xkcd.com/1172/

The process of API design – 1-slide version

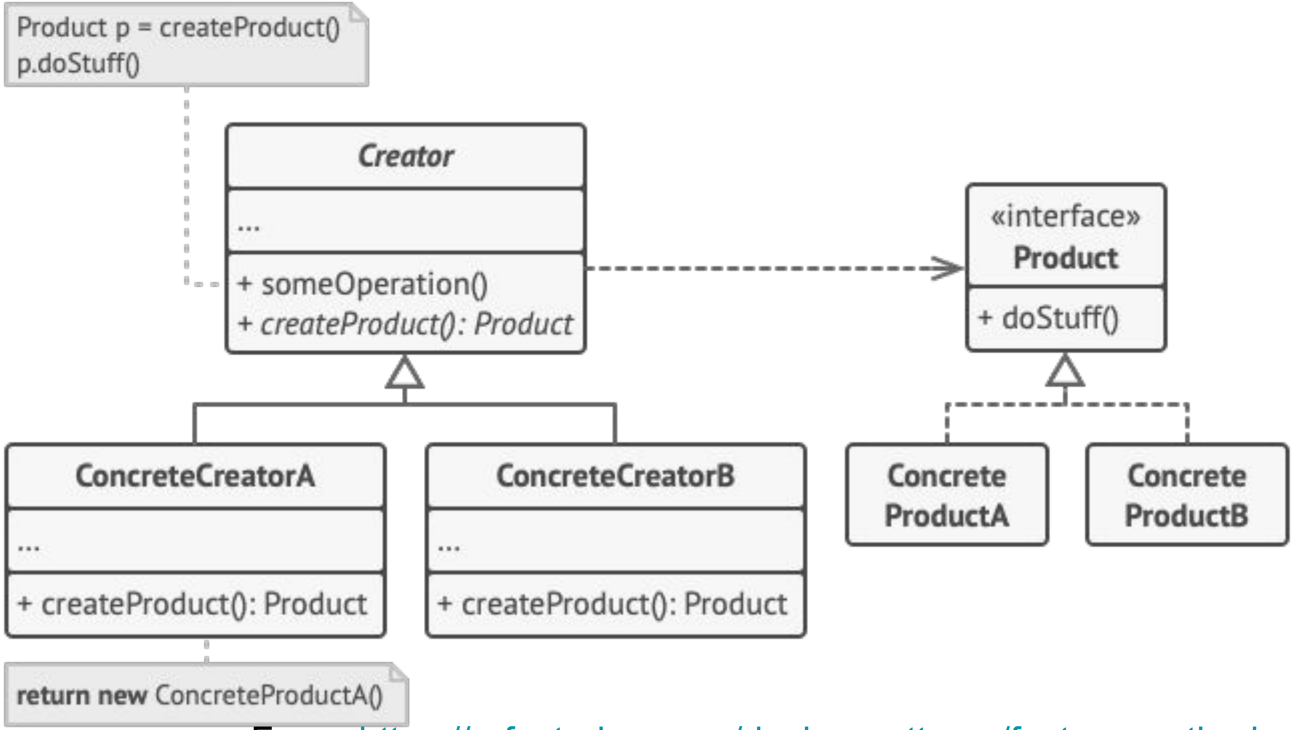
Not sequential; if you discover shortcomings, iterate!

1. **Gather requirements** skeptically, including *use cases*
2. **Choose an abstraction** (model) that appears to address use cases
3. **Compose a short API sketch** for abstraction
4. **Apply API sketch to use cases** to see if it works
   - If not, go back to step 3, 2, or even 1
5. **Show API** to anyone who will look at it
6. **Write prototype** implementation of API
7. **Flesh out** the documentation & harden implementation
8. **Keep refining it** as long as you can

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);
```

Aside: The *Factory Method* Design Pattern



From: https://refactoring.guru/design-patterns/factory-method

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

Principles of Software Construction

API Design (Part 2)

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Teamwork

Teamwork essential in software projects

Teamwork needed to scale available work and available skills

Teamwork is a key motivation for
design for understandability, documentation, etc

Good names drive good design

- Be consistent
  - `computeX()` vs. `generateX()`?
  - `deleteX()` vs. `removeX()`?
- Avoid cryptic abbreviations
  - Good: `Font, Set, PrivateKey, Lock, ThreadFactory, TimeUnit, Future<T>`
  - Bad: `DynAnyFactoryOperations, _BindingIteratorImplBase, ENCODING_CDR_ENCAPS, OMGVMCID`

Principle: Favor composition over inheritance

```
// A Properties instance maps Strings to Strings
public class Properties extends HashTable {
    public Object put(Object key, Object value);
    …
}
public class Properties {
    private final HashTable data = new HashTable();
    public String put(String key, String value) {
        data.put(key, value);
    }
    …
```

Principle: Fail fast

- Report errors as soon as they are detectable
  - Check preconditions at the beginning of each method
  - Avoid dynamic type casts, run-time type-checking

```java
// A Properties instance maps Strings to Strings
public class Properties extends HashTable {
    public Object put(Object key, Object value);

    // Throws ClassCastException if this instance
    // contains any keys or values that are not Strings
    public void save(OutputStream out, String comments);
}
```

CRUD Operations

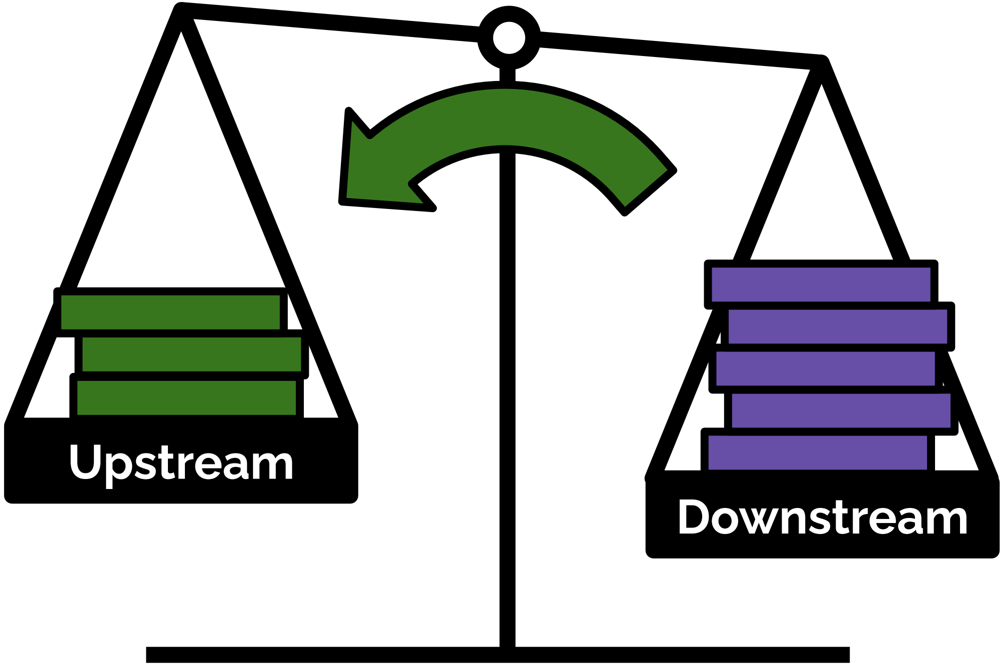
Path correspond to nouns, not verbs, nesting common:

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

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

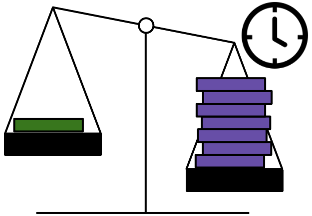
Parameters for filtering, searching, sorting, e.g., `/articles?sort=date`

```
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'));
```



Announcements
Documentation
Migration guide

Easy and fast to publish and use for developers



Breaking changes easy

More common to remove technical debt, fix APIs

Signaling intention with SemVer

No central release planning

Parallel releases more common

Upstream

HW6: Data Analytics Framework

Principles of Software Construction: Objects, Design, and Concurrency

Design for Robustness: Distributed Systems

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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

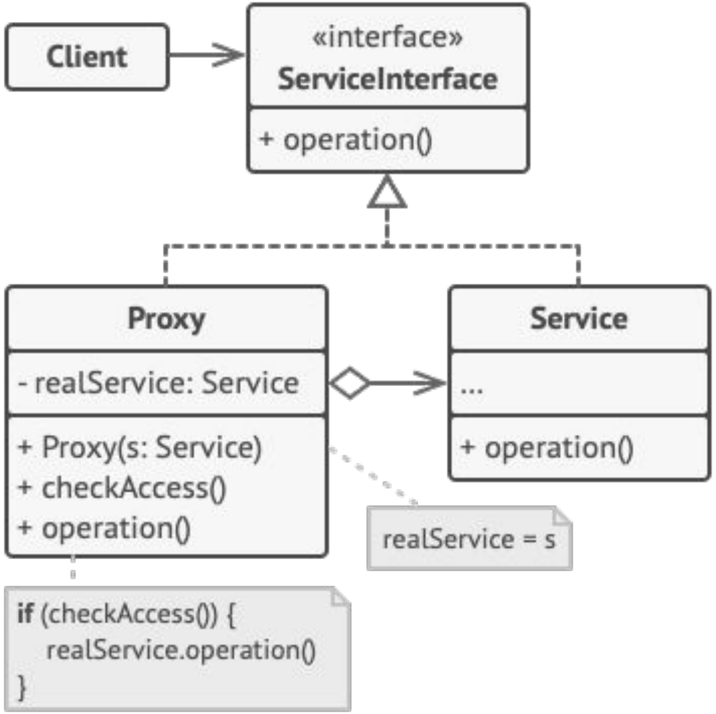
```
const delay = retryCount => new Promise(resolve =>
                    setTimeout(resolve, 10 ** retryCount));

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);
  }
```

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*

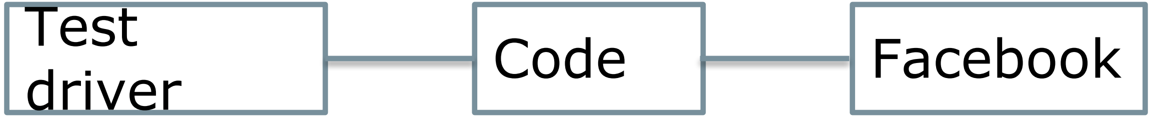


https://refactoring.guru/design-patterns/proxy

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 receiv
updates.
npm WARN deprecated chokidar@2.1.8: Chokidar 2 will break on node v14+. Upgrade to chokidar 3 with 15x less dependenc
s.
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 URLSearchPar
s 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 u
 @rollup/plugin-babel.
npm WARN deprecated fsevents@1.2.13: fsevents 1 will break on node v14+ and could be using insecure binaries. Upgrade
o fsevents 2.
npm WARN deprecated uuid@3.4.0: Please upgrade  to version 7 or higher.  Older versions may use Math.random() in cert
n 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 URLSearchPar
s API instead.
npm WARN deprecated sane@4.1.0: some dependency vulnerabilities fixed, support for node < 10 dropped, and newer ECMAS
ipt 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
```

Eliminating Android dependency




```
@Test void testGetFriends() {
   assert getFriends() == ...;
}
List<Friend> getFriends() {
   Connection c = http.getConnection();
   FacebookAPI api = new FacebookAPI(c);
   List<Node> persons = api.getFriends("john");
   for (Node person1 : persons) {
      ...
   }
   return result;
}
```

How about this one?

