Principles of Software Construction: Objects, Design, and Concurrency (Part 1: Designing Classes)

Design for Change (class level)

Christian Kästner **Bogdan Vasilescu**

School of Computer Science

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Administrivia

- Homework 1 due today
- Homework 2:
  - out tonight
  - due next Thursday (Feb 2)
- Reading assignment due next Tuesday (Jan 31)

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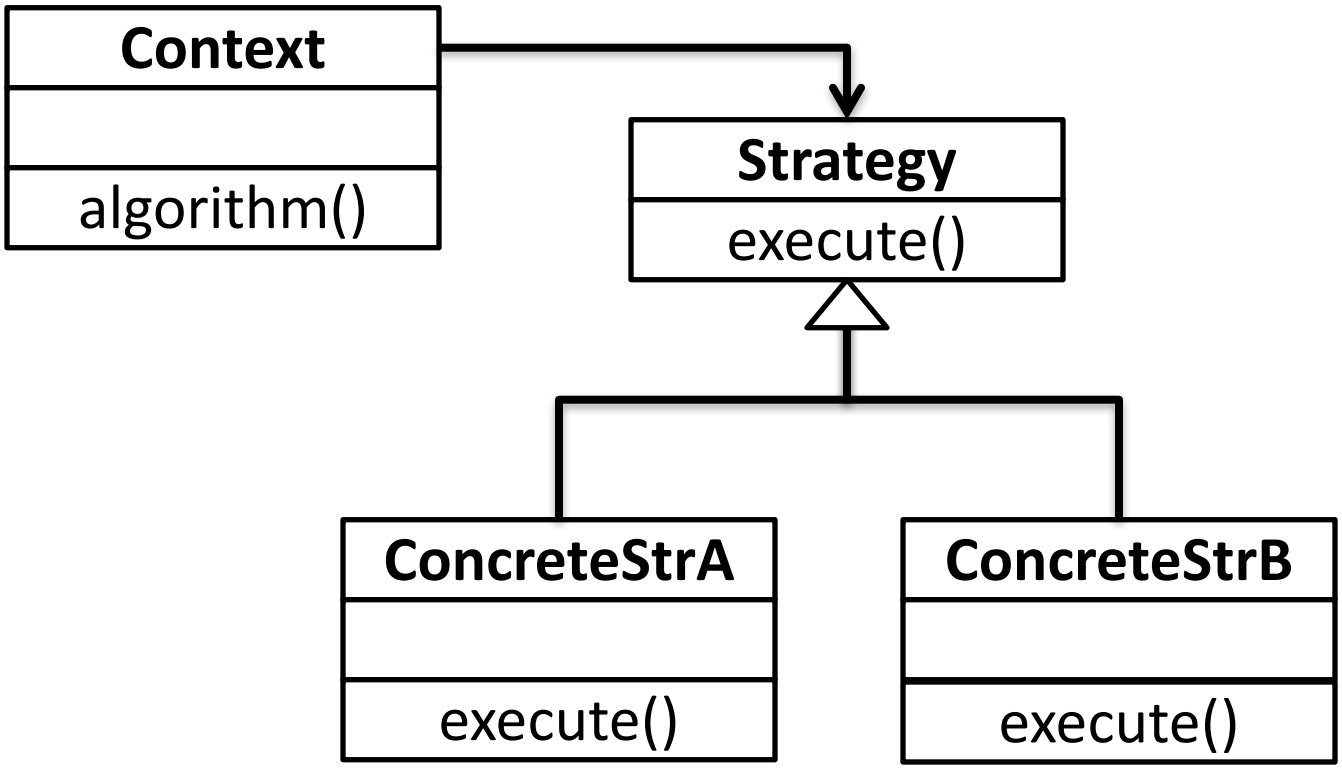
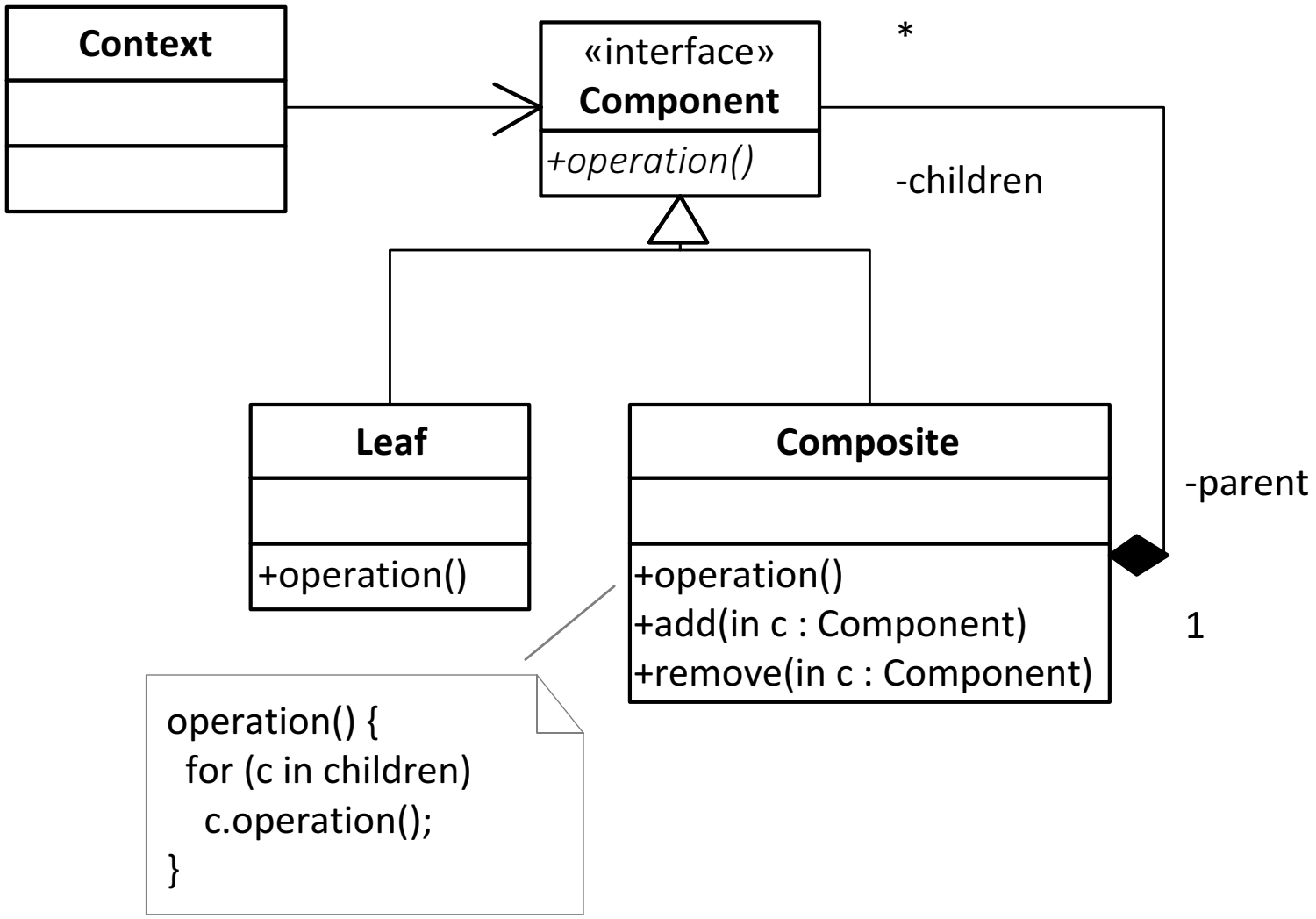
The Strategy Design Pattern



Review

The Composite Design Pattern



Review

Design Exercise (on paper)

Review

- You are designing software for a shipping company.
- There are several different kinds of items that can be shipped: letters, books, packages, fragile items, etc.
- Two important considerations are the **weight** of an item and its **insurance cost**.
  - Fragile items cost more to insure.
  - All letters are assumed to weigh an ounce
  - We must keep track of the weight of other packages.
- The company sells **boxes** and customers can put several items into them.
  - The software needs to track the contents of a box (e.g. to add up its weight, or compute the total insurance value).
  - However, most of the software should treat a box holding several items just like a single item.
- Think about how to represent packages; what are possible interfaces, classes, and methods? (letter, book, box only)

