VE280 Programming and Elementary Data Structures

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Testing

IF WE BUILD OUR SOFTWARE WITH NO BUGS, WE CAN MAKE A 10% RETURN ON OUR INVESTMENT.
10%
BUT IF WE DO A POOR JOB, WE CAN MAKE A 40% RETURN BY SELLING UPGRADES AND SERVICE.
BUT DON'T WORRY. WE ONLY HAVE THE BUDGET FOR A POOR JOB.
I CAN'T REMEMBER IF WE'RE CHEAP OR SMART.
PHEW!
Dilbert.com DilbertCartoonist@gmail.com
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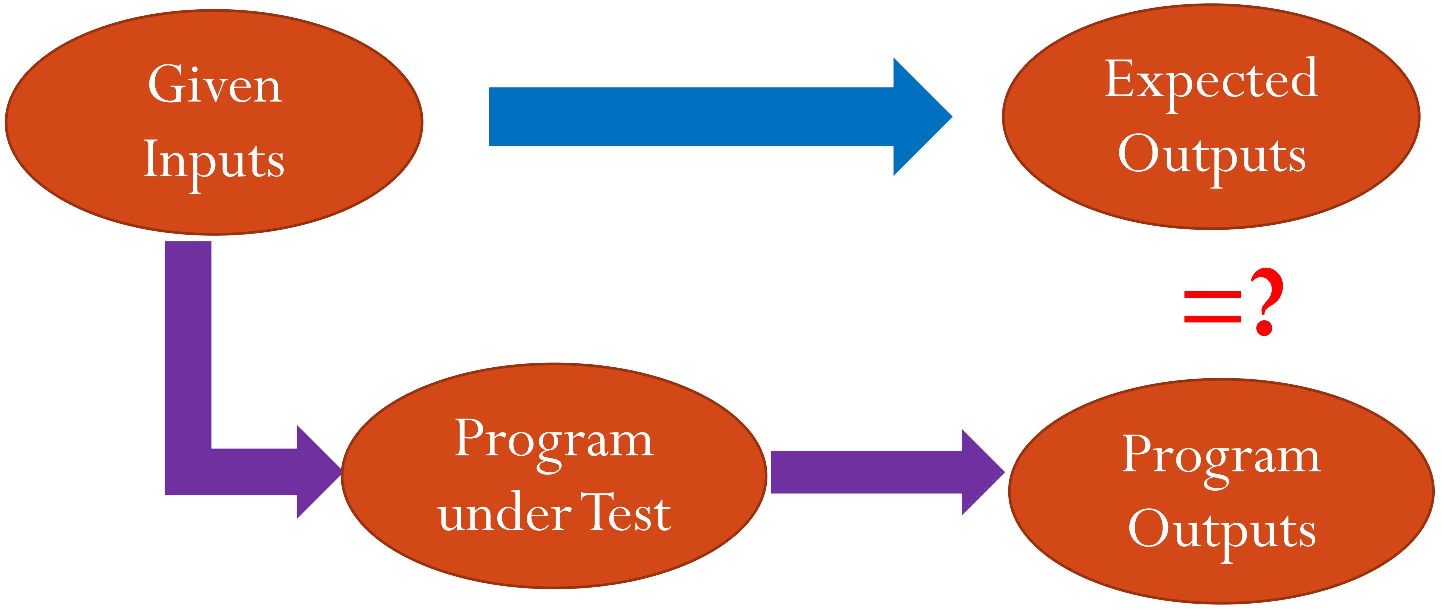
Learning Objectives

- Understand the importance of testing
- Know how to test your code
- Understand the difference between testing and debugging
- Know how to write unit tests and automate tests
- Know how to debug

Testing


Given Inputs
Expected Outputs
=?
Program under Test
Program Outputs

Testing
It's important!

- Be skeptical.

- Typically, the difference between a good and bad score on a project doesn't have much to do with your talent as a programmer. **It has much more to do with your talents as a tester!**

- Testing is not the same as debugging
  - Debugging: **Fixing** something once you know it's broken.
  - Testing: **Discovering** that something is broken.

Testing

It's important!

- Some tips and truths about being a good tester:

1. Convince yourself that the code is broken.
2. Be in an adversarial frame of mind.
3. NEVER REST and must ALWAYS BE DILIGENT, because the code is NEVER FINISHED!
4. Everyone makes mistakes, and one essential nature of a mistake is that the person who made it didn't realize it was wrong – you thought it was perfect!

Testing

End-to-end vs. incremental testing

- End-to-end testing is not a good idea
  - Errors made early tend to be pervasive and fixing them requires re-writing a large fraction of the existing program
  - Putting off testing until the program is "finished" increases your workload

- Instead, **test individual pieces of your program (such as functions) as you write them**
  - This is **incremental testing**

Incremental Testing

The better type of testing

- There are two advantages of incremental testing:

1. You are testing smaller, less complex, easier to understand units.
2. You just wrote the code, so you have a firm expectation of what it should do. If it's broken, it is fresh in your mind, so you can more easily fix it.

- This will often require you to write extra code (**the driver program**) to test your program effectively. However, this is usually time well spent.

Five Steps in Testing

- To test some piece of code (either a component or a whole piece):

1. Understand the specification
2. Identify the required behaviors
3. Write specific tests
4. Know the answers in advance
5. Include stress tests

Five Steps in Testing

1. Understand the specification

- For an entire assignment, read through the specification very carefully, and make a note of everything it says you have to do – and stay away from the computer ☺
- Since you have to break down the solution into (smaller) constituent parts, you must write the specifications for these parts.

