

Introduction to Software Engineering (ISAD1000)

Lecture 8: Test Fixtures & White-Box Testing

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Discipline of Computing

School of Electrical Engineering, Computing and Mathematical Sciences (EECMS)

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Outline

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Testing So Far

- ▶ So far, our discussion of testing has focused on parameters and return values.
- ▶ We see the range of possible parameter values, and divide (partition) them into categories.
 - ▶ Equivalence partitioning and boundary value analysis.
 - ▶ But we *haven't* looked *inside* the method/function. We've treated it as a black box.
- ▶ For the return values, we obtain them using actual parameter value, and compare to what we expected.
 - ▶ We've *assumed* that methods/functions are like mathematical functions: transforming one or more parameters into a single return value.

Examples from lecture 6

Submodule **abs**

Imports: **n (real)**

Exports: **result (real)**

Implements the absolute value function. If n is non-negative, returns. Otherwise, returns the inverse of n.

Submodule **palindrome**

Imports: **s (string)**

Exports: **result (Boolean)**

Checks whether s is a palindrome; i.e. if it reads the same forwards and backwards. Returns true if it is, or false otherwise.

Submodule **findMax**

Imports: **value1, value2 (integers)**

Exports: **maximum (integer)**

Determines the highest out of value1 and value2, and returns it.

Generalizing of testing

- ▶ Unit testing can get more complicated.
- ▶ We *do still* have the following basic ingredients:
 - ▶ Test cases;
 - ▶ For each test case: test data, production code call, expected results, and actual results.

But:

- ▶ We can also do “white-box” testing, where we find test cases based on the code. (Part 2 of this lecture)
- ▶ In either white- or black-box testing, we sometimes need additional “setting up” for each test case. (Part 1 of this lecture)
 - ▶ Some test data are **not provided via parameters**.
 - ▶ Some test results are **not obtained via return values**.
 - ▶ There can be multiple results per test case, and hence **multiple assertions**.

Input (Sources of Data) for methods

- ▶ Methods/functions can get data from various sources:
 - ▶ **Parameter values;**
 - ▶ User input;
 - ▶ Fields (variables outside the method/function);
 - ▶ Files on disk;
 - ▶ Databases;
 - ▶ The operating system;
 - ▶ Other running programs on the same computer;
 - ▶ Online services.
- ▶ Testing must account for *all* the data a method/function uses.
- ▶ Test code must control and mimick these sources of data.
 - ▶ e.g. We need to fool the production code into accepting fake “user input” that really comes from the test code.

Output (Actions) resulted from methods

- ▶ Methods/functions can also send data to many different places:
 - ▶ **Return value;**
 - ▶ Exceptions;
 - ▶ The screen/console;
 - ▶ Fields;
 - ▶ Files;
 - ▶ Databases;
 - ▶ Other running programs;
 - ▶ Online services.

} Called “*side effects*”, though they’re often the main purpose of a method/function.
- ▶ Testing must check that all of these are as expected.
 - ▶ e.g., if you’re writing to a file, your test code must ensure that actually happens properly.
- ▶ We need to capture these outputs and run them all through assertion statements.

Testing methods with different forms of input/output

- ▶ We'll consider how to test methods/functions that:
 - ▶ Take user input (console input);
 - ▶ Display output (console output);
 - ▶ Read text files (file input);
 - ▶ Write text files (file output);
 - ▶ Generate exceptions.
- ▶ The first four of these have something in common:
- ▶ Everything is a **string**!

GUIs

- ▶ For programs that display *windows*, *buttons*, *scroll-bars*, etc., and respond to mouse clicks or touch-based input, these things are *not* strings.
- ▶ **Testing this is outside the scope of this unit.**
- ▶ It can be quite tricky:
 - ▶ How many different ways are there to move the mouse?
 - ▶ How many different positions on the screen can windows and buttons occupy?
 - ▶ Nonetheless, there are mechanisms to automate GUI input;
e.g. `java.awt.Robot`.

Input/Output is String-Based

- ▶ We'll consider how to test methods/functions that:
 - ▶ Take user input (console input);
 - ▶ Display output (console output);
 - ▶ Read text files (file input);
 - ▶ Write text files (file output);
 - ▶ Generate exceptions.
- ▶ The first four of these have something in common:
- ▶ Everything is a **string**!
 - ▶ **Reading console input? The user enters a *string*.**
 - ▶ If you ask for an integer, the user enters a string containing digit characters. Then you calculate what integer they form.
 - ▶ **Writing real numbers to a file? You're writing a string.**
 - ▶ You take each number, and generate a string that contains various digit characters and a ".".



