CSE2031 Software Tools - Testing and C (cont.)

Summer 2010

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May 11, 2010

What we did last time

Overview of C

- Introduction to the language
- Program structure
- Types in C
- Operators in C
- IO and Files in C

Overview of UNIX

- Why UNIX?
- Philosophy of UNIX
- Structure of UNIX

What we will do today?

Plan

Why Tests?

- 1990 AT&T long distance calls fail for 9 hours
  - Wrong location for C break statement
- 1996 Ariane rocket explodes on launch
  - Overflow converting 64-bit float to 16-bit integer
- 1999 Mars Climate Orbiter crashes on Mars
  - Missing conversion of English units to metric units
- Therac: A radiation therapy machine that delivered massive amount of radiations killing at leaset 5 people
  - Among many others, the reuse of software written for a machine with hardware interlock. Therac did not have hardware interlock.

Idea of testing

- Testing is getting sure your code is correct (no bugs).
- In reality, you can only detect the existence of bugs, not their absence (Dijkstra).
- Multiple runs of code using different inputs.

Unit tests

- Do not wait till you complete the program to test it, test every piece that you write (function, block, if,)
- If you wait until something breaks, you probably have forgotten what the code does.
- It takes time because sometimes additional work has to be done i.e. stub

Testing

What do you need for testing?

- The code you want to test
- Some inputs
- What is the "correct" output of the above inputs, so you can compare.

Test Coverage

Did you cover every statement in the code?

Random input

- Random inputs to the program
- Easy to do
- Without a statistical framework, the results are meaningless.

Black-box

- No knowledge of the implementation (code)
- Test based on the specifications.
- Tests prepared before implementation.
- Tests prepared by some one else other than the person who will write (wrote) the code.
- May not test every path in the program!

Glass-box

- Full knowledge of the program.
- Test cases should test (cover) all different paths in the program.

```
if( a> b) {
    x=...;
    if( c>=d) {
        x=...;
        y=...;
    }
        else {
        ....
        }
    else {
        .....
    }
}
```

Over and over again

- When you fix a bug, you may introduce another bug.
- When you fix a bug, you may break another fix
- When you create a test, keep it
- When you fix a bug, apply all previous tests

Boundary conditions testing

Example

What is the boundary condition?
How can we identify boundary conditions?

Pre- and Post-conditions

Preconditions

Check if the input is correct

Postconditions

Check if your output is correct

Assertions

- You can use assertion facilities in `<assert.h>`
- Use it only when the failure is really unexpected and there is no way to recover (however you may use it to test pre-, post-conditions and loops' invariants)
- `assert (n>0);`
  If that is not true, the program terminates with a message saying the assertion failed.

Example

Lets consider the GCD

Plan

Functions and Scope

Functions

- Brake large computing tasks into smaller
- Can be *reused*

Scope

Where the name can be used/visible?

Function – basics

Limitations of human perception

Human usually can focus on 5+/-2 elements

Brake complex tasks into smaller

During the design stage try to separate small tasks that may be implemented as single function.

Simple rule

Try to fit the function on one screen

Definition and Declaration

Declaration

```
returned_type function_name(list_of_arguments);
```

Definition

```
returned_type function_name(list_of_arguments)
{
    declarations and statements
}
```

Return statement

```
return expression;
```

".c", ".h", ".o"

Header ".h"

- System header files declare the interfaces to parts of the operating system.
- Your own header files contain declarations for interfaces between the source files of your program.
- Including a header file produces the same results as copying the header file into each source file that needs it.
- In C, header files names end with *.h*. It is most portable to use only letters, digits, dashes, and underscores in header file names, and at most one dot.

Body ".c"

Contains includes of headers and definitions of functions.

Object ".o"

Object files are compiled from the source+header files. We can have program divided into several "modules". All modules then can be compiled separately and linked later into the one executable.

Return

- Function uses *return* statement to return the result to the caller
- Functions can return arbitrary type: void, int, double, pointer (to the variable or function) etc
- Inconsistent expression will be casted to the *returned_type* of the function

External variables

Internal variables

Defined inside of the function body and exists only when the function is executed

External objects

- External variables and function are defined outside of any function.
- External variables may be used as a tool to communicate between functions

Too many externals is not good

Important!

