Testing and Debugging

CS 5010 Program Design Paradigms "Bootcamp"

Lesson 2.4

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Outline

- This lesson covers testing in more detail
- We will learn about
  - different kinds of testing
  - the rackunit test framework that we will use in this course
  - how to use testing to help in debugging.

Learning Objectives

- At the end of this lesson, the student should be able to:
  - list and explain four different testing goals and two different kinds of testing.
  - use the rackunit framework to write test suites for simple programming problems
  - use the rackunit framework to help in debugging simple programs

Goals of Testing

- *Qualification Testing:* Make sure program is ready for more serious testing
- *Acceptance Testing:* Make sure program works on the given examples or use cases
- *Requirements Testing*: Make sure program works as intended on other examples
- *Regression Testing*: Make sure that a change hasn't broken anything.
- *Stress Testing*: How does the program perform for large inputs, heavy loads, etc.?
- *Usability Testing*: Is the program usable by its intended audience?

Qualification Testing

- Does the program provide the functions that are specified in the problem?
- Do they take the right number and type of arguments? Do they return the right type of result?

If they don't, then the program is not ready for further testing...

Acceptance Testing

- The requirements probably give some examples. Be sure to test them!
- Sometimes the requirements are more complicated, so you'll have to make up examples to check the requirements.

Another classification: Kinds of Testing

- *Black-box testing*: Tests where we don't know anything about the internals of the program
- *White-box testing*: Tests where we take advantage of what we know about the program or the requirements
  - Example: our tests for f2c took advantage of the fact that f2c was a linear relationship: if the program worked for two values, we can be confident that it will work for others
    - Except for overflow, etc. ☺
- We will do mostly white-box testing.

Still another classification: unit testing vs. integration testing

- *Unit testing* is about testing single functions or small groups of functions.
- *Integration testing* is about checking to see that larger pieces of the system fit together.
- We will do mostly unit testing. For us, a unit is either a single function or a small group of functions.
- It's important to understand just what function(s) your test is testing. More on this shortly.

Test Coverage

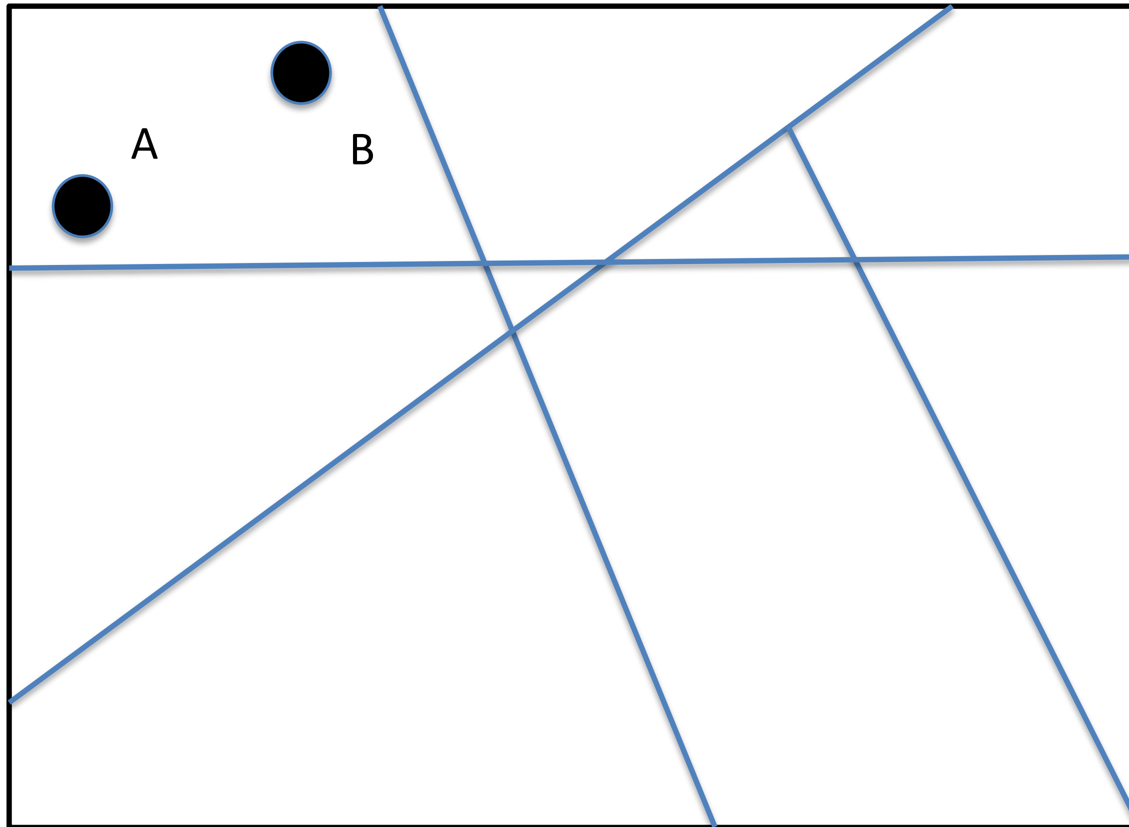
- How much of the possible behaviors have we tested?
- Want every line in the program exercised. This is called *100% expression coverage*.
- This is our **minimum** testing requirement.
- But this doesn't necessarily test all the desired behaviors of our program.
- To get a better handle on this, we introduce the idea of *equivalence partitioning*.

