COMP5111 – Fundamentals of Software Analysis

Overview of Software Testing

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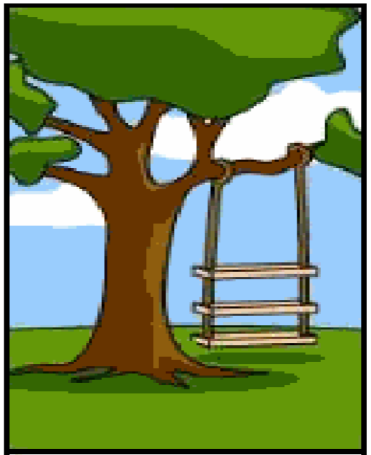
Computer Science & Engineering

HKUST



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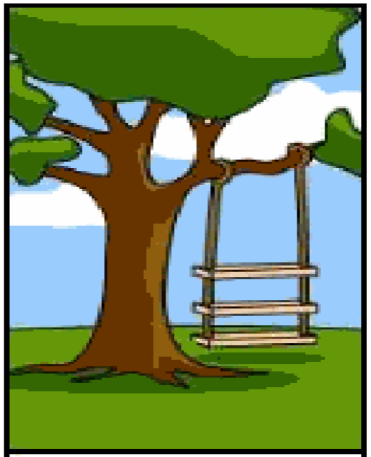

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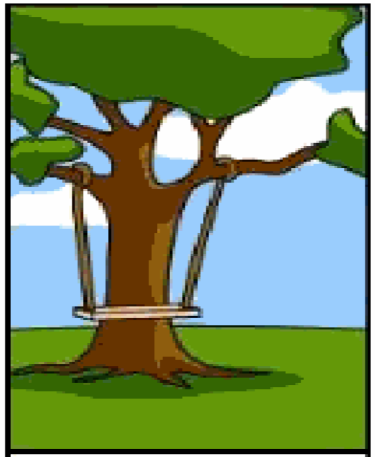

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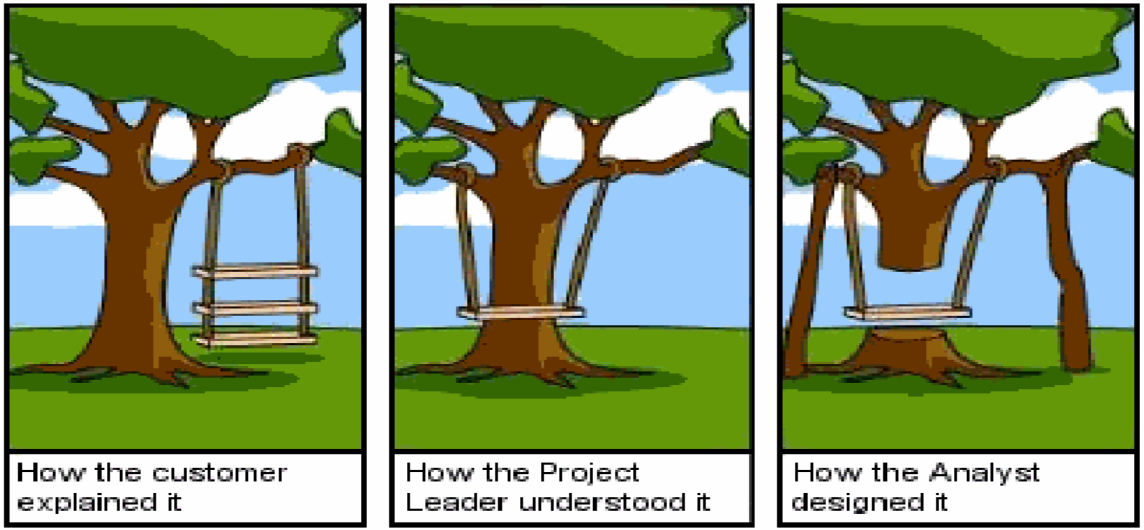
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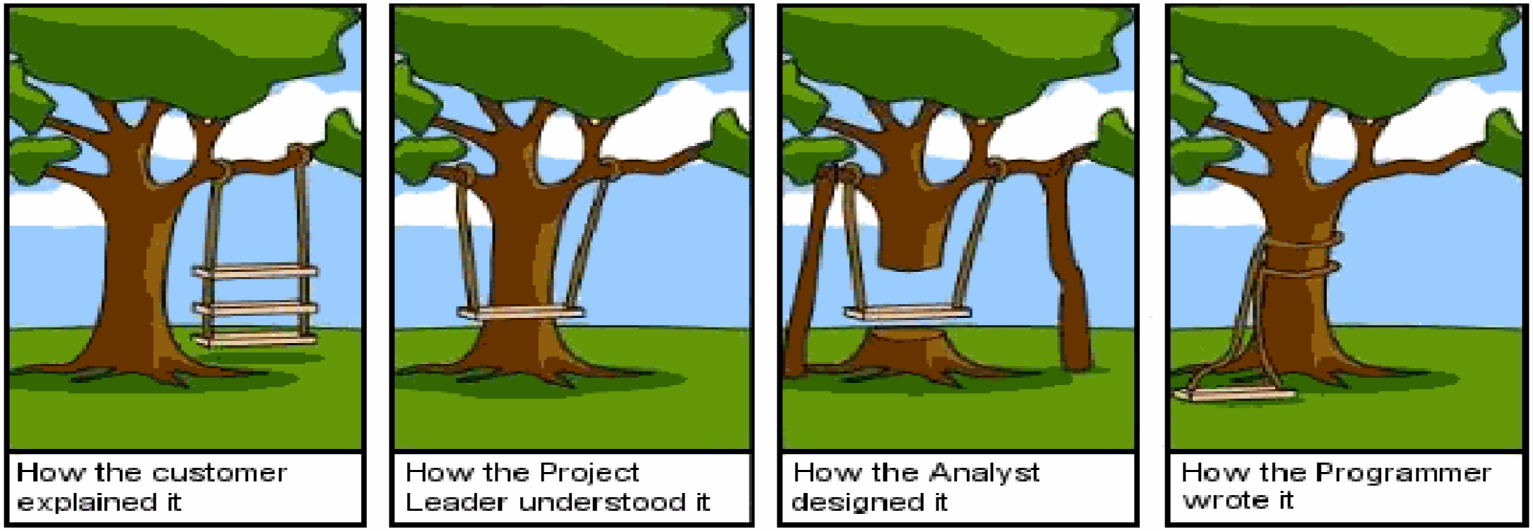
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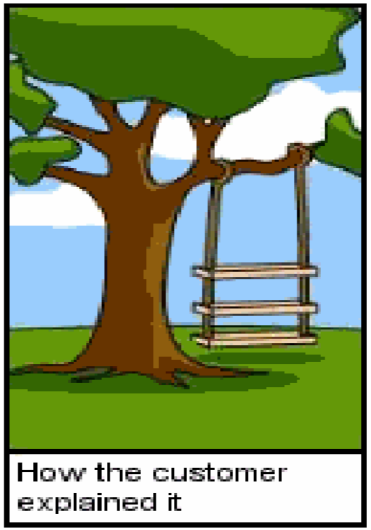
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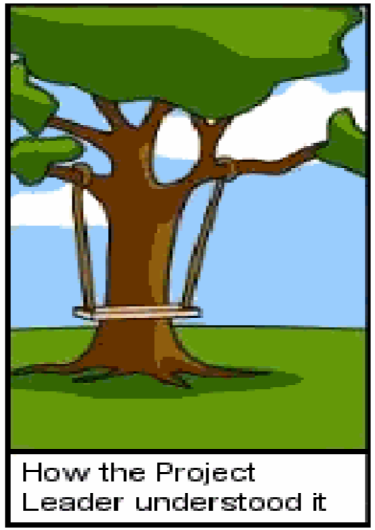
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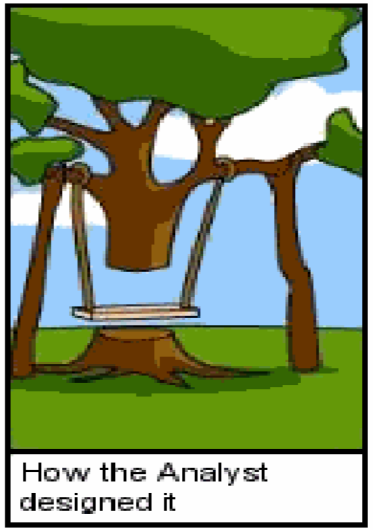
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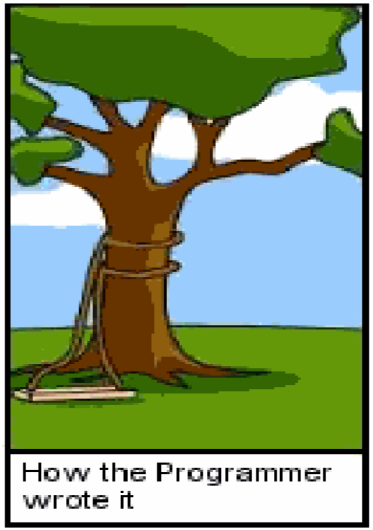
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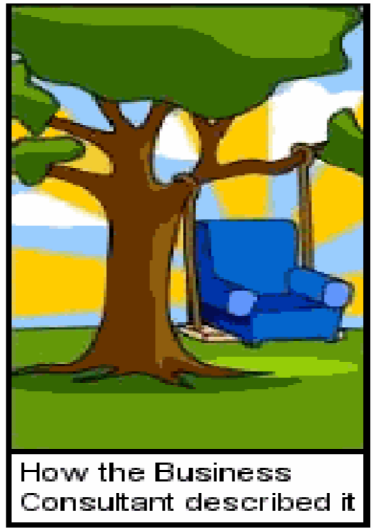
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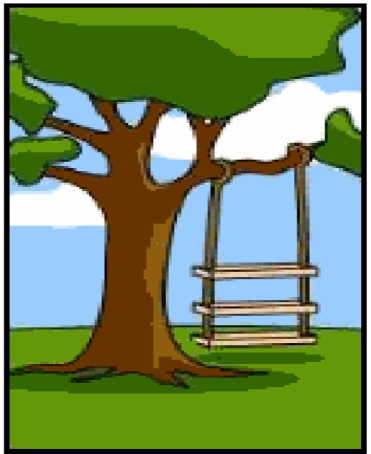