Do not misuse external definitions (global variables)!

Problem with externals

- Everyone can access the variable (like *public* member in Java)
- Low level of control
- Too many externals leads to bad program structure with too many data connections between functions (problem with reusing)

Scope - Definition

Following questions should be answered:

- How to write declarations so that variables are properly declared during compilation?
- How are declarations arranged so that all the pieces will be properly connected when program is loaded?
- How are declarations organized so there is only one copy?
- How external variables are initialized (so that all of them are initialize once)?

Scope – Definition

Scope is a part of the program within which declared name can be used

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Scope – Definition

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Extern declaration

If we want to use the variable before it's definition or in other file then `extern` declaration is required.

file1.c

```
extern int size;
extern char buf[];
```

file2.c

```
int size = SIZE;
char buf[SIZE];
```

Static Variables

Declaration `static` allows us to restrict the visibility (scope) of the variable (hide).

file1.c

```
static int size = SIZE;
static char buf[SIZE];
```

file2.c

```
static int size = SIZE;
static char buf[SIZE];
```

Static variables – Example

Register

Just a suggestion

Declaration `register` is a suggestion or advice addressed to the compiler that the variable will be often used and should be placed in the machine register (fast access).

Restrictions

- Size of registers
- Number of registers
- Size of type

Blocks and Declarations

- Variables can be defined in the beginning of the block:
  - function
  - compound statement (just after the left brace {)
- inner declaration hides outer declaration
- automatic variables (i.e. parameters) hides external variables

```
int i=1;

if (i>0)
{
    int i;
    for(i=0;i<MAX;i++)
    {
        ...
    }
}
```

Initialization

In absence of explicit initialization:

- external and static variables are initialized to be zero;
- automatic and register variables have undefined value (garbage!!!)

How to do it?

- external and static – needs constant expression, done once before program runs;
- automatic and register – initializer not restricted, done each time the block is entered;
- arrays – are initialized by the list of members

```
int x = 0;
int array_x[]={1, 3, 10, 11, 15};
char txt1[] = "text";
char txt2[] = {'t','e','x','t','\0'};
```

Recursion

Definition

Calling the function by itself directly or indirectly

```
/*
 * recursive GCD
 */
int gcd(int m, int n)
{
    /* base case(s) m or n equals 0*/
    if (m == 0)
        return(n);
    if (n == 0)
        return(m);

    /* now recurse */
    return(gcd(n, m % n));
}
```

Recursion – Example

Include

`#include "file"` or `#include <file>`

- includes content of file during the compilation
- when file is quoted (""") searching for the file begins in the dir where source program is
- if it is not found there or it is surrounded by "<" and ">" implementation defined rule is used to find included file (in in specified directory)
- includes may be cascade (included file may contain another includes)
- when included file changes all dependent source files (that have included it) should be recompiled

Define

```
#define name replacement_text
```

How it works?

Subsequent occurrences of `name` will be replaced by the `replacement_text`.

How to build it?

- Name has the same form as variable name
- replacement text usually is the rest of the line, but long texts can be continued in multiple lines with \ at the end of the line
- it is done for tokens – quoted strings are not processed
- name can have parameters

Define – Example


```
#define MAX_SIZE 100
#define MAX(A,B) ((A)>(B)?(A):(B))
#define FOREVER for(;;) /*infinite loop*/
#define dprint(expr) printf(#expr "=␣%g\n", expr)
```

Conditional inclusion

Conditional inclusion provides us a way to control preprocessing and to include code selectively.

#if, #elif, #else and #endif

`#if` evaluates constant integer expression (except sizeof, cast and enum constants) if this expression is non-zero then subsequent lines are included until `#elif`, `#else` or `#endif`.

defined(name)

This expression has a value 1 if the name has been defined or 0 otherwise #ifdef *name* and #ifndef *name* can be used instead of #if defined(*name*) and #if !defined(*name*) respectively

Conditional inclusion – Example

What have we done today?

1. Introduction to Tests
   - Random tests
   - Black-box tests
   - Glass-box tests
   - Regression tests
   - Boundary conditions testing
   - Pre- and Post-condition testing
   - Assertions
   - Example
2. C-continuation
   - Functions
   - Scope
   - Preprocessor

Next time

[KR] Chapter 5

- Arrays
- Pointers