New Lines (“\n”) in Input/Output

- ▶ The string-iness of input/output goes a bit further.
- ▶ You can think of *all* console input as just *one big string* put together.
 - ▶ And, similarly, all console output is another big string.
 - ▶ And an entire text file is really just a single string.
- ▶ To make sense of this, you need to understand the “newline” character “\n”.
 - ▶ It’s written backslash-n, though it doesn’t really *look* like anything.
 - ▶ But it can be part of any string, just like a letter or digit.
 - ▶ It represents a line break; a point at which one line of text ends and another begins.
 - ▶ It’s the ENTER key, when pressed by the user.

New Lines (“\n”) in Input/Output

- ▶ The newline character “\n” lets us think of multiple inputs or outputs as all being one string.
- ▶ Say you write a program that asks the user some questions, and they answer like this:

```
Enter an integer: 50
Enter another integer: -71
Enter a word: smile
```

- ▶ You can represent the input as the string `"50\n-71\nsmile\n"`.
 - ▶ That's the string the user has actually typed in.
- ▶ An aside: to represent an actual backslash, you must write `“\\”`. (For two backslashes, write `“\\\\”`, etc.)

Simulating User Input

- ▶ To test a method/function that takes console input:
 - ▶ Our test data will be a string representing that input.
 - ▶ We have to set things up so that the production code *thinks* this string is actual input.
- ▶ And remember: the production code still has to work as normal.
 - ▶ We can't change it to make this work.
 - ▶ Everything we do to test it must be in the test code.
- ▶ Fortunately, languages like Java and Python provide a couple of tricks to help. . .

Simulating Console Input : Example

```
import sys, io # Test code:
```



```
...
```

```
simInput = "123"
```

```
sys.stdin = io.StringIO(simInput)
```

```
... # call production code
```

- ▶ We decide what the simulated input should be (e.g. “abc”)
- ▶ We create an “object” that behaves like a source of input, but actually just gives you back what you put into it.



Java “ByteArrayInputStream”




Python “io.StringIO”

- ▶ We tell the system to read from this, instead of the console.





Simulating Console Input: Example

```
import java.io.*; // Test code:
...
String simInput = "abc"; System.setIn(new
ByteArrayInputStream(
    simInput.getBytes()));
... // call production code
```




- ▶ We decide what the simulated input should be (e.g. “abc”)
- ▶ We create an “object” that behaves like a source of input, but actually just gives you back what you put into it.

 **Java** “ByteArrayInputStream”
 **Python** “io.StringIO”

- ▶ We tell the system to read from this, instead of the console.

Using Simulated Input

- ▶ Say your test code sets up some simulated input; specifically, a value of “abc”.
- ▶ Your test code then calls the production code.
- ▶ The production code tries to read some console input.

 `Java: String val = scanner.nextLine();`

 `Python: val = input()`

- ▶ The production code receives the simulated input; i.e., val becomes equal to “abc”.
 - ▶ The production code assumes the user has entered this value.
 - ▶ It can't tell the difference between real and simulated input, which is the point.
- ▶ The test code uses this to check what happens for different kinds of input.

Using Simulated Input: Example Test Code

- ▶ Remember “max()”? Say we also have “inputMax()”.
- ▶ Instead of importing two numbers, it *inputs* them.
- ▶ Here's how we might test it:


```
def testInputMax():  
    sys.stdin = io.StringIO("10\n15")  
    assert 15 == MyUtils.inputMax()  
    sys.stdin = io.StringIO("10\n-10")  
    assert 10 == MyUtils.inputMax()  
    ... # One other test case
```



Using Simulated Input: Example Test Code

- ▶ Remember “max()”? Say we also have “inputMax()”.
- ▶ Instead of importing two numbers, it *inputs* them.
- ▶ Here's how we might test it:

```
public static void testInputMax()  
{  
    System.setIn(  
        new ByteArrayInputStream("10\n15".getBytes()));  
    assert 15 == MyUtils.inputMax();  
  
    System.setIn(  
        new ByteArrayInputStream("10\n-10".getBytes()));  
    assert 10 == MyUtils.inputMax();  
    ... // One other test case  
}
```

 **Java**

Capturing Output

- ▶ A “mirror image” of the problem of simulating input.
- ▶ If production code *displays* something, test code must be able to check it.
 - ▶ But, *normally*, your code cannot see its own output. Only the user can.
 - ▶ We must do something to *capture* it, before it is actually displayed.



Capturing Console Output



```
import sys
import io

...
capOut = io.StringIO()
sys.stdout = capOut
... // call production code
actualOutput = capOut.getvalue()
```

- ▶ Create an “object” that can receive output, but *stores* it instead of displaying it.

 Java “ByteArrayOutputStream”
 Python “io.StringIO” (same as for input)

- ▶ Tell the system to use this, instead of the console.
- ▶ Afterwards, retrieve the text that was “displayed”.

Capturing Console Output



```
import java.io.*;
...
ByteArrayOutputStream capOut = new ByteArrayOutputStream();
System.setOut(new PrintStream(capOut));
... // call production code
String actualOutput = capOut.toString();
```

- ▶ Create an “object” that can receive output, but *stores* it instead of displaying it.



