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Software Engineering

Software Testing & Unit Tests

TECHNISCHE UNIVERSITÄT DARMSTADT

- Resources
  - **Ian Sommerville**
    Software Engineering 8th Edition
    Addison Wesley 2007
  - **Robert v. Binder**
    Testing Object-Oriented Systems - Models, Patterns, and Tools
    Addison Wesley 2000

Software Testing

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Validation

*"Are we building **the right product**?"*

Verification

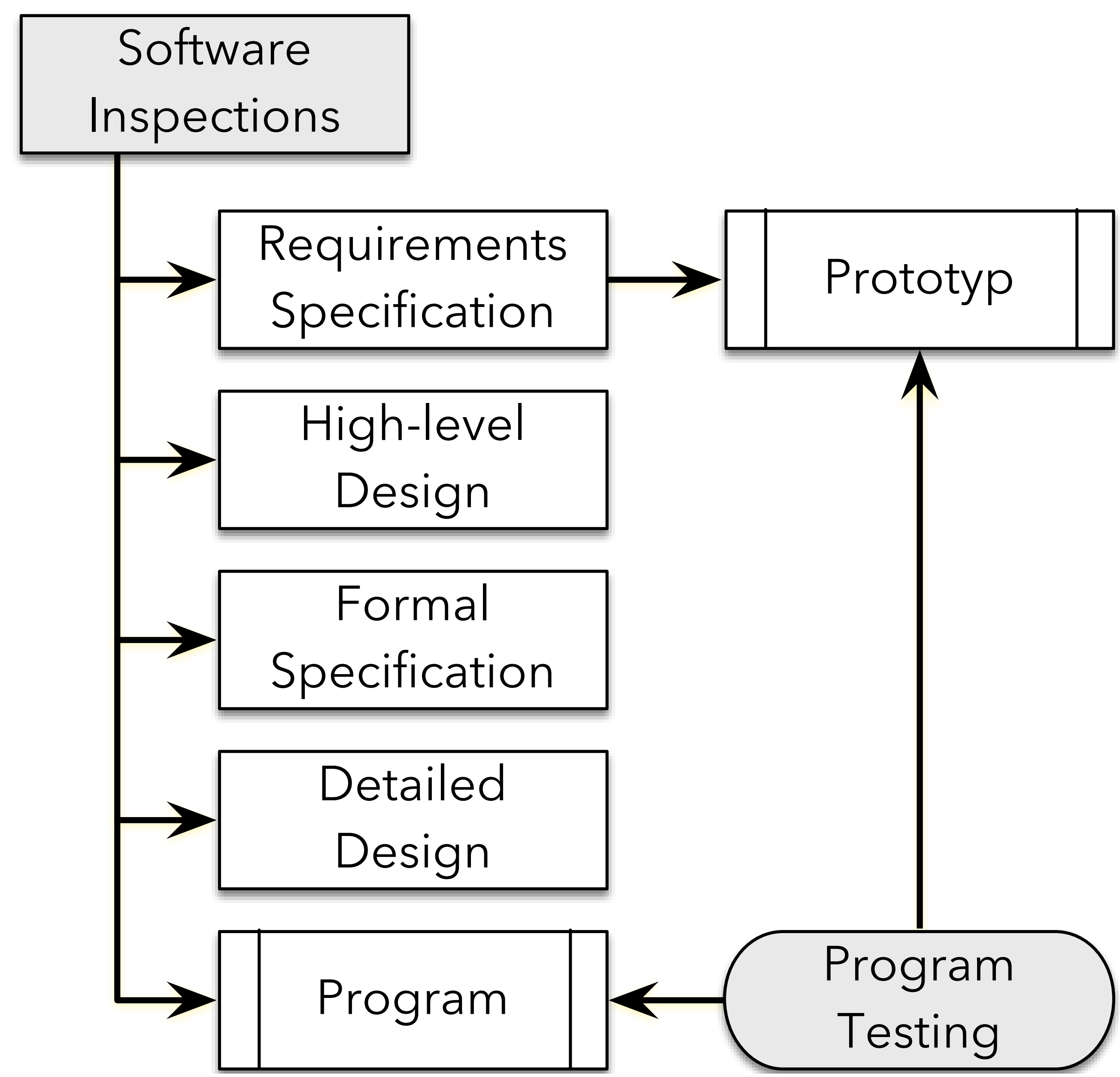
*"Are we **building the product right**?"*

Ian Sommerville

Software Engineering 8th Edition; Addison Wesley 2007

Two **complementary** approaches for verification and validation (V&V) can be distinguished.

- **Software Inspections or Peer Reviews**
  (Static Technique)
  "Software inspections" can be done at all stages of the process.
- **Software Testing**
  (Dynamic Technique)



Software inspections check the correspondence between a program and its specification.

- Some techniques
  - **Program inspections**
    The goal is to find program defects, standards violations, poor code rather than to consider broader design issues; it is usually carried out by a team and the members systematically analyze the code.
    An inspection is usually driven by checklists.
    (Studies have shown that an inspection of roughly 100LoC takes about one person-day of effort.)
  - ...

Software inspections check the correspondence between a program and its specification.

- Some techniques
  - …
  - **Automated source code analysis**
    Includes - among others - control flow analysis, data use / flow analysis, information flow analysis and path analysis.
    Static analyses draw attention to anomalies.
  - …

Software inspections check the correspondence between a program and its specification.

- Some techniques
  - …
  - **Formal verification**
    Formal verification can guarantee the absence of specific bugs. E.g., to guarantee that a program does not contain dead locks, race conditions or buffer overflows.

Software inspections check the correspondence between a program and its specification.

Software inspections do not demonstrate that the software is useful.

Software testing refers to running an implementation of the software with test data to discover program defects.

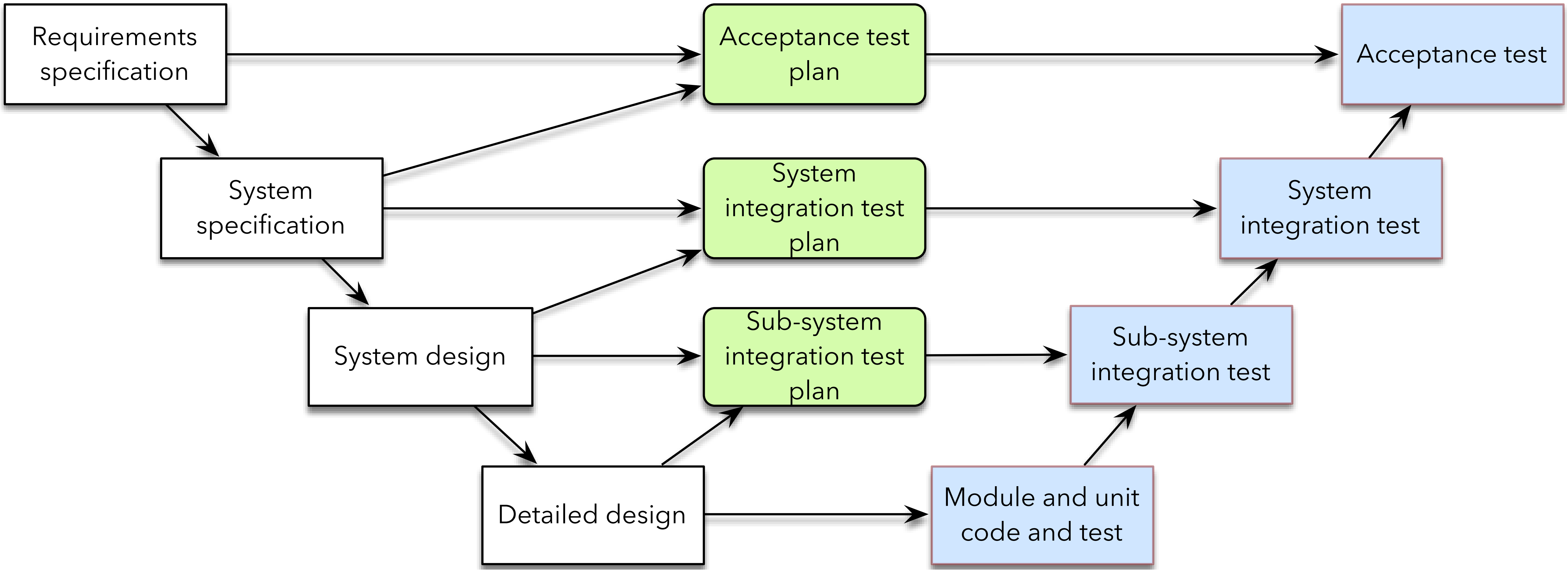
- **Validation testing**
  Intended to show that the software is what the customer wants
  (Basically, there should be a test case for every requirement.)

- **Defect testing**
  Intended to reveal defects
  - (Defect) Testing is…
    - fault directed when the intent is to reveal faults
    - conformance directed when the intent is to demonstrate conformance to required capabilities

No Strict Separation

Test plans set out the testing schedule and procedures; they establish standards for the testing process. They evolve during the development process.

- V&V is expensive; sometimes half of the development budget is spent on V&V



The scope of a test is the collection of software components to be verified.

- **Unit tests**
  (dt. Modultest)
  Comprises a relatively small executable; e.g., a single object
- **Integration test**
  Complete (sub)system. Interfaces among units are exercised to show that the units are collectively operable
- **System test**
  A complete integrated application. Categorized by the kind of conformance they seek to establish: functional, performance, stress or load

> *Testing can only show the presence of errors, not their absence.*

E. Dijkstra

The design of tests is a multi-step process.

1. Identify, model and analyze the responsibilities of the system under test (SUT)
   (E.g., use pre- and postconditions identified in use cases as input.)
2. **Design test cases based on this external perspective**
3. Add test cases based on code analysis, suspicions, and heuristics
4. Develop expected results for each test case or choose an approach to evaluate the pass / no pass status of each test case

A test automation system (TAS) will be used to execute the tests.

A test automation system will…

- start the implementation under test (IUT)
- set up its environment
- bring it to the required pretest state
- apply the test inputs
- evaluate the resulting output and state

Complex systems often require a significant customization of existing test automation systems.

The goal of the test execution is to **establish that the implementation under test (IUT) is minimally operational** by exercising the interfaces between its parts.

To establish the goal...

1. execute the test suite; the result of each test is evaluated as pass or no pass
2. use a coverage tool to instrument the implementation under test; rerun the test suite and evaluate the reported coverage
3. if necessary, develop additional tests to exercise uncovered code
4. stop testing when the test goal is met; all tests pass
(*"Exhaustive"* testing is generally not possible!)

Test Point
(dt. Testdatum (Prüfpunkt))

- A test point is a specific value for…
  - test case input
  - a state variable
- The test point is selected from a domain; the domain is the set of values that input or state variables may take

- Heuristics for test point selection:
  - Equivalence Classes
  - Boundary Value Analysis
  - Special Values Testing

Test Case
(dt. Testfall)

- Test cases specify:
  - pretest state of the implementation under test (IUT)
  - test inputs / conditions
  - expected results

Test Suite

- A test suite is a collection of test cases

Test Run
(dt. Testlauf)

- A test run is the execution (with results) of a test suite
- The IUT produces actual results when a test case is applied to it; a test whose actual results are the same as the expected results is said to pass

Test Driver
&
Test Harness/Automated Test Framework

- Test driver is a class or utility program that applies test cases to an IUT
- Test harness is a system of test drivers and other tools to support test execution

Failures, Errors & Bugs

Failure =dt. Defekt(, Fehlschlag)

Fault =dt. Mangel

Error =dt. Fehler

- A **failure** is the (manifested) inability of a system or component to perform a required function within specified limits
- A **software fault** is missing or incorrect code
- An **error** is a human action that produces a software fault
- Bug: error or fault.

Test Plan

- A document prepared for human use that explains a testing approach:
  - the work plan,
  - general procedures,
  - explanation of the test design,
  - ...

Testing must be based on a **fault model**.

Because the number of tests is infinite, we have to make (for practical purposes) an assumption about where faults are likely to be found!

Testing must be based on a **fault model**.

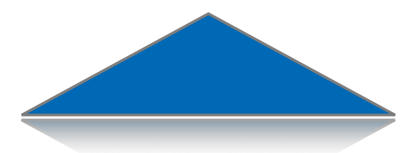
Two general fault models and corresponding testing strategies exist:

- Conformance-directed testing
- Fault-directed testing

Testing has to be efficient.