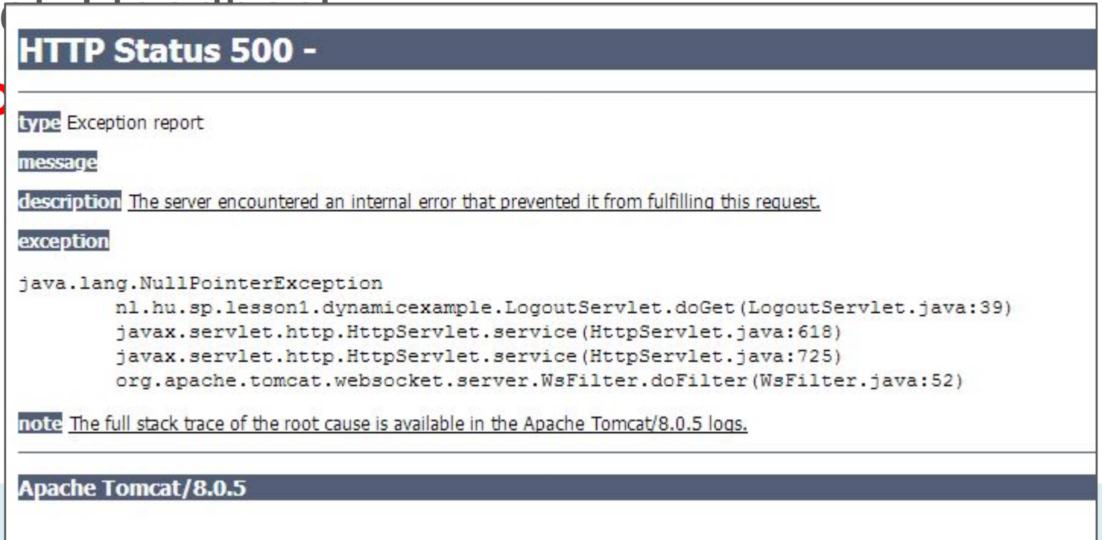
Test Doubles

- 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

Principle: Modular Protection

- Errors should be contained and isolated
  - A failing printer should not corrupt a document
  - Handle exceptions locally as much as possible, return us
  - **Do**



Ensuring Idempotence

- How about writing/sending new data?
  - Could fail anywhere
    - Including in displaying success message after payment!
  - POST is not idempotent
  - Use Unique Identifiers
  - Server keeps track of requests already handled

```
curl https://api.stripe.com/v1/charges \
   -u sk_test_BQokikJOvBiI2HlWgH4olfQ2: \
   -H "Idempotency-Key: AGJ6FJMkGQIpHUTX" \
   -d amount=2000 \
   -d currency=usd \
   -d description="Charge for Brandur" \
   -d customer=cus_A8Z5MHwQS7jUmZ
```

https://stripe.com/blog/idempotency

Principles of Software Construction: Objects, Design, and Concurrency

Organizing Systems at Scale: Modules, Services, Architectures

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Libraries.io

Search open source packages, frameworks and tools... | Search

Libraries.io monitors **6,216,328** open source packages across **32** different package managers, so you don't have to. Find out more

Discover new software

Search 6.22M packages by license, language or keyword, or explore new, trending or popular packages.

Explore

Monitor your dependencies

Stay up to date with notifications of updates, license incompatibilities or deleted dependencies.

Login

Maintain your OSS project

Understand your users and make informed decisions about features with usage and version data.

Login

Use Libraries.io data

Use Libraries.io data in your applications, services or research. Use our API to stay up to date.

Documentation

Supported Package Managers

npm 2.1M Packages

Go 444K Packages

Maven 443K Packages

PyPI 405K Packages

Packagist

NuGet

Rubygems

CocoaPods

Packages enough?

```
edu.cmu.cs214.santorini
edu.cmu.cs214.santorini.gui
edu.cmu.cs214.santorini.godcards
edu.cmu.cs214.santorini.godcards.impl
edu.cmu.cs214.santorini.logic
edu.cmu.cs214.santorini.utils
```

ES2015 Modules

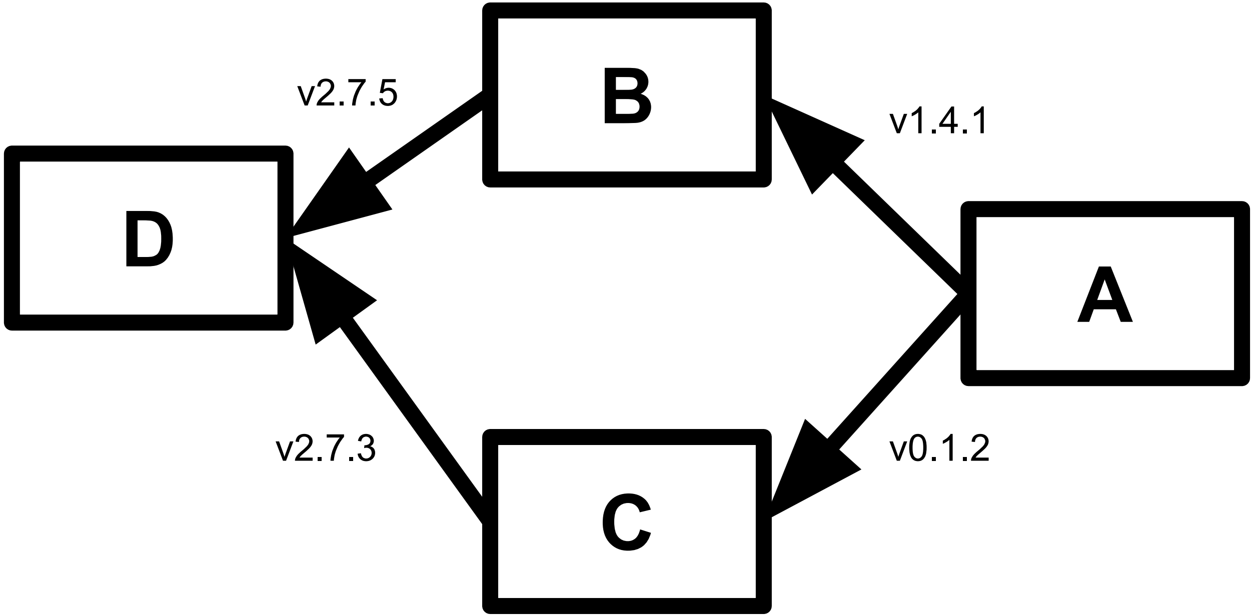
Syntax extension for modules (instead of module pattern)

Explicit imports / exports

Static import names (like Java), supports better reasoning by tools

```
import { Location } from './location'
import { Game } from './game'
import { Board } from './board'
// module code
export { Worker, newWorker }
```

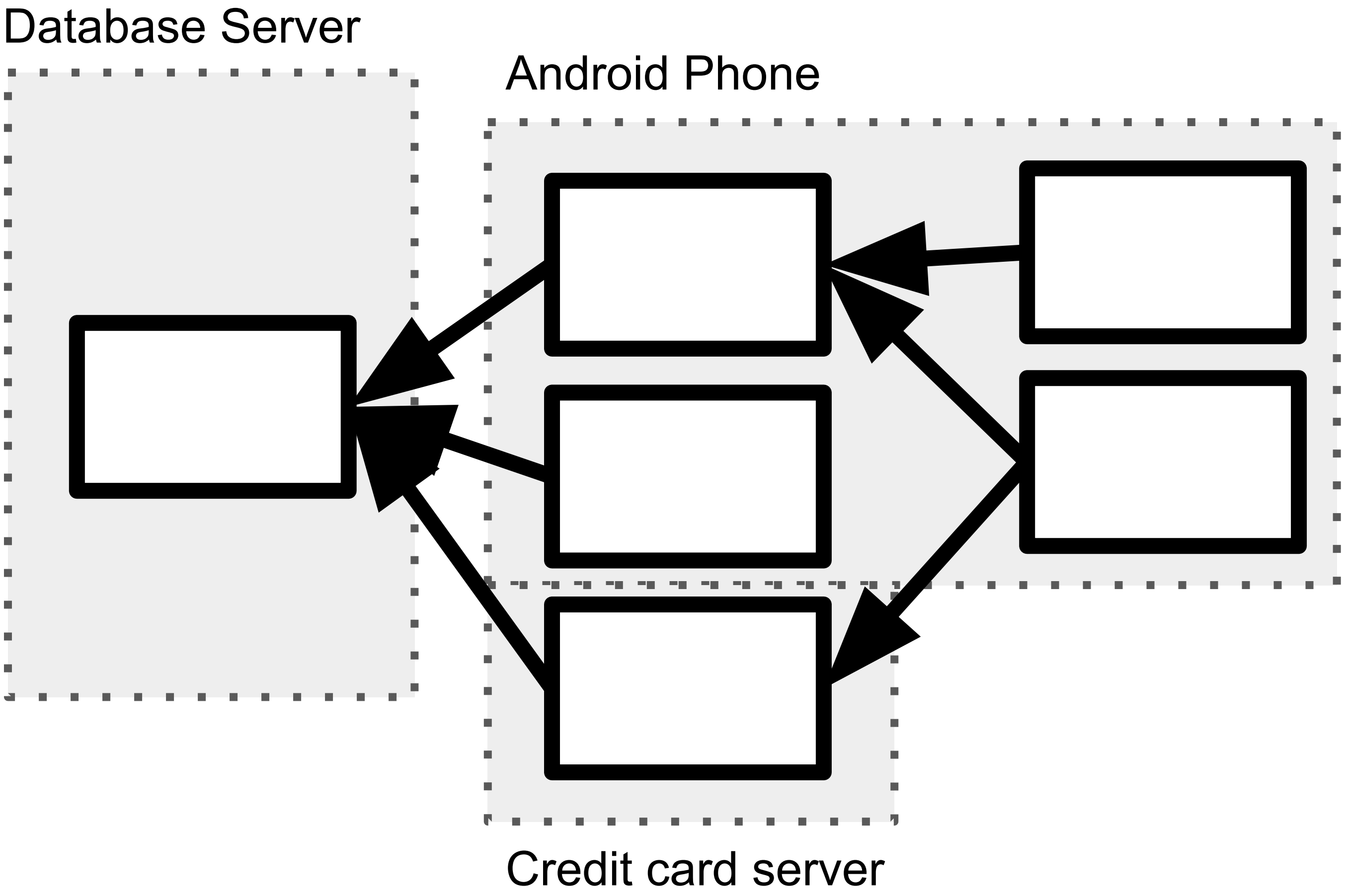
The Diamond Problem



What now?