Java “ByteArrayOutputStream”



Python “io.StringIO” (same as for input)

- ▶ Tell the system to use this, instead of the console.
- ▶ Afterwards, retrieve the text that was “displayed”.

Capturing Output: Example Test Code

- ▶ Say we have another variation of `max()` called `outputMax()`.
- ▶ Instead of returning the result, it *outputs* it.
- ▶ Here's how we might test it:

```
def testOutputMax():  
    capOut = io.StringIO()  
    sys.stdout = capOut  
    MyUtils.outputMax(10, 15) # Production code call  
    assert "15" == capOut.getvalue()  
  
    ... # Other test cases
```



Capturing Output: Example Test Code

- ▶ Say we have another variation of `max()` called `outputMax()`.
- ▶ Instead of returning the result, it *outputs* it. (output to the screen)
- ▶ Here's how we might test it:



```
public static void testOutputMax()  
{  
    ByteArrayOutputStream capOut  
        = new  
        ByteArrayOutputStream();  
    System.setOut(new PrintStream(capOut));  
    MyUtils.outputMax(10, 15); // Production code  
    call assert "15".equals(capOut.toString());  
  
    ... // Other test cases  
}
```


Simulating Input *and* Capturing Output

- ▶ What about `inputOutputMax()`?
- ▶ We can simulate input and capture output at the same time:



```
def testInputOutputMax():  
    capOut = io.StringIO()  
    sys.stdout = capOut  
    sys.stdin = io.StringIO("10\n15")  
    MyUtils.inputOutputMax() # Production code  
    call assert "15" == capOut.getvalue()  
    ... # Other test cases
```

Simulating Input *and* Capturing Output

- ▶ What about `inputOutputStreamMax()`?
- ▶ We can simulate input and capture output at the same time:

```
public static void testInputOutputStreamMax()  
{  
    ByteArrayOutputStream capOut = new  
        ByteArrayOutputStream();  
    System.setOut(new PrintStream(capOut));  
    System.setIn(  
        new ByteArrayInputStream("10\n15".getBytes()));  
    MyUtils.inputOutputStreamMax(); // Production code call  
    assert "15".equals(capOut.toString());  
    ... // Other test cases  
}
```



Testing with Files

- ▶ If the production code deals reads/writes data files, the test code must also deal with them.
- ▶ *Conceptually* this is quite similar to console IO, but the fine details a bit different.
- ▶ To test a method/function that reads an input file:
 - ▶ The test code must setup (i.e. write) the input file beforehand.
- ▶ To test a method/function that writes an output file:
 - ▶ The test code must verify (i.e. read) the output file afterwards.

File Reading and Writing Syntax

- ▶ The following slides show code for reading/writing files.
 - ▶ In Java, we'll use `PrintWriter` and `Scanner`.
 - ▶ In Python, we'll use the “with” statement, and `open()`, `write()` and `read()`.
- ▶ There are other valid ways to do this.
- ▶ There's nothing particularly special about these particular reading/writing approaches.
 - ▶ Except that they're reasonably short and easy to put into slide form.
- ▶ The most important thing is that you understand the *concept* of what is happening.

Testing with Input Files



```
def testInputFileMax():  
    with open("inputfile.txt", mode = "w") as inputFile:  
        inputFile.write("10\n15") # <-- The test data  
    assert 15 == MyUtils.inputFileMax("inputfile.txt")  
    ... # Other test cases
```

- ▶ First, we create a file containing test data.
- ▶ Then, we call the production code, which (in theory) reads that file and thus gets the test data.
- ▶ Let's assume the production code takes a filename parameter.
 - ▶ If so, this must be the same as the file we created.


Testing with Input Files

```
public static void testInputFileMax()  
{  
    PrintWriter inputFile = new  
        PrintWriter("inputfile.txt");  
    inputFile.println("10\n15"); // <-- The test data  
    inputFile.close();  
  
    assert 15 == MyUtils.inputFileMax("inputfile.txt");  
    ... // Other test cases  
}
```



- ▶ First, we create a file containing test data.
- ▶ Then, we call the production code, which (in theory) reads that file and thus gets the test data.
- ▶ Let's assume the production code takes a filename parameter.
 - ▶ If so, this must be the same as the file we created.

Testing with Output Files

 Python

```
def testOutputFileMax():
    MyUtils.outputFileMax(10, 15, "output.txt")

    with open("output.txt") as outputFile:
        actual = outputFile.read().strip() # <-- Actual
        assert "15" == actual           # result

    ... # Other test cases
```

- ▶ First, we call the production code, which (in theory) creates a file and writes a result to it.
- ▶ Then, the test code reads that file, gets the result, and runs it through an assertion.

