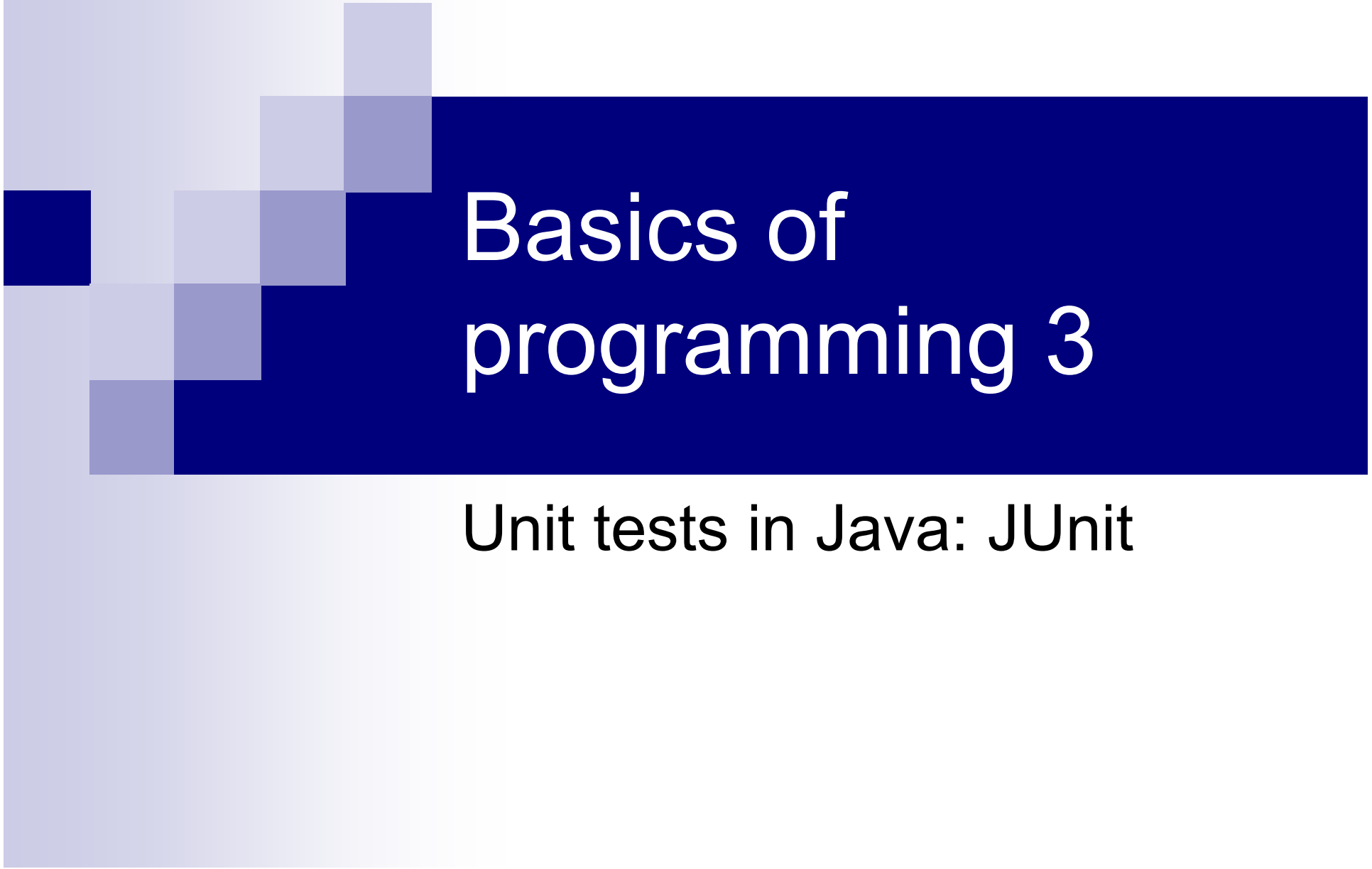

Basics of
programming 3
Unit tests in Java: JUnit

Unit tests

- Verification and validation has many levels
  - system tests
  - integration tests
  - unit tests
  - etc
- Testing a single unit is *unit test*
  - units in OO are classes and objects
- Automatism and repeatability are important
  - regression tests

Unit testing

- Small part of the software is tested
  - Single class or method
  - Each and every non-trivial method
- Tests are independent
  - Tests are stateless
- Developer and tester should be different persons

Unit testing – classical approach

- Code review
  - Useful if rules are observed
  - Not enough
- Manual testing
  - Develop tester applications
  - Simple
  - Becomes unmaintainable with time
    - Test are not organised
    - Results are not coherent