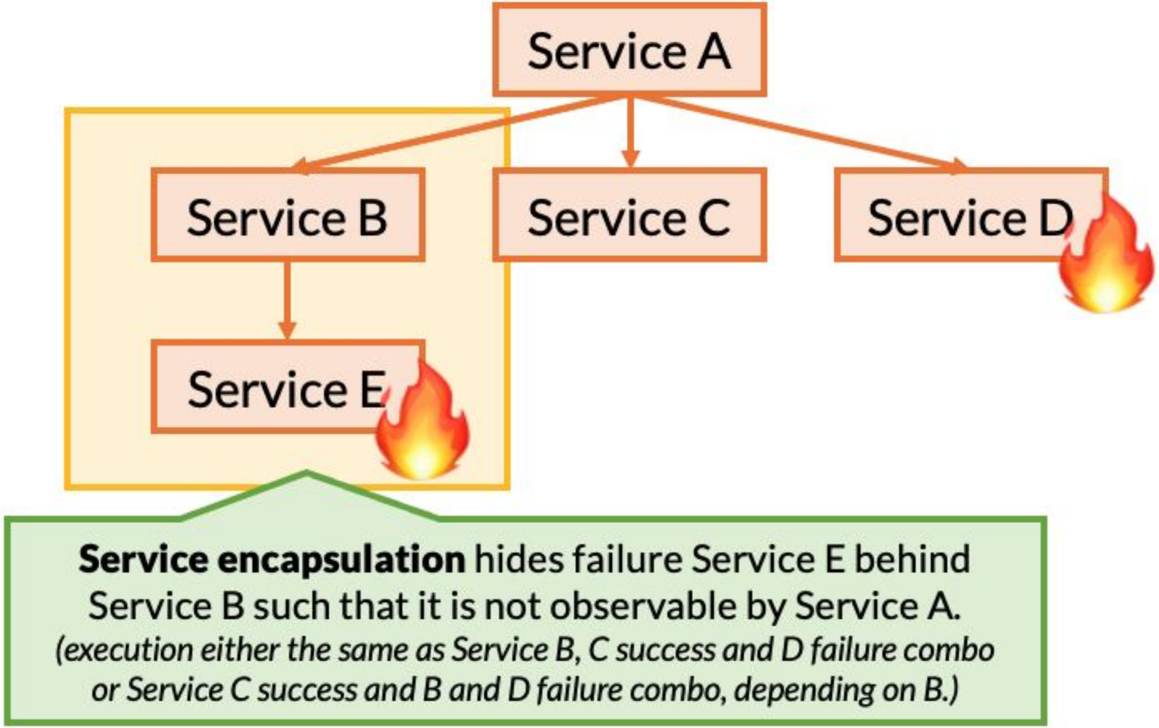
EQUIFAX

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


Database Server
Android Phone
Credit card server

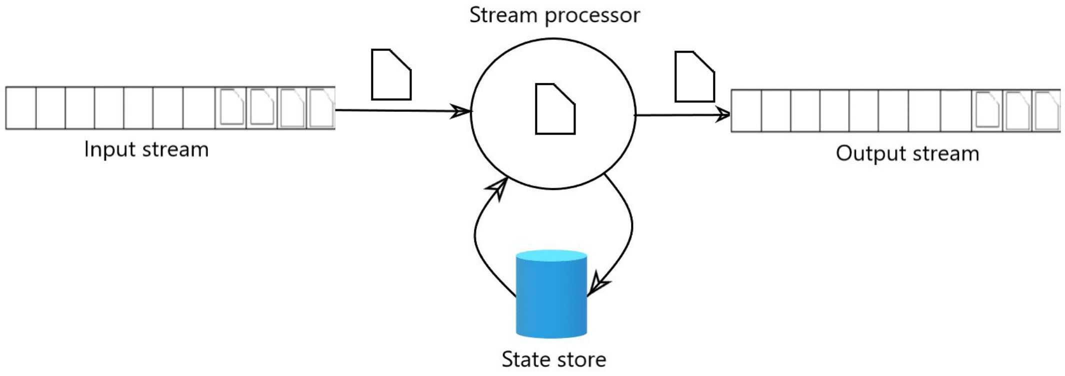

Microservices
Microservices Everywhere

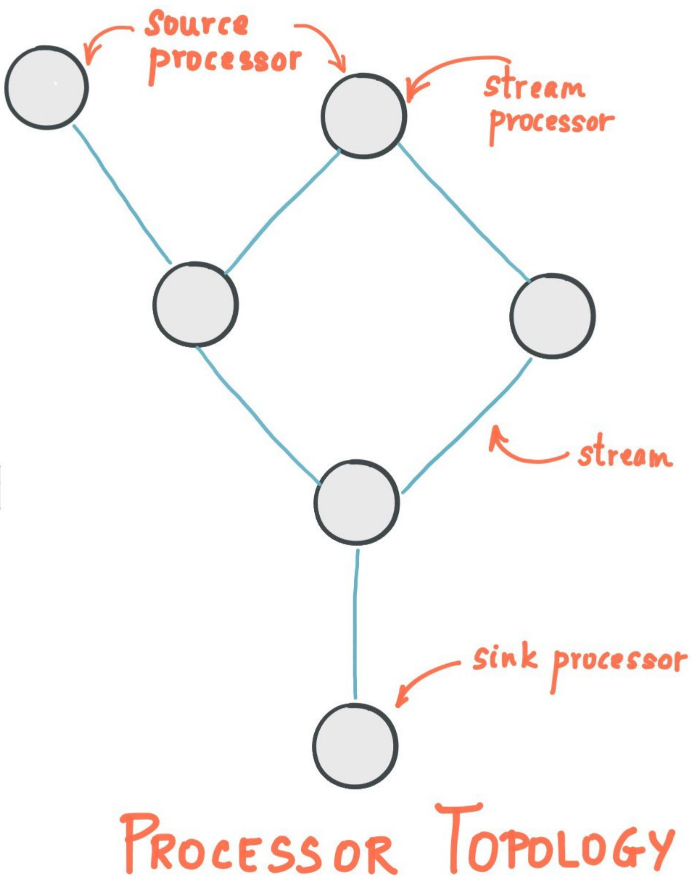
Handle Errors Locally



http://christophermeiklejohn.com/filibuster/2021/10/14/filibuster-4.html

Apache Kafka





https://www.novatec-gmbh.de/en/blog/kafka-101-series-part-2-stream-processing-and-kafka-streams-api/

Principles of Software Construction: Objects, Design, and Concurrency

A Quick Tour of all 23 GoF Design Patterns

Christian Kästner Vincent Hellendoorn

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I. Creational Patterns

1. Abstract factory
2. Builder
3. Factory method
4. Prototype
5. Singleton

Singleton Illustration

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

```javascript
const elvis = { … }
function getElvis() {

export { getElvis }
```

II. Structural Patterns

1. Adapter
2. Bridge
3. Composite
4. Decorator
5. Façade
6. Flyweight
7. Proxy

Decorator vs Strategy?

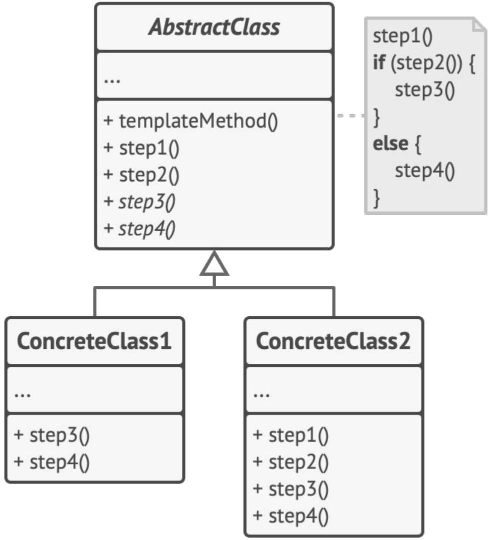
```
interface GameLogic {
     isValidMove(w, x, y)
     move(w, x, y)
}

class BasicGameLogic
     implements GameLogic { … }

class AbstractGodCardDecorator
     implements GameLogic { … }

class PanDecorator
     extends AbstractGodCardDecorator
     implements GameLogic { … }
```

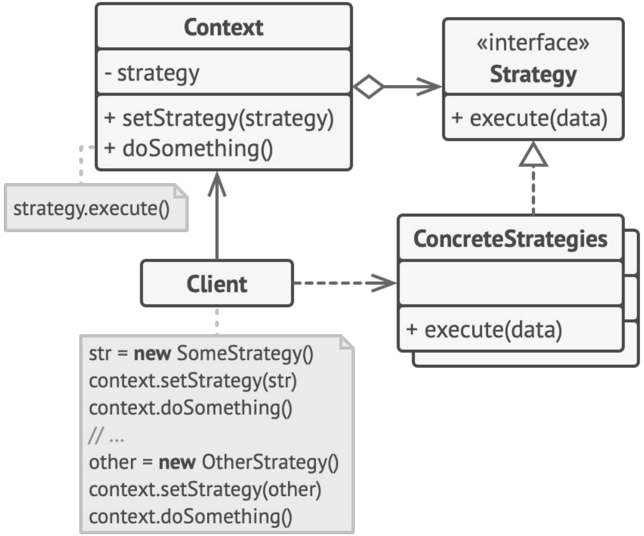
```
interface GameLogic {
     isValidMove(w, x, y)
     move(w, x, y)
}
class BasicGameLogic
          implements GameLogic {
     constructor(board) { … }
     isValidMove(w, x, y) { … }
     move(w, x, y) { … }
}
class PanDecorator
          extends BasicGameLogic {
     move(w, x, y} { /* super.move(w,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

III. Behavioral Patterns

1. Chain of Responsibility
2. Command
3. Interpreter
4. Iterator
5. Mediator
6. Memento
7. Observer
8. State
9. Strategy
10. Template method
11. Visitor

Strategy vs Template Method





Principles of Software Construction: Objects, Design, and Concurrency

{Static & Dynamic} x {Typing & Analysis}

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

How Do You Find Bugs?

- Run it?

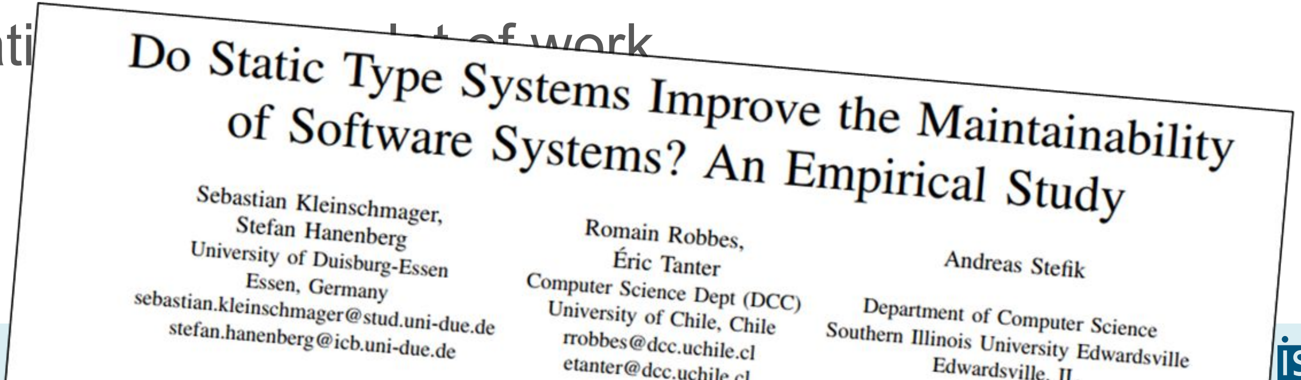
```java
public class Fails {
    public static void main(String[] args) {
        getValue( i: null);
    }

    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

- The more knowledge we inject in the code, the more bugs we can catch at compile time
  - Types, nullity annotations, invariants
- Is it worth it?
  - Dynamic typing can severely limit inference
  - But… stati



Do Static Type Systems Improve the Maintainability of Software Systems? An Empirical Study

Sebastian Kleinschmager,
Stefan Hanenberg
University of Duisburg-Essen
Essen, Germany
sebastian.kleinschmager@stud.uni-due.de
stefan.hanenberg@icb.uni-due.de

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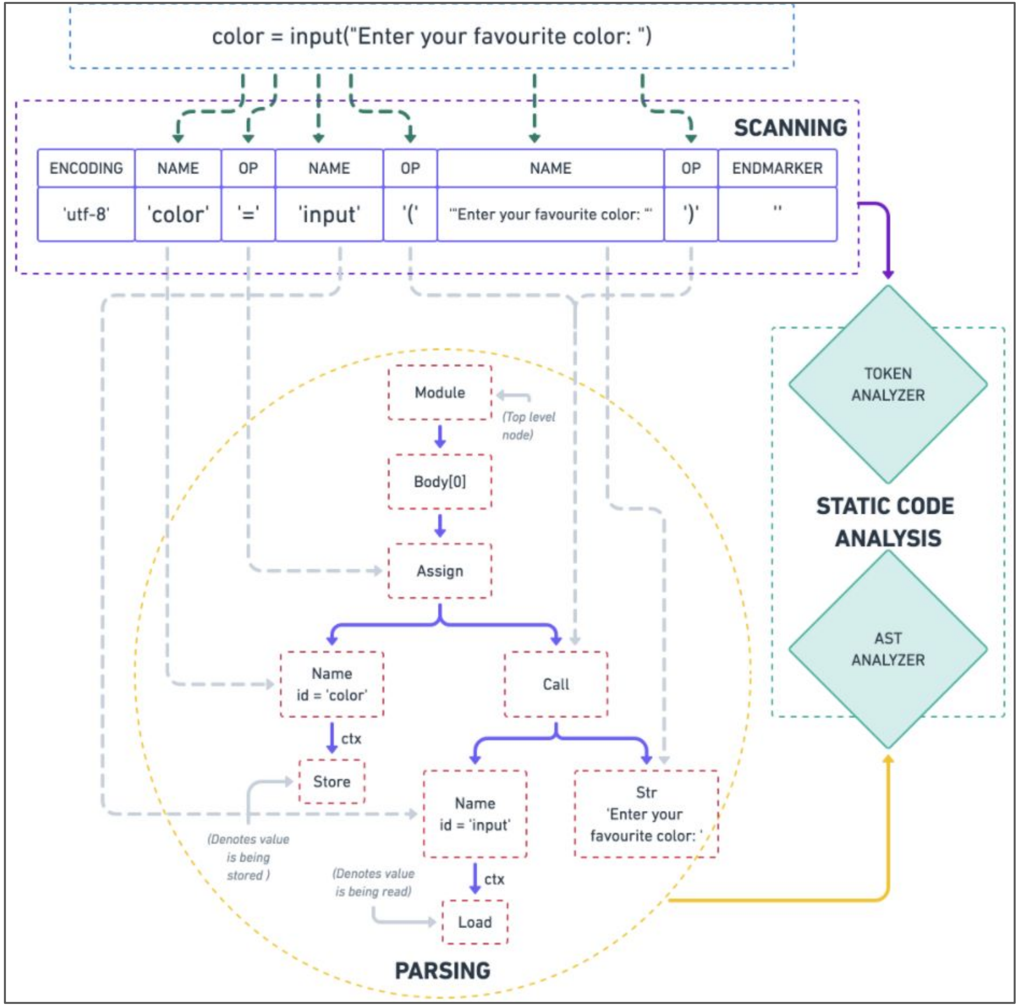
Éric Tanter
Computer Science Dept (DCC)
University of Chile, Chile
rrobbes@dcc.uchile.cl

Andreas Stefik
Department of Computer Science
Southern Illinois University Edwardsville

