Lecture 18: Automated Testing

Automated testing
- JUnit and family

Testing GUI-based software

Testing Object-Oriented Systems

When to stop testing

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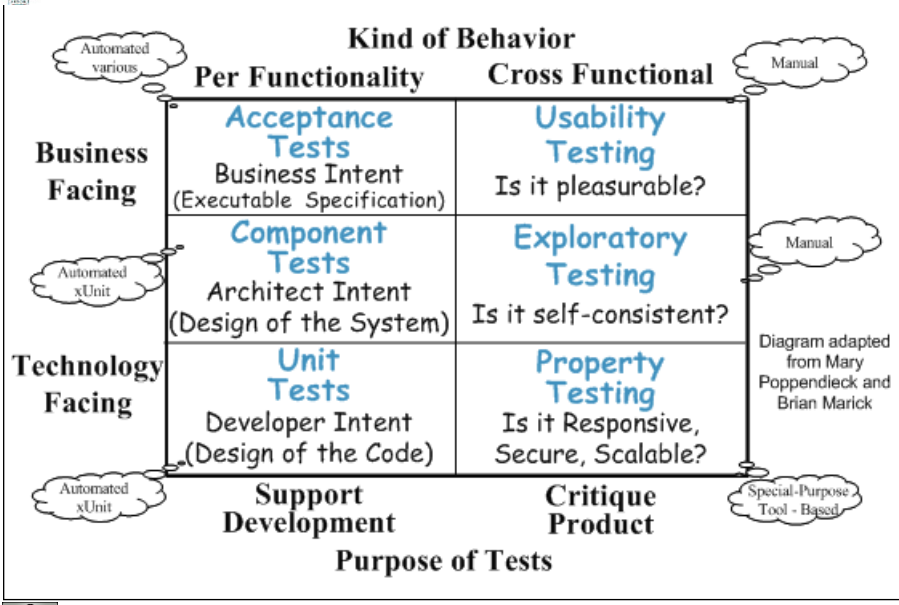

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Automated Testing

Source: Adapted from Liskov & Guttag, 2000, pp239-242

Where possible, automate your testing:

- tests can be repeated whenever the code is modified ("regression testing")
- takes the tedium out of extensive testing
- makes more extensive testing possible

Will need:

- test drivers - automate the process of running a test set
  - sets up the environment
  - makes a series of calls to the Unit-Under-Test (UUT)
  - saves results and checks they were right
  - generates a summary for the developers

May need:

- test stubs - simulate part of the program called by the unit-under-test
  - checks whether the UUT set up the environment correctly
  - checks whether the UUT passed sensible input parameters to the stub
  - passes back some return values to the UUT (according to the test case)
  - (stubs could be interactive - ask the user to supply return values)

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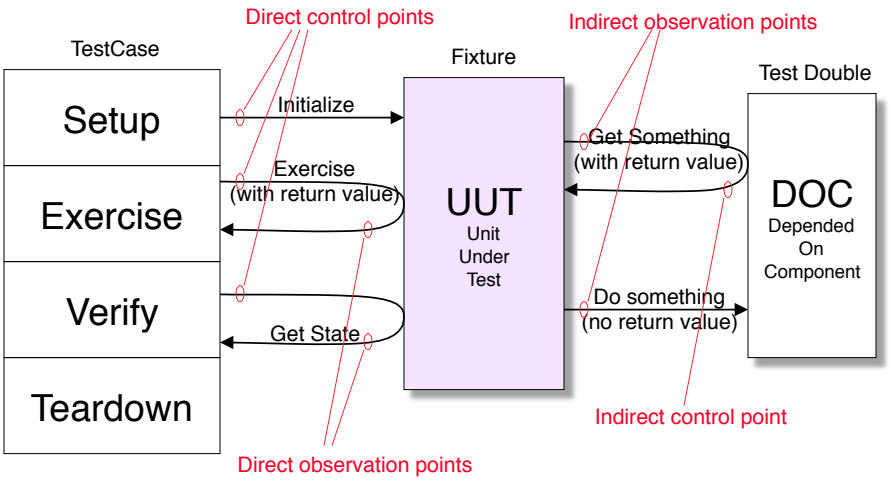
Automated Testing Strategy