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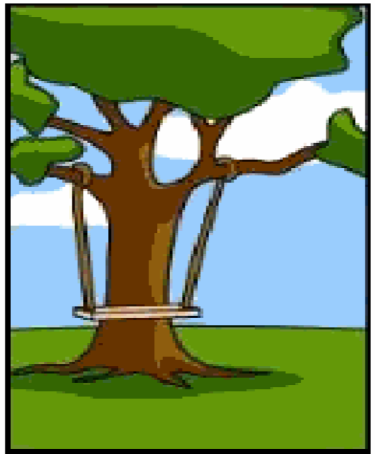

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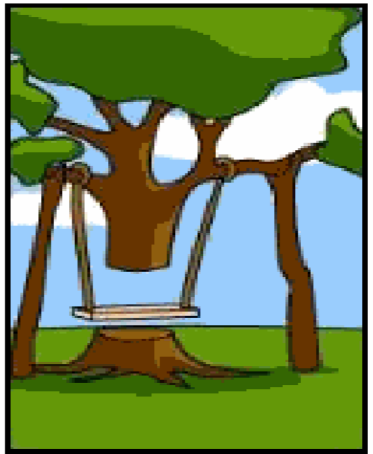

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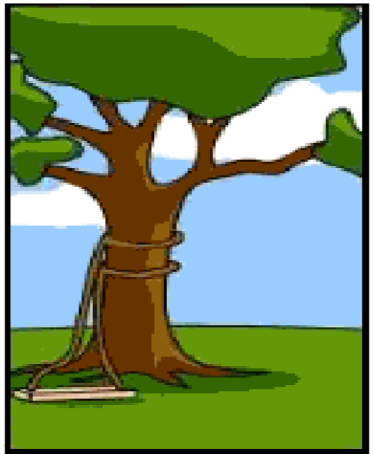

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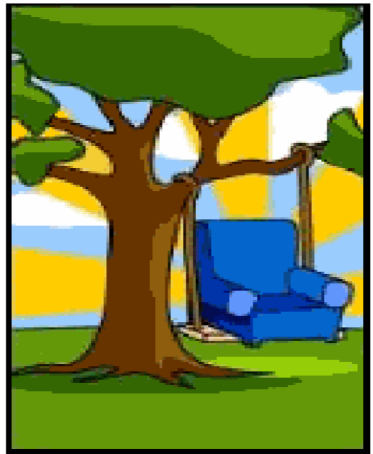

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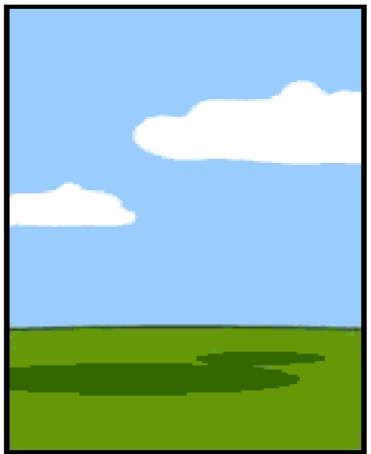

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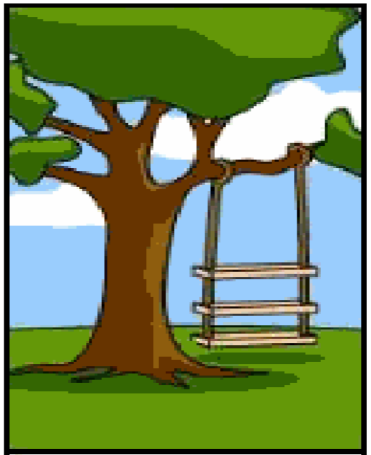

