

Announcements

- Program #2
 - Due TODAY at 8pm
- Reading
 - Notes (Today)
 - Notes (Thursday)
- Dr. Hollingsworth's Thursday Office hours
 - will not be held this week

Testing

- Why Test Software
 - Find bugs in the implementation
 - Find bugs in the specification
- Testing is a major part of Software Development
 - Around 50% of time in many systems are spent on testing
 - For life critical software, can be 3-5 times development
- Testing Process
 - Execute a program with the intent of finding an *error*.
 - Run special code (or inputs) called a test case.
 - Goal is that each new test should increase likelihood of finding a yet undiscovered bug.

What do we try to test?

- Normal Cases

- Does the program work on good inputs/parameters
 - Does it not crash?
 - Does it perform as expected?
- Generally the easiest type of test to write

- Error Cases

- Does the program work on bad inputs/parameters?
 - Debugged software should never crash.
 - What happens **after** an error (can we continue)?
- Often most bugs lie in this part of the code
 - Many infrequently executed cases

- Environmental Errors

- Often very hard to test
- Examples: Computer out of memory, disk drive removed

Tests are an integral part of the software

- Write Tests as you write software
 - Don't wait until code is done to write tests
 - Sometimes write test code **before** software
 - Test each function/method as you write it
- Tests code can be big
 - Sample Project:
 - Dyninst 133,000 lines, 16,000 lines of testing code
- When the software is “done”, tests continue as part of it
 - Need to be able to re-test when code changes
 - Need to validate code on new platforms
 - Sometimes even individual systems

White Box Testing

- Examine Statements of a Program
 - Look for places errors can occur
 - Writes tests cases designed to have program run all possible combinations
- Try to get maximum **coverage** of a test and test suite
 - Coverage can be expressed in:
 - Lines of a program (statement coverage)
 - Control points in a program (branch coverage)
 - Sequences of statements (path coverage)
 - Try to write minimum set of tests to achieve
 - Acceptable coverage level
 - 100% coverage rarely possible

Examples of Statements and How to Test

- If then else
 - Are all cases run?
- Loops
 - Inputs that run the loop:
 - Not at all
 - Only one time
 - Two times
 - A large number of times
 - Test all possible termination conditions
- Assignment statements
 - With range of possible values
 - For ints: positive, negative and 0

Black box testing

- Test Program based on specifications
 - Does it perform as expected
 - Don't examine how it does the job, just does it do it?
- Try to look for:
 - Incorrect or missing functions
 - Interface errors
 - Errors in data structures or external database access
 - After the calls is the file/db correct?
 - Performance errors
 - Timing specs can be as critical as correctness specs
 - Initialization and termination errors
 - Is all memory initialized before its value is tested?
 - Is all allocated memory freed?

Notes on Testing

- Often Tests may be hybrid of white/black box
 - Example: Test cases for project #1B
 - Really designed as black box tests for students
 - After sample solution, initial test cases
 - Look at sample solution for un-tested items
 - Added additional test cases to increase coverage
- Can spend near infinite amounts of effort on testing
 - Concentrate on tests that demonstrate a wide variety in categories of problems
- Approach with the mindset:
 - What ever can go wrong will go wrong

Tools To Aid in Testing

- Test Harness Tools

- Environment for running functions or methods
- Allows small bits of code to be run without entire system
- Example: Junit
- Can sometimes even be hardware built for this
 - Example: simulator for testing cell phone hardware

- Code Coverage Tools

- Instrument program to measure what runs
- Run program on a set of tests
- Report on what was run and what was not run:
 - Can be at the statement, line, branch, or path level

- C-language code feature

- `assert(ptr != NULL)`
- if the asserted condition is false, then the program will give an error message and the program will terminate

Using Icov

- One example of a Statement Coverage tool
- Steps:
 - Compile program with flags `-fprofile-arcs -ftest-coverage`
 - Run programs on test cases
 - `lcov -c -d . -o coverage.out`
 - `genhtml coverage.out`
 - Creates `index.html` file in current directory

Demo of Icov viewer

- Coverage of Tests on project #1B
- Drilling down from summary to individual files
- Looking at a given statement
 - Notice coverage counts for individual statements

Process of Writing Test Cases

- Figure out what to test
- Write code to setup conditions for test
 - For example, call init API functions as needed
- Invoke routines to be tested
- Write Code to verify desired property
 - Example: Does the table have the correct items?
- Tricky Issues:
 - How to keep the tests small
 - How to test what you want to and not other things
 - Does an insert test depend on lookup working?

Example: Public Test #0 from P2

```
int main()
{
    int ret;
    char *ptr;
    int errorCount=0;
    assocTable *table;

    table = createTable(4);
    if (!table) {
        printf("ERROR: unable to create a table\n");
        exit(-1);
    }

    ptr = lookupTable(table, "foo") ;
    if (ptr) {
        printf("ERROR: found non-existent element foo in table\n");
        errorCount++;
    }

    ret = addTableItem(table, "foo", "bar");
    if (ret != 0) {
        printf("ERROR: AddTableItem returned an error\n");
        errorCount++;
    }

    ptr = lookupTable(table, "foo") ;
    if (!ptr || strcmp(ptr, "bar")) {
        printf("ERROR: unable to find element bar in table\n");
        errorCount++;
    }

    if (errorCount) {
        printf("Test simpleOps failed: %d sub-tests failed\n", errorCount);
        exit(-1);
    } else {
        printf("Test simpleOps passed\n");
        exit(0);
    }
}
```

Building a Test Suite

- API:

- Int createEmployee(char *lastName, char *firstName);
 - Return unique id for that employee
- Int lookupEmployee(char *lastName, char *firstName, int *id);
 - Return 0 on success, -1 on failure (not found or > 1 match)
 - Fills out id on success
 - firstName can be null
- Int deleteEmployee(int id);
- Int setSalary(int id, float salary);

Possible Test Cases

- `Int createEmployee(char *lastName, char *firstName);`
 - Pass valid data
 - Pass same last name, different first name
 - Pass same last name, first name same as previous
 - Pass null for lastName and/or for firstName
 - Pass an lastName/firstName that has 10MB before null termination.
 - Create 10,000 employees

Test Cases Continued

- `Int lookupEmployee(char *lastName, char *firstName, in *id);`
 - Call before inserting anyone
 - Lookup someone that was created
 - Lookup someone with the same lastname, but different firstName
 - Lookup null last/first names
 - Pass id as null
- `Int deleteEmployee(int id);`
 - Pass valid id
 - Pass invalid id
 - Pass id of someone who has just been deleted
- `Int setSalary(int id, float salary);`
 - Invalid id
 - Negative salary