Equivalence Partitioning

- Possible arguments to your function typically fall into classes for which the program yields similar results.
- Example: f2c had only 1 partition.
- Example: ball-after-mouse depends on
  - Which mouse event we're dealing with
  - Whether the mouse event is inside or outside the ball
  - Whether the ball is selected
- So we need 3 x 2 x 2 = 12 tests to cover all these combinations.

Equivalence Partitioning

Regions of similar behavior



If the program works for input A, it will probably work for input B

Boundary Testing

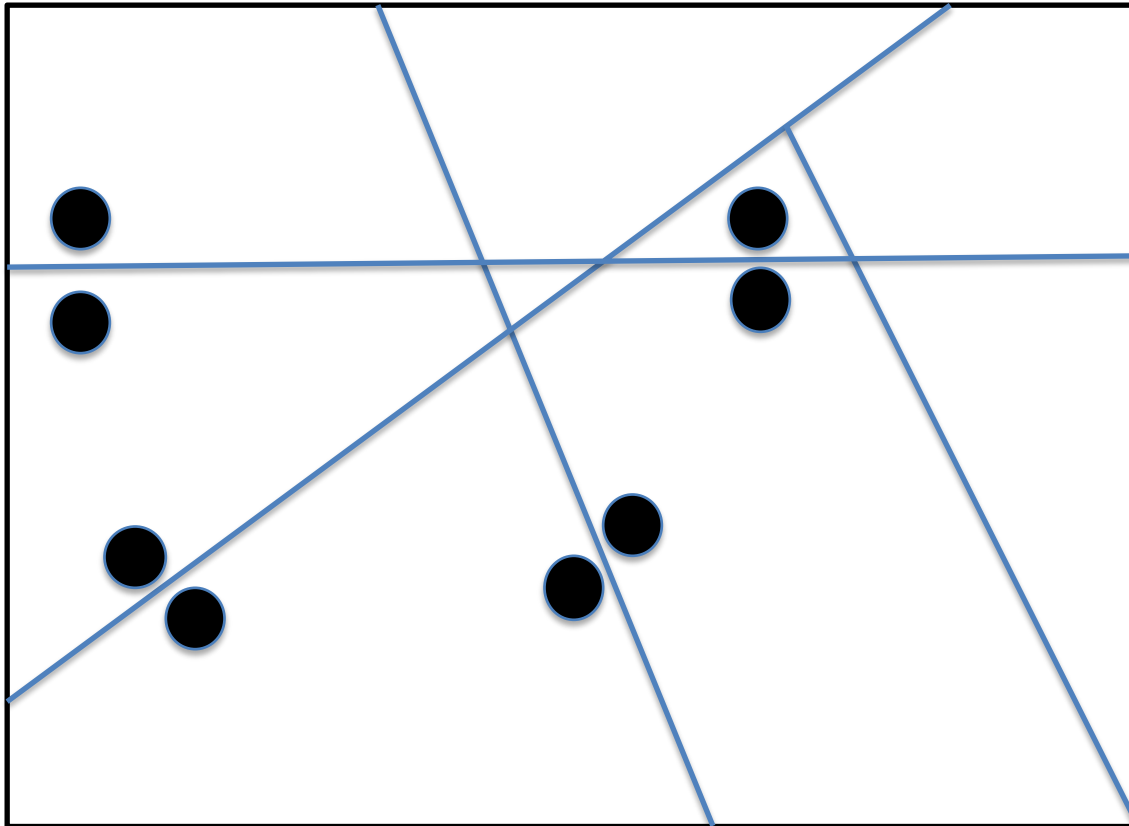
- Want to make sure that the boundaries between these equivalence classes are in the right place.
- Example: int-square-root
  - `(int-square-root 24) = 4`
  - `(int-square-root 25) = 5`
  - `(int-square-root 26) = 5`
  - `...`
  - `(int-square-root 35) = 5`
  - `(int-square-root 36) = 6`