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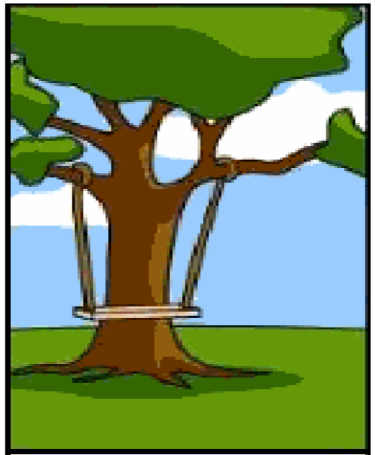

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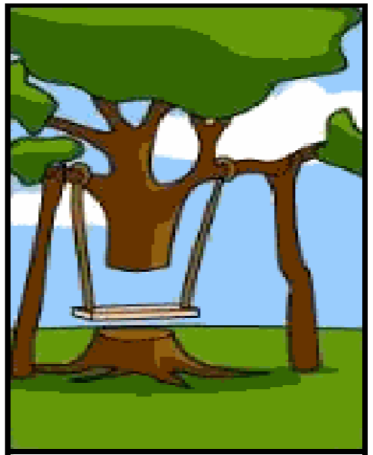

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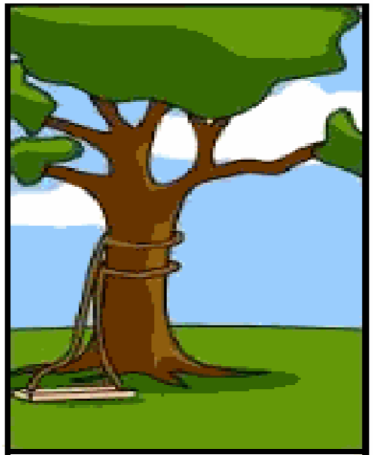

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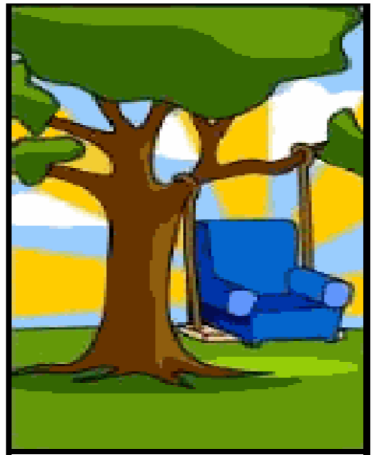

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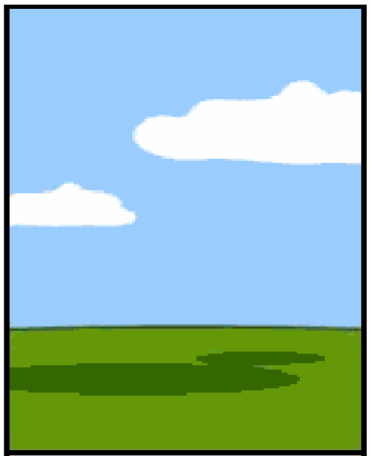

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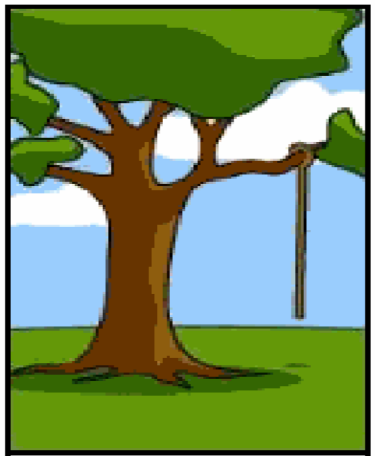

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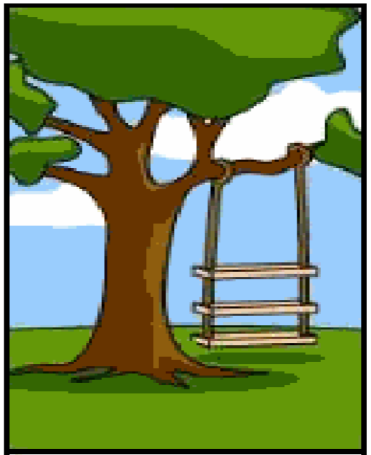

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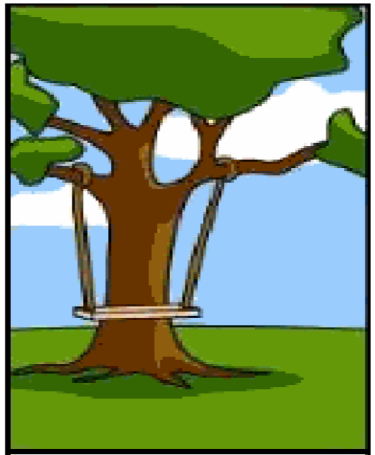

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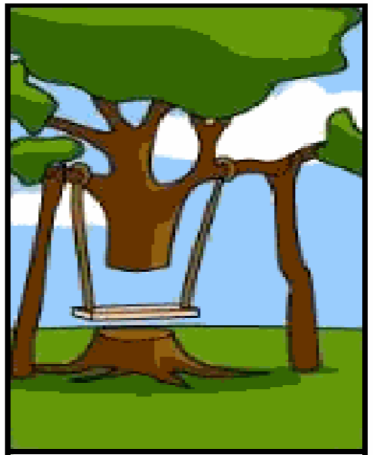

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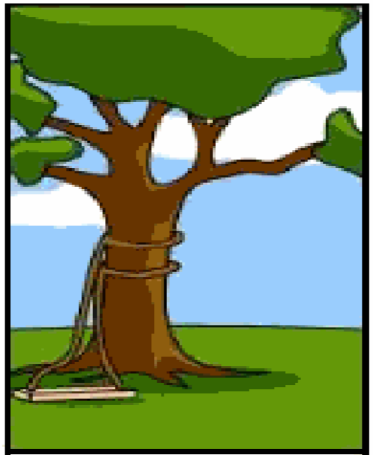

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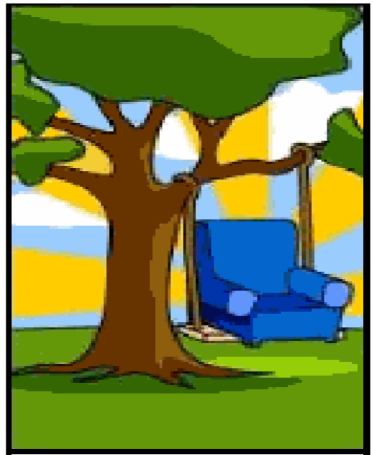

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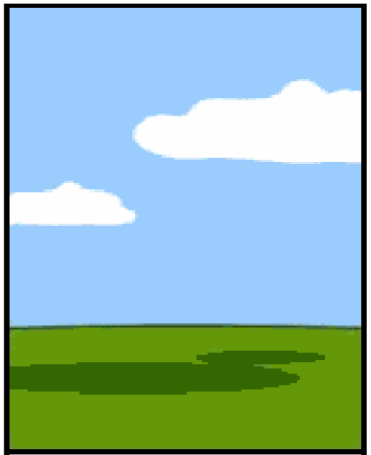

