Software Reengineering:
Dynamic Analysis: Testing

Henrique Rocha

Universiteit
Antwerpen

Introduction

- Dynamic Analysis verifies properties of a system during execution.
- Testing Analysis is one example of Dynamic Analysis
    - Unit tests, integration tests, system tests, and acceptance tests use dynamic testing

Testing

- Tests are your life insurance! (OORP, p. 149)
- Tests are essential to assure the quality of refactoring activities.
- Write Tests to Enable Evolution (OORP, p.153)
  - Good tests can find bugs on your artifact
  - Tests can also detect unwanted behavior
- You can also write tests to understand a part of a system (OORP, p.179)
- Black box testing is usually more stable for the evolution of a system (“Test the Interface, Not the Implementation”, OORP, p.171).

Unit Testing

- In this session, we focus on Unit Testing.
- There are other types of testing (Integration, Performance, Security, etc.).
- It does not mean that Unit Testing is more important, but those are the tests we can more easily automatize and benefit from tool support.

Quality of a Test Suite

How do you know if your unit test cases are good enough?

Are they really testing the application?

When do we stop testing?

Solution: Test Coverage!

Test Coverage

$$Coverage = \frac{Number\ of\ Covered\ Items}{Total\ Number\ of\ Items} \times 100\%$$

- Statement (Line, or Code) Coverage
- Branch (Condition) Coverage
- Path Coverage
- Mutation Coverage

Example: a function to test

```
int foo(int input, bool b1, bool b2, bool b3){
    int x = input;
    int y = 0;
    if(b1)
        x++;
    if(b2)
        x--;
    if(b3)
        y=x;
    return y;
}
```

Statement/Line/Code Coverage

Test Case(s)

```
ASSERT foo(0, true, true, true) == 0;
```

```
int foo(int input, bool b1, bool b2, bool b3){
   int x = input;
   int y = 0;
   if(b1)
      x++;
   if(b2)
      x--;
   if(b3)
      y=x;
   return y;
}
```

Statement/Line/Code Coverage

Test Case(s)

