Programming by Contract

Defensive Programming

Ch 3.6-3.7

Topics

- What can go wrong with using the following?

  ```
  double squareRoot(double n) {
      ... // compute x
      return x;
  }
  ```

- So, why do your classes interact correctly? Options:
  - Magic!
  - Your client code agrees to..
  - Your classes check all arguments and operations for correctness

Programming by Contract

- Programming by Contract:
  Each method and class has a contract.
  - Client code..
  - Class..
- ..
  - What the client ensures before calling the method.
- ..
  - What the class ensures when method finishes.
- ..
  - Properties that must always be true; often on a class.

```
/**
 * Returns the real number x,
 *    such that x * x = n
 * Precondition:
 *    Input n is 0 or greater.
 */
double squareRoot(double n) {
    // compute x
    ..
    return x;
}
```

Example

- The method assumes the client enforces the contract
  - ..
  - Client code's responsibility to ensure contract preconditions are not violated

```
/**
 * Removes top element from the stack
 * @pre     stack is not empty
 * @post    stack is not full,
 * @post    top element removed,
 * @post    size decreased by one
 */
public void pop(){
     elements.remove(0);
}
```

- Client must be..

Example:
Stack must have an isEmpty() method.

Driving Analogy

- Driving could be a contract:
  - Given the preconditions that everyone else obeys the law, you will be safe.
- Defensive Driving:
  - You are never sure what other drivers will do, so always..
- Example:
  - Shoulder check when making a left turn to make sure nobody is illegally passing you on the left
  - Staying out of a car's blind spot to avoid getting hit if they fail to shoulder check while changing lanes

Defensive Programming

- A class is responsible for..
  - All input values and actions are checked for correctness.

    ex: prevent adding a duplicate element to a "set"

    ex: prevent adding an element to a full array.
- Brian's "Defensive Programming"
  - Find bad inputs/actions and..
  - How?..

Assert Basics

- Assert (basics)
  - Usage:

    ```
    assert condition;
    ```

  - If the condition is false,..
    (throws an AssertionError exception)
- Example Statement:

  ```
  assert age >= 0;
  ```

- Example Method:

  ```
  public void pop() {
      assert !isEmpty();
      elements.remove(0);
  }
  ```

Comparison

- Should a square-root method check that the input is non-negative?
  - Design by Contract:..
  - Defensive Programming:..
    client may call us with a bad value we should check.
- Benefit of Design by Contract
  - ..
    - otherwise client & class check for valid values.
  - Duplicate checks make system more complicated.
- Benefit of Defensive Programming
  - ..
  - Should use for all calls accessible by untrusted code.

Used Together

- Enforcing Design by Contract is hard
  - Some languages can automatically enforce the contract, such as Eiffel.
  - Not as easy in many other languages!
    If not enforced, then contract violations not caught.
- Complementary Ideas
  - Use design by contract to clearly communicate your expectations to other programmers.
  - Use defensive programming to verify these expectations using asserts and exceptions.

Error Handling Options

1. - BAD idea!
   - EX: sqrt() w/o any checking or documentation
2. - Programming by contract
   - Works best with language support.
   - EX: sqrt() w/o any checking, but with documentation
3. (assert) - Check for programmer errors
   - EX: sqrt() w/ assert
4.
   - EX: sqrt() w/ exception
5. (null, -1, ...)
   - EX: sqrt() w/ return -1
6.
   - Given incorrect input, try to correct it as best as possible.
   Ex: sqrt() w/ abs(x) call to make positive.

Asserts:

Enforce constraints on developers.

Assertions

- Assert statements
  - Trigger a runtime error if a condition is false
  - ..
- Example Usage

```
double rSquared = getCircleArea() / Math.PI;
assert rSquared >= 0;
double r = squareroot(rSquared);
```

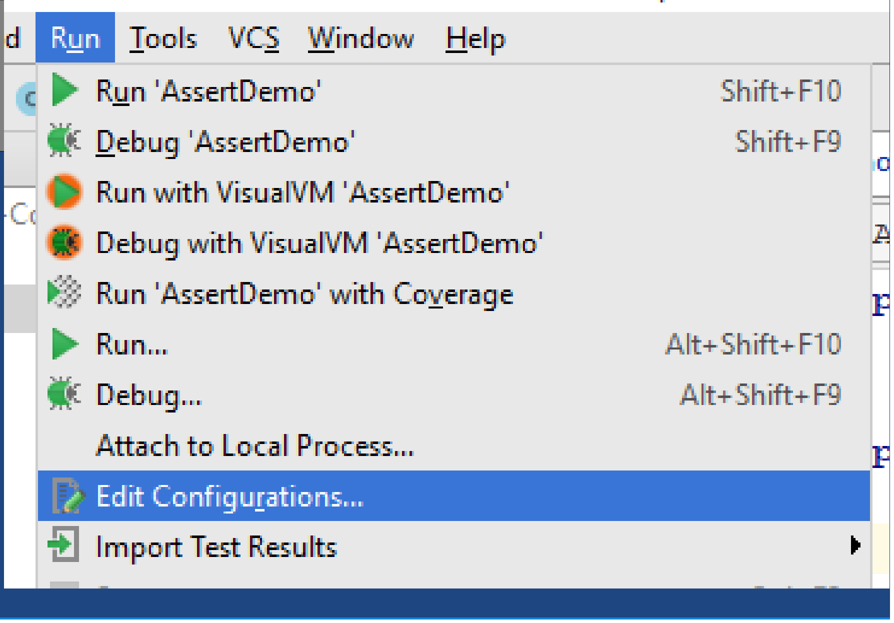
- Assertion failure
  - Displays source file & line number via an exception.