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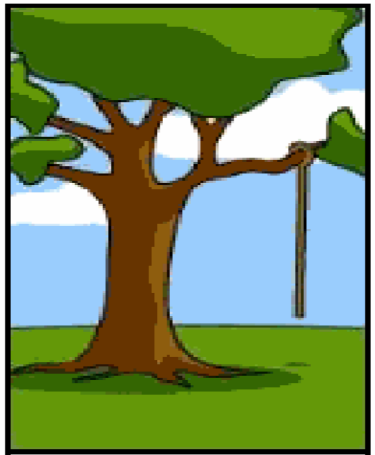

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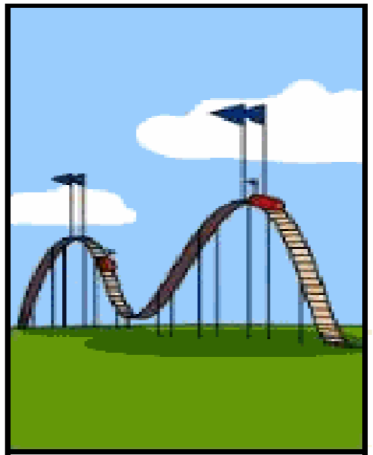

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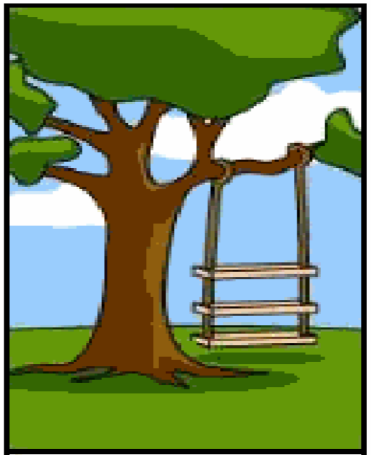

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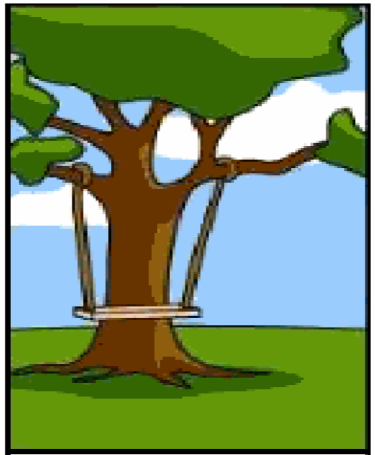

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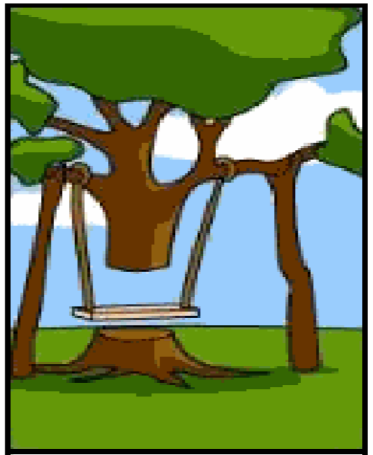

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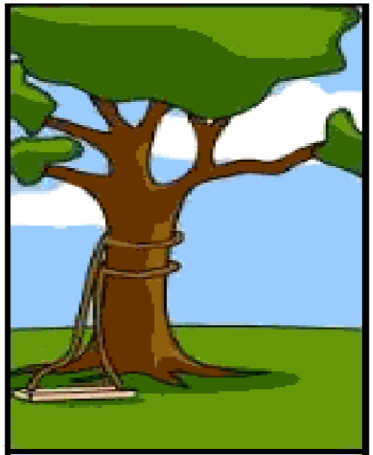

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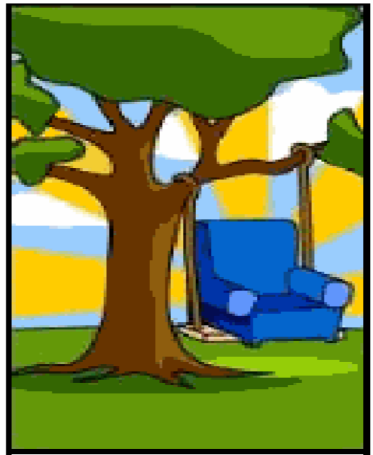

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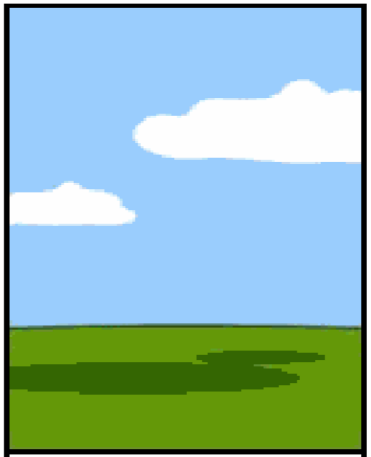

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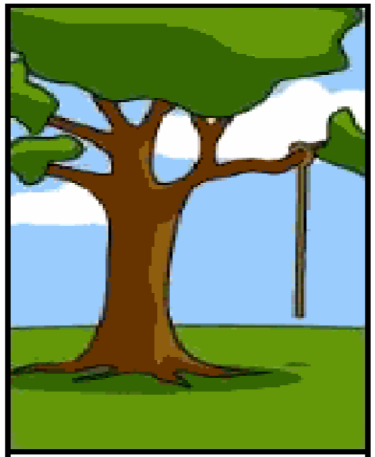

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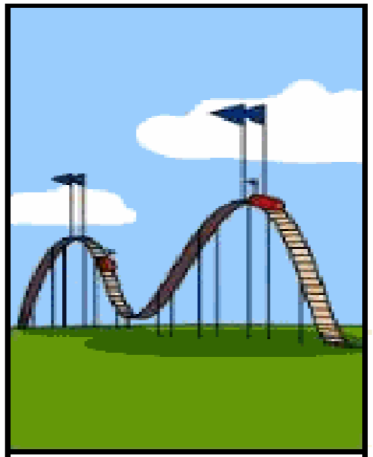

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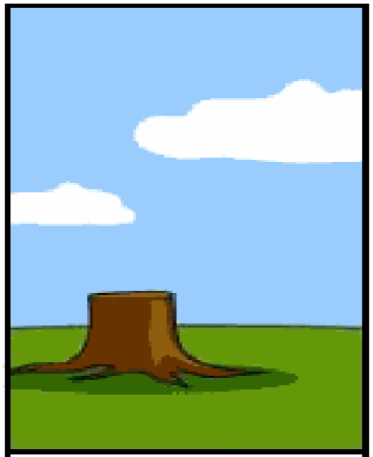

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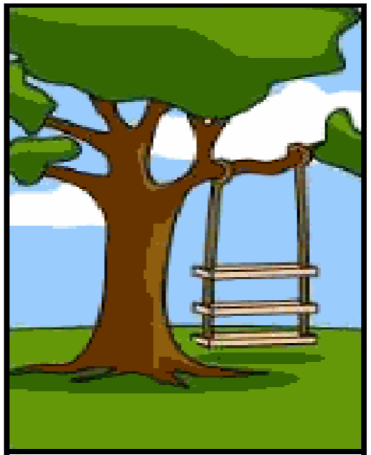

