Joint Degree Program of Fudan University and University College Dublin (UCD)

SOFT620020.02

Advanced Software Engineering

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Course Structure

- In-Class Teaching and **Discussion** (Every Monday 11-13)
- No After-Class Assignments

- Discussion (30%): a range of topics
- Survey or New Ideas Presentation (30%): 13 + 2 minutes
- Survey or New Ideas Paper (40%): **Jan. 11, 2019**
  - **3 pages in English**
  - **Use Latex** (a template will be provided at the website **https://chenbihuan.github.io/course/ase/**)

Course Outline

Date	Topic	Date	Topic
Sep. 10	Introduction	Nov. 05	Compiler Testing
Sep. 17	**Testing Overview**	Nov. 12	Mobile Testing
Sep. 24	Holiday	Nov. 19	Bug Prediction
Oct. 01	Holiday	Nov. 26	Bug Localization
Oct. 08	Guided Random Testing	Dec. 03	Delta Debugging
Oct. 15	Search-Based Testing	Dec. 10	Automatic Repair
Oct. 22	Performance Analysis	Dec. 17	Symbolic Execution
Oct. 29	Security Testing	Dec. 24	Presentation

Why Software Testing is Needed?

Railway Traffic Accident at Yong Wen Line
Two trains crashed and 40 people died.

ATM Machine Accident in Guangzhou
Only 1 RMB was deducted from the account after withdrawing 1000 RMB from the ATM.

Discussion 1 – Software Accidents

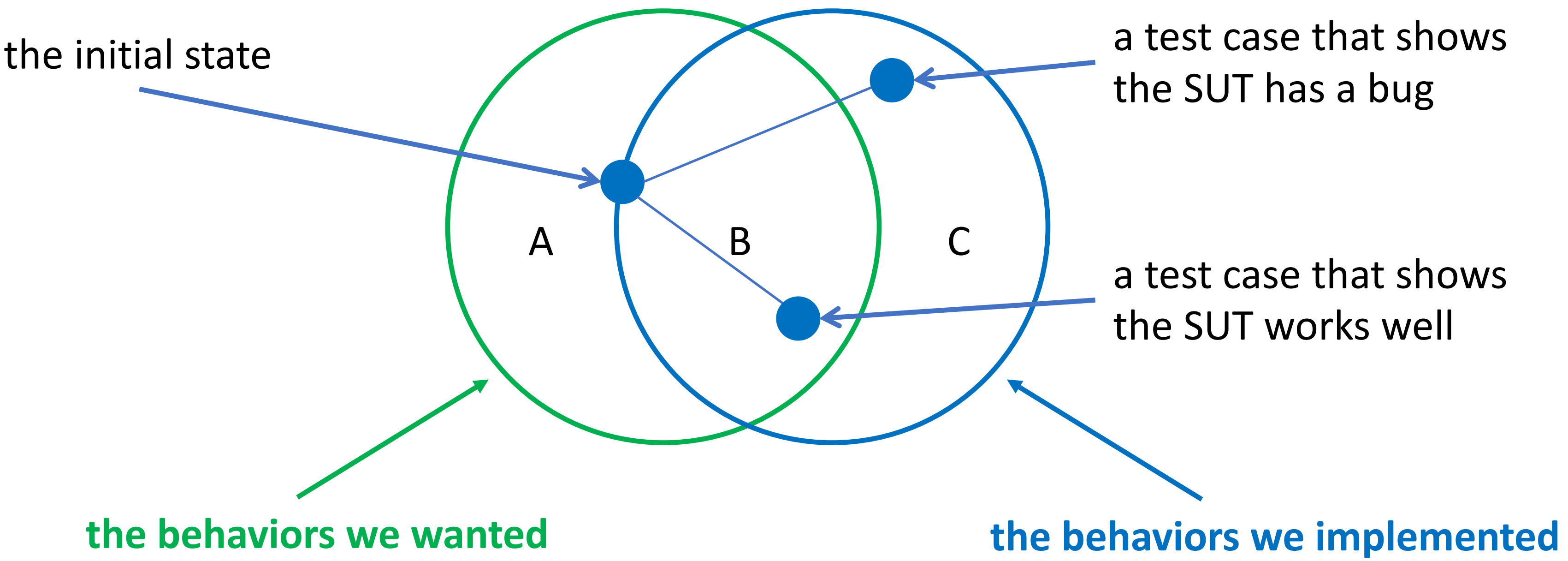
Do you know any accident that was caused by software defects?