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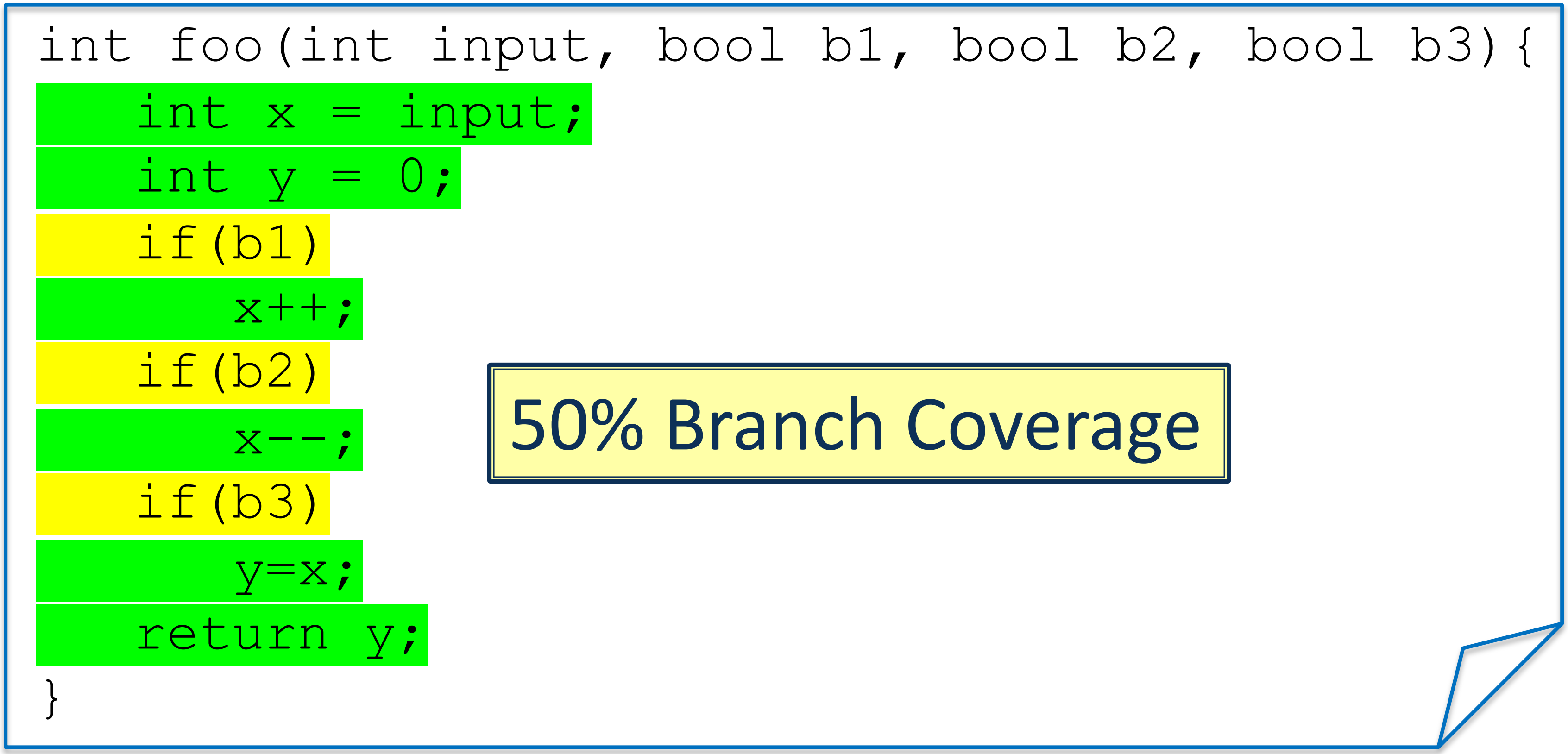
    if(b1)
        x++;
    if(b2)
        x--;
    if(b3)
        y=x;
    return y;
}
```

100% Statement Coverage

Branch/Condition Coverage

Test Case(s)

```
ASSERT foo(0, true, true, true) == 0;
```



```
int foo(int input, bool b1, bool b2, bool b3){
    int x = input;
    int y = 0;
    if(b1)
        x++;
    if(b2)
        x--;
    if(b3)
        y=x;
    return y;
}
```

50% Branch Coverage

Branch/Condition Coverage

Test Case(s)