Source: Adapted from Meszaros 2007, p66



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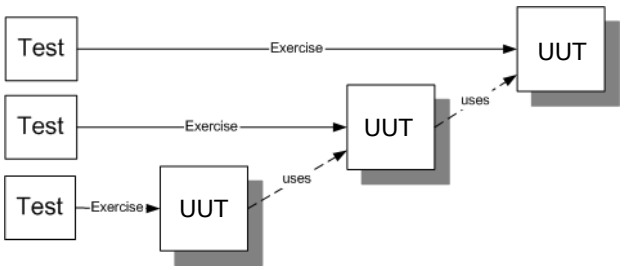
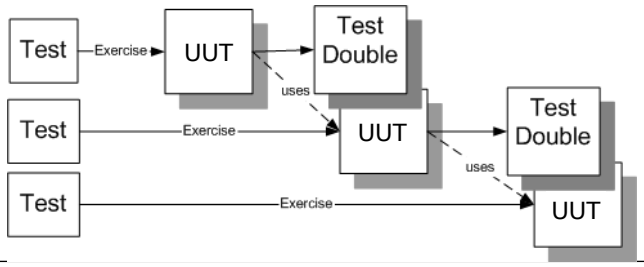
Test Order?

Source: *Adapted from Meszaros 2007, p35*

Inside Out



Outside In



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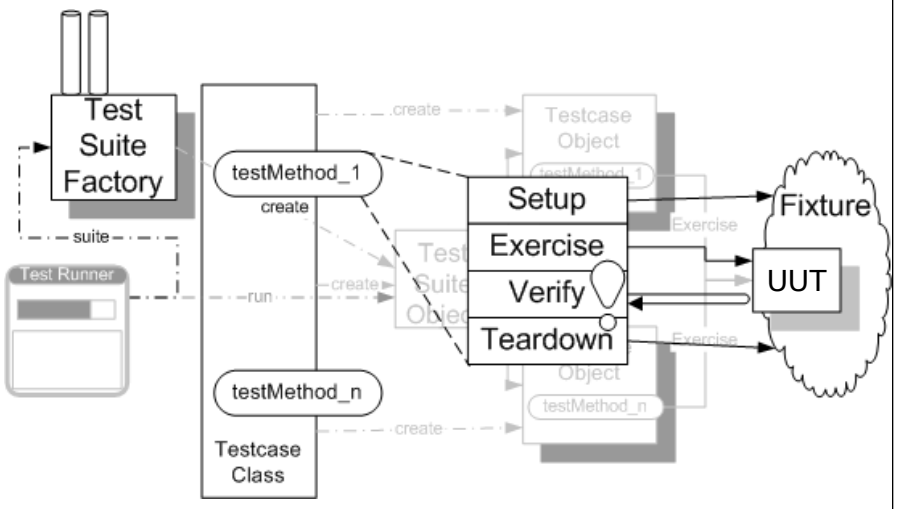
How JUnit works

Source: *Adapted from Meszaros 2007, p77*



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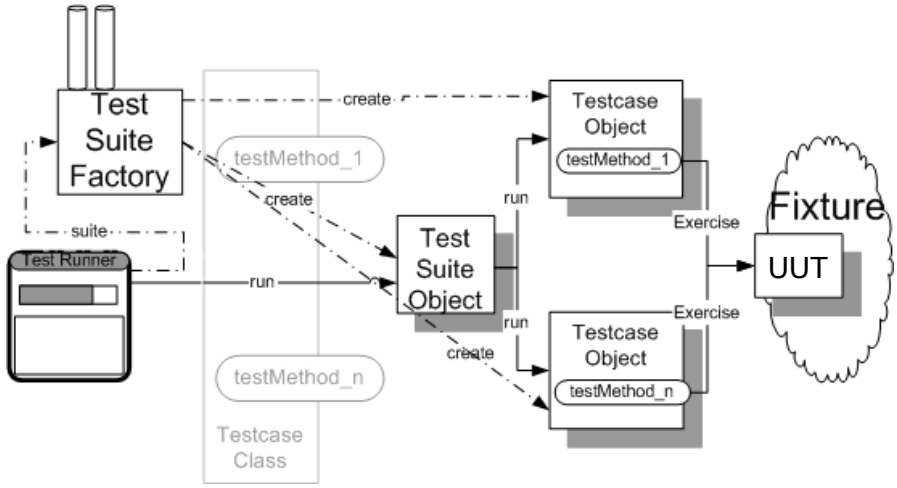
How JUnit works

Source: *Adapted from Meszaros 2007, p77*



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Assertion methods in JUnit

Source: *Adapted from Meszaros 2007, p365*

Single-Outcome Assertions

fail;

Stated Outcome Assertions

assertNotNull(anObjectReference);
assertTrue(booleanExpression)

Expected Exception Assertions

assert_raises(expectedError) {codeToExecute };

Equality Assertions

assertEqual(expected, actual);

Fuzzy Equality Assertions

assertEqual(expected, actual, tolerance);