Static Analysis

- How?
  - Program analysis + Vocabulary of patterns



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

Static Analysis

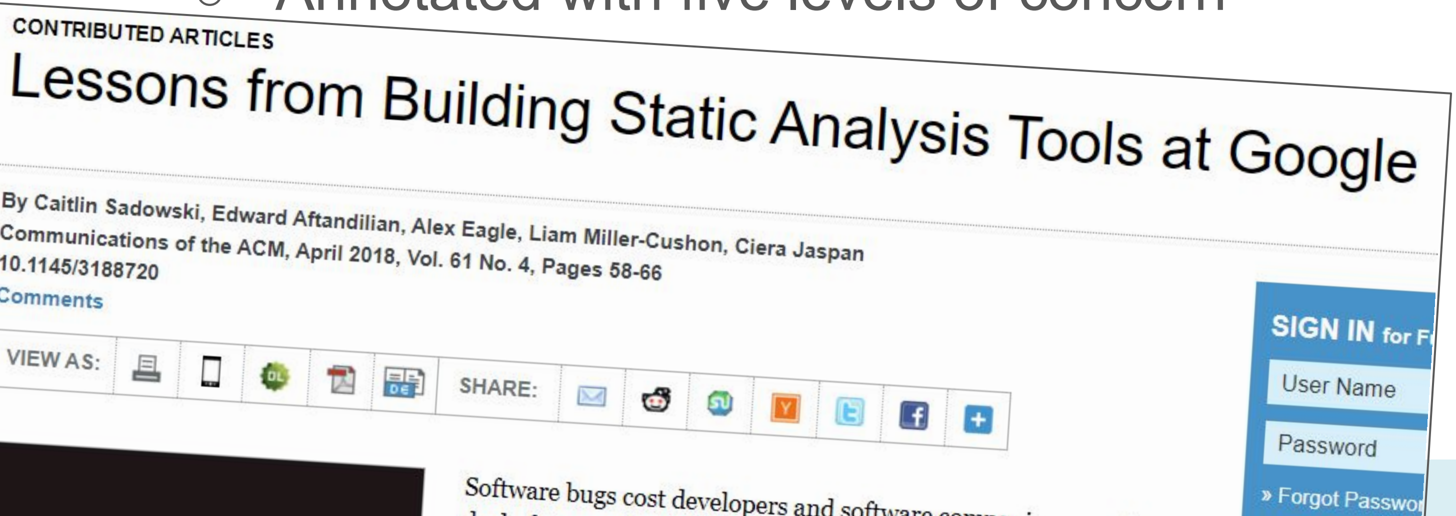
- Step 3: register analyz
  - At the core: walk the tr
  - Sometimes more comp

```
class UnusedImportChecker(BaseChecker):
    def __init__(self):
        self.import_map = defaultdict(set)
        self.name_map = defaultdict(set)

    def _add_imports(self, node):
        for import_name in node.names:
            # Store only top-level module name ("os.path" -> "os").
            # We can't easily detect when "os.path" is used.
            name = import_name.name.partition(".")[0]
            self.import_map[self.filename].add((name, node.lineno))

    def visit_Import(self, node):
        self._add_imports(node)

    def visit_ImportFrom(self, node):
        self._add_imports(node)

    def visit_Name(self, node):
        # We only add those nodes for which a value is being read from.
        if isinstance(node.ctx, ast.Load):
            self.name_map[self.filename].add(node.id)
```

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

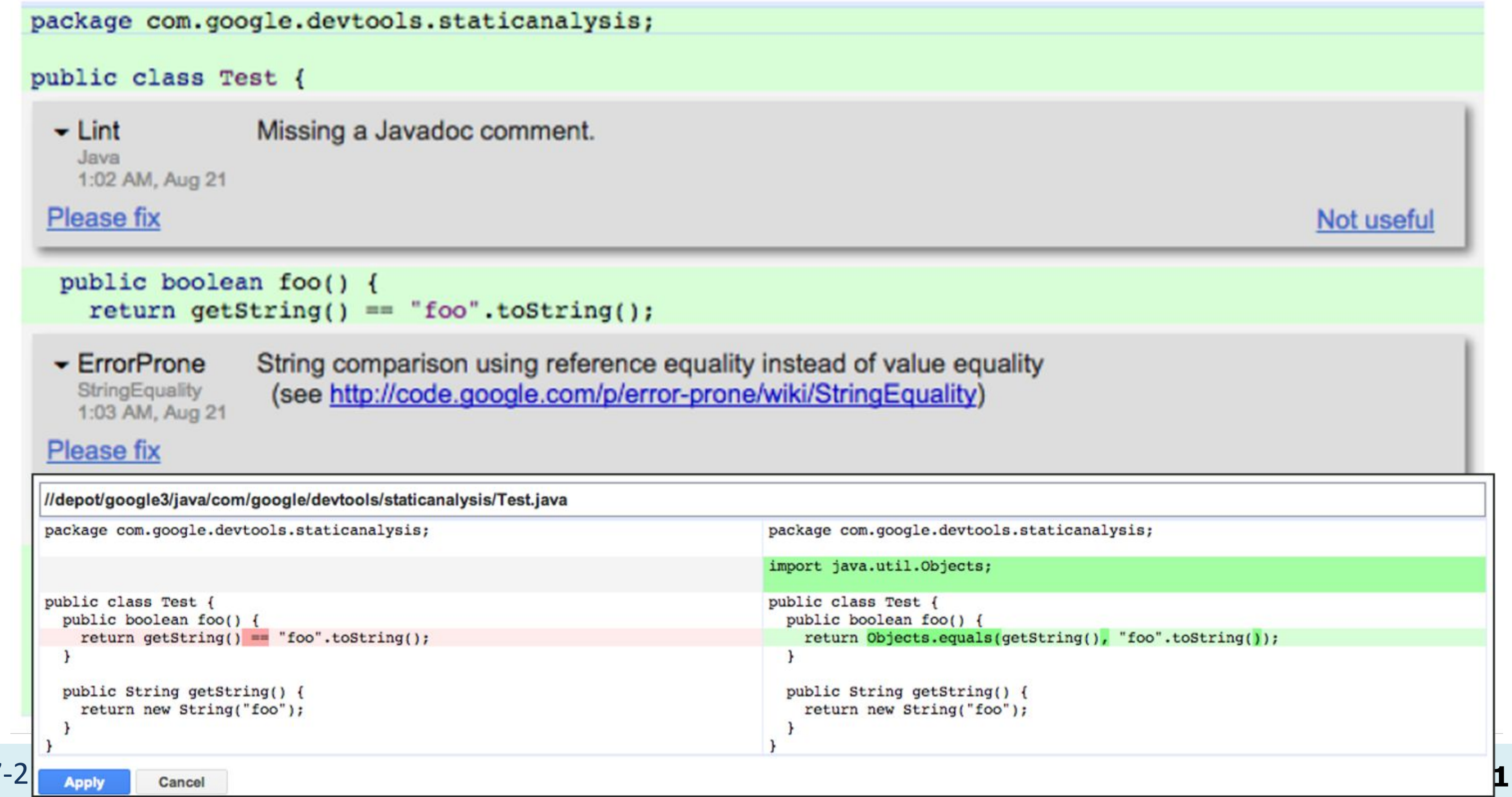
Static Analysis at Google

- Centered around FindBugs (succeeded by SpotBugs)
  - Essentially, a huge collection of risky patterns on Java bytecode
  - Annotated with five levels of concern



FindBugs™

TriCoder


package com.google.devtools.staticanalysis;
public class Test {
Lint
Java
1:02 AM, Aug 21
Missing a Javadoc comment.
Please fix
Not useful
public boolean foo() {
return getString() == "foo".toString();
ErrorProne
StringEquality
1:03 AM, Aug 21
String comparison using reference equality instead of value equality
(see http://code.google.com/p/error-prone/wiki/StringEquality)
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");
}
}
Apply
Cancel

Principles of Software Construction: Objects, Design, and Concurrency

DevOps

Christian Kästner Vincent Hellendoorn

Carnegie Mellon University
School of Computer Science
institute for SOFTWARE RESEARCH