- The ticketing system of the Olympic Game in 2008 suffered a performance degradation and was offline.

The ticketing center made an apology to the public.

Software Testing

- Testing is a verification and validation process that executes a **system under test** (SUT) with a set of **test cases** to decide whether the SUT works **correctly** or **unexpectedly**
  - Verification: are we building the system right?
  - Validation: are we building the right system?



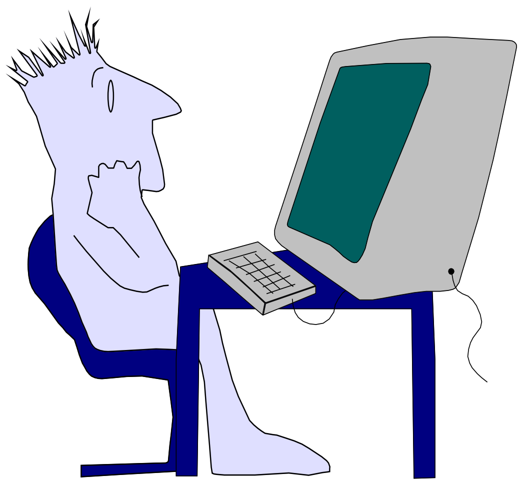
Discussion 2 – Let's Warm Up

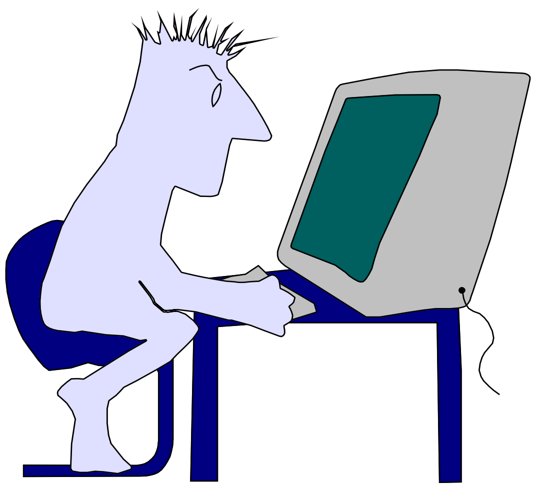
Write test cases that can respectively trigger the desired and unexpected behaviors.

```
public int divide (int a, int b) {
    return a/b;
}
```

- Test case for the desired behaviour: **a = 8, b = 2**
- Test case for the unexpected behaviour: **a = 8, b = 0**

Who Tests the System?





Developers

- understand the system
- but will test "gently”
- and are driven by “delivery”

Independent Testers

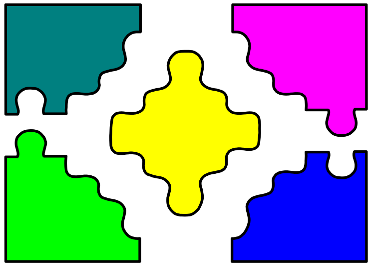
- must learn about the system
- but will attempt to break it
- and are driven by “quality”

Discussion 3 – Testing Classification

- What are the kinds of testing you know?
- Can you try to classify them?