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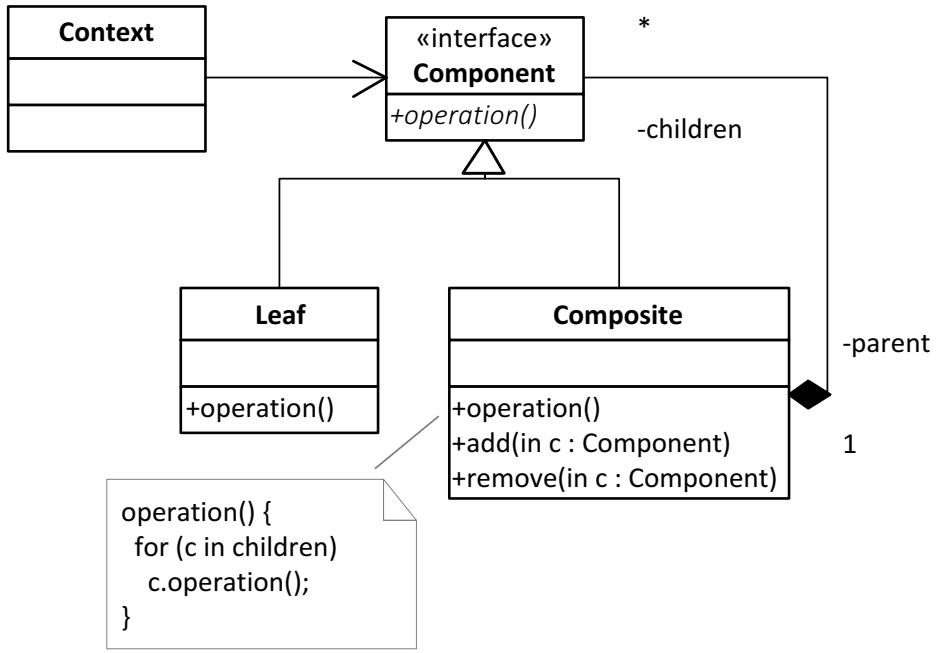
Review

```
interface Item {
    double getWeight();
}

class Letter implements Item {
    double weight;
    double getWeight() {...}
}

class Box implements Item {
    ArrayList<Item> items=new ArrayList<>();
    double getWeight() {
        double weight = 0.0
        for(Item item : items) {
            weight += item.getWeight();
        }
    }
    void add(Item item){
        items.add(item);
    }
}
```



Best practices for information hiding

- Carefully design your API
- Provide *only* functionality required by clients
  - *All* other members should be private
- You can always make a private member public later without breaking clients
  - But not vice-versa!

Review

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CONTRACTS (BEYOND TYPE SIGNATURES)

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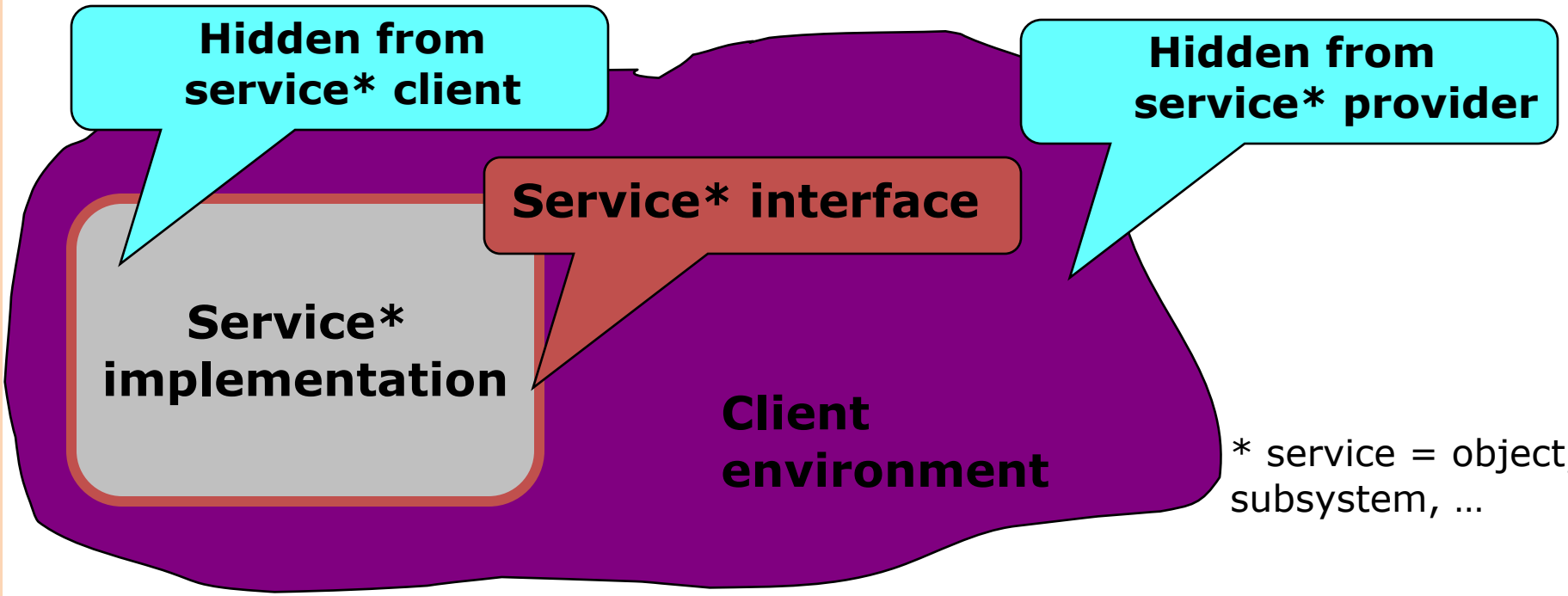
Contracts and Clients



* service = object, subsystem, …

Review

What is a contract?

- Agreement between an object and its user
- Includes
  - Method signature (type specifications)
  - Functionality and correctness expectations
  - Performance expectations
- **What the method does**, not how it does it
  - **Interface (API)**, not implementation

Review

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Who's to blame?

```
Math.sqrt(-5);

> 0
```

```
/**
  * Returns the correctly rounded positive square root of a
  * {@code double} value.
  * Special cases:
  * <ul><li>If the argument is NaN or less than zero, then the
  * result is NaN.
  * <li>If the argument is positive infinity, then the result
  * is positive infinity.
  * <li>If the argument is positive zero or negative zero, then
  * the result is the same as the argument.</ul>
  * Otherwise, the result is the {@code double} value closest to
  * the true mathematical square root of the argument value.
  *
  * @param a a value.
  * @return the positive square root of {@code a}.
  * If the argument is NaN or less than zero, the result is NaN.
  */
public static double sqrt(double a) { …}
```

Review

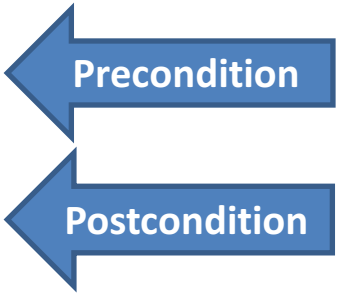
Method contract details

- States method's and caller's responsibilities
- Analogy: legal contract
  - If you pay me this amount on this schedule I will build you a house with the following detailed specification…
  - Some contracts have remedies for nonperformance
- Method contract structure
  - **Preconditions**: what method requires for correct operation
  - **Postconditions**: what method establishes on completion
  - **Exceptional behavior**: what it does if precondition violated
- Defines what it means for implementation to be correct

Formal contract specification

Java Modelling Language (JML)

```
/*@ requires len >= 0 && array != null && array.length == len;
  @
  @ ensures \result ==
  @           (\sum int j;  0 <= j && j < len;  array[j]);
  @*/
int total(int array[], int len);
```



- Theoretical approach
  - Advantages
    - Runtime checks generated automatically
    - Basis for formal verification
    - Automatic analysis tools
  - Disadvantages
    - Requires a lot of work
    - Impractical in the large
    - Some aspects of behavior not amenable to formal specification

Runtime Checking of Specifications with Assertions

```
/*@ requires len >= 0 && array.length == len
   @ ensures \result ==
   @                (\sum int j;  0 <= j && j < len;  array[j])
   @*/
float sum(int array[], int len) {
    assert len >= 0;
    assert array.length == len;
    float sum = 0.0;
    int i = 0;
    while (i < len) {
        sum = sum + array[i]; i = i + 1;
    }
    assert sum …;
    return sum;
}
```

Enable assertions with `-ea` flag, e.g.,

```
> java -ea Main
```

Runtime Checking of Specifications with Exceptions

```
/*@ requires len >= 0 && array.length == len
   @ ensures \result ==
   @                (\sum int j;  0 <= j && j < len;  array[j])
   @*/
float sum(int array[], int len) {
    if (len < 0 || array.length != len)
        throw IllegalArgumentException(…);
    float sum = 0.0;
    int i = 0;
    while (i < len) {
        sum = sum + array[i]; i = i + 1;
    }
    return sum;
}
```

Check arguments even when assertions are disabled.
Good for robust libraries!