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Principles of Automated Testing

Source: *Adapted from Meszaros 2007, p39-48*

Write the Test Cases First

Design for Testability

Use the Front Door First
- test via public interface
- avoid creating back door manipulation

Communicate Intent
- Tests as Documentation!
- Make it clear what each test does

Don't Modify the UUT
- avoid test doubles
- avoid test-specific subclasses
- (unless absolutely necessary)

Keep tests Independent
- Use fresh fixtures
- Avoid shared fixtures

Isolate the UUT

Minimize Test Overlap

Check One Condition Per Test

Test Concerns Separately

Minimize Untestable code
- e.g. GUI components
- e.g. multi-threaded code
- etc

Keep test logic out of production code
- No test hooks!

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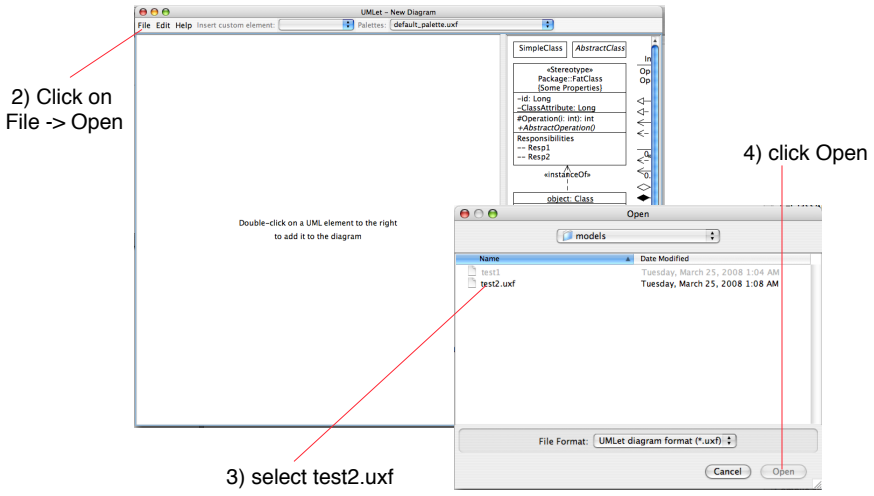
Testing interactive software

1) Start the application (e.g. UMLet)



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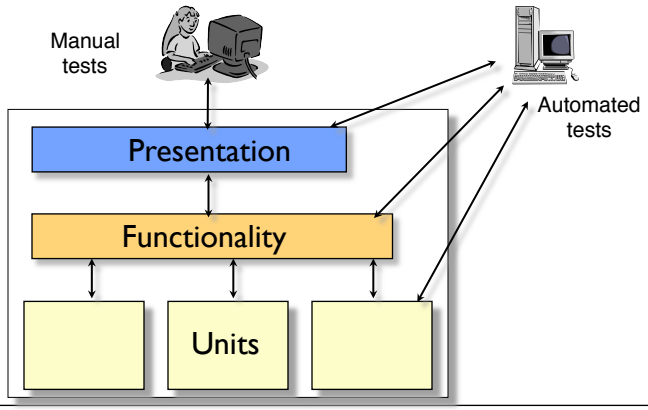
Automating the testing

Source: Adapted from Zeller 2006, p57

Challenges for automated testing:

- Synchronization - How do we know a window popped open that we can click in?
- Abstraction - How do we know it's the right window?
- Portability - What happens on a display with different resolution / size, etc



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Testing the Presentation Layer

Source: Adapted from Zeller 2006, chapter 3

Script the mouse and keyboard events

- script can be recorded (e.g. "send_xevents @400,100")
- script is write-only and fragile

Script at the application function level

- E.g. Applescript: **tell** application "UMLet" **to** activate
- Robust against size and position changes
- Fragile against widget renamings, layout changes, etc.

Write an API for your application…

- Allow an automated test to create windows, interact with widgets, etc.

