OO Testing

Overview

- OO Software Testing
- OO Unit Testing: class testing
- OO Integration Testing: multiple class testing

OO Software Testing

- Some of the older testing techniques are still useful
  - Class testing is similar to unit testing
  - Multiple class testing is similar to integration testing
- New testing techniques are specially designed for OO software
  - State-based testing

OO Unit Testing: Class Testing

- Traditional view of "unit": a procedure
- In OO: a method is similar to a procedure
- But a method is a part of a class, and is tightly coupled with other methods and fields in the class
- The smallest testable unit is a **class**

Class Testing

- DU pairs can still be used to design data flow based testing
  - However, test cases should cover both DU pairs inside a method and crossing method boundaries
    - i.e., intra-method and inter-method
- Testing method ordering
- Testing polymorphism

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DU-Pair Testing Example

```
class A {
    private int index;
    public void m1() {
        index = …;
        …
        m2();
    }
    private void m2() { … x = index; … }
    public void m3() { … z = index; … }
}
```

test 1: call m1, which writes index and then call m2 which reads the value of index

test 2: call m1, and then call m3

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Testing Method Ordering

- Random testing
  - Conduct random test to exercise different call sequences and different class instance life histories
- Partition testing
  - Similar to equivalence partition to reduce test cases

Random Testing Example

Account
...
open() setup() deposit() withdraw() balance() summarize() creditLimit() close()

- Test case 1
  - open•setup•deposit•deposit• balance•summarize•withdraw•close
- Test case 2
  - open•setup•deposit•withdraw•deposit• balance•creditLimit•withdraw•close
- Limitation
  - too random to be effective
  - may test some infeasible cases

Partition Testing

- State-based partitioning
  - To categorize class operations based on their ability to change the state of the class
  - To design different test cases to
    - cover every set of operations
    - cover every state of the class

Finite State Machine Diagram

- Two types of operations
  - State operations
    - open(), setup(), deposit(), withdraw(), close()
  - Nonstate operations
    - balance(), summarize(), creditLimit()

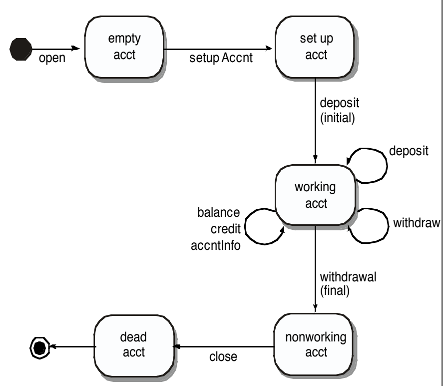
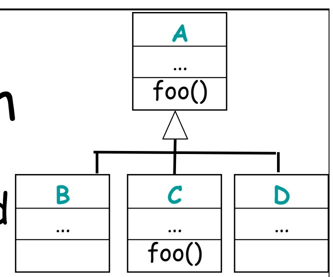


Figure 14.3 State diagram for Account class (adapted from [KIR94])

Test Cases

- Test case 1
  - open•setup•deposit(initial)•withdraw(final)•close
- Test case 2
  - open•setup•deposit(initial)•deposit•balance•credit•withdraw(final)•close
- Test case 3
  - open•setup•deposit(initial)•deposit•withdraw•accountInfo•withdraw(final)•close

Polymorphism



- Suppose class X has a method calling a.foo(), where variable **a** is of type ***A***
  - The function call may invoke A.foo(), B.foo(), C.foo(), D.foo()
- How to “drive” call site a.foo() through all possible bindings?

Testing Polymorphism

- **All-receiver-classes:** execute every possible receiver of type *A*
  - A.foo(), B.foo(), C.foo(), D.foo()
- **All-invoked-methods:** execute with receivers whose classes define foo()
  - A.foo() (or B.foo() or D.foo()), C.foo()

How to Find All Possible Method Targets?

- Class Hierarchy Analysis (CHA)
  - Conduct compile-time analysis to get type hierarchy info and find all possible method targets at call site a.foo()
    - Know all subclasses of class *A*
    - Know all methods defined in those classes and *A* with method signature foo()
    - Every found method is a possible method target

Refinement: Rapid Type Analysis

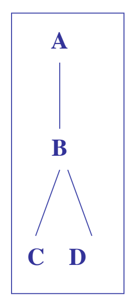
- Limitation of CHA
  - Not all "possible" method targets are actually invoked
- Rapid Type Analysis (RTA)
  - Also collect info on which classes are actually instantiated

Example

cf Frank Tip, OOPSLA' 00

```
static void main(){
   B b1 = new B();
   B b2 = new C();
   f(b1);
   g(b2);
}
static void f(A a2){
   a2.foo();
}
static void g(B b2){
   b2.foo();
}
```

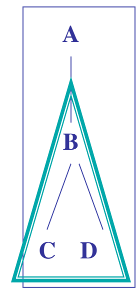
```
class A {
   foo(){..}
}
class B extends A{
   foo() {…}
}
class C extends B{
   foo() {…}
}
class D extends B{
   foo(){…}
}
```



CHA Result

```
static void main(){
    B b1 = new B();
    B b2 = new C();
    f(b1);
    g(b2);
}
static void f(A a2){
    a2.foo();
}
static void g(B b2){
    b2.foo();
}
```

```
class A {
    foo(){..}
}
class B extends A{
    foo() {…}
}
class C extends B{
    foo() {…}
}
class D extends B{
    foo(){…}
}
```

