CMPT 473
Software Quality Assurance

Unit Testing & Testability

Nick Sumner
with material from the GoogleTest documentation
Levels of Testing

• Many different levels of testing can be considered:
  – Unit Tests
  – Integration Tests
  – System Tests
  – Acceptance Tests
  – ...

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- Integration Tests
- System Tests
- Acceptance Tests
- ...

The simplest of these is **Unit Testing**

- Testing the smallest possible fragments of a program
Unit Testing

• Try to ensure that the *functionality* of each component works in isolation
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    Driving down the highway with the air conditioning on works....
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- Not testing how well things are glued together.
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Why? How is this beneficial?
Unit Tests

• A dual view:
  – They specify the expected behavior of individual components
Unit Tests

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  – An executable specification
Unit Tests

- A dual view:
  - They specify the expected behavior of individual components
  - An executable specification
- Can even be built first & used to guide development
  - Usually called Test Driven Development
Unit Tests

• Some guiding principles:
  – *Focus* on one component *in isolation*
  – Be *simple* to set up & run
  – Be easy to *understand*
Unit Tests

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- Usually managed by some automating framework ....
GoogleTest

- Increasingly used framework for C++
  - Not dissimilar from JUnit, which you have already seen.
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- Test cases are written as functions:

  ```
  TEST(TriangleTest, isEquilateral) {
    Triangle tri{2,2,2};
    EXPECT_TRUE(tri.isEquilateral());
  }
  ```
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The TEST macro defines individual test cases.
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TEST(TriangleTest, isEquilaterial) {
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  EXPECT_TRUE(tri.isEquilaterial());
}
```

The first argument names related tests.
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EXPECT and ASSERT macros provide correctness oracles.
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**ASSERT** oracles terminate the program when they fail.
**EXPECT** oracles allow the program to continue running.
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- TEST() cases are automatically registered with GoogleTest and are executed by the test driver.
- Some tests require common setUp & tearDown
  - Group them into test fixtures
  - A fresh fixture is created for each test
GoogleTest - Fixtures

class StackTest : public ::testing::Test {
  protected:
    void SetUp() override {
      s1.push(1);
      s2.push(2);
      s2.push(3);
    }

    void TearDown() override {
    }

    Stack<int> s1;
    Stack<int> s2;
  }

Derive from the fixture base class
class StackTest : public ::testing::Test {
protected:
  void SetUp() override {
    s1.push(1);
    s2.push(2);
    s2.push(3);
  }
  void TearDown() override {
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SetUp() will be called before all tests using the fixture
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   Stack<int> s1;
   Stack<int> s2;
};

TearDown() will be called after all tests using the fixture
Use the fixture in test cases defined with TEST_F:

```cpp
TEST_F(StackTest, popOfOneIsEmpty) {
    s1.pop();
    EXPECT_EQ(0, s1.size());
}
```
GoogleTest - Fixtures

Use the fixture in test cases defined with TEST_F:

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Behaves like

```cpp
{
    StackTest t;
    tSetUp();
    t.popOfOneIsEmpty();
    tTearDown();
}
```
Use the fixture in test cases defined with TEST_F:

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TEST_F(StackTest, popOfOneIsEmpty) {
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A different expectation than before!
GoogleTest - Fixtures

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- TEST() cases are automatically registered with GoogleTest and are executed by the test driver.
- Some tests require common setUp & tearDown

- Many different assertions and expectations available

  ```
  ASSERT_TRUE(condition);
  ASSERT_FALSE(condition);
  ASSERT_EQ(expected, actual);
  ASSERT_NE(val1, val2);
  ASSERT_LT(val1, val2);
  ASSERT_LE(val1, val2);
  ASSERT_GT(val1, val2);
  ASSERT_GE(val1, val2);
  ```

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- Many different assertions and expectations available
- More information available online
  - [github.com/google/googletest/blob/master/googletest/docs/Primer.md](https://github.com/google/googletest/blob/master/googletest/docs/Primer.md)
  - [github.com/google/googletest/blob/master/googletest/docs/AdvancedGuide.md](https://github.com/google/googletest/blob/master/googletest/docs/AdvancedGuide.md)
Common Patterns (Ammonn & Offutt)

- Checking State
  - Final State
    - Prepare initial state
    - Run test
    - Check final state
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  - Round trips
    - Check behavior on transform/inverse transform pairs
Common Patterns (Ammonn & Offutt)

- Checking Interactions/Behavior
  - Use *mocks*
Common Patterns (Ammonn & Offutt)

• Checking Interactions/Behavior
  – Use *mocks*
    • Testing 'fakes' that verify expected interactions
    • http://martinfowler.com/articles/mocksArentStubs.html
    • http://googletesting.blogspot.ca/2013/03/testing-on-toilet-testing-state-vs.html
Testability

- What makes testing hard?
  - Not just difficult to get adequacy
  - What makes it difficult to write tests?
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• Dependencies
  – Connections between classes
  – Singletons
  – Nondeterminism
  – Static binding (mitigated by parametric polymorphism)
Testability

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  – Mixing construction & application logic
  – ...

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But solutions exist! 
You can *design* code to be testable!
Testability (by example)

• Let's work together to improve some difficult to test code....
Testability

- Keys things to notice:
  - *Mocks* & *stubs* allow us to isolate components under test
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Given dependency injection, what happens to the way we create objects?
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  – *Mocks & stubs* allow us to isolate components under test
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Given dependency injection, what happens to the way we create objects?

How might we mitigate boilerplate issues?
Mocking Framework Example

- Frameworks exist that can automate the boilerplate behind:
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  - Mocking
    - e.g. GoogleMock, Mockito, etc.
  - Dependency Injection
    - e.g. Google Guice, Pico Container, etc.
Using GoogleMock

• Steps:
  1) Derive a mock class from the class you wish to fake

```cpp
class MockThing : public Thing {
    ...
};
```
Using GoogleMock

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  1) Derive a mock class from the class you wish to fake

  2) Replace virtual calls with uses of `MOCK_METHODn()` or `MOCK_CONST_METHODn()`.

```cpp
class MockThing : public Thing {
public:
  ...
  MOCK_METHOD1(foo, int(int));
  MOCK_METHOD1(bar, void(int));
};
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  3) Use the mock class in your tests.
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2) Replace virtual calls with uses of `MOCK_METHODn()` or `MOCK_CONST_METHODn()`.
3) Use the mock class in your tests.
4) Specify expectations before use via `EXPECT_CALL()`.
   • What arguments? How many times? In what order?

```cpp
InSequence dummy;
EXPECT_CALL(mockThing, foo(Ge(20)))
  .Times(2)
  .WillOnce(Return(100))
  .WillOnce(Return(200));
EXPECT_CALL(mockThing, bar(Lt(5)));
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     • What arguments? How many times? In what order?
  5) Expectations are automatically checked in the destructor
     of the mock.
Using GoogleMock

- Precisely specifying mock behavior

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InSequence dummy;
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  .Times(2) // Can be omitted here
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Complex behaviors can be checked using these basic pieces.
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- Unit testing provides a way to *automate* much of the testing process.
- Testing small components *bootstraps confidence* in the system on confidence in its constituents.
- Tests can verify *state* or *behaviors*.
- Software must be *designed for testing* (or designed by testing)