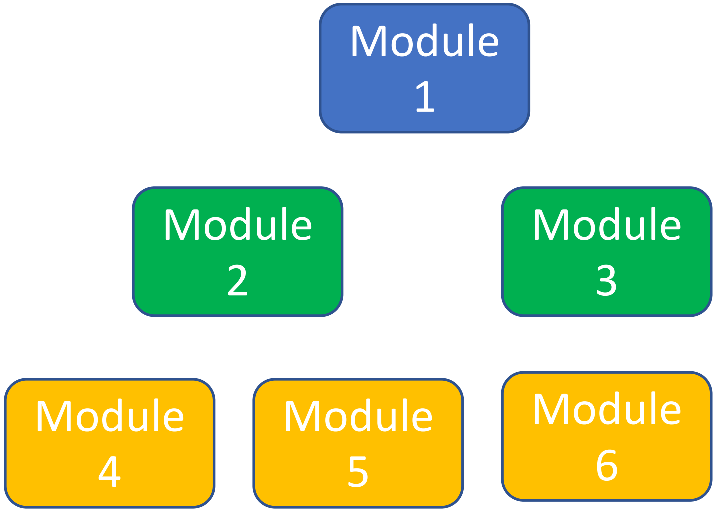
- By the **component level of the SUT**: unit, integration, and system testing
- By the **knowledge of the SUT**: black-box, white-box, and grey-box testing
- By the **object of testing**: functional, **security**, usability, **performance**, compatibility testing, etc.
- By the **type of the SUT**: **mobile**, protocol, **compiler**, smart contract, web testing, etc.
- ……

Unit Testing



- Test individual units/components/modules of a system
  - A unit is often an entire **interface**, but can be an individual **method**
  - Ensure the correctness of a unit, or find bugs in a unit

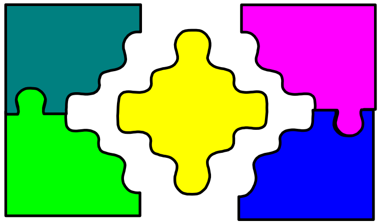
- Advantages
  - Find problems early
  - Facilitate changes
  - Simplify integration
  - Provide live documentation



Unit Testing (cont.)

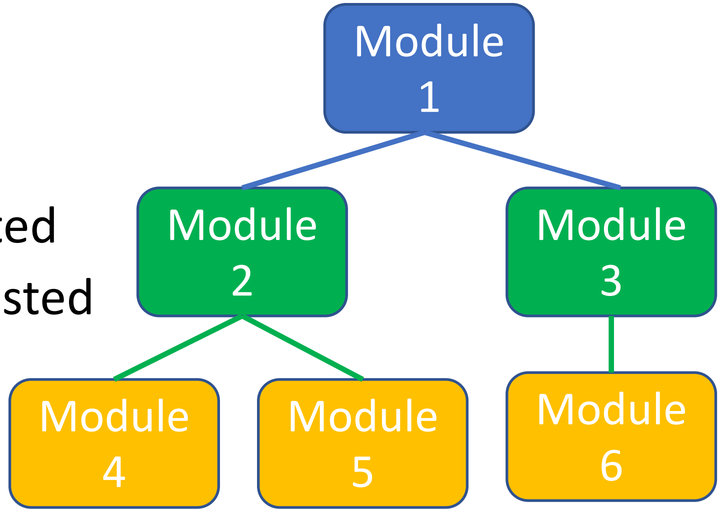
```
public class C1 {
    // assume that both a and b
    // are positive integers
    public int divide (int a, int b) {
        return a/b;
    }
}

@Test
public void testDivide() {
    C1 c1 = new C1();
    assert(c1.divide(8, 2) == 4);
}
```

Integration Testing



- Combine individual units/components/modules of a system, and test them as a group
  - Expose problems in the interface interactions among modules, often caused by **inconsistent assumptions** about interfaces

- Typical approaches
  - Big-bang: difficult to locate bugs
  - Top-Down: lower modules less tested
  - Bottom-Up: higher modules less tested



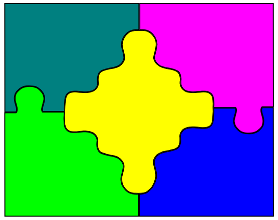
Integration Testing (cont.)

```java
public class C1 {
    // assume that both a and b
    // are positive integers
    public int divide (int a, int b) {
        return a/b;
    }
}
```

```java
public class C2 {
    // both a and b can be any integers
    public int calculate (int a, int b, int c) {
        C1 c1 = new C1();
        return c1.divide(a, b) * c;
    }
}
```