```
ASSERT foo(0, true, true, true) == 0;
ASSERT foo(0, false, false, false) == 0;
```

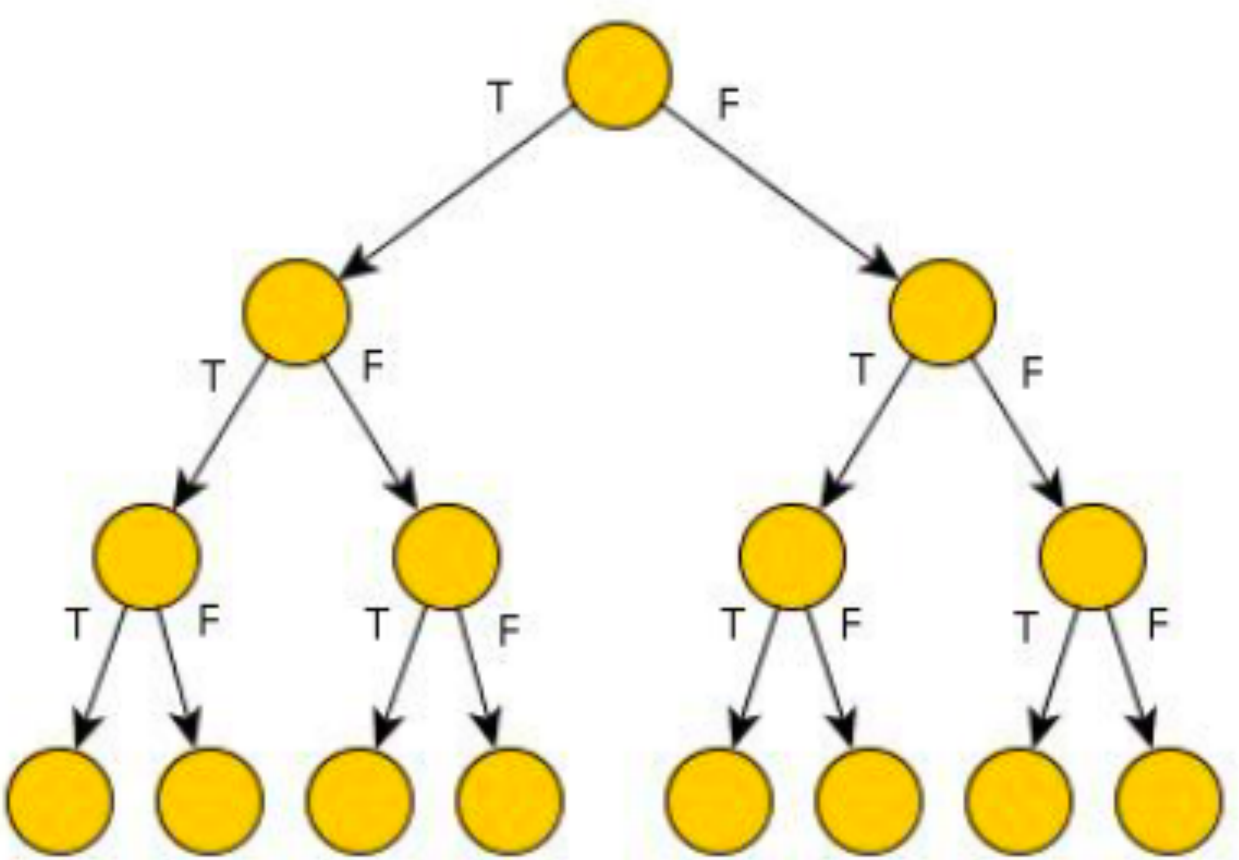
New Test

```
int foo(int input, bool b1, bool b2, bool b3){
    int x = input;
    int y = 0;
    if(b1)
        x++;
    if(b2)
        x--;
    if(b3)
        y=x;
    return y;
}
```

100% Branch Coverage

Path Coverage

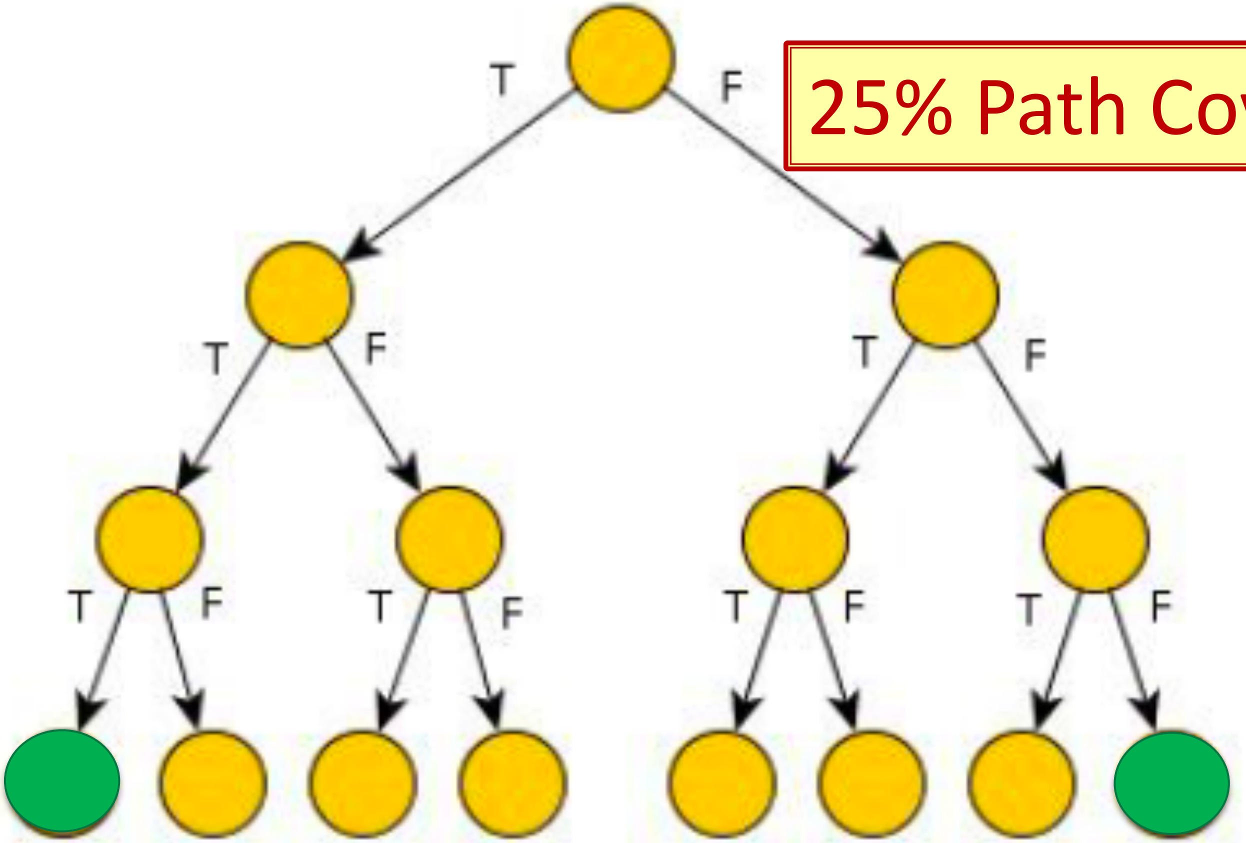
Paths for three “if” each can be either true (T) or false (F)



Path Coverage

Test Case(s)