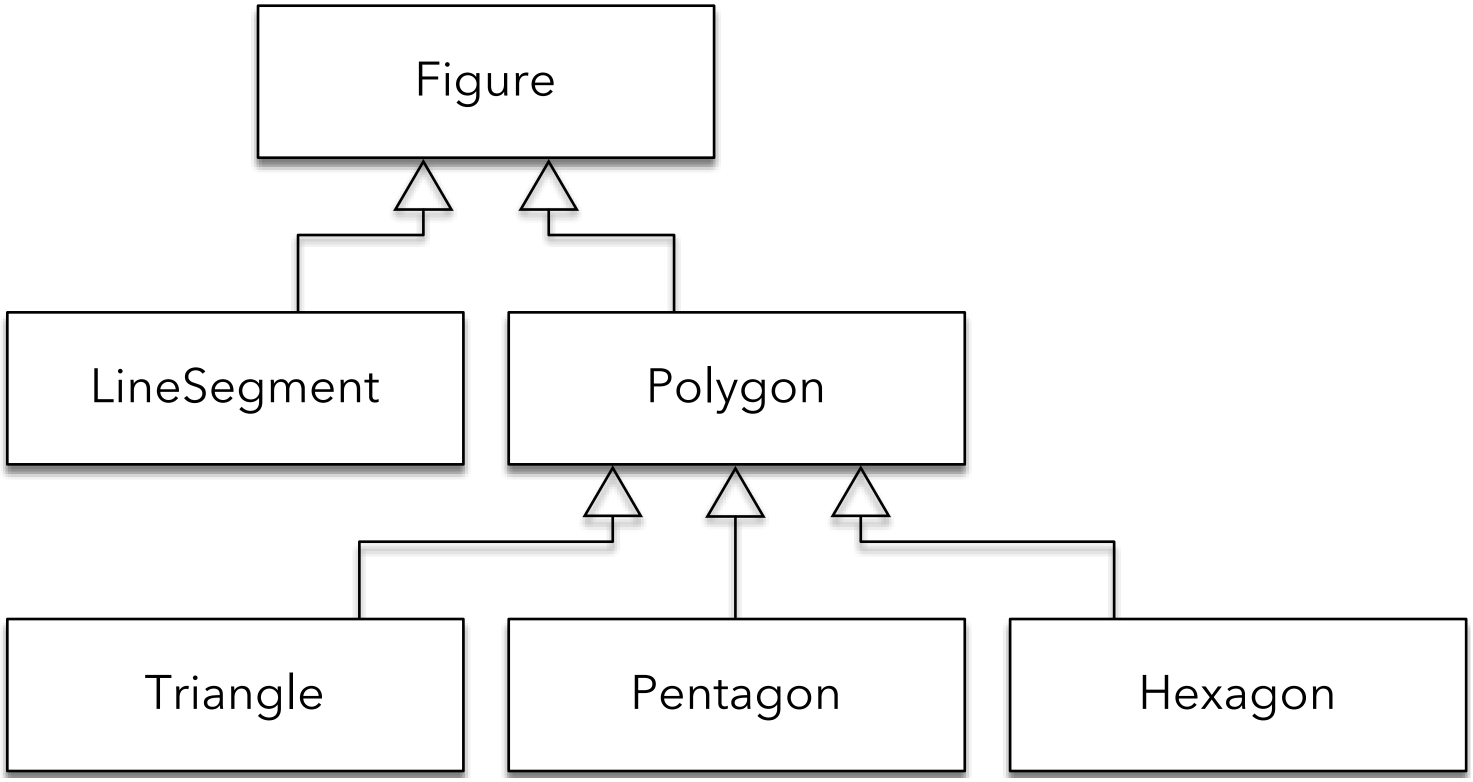
Developing a Test Plan

- Devise a test plan for a program that:
  - reads three integer values,
  - which are interpreted as the length of the sides of a triangle
  - The program states whether the triangle is
    - scalene (dt. schief),
    - isosceles (dt. gleichschenklig), or
    - equilateral (dt. gleichseitig)



- A valid triangle must meet two conditions:
  - No side may have a length of zero
  - Each side must be shorter than the sum of all sides divided by 2

An Implementation of a Triangle




```java
class Polygon extends Figure {
   abstract void draw(…);
   abstract float area();
}
class Triangle extends Polygon {
   public Triangle(...);
   public void setA(LineSegment a);
   public void setB(LineSegment b);
   public void setC(LineSegment c);
   public boolean isIsosceles();
   public boolean isScalene();
   public boolean isEquilateral();
}
```

Test Descriptions

Description	A	B	C	Expected Output
Valid scalene triangle	5	3	4	Scalene
Valid isosceles triangle	3	3	4	Isosceles
Valid equilateral triangle	3	3	3	Equilateral
First perm. of two equal sides	50	50	25	Isosceles
(Permutations of previous test case)	...	...	...	*Isosceles*
One side zero	1000	1000	0	Invalid
First perm. of two equal sides	10	5	5	Invalid
Sec. perm. of two equal sides	5	10	5	Invalid
Third perm. of two equal sides	5	5	10	Invalid
Three sides greater than zero, sum of two smallest less than the largest	8	5	2	Invalid

Test Descriptions

Description	A	B	C	Expected Output
(Permutations of previous test case)	…	…	…	*Invalid*
All sides zero	0	0	0	Invalid
One side equals the sum of the other	12	5	7	Invalid
(Permutations of previous test case)	…	…	…	*Invalid*
Three sides at maximum possible value	MAX	MAX	MAX	Equilateral
Two sides at maximum possible value	MAX	MAX	1	Isosceles
One side at maximum value	1	1	MAX	Invalid
+ Further OO related tests w.r.t. the type hierarchy etc. *(e.g. are the line segments connected.)*				

Developing a Test Plan

Let's assume that we are going to write a tool for verifying Java code. In particular, we would like to assert that specific int based calculations always satisfies the stated assertion.

```java
public int doCalc(int i, int j) {
    if (i < 0 || i > 10 || j < 0 || j > 100)
         throw new IllegalArgumentException();

     return i * j; //ASSERT(i * j in [0,1000])
 }
```

Developing a Test Plan

To represent Java int values, we are using the following classes and map the calculations to the respective methods.

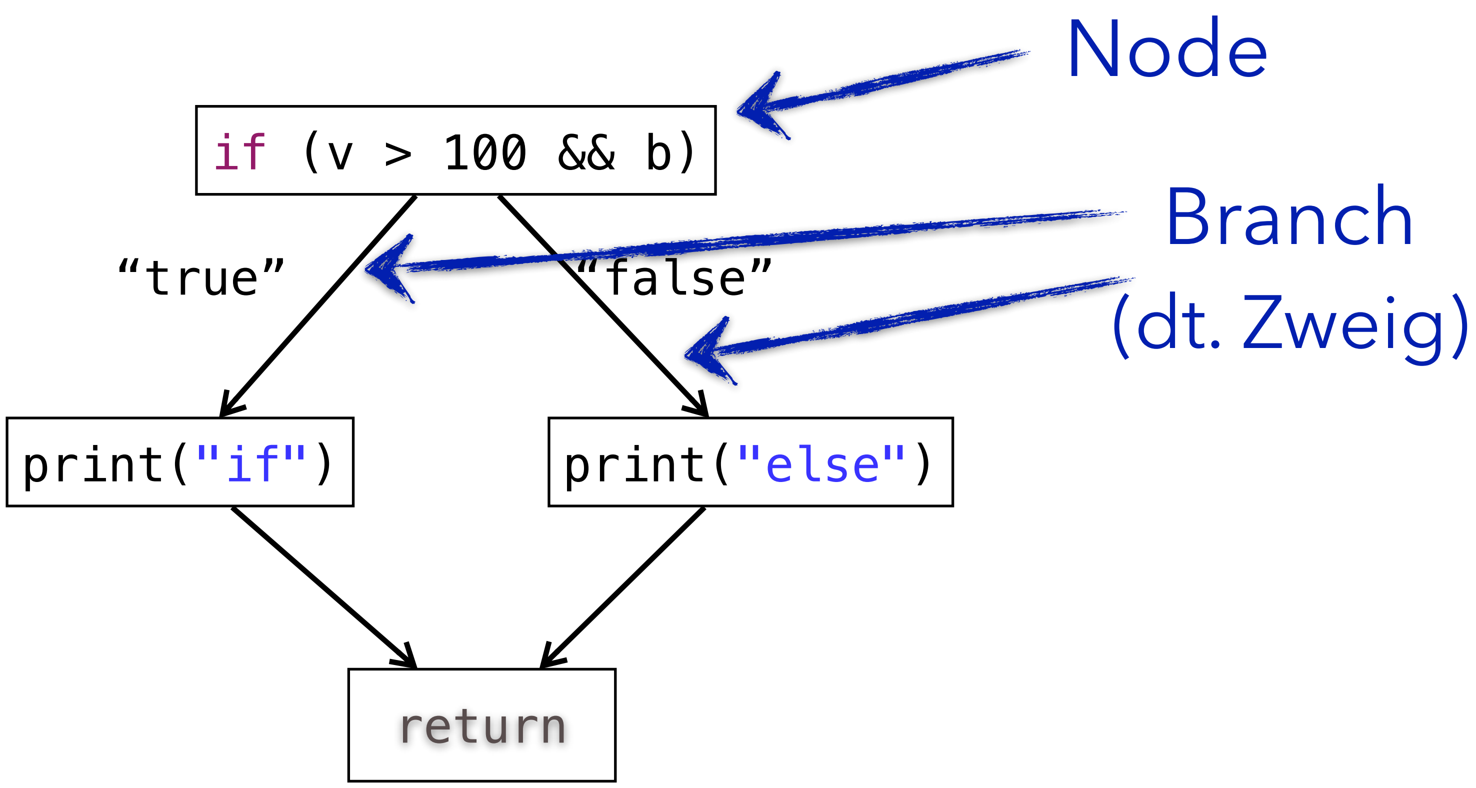
```
/** Representation of a primitive Java int value. */
abstract class IntValue {

    /**
     * Calculates the result of multiplying a and b. The result is as precise as possible given
     * the available information. If the result is either a or b, the respective object is
     * returned.
     */
    public abstract IntValue mul(IntValue other);
}

/** Represents a specific but unknown Java int value. */
class AnInt extends IntValue {

    public IntValue mul(IntValue other) {…}
}

/** Represents a value that is in the range [lb,ub]; however, the specific v … nown. */
class Range extends IntValue {

    public final int lb;
    public final int ub;

    public Range(int lb, int ub) {
        this.lb = lb;
        this.ub = ub;
    }

    public IntValue mul(IntValue other) {…}
}
```

How does the test plan look like?

The Control-flow Graph of a Method

A representation of all paths through a program.

```
static void doThat(int v, boolean b) {

    if (v > 100 && b) {
        print("if");
    }

    else {
        print("else");
    }

  return;

}
```



A Node consists of a sequence of statements without any branches in or out (except of the last statement).

A branch describes a possible control-flow.

Common Method Scope Code Coverage Models

- **Statement Coverage** is achieved when all statements in a method have been executed at least once
- **Branch Coverage** is achieved when every path from a node is executed at least once by a test suite; compound predicates are treated as a single statement
- **Simple Condition Coverage** requires that each simple condition be evaluated as true and false at least once
  (Hence, it does not require testing all possible branches.)
- **Condition Coverage =**
  Simple Condition Coverage + Branch Coverage
- **Multiple-condition Coverage** requires that all true-false combinations of simple conditions be exercised at least once
- **Modified condition/decision coverage** **(Recommended for, e.g., SIL 4 Software)**

branch =dt. Verzweigung; condition =dt. Bedingung;
branch coverage =dt. Zweigüberdeckung
simple condition coverage =dt. einfache Bedingungsüberdeckung

Conditions - Exemplified


```
static void doThat(int v, boolean b) {

   if (v > 100 && b) {
      print("if");
   }
   else {
      print("else");
   }

}
```

simple/atomic condition(s)

Here, “v > 100” is the first condition and “b” is the second condition.

In Java, simple/atomic conditions are separated by “&&” / “&” or “||”/“|” operators.

Compound Predicates - Exemplified

(compound) predicate (expression)

```
static void doThat(int v, boolean b) {

    if (v > 100 && b) {
        print("if");
    }
    else {
        print("else");
    }

}
```

Here, “v > 100 && b” is called a predicate resp. a compound predicate. This compound predicate consists of two “simple” conditions.

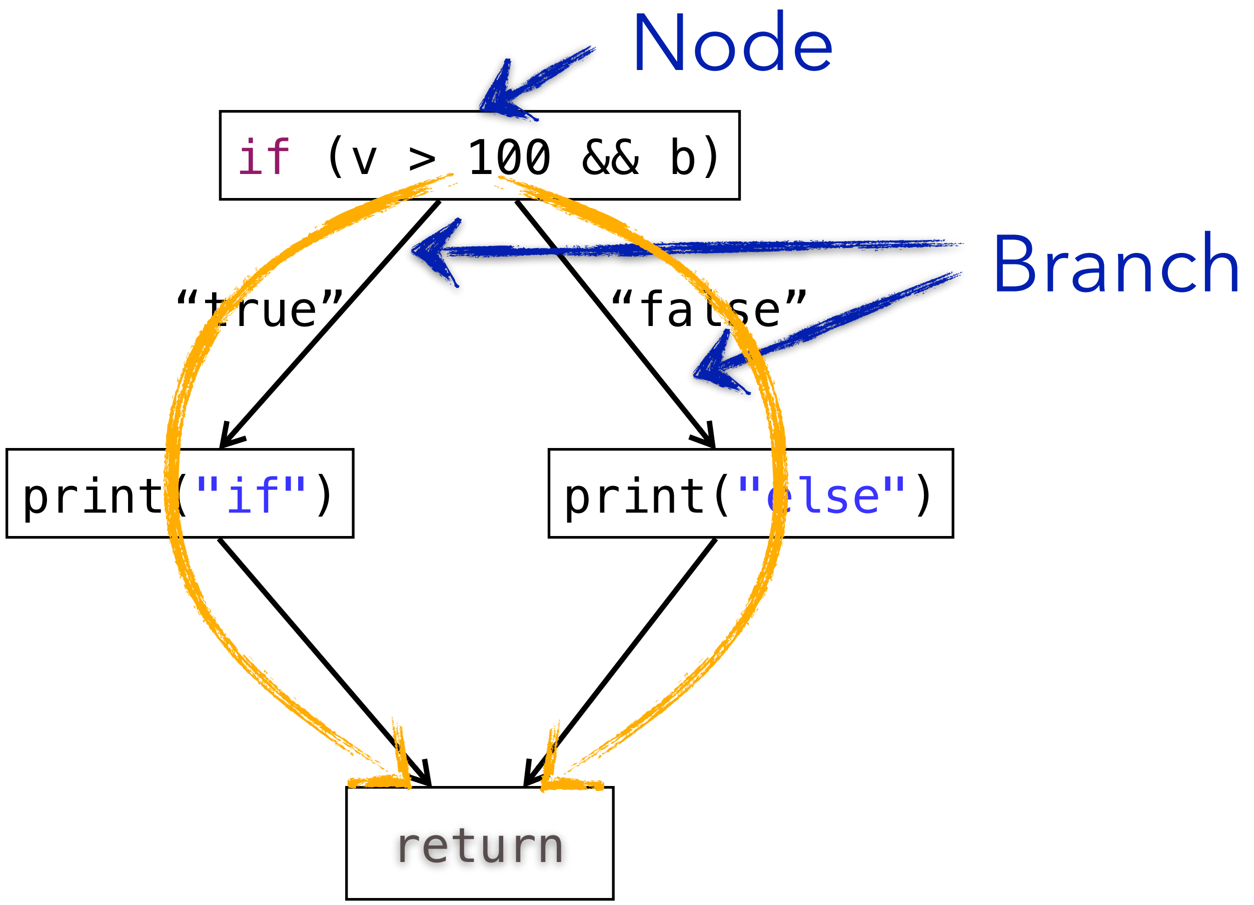
Branch Coverage Exemplified

100% Branch Coverage

v = 90, b = true

v = 101, b = true

```
static void doThat(int v, boolean b) {

    if (v > 100 && b) {
        print("if");
    }
    else {
        print("else");
    }

}
```



When we have shortcut evaluation, simple condition coverage implies branch coverage!