Testing with Output Files

```
public static void testOutputFileMax()  
{  
    MyUtils.outputFileMax(10, 15, "output.txt");  
    Scanner outputFile = new Scanner(new File("output.txt"));  
    String actual = outputFile.nextLine(); // <-- Actual  
    assert "15".equals(actual);           //      result  
  
    ... // Other test cases  
}
```



- ▶ First, we call the production code, which (in theory) creates a file and writes a result to it.
- ▶ Then, the test code reads that file, gets the result, and runs it through an assertion.

Exceptions During Testing

Exceptions during testing occur because:

- ▶ The production code gave the wrong result.
- ▶ The production code unexpectedly threw an exception.
 - ▶ The test fails, but before we even get to the assert statement.
- ▶ The test code itself is broken.
 - ▶ Maybe the “expected result” is incorrect.
 - ▶ Maybe you didn’t set up a test input file properly.
- ▶ **The production code *expectedly* threw an exception.**
 - ▶ Often the production code *must* throw an exception, under certain circumstances.
 - ▶ So, the test code must check that it does.
 - ▶ Such a test should fail in the *absence* of an exception.

Handling Unexpected Exceptions

- ▶ You could use a `try-catch/except` statement.
- ▶ But *in test code*, it's simpler to just pass-on the exception.
- ▶ This will be interpreted as a test failure, as it should be.

 Python: nothing additional needs to be done!

 Java: add a `throws` clause:

```
public static void testThing() throws ExceptionType
{
    ...
}
```

ExceptionType is the particular kind of exception that the production code might generate.

Handling *Expected* Exceptions

- ▶ Remember `formatTime()`?
- ▶ It returned "error" when passed invalid hours/minutes.
 - ▶ i.e., if we write "`actual = MyUtils.formatTime(12, -10)`", we should expect `actual` to be "error".
- ▶ But, in the real world, it's more likely to be designed to throw an exception.
 - ▶ In this case, there is no string value at all, and by default the exception means a test failure.
 - ▶ But *this* exception means the code actually works!
 - ▶ i.e. it successfully identifies invalid values, and takes appropriate action.
 - ▶ The test should only fail if there *isn't* an exception.
 - ▶ How do we test for this?

Handling Expected Exceptions

- ▶ We need to use a `try` statement to sort this out.
- ▶ The test passes only if an exception makes the code jump to the `catch/except` block.

```
def testFormatTime():  
    try:  
        actual = MyUtils.formatTime(12, -10)  
        assert False # Test fails if it reaches this point  
  
    except ValueError:  
        pass # Do nothing.  
  
    ... # Other test cases
```



Handling Expected Exceptions

- ▶ We need to use a `try` statement to sort this out.
- ▶ The test passes only if an exception makes the code jump to the `catch/except` block.

```
public static void testFormatTime()  
{  
    try  
    {  
        String actual = MyUtils.formatTime(12, -10);  
        assert false; // Test fails if it reaches this point  
    }  
    catch(IllegalArgumentException e) {} // Do nothing.  
  
    ... // Other test cases  
}
```



Test Fixtures

- ▶ We're now seen various situations where test cases are written like this:
 1. Perform setting up.
 2. Call production code.
 3. Compare results.
- ▶ And there's one more step we sometimes have:
 4. **Tear down: restore everything to its original state.**

For instance:

- ▶ If the test code (or production code) created a file, we should delete it afterwards.
 - ▶ If the test code redirected console input or output, it should set it back afterwards.
- ▶ **The “setting up” and “tearing down” defines a *test fixture*:**
 - ▶ A set of things in-place to make the test case work, and to isolate the test case from external factors.

Common Setting-Up and Tearing-Down

- ▶ Multiple test cases often require at least some of the same setting-up and tearing-down.
 - ▶ Some of the setting-up may be separate from providing the test data.
 - ▶ Perhaps *all* test cases require the same console input, just to make the production code work.
 - ▶ Or perhaps they all require the same file to exist.
- ▶ Reuse applies to test code too! We don't want to repeat ourselves.
- ▶ So, the convention is to have `setUp()` and `tearDown()` helper method/functions.
 - ▶ These do all the *common* work to establish a test fixture.
 - ▶ `setUp()` will be called immediately before *every* test method/function.
 - ▶ `tearDown()` will be called immediately after.

Text Fixture Example – *Without* a Test Framework



```
def setUp(): ...
def testFunction1(): ...
def testFunction2(): ...
def tearDown(): ...

if name == "__main__":
    setUp()
    testMethod1()
    tearDown()
    setUp()
    testMethod2()
    tearDown()
```


Text Fixture Example – *Without* a Test Framework



```
public class TestSuite
{
    public static void main(String[] args)
    {
        setUp();
        testMethod1();
        tearDown();
        setUp();
        testMethod2();
        tearDown();
    }

    public static void setUp() { ... }
    public static void testMethod1() { ... }
    public static void testMethod2() { ... }
    public static void tearDown() { ... }
}
```

Test Fixtures in JUnit/unittest

- ▶ JUnit understands methods that have `@Before` and `@After` annotations.
 - ▶ It doesn't actually care what the names are.
- ▶ Python's unittest module looks for methods specifically called `setUp()` and `tearDown()`.
- ▶ In either case, the framework will automatically:
 - ▶ Call the `@Before/setup()` method before *each* test method.
 - ▶ Call the `@After/tearDown()` method after each test method.