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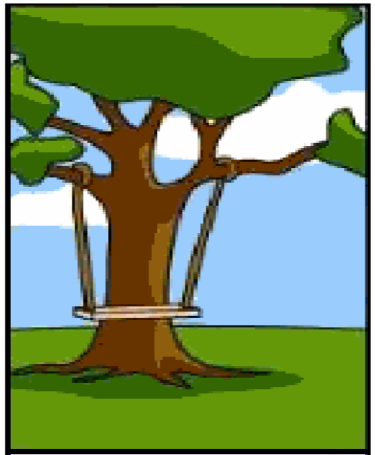

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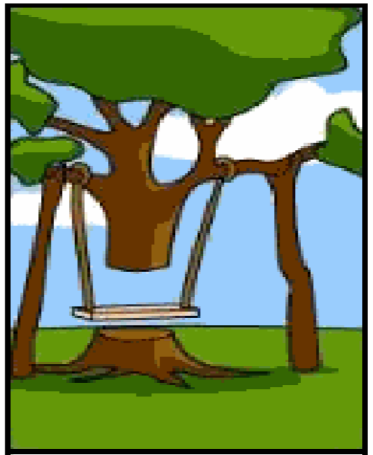

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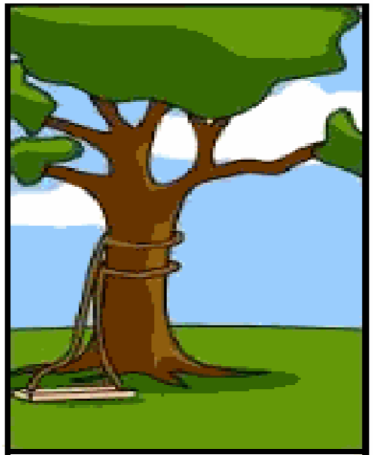

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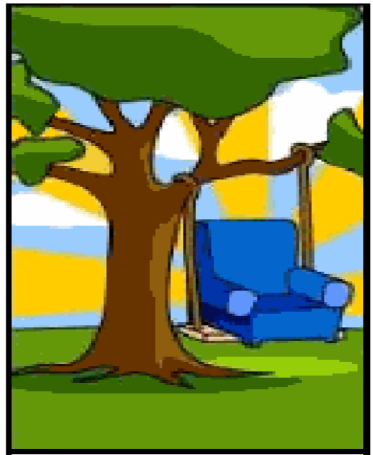

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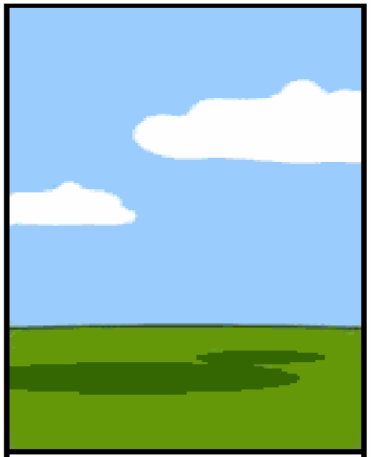

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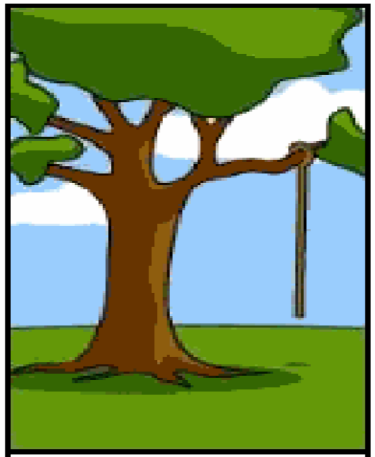

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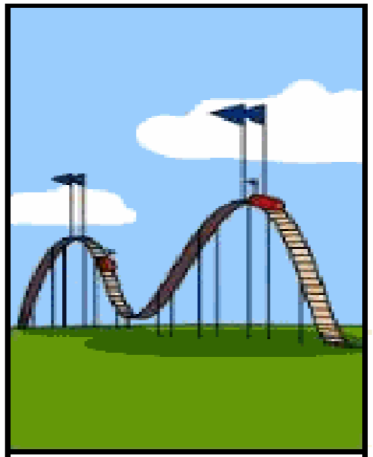

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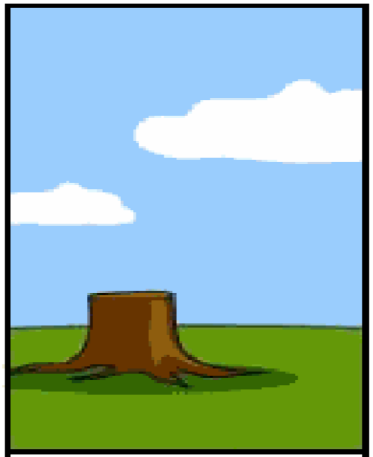

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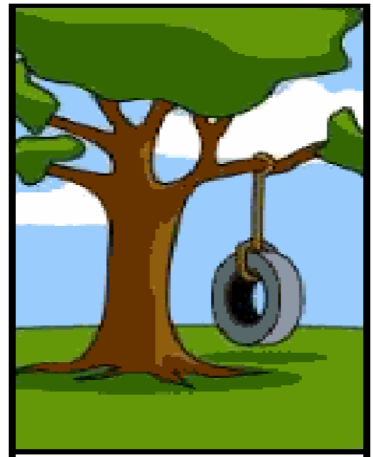
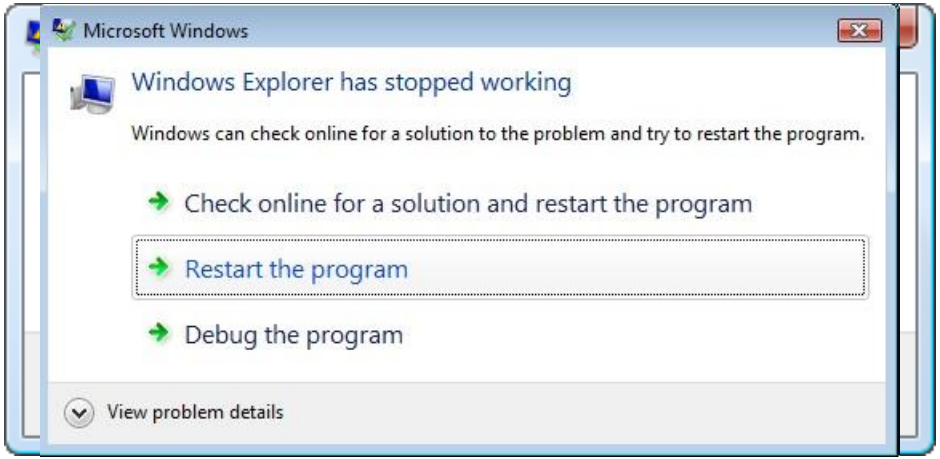
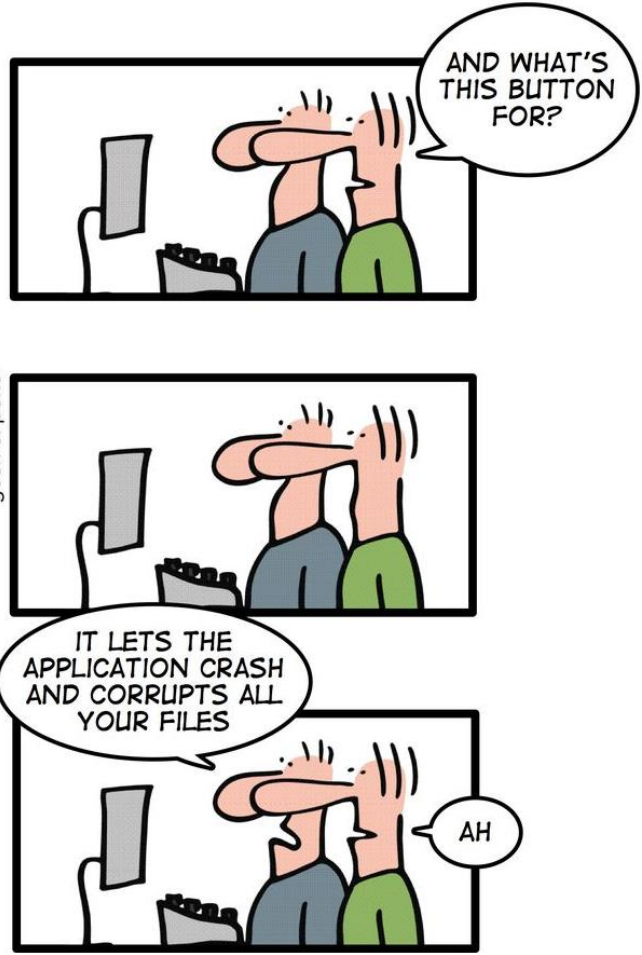