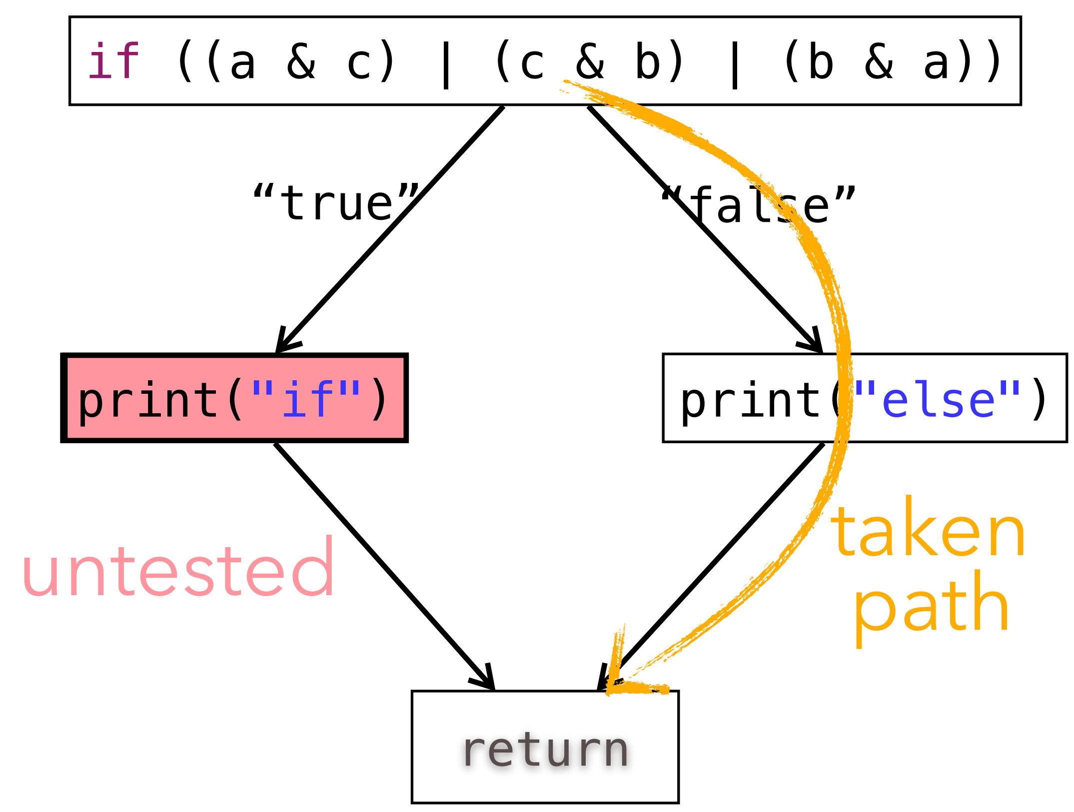
Simple Condition Coverage Exemplified

Recall: The condition is an expression that evaluates to true or false. I.e., an expression such as !b (not b) is the condition.

100% Simple Condition Coverage

a = true, b = false, c = false
a = false, b = true, c = false
a = false, b = false, c = true

```
static void doThat(
    boolean a,
    boolean b,
    boolean c) {

    if ((a & c) | (c & b) | (b & a)) {
        print("if");
    }
    else {
        print("else");
    }

}
```



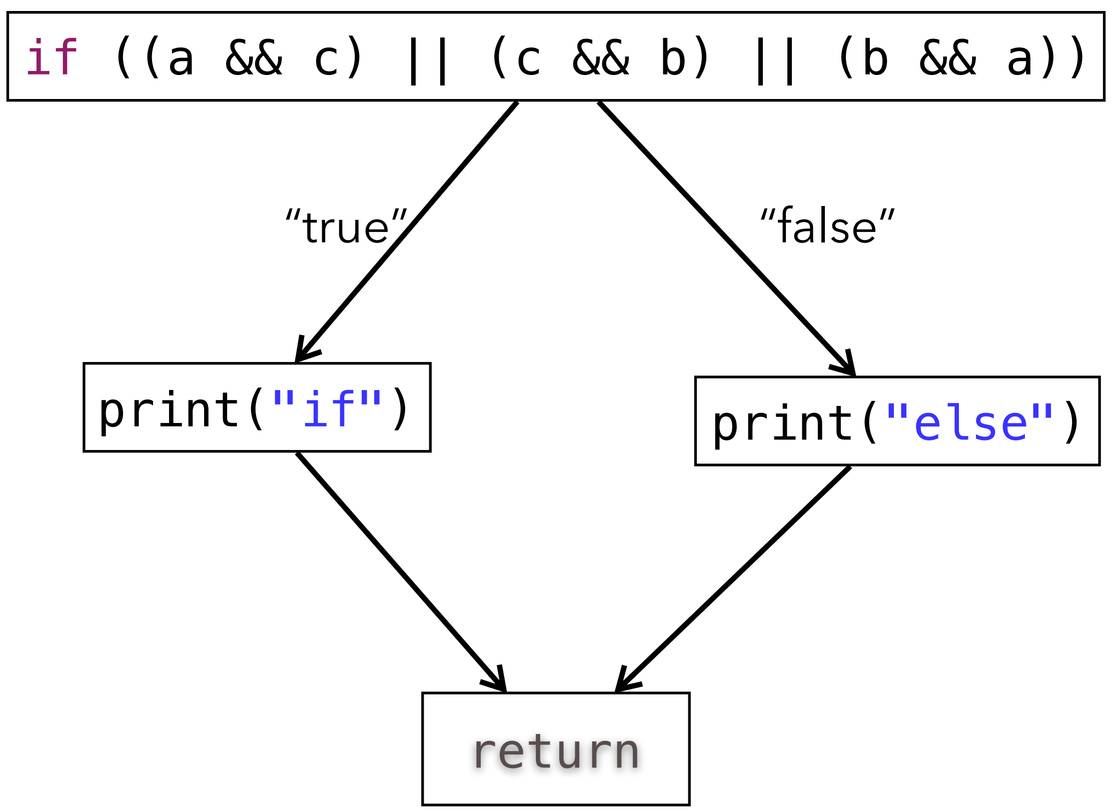
Using “plain” logical boolean operators!

(Simple) Condition Coverage Exemplified

100% (Simple) Condition Coverage

a = true, c = true (b is not relevant)
a = false, c = true, b = true
a = false, c = false, b = false

```
static void doThat(
    boolean a,
    boolean b,
    boolean c) {

    if ((a && c) || (c && b) || (b && a)) {
        print("if");
    }
    else {
        print("else");
    }

}
```



Recall, if we have shortcut evaluation, simple condition coverage implies branch coverage!

Using conditional-and/or operators!

Basic Block Coverage

- A basic block is a sequence of consecutive instructions in which flow of control enters at the beginning and leaves at the end without halt or possibility of branching except at the end.
- Basic block coverage is achieved if all basic blocks of a method are executed

(⚡Sometimes “statement coverage” is used as a synonym for “basic block coverage” - however, we do not use these terms synonymously.)
(Basic blocks are sometimes called segments.)

Used by tools that measure coverage!

Basic Block Coverage Exemplified

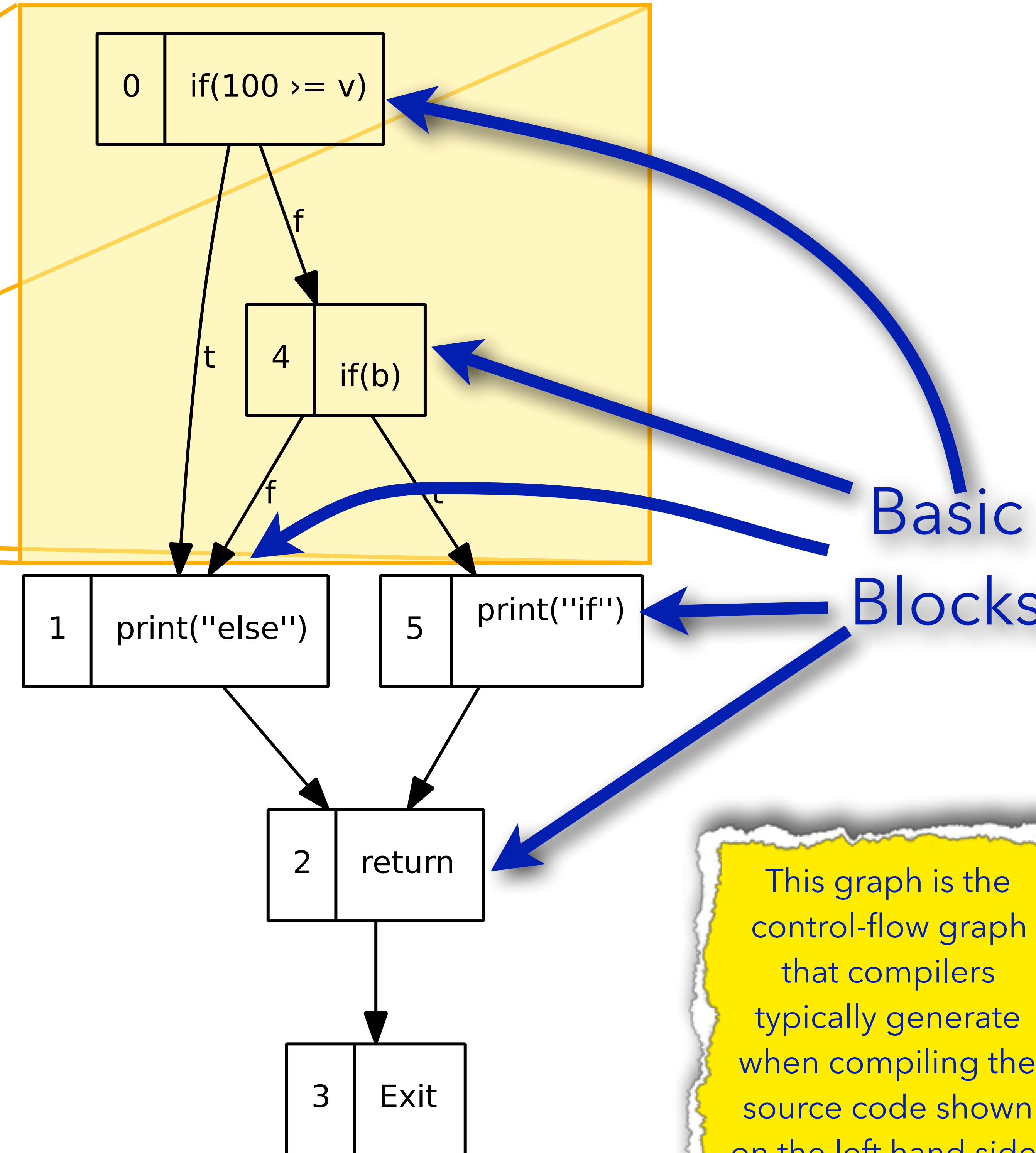
100% Basic Block Coverage

v = 90, b = “not relevant”

v = 101, b = true

```
static void doThat(int v, boolean b) {

    if (v > 100 && b) {
        print("if");
    }
    else {
        print("else");
    }

}
```

At the bytecode level (or lower), no explicit support for conditional boolean operators exists and are therefore compiled using respective “if”s.



static void doThat(int v,boolean b)

This graph is the control-flow graph that compilers typically generate when compiling the source code shown on the left hand side.

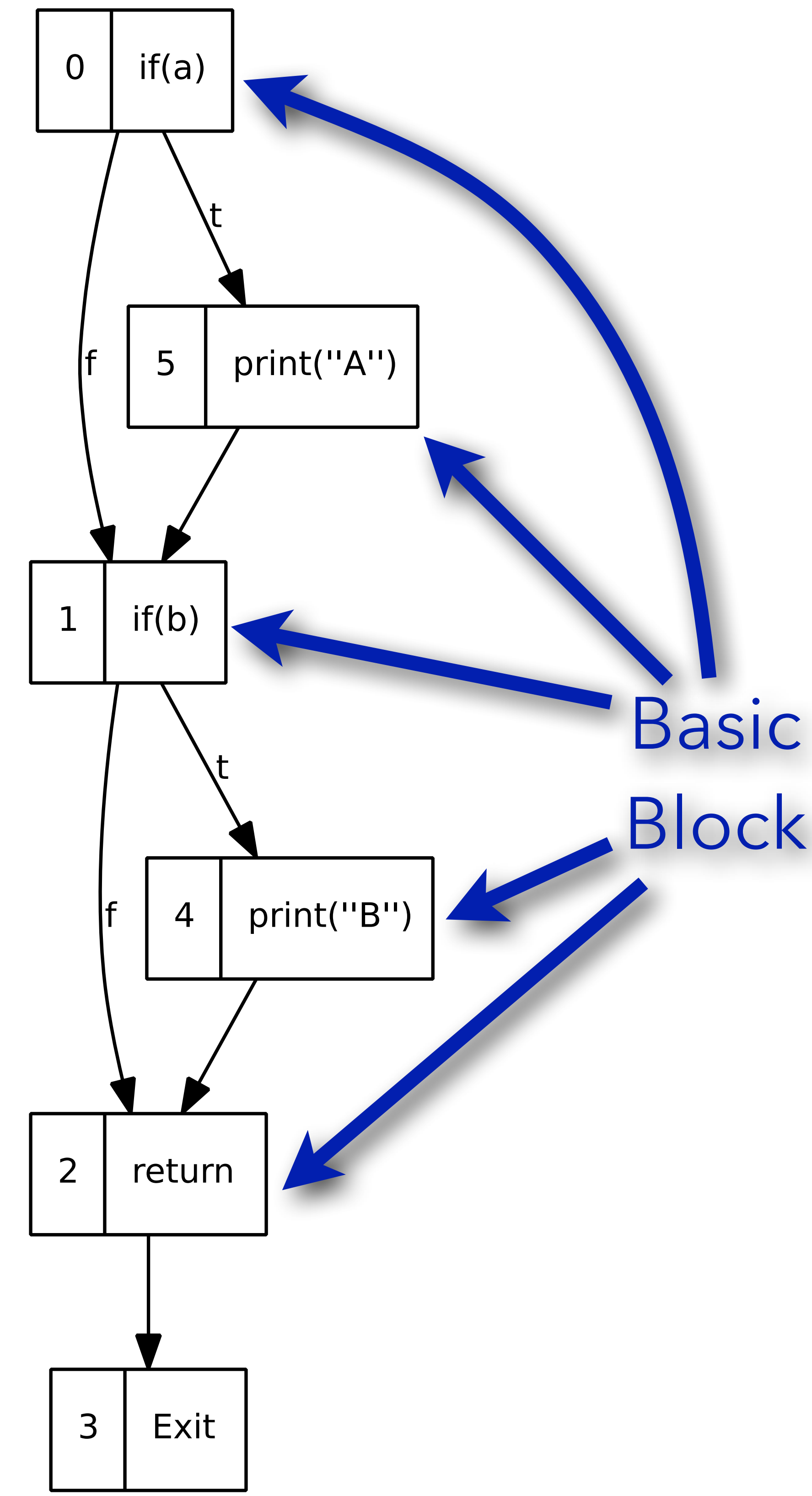
Control-flow Graph


```java
static void doThis(boolean a, boolean b) {

    if (a) {
        print("A");
    }
    if (b) {
        print("B");
    }

}
```

	a	b	Minimal Number of Tests to Achieve … Coverage
Statement	TRUE	TRUE	
Basic Block	TRUE	TRUE	
(Simple) Condition Coverage	TRUE	TRUE	
	FALSE	FALSE	
Branch Coverage	FALSE	FALSE	
	TRUE	TRUE	

Here, condition coverage can also be achieved using other test cases. (E.g. a=false; b=true and a=true; b=false.)