Unit testing – manual approach

- System.out.println()
  - Continuous diagnostic messages
  - Simple
  - Code is full with println-s
    - how to turn off?
  - Output tends to be unreadable
  - Manual control is needed

Unit testing – manual approach

- Debugger
  - IDE support for observing variables
  - Slow
  - Cumbersome for complex (multithreaded) applications
  - Has to be done after each change
  - Still manual

Unit testing – frameworks

- *X*Unit for many languages and environments
  - CppUnit (C++)
  - unittest (python)
  - etc.
- JUnit
  - open source Java testing framework
  - available as a JAR file
  - tests are written in Java
  - IDE-s provide built-in support
    - separate windows, perspectives, etc

JUnit features

- Assertions for testing expected results
  - standard result checks
- Test fixtures for sharing common test data
  - common functionality written once
- Test runners for running tests
  - automated testing
  - regression is easy

JUnit example

- Simple *integer* implementation

```
public class MyInt {
    private int value;
    public MyInt(int aValue) {
        value = aValue;
    }
    public void add(MyInt anInt) {
        value += anInt.getValue();
    }
    public int getValue() {
        return value;
    }
}
```

Example test

- Simple test – naïve
  - Create some objects – testing context, fixture
  - Send messages to those objects
  - Verify some assertions

```
public class MyTest {
  public static void main(String[] args) {
    MyInt m1 = new MyInt(5);
    MyInt m2 = new MyInt(30);
    m1.add(m2);
    if (m1.getValue() != 35)
      System.out.println("Sum failed");
    if (m2.getValue() != 30)
      System.out.println("m2 failed");
}}
```

Initialization

Test run

Check

Example Junit test

```
public class MyIntTest1 {
     MyInt m1, m2;
     @Before
     public void setUp() {
       m1 = new MyInt(5);
       m2 = new MyInt(30);
     }
     @Test
     public void testAddInt() {
       m1.add(m2);
       assertEquals("sum Test", 35, m1.getValue());
       assertEquals("m2 Test", 30, m2.getValue());
     }
}
```

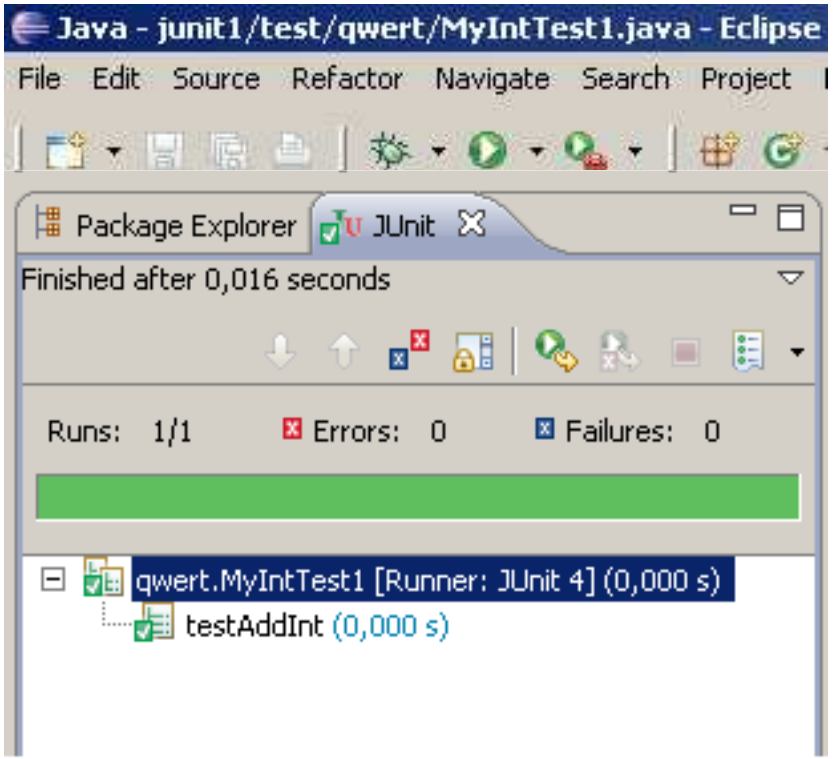
Initialization

Check

Test run

JUnit in Eclipse

- Java Build Path/Libraries/Add Library/Junit 4
- Run As/Junit Test



Test method

- Constraints
  - Each test is implemented as a method
  - It takes no parameters and returns no value
  - Test methods must be public
  - Annotated by `@Test`
  - Default test order is undefined but deterministic
    - order not known, but always the same
    - class annotation for lexicographic ordering (v4.11): `@FixMethodOrder(MethodSorters.NAME_ASCENDING)`