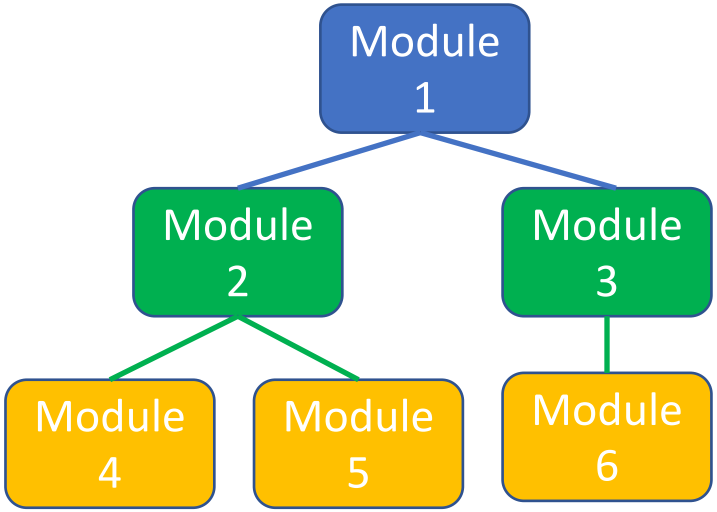
```java
@Test
public void testCalculate() {
    C2 c2 = new C2();
    assert(c2.calculate(8, 0, 0) == 0);
}
```

System Testing



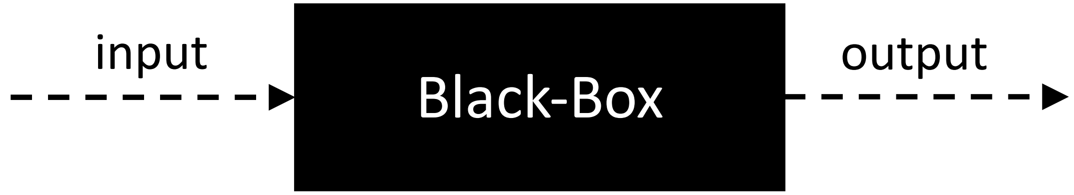
- Test a complete, integrated system to evaluate the system's compliance with its specified requirements

- Approaches
  - Functional testing
  - Security testing
  - Performance testing
  - ……



Black-Box Testing

- Test a system without any knowledge about the code and its internal structure
    - Testers are aware of what the system is supposed to do but are not aware of how it does it

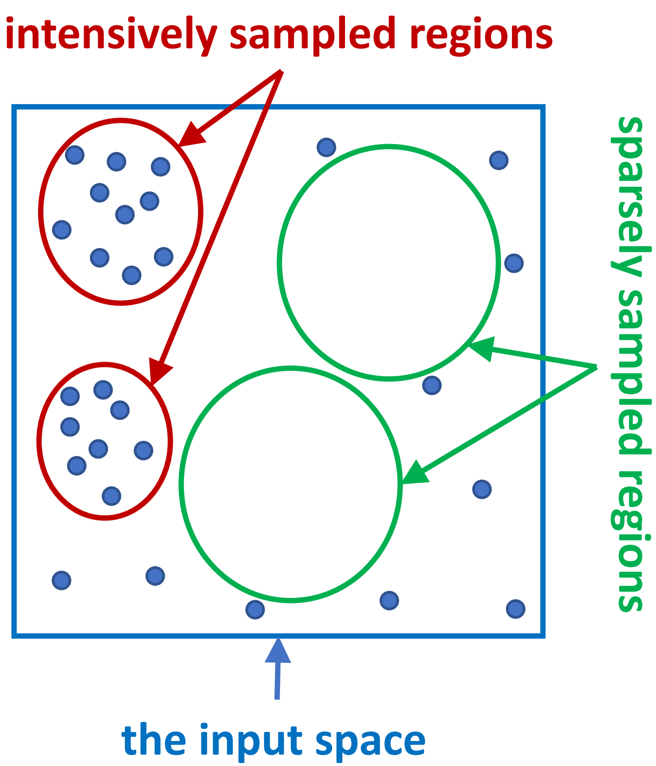


Discussion 4 – Triangle Problem

How do you generate black-box test cases for the triangle problem?