No case covers all possible paths!

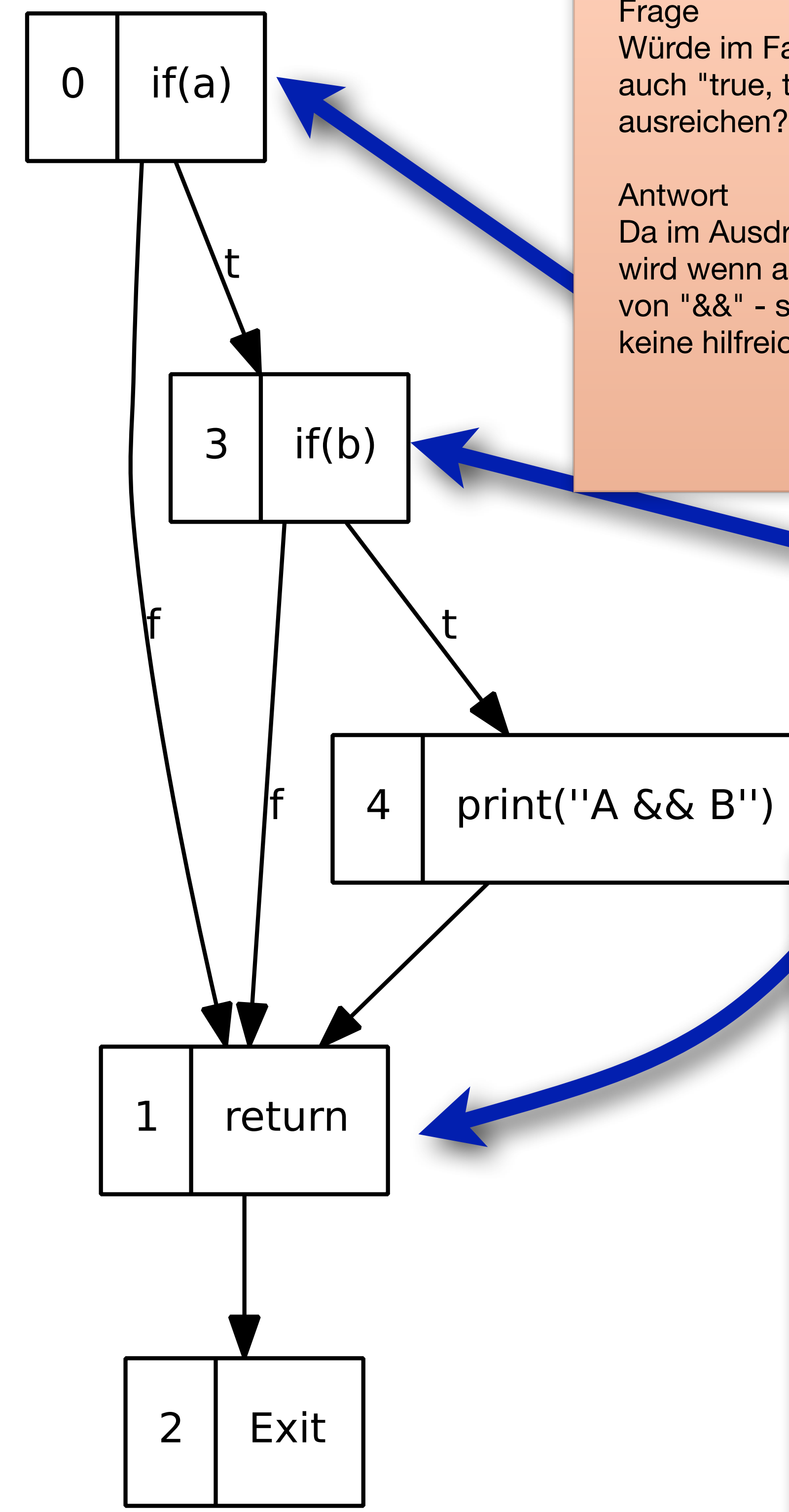


static void doThis(boolean a,boolean b)

Control-flow Graph


```java
static void doThis(boolean a, boolean b) {

    if (a && b) {
        print("A && B");
    }
}
```

	a	b	
Statement	TRUE	TRUE	Minimal Number of Tests to Achieve ... Coverage
Basic Block	TRUE	TRUE	
(Simple) Condition Coverage	TRUE	TRUE	
	TRUE	FALSE	
	FALSE	/	
Branch Coverage (w.r.t. the given source code)	TRUE	TRUE	
	FALSE	/	
Multiple Condition Coverage	TRUE	TRUE	
	TRUE	FALSE	
	FALSE	/	



Basic Block

Frage
Würde im Falle von Condition Coverage nicht auch "true, true" und "false, false" ausreichen?

Antwort
Da im Ausdruck "a && b", "b" nur evaluiert wird wenn a wahr ist (Short-circuit Evaluation von "&&" - siehe Graph) - ist "false / false" keine hilfreiche Belegung der Parameter.

Frage / Antwort:
Wäre der Code:

```
if (a) {
  if (b)
    print("A && B")
  else
    print("Hello!")
}
return;
```

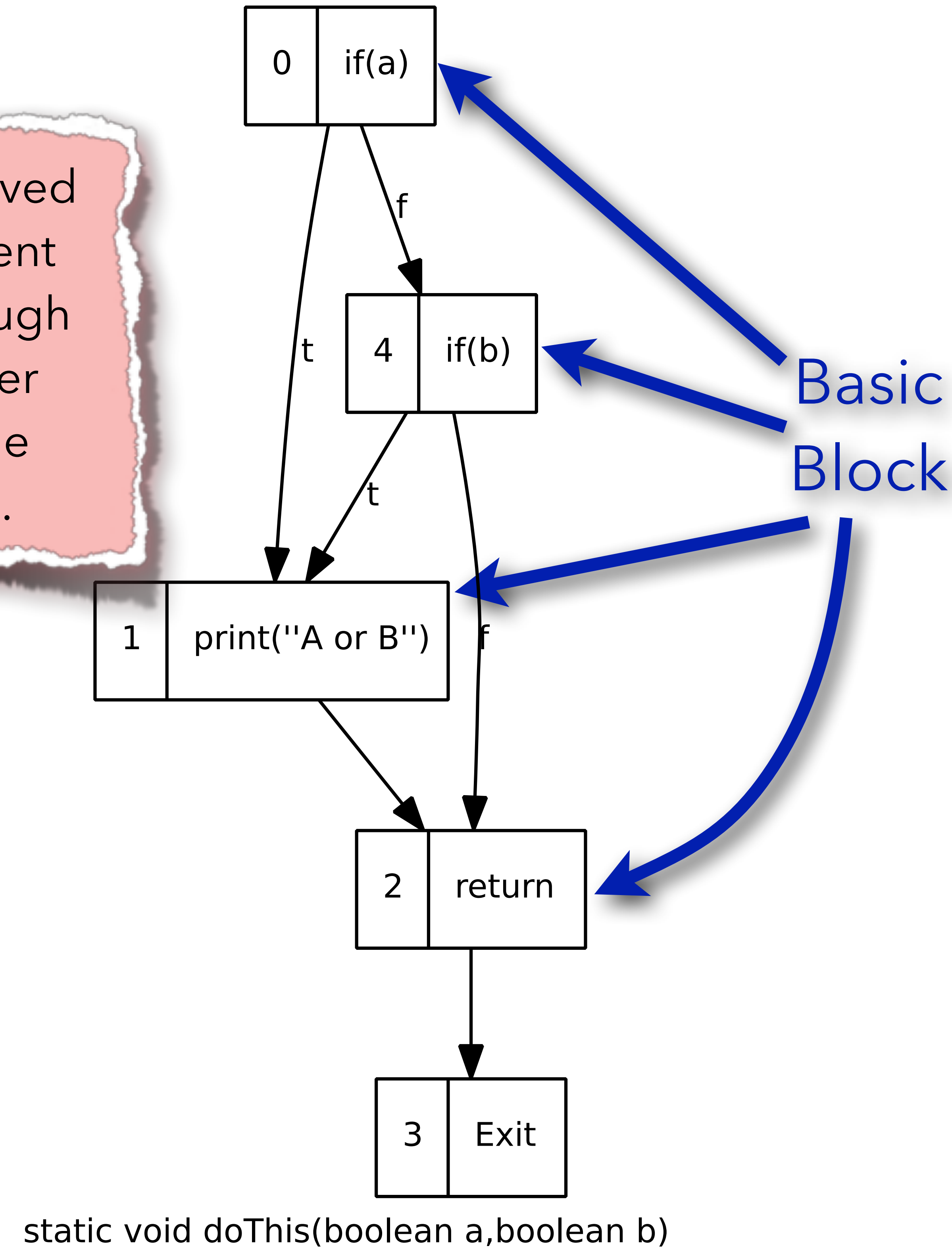
dann wäre für "Statement Coverage"folgende Testfälle notwendig: a=true; b=false und a=true; b=true. (Ebenso für Basic Block Coverage)

Control-flow Graph


```java
static void doThis(boolean a, boolean b) {

    if (a || b) {
        print("A or B");
    }
}
```

We have achieved 100% statement coverage, though we have never evaluated the condition b.

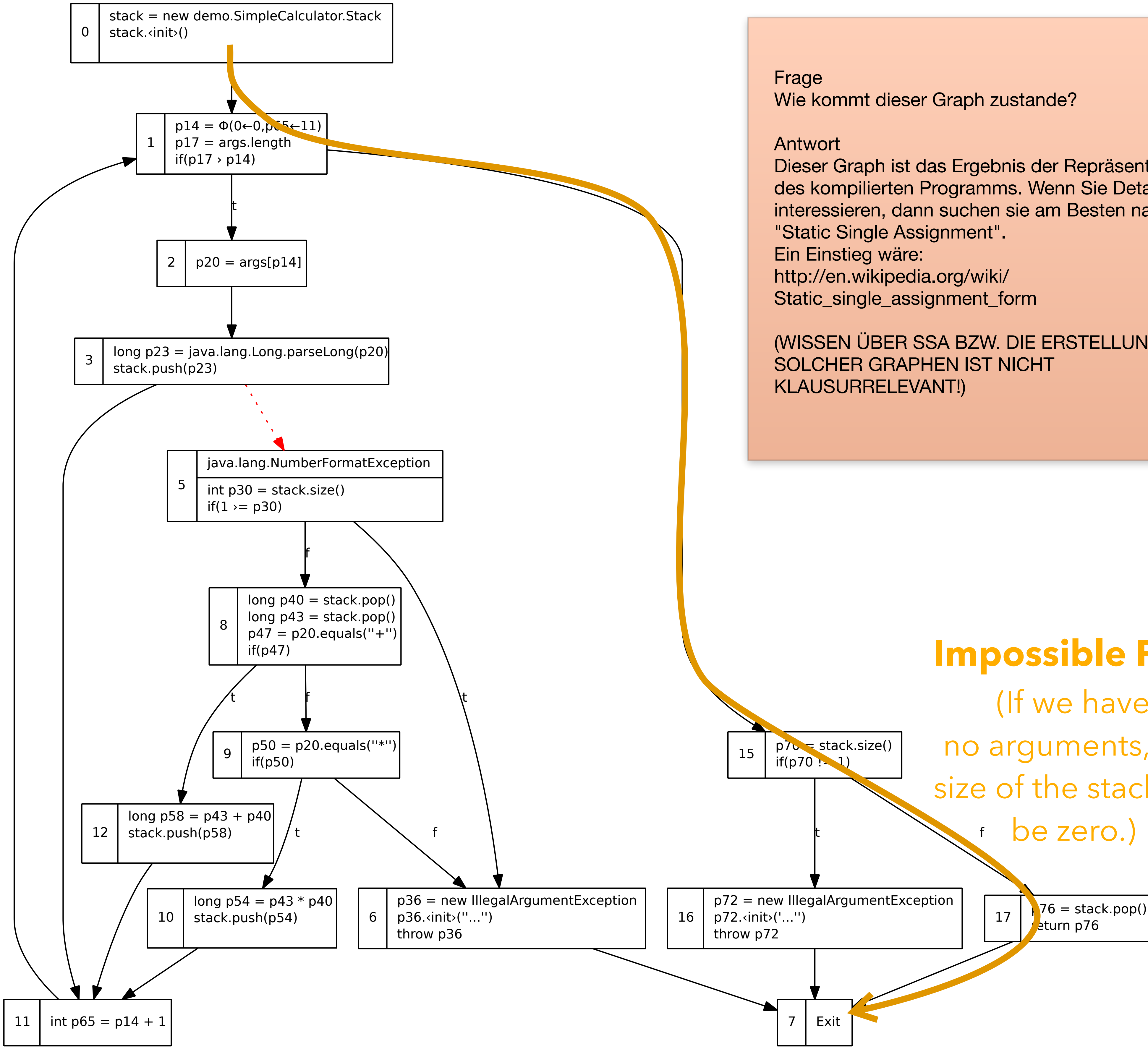
	a	b	Minimal Number of Tests to Achieve … Coverage
Statement	TRUE	/	
Basic Block	FALSE	TRUE	
(Simple) Condition Coverage	FALSE	TRUE	
	FALSE	FALSE	
	TRUE	/	
Branch Coverage (w.r.t. the source code)	TRUE	/	
	FALSE	FALSE	



```java
static long process(String[] args) throws IllegalArgumentException {

    Stack values = new Stack();
    for (int i = 0; i < args.length; i++) {
        String arg = args[i];
        try {
            long value = Long.parseLong(arg);
            values.push(value);
        } catch (NumberFormatException nfe) {
            // there is no method to test if a string is a number ...

            if (values.size() > 1) {
                long r = values.pop();
                long l = values.pop();
                if (arg.equals("+")) {
                    values.push(l + r);
                    continue;
                }
                if (arg.equals("*")) {
                    values.push(l * r);
                    continue;
                }
            }
            throw new IllegalArgumentException("Too few operands or operator unknown.");
        }
    }
    if (values.size() == 1) return values.pop();
    else throw new IllegalArgumentException("Too few (0) or too many (>1) operands.");
}
```

Calculating the result of an arithmetic expression in postfix notation; e.g.:
4 5 + 5 * 3 4 * * = ?