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Textual contract specification - Javadoc

- Practical approach
  - Writing specifications is good practice
  - Especially necessary when reusing code and integrating code
  - Writing fully formal specifications is often unrealistic
- Document
  - Every parameter
  - Return value
  - Every exception (checked and unchecked)
  - What the method does, including
    - Purpose
    - Side effects
    - Any thread safety issues
    - Any performance issues
- Do **not** document implementation details

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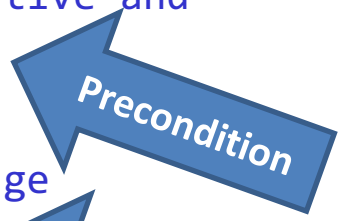
Specifications in the real world

Javadoc

```
/**
 * Returns the element at the specified position of this list.
 *
 * <p>This method is <i>not</i> guaranteed to run in constant time.
 * In some implementations, it may run in time proportional to the
 * element position.
 *
 * @param index position of element to return; must be non-negative and
 *              less than the size of this list.
 * @return the element at the specified position of this list
 * @throws IndexOutOfBoundsException if the index is out of range
 *         ({@code index < 0 || index >= this.size()})
 */
E get(int index);
```



Write a Specification

- Write
  - a type signature,
  - a textual (Javadoc) specification, and
  - a formal specification

for a function **slice(list, from, until)** that returns all values of a list between positions <from> and <until> as a new list

Reminder: Formal specification

```
/*@ requires len >= 0 && array != null &&
  @                  array.length == len;
  @
  @ ensures \result ==
  @            (\sum int j;  0 <= j &&
  @                  j < len;  array[j]);
  @*/
int total(int array[], int len);
```

Reminder: Javadoc specification

```
/**
 * Returns …
 * @param index position of element …
 * @return the element at the specified posi
 * @throws IndexOutOfBoundsException if the
 *         ({@code index < 0 || index >= thi
 */
E get(int index);
```

Contracts and Interfaces

- All objects implementing an interface must adhere to the interface's contracts
  - Objects may provide different implementations for the same specification
  - Subtype polymorphism: Client only cares about interface, not about the implementation

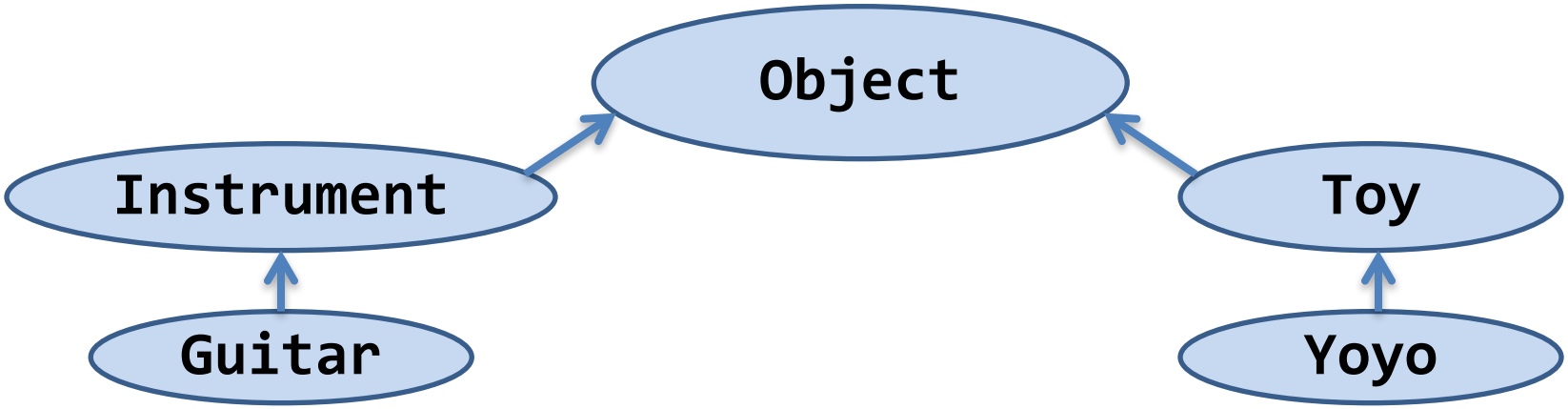
p.getX() **s.read()**

=> **Design for Change**

ASIDE:
THE EQUALS CONTRACT

The class hierarchy

- All Java objects inherit from `java.lang.Object`



- Commonly-used/overridden public methods:
  - `equals` - returns true if the two objects are "equal"
  - `hashCode` - returns an `int` that must be equal for equal objects, and is likely to differ on unequal objects
  - `toString` - returns a printable string representation

The `.equals(Object obj)` contract

- **Reflexive** – every object is equal to itself
- **Symmetric** – `if a.equals(b)` then `b.equals(a)`
- **Transitive** – if `a.equals(b)` and `b.equals(c)`, then `a.equals(c)`
- **Consistent** – Invoking `a.equals(b)` repeatedly returns the same value unless `a` or `b` is modified; implemented by `.hashCode()`
- **"Non-null"** – `a.equals(null)` returns false
- Taken together these ensure that equals is a global **equivalence relation** over all objects

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The == operator vs. the `equals()` method

- The == operator determines if two references are identical to each other
- The `equals` method determines if objects are equal
- User classes can override the `equals` method to implement a domain-specific test for equality

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What's the output?

```
public class Point {
  private int x;
  private int y;
  public Point(int x, int y) {
    this.x = x;
    this.y = y;
  }
  ...
}
...
Point p1 = new Point(1, 2);
Point p2 = new Point(1, 2);
```

```
System.out.println(p1 == p2);
```

False

What's the output?

```
public class Point {
  private int x;
  private int y;
  public Point(int x, int y) {
    this.x = x;
    this.y = y;
  }
  ...
}
...
Point p1 = new Point(1, 2);
Point p2 = new Point(1, 2);
```

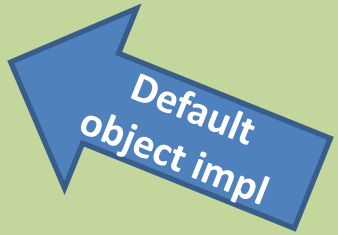
```
System.out.println(p1.equals(p2));
```

False

What's the output?

```
public class Point {
  private int x;
  private int y;
  public Point(int x, int y) {
    this.x = x;
    this.y = y;
  }
  ...
}
...
Point p1 = new Point(1, 2);
Point p2 = new Point(1, 2);
```

```
public boolean equals(Object obj) {
  return this == obj;
}
```




```
System.out.println(p1.equals(p2));
```

What's the output?

```
public class Point {
  private int x;
  private int y;
  public Point(int x, int y) {
    this.x = x;
    this.y = y;
  }
  ...
}
...
Point p1 = new Point(1, 2);
Point p2 = new Point(1, 2);
```

```
@Override
public boolean equals(Object obj) {
  boolean result = false;
  if (obj instanceof Point) {
    Point that = (Point) obj;
    result =
        (this.getX() == that.getX()
        && this.getY() == that.getY());
   }
   return result;
}
```