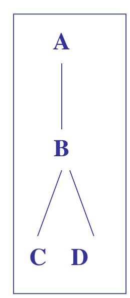


Cone(Declared_type(receiver))

RTA Result

```
static void main(){
    B b1 = new B();
    B b2 = new C();
    f(b1);
    g(b2);
}
static void f(A a2){
    a2.foo();
}
static void g(B b2){
    b2.foo();
}
```

```
class A {
    foo(){..}
}
class B extends A{
    foo() {…}
}
class C extends B{
    foo() {…}
}
class D extends B{
    foo(){…}
}
```



Cone(Declared_type(receiver)) ∧ Instantiated

Myths about Inheritance

- "If we have a well-tested superclass, we can reuse its code (in subclasses, through inheritance) without retesting inherited code"
- "A good-quality test suite used for a superclass will also be good for a subclass"

Problems with Inheritance

- P1: Incorrect initialization of superclass attributes by the subclass
- P2: Missing overriding methods
  - Typical example: **equals()** and **clone()**
- P3: Subclass may cause side effects and violate an invariant from the superclass

Example 1

```
class A {
  protected int x; // invariant: x > 100
  void m() { // correctness depends on
             // the invariant … } … }
class B extends A {
  void m1() { x = 1; … } … }
```

- If m1 has a bug and breaks the invariant, m is incorrect in the context of B, even though it is correct in A
  - P1, P3

Example 2

```
class A {
    void m() { … m2(); … }
    void m2 { … } … }
class B extends A {
  void m2() { … } … }
```

- If m2() is buggy, so is m() called on B instance
  - P3

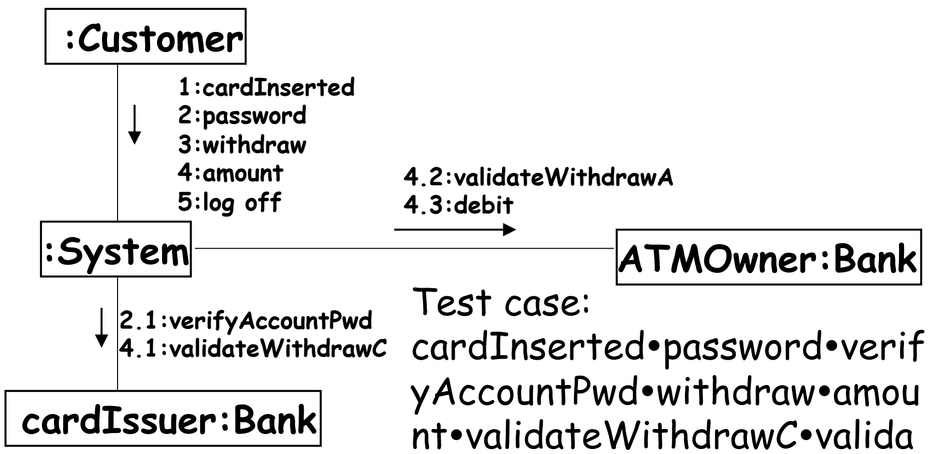
Testing of Inheritance

- **Principle: inherited method should be retested in the context of a subclass**
  - Example 1: if we change some method m() in a superclass, we need to retest m() inside all subclasses that inherit it
  - Example 2: if we add or change a subclass, we need to retest all methods inherited from a superclass in the context of the new/changed subclass
  - Goal: check **behavioral conformance** of the subclass w.r.t. to the superclass (LSP)

Multiple Class Testing

- UML interaction diagrams: sequences of messages among a set of objects
- Basic idea: devise tests that cover all diagrams, all messages, and all conditions inside each diagram
  - If a diagram does not have conditions and iteration, it contains only one path

Communication Diagram



Test case:
cardInserted•password•verifyAccountPwd•withdraw•amount•validateWithdrawC•validateWithdrawA•debit•logoff

Alternative Scenario 1

- If the password is not correct
  - ATM prompts the customer to try again
  - Customer enters a password
  - ATM requests the card issuer bank to verify again
  - Repeat the above steps until verification succeeds or trialNumber == limit

Alternative Scenario 2

- If the verification finally fails and no retry is allowed
  - ATM reports the failure and returns the card

Alternative Scenario 3

- If the amount to withdraw is greater than the cash amount in ATM
  - ATM reports "not enough money"
  - ATM prompts the customer to retry
  - If the customer wants to cancel the transaction, logoff; Otherwise, the customer enters an amount
  - Repeat the above steps until the amount meets the requirement

Homework 3: Multiple Class Testing

- Withdraw money from ATM
  - Draw a CFG to cover all scenarios shown by the communication diagram and alternative descriptions
  - Devise test cases based on that
  - Feel free to define new operations if necessary

Requirements of Test Cases

- Cover all scenarios (successful + failing)
  - basis path testing (assume limit = 3)
  - loop testing
    - for an n-iteration loop, test scenarios: 0, 1, n-1, n
    - for an infinite loop, test scenarios: 0, 1, m (m > 1)
- List test cases for each technique
  - Briefly explain why these test cases are selected