Basic Blocks of `long process(String[] args)`



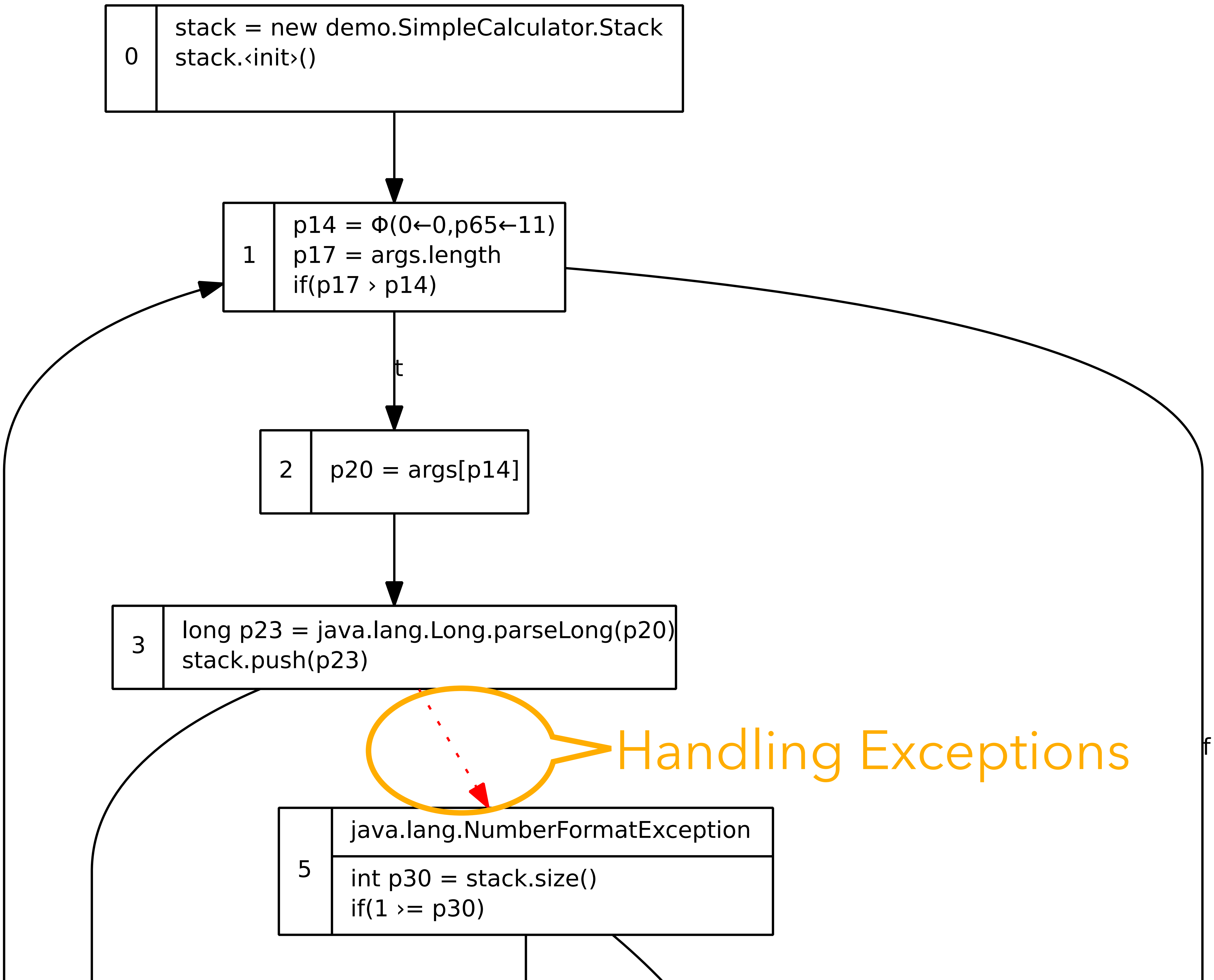
Frage
Wie kommt dieser Graph zustande?

Antwort
Dieser Graph ist das Ergebnis der Repräsentation des kompilierten Programms. Wenn Sie Details dazu interessieren, dann suchen sie am Besten nach "Static Single Assignment".
Ein Einstieg wäre:
http://en.wikipedia.org/wiki/Static_single_assignment_form

(WISSEN ÜBER SSA BZW. DIE ERSTELLUNG SOLCHER GRAPHEN IST NICHT KLAUSURRELEVANT!)

Impossible Path

(If we have no arguments, the size of the stack will be zero.)


0
stack = new demo.SimpleCalculator.Stack
stack.‹init›()
1
p14 = Φ(0←0,p65←11)
p17 = args.length
if(p17 › p14)
t
2
p20 = args[p14]
3
long p23 = java.lang.Long.parseLong(p20)
stack.push(p23)
Handling Exceptions
f
5
java.lang.NumberFormatException
int p30 = stack.size()
if(1 ›= p30)

> *Do not use a code coverage model as a test model.*
>
> *Do not rely on code coverage models to devise test suites. Test from responsibility models and use coverage reports to analyze test suite adequacy.*
>
> *Covering some aspect of a method [...] is never a guarantee of bug-free software.*

Robert V. Bender

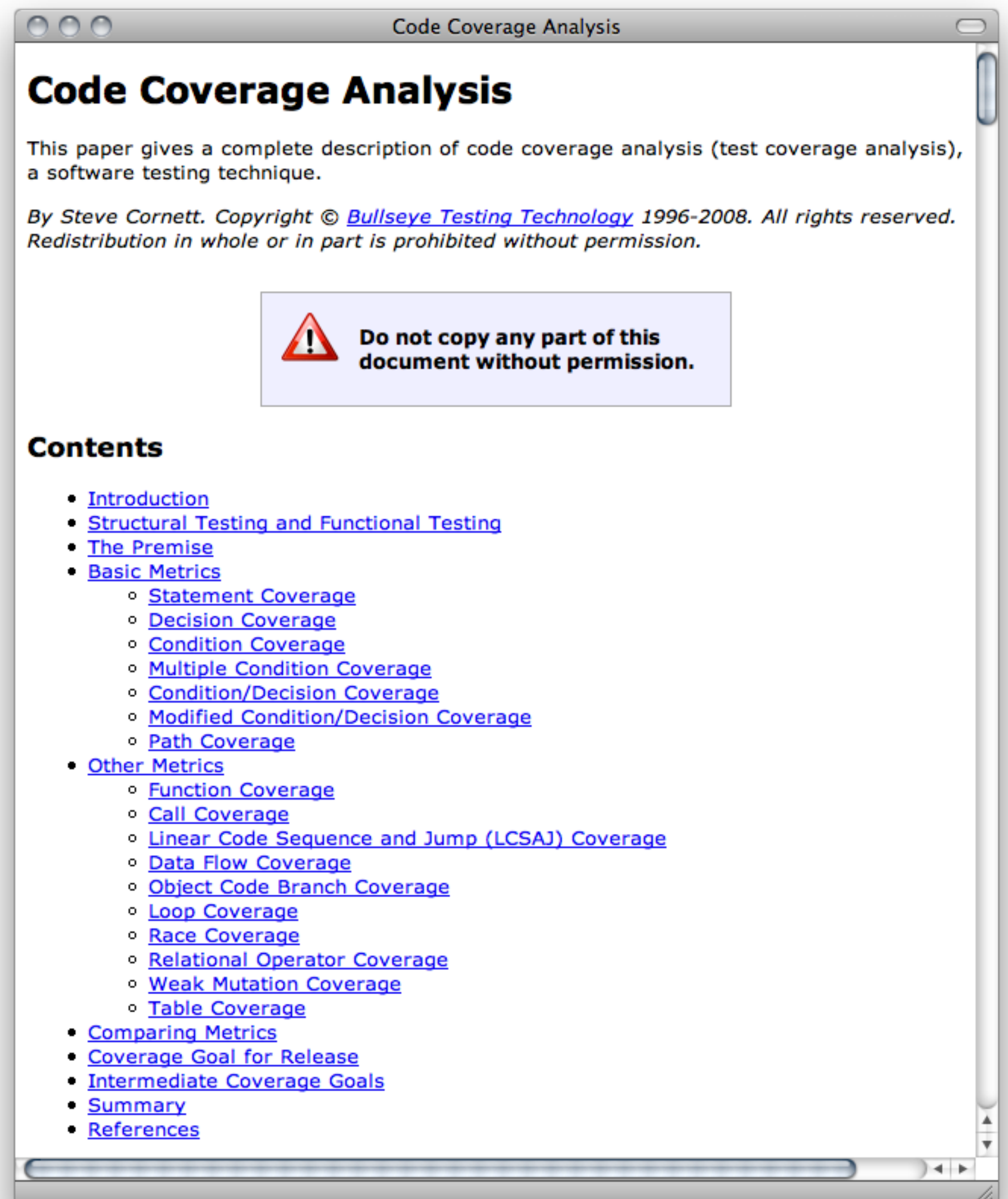
Testing Object-Oriented Systems

Addison Wesley 2000

Steve Cornett

http://www.bullseye.com/coverage.html

- Recommended Reading



Code Coverage Analysis

Code Coverage Analysis

This paper gives a complete description of code coverage analysis (test coverage analysis), a software testing technique.

Contents

Limits of Testing

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Limits of Testing

The number of input and output combinations for trivial programs is already (very) large.

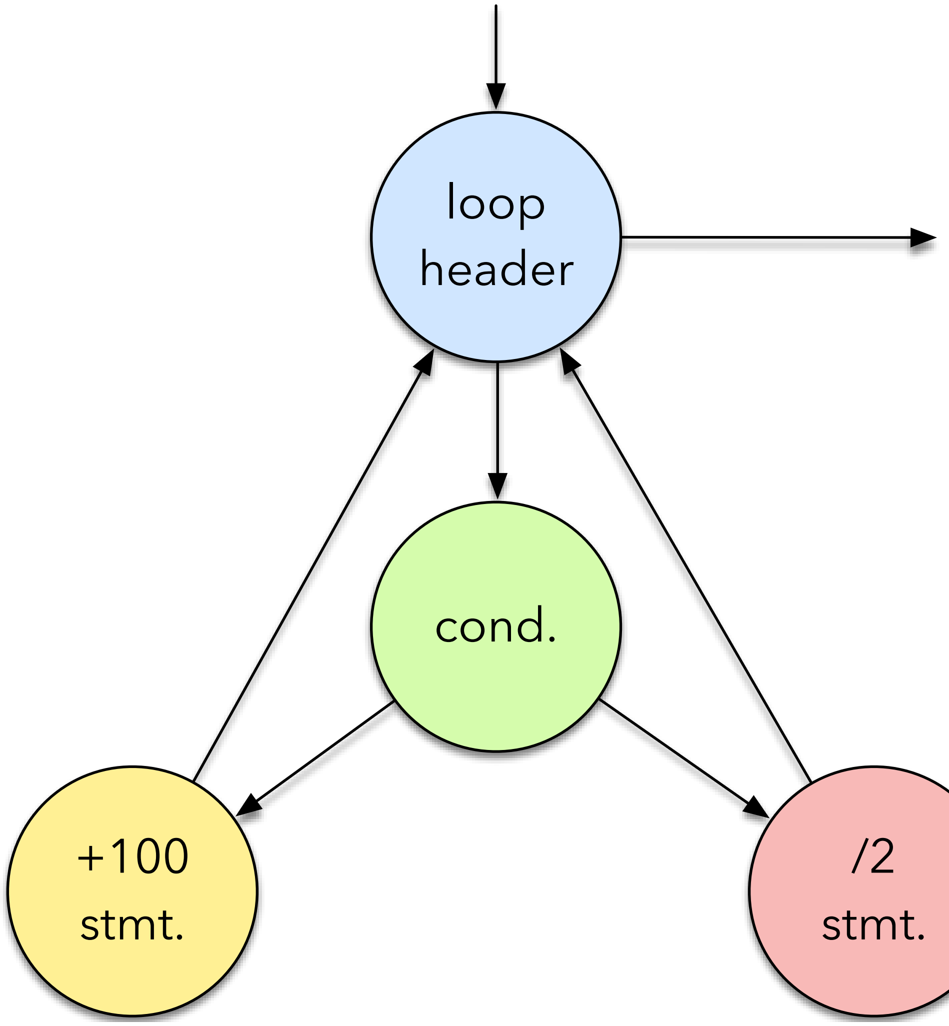
Assume that we limit points to integers between 1 and 10; there are 10^4 possible ways to draw (a single) line.

Since a triangle has three lines we have $10^4 \times 10^4 \times 10^4$ possible inputs of three lines (including invalid combinations).

We can never test all inputs, states, or outputs.

Limits of Testing

Branching and (dynamic binding) result in a very large number of unique execution sequences. Simple iteration increases the number of possible sequences to astronomical proportions.