True

```
System.out.println(p1.equals(p2));
```

What's the output?

```
public class Point {
  private int x;
  private int y;
  public Point(int x, int y) {
    this.x = x;
    this.y = y;
  }
  ...
}
...
Point p1 = new Point(1, 2);
Point p2 = new Point(1, 2);
```

```
@Override
public boolean equals(Object obj) {
  boolean result = false;
  if (obj instanceof Point) {
    Point that = (Point) obj;
    result =
        (this.getX() == that.getX()
        && this.getY() == that.getY());
   }
   return result;
}
```

False

```
HashSet<Point> coll = new HashSet<Point>();
coll.add(p1);
System.out.println(coll.contains(p2));
```

The `.hashCode()` contract

- Consistent
  - Invoking `x.hashCode()` repeatedly returns same value unless x is modified
- `x.equals(y)` implies `x.hashCode() == y.hashCode()`
  - The reverse implication is not necessarily true:
    - `x.hashCode() == y.hashCode()` does not imply `x.equals(y)`
- Advice: Override `.equals()` if and only if you override `.hashCode()`

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What's the output?

```
public class Point {
  private int x;
  private int y;
  public Point(int x, int y) {
    this.x = x;
    this.y = y;
  }
  ...
}
...
Point p1 = new Point(1, 2);
Point p2 = new Point(1, 2);
```

```
@Override
public boolean equals(Object obj) {
  boolean result = false;
  if (obj instanceof Point) {
    Point that = (Point) obj;
    result =
        (this.getX() == that.getX()
        && this.getY() == that.getY());
   }
   return result;
}
@Override public int hashCode() {
   return (41*(41 + getX()) + getY());
}
```

True

```
HashSet<Point> coll = new HashSet<Point>();
coll.add(p1);
System.out.println(coll.contains(p2));
```

What's the output?

```
public class Point {
  private int x;
  private int y;
  public Point(int x, int y) {
    this.x = x;
    this.y = y;
  }
  ...
}
...
Point p1 = new Point(1, 2);
Point p2 = new Point(1, 2);
```

```
@Override
public boolean equals(Object obj) {
  boolean result = false;
  if (obj instanceof Point) {
    Point that = (Point) obj;
    result =
        (this.getX() == that.getX()
        && this.getY() == that.getY());
   }
   return result;
}
@Override public int hashCode() {
   return (41*(41 + getX()) + getY());
}
```

But it's not over; see Effective Java #8

The lesson: Conforming to contracts can be difficult!

FUNCTIONAL CORRECTNESS (UNIT TESTING AGAINST INTERFACES)

Context

- **Design for Change** as goal
- **Encapsulation** provides technical means
- **Information Hiding** as design strategy
- **Contracts** describe behavior of hidden details
- **Testing** helps gaining confidence in functional correctness (w.r.t. contracts)

Functional correctness

- Compiler ensures types are correct (type-checking)
  - Prevents many runtime errors, such as “Method Not Found” and “Cannot add boolean to int”

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Type Checking Example


```
interface Animal {
    void makeSound();
}
class Dog implements Animal {
    public void makeSound() { System.out.println("bark!"); }
}
class Cow implements Animal {
    public void makeSound() { mew(); }
    public void mew() {System.out.println("Mew!"); }
}
```

```
1 Animal a = new Animal();
2 a.makeSound();
3 Dog d = new Dog();
4 d.makeSound();
5 Animal b = new Cow();
6 b.mew();
7 b.jump();
```

- What happens?

Functional correctness

- Compiler ensures types are correct (type-checking)
  - Prevents many runtime errors, such as "Method Not Found" and "Cannot add boolean to int"
- Static analysis tools (e.g., FindBugs) recognize many common problems (*bug patterns*)
  - Warns on possible NullPointerExceptions or forgetting to close files

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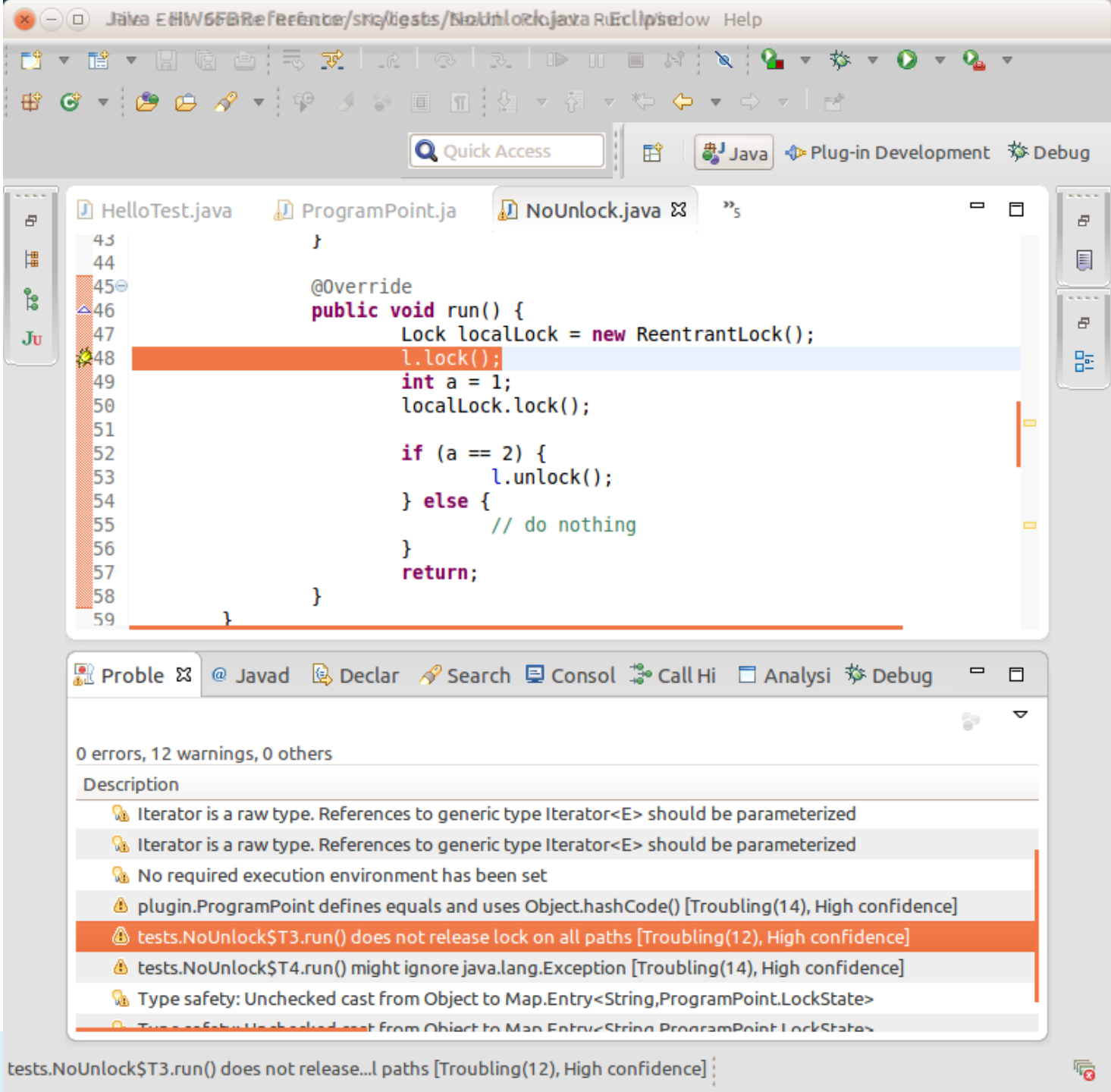
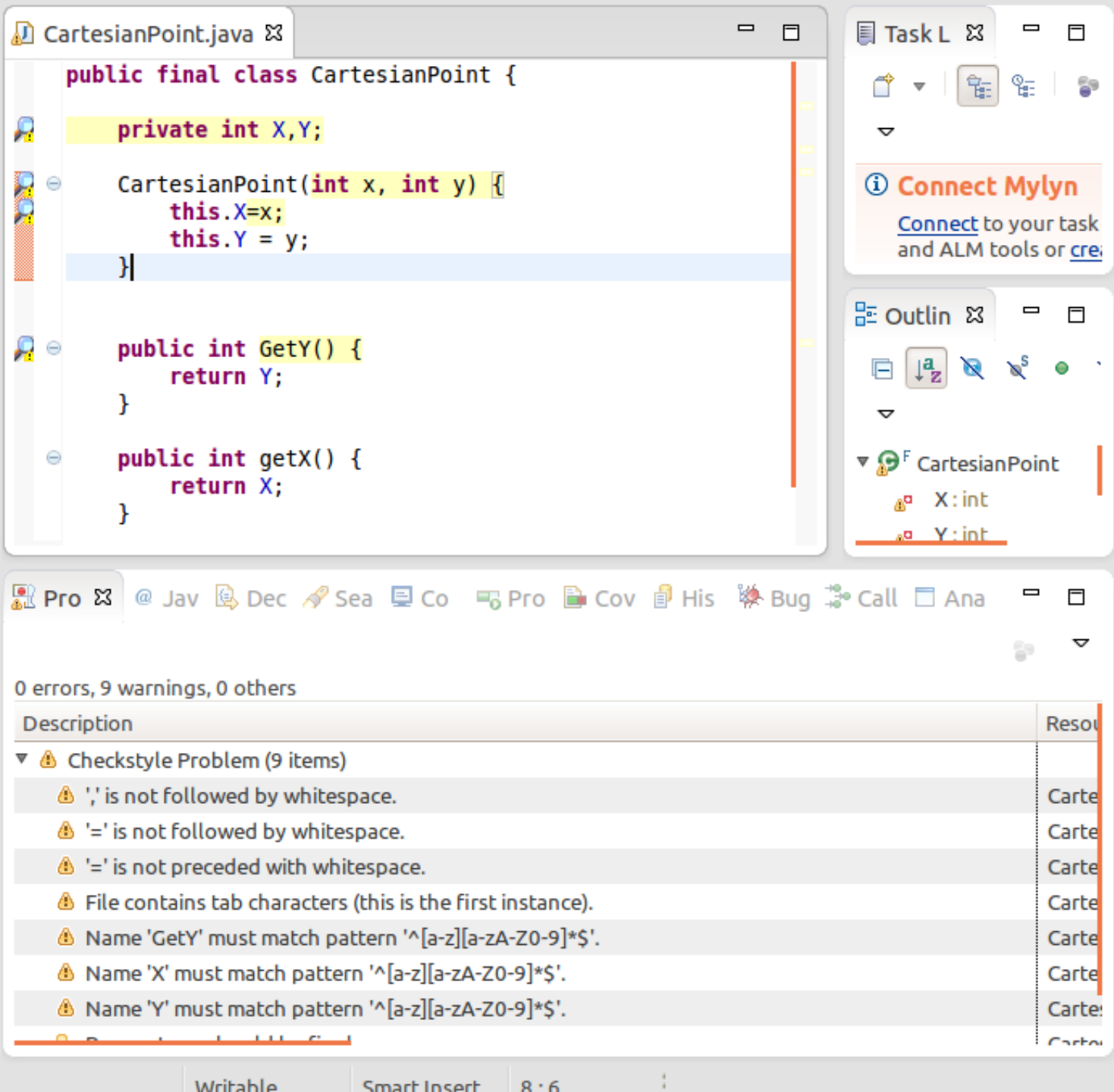
FindBugs