boundary

boundary

Boundary Testing

Regions of similar behavior



Mechanics of Testing

- We will give you a file called **extras.rkt** that you should put in the folder with your work.
- Near the top of your file, write

```
(require rackunit)
(require "extras.rkt")
```

to load our testing framework.

- Tests live in the file with the code
- That way they get run every time the code is loaded
  - This accomplishes regression testing.
- Wrap your tests in **`(begin-for-test ....)`**
  - that way you can put the tests anywhere in your file, and they will be run at the end of the file

Choosing test cases

- We'll concentrate on the equivalence partitioning.
- The first step in choosing test cases is to divide your program into equivalence partitions.
- Then give mnemonic names to the input and output values in each partition. You can put these definitions with your data definitions, so you can use the names in your examples.

Testing ball-after-mouse

- For ball-after-mouse, we decided there were 12 partitions: 3 mouse events, 2 points (inside or outside the ball), and 2 balls (selected or unselected).
- So we create two balls at position (20,30), with radius 10, one unselected and one selected, and define two points, one inside the ball and one outside.

Example (1)

```
;; two balls at (20,30), one unselected and one selected
(define ball-unselected (make-ball 20 30 10 false))
(define ball-selected   (make-ball 20 30 10 true))

;; (22,28) is inside the ball at (20,30)
(define point-inside-x 22)
(define point-inside-y 28)

;; (31,19) is outside the ball at (20,30)
(define point-outside-x 31)  ;; 20+10 = 30, so 31 is outside
(define point-outside-y 19)  ;; 30-10 = 20, so 19 is outside
```

The names of these values must be descriptive. Calling them **ball-1** and **ball-2** is not acceptable.

Example (2)

```
;; next we make two balls, one moved to the inside point
;; and one moved to the outside point.

;; When a ball is moved, it will stay selected, so we make
;; selected? true for both of these.

(define ball-moved-to-point-inside
  (make-ball point-inside-x point-inside-y 10 true))

(define ball-moved-to-point-outside
  (make-ball point-outside-x point-outside-y 10 true))
```

Example

```
(check-equal?
  (ball-after-mouse ball-unselected point-inside-x point-inside-y "button-down")
  ball-selected
  "button-down inside the ball failed to select it")

(check-equal?
  (ball-after-mouse ball-unselected point-outside-x point-outside-y "button-down")
  ball-unselected
  "button-down outside the ball did not leave it unchanged")
```

- check-equal? takes 3 arguments: the expression to be tested, the value we believe is the correct answer, and an optional string that is printed if the test fails.
- Supply an informative error message if you can. An uninformative error message, like “wrong answer” is worse than no message at all.