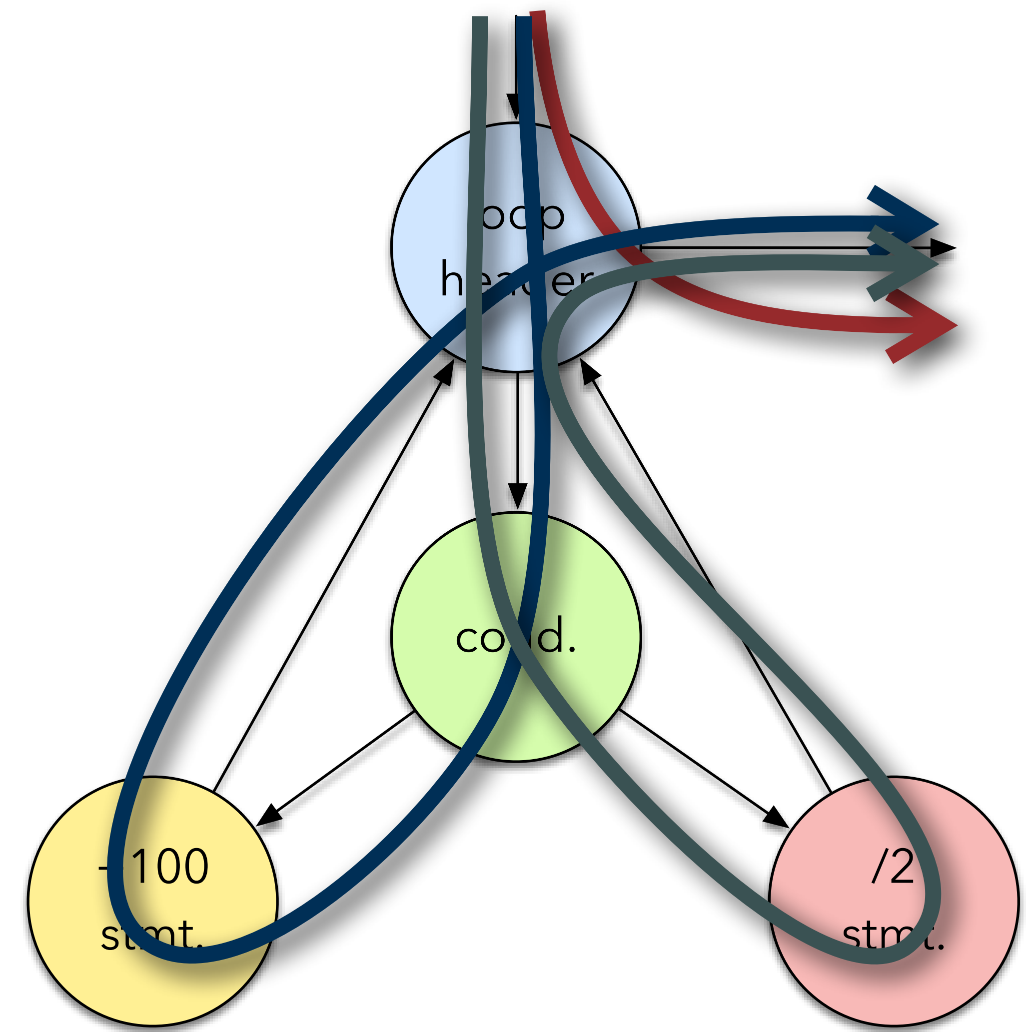



```
for (
  int i = 0;
  i < n;
  ++i
)
{
    if (a.get(i) == b.get(i))
      x[i] = x[i]+100;
    else
      x[i] = x[i] / 2;
}
```

Limits of Testing

Branching and dynamic binding result in a very large number of unique execution sequences.

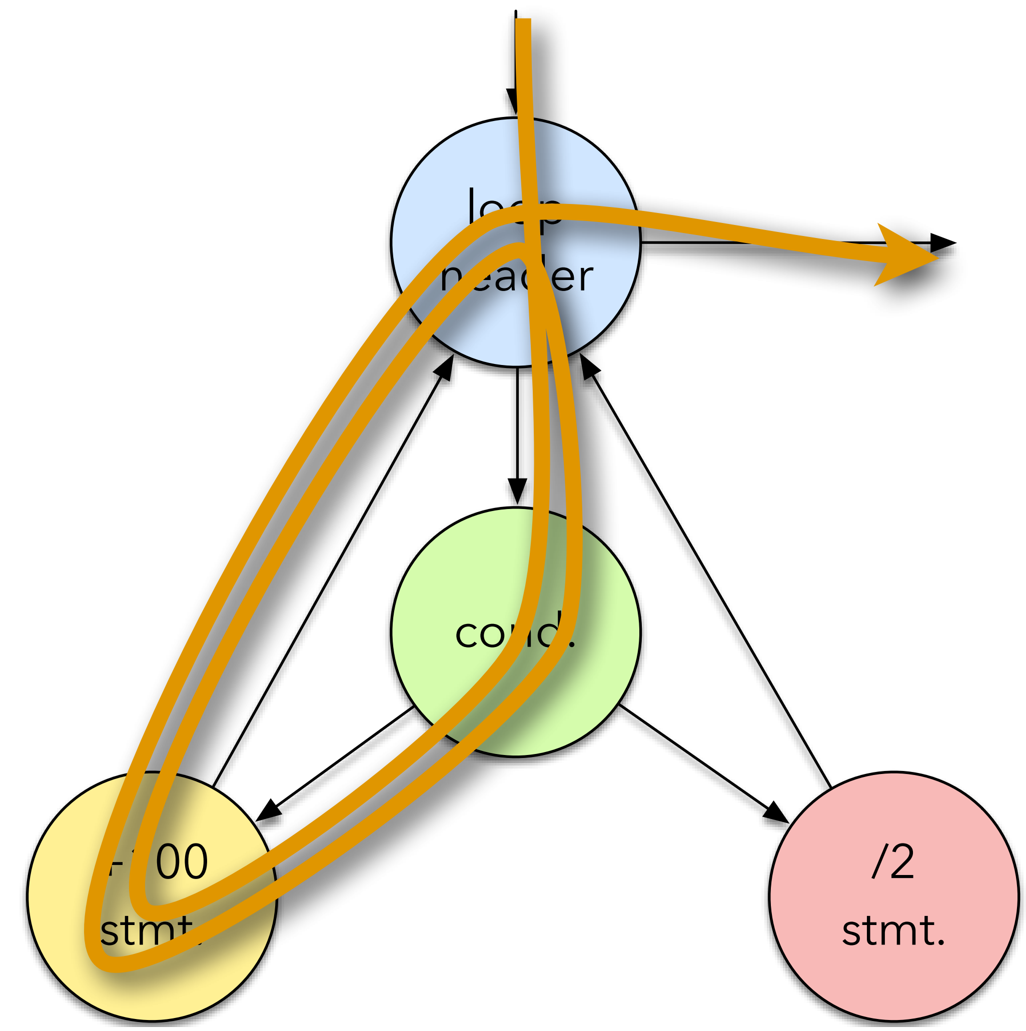
- If we count entry-exit paths without regarding iteration there are only three paths:
  - loop header, exit
  - loop header, cond., +100
  - loop header, cond., /2



Limits of Testing

Branching and dynamic binding result in a very large number of unique execution sequences. Simple iteration increases the number of possible sequences to astronomical proportions.

Number of iterations	Number of paths
1	$2^1 + 1 = 3$
2	$\mathbf{2^2 + 1 = 5}$
3	$2^3 + 1 = 9$
10	1.025
20	1.048.577

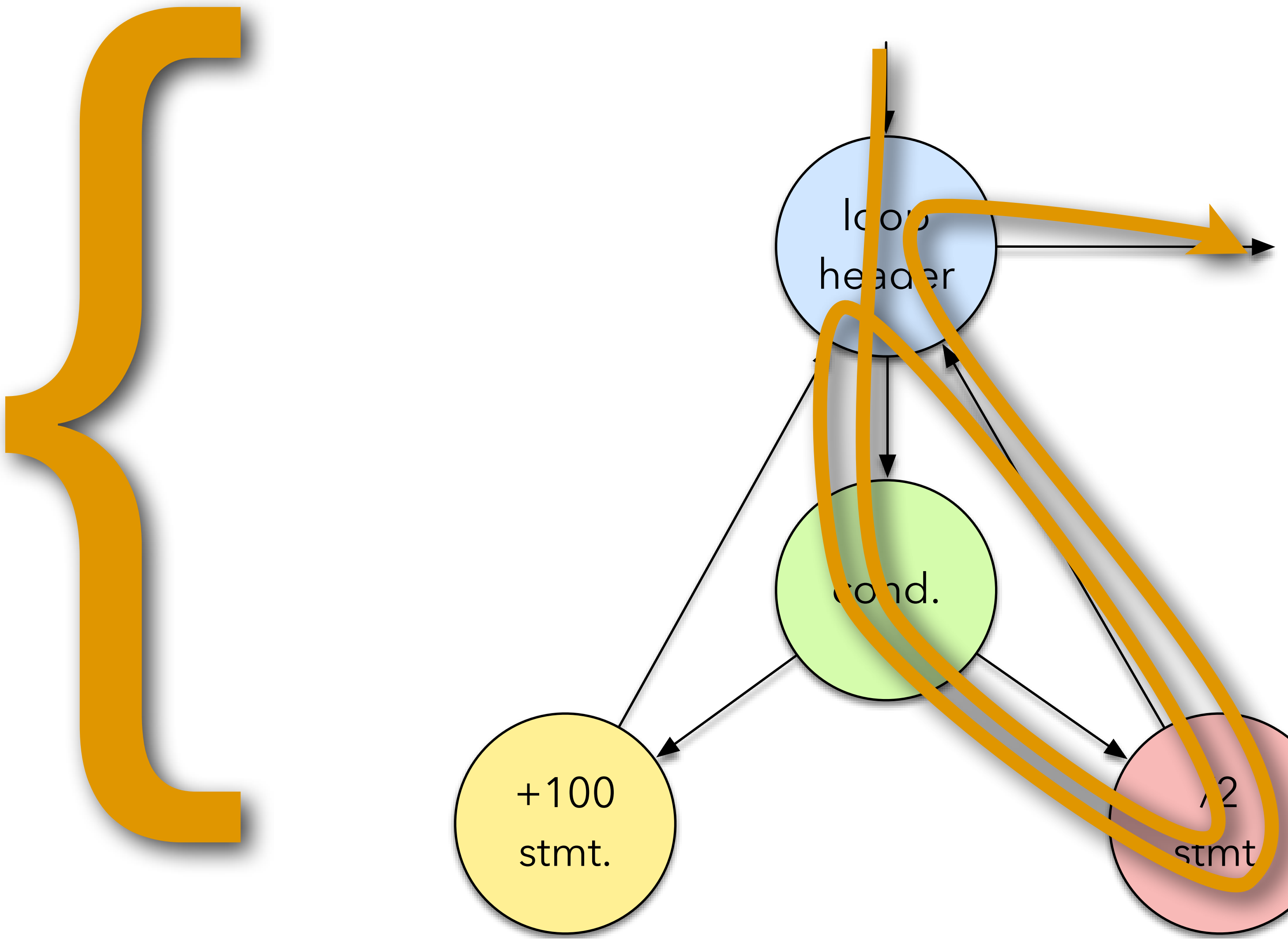


1. Path

Limits of Testing

Branching and dynamic binding result in a very large number of unique execution sequences. Simple iteration increases the number of possible sequences to astronomical proportions.

Number of iterations	Number of paths
1	$2^1 + 1 = 3$
2	**$2^2 + 1 = 5$**
3	$2^3 + 1 = 9$
10	1.025
20	1.048.577

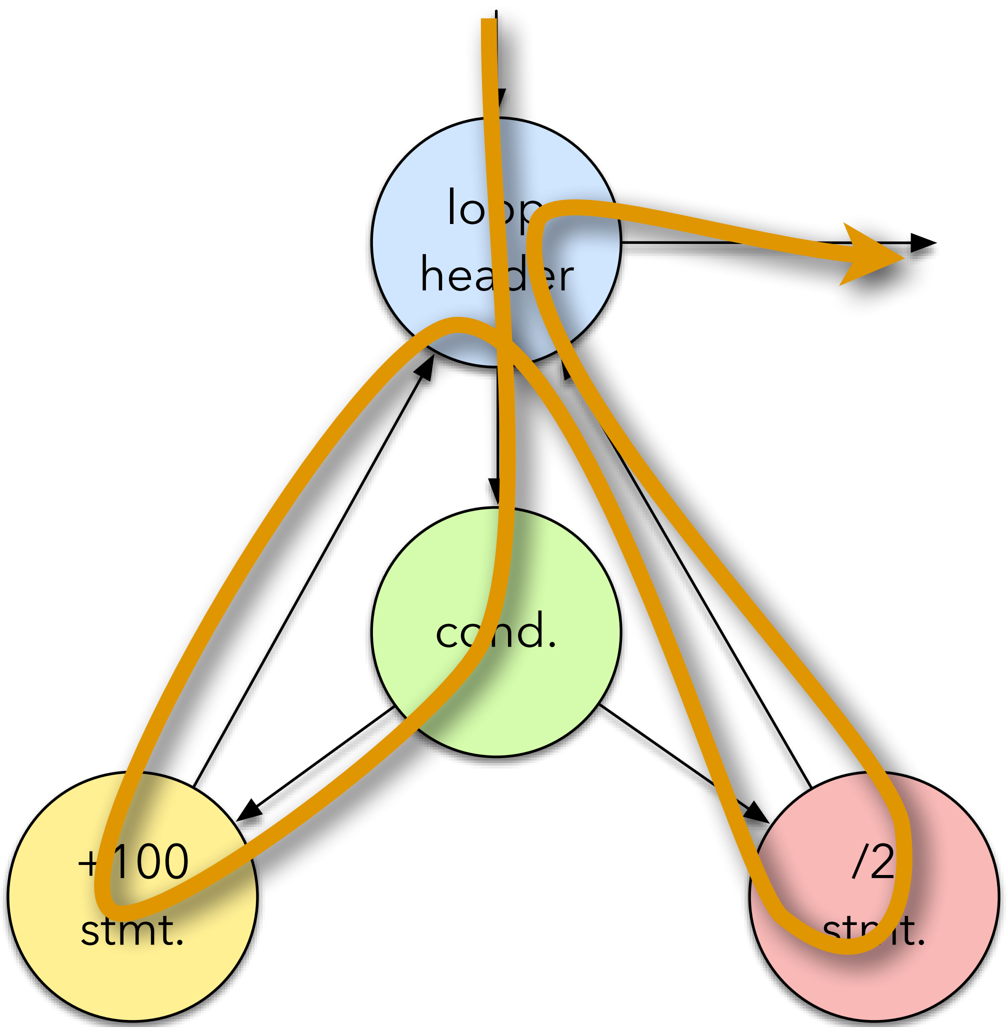


2. Path

Limits of Testing

Branching and dynamic binding result in a very large number of unique execution sequences. Simple iteration increases the number of possible sequences to astronomical proportions.