Test Fixture Example – *With* a Test Framework



Python

```
import unittest

class TestSuite(unittest.TestCase):
    def setUp(self): ...
    def testMethod1(self): ...
    def testMethod2(self): ...
    def tearDown(self): ...
```

Test Fixture Example – *With* a Test Framework

```
@RunWith(JUnit4.class) public class TestSuite
{

    @Before
    public void setUp() { ... }

    @Test
    public void testMethod1() { ... }

    @Test
    public void testMethod2() { ... }

    @After
    public void tearDown() { ... }

}
```



White –box testing

White-Box Testing

- ▶ We will go back go back to *test design* now.
 - ▶ i.e., how to decide which test cases we need in the first place.
- ▶ We have e looked at designing “Black Box” testing:
 - ▶ We design test cases *without* looking at the code.
 - ▶ We just look at the parameters, return type, and documentation.
 - ▶ This is what Equivalence Partitioning and Boundary Value Analysis are doing.
- ▶ In “**White Box**” (or “**Clear Box**”) testing, test cases are based on the *paths* through a method/function.

Paths

- ▶ A “path” is (roughly speaking) one possible way to “get through” a method/function, from start to end.
- ▶ There’s always at least one path, but there are often more.
- ▶ Different paths are created by conditional statements, like `if`.
 - ▶ When there are multiple choices, this translates to multiple paths.
 - ▶ Multiple paths are also created by `switch`, `while`, `do-while`, `for` and `try-catch/except`.
 - ▶ (Not all of these exist in Python.)
- ▶ White-box testing ensures that we test each path – each possible way through the production code.
 - ▶ Each path becomes a test case!

Example : if Statement Paths

- ▶ if statements have two paths.
- ▶ 1st path:



```
double abs(double n)
{
    if(n < 0)
    {
        n = -n;
    }
    return
    n;
}
```

The control flow graph for the Java `abs` method starts at the opening curly brace of the function. A pink arrow leads to the `if(n < 0)` statement. From the `if` statement, a pink arrow leads to the `n = -n;` statement, and another pink arrow leads to the `return n;` statement. Both paths converge at the closing curly brace of the function.



```
def myAbs(n):
    if n < 0:
        n = -n
    return n
```

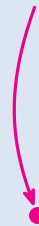
The control flow graph for the Python `myAbs` function starts at the `def` statement. A pink arrow leads to the `if n < 0:` statement. From the `if` statement, a pink arrow leads to the `n = -n` statement, and another pink arrow leads to the `return n` statement. Both paths converge at the end of the function.

if Statement Paths

- ▶ `if` statements have two paths.
- ▶ 2nd path:


Java

```
double abs(double n)
{
    if(n < 0)
    {
        n = -n;
    }
    return
    n;
}
```



Python

```
def myAbs(n):
    if n < 0:
        n = -n
    return n
```



White Box Test Design – `if` statements

- ▶ In drawing up our test design, we work with paths instead of equivalence categories.
- ▶ We still need to pick test data and expected results:

Test design for `abs`:

Path	Test Data	Expected Result
1. Enter the <code>if</code>	$n = -5$	5
2. DO NOT enter the <code>if</code>	$n = 10$	10

if-else Paths

- ▶ if-else statements also have two paths.
- ▶ 1st path:



Java

```
void printMax(int x, int y)
{
    if(x > y)
    {
        System.out.println(x);
    }
    else
    {
        System.out.println(y);
    }
    return n;
}
```



Python

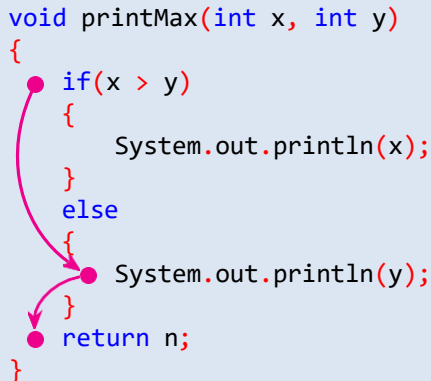
```
def printMax(x, y):
    if x > y:
        print(x)
    else:
        print(y)
```

if-else Paths

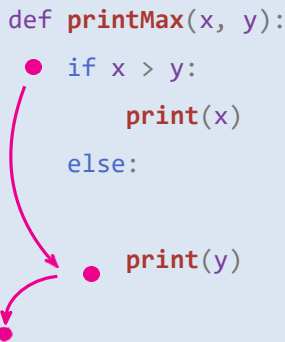
- ▶ if-else statements also have two paths.
- ▶ 2nd path:



```
void printMax(int x, int y)
{
    if(x > y)
    {
        System.out.println(x);
    }
    else
    {
        System.out.println(y);
    }
    return n;
}
```



```
def printMax(x, y):
    if x > y:
        print(x)
    else:
        print(y)
```



if-else Test Design

Path	Test Data	Expected Result
1. Enter the <code>if</code> part	$x = 10, y = 5$	output: "10"
2. Enter the <code>else</code> part	$x = 10, y = 20$	output: "20"