Testing Pitfalls

- DON'T just paste in the actual results of your function.
- Some functions may have more than one correct answer;
  - your tests should accept *any* correct answer, not just the one your solution happens to produce
  - will see how to do this later

Testing Pitfalls (2)

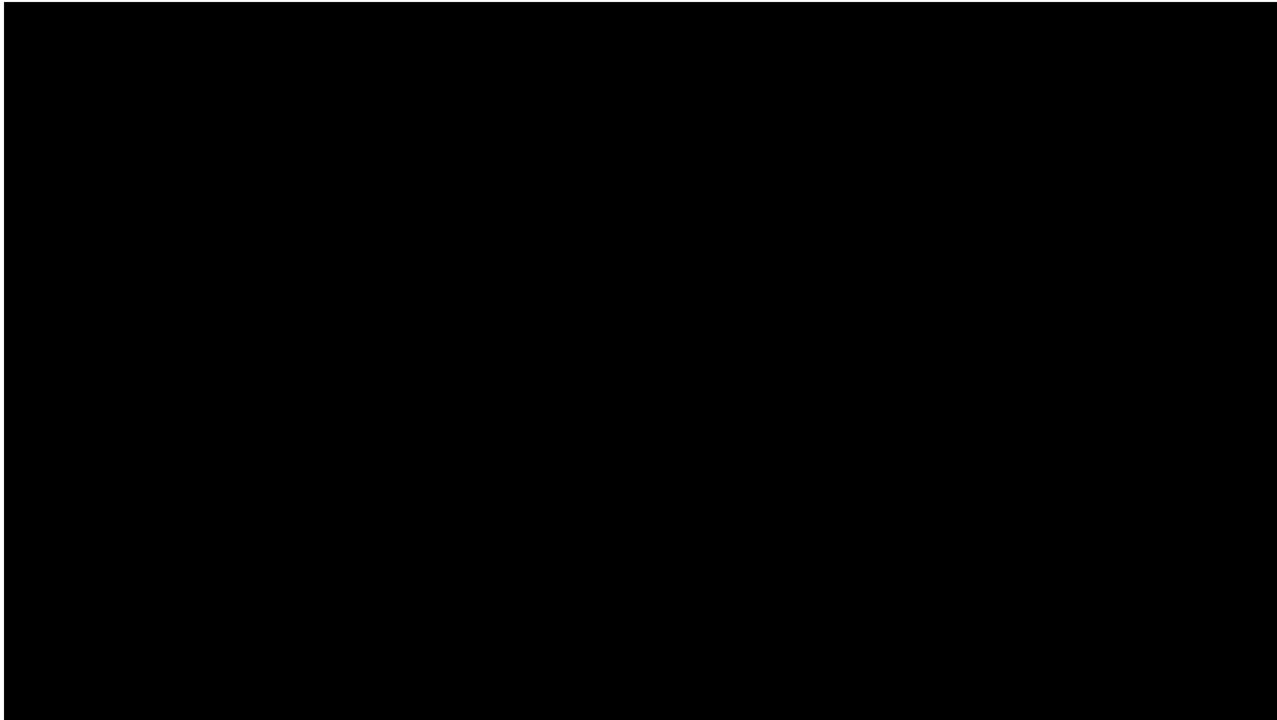
- Avoid coincidences in your tests, just as you did in your examples
- Bad:

```
(check-equal?
 (book-profit-margin
  (make-book "Little Lisper" "Friedman" 2.00 4.00))
 2.00)
```

- Better:

```
(check-equal?
 (book-profit-margin
  (make-book "Little Lisper" "Friedman" 2.00 5.00))
 3.00)
```

Video: ball-after-mouse-with-tests



YouTube link

Note: this video uses an older version of our testing technology. The details are a little different, but the principles are the same.

Using Tests

- Run your program with its tests
- Debug so that all your tests pass
- If you didn't achieve 100% expression coverage, go back and add more tests.
  - Just because your tests pass with 100% coverage doesn’t mean your program is right!
  - But 100% expression coverage is our standard for this course.
  - Your workplace may have different standards.