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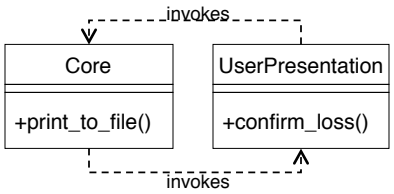
Dealing with Circular Dependencies

Source: Adapted from Zeller 2006, chapter 3




```
void print_to_file(string filename)
{
    if (path_exists(filename)) {
        // FILENAME exists; ask user to confirm overwrite
        bool confirmed = confirm_loss(filename);
        if (!confirmed)
            return;
    }
    // Proceed printing to FILENAME...
}
```

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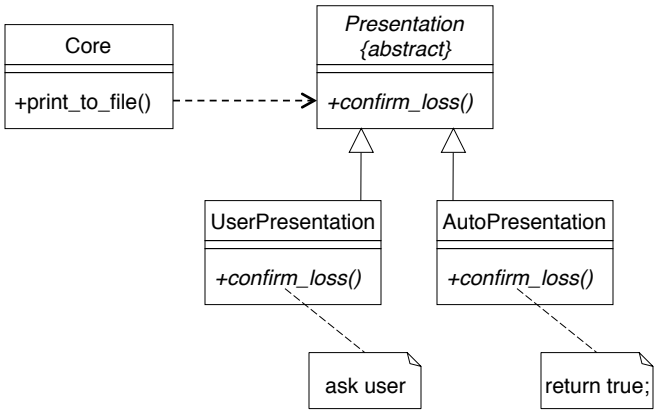
Revised Dependency

Source: Adapted from Zeller 2006, chapter 3



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How to Test Object Oriented Code?

Encapsulation

- If the object hides it's internal state, how do we test it?
- Could add methods that expose internal state, only to be used in testing
- But: how do we know these extra methods are correct?

Inheritance

- When a subclass extends a well-tested class, what extra testing is needed?
  - e.g. Test just the overridden methods?
- But with dynamic binding, this is not sufficient
  - e.g. other methods can change behaviour because they call over-ridden methods

Polymorphism

- When class A calls class B, it might actually be interacting with any of B's subclasses…

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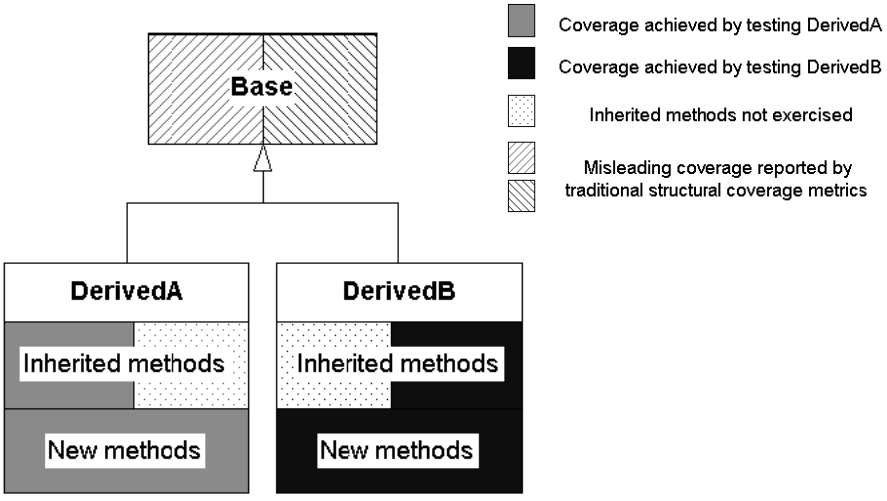
Inheritance Coverage

Source: Adapted from IPL 1999



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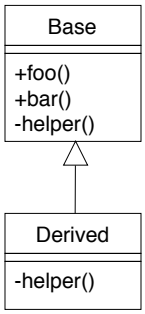
Consider this program…

Source: Adapted from IPL 1999




```
class Base {
  public void foo() {
    … helper(); …
  }
  public void bar() {
    … helper(); …
  }
  private helper() {…}
}

class Derived extends Base {
  private helper() {…}
}
```

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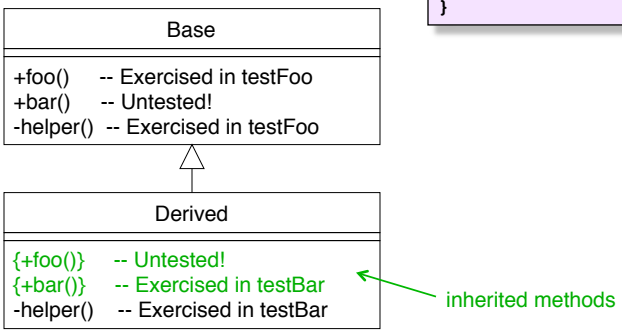
Test Cases

Source: Adapted from IPL 1999

```
public void testFoo() {
  Base b = new Base();
  b.foo();
}
public void testBar() {
  Derived d = new Derived();
  d.bar();
}
```