Java EE - HW6FBReference/src/tests/NoUnlock.java - Eclipse
Window Help
Quick Access
Java
Plug-in Development
Debug
HelloTest.java
ProgramPoint.ja
NoUnlock.java
43 }
44
45 @Override
46 public void run() {
47 Lock localLock = new ReentrantLock();
48 l.lock();
49 int a = 1;
50 localLock.lock();
51
52 if (a == 2) {
53 l.unlock();
54 } else {
55 // do nothing
56 }
57 return;
58 }
59 }
Proble
Javad
Declar
Search
Consol
Call Hi
Analysi
Debug
0 errors, 12 warnings, 0 others
Description
Iterator is a raw type. References to generic type Iterator<E> should be parameterized
Iterator is a raw type. References to generic type Iterator<E> should be parameterized
No required execution environment has been set
plugin.ProgramPoint defines equals and uses Object.hashCode() [Troubling(14), High confidence]
tests.NoUnlock$T3.run() does not release lock on all paths [Troubling(12), High confidence]
tests.NoUnlock$T4.run() might ignore java.lang.Exception [Troubling(14), High confidence]
Type safety: Unchecked cast from Object to Map.Entry<String,ProgramPoint.LockState>
tests.NoUnlock$T3.run() does not release...l paths [Troubling(12), High confidence]

CheckStyle


CartesianPoint.java
public final class CartesianPoint {
private int X,Y;
CartesianPoint(int x, int y) {
this.X=x;
this.Y = y;
}
public int GetY() {
return Y;
}
public int getX() {
return X;
}
Task L
Connect Mylyn
Connect to your task
and ALM tools or
Outlin
CartesianPoint
X : int
Y : int
Pro
Jav
Dec
Sea
Co
Pro
Cov
His
Bug
Call
Ana
0 errors, 9 warnings, 0 others
Description
Checkstyle Problem (9 items)
',' is not followed by whitespace.
'=' is not followed by whitespace.
'=' is not preceded with whitespace.
File contains tab characters (this is the first instance).
Name 'GetY' must match pattern '^[a-z][a-zA-Z0-9]*$'.
Name 'X' must match pattern '^[a-z][a-zA-Z0-9]*$'.
Name 'Y' must match pattern '^[a-z][a-zA-Z0-9]*$'.
Writable
Smart Insert
8 : 6

Functional correctness

- Compiler ensures types are correct (type-checking)
  - Prevents many runtime errors, such as "Method Not Found" and "Cannot add boolean to int"
- Static analysis tools (e.g., FindBugs) recognize many common problems (*bug patterns*)
  - Warns on possible NullPointerExceptions or forgetting to close files
- How to ensure functional correctness of contracts beyond type correctness and bug patterns?

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Formal verification

- Use mathematical methods to prove correctness with respect to the formal specification
- Formally prove that all possible executions of an implementation fulfill the specification
- Manual effort; partial automation; not automatically decidable

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Testing

- Executing the program with selected inputs in a controlled environment
- Goals
  - Reveal bugs, so they can be fixed (main goal)
  - Assess quality
  - Clarify the specification, documentation

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Re: Formal verification, Testing

“Beware of bugs in the above code; I have only proved it correct, not tried it.”

Donald Knuth, 1977

"Testing shows the presence, not the absence of bugs.”

Edsger W. Dijkstra, 1969

Q: Who's right, Dijkstra or Knuth?

```
1:      public static int binarySearch(int[] a, int key) {
2:          int low = 0;
3:          int high = a.length - 1;
4:
5:          while (low <= high) {
6:              int mid = (low + high) / 2;
7:              int midVal = a[mid];
8:
9:              if (midVal < key)
10:                 low = mid + 1
11:             else if (midVal > key)
12:                 high = mid - 1;
13:             else
14:                 return mid; // key found
15:         }
16:         return -(low + 1);  // key not found.
17:     }
```

Q: Who's right, Dijkstra or Knuth?

```
1:     public static int binarySearch(int[] a, int key) {
2:         int low = 0;
3:         int high = a.length - 1;
4:
5:         while (low <= high) {
6:             int mid = (low + high) / 2;
7:             int midVal = a[mid];
8:
9:             if (midVal < key)
10:                 low = mid + 1
11:             else if (midVal > key)
12:                 high = mid - 1;
13:             else
14:                 return mid; // key found
15:         }
16:         return -(low + 1);  // key not found.
17:     }
```

Spec: sets `mid` to the average of `low` and `high`, truncated down to the nearest integer.