What the customer really needed

What is users' experience

- Sounds familiar when using Windows sometimes?





WE'VE GOTTEN USED TO IT

What? You want to test my code! Why? We haven't got time anyway.

1960s – 1980s
Constraint

OK, maybe you were right about testing. A nasty bug likely exists and customers are complaining.

1990s
Need

Testers! You must work harder! Longer! Faster!

2000+
Asset

Facts in Google as at 2011

- Principles
  - Quality must be owned by engineering
  - Test must be part of engineering
- 15,000 developers run 100+ million tests per day.
- 20+ code changes/minute
- 30K code commits per day (one every 3 seconds)

Software Testing - Facts

expensive

30-90% of development effort

	Cost of inadequate testing on US economy (billions)
developers	$21.2
users	$38.3
TOTAL	**$59.5**

source: NIST 2002

Recall: Lessons Learnt with FindBugs

- Static analysis, at best, might catch 5-10% of software quality problems
- Need to understand which types of bugs matter to your project
- Example: public static final field pointing to an array where anyone can change the content of the array
  - It is likely a big concern if your program run with other untrusted code in the same VM
  - Otherwise, it is likely a minor concern

Recall: Lessons Learnt with FindBugs

- High false positives
  - Only a small portion of warnings are real; most of them are false alarms.
  - Allow users to enable/disable the rules individually.
  - Focus on the new ones not found in the baseline

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difficult

complex software

› many behaviors to test

large input spaces

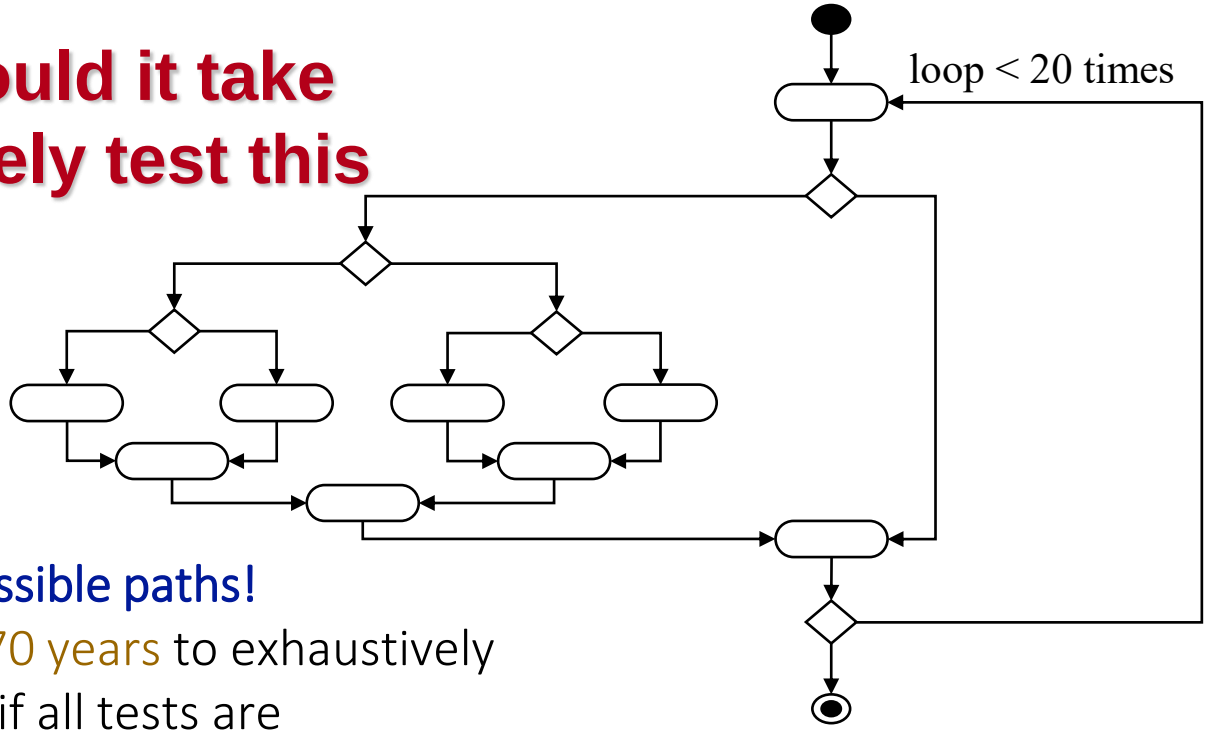
› selecting subset is hard

done mostly by hand

› at Microsoft, ½ of engineers

WHY is Testing Difficult?

How long would it take to exhaustively test this program?