Fixtures

- Intro
  - combine tests for a common set of objects
  - e.g. initialization, clean-up etc
  - tests don’t share the objects
    - each test separately tests its own set of objects
  - common objects are instance variables

Fixtures 2

- Types
  - **@Before**
    - called before each test: builds the context
  - **@After**
    - called after each test: tears down the context
  - **@BeforeClass / @Afterclass**
    - called before first test / after last test
    - for resource-intensive objects and initialization

Example Junit test

```
public class MyIntTest1 {
     MyInt m1, m2;
     @Before
     public void setUp() {
       m1 = new MyInt(5);
       m2 = new MyInt(30);
     }
     @Test
     public void testAddInt() {
       m1.add(m2);
       assertEquals("sum Test", 35, m1.getValue());
       assertEquals("m2 Test", 30, m2.getValue());
     }
}
```

Initialization

Check

Test run

Fixtures and tests

- Execution order for two tests:

@BeforeClass methods

@Before methods

@Test method #1

@After methods

@Before methods

@Test method #2

@After methods

@AfterClass methods

Testing results

- How to check if result is correct?
  - static void **assertTrue**([String msg,] boolean condition)
  - static void **assertFalse**([String msg,] boolean condition)
  - static void **assertNull**([String msg,] Object object)
  - static void **assertNotNull**([String msg,] Object object)
  - static void **assertSame**([String msg,] Object exp, Object act)
  - static void **assertNotSame**([String msg,] Object unexp, Object act)
  - static void **assertEquals**([String msg,] X exp, X act)
  - static void **assertArrayEquals**([String msg,] X exp, X act)
  - static void **fail**([String msg])

msg for exception when fail

Running tests

- Command line
  - `java org.junit.runner.JUnitCore TestClass1 [...other test classes...]`
- Inside application
  - `org.junit.runner.JUnitCore.runClasses(TestClass1.class, ...);`
- Inside IDE
  - click on *run tests*…

Test results

- Success
  - OK
- Failure
  - result is different from expected
  - tests fail if any assertion fails
- Error
  - unexpected exception was thrown
- Ignore
  - test was ignored (*assume* or *@Ignore*)

Test results 2

- Expecting exceptions

```
@Test(expected=NumberFormatException.class) ...
```

- Setting timeout

```
@Test(timeut=100) ...
```

- Ignoring test

```
@Ignore("some message") @Test ...
```

  - using *Assume.assumeXXX* method changes fails into ignores
    - *assertNotNull(obj)* → *assumeNotNull(obj)*

      if *obj* is null, test is ignored (instead of fail)

Rules

- Same init for different test classes
  - put code into subclass of *ExternalResource*
    - *public void before()*: runs before each test
    - *public void after()*: runs after each test
    - newly constructed for each test
  - add resource class to test

```
@Rule public ExternalResource resource =
        new MyExternalResource();
```

  - class level rules (like *BeforeClass*, etc)

```
@ClassRule ...
```

Subclassing test classes

- Test execution for subclass tests
  - bottom-up in inheritance hierarchy
- Before execution
  - top-down in inheritance hierarchy
- After execution
  - bottom-up in inheritance hierarchy

Parameterized testing

- For same test with different parameters
  - instances are created for the cross-product of the test methods and the test data elements

```
@RunWith(value = Parameterized.class)
public class ParamTest {
  private int a, b;
  public ParamTest(int a1, int b1) {a = a1; b = b1;}
  @Parameters public static Collection<Object[]> data() {
    return Arrays.asList(new Object[][]{{1,5},{4,9},{2,7}});
  }
  @Test public void runTest() {Assert.assertTrue(a < b);}
}
```

Creating test suites

- Grouping tests together

```
@RunWith (Suite.class)
@Suite.SuiteClasses ({
      TestFeatureLogin.class,
      TestFeatureLogout.class,
      TestFeatureNavigate.class,
      TestFeatureUpdate.class
})
public class FeatureTestSuite {
      // empty class holding the annotations
}
```

Categories of tests

- Tests can be annotated with categories
- Categories are simple annotations
- Tests can be category-annotated both on method and class level

```
@Category(categoryType1.class)

@Category({categoryType1.class,
                  categoryType2.class})
```