Fails if
`low + high` > MAXINT ($2^{31} - 1$)
Sum overflows to negative value

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A: They're both right

- There is no silver bullet!
- Use all the tools at your disposal
  - Careful design
  - Testing
  - Formal methods (where appropriate)
  - Code reviews
  - …
- You'll still have bugs, but hopefully fewer.

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What to test?

- Functional correctness of a method (e.g., computations, contracts)
- Functional correctness of a class (e.g., class invariants)
- Behavior of a class in a subsystem/multiple subsystems/the entire system
- Behavior when interacting with the world
  - Interacting with files, networks, sensors, …
  - Erroneous states
  - Nondeterminism, Parallelism
  - Interaction with users
- Other qualities (performance, robustness, usability, security, …)

Our focus now

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Manual testing

GENERIC TEST CASE: USER SENDS MMS WITH PICTURE ATTACHED.

Step ID	User Action	System Response
1	Go to Main Menu	Main Menu appears
2	Go to Messages Menu	Message Menu appears
3	Select "Create new Message"	Message Editor screen opens
4	Add Recipient	Recipient is added
5	Select "Insert Picture"	Insert Picture Menu opens
6	Select Picture	Picture is Selected
7	Select "Send Message"	Message is correctly sent

- Live System?
- Extra Testing System?
- Check output / assertions?
- Effort, Costs?
- Reproducible?

Automated testing

- Execute a program with specific inputs, check output for expected values
- Easier to test small pieces than testing user interactions
- Set up testing infrastructure
- **Execute tests regularly**
  - After *every* change

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Example

Black box testing

```
/**
 * computes the sum of the first len values of the array
 *
 * @param array array of integers of at least length len
 * @param len number of elements to sum up
 * @return sum of the array values
 */
int total(int array[], int len);
```

Example

Black box testing

```
/**
 * computes the sum of the first len values of the array
 *
 * @param array array of integers of at least length len
 * @param len number of elements to sum up
 * @return sum of the array values
 */
int total(int array[], int len);
```

- Test empty array
- Test array of length 1 and 2
- Test negative numbers
- Test invalid length (negative / longer than array.length)
- Test null as array
- Test with a very long array

Unit Tests

- Tests for small units: functions, classes, subsystems
  - Smallest testable part of a system
  - Test parts before assembling them
  - Intended to catch local bugs
- Typically written by developers
- Many small, fast-running, independent tests
- Little dependencies on other system parts or environment
- Insufficient but a good starting point, extra benefits:
  - Documentation (executable specification)
  - Design mechanism (design for testability)

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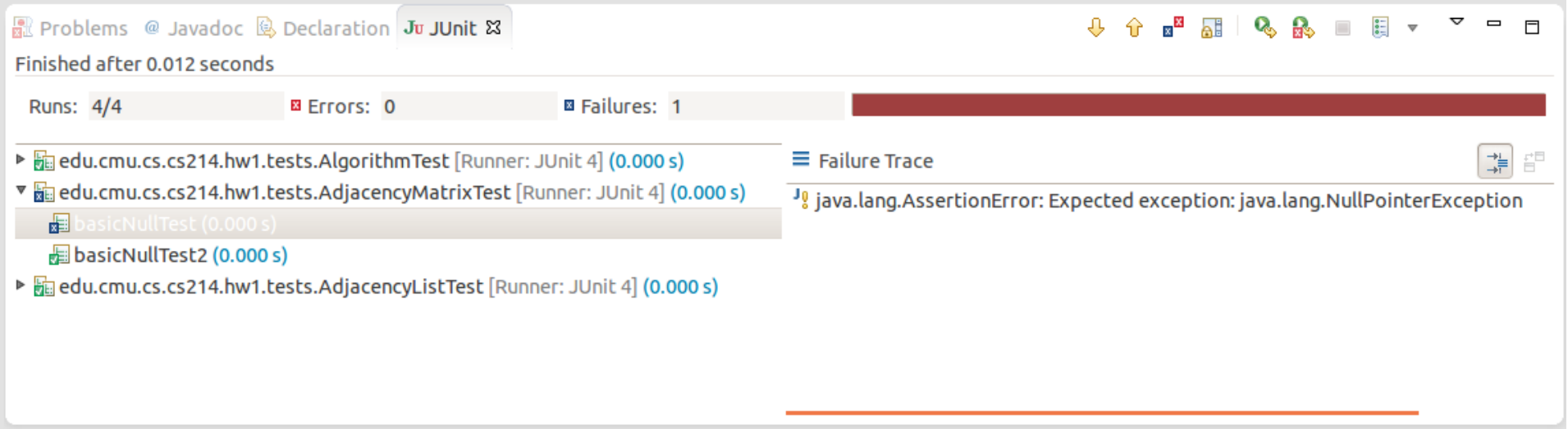
JUnit

- Popular unit-testing framework for Java
- Easy to use
- Tool support available
- Can be used as design mechanism



JUnit

```
import org.junit.Test;
import static org.junit.Assert.assertEquals;

public class AdjacencyListTest {
        @Test
        public void testSanityTest(){
                Graph g1 = new AdjacencyListGraph(10);
                Vertex s1 = new Vertex("A");
                Vertex s2 = new Vertex("B");
                assertEquals(true, g1.addVertex(s1));
                assertEquals(true, g1.addVertex(s2));
                assertEquals(true, g1.addEdge(s1, s2));
                assertEquals(s2, g1.getNeighbors(s1)[0]);
        }

        @Test
        public void test….

        private int helperMethod…
}
```

Set up tests

Check expected results

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assert, Assert

- assert is a native Java statement throwing an AssertionError exception when failing
  - **assert** expression: "Error Message";
- org.junit.Assert is a library that provides many more specific methods
  - static void **assertTrue**(java.lang.String message, boolean condition)
    // Asserts that a condition is true.
  - static void **assertEquals**(java.lang.String message, long expected, long actual);
    // Asserts that two longs are equal.
  - static void **assertEquals**(double expected, double actual, double delta);
    // Asserts that two doubles are equal to within a positive delta
  - static void **assertNotNull**(java.lang.Object object)
    // Asserts that an object isn't null.
  - static void **fail**(java.lang.String message)
    //Fails a test with the given message.

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JUnit conventions

- TestCase collects multiple tests (in one class)
- TestSuite collects test cases (typically package)
- Tests should run fast
- Tests should be independent

- Tests are methods without parameter and return value
- AssertError signals failed test (unchecked exception)

- Test Runner knows how to run JUnit tests
  - (uses reflection to find all methods with @Test annotat.)

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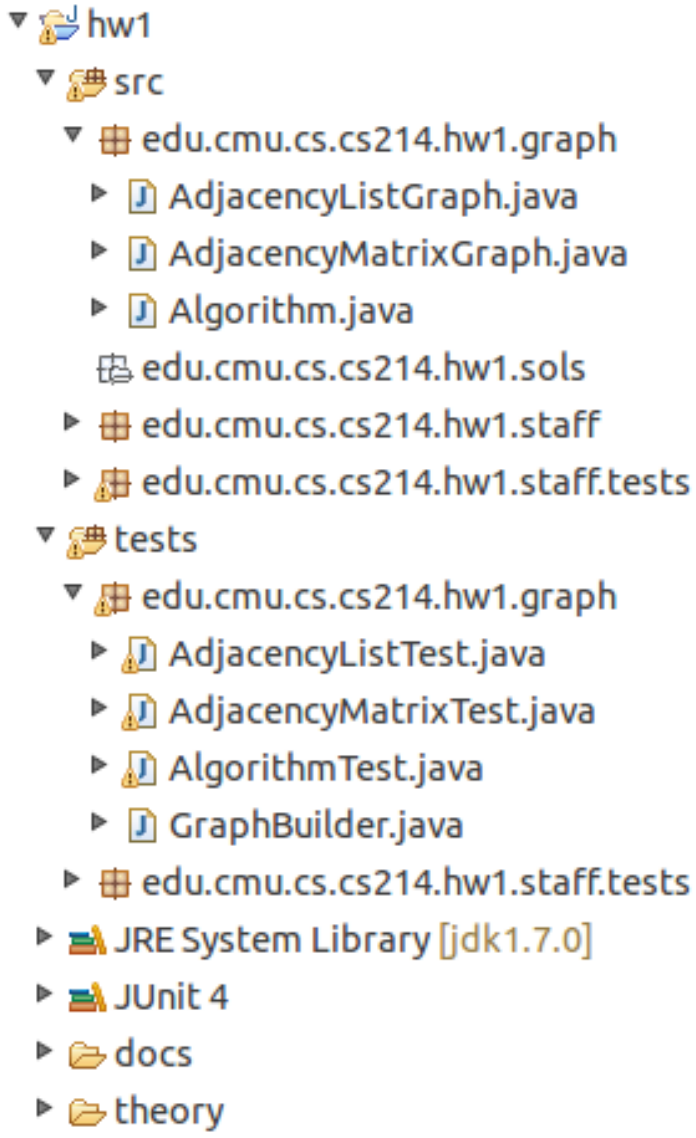
Test organization