Where we are

	Small scale: One/few objects	*Mid scale:* Many objects	*Large scale:* Subsystems
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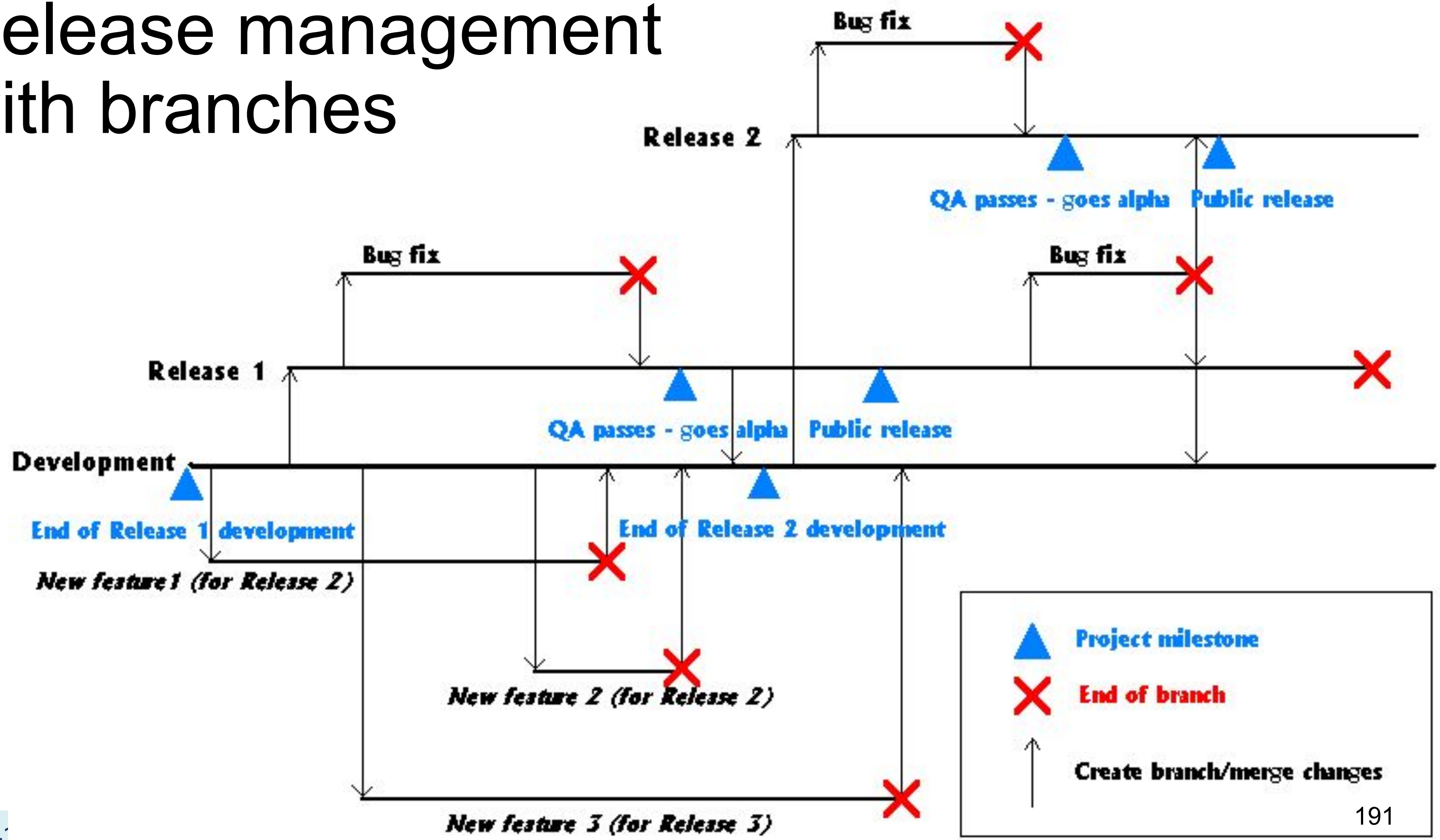
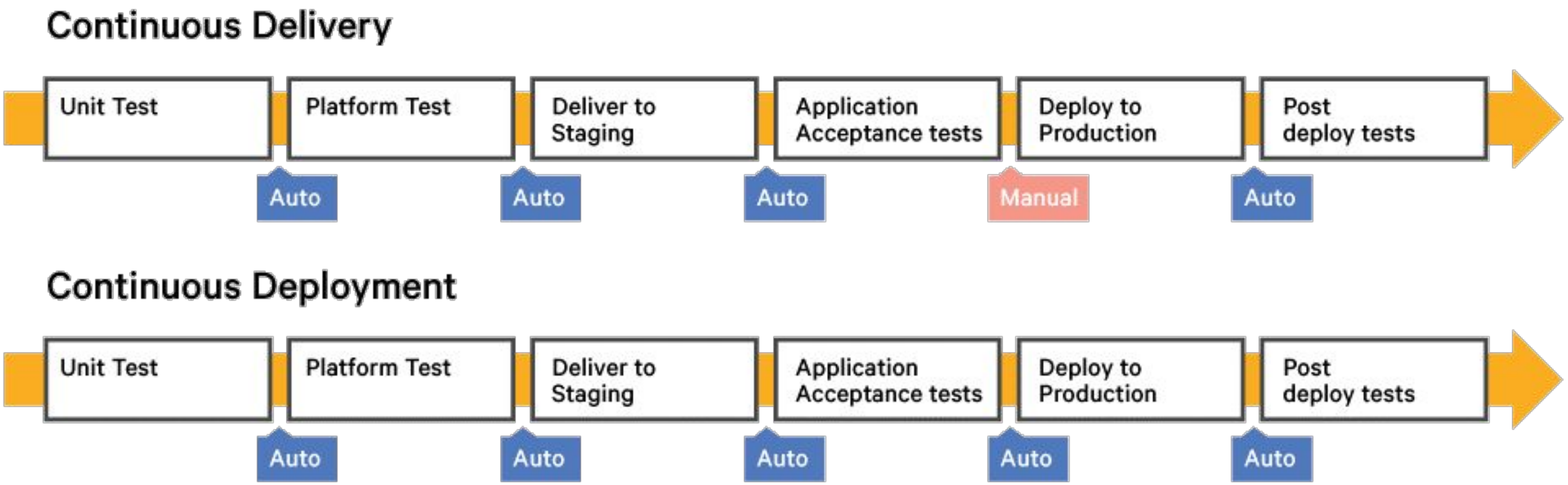
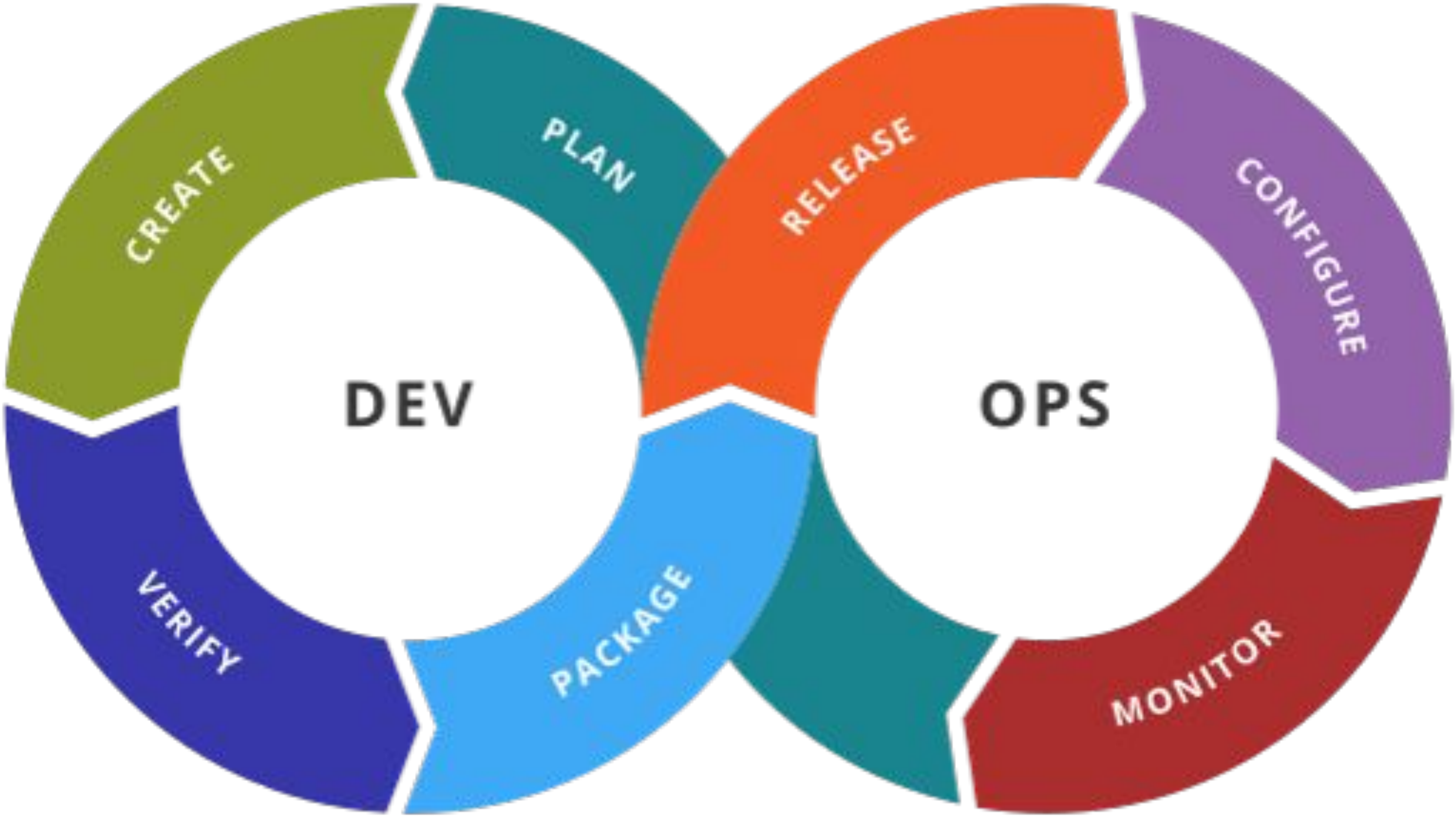
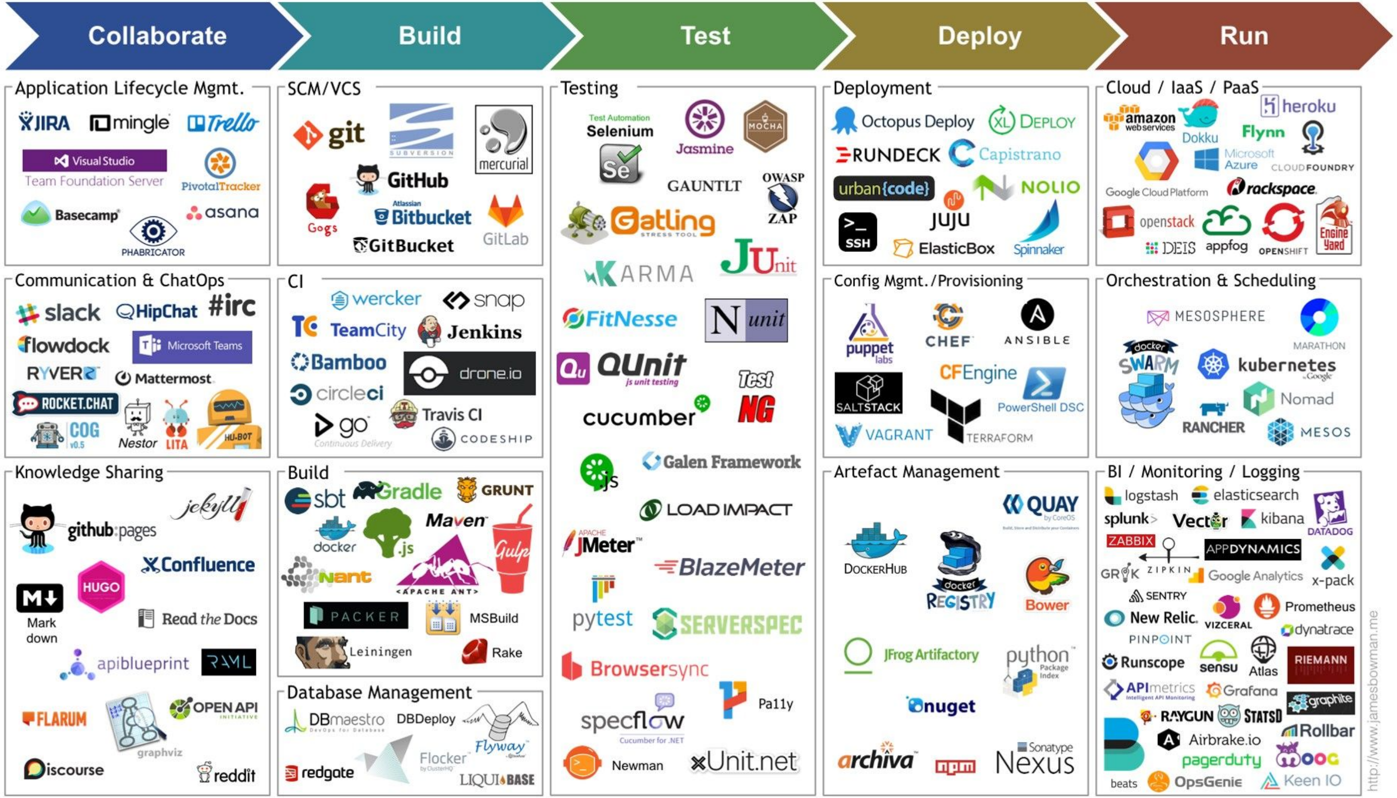
Release management with branches




Continuous Delivery
Unit Test
Platform Test
Deliver to Staging
Application Acceptance tests
Deploy to Production
Post deploy tests
Auto
Auto
Auto
Manual
Auto
Continuous Deployment
Unit Test
Platform Test
Deliver to Staging
Application Acceptance tests
Deploy to Production
Post deploy tests
Auto
Auto
Auto
Auto
Auto


CREATE
PLAN
RELEASE
CONFIGURE
DEV
OPS
VERIFY
PACKAGE
MONITOR

Heavy Tooling and Automation



institute for SOFTWARE RESEARCH

A/B Testing

Original: 2.3%

Long Form: 4.3%

Looking Forward: Beyond Code-Level Concerns

Where we are

	Small scale: One/few objects	*Mid scale:* Many objects	*Large scale:* Subsystems
Design for understanding change/ext. reuse robustness ...	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**

This Course

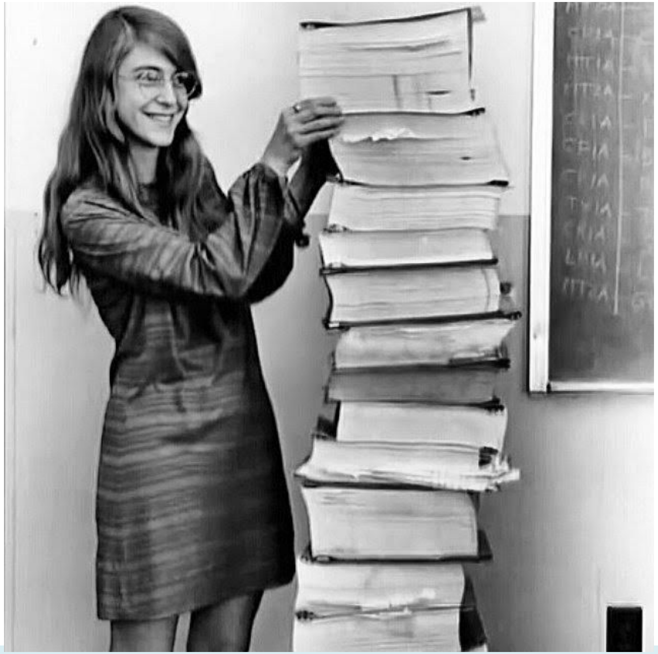
We focused on code-level concerns

Writing maintainable, extensible, robust, and correct code

- Design from classes to subsystems
- Testing, concurrency, basic user interfaces