- Sometimes your program as a whole may not work correctly, because you misunderstand the specification.

Five Steps in Testing

2. Identify the required behaviors

- For any specification, boil the specification down to a list of things that must happen.
- These are the "**required behaviors**" and a correct implementation **must exhibit all of them**.

Example: you are asked to write a command-line program called `fact` which takes one argument and calculates the factorial of the argument

Required behaviors

- If there is no argument, output "missing argument"
- If there is more than one argument, just work on the first, ignoring the remaining
- If the argument is not an integer, report "non-integral value"
- If it is a negative integer, report "negative integer"
- If it is 0, output 1
- If it is positive integer n, output n!

Five Steps in Testing

3. Write specific tests

- For each of your required behaviors, write one or more test cases that check them.

- To the extent possible, the test case should check **exactly** one behavior – no more!
  - That way, if the case fails, you know where to start looking.

Five Steps in Testing

3. Write specific tests

- There are three classes of test cases that make sense:
  - **Simple inputs**
  - **Boundary conditions**
  - **Nonsense**
- Simple cases are those that are “normal” for the problem at hand.
- “Boundary” cases are at the edges of what is expected, or formed to exploit some detail of implementation.
- “Nonsense” cases are those that are clearly unexpected.

Example: Testing Factorial Function

Assume use `cin` to get the input

- Simple inputs
  - An integer >= 1
- Boundary conditions
  - Value 0
- Nonsense
  - Negative values or non-integer values

What are examples of cases for testing the power number?

An integer is called a power number if it equals m^n, where $m \geq 1$ and $n \geq 2$ are both integers.

Select all the correct answers for simple inputs.

- **A.** -1
- **B.** 0
- **C.** 1
- **D.** 1 234 567 890

What are examples of cases for testing the power number?

An integer is called a power number if it equals m^n, where $m \geq 1$ and $n \geq 2$ are both integers.

Select all the correct answers for boundary conditions.

- **A.** -1
- **B.** 0
- **C.** 1
- **D.** 1 234 567 890

What are examples of cases for testing the power number?

An integer is called a power number if it equals m^n, where $m \geq 1$ and $n \geq 2$ are both integers.

Select all the correct answers for nonsense cases.

- **A.** -1
- **B.** 0
- **C.** 1
- **D.** 1 234 567.890

Five Steps in Testing

4. Know the answers in advance

- Instead of quickly running test cases and glancing at the output:
  - First write down what you expect to be a correct answer.
- If the result differs in **any** way from what you expected, try to figure out why.
- It's possible that your **expectation** had been wrong…or your **implementation** is incorrect.
- However, doing this ABSOLUTELY REQUIRES that you understand the specification.
  - If you don't, you will create an incorrect solution that satisfies your incorrect expectation!

Five Steps in Testing

5. Include stress tests

- Once you've tested each individual behavior, it's time to test all of them in concert.
- For this, you want **large** and **long running** test cases.
  - They must be **large**, to exercise resource limits in your program.
    - E.g., some web applications need to be tested under a large amount of simultaneous accesses.
  - They must be **long running**, because some errors are the result of lots of little bugs that individually don't matter much, but as they cascade produces catastrophic results.
    - E.g., the accumulation of the round-off error
    - E.g., the memory leakage

Testing

The joys of automation

- As you develop test cases for some code, it pays to write **other** programs that **automatically** test the code using those test cases.

```
for each test case ti {
   run your program on ti
   compare output with expected output
}
```

- This is important because, as the number of test cases grows (and the hour grows late) people get tired, and start to make mistakes.
- Computers, however, never get tired, so take advantage of this.

Testing

The joys of automation

- Once you have your test programs, every time you change even the smallest part of your code, you can go back and test all of the behaviors. This is also referred to as **regression testing.**

General Debugging Techniques

- Using `cout` or better `clog`
- Using a debugger, such as gdb
- Using the `assert` function
  - The `assert` function is a special function, defined in `<cassert>`, which takes a Boolean argument.
  - If the argument is **true**, `assert()` does nothing.
  - If the argument is **false**, `assert()` causes your program to stop, printing an **error message** to the `cerr` stream.

Using Assert Function

- `#include <cassert>`
- `assert` for the condition that should hold.
  - Example: In testing function `int min(int a, int b)`, assert that the return value is the smaller one.

```
int smaller = min(a, b);
assert(smaller <= a && smaller <= b);
```

Can you improve this?

Disable Assert

- Note that things to be asserted might be expensive.
  - `assert(very_expensive_func());`
- If it is, you can disable it, by compiling with the NDEBUG preprocessor variable.
- There are two ways to do this:
  1. Define it **before** including `<cassert>`:

     ```
     #define NDEBUG   // disable assert()
     #include <cassert>
     ```

  2. Specify it on the command line of the compiler:

     ```
     g++ -DNDEBUG ...
     ```

     -DMARCO: Define a MARCO for you code

     Same as putting “#define MARCO” in your code
- This way, you can turn it off for "production" code, but leave it in during development and testing.

Exploiting NDEBUG for debugging

- Using #ifndef, we can write conditional code like this:

```
 void fun(…){
 …
     #ifndef NDEBUG
     cerr << __func__ << ": var=" << var;
     #endif
 …
}
```

- Var. `__func__` defined by compiler holds function’s name
- Other useful variables:
  - `__FILE__` name of current file
  - `__LINE__` current line number

Reference

- Test-driven development and unit testing
  - http://alexott.net/en/cpp/CppTestingIntro.html