- Conventions (not requirements)
- Have a test class FooTest for each public class Foo
- Have a source directory and a test directory
  - Store FooTest and Foo in the same package
  - Tests can access members with default (package) visibility



Selecting test cases: common strategies

- Read specification
- Write tests for
  - Representative case
  - Invalid cases
  - Boundary conditions
- Are there difficult cases? (error guessing)
  - Stress tests?
  - Complex algorithms?
- Think like an attacker
  - The tester's goal is to find bugs!
- How many test should you write?
  - Aim to cover the specification
  - Work within time/money constraints

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Testable code

- Think about testing when writing code
- Unit testing encourages you to write testable code
- Separate parts of the code to make them independently testable
- Abstract functionality behind interface, make it replaceable

- Test-Driven Development
  - A design and development method in which you write tests before you write the code

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Write testable code

```
//700LOC
public boolean foo() {
    try {
        synchronized () {
            if () {
            } else {
            }
            for () {
                if () {
                    if () {
                        if () {
                            if ()?
                            {
                                if () {
                                    for () {
                                    }
                                }
                            }
                        } else {
                            if () {
                                for () {
                                    if () {
                                    } else {
                                    }
                                    if () {
                                    } else {
                                        if () {
                                        }
                                    }
                                    if () {
                                        if () {
                                            if () {
                                                for () {
                                                }
                                            }
                                        }
                                    } else {
                                    }
                                }
```

Unit testing as design mechanism

* Code with low complexity

* Clear interfaces and specifications

Source: http://thedailywtf.com/Articles/Coding-Like-the-Tour-de-France.aspx

When to stop writing tests?

- Outlook: statement coverage
  - Trying to test all parts of the implementation
  - Execute every statement, ideally

Does 100% coverage guarantee correctness?

A: No

```
1:      public static int binarySearch(int[] a, int key) {
2:          int low = 0;
3:          int high = a.length - 1;
4:
5:          while (low <= high) {
6:              int mid = (low + high) / 2;
7:              int midVal = a[mid];
8:
9:              if (midVal < key)
10:                  low = mid + 1
11:              else if (midVal > key)
12:                  high = mid - 1;
13:              else
14:                  return mid; // key found
15:          }
16:          return -(low + 1);  // key not found.
17:      }
```


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When to stop writing tests?

- Outlook: statement coverage
  - Trying to test all parts of the implementation
  - Execute every statement, ideally

Does less than 100% coverage guarantee incorrectness?

Sample.java | coverage-test/pom.xml | coverage-test 0.0.1-... | SampleTest.java

```
10
11 1     public int subtract(int a, int b) {
12 1         int x = a - b;
13 1
14 1         return x;
15 1     }
16
17 1     public boolean conditional(int a, int b) {
18 1         return a == b;
19 1     }
20
21 0     public void uncoveredMethod() {
22 0         String line = "not covered";
23 0     }
24
25 1     public String coveredMethod() {
26 1         String a = "hello"; String b = "world"; return a.concat(b);
27 1     }
28 }
29
```

A: No

Problems | Javadoc | Declaration | Console | Search | Coverage | Coverage Sessi | Clover Dashbo | Coverage Expl | Te

Name	Lines	Total	%	Branches
All Packages (2010-10-21 21:38:34)	38	46	82.61 %	1
com.copperykeenclaws	38	46	82.61 %	1
Sample	11	14	78.57 %	1
Sample$__CLR3_0_100gfkf1nq8	1	1	100.00 %	0
SampleTest	25	30	83.33 %	0

Packages

All
net.sourceforge.cobertura.ant
net.sourceforge.cobertura.check
net.sourceforge.cobertura.coveragedat
net.sourceforge.cobertura.instrument
net.sourceforge.cobertura.merge
net.sourceforge.cobertura.reporting
net.sourceforge.cobertura.reporting.htr
net.sourceforge.cobertura.reporting.htr
net.sourceforge.cobertura.reporting.xm
net.sourceforge.cobertura.util

All Packages

Classes

AntUtil *(88%)*
Archive *(100%)*
ArchiveUtil *(80%)*
BranchCoverageData *(N/A)*
CheckTask *(0%)*
ClassData *(N/A)*
ClassInstrumenter *(94%)*
ClassPattern *(100%)*
CoberturaFile *(73%)*
CommandLineBuilder *(96%)*
CommonMatchingTask *(88%)*
ComplexityCalculator *(100%)*
ConfigurationUtil *(50%)*
CopyFiles *(87%)*
CoverageData *(N/A)*
CoverageDataContainer *(N/A)*
CoverageDataFileHandler *(N/A)*
CoverageRate *(0%)*
ExcludeClasses *(100%)*
FileFinder *(96%)*
FileLocker *(0%)*
FirstPassMethodInstrumenter *(100%)*
HTMLReport *(94%)*
HasBeenInstrumented *(N/A)*
Header *(80%)*

Coverage Report - All Packages

Package	# Classes	Line Coverage		Branch Coverage		Compl
All Packages	55	75%	1625/2179	64%	472/738	
net.sourceforge.cobertura.ant	11	52%	170/330	43%	40/94	
net.sourceforge.cobertura.check	3	0%	0/150	0%	0/76	
net.sourceforge.cobertura.coveragedata	13	N/A	N/A	N/A	N/A	
net.sourceforge.cobertura.instrument	10	90%	460/510	75%	123/164	
net.sourceforge.cobertura.merge	1	86%	30/35	88%	14/16	
net.sourceforge.cobertura.reporting	3	87%	116/134	80%	43/54	
net.sourceforge.cobertura.reporting.html	4	91%	475/523	77%	156/202	
net.sourceforge.cobertura.reporting.html.files	1	87%	39/45	62%	5/8	
net.sourceforge.cobertura.reporting.xml	1	100%	155/155	95%	21/22	
net.sourceforge.cobertura.util	9	60%	175/291	69%	70/102	
someotherpackage	1	83%	5/6	N/A	N/A	

Report generated by Cobertura 1.9 on 6/9/07 12:37 AM.

Run tests frequently

- You should only commit code that is passing all tests
- Run tests before every commit
- If entire test suite becomes too large and slow for rapid feedback:
  - Run local tests ("smoke tests", e.g. all tests in package) frequently
  - Run all tests nightly
  - Medium sized projects easily have 1000s of test cases and run for minutes
- Continuous integration servers help to scale testing