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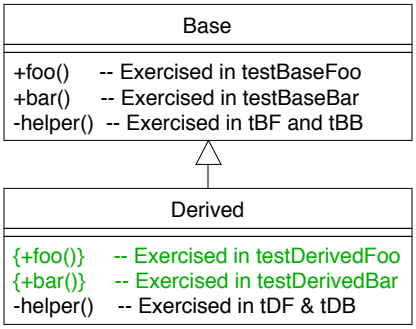
Extend the test suite

Source: Adapted from IPL 1999

```
public void testBaseFoo() {
  Base b = new Base();
  b.foo();
}
public void testBaseBar() {
  Base b = new Base();
  b.bar();
}
public void testDerivedFoo() {
  Base d = new Derived();
  d.foo();
}
public void testDerivedBar() {
  Derived d = new Derived();
  d.bar();
}
```



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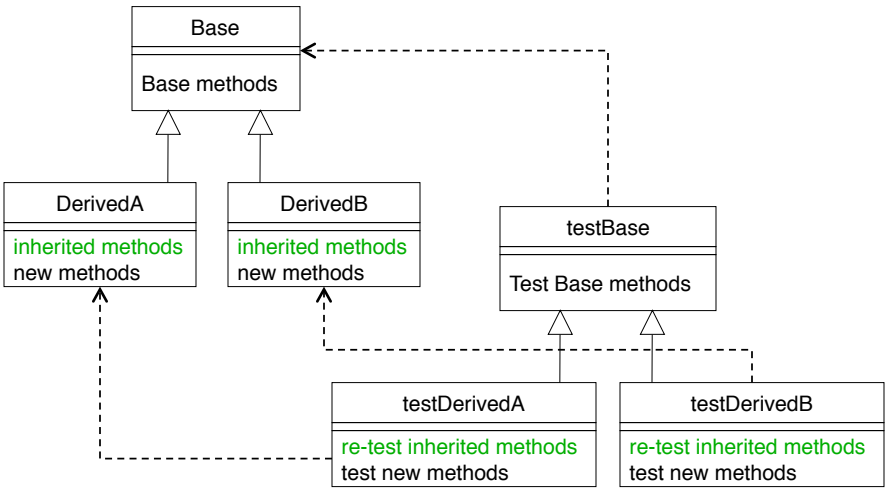
Subclassing the Test Cases

Source: Adapted from IPL 1999



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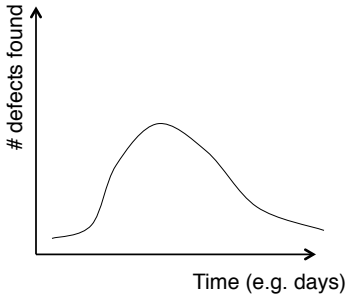
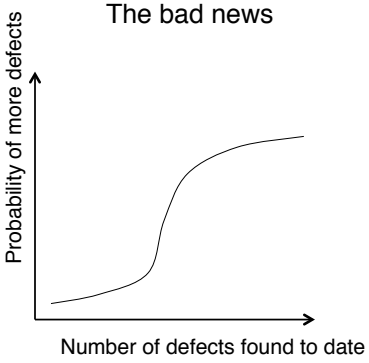
When to stop testing?

Typical testing results



The bad news



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When to stop testing?

Source: Adapted from Pfleeger 1998, p359

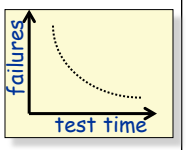
Motorola's Zero-failure testing model

Predicts how much more testing is needed to establish a given reliability goal

basic model:

$$failures = ae^{-b(t)}$$

(a: empirical constants; b(t): testing time)



Reliability estimation process

Inputs needed:

- fd = target failure density (e.g. 0.03 failures per 1000 LOC)
- tf = total test failures observed so far
- th = total testing hours up to the last failure

Calculate number of further test hours needed using:

$$\frac{\ln(fd/(0.5 + fd)) \times th}{\ln((0.5 + fd)/(tf + fd))}$$

Result gives the number of further failure free hours of testing needed to establish the desired failure density

- if a failure is detected in this time, you stop the clock and recalculate

Note: this model ignores operational profiles!

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Fault Seeding

Seed N faults into the software

Start testing, and see how many seeded faults you find

Hypothesis:

$$\frac{\text{Detected seeded faults}}{\text{Total seeded faults}} = \frac{\text{Detected nonseeded faults}}{\text{Total nonseeded faults}}$$

Use this to estimate test efficiency

Estimate # remaining faults

Alternatively

Get two teams to test independently

Estimate each team's test efficiency by:

$$\text{Efficiency(team1)} = \frac{\text{\# faults found by team 1}}{\text{Total number of faults}} = \frac{\text{Faults found by both teams}}{\text{Total \# faults found by team 2}}$$

unknown

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