From Programming to 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

Software engineering in the real world

- e.g., HealthCare.gov
  - 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

Software is written by humans

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

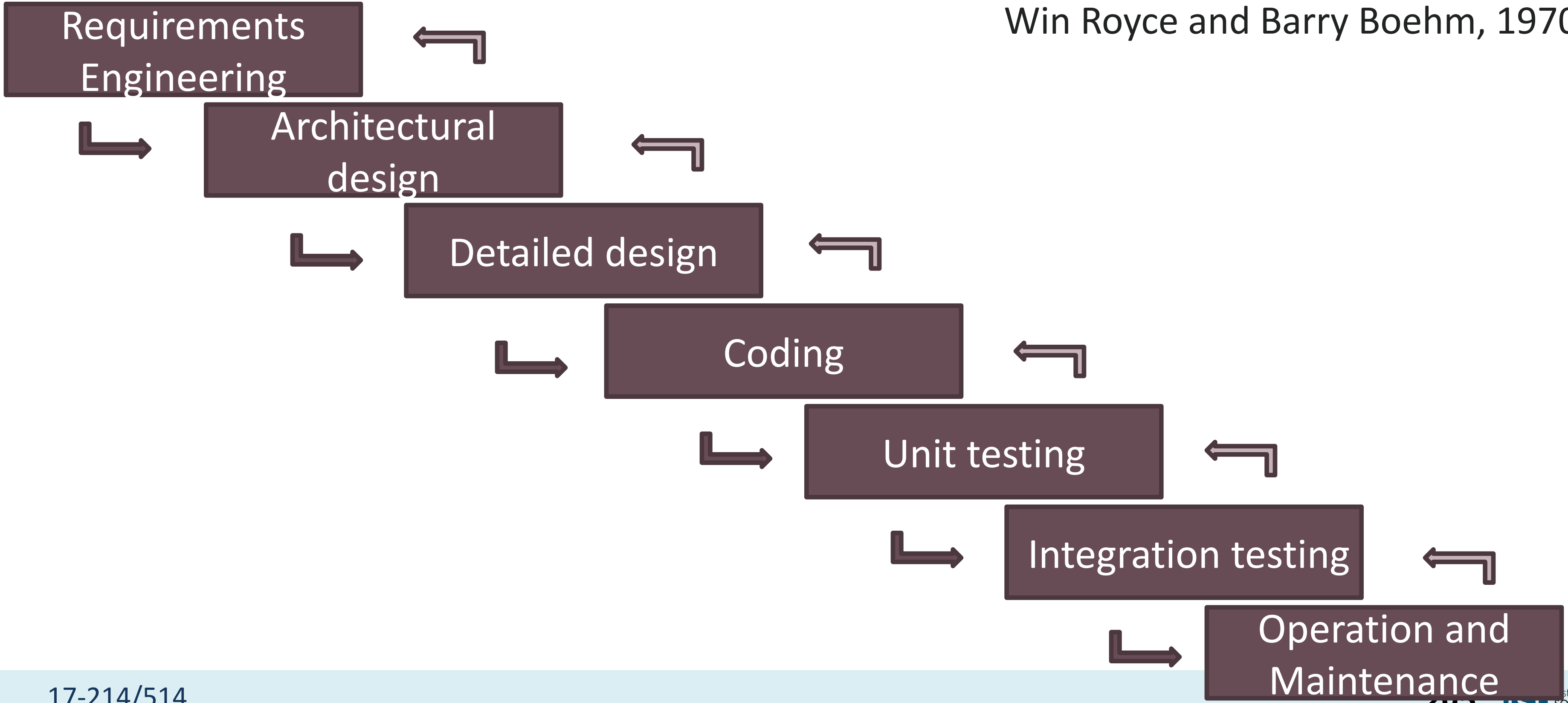
Key challenges in how to

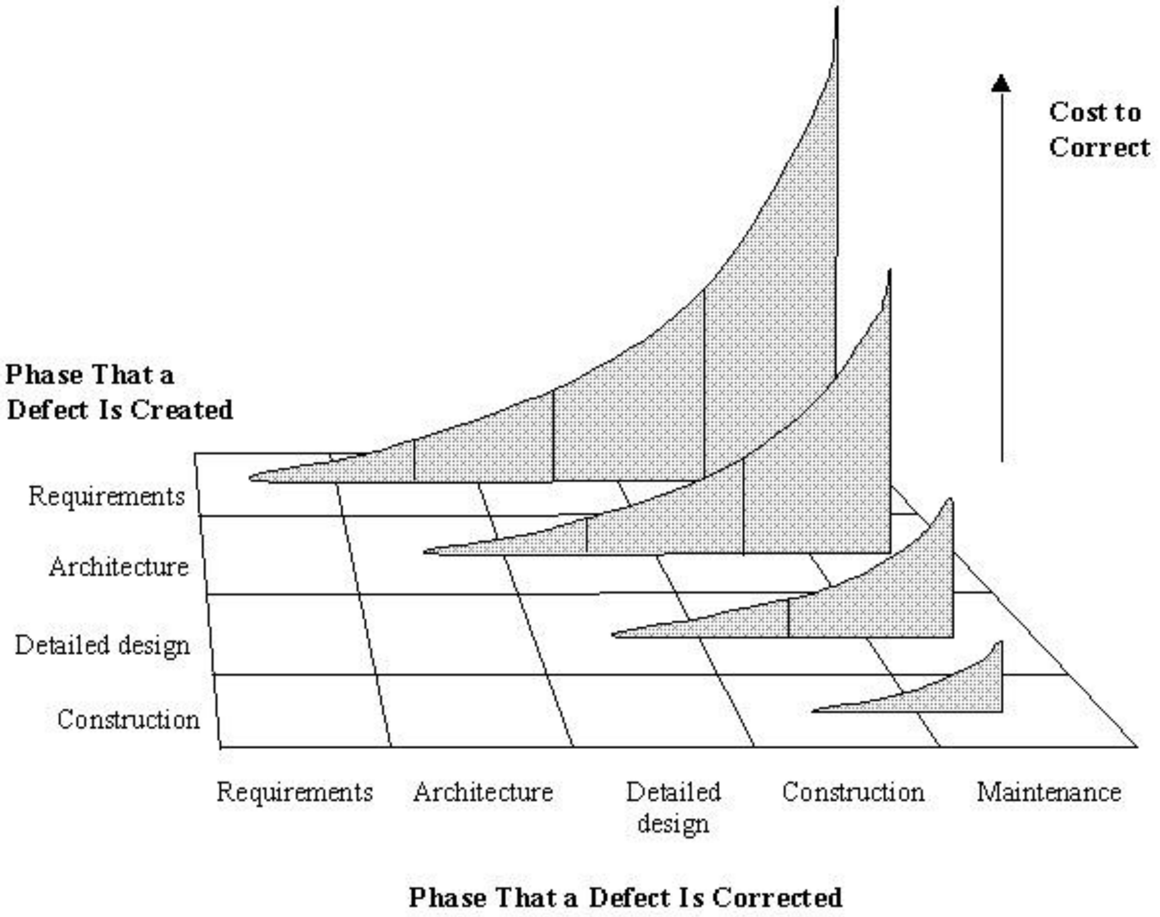
- identify what to build (requirements)
- coordinate people building it (process)
- assure quality (speed, safety, fairness)
- contain risk, time and budget (management)
- sustain a community (open source, economics)

Process

Example: Process

Win Royce and Barry Boehm, 1970




Cost to Correct
Phase That a Defect Is Created
Requirements
Architecture
Detailed design
Construction
Requirements
Architecture
Detailed design
Construction
Maintenance
Phase That a Defect Is Corrected

Agile in a nutshell

- A project management approach that seeks to respond to change and unpredictability, primarily using incremental, iterative work sequences (often called “sprints”).
- Also: a collection of practices to facility that approach.
- All predicated on the principles outlined in “The Manifesto for Agile Software Development.”

The Manifesto for Agile Software Development (2001)

Value

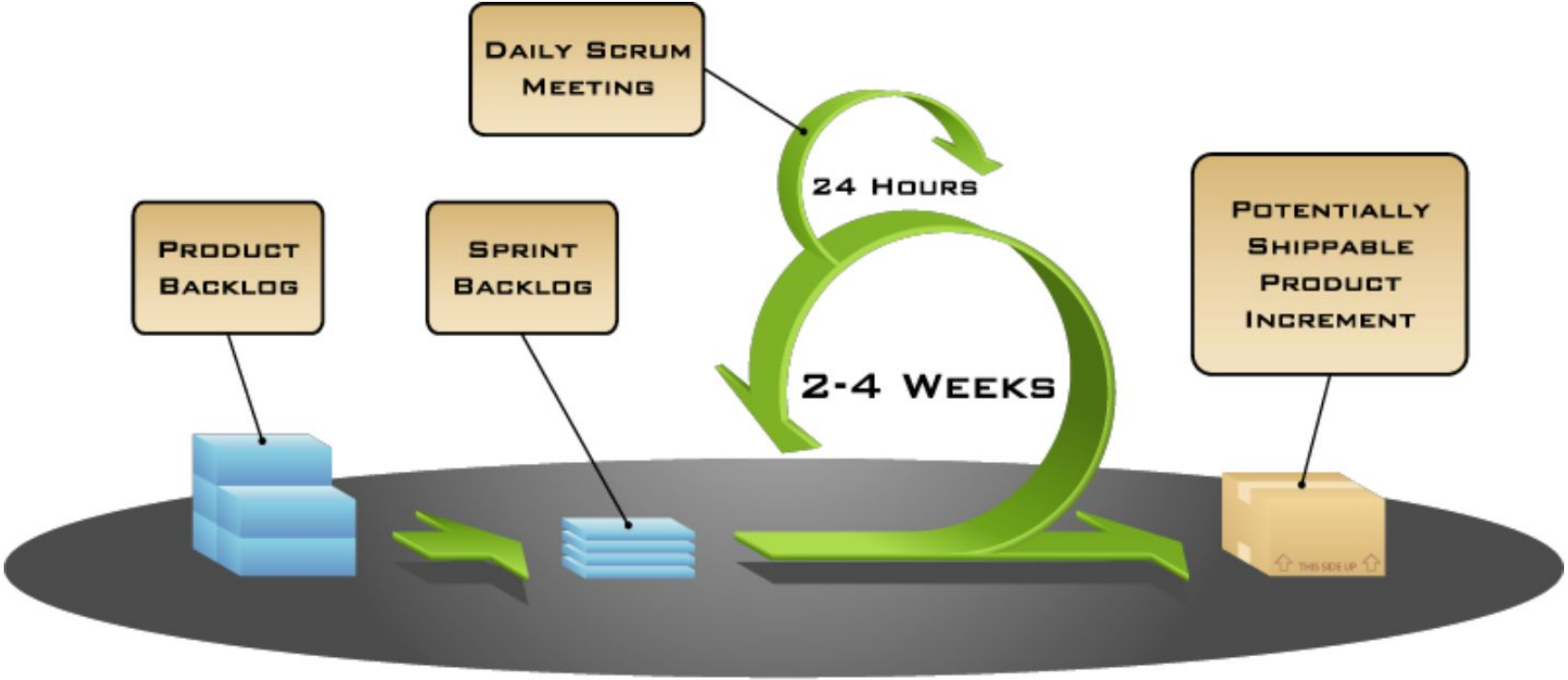
Individuals and interactions	*over*	Processes and tools
Working software	*over*	Comprehensive documentation
Customer collaboration	*over*	Contract negotiation
Responding to change	*over*	Following a plan

Pair Programming

Navigator

Driver

Scrum Process



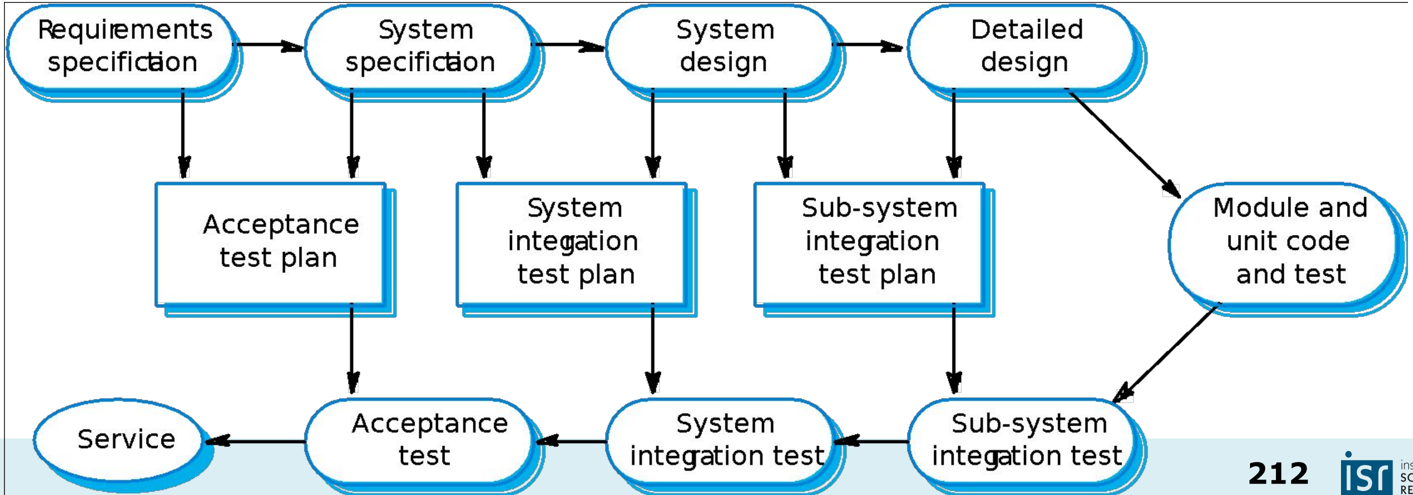
QA and Process

Beyond testing

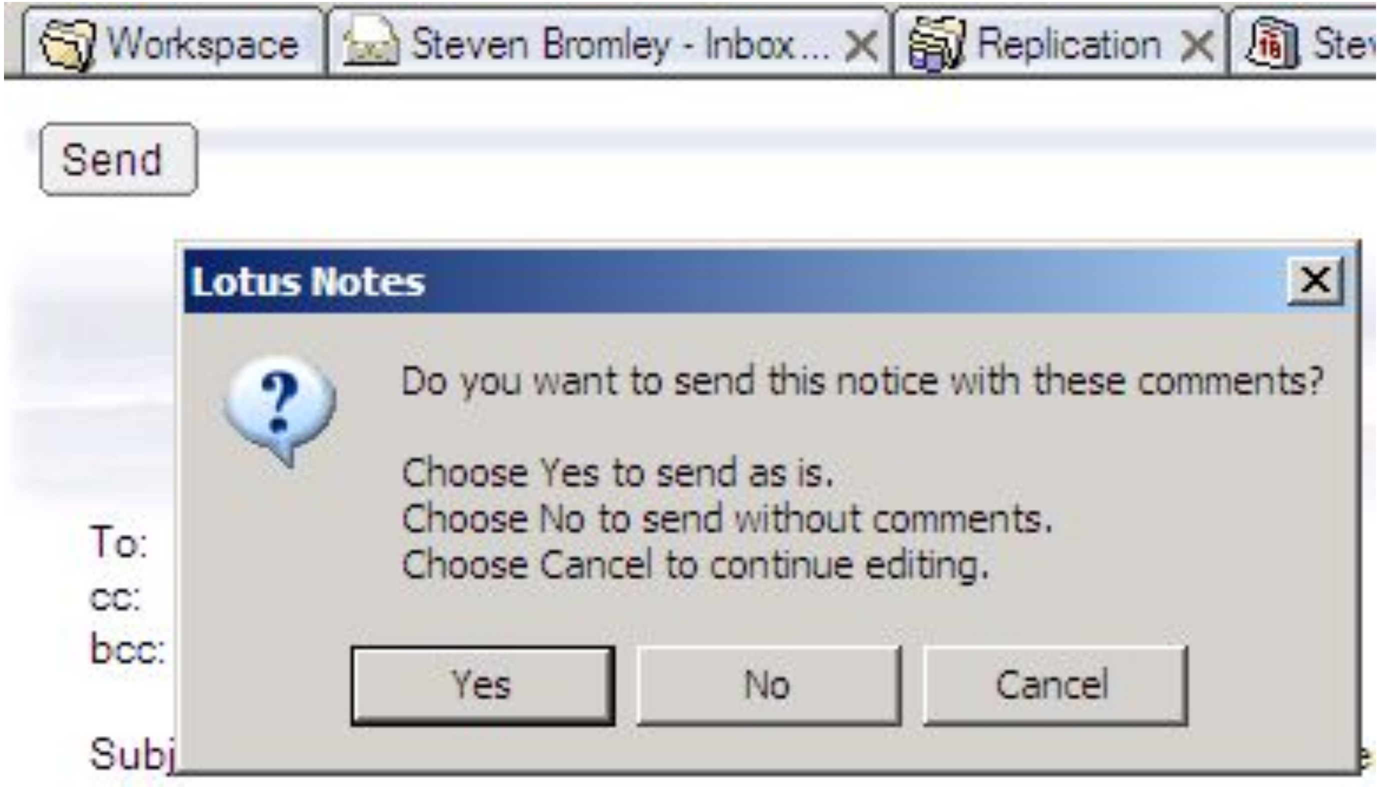
Many QA approaches

- Code review, static analysis, formal verification, …

Which to use when, how much?




twitter
Home Public Timeline Help
Twitter is over capacity.
Too many tweets! Please wait a moment and try again.