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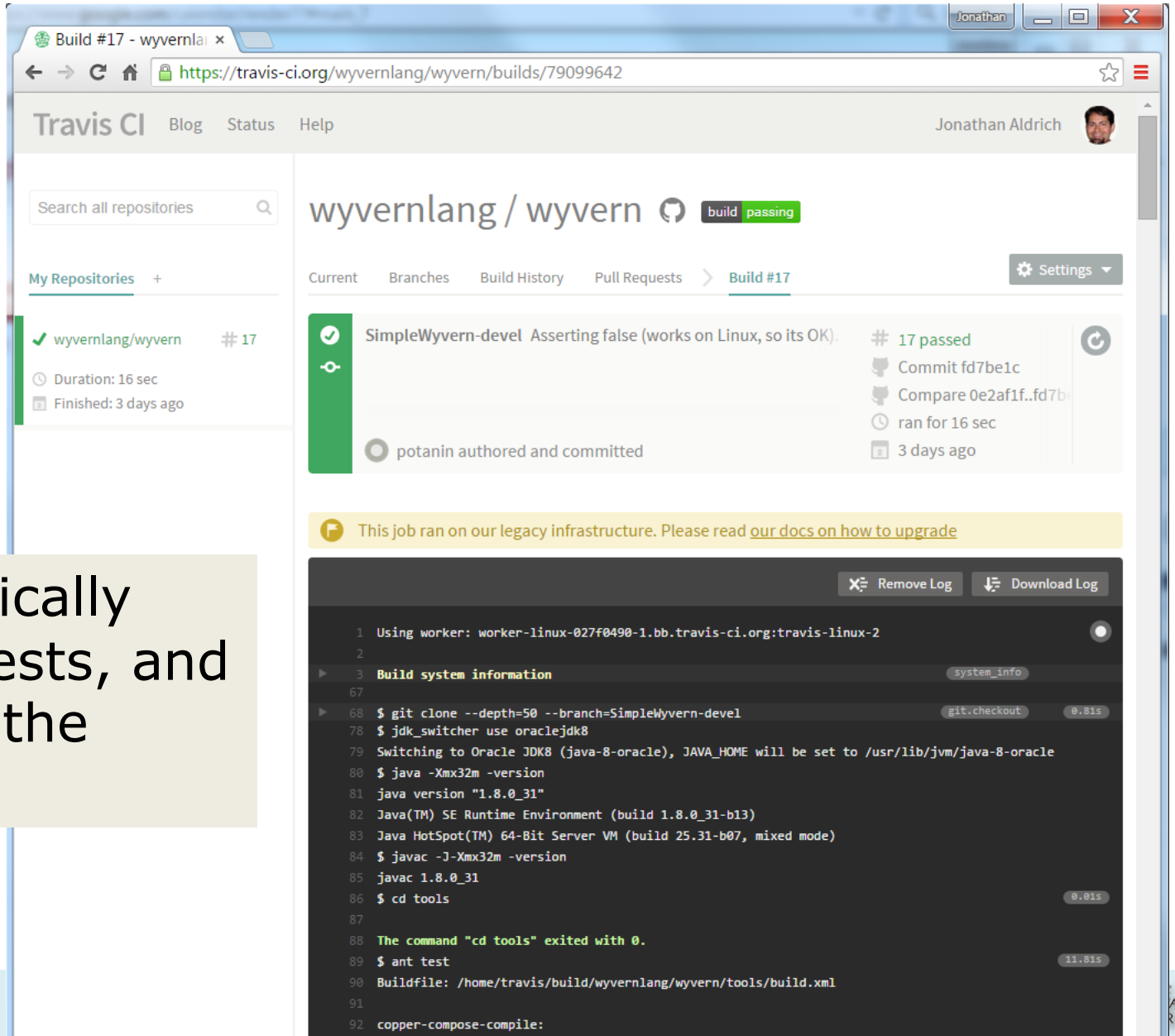
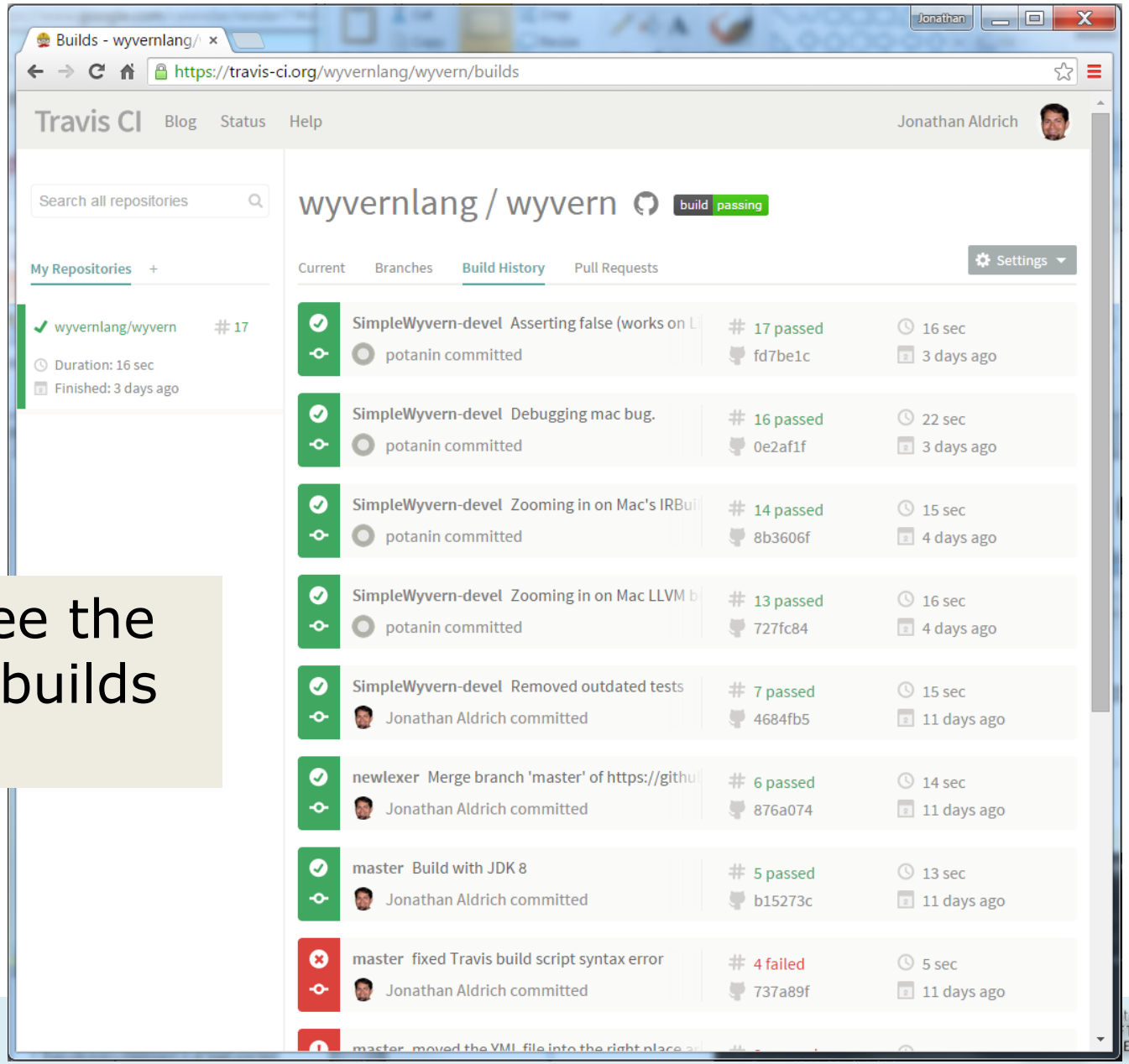
Continuous integration - Travis CI



Automatically builds, tests, and displays the result

Continuous integration - Travis CI



You can see the results of builds over time

Testing, Static Analysis, and Proofs

- Testing
  - Observable properties
  - Verify program for one execution
  - Manual development with automated regression
  - Most practical approach now
  - Does not find all problems (unsound)
- Static Analysis
  - Analysis of all possible executions
  - Specific issues only with conservative approx. and bug patterns
  - Tools available, useful for bug finding
  - Automated, but unsound and/or incomplete
- Proofs (Formal Verification)
  - Any program property
  - Verify program for all executions
  - Manual development with automated proof checkers
  - Practical for small programs, may scale up in the future
  - Sound and complete, but not automatically decidable

What strategy to use in your project?

SUMMARY: DESIGN FOR CHANGE/ DIVISION OF LABOR

Design Goals

- Design for Change such that
  - Classes are *open for extension* and modification without invasive changes
  - Subtype polymorphism enables changes behind interface
  - Classes encapsulate details likely to change behind (small) stable interfaces
- Design for Division of Labor such that
  - Internal parts can be *developed* independently
  - Internal details of other classes do not need to be *understood*, contract is sufficient
  - Test classes and their contracts separately (unit testing)

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