```
        ASSERT foo(0, true, true, true) == 0;
        ASSERT foo(0, false, false, false) == 0;
```



25% Path Coverage

Mutation Testing

- The steps for Mutation Testing are basically:
  - Make small changes to the code (Mutants).
    Each change is a different mutant.
  - For each mutant, run the test cases:
    - If one test fails it means your test was good enough to detect the changes (the mutant is killed).
    - If all tests passes, it means your tests did not detect the changed behavior (the mutant survives).
  - Therefore, the more mutants you kill, the better.

$$Mutation\ Coverage = \frac{Number\ of\ Killed\ Mutants}{Total\ Number\ of\ Mutants}$$

Mutation Testing: Small Example

Original

```
int f(bool a, bool b){
  if(a && b) return 1;
  else return 0;
}
```

Test Case

```
void testf(){
  assert f(true, true)==1;
  assert f(false, false)==0;
}
```

Mutant

```
int f(bool a, bool b){
  if(a || b) return 1;
  else return 0;
}
```

Mutant Survives the Test Case

Mutation Testing: Small Example

Original

```
int f(bool a, bool b){
  if(a && b) return 1;
  else return 0;
}
```

Mutant

```
int f(bool a, bool b){
  if(a || b) return 1;
  else return 0;
}
```

Test Case

```
void testf(){
  assert f(true, true)==1;
  assert f(false, false)==0;
}
```

Missing Assertions that Could Kill this Mutant

```
assert f(false, true)==0;
assert f(true, false)==0;
```

Mutation Coverage

- Assess how good your test cases are at catching faults by introducing defects into the source code.

- More reliable metric to validate test suite effectiveness.

Testing Coverage for the Project

- It is required to show coverage for your Project (in both the Intermediate and the Final Report)
  - At least Statement Coverage, but Branch Coverage is better.
  - You should show the chosen coverage before the refactoring, and after (where hopefully you also added new tests).

- There is no set coverage limit to reach for the project.
  - But if your project has a very low coverage you better have a good explanation for that.
  - Focus on increasing the coverage for the parts of the system that is going to be affected by your refactorings.