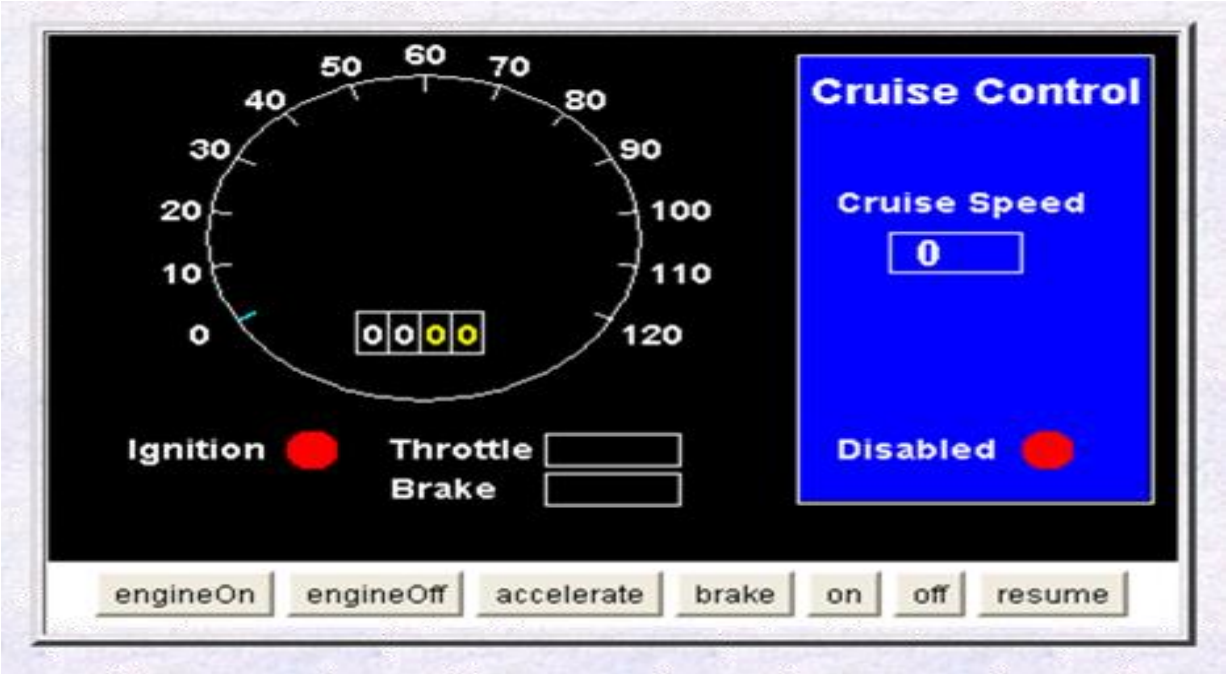
➔ There are 10^{14} possible paths!

It would take 3,170 years to exhaustively test the program if all tests are automated and each test requires 1 ms!!

Recall: Facts of real projects

- Eclipse is known for its high reliability
- Defect density of Eclipse 3.0
  - Scariest defects: 30 per million LOC
  - Scary: 160 per million LOC
  - Troubling: 480 per million LOC
  - Of concern: 6,000 per million LOC

Here! Try it out Yourself!



http://www.cse.ust/hk/~scc/CruiseWithBugs.zip

Software Testing - Facts

expensive

30-90% of development effort

	Cost of inadequate testing on US economy (billions)
developers	$21.2
users	$38.3
TOTAL	**$59.5**

source: NIST 2002

difficult

complex software

› many behaviors to test

large input spaces

› selecting subset is hard

done mostly by hand

› at Microsoft, ½ of engineers

goal: automation

automate test case creation

› a principal testing activity

› a significant portion of cost

Understanding Basic Terminologies

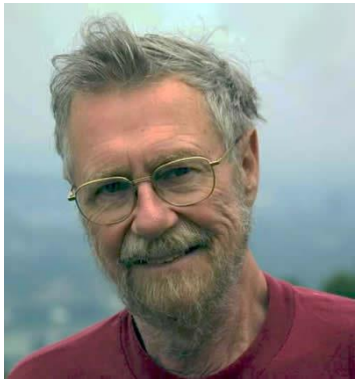
What is Testing?

Testing is the activity of finding out whether a piece of code (a method, class, or program) produces the intended behavior.

taken from “Objects First with Java”

Edsger Dijkstra (1930-2002):

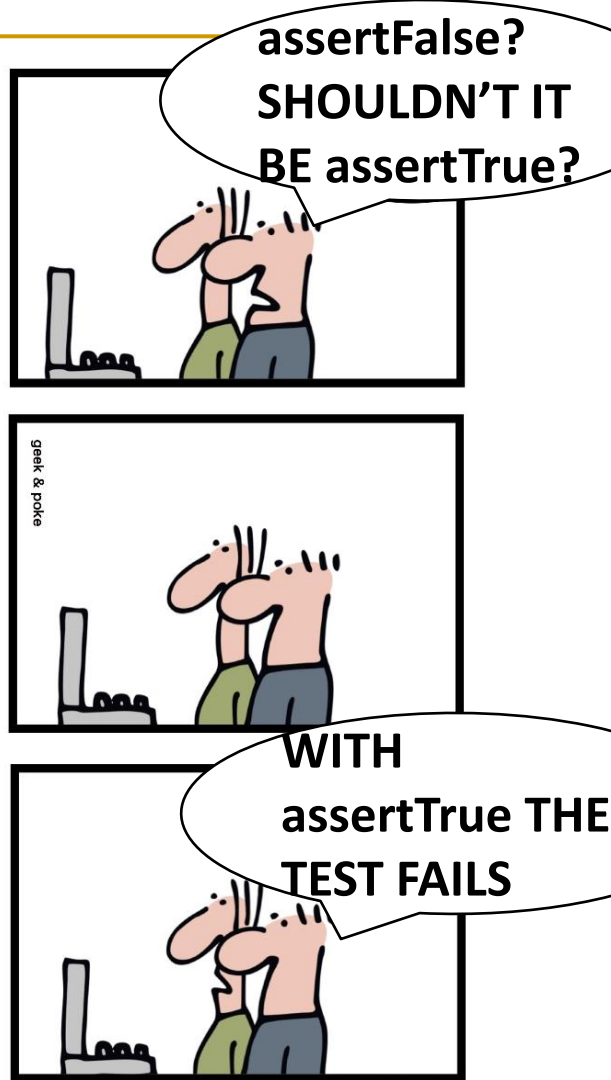
Program testing can be used to show the presence of bugs, but never to show their absence *unless …*