Workspace
Steven Bromley - Inbox ...
Replication
Send
Lotus Notes
Do you want to send this notice with these comments?
Choose Yes to send as is.
Choose No to send without comments.
Choose Cancel to continue editing.
Yes
No
Cancel
To:
cc:
bcc:
Subj

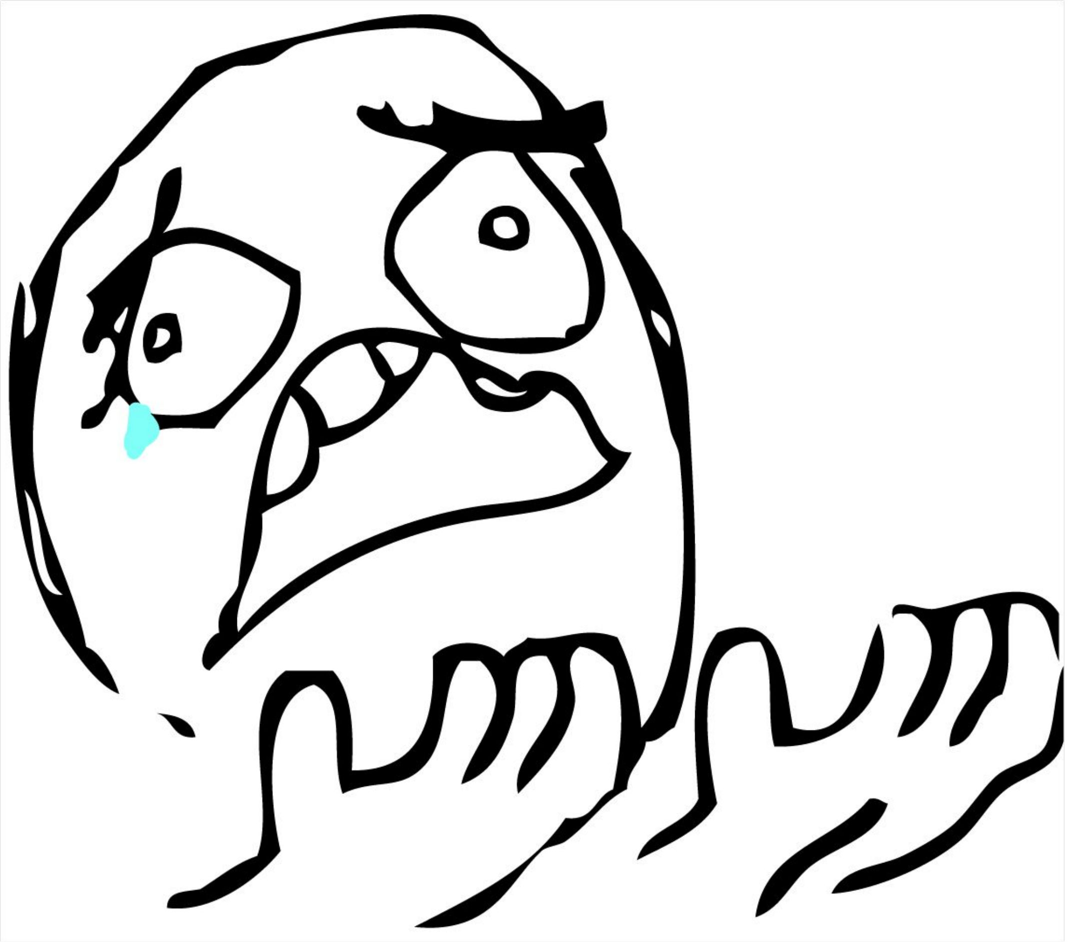
How to get students to write tests?

“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



219

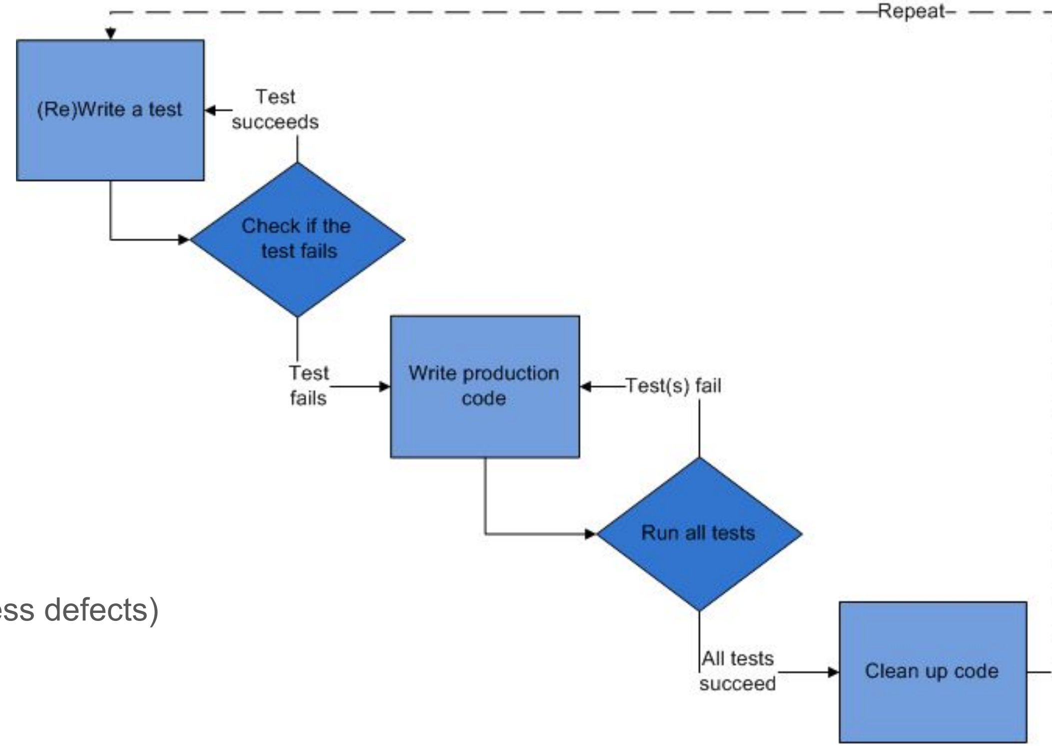
How to get students to write tests?

How to get them to take testing seriously, not just as an afterthought?

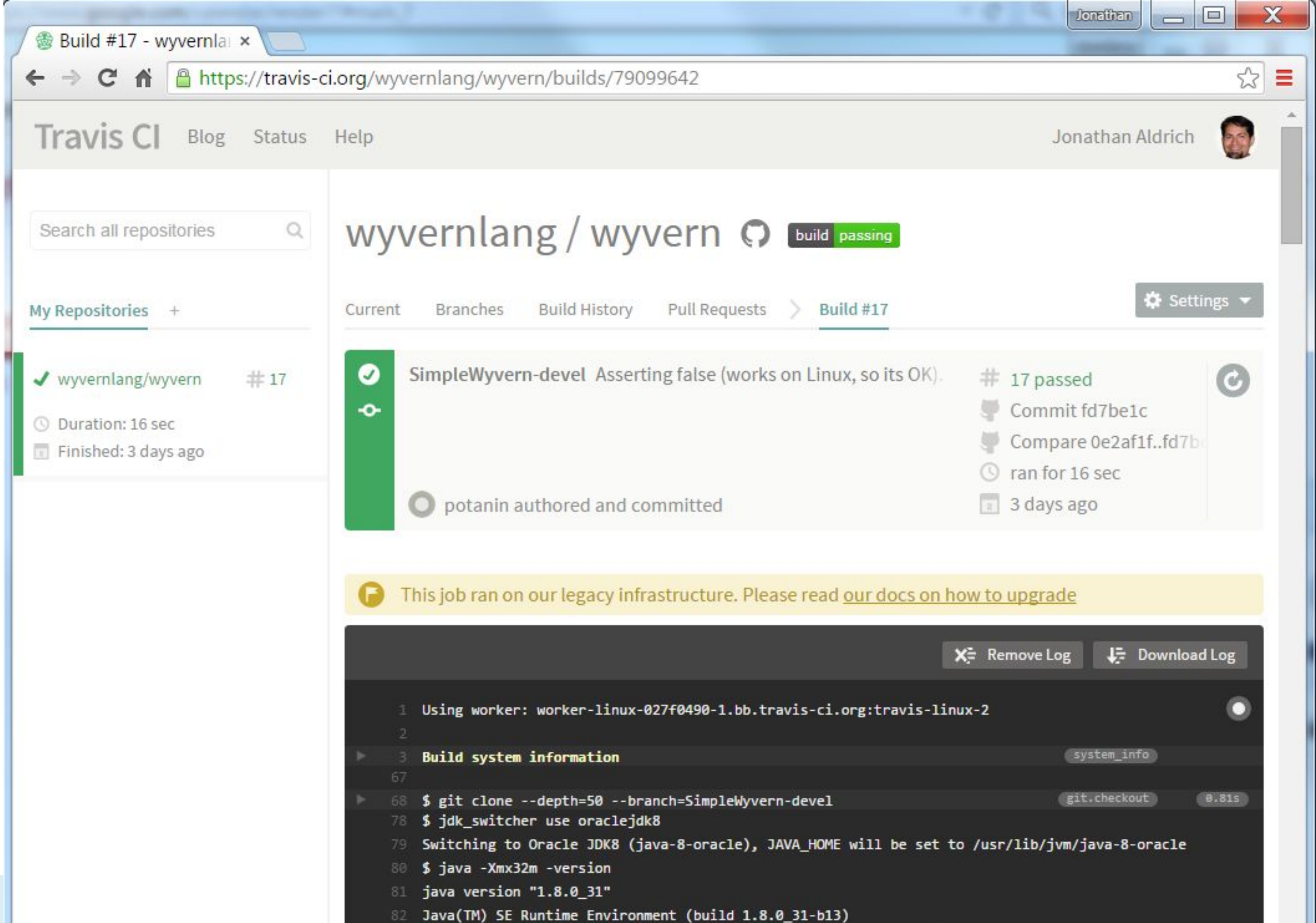
How to get developers to write tests?