- The program reads **three positive integers** as inputs. These integers represent the lengths of the three sides of a triangle.
- The purpose of this program is to display a message which states whether the triangle is **scalene** (i.e., no two sides are equal), **isosceles** (i.e., two sides are equal) or **equilateral** (i.e., all three sides are equal).

Black-Box Testing – Random Testing



- Test a system by generating random, independent inputs
  - Efficient, and cheap to use
  - Ununiform sampling
  - Redundant test cases
  - Hard to cover corner cases

Black-Box Testing – Equivalence Partitioning

- Divide the input space of a system into partitions of (**valid** and **invalid**) equivalent classes according to the input conditions, and then derive test cases from the partitions

Input Condition	Valid Equivalent Classes	Invalid Equivalent Classes
Three sides are positive integers	(1) a > 0 (2) b > 0 (3) c > 0	(4) a <= 0 (5) b <= 0 (6) c <= 0
Scalene triangles	(7) a < b + c (8) b < a + c (9) c < a + b	(10) a >= b + c (11) b >= a + c (12) c >= a + b
Isosceles triangles	(13) a = b, a != c (14) a = c, a != b (15) b = c, b != a	
Equilateral triangles	(16) a = b = c	

Black-Box Testing – Equivalence Partitioning (cont.)

- Divide the input space of a system into partitions of (**valid** and **invalid**) equivalent classes according to the input conditions, and then derive test cases from the partitions

Test Input	Expected Output	Covered Equivalent Classes
a = 50, b = 60, c = 70	Scalene triangle	(1) (2) (3) (7) (8) (9)
a = 50, b = 50, c = 50	Equilateral triangle	(16)
a = 50, b = 50, c = 10	Isosceles triangle	(13)
a = 50, b = 10, c = 50	Isosceles triangle	(14)
a = 10, b = 50, c = 50	Isosceles triangle	(15)
a = 0, b = 0, c = 0	Invalid input	(4) (5) (6)
a = 80, b = 30, c = 40	Invalid input	(10)
a = 30, b = 80, c = 40	Invalid input	(11)
a = 30, b = 40, c = 80	Invalid input	(12)

Discussion 5 – Let’s Fight!

Compute the equivalent classes of the annual leave problem.

- The program takes the number of working years as an input.
- If the employee has worked for more than 1 year but less than 10 years, the annual leave is 5 days; if the employee has worked for more than 10 years but less than 20 years, the annual leave is 10 days; and if the employee has worked for more than 20 years, the annual leave is 15 days.

- Valid: (1) 0 <= year < 1, (2) 1 <= year < 10, (3) 10 <= year < 20, (4) year >= 20
- Invalid: (5) year < 0

White-Box Testing

- Test a system with full knowledge about the code and its internal structure (e.g., control flow, data flow, and paths)
  - Testers choose inputs to exercise paths through the code and determine the expected outputs

Discussion 6 – Credit Problem

How do you generate white-box test cases for the shopping credit problem? (hint: code coverage)

```
public int getShoppingCredit (double amount, boolean vip, int quantity) {
    int credit = 0;
    if (amount >= 200 && vip) {
        credit = (int) (amount * 0.1);
    }
    if (amount >= 400 || quantity > 10) {
        credit += 5;
    }
    return credit;
}
```