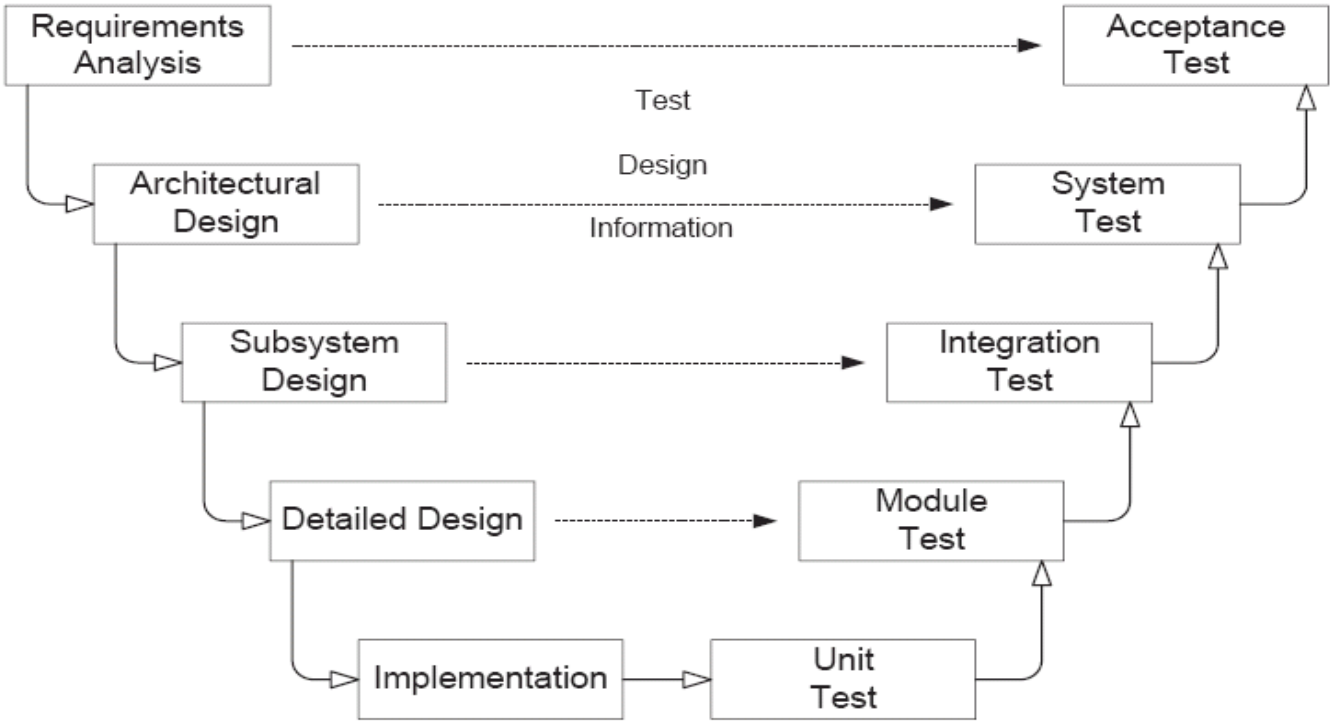
Received the ACM Turing Award at the age of 42 - the most prestigious computer science award

Tests should be designed to reveal execution failures

- not execution successes
- must be augmented with proper assertions



Software development activities and testing levels



Recall: Three Analysis Approaches

- Static Analysis: Validate without executing the program.
  - This include software inspections.
- Dynamic Analysis: Validate by executing the program with real inputs
  - Testing
- Repository Mining: Validate by the patterns/knowledge mined from various project repositories and forums

Software Faults, Errors & Failures

- Software Fault : A static defect in the software

Software faults are coding mistakes and hard to eliminate

- Software Error : An incorrect internal state that is the manifestation of some fault
- Software Failure : Observable incorrect behavior with respect to the requirements or other description of the expected behavior

Illustrative Example

```
public static int numZero (int[] x) {
// Effects: if x == null throw NullPointerException
// else return the number of occurrences of 0 in x
   int count = 0;
   for (int i = 1; i < x.length; i++) {
       if (x[i] == 0) {
             count++;
       }
   }
   return count;
}
```

Illustrative Example – Software Fault

```
public static int numZero (int[] x) {
// Effects: if x == null throw NullPointerException
// else return the number of occurrences of 0 in x
   int count = 0;
   for (int i = 1; i < x.length; i++) {
       if (x[i] == 0) {
             count++;
       }
   }
   return count;
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Illustrative Example – Software Error

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// Effects: if x == null throw NullPointerException
// else return the number of occurrences of 0 in x
   int count = 0;
   for (int i = 1; i < x.length; i++) {
       if (x[i] == 0) {
            count++;
       }
   }
   return count;
}
```

numZero([2, 7, 0])

Any failure occur?
Any error occur?

Illustrative Example – Software Error

```
public static int numZero (int[] x) {
// Effects: if x == null throw NullPointerException
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       if (x[i] == 0) {
             count++;
       }
   }
}
```

numZero([2, 7, 0])

Any failure occur?

Any error occur?

State error occurs at the first iteration where the state is (x=[2,7,0], count=0, i=1, PC=if). The correct state should be (x=[2,7,0], count=0, i=0, PC=if).

Illustrative Example – Software Error

```
public static int numZero (int[] x) {
// Effects: if x == null throw NullPointerException
// else return the number of occurrences of 0 in x
   int count = 0;
   for (int i = 1; i < x.length; i++) {
       if (x[i] == 0) {
             count++;
       }
   }
   return count;
}
```

numZero([0, 7, 2])

Any failure occur?
Any error occur?

Can you think of a program example and a test case that triggers a fault but causes no error and failure?

```
int square (int x) {
   int result = x + x;
   return result;
}
```

Test case: square(2)

Coincidental correctness occurs when a test triggers a fault but outputs a correct result.

Testing & Debugging

- Testing : Finding inputs that cause the software to fail

- Debugging : The process of finding a fault given a failure

Fault & Failure Model

Three conditions necessary for a failure to occur

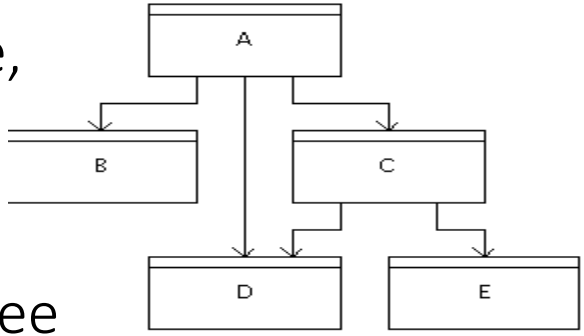
1. Reachability : The location or locations in the program that contain the fault must be reached
2. Infection : The state of the program must be incorrect
3. Propagation : The infected state must propagate to cause some output of the program to be incorrect

Test Case (=Test Case Values + Expected Results)

- Test Case Values (a.k.a. **test inputs**) : The input values necessary to complete the intended program execution of a test case.
- Expected Results : The result that will be produced when executing the test if the program satisfies its intended behavior.
- Test Set (or **test suite**) : A set of test cases.
- Test Script : A test case that is prepared in a form for automatic execution.

Top-Down and Bottom-Up Testing

- Top-Down Testing : Test the main procedure, then go down through procedures it calls



- Bottom-Up Testing : Test the leaves in the tree (procedures that make no calls) and move up to the root.
  - Each procedure is not tested until all of its children have been tested

White-box and Black-box Testing

- Black-box testing : Deriving tests from external descriptions of the software, including specifications, requirements, and design
- White-box testing : Deriving tests from the source code internals of the software, specifically including branches, individual conditions, and statements

A federal agency says an overreliance on Tesla's Autopilot contributed to a fatal crash

The National Transportation Safety Board met on Tuesday to determine the cause of May's fatal Tesla crash.

BY JOHANA BHUIYAN | @JMBOOYAH | SEP 12, 2017, 11:57AM EDT

TWEET SHARE LINKEDIN

The National Transportation Safety Board said that its investigation into a fatal Tesla crash showed that the limitations of the company's automated driver system, Autopilot, played a role in the May 2016 collision.

References

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  - https://vimeo.com/47959189
- Inheritance, polymorphism and testing (a video from Google Tech Talk)
  - http://www.youtube.com/watch?v=4F72VULWFvc&feature=relmfu
- Your tests aren't flaky (a video from Google Tech Talk)
  - https://www.youtube.com/watch?v=hmk1h40shaE