Test Driven Development

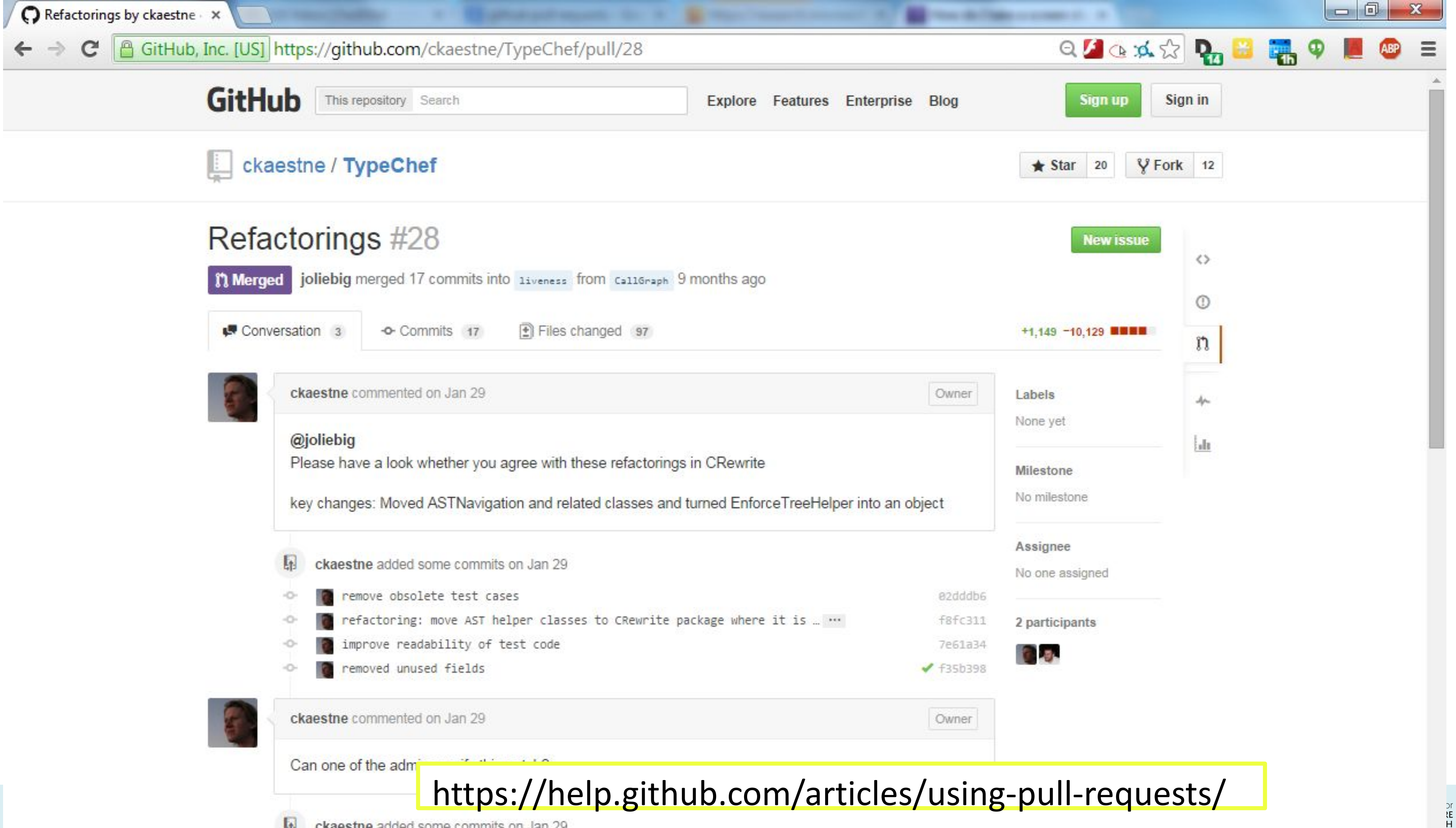
- Tests first!
- Popular agile technique
- Write tests as specifications before code
- Never write code without a failing test
- Claims:
  - Design approach toward testable design
  - Think about interfaces first
  - Avoid writing unneeded code
  - Higher product quality (e.g. better code, less defects)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



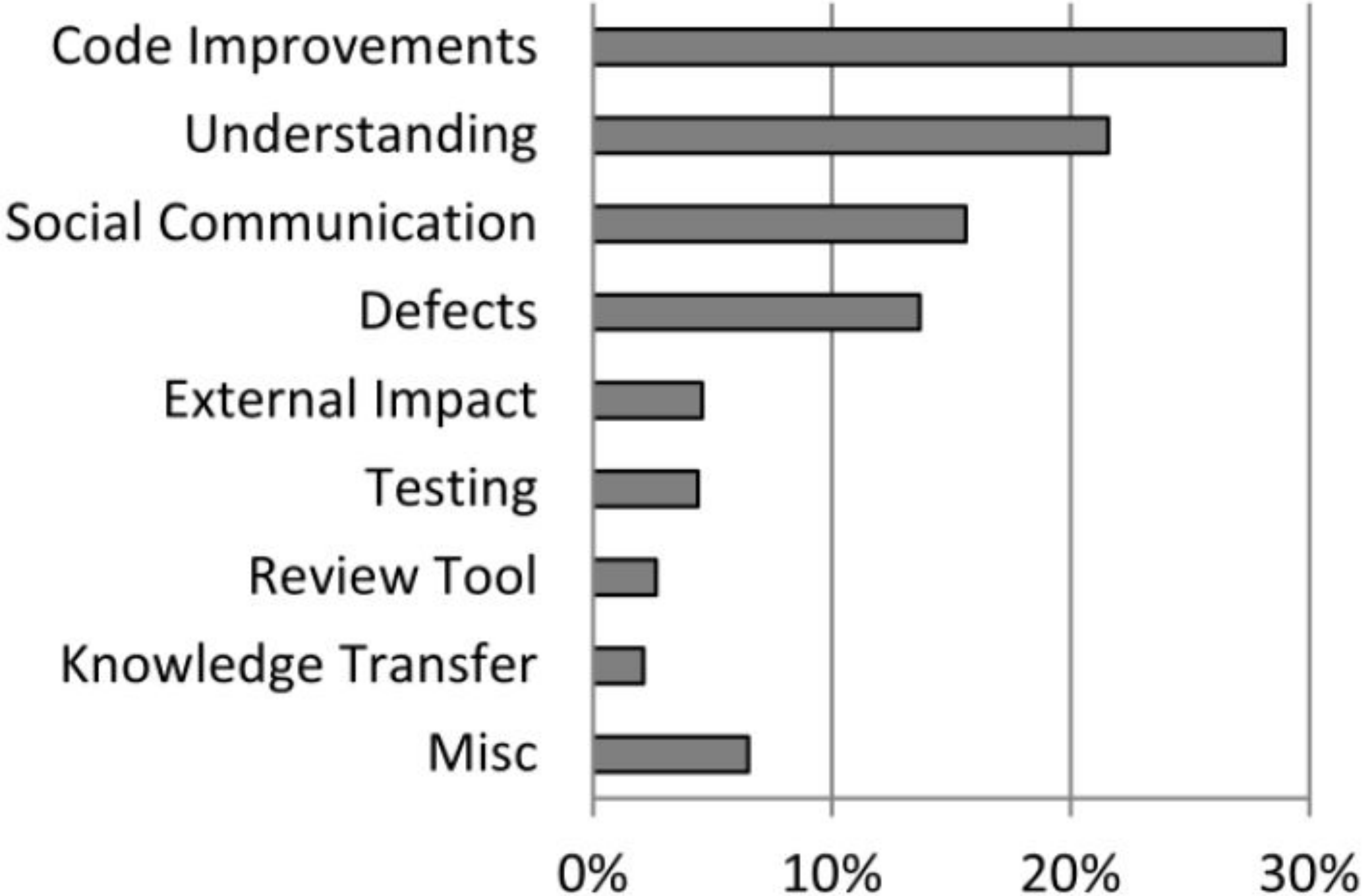
How to get developers to run tests?


Build #17 - wyvernla
https://travis-ci.org/wyvernlang/wyvern/builds/79099642
Travis CI
Blog
Status
Help
Jonathan Aldrich
Search all repositories
My Repositories
wyvernlang/wyvern
17
Duration: 16 sec
Finished: 3 days ago
wyvernlang / wyvern
build passing
Settings
Current
Branches
Build History
Pull Requests
Build #17
SimpleWyvern-devel Asserting false (works on Linux, so its OK).
potanin authored and committed
17 passed
Commit fd7be1c
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
Using worker: worker-linux-027f0490-1.bb.travis-ci.org:travis-linux-2
Build system information
system_info
$ git clone --depth=50 --branch=SimpleWyvern-devel
git.checkout
0.81s
$ jdk_switcher use oraclejdk8
Switching to Oracle JDK8 (java-8-oracle), JAVA_HOME will be set to /usr/lib/jvm/java-8-oracle
$ java -Xmx32m -version
java version "1.8.0_31"
Java(TM) SE Runtime Environment (build 1.8.0_31-b13)

How to get developers to use static analysis?



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


Code Improvements
Understanding
Social Communication
Defects
External Impact
Testing
Review Tool
Knowledge Transfer
Misc
0%
10%
20%
30%

How to get developers to use static analysis?

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

public class Test {
```

Lint — Missing a Javadoc comment.
Java
1:02 AM, Aug 21
Please fix — Not useful

```java
  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
Suggested fix attached: show — Not useful

```java
  }

  public String getString() {
```

Are code reviews worth it?

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?)

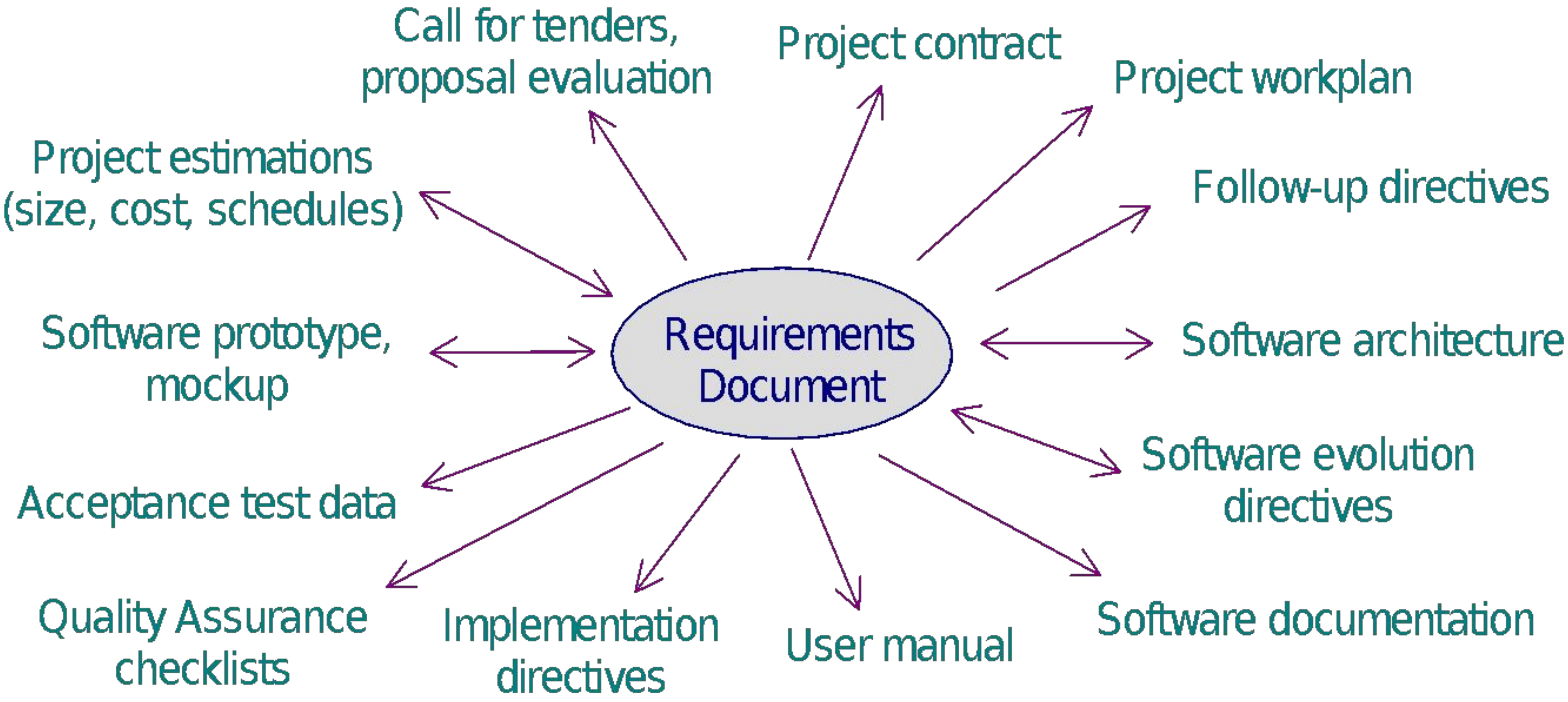
Lufthansa Flight 2904

- The Airbus A320-200 airplane has a software-based braking system
- Engaging reverse thrusters while in the air is very dangerous: **Only allow breaking when on the ground**

Lufthansa Flight 2904

Two conditions needed to “be on the ground”:

1. Both shock absorber bear a load of 6300 kgs
2. Both wheels turn at 72 knots (83 mph) or faster


Call for tenders,
proposal evaluation
Project contract
Project workplan
Project estimations
(size, cost, schedules)
Follow-up directives
Requirements
Document
Software prototype,
mockup
Software architecture
Software evolution
directives
Acceptance test data
Quality Assurance
checklists
Implementation
directives
User manual
Software documentation

Interviews

Abby Jones[1]

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,

Advertisement: SE @ CMU

Many courses

Spring: SE for Startups, ML in Production, Program Analysis, WebApps
Fall: Foundations of SE, API Design

Master level: Formal methods, Requirements, Architecture, Agile, QA, DevOps, Software Project Mgmt, Scalable Systems, Embedded Sys., …
Technical foundations: ML, Distributed Systems

Many research opportunities -- contact us for pointers

https://www.cmu.edu/scs/isr/reuse/
https://se-phd.isri.cmu.edu/

Software Engineering Concentration / Minor

One Last Survey

https://bit.ly/214last

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