White-Box Testing – Coverage Testing

- **Statement coverage**: design a set of test cases that can execute each statement for at least once

amount = 350, vip = 1, quantity = 12; expected output: 40

```
public int getShoppingCredit (double amount, boolean vip, int quantity) {
    int credit = 0;
    if (amount >= 200 || vip) {
        credit = (int) (amount * 0.1);
    }
    if (amount >= 400 || quantity > 10) {
        credit += 5;
    }
    return credit;
}
```

the test case fails to detect this bug

White-Box Testing – Coverage Testing

- **Branch coverage**: design a set of test cases that can execute the true and false branch of each conditional for at least once

amount = 350, vip = 1, quantity = 12; expected output: 40

amount = 150, vip = 0, quantity = 7; expected output: 0

```
public int getShoppingCredit (double amount, boolean vip, int quantity) {
    int credit = 0;
    if (amount >= 200 && vip) {
        credit = (int) (amount * 0.1);
    }
    if (amount >= 400 || quantity > 8) {      the test case fails to detect this bug
        credit += 5;
    }
    return credit;
}
```

White-Box Testing – Coverage Testing

- **Path coverage**: design a set of test cases that can execute each program execution path for at least once

amount = 350, vip = 1, quantity = 12; expected output: 40
amount = 150, vip = 0, quantity = 7; expected output: 0
amount = 300, vip = 1, quantity = 7; expected output: 30
amount = 150, vip = 1, quantity = 12; expected output: 5

```
public int getShoppingCredit (double amount, boolean vip, int quantity) {
    int credit = 0;
    if (amount >= 200 && vip) {
        credit = (int) (amount * 0.1);
    }
    if (amount >= 400 || quantity > 10) {
        credit += 5;
    }
    return credit;
}
```

Discussion 7 – Let's Fight!

Write test cases that satisfy statement coverage, branch coverage and path coverage, respectively.

```
public int exercise(int a, int b, double c) {
    if (a > 0 && b > 0) {
        c = c / a;
    }
    if (a > 2 || c > 1) {
        c = c + 1;
    }
    return b + c;
}
```

White-Box Testing – Mutation Testing

- Mutate (change) certain statements in the source code to introduce potential bugs, and check whether the test cases are able to find the introduced bugs
- **Mutation operators**
  - Replace true with false; replace + with -, *, /; replace > with >=, ==, <=, <; ……
- **Mutant**
  - The program after applying the mutation operators
- **A test case kills a mutant**
  - The output of the original program is different from the output of the mutant after running a test case

White-Box Testing – Mutation Testing

The Original Program

```
public int getShoppingCredit (double
  amount, boolean vip, int quantity) {
    int credit = 0;
    if (amount >= 200 && vip) {
        credit = (int) (amount * 0.1);
    }
    if (amount >= 400 || quantity > 10) {
        credit += 5;
    }
    return credit;
}
```

The Mutant

```
public int getShoppingCredit (double
  amount, boolean vip, int quantity) {
    int credit = 0;
    if (amount >= 200 || vip) {
        credit = (int) (amount * 0.1);
    }
    if (amount >= 400 || quantity > 10) {
        credit += 5;
    }
    return credit;
}
```

The test case "amount = 350, vip = 1, quantity = 12" fails to kill the mutant

Discussion 8 – Let's fight!

Write a test case that can kill the mutant.

The Original Program

```
public int getShoppingCredit (double
  amount, boolean vip, int quantity) {
    int credit = 0;
    if (amount >= 200 && vip) {
        credit = (int) (amount * 0.1);
    }
    if (amount >= 400 || quantity > 10) {
        credit += 5;
    }
    return credit;
}
```

The Mutant

```
public int getShoppingCredit (double
  amount, boolean vip, int quantity) {
    int credit = 0;
    if (amount >= 200 || vip) {
        credit = (int) (amount * 0.1);
    }
    if (amount >= 400 || quantity > 10) {
        credit += 5;
    }
    return credit;
}
```

Grey-Box Testing

- Test a system with partial knowledge about the code and its internal structure

Challenges

- Theoretically, testing can never be complete
  - Tradeoff between completeness and cost
- Automatic test generation

Q&A?