Number of iterations	Number of paths
1	$2^1 + 1 = 3$
2	**$2^2 + 1 = 5$**
3	$2^3 + 1 = 9$
10	1.025
20	1.048.577



3. Path

Limits of Testing

Branching and dynamic binding result in a very large number of unique execution sequences. Simple iteration increases the number of possible sequences to astronomical proportions.

Number of iterations	Number of paths
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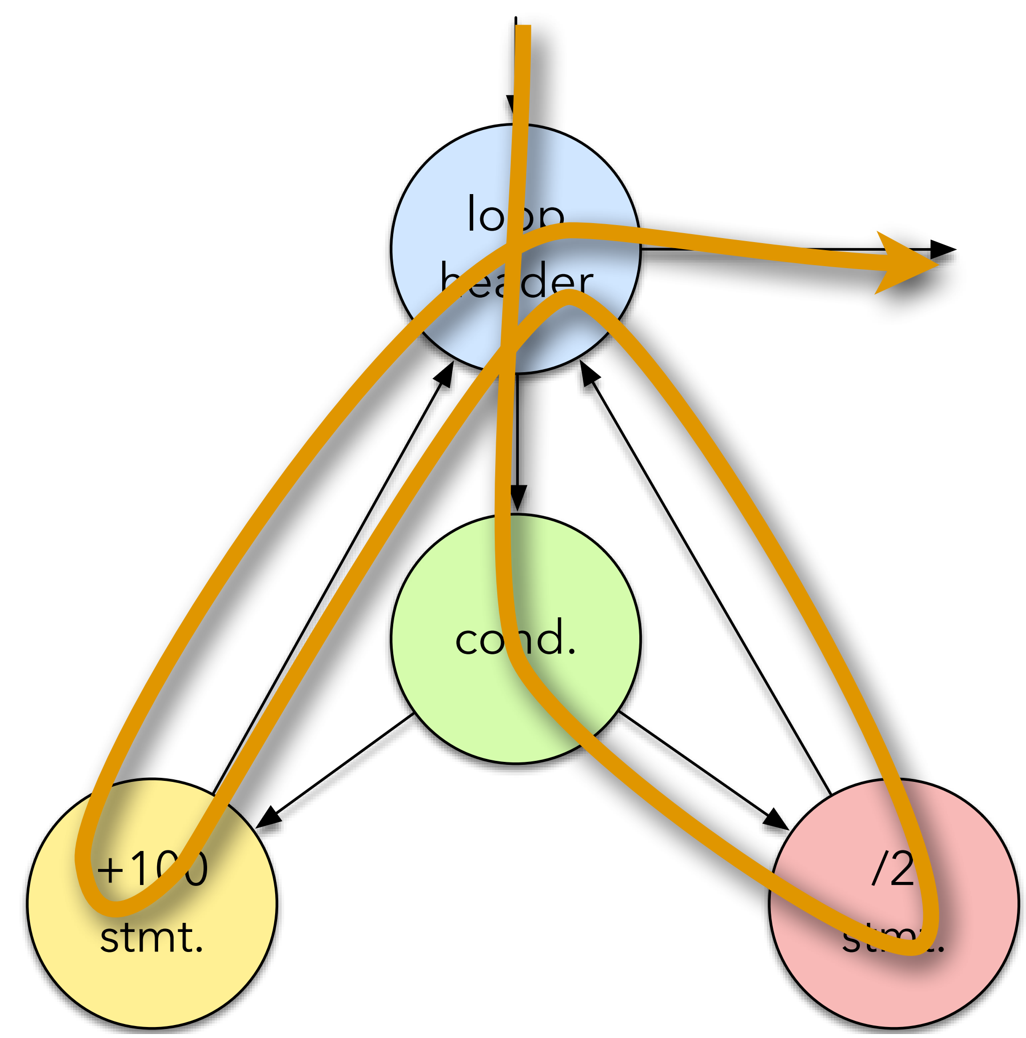

4. Path

Limits of Testing

Branching and dynamic binding result in a very large number of unique execution sequences. Simple iteration increases the number of possible sequences to astronomical proportions.

Number of iterations	Number of paths
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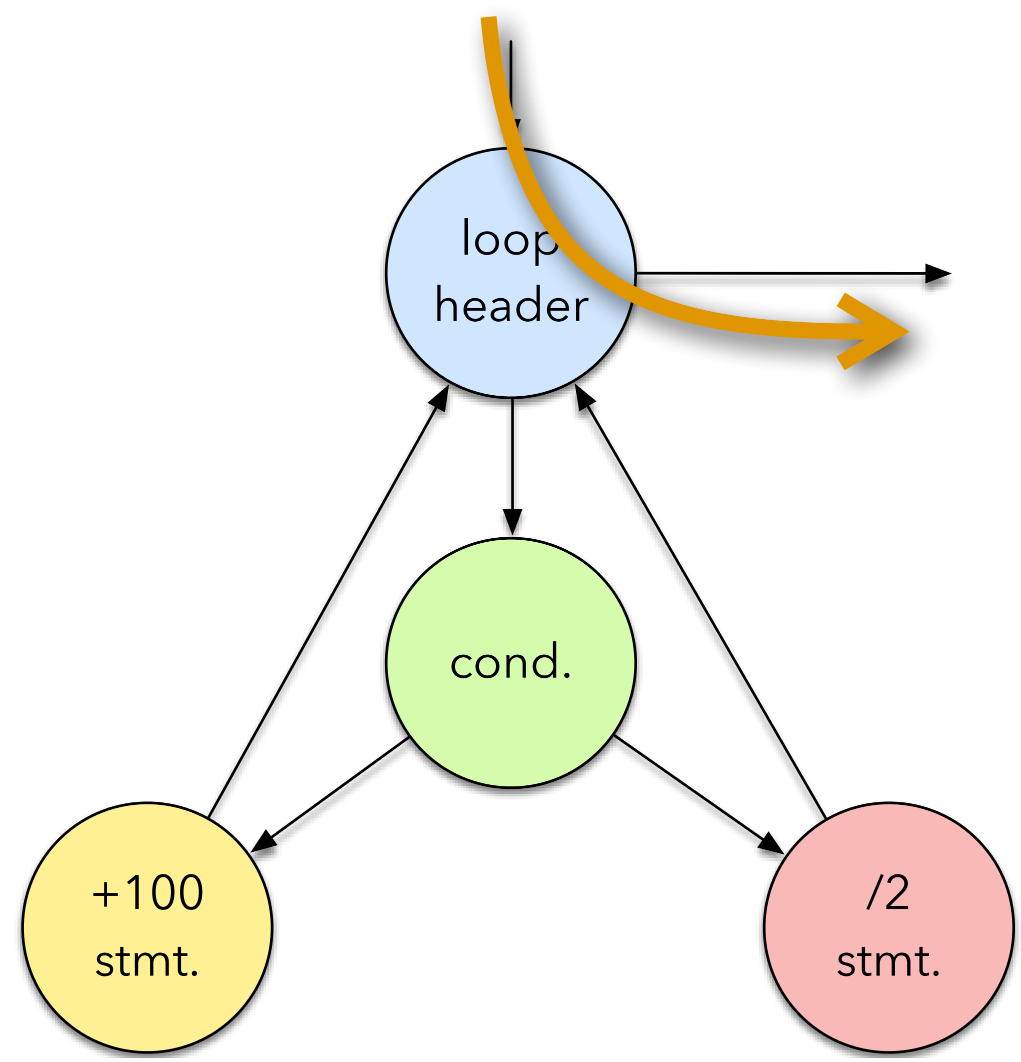

5. Path

The ability of code to hide faults from a test suite is called its fault sensitivity.

Coincidental correctness is obtained when buggy code can produce correct results for some inputs.

E.g. assuming that the correct code would be:

x = x+x

but you wrote

x = x*x

If x = 2 or x = 0 is tested the code hides the bug: it produces a correct result from buggy code. However, this bug is easily identified.

Implementing Tests

- A Very First Glimpse

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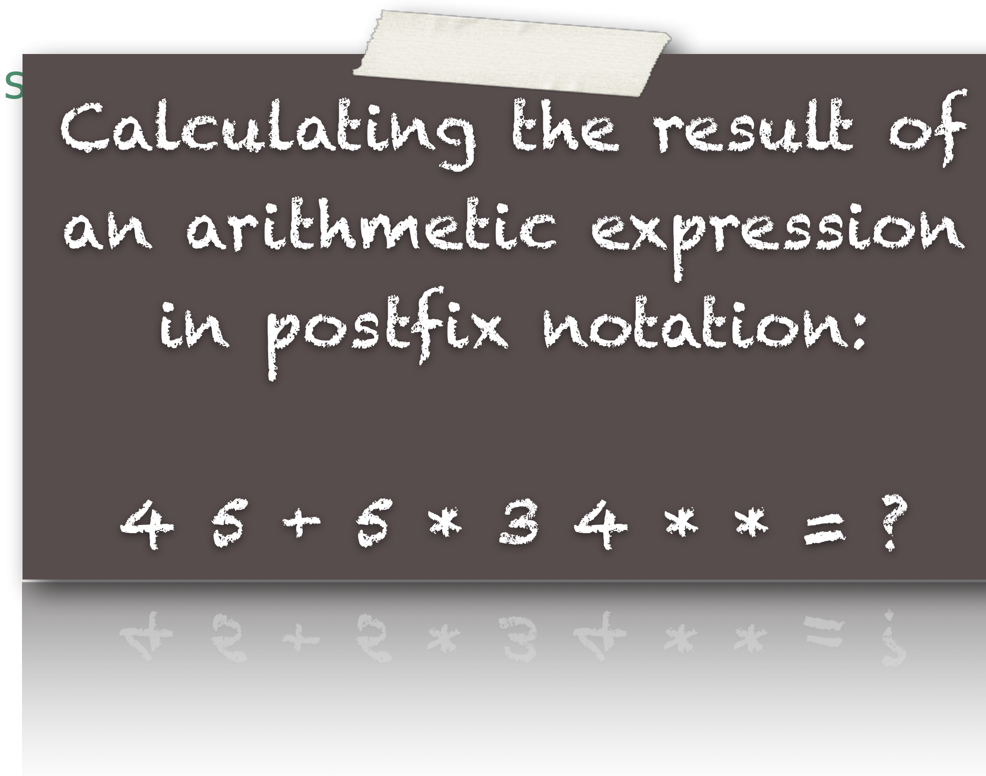
```java
static long process(String[] args) throws IllegalArgumentException {

    Stack values = new Stack();
    for (int i = 0; i < args.length; i++) {
        String arg = args[i];
        try {
            long value = Long.parseLong(arg);
            values.push(value);
        } catch (NumberFormatException nfe) {
            // there is no method to test if a string is

            if (values.size() > 1) {
                long r = values.pop();
                long l = values.pop();
                if (arg.equals("+")) {
                    values.push(l + r);
                    continue;
                }
                if (arg.equals("*")) {
                    values.push(l * r);
                    continue;
                }
            }
            throw new IllegalArgumentException("Too few operands or operator unknown.");
        }
    }
    if (values.size() == 1) return values.pop();
    else throw new IllegalArgumentException("Too few (0) or too many (>1) operands.");
}
```



A Test Plan That Achieves Basic Block Coverage

Description	Input	Expected Output
Test calculation of the correct result	{"4", "5", "+", "7", "*"}	63
Test that too few operands leads to the corresponding exception	{"4", "5", "+", "*"}	*Exception: "Too few operands or operator unknown."*
Test that an illegal operator / operand throws the corresponding exception	{"4", "5327h662h", "*"}	*Exception: "Too few operands or operator unknown."*
Test that an expression throws the corresponding exception	{}	*Exception: "Too few (0) or too many (>1) operands left."*
Test that too few operates leads to the corresponding exception	{"4", "5"}	*Exception: "Too few (0) or too many (>1) operands left."*