Loop Paths

- ▶ How does the concept of a “path” apply to loops?
 - ▶ `while`, `do-while`, `for`.
- ▶ It may seem like a loop should have *many* paths.
 - ▶ You can go around a while loop *any number* of times, for instance.
- ▶ In fact, loops have exactly two paths, just like `if` statements.
 1. The path that never enters the loop.
 - ▶ (Or, for Java’s `do-while` loop, never repeats the loop.)
 2. A path that *does* enter the loop.
- ▶ Whether the loop repeats twice, or a million times, it’s considered the same path.

while Paths

1st path:



```
int readPositive()  
{  
    int val = ...; // Input  
    while(val <= 0) {  
        System.out.println(  
            "Not positive");  
        val = ...; // Input  
    }  
    return val;  
}
```



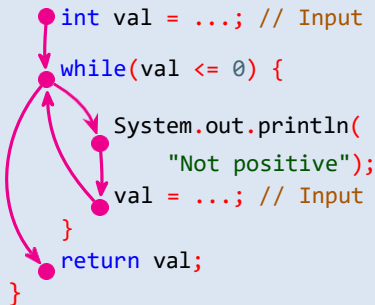
```
def readPositive():  
    val = int(input())  
    while val <= 0:  
        print(  
            "Not positive")  
        val = int(input())  
    return val
```

while Paths

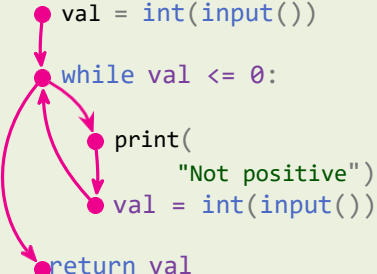
2nd path:



```
int readPositive()  
{  
    int val = ...; // Input  
    while(val <= 0) {  
        System.out.println(  
            "Not positive");  
        val = ...; // Input  
    }  
    return val;  
}
```



```
def readPositive():  
    val = int(input())  
    while val <= 0:  
        print(  
            "Not positive")  
        val = int(input())  
    return val
```



while Test Design

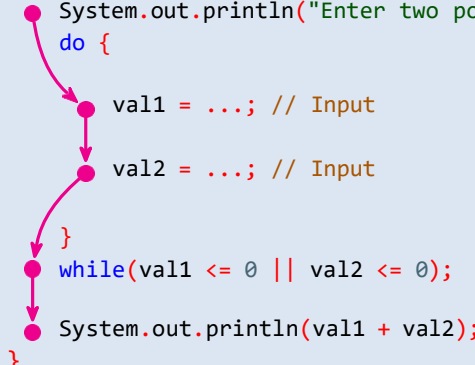
Path	Test Data	Expected Result
1. Enter loop	input: "-5\n10"	val = 10, output: "Not positive"
2. Skip loop	input: "5"	val = 5, output: ""

We have to use simulated input and captured output as test data here.

do-while Paths

- ▶ **do-while** loops don't exist in Python, so this is just FYI.
- ▶ 1st path (no iteration):

```
void userAdd() {  
    int val1, val2;  
    System.out.println("Enter two positive numbers");  
    do {  
        val1 = ...; // Input  
        val2 = ...; // Input  
    }  
    while(val1 <= 0 || val2 <= 0);  
    System.out.println(val1 + val2);  
}
```



The flowchart illustrates the execution of the `userAdd()` function. It starts at the `System.out.println("Enter two positive numbers");` line, indicated by a red dot. A red arrow points down to another red dot at the start of the `do` block. From there, the path continues down through `val1 = ...; // Input` and `val2 = ...; // Input`, each marked with a red dot. The path then reaches the closing brace of the `do` block, marked with a red dot. A red arrow points down to a red dot at the start of the `while` loop condition `while(val1 <= 0 || val2 <= 0);`. From there, the path continues down to a red dot at the `System.out.println(val1 + val2);` line, and finally to a red dot at the closing brace of the function `}`. The `while` loop condition is not reached in this specific path.

do-while Paths

- ▶ `do-while` loops don't exist in Python, so this is just FYI.
- ▶ 2nd path (some iteration):

```
void userAdd() {  
    int val1, val2;  
    System.out.println("Enter two positive numbers");  
    do {  
        val1 = ...; // Input  
        val2 = ...; // Input  
    }  
    while(val1 <= 0 || val2 <= 0);  
    System.out.println(val1 + val2);  
}
```