Category example

```
public interface FastTests{}
public interface SlowTests {}

public class A {
  @Test public void a() { ... }

  @Category(SlowTests.class)
  @Test public void b() { ... }
}

@Category({SlowTests.class, FastTests.class})
public class B {
  @Test public void c() { ... }
}
```

category markers

Categories used in suites

- In test suites one can select a set of categories

```
@RunWith(Categories.class)
@IncludeCategory(SlowTests.class)
@ExcludeCategory(FastTests.class)
@SuiteClasses({ A.class, B.class })
public class SlowTestSuite {
  // Will run only test annotated
  // with SlowTests in test cases A and B
}
```

JUnit conventions

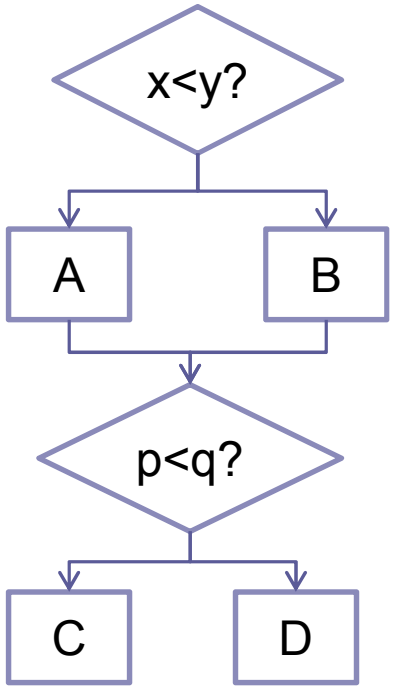
- Separate tests from sources
  - Usually separare directories (**src** vs. **test**)
  - Final application doesn't contain tests
- Test classes in same package as tested classes
  - Allows tests to access package, protected members
- For each tested class a single test class
  - Not a strict rule ☺

Concurrent testing

- Testing concurrent classes is hard
  - help: *ConcurrentUnit*
    1. Create a *Waiter*
    2. Use *Waiter.await* to block the main test thread.
    3. Use the *Waiter.assert* calls from any thread to perform assertions.
    4. Once expected assertions are completed, use *Waiter.resume* call to unblock the main thread.

Test coverage

- How much of the code is tested?
  - coverage = tested / total
  - including exceptions
  - static vs dynamic check
    - are all paths tested?
- Goal: 100% coverage
  - bugs might still remain ☹



Runtime checks

- Not considered testing
- Design by contract
  - precondition
    - method expects this from callers
  - invarinant
    - what does not change during method call
  - postcondition
    - method assures this condition
  - Supported by some languages (e.g. Eiffel)

Design by contract example

```
public interface Stack<T> {
   /** Pushes t on top of Stack */
   void push(T t);
   /** removes topmost element */
   T pop();
   /** returns topmost element */
   T top();
   /** returns number of stored elements */
   int size();
}
```

Design by contract example

- `void push(T t)`
  - *invariant*: all previously pushed items retained
    order does not change
  - *post*: **t** is on top
- `void pop()`
  - *pre*: stack is not empty
  - *invariant*: all but top previously pushed items retained
    order does not change
  - *post*: topmost element is removed

Design by contract example

- `T top()`
  - *pre*: stack is not empty
  - *invariant*: all pushed items retained
    order does not change
  - *post*: returned element is topmost element
- `int size()`
  - *invariant*: all pushed items retained
    order does not change
  - *post*: returned value equals number of items

Tests vs Design by contract

- Tests can be generated from DbC
  - pre, inv, post must be formally specified
  - conditions can be turned into test cases
- Tests during development
  - tests check software before regular use
- DbC during regular use
  - what to do if something happens?
  - mostly for prototyping

Java: assert keyword

- Runtime check of condition
  - *assert expression;*
    - e.g. `assert (stack.size() > 0);`
  - *assert expression1 : expression2;*
    - e.g. `assert (i % 5 == 0 : i);`
    - assert cause is set to expression2
- When assertion fails
  - *AssertionError* is thrown
  - its an error -> should not be handled, may not be indicated

Java assert rules

- No public method parameter checking
  - use *IllegalArgumentException*, *NullPointerException*, etc instead
- No regular work should be done
  - e.g.
```
assert (stack.pop() == x); // NO!
```
```
Object o = stack.pop();
assert (o==x);              // OK
```
- Allowing assertions
  - `javac -source 1.4 MyClass.java`
  - otherwise *assert* is not a keyword

Java assert runtime enabling

- For packages and classes
  - *-enableassertions* or *-ea*
  - *-disableassertions* or *-da*
    - arguments (like *-ea:hu.bme.iit…*)
      - *none*: for whole application
      - `packageName...`: for package and subpackages
      - `...`: for the unnamed package
      - `classname`: for the given class
- For system classes
  - *-enablesystemassertions* or *-esa*
  - *-disablesystemassertions* or *-dsa*