A Test Plan That Achieves Basic Block Coverage

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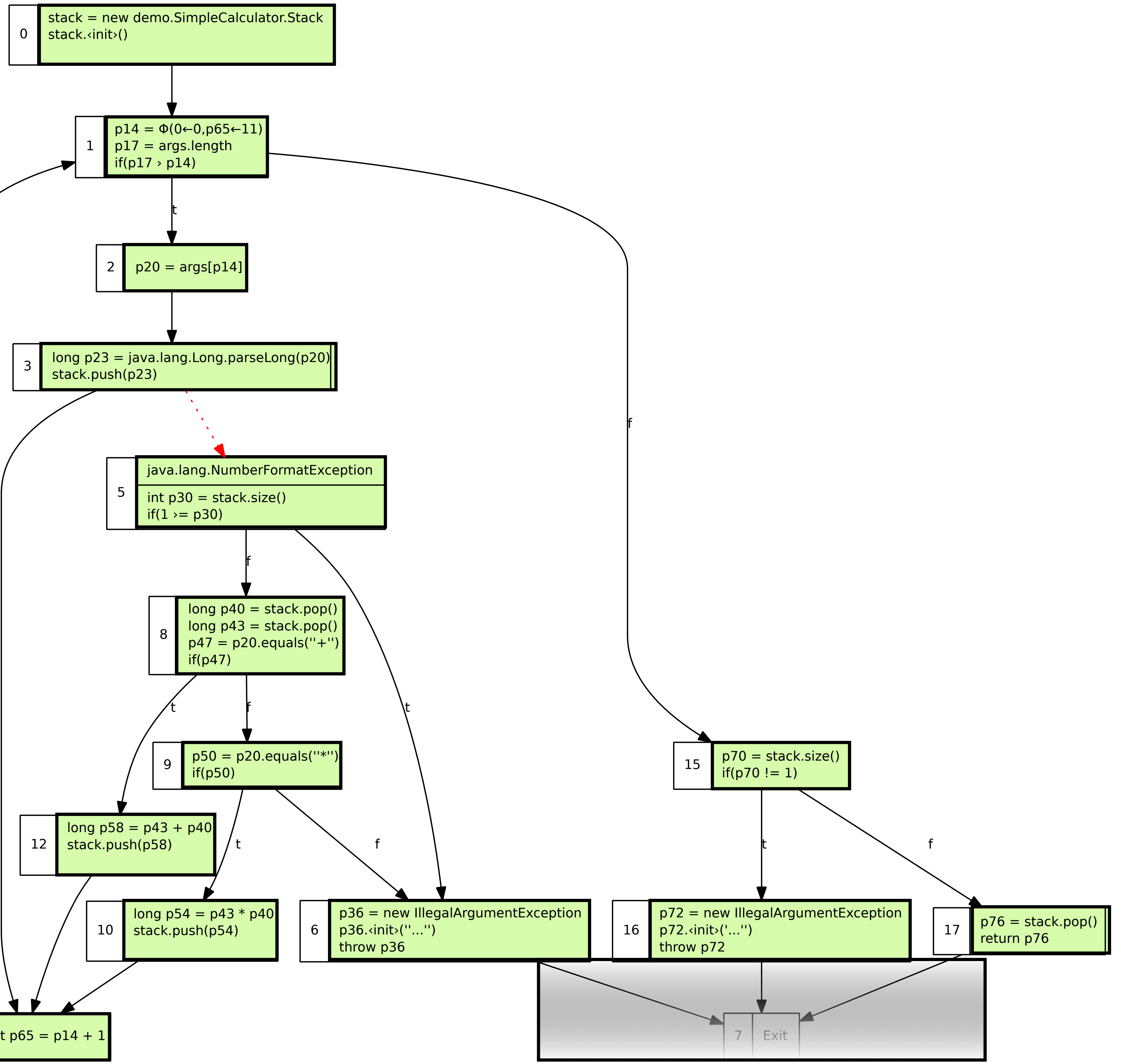
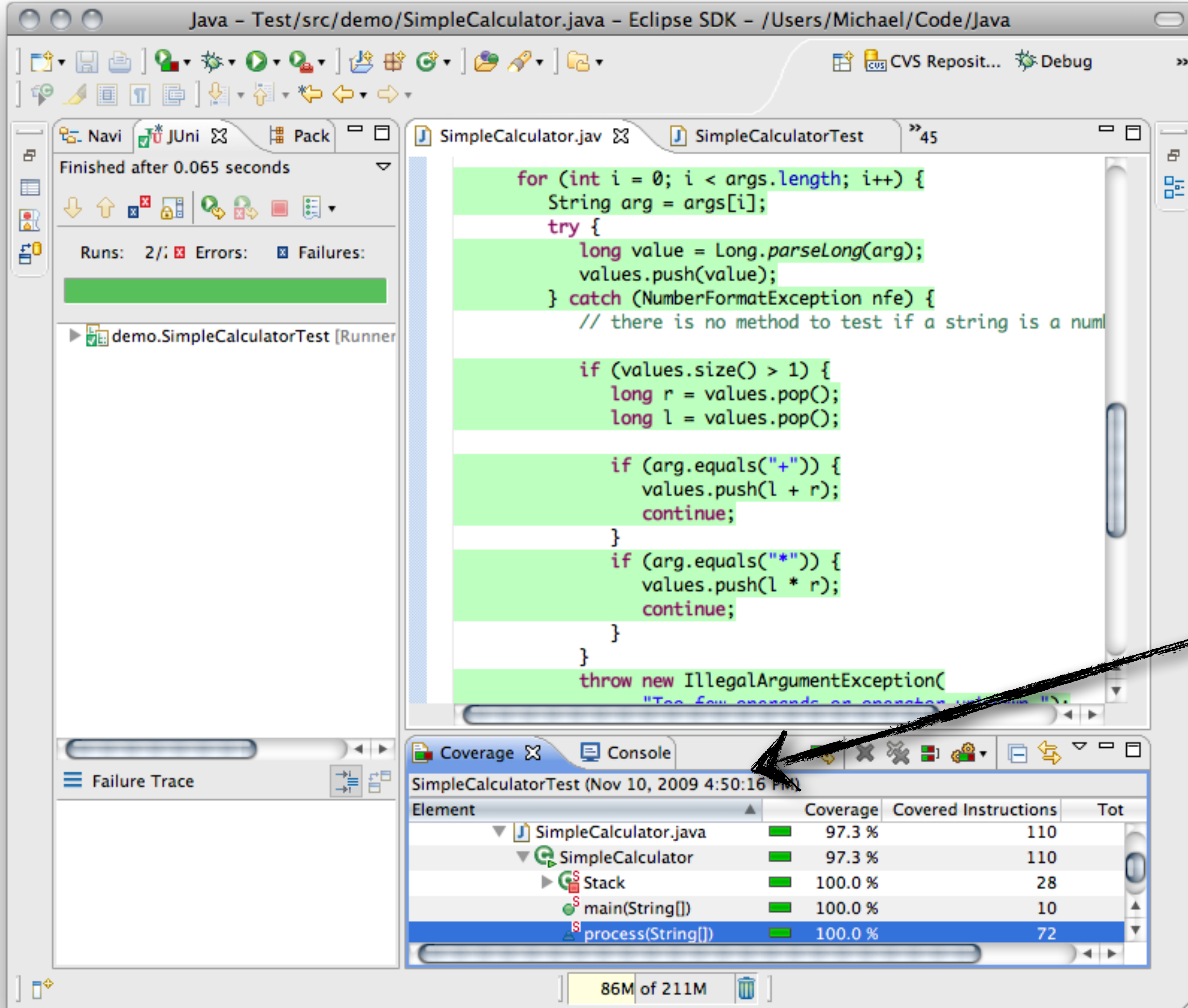
Is this test plan "sufficient"?

Basic Blocks of long process(String[] args)





ECL Emma (Eclipse Plug-in)

Writing a Test Case using JUnit (3)
-
Testing Exception Handling

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

import java.util.Arrays;

import org.junit.Test;


public class SimpleCalculatorTest extends ... {


  public void testProcess() {

    try {
        SimpleCalculator.process(new String[0]);
      fail();
    } catch (IllegalArgumentException iae) {
        assertEquals(
      "Too few (0) or too many (>1) operands.",
      iae.getMessage());
    }
  }
}
```

Writing a Test Case using JUnit (4)

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

import java.util.Arrays;

import org.junit.Test;


public class SimpleCalculatorTest {

    @Test
    public void testProcess() {

        String[] term = new String[] {
            "4", "5", "+", "7", "*"
        };
        long result = SimpleCalculator.process(term);
        assertEquals(Arrays.toString(term), 63, result);
    }


}
```

Writing a Test Case using JUnit (4) - Testing Exception Handling

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

import java.util.Arrays;

import org.junit.Test;


public class SimpleCalculatorTest {

  @Test(expected=IllegalArgumentException.class)
  public void testProcess() {



        SimpleCalculator.process(new String[0]);



  }
}
```

TestNG


```java
// This method will provide data to any test method
// that declares that its Data Provider is named "provider1".
@DataProvider(name = "provider1")
public Object[][] createData1() {
  return new Object[][] {
    { "Cedric", new Integer(36) },
    { "Anne", new Integer(37) }
  };
}

// This test method declares that its data should be
// supplied by the Data Provider named "provider1".
@Test(dataProvider = "provider1")
public void verifyData1(String n1, Integer n2) {
  System.out.println(n1 + " " + n2);
```

Hamcrest


```
import static org.hamcrest.MatcherAssert.assertThat;
import static org.hamcrest.Matchers.*;

import junit.framework.TestCase;

public class BiscuitTest extends TestCase {
   public void testEquals() {
      Biscuit theBiscuit = new Biscuit("Ginger");
      Biscuit myBiscuit = new Biscuit("Ginger");
      assertThat(theBiscuit, equalTo(myBiscuit));
   }
}
```

ScalaTest

(Can also be used for testing Java.)


```
class DefaultIntegerRangesTest
   extends FunSpec with Matchers with ParallelTestExecution {

   describe("IntegerRange values") {

      describe("the behavior of irem") {

         it("AnIntegerValue % AnIntegerValue => AnIntegerValue + Exception") {
              val v1 = AnIntegerValue()
              val v2 = AnIntegerValue()

              val result = irem(-1, v1, v2)
              result.result shouldBe an[AnIntegerValue]
              result.exceptions match {
                  case SObjectValue(ObjectType.ArithmeticE
                  case v ⇒ fail(s"expected ArithmeticException; found $v")
} } }   }   }
```

small concise tests (“atomic tests”)

very good support for Pattern Matching

Behavior-Driven Development

The goal is that developers define the behavioral intent of the system that they are developing.
http://behaviour-driven.org/


```
import org.specs.runner._
import org.specs._

object SimpleCalculatorSpec extends Specification {

  "The Simple Calculator" should {
    "return the value 36 for the input {“6”,“6”,“*”}" in {
      SimpleCalculator.process(Array("6","6","*")) must_== 36
    }
  }

}
```

Using ScalaSpec 1.5: http://code.google.com/p/specs/

(Method-) Stub

- A stub is a partial, temporary implementation of a component (e.g., a placeholder for an incomplete component)
- Stubs are often required to simulate complex systems; to make parts of complex systems testable in isolation

> An alternative is to use a Mock object that mimics the original object in its behavior and facilitates testing.

Testing comprises the efforts to find defects.

Debugging is the process of locating and correcting defects.

(Hence, debugging is not testing, and testing is not debugging.)

Summary

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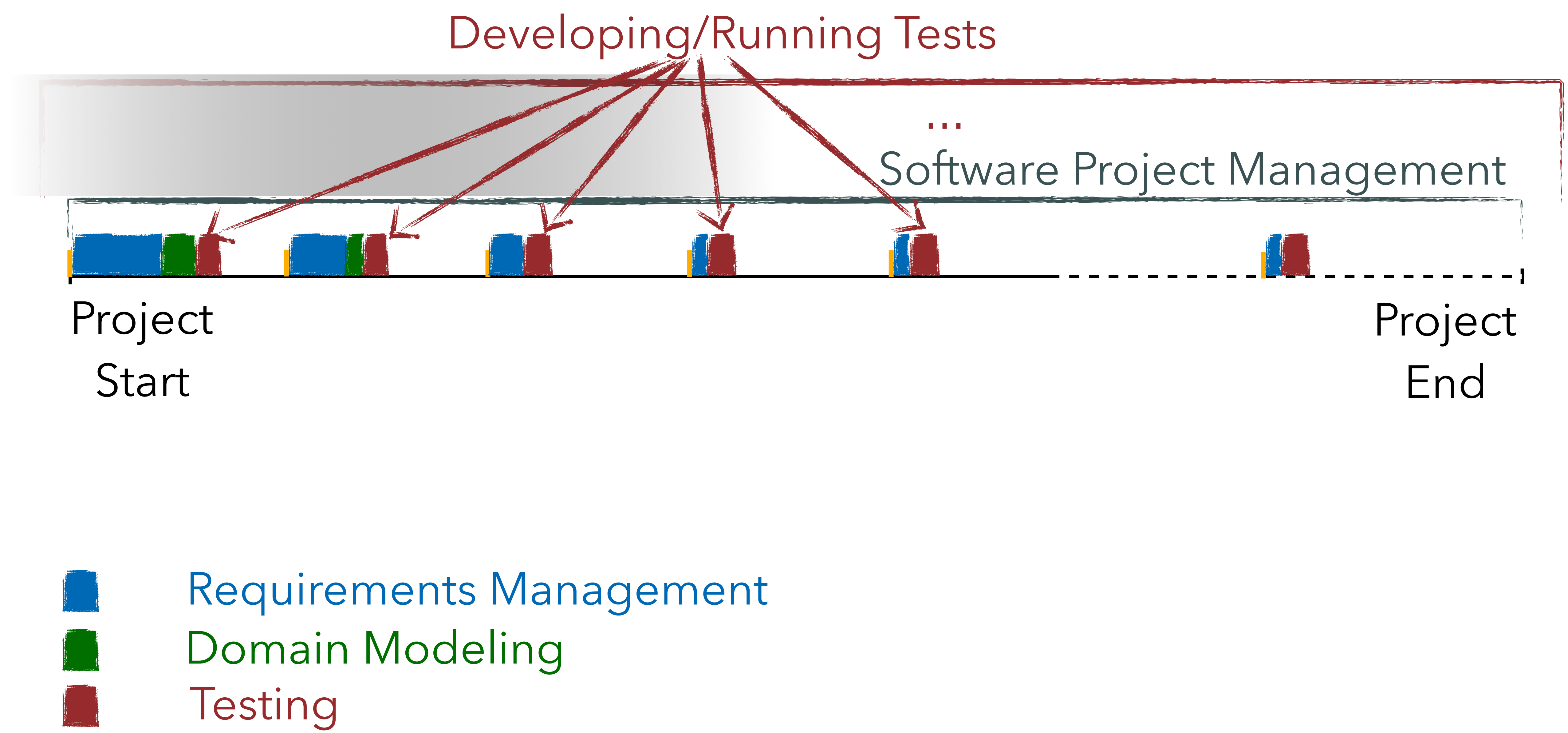
The goal of this lecture is to enable you to systematically carry out small(er) software projects that produce quality software.

- Testing has to be done systematically; exhaustive testing is not possible.
- Test coverage models help you to assess the quality of your test suite; however, "just" satisfying a test coverage goal is usually by no means sufficient.
- Do take an "external" perspective when you develop your test suite.

The goal of this lecture is to enable you to systematically carry out small(er) commercial or open-source projects.



A Tester's Courage

The Director of a software company proudly announced that a flight software developed by the company was installed in an airplane and the airline was offering free first flights to the members of the company. "Who are interested?" the Director asked. Nobody came forward. Finally, one person volunteered. The brave Software Tester stated, ***'I will do it. I know that the airplane will not be able to take off.'***

Unknown Author

http://www.softwaretestingfundamentals.com