Java

try-catch/except Paths

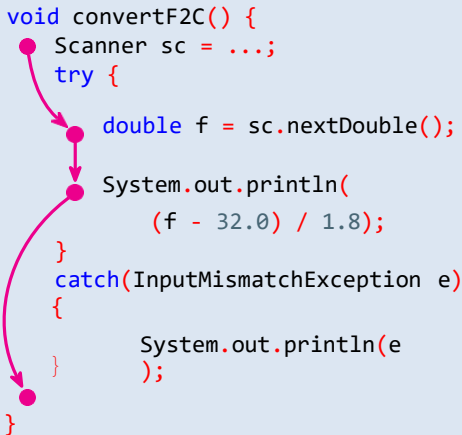
- ▶ This construct is intended for exception handling.
 - ▶ Java has a `try-catch` statement.
 - ▶ Python has a `try-except` statement.
 - ▶ Same thing (but the names of exceptions are different).
- ▶ You'd have one path for "success", where no exception occurs.
- ▶ You'd have one additional path for each `catch/except` clause.
 - ▶ i.e., for each different kind of exception that you're handling.

try-catch/except Paths

1st path (success):

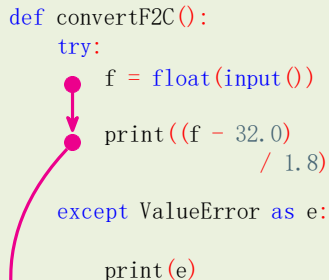


```
void convertF2C() {  
    Scanner sc = ...;  
    try {  
        double f = sc.nextDouble();  
        System.out.println(  
            (f - 32.0) / 1.8);  
    }  
    catch(InputMismatchException e)  
    {  
        System.out.println(e  
            );  
    }  
}
```



A flow diagram for the Java code. It starts at a pink dot at the beginning of the try block, goes down to a pink dot at the end of the try block, then curves around to a pink dot at the end of the catch block, and finally goes down to a pink dot at the end of the method.

```
def convertF2C():  
    try:  
        f = float(input())  
        print((f - 32.0)  
              / 1.8)  
    except ValueError as e:  
        print(e)
```



A flow diagram for the Python code. It starts at a pink dot at the beginning of the try block, goes down to a pink dot at the end of the try block, then curves around to a pink dot at the end of the except block, and finally goes down to a pink dot at the end of the function.

try-catch/except Paths

2nd path (invalid, non-numerical input):



```
void convertF2C() {  
    Scanner sc = ...;  
    try {  
        double f = sc.nextDouble();  
        System.out.println(  
            (f - 32.0) / 1.8);  
    }  
    catch (InputMismatchException e)  
    {  
        System.out.println(e  
            );  
    }  
}
```

```
graph TD; A(( )) --> B(( )); B --> C(( )); C --> D(( )); D --> E(( ))
```

```
def convertF2C():  
    try:  
        f = float(input())  
        print((f - 32.0)  
              / 1.8)  
    except ValueError as e:  
        print(e)
```

```
graph TD; A(( )) --> B(( )); B --> C(( )); C --> D(( ))
```



Other Control Statements and Combinations

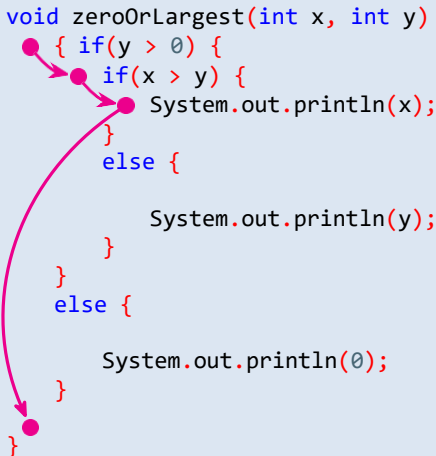
- ▶ `for` loops are like specialised `while` loops.
- ▶ `if-else-if-...-else` sequences create several paths.
 - ▶ Two paths for the first `if`.
 - ▶ One additional path for each additional `else-if/elif`.
- ▶ `switch` statements (in Java) create several paths.
 - ▶ One for each case, plus one for the default (even if the default is not specified).
 - ▶ These do not exist in Python.
- ▶ Everything can occur in combinations.
 - ▶ Think about control constructs as *splitting* one path into two (or more).
 - ▶ A single `if` gives you two paths.
 - ▶ *Another* nested `if` will split one of paths into *two more* paths, giving you three.