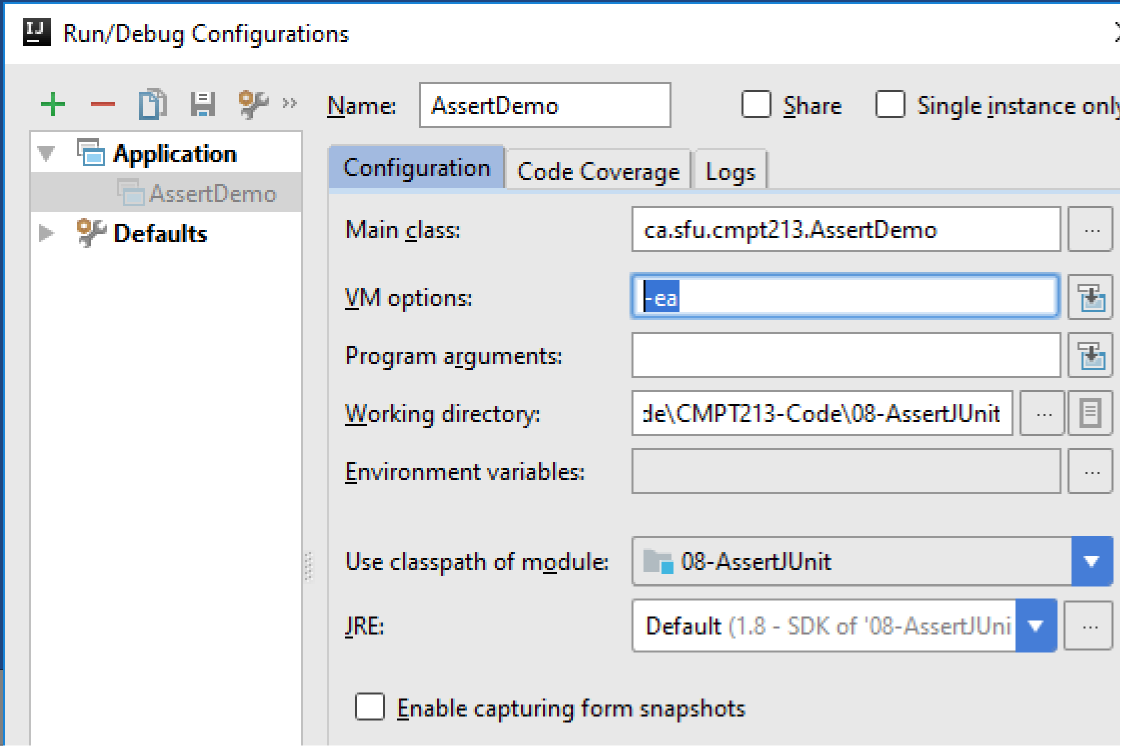
```
Exception in thread "main" java.lang.AssertionError
at ca.sfu.cmpt213.AssertDemo.assertRadius(AssertDemo.java:14)
at ca.sfu.cmpt213.AssertDemo.main(AssertDemo.java:9)
```

Enabling Assertions

- Enabling Assertions
  - Turned on/off at runtime by JVM
  - Pass -ea argument to the JVM
  - -ea means..

- In IntelliJ
  Run > Edit Configurations
  in VM options: add -ea


Run
Tools
VCS
Window
Help
Run 'AssertDemo' Shift+F10
Debug 'AssertDemo' Shift+F9
Run with VisualVM 'AssertDemo'
Debug with VisualVM 'AssertDemo'
Run 'AssertDemo' with Coverage
Run... Alt+Shift+F10
Debug... Alt+Shift+F9
Attach to Local Process...
Edit Configurations...
Import Test Results



Name: AssertDemo

□ Share □ Single instance only

Main class: ca.sfu.cmpt213.AssertDemo

VM options: -ea

Program arguments:

Working directory: de\CMPT213-Code\08-AssertJUnit

Environment variables:

Use classpath of module: 08-AssertJUnit

JRE: Default (1.8 - SDK of '08-AssertJUni

□ Enable capturing form snapshots

Demo: assertion failing.

Assert User Guide (1)

- Assertions check for..
  which should crash the program.
- Guide to using Asserts
  - Assert the expectations you place..
    - Ex: Calling pop() on a non-empty stack.
  - Don't assert things that could reasonably be false.
    - Ex: Don't assert a user's input is > 0 because they may have typed in -1.
    - Must check for and handle these errors.

Assert User Guide (2)

- Don't assert things that..

```
String getDescription(Car car) {
      assert car != null;
      String str = car.toString();
      return str;
}
```

If *car* is *null*, it will generate an exception on it's own.

- Use assertions to catch..

```
switch(productType) {
case SOFTWARE:
      // ...
      break;
case HARDWARE:
      // ...
      break;
default:
      assert false;
}
```

Assert User Guide (3)

- ..

```
int age = getUserAge();
if (age < 50) {
    // ...
} else if (age >= 50) {
    // ...
} else {
    assert false;
}
```

- ..

Problems with Assert

- Too many asserts can..
  - Ex: in a graphics engine for a game.
  - Solution: disable them at runtime.
- Too many asserts can..
  - Solution: only use where they will help.
- Not for handling errors at runtime
  - Ex: Asserts can be disable at runtime; ..
  - Solution:
    - assert for programmer errors or “invalid” conditions.
    - use error handling for "possible" errors (file not found)

Summary

- Programming by Contract
  - Class states the contract
  - Client enforces it meets preconditions.
- Defensive Programming
  - Class ensures it's always in a valid state.
  - It validates all actions and values.
- Use asserts to validate assumptions
  - Check for programmer errors, not “possible” errors.
  - Asserts must be enabled in JVM (-ea)