Tests Written?

- Once you've written the deliverables for the 6 steps of the design recipe, it's time to run the program.
- What could possibly go wrong?
- Let's make a short list...

What could go wrong?

- Program fails to load
  - unbalanced parens? The unmatched paren is highlighted in the interaction window.
  - missing function?
    - forgot to write definition
    - misspelled function name
    - forgot to **`require`** the library module
    - misspelled library name
      - *the error message Racket gives you in this case is especially scary. But don't be frightened. It just means that it couldn't find the library you told it to look for.*

What could go wrong? (2)

- You could get an error calling a Racket primitive.
  - eg: "can't apply string=? to 1"
  - this may be something simple, like the wrong test,
  - or it may be more subtle-- "how did I manage to pass a 1 to string=?"
  - Write more tests to see how you got to this.
    - We’ll see how to do this in a minute.

What could go wrong (3)

- A test fails
  1. Identify the test that failed
     - Racket will highlight the test that failed. Having an informative error message will also help you identify the test
  2. Check the test: is the answer that it asked for really the right one?
     - If not, fix the test
     - DON'T just paste in the actual results of your function.
  3. If the test is right, play detective by adding new tests.
     - Did your function call the right helper?
       - yes: test the helper
       - no: test the predicate

Example: Debugging by Testing

Imagine we have this function definition and this failing test.

Code:

```
(define (ball-after-mouse b mx my mev)
  (cond
    [(mouse=? mev "button-down")
     (ball-after-button-down b mx my)]
    [(mouse=? mev "drag") (ball-after-drag b mx my)]
    [(mouse=? mev "button-up") (ball-after-button-up b mx my)]
    [else b]))
```

Failing Test:

```
 (check-equal?
    (ball-after-mouse
      ball-unselected point-inside-x point-inside-y
      "button-down")
    ball-selected)
```

This test checks the *combination* of **ball-after-mouse** and **ball-after-button-down**. If it fails, either procedure might be at fault.

Debugging by Testing (2)

```
(check-equal?
  (ball-after-mouse
    ball-unselected
     point-inside-x point-inside-y
    "button-down")
  (ball-after-button-down
    ball-unselected
    point-inside-x point-inside-y))
```

On a button-down, we were supposed to call **ball-after-button-down**. So let's create a test to see if that happened.

We know that **ball-after-button-down** was supposed to be called, so these two expressions should return the same thing, even if it's the wrong thing. So if this test fails, we know that **ball-after-mouse** didn't call ball-after-button-down correctly. If the test succeeds, we know that **ball-after-button-down** was called, but it is returning the wrong thing, because the test on the previous slide is still failing.

Test fails: problem is in **ball-after-mouse**

Test succeeds: problem is in **ball-after-button-down**

Tracking down your bug

```
(define (ball-after-button-down b mx my)
  (if (inside-ball? mx my b)
    (ball-make-selected b)
    b))

(check-equal?
  (ball-after-button-down
    ball-unselected
    point-inside-x point-inside-y)
  (ball-make-selected ball-unselected))
```

Let's imagine we've identified **ball-after-button-down** as the likely culprit. We could write another test to see whether **ball-after-button-down** is calling **ball-make-selected** correctly.

Test succeeds: problem is in **`ball-make-selected`**

Test fails: problem is in **`inside-ball?`**

What else could have gone wrong?

- You could have called your help function with the wrong arguments.
- You can use the same techniques to identify this.

Keep your bug from re-appearing

- Leave the extra tests in your file
- That way if your bug reappears you will have the detective work all set up.

Disclaimer

- Our presentation has been specific to Racket and to this course, but the ideas and techniques are adaptable to other settings and other languages.
- Your employer may have different conventions for managing tests.
- If your employer does not have conventions for systematic testing, you should urge him (or her) to introduce one.

Next Steps

- Study 02-6-ball-after-mouse-with-tests.rkt .
- If you have questions or comments about this lesson, post them on the discussion board.
- Go on to the next lesson.