Nested ifs

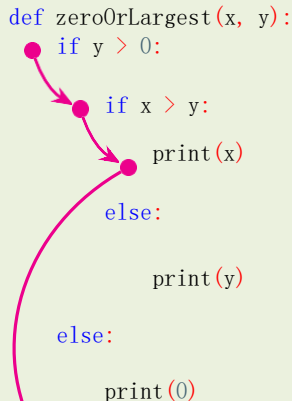
1st path:



```
void zeroOrLargest(int x, int y)
{
    if(y > 0) {
        if(x > y) {
            System.out.println(x);
        }
        else {
            System.out.println(y);
        }
    }
    else {
        System.out.println(0);
    }
}
```



```
def zeroOrLargest(x, y):
    if y > 0:
        if x > y:
            print(x)
        else:
            print(y)
    else:
        print(0)
```

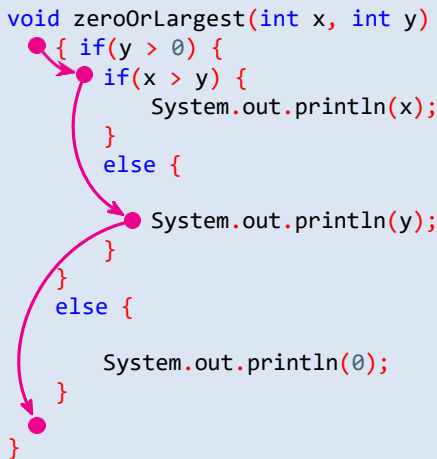


Nested ifs

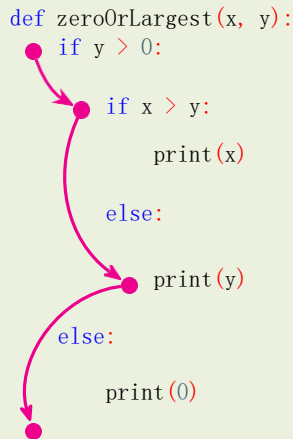
2nd path:



```
void zeroOrLargest(int x, int y)
{
    if(y > 0) {
        if(x > y) {
            System.out.println(x);
        }
        else {
            System.out.println(y);
        }
    }
    else {
        System.out.println(0);
    }
}
```



```
def zeroOrLargest(x, y):
    if y > 0:
        if x > y:
            print(x)
        else:
            print(y)
    else:
        print(0)
```




Nested ifs


3rd path:



```
void zeroOrLargest(int x, int y) {  
    if(y > 0) {  
        if(x > y) {  
            System.out.println(x);  
        }  
        else {  
            System.out.println(y);  
        }  
    }  
    else {  
        System.out.println(0);  
    }  
}
```



```
def zeroOrLargest(x, y):  
    if y > 0:  
        if x > y:  
            print(x)  
        else:  
            print(y)  
    else:  
        print(0)
```



Nested ifs Test Design

Path	Test Data	Expected Result
1. Enter both if parts	$y = 5, x = 10$	output: "10"
2. Enter inner else part	$y = 5, x = 2$	output: "5"
3. Enter outer else part	$y = -5$	output: "0"

- ▶ Notice that we've omitted x in the 3rd test case.
 - ▶ We must provide *some* x value when calling `zeroOrLargest()`, but the value is irrelevant to the test design.
- ▶ In a *black box* design, we would have *four* test cases instead:
 1. $y > 0, x > y$ (equivalent to 1 above);
 2. $y > 0, x \leq y$ (equivalent to 2 above);
 3. $y \leq 0, x > y$;
 4. $y \leq 0, x \leq y$.

Black Box or White Box?

- ▶ Why choose one over the other?
- ▶ Number of paths (in white-box testing) may differ from the number of equivalence categories (in black-box testing).
- ▶ Black Box testing:
 - ▶ Test cases can be designed *before* the production code exists.
 - ▶ You can change algorithms without changing the test code.
- ▶ White Box testing:
 - ▶ You can better understand the different behaviours that the production code should have.
 - ▶ What decisions must the production code make?
 - ▶ In black-box testing, you take an educated guess.
 - ▶ In white-box testing, you can see the decisions.
 - ▶ Changes to production code usually mean changes to test code.
 - ▶ However, your test code may be more up-to-date as a result.

Summary

- ▶ Methods/functions can get data from different streams other than parameter values, such as user input via keyboard, file input etc.
- ▶ Similarly, output also can be directed to screen or saved to text files instead of returning a value as the result of the function/method.
- ▶ Test code need to simulate such inputs and capture such outputs to assert the outcomes of the production code with different input/output streams
- ▶ Exceptions in production code may mean that some expected error has occurred and it means the code is working correctly. Therefore, if no exception is raised , then the test code needs to consider that as a failed test.
- ▶ Simulated test inputs and output capturing methods needs to be set -up before calling the production code. After the test code is run, set-up code needs to be tear-down. Test fixture is the term used for this process.
- ▶ In white-box testing, we go through the code , identify different paths through the code and design test cases. *If, if-else, while* , nested *if statements* etc. can be effectively tested with white box approach.

That's all for now!

We will have Testing A and Testing B worksheets sign-off
this week

This week's practical : Modularity

Next week

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Lecture : Ethics and Professionalism

Sign-off : Modularity

Practical : Test Fixtures and White-box testing