Operating Systems Exercise 1

Georgios Georgiadis
Negin F.Nejad

Prelude

- We do **not** teach programming
  - Take a course
- We do **not** teach C
  - Read a book
  - *The C Programming Language*, Kernighan, Richie
- This is a brief tutorial on C's traps and pitfalls
  - For those that already know C programming
  - "*C Traps and Pitfalls*", Andrew Koenig, Addison-Wesley 1989 (link at course's webpage)

C Traps and Pitfalls

The C language is like a carving knife: simple, sharp, and extremely useful in skilled hands. Like any sharp tool, C can injure people who don't know how to handle it.

Andrew Koenig

Overview

- Declarations and Definitions
- Memory Allocation
- Pointers and Arrays
- Lexical Pitfalls
- Syntactic Pitfalls
- Semantic Pitfalls

Declarations and Definitions

- We can declare something without defining it
  - But we cannot define it without declaring it.
- The confusing part is that the definition will repeat the declaration specifications.

Declarations and Definitions

- A variable declaration specifies its name, and type.

```
extern int x;
```

- A function declaration specifies its name, and the types of its input parameters and its output parameter.

```
int foo(int x);
extern int foo(int x);
```

- A data structure declaration specifies its type and format.

```
struct LENGTH {
  unsigned int yards;
  unsigned int feet;
  unsigned int inches;
};
typedef struct LENGTH len;
```


Declarations and Definitions

- A function definition specifies the exact sequence of operations to execute when it is called.

```
int foo(int x) {return 1};
```

- A data structure definition will reserve space in memory for it.

```
len length;
```


Memory Allocation

- **Static/global allocation**
  - Each static or global variable defines one block of space, of a fixed size.
  - The space is allocated once, when your program is started (part of the exec operation), and is never freed.
- **Automatic allocation**
  - Such as a function argument or a local variable.
  - The space for an automatic variable is allocated when the compound statement containing the declaration is entered, and is freed when that compound statement is exited.
  - The size of the automatic storage should be a constant.
- **Dynamic Memory Allocation** – not covered.

Example

```
#include ...
int i;
 /* i is static, and visible to the entire
 program */

extern j;
 /* j is static, and visible to the entire
 program */

static int k;
 /* k is static, and visible to the routines
 in this source file */
```


Example

```
void func (void) {   /* no arguments, doesn't return value */
  int m = 1;         /* automatic, local, initialized each time */
  auto int n = 2;    /* automatic, local, initialized each time */
  static int p = 3;  /* static, local, initialized once when the
                        program is first started up */
  extern int q;      /* static, defined in external module */
  for (i = 0; i < 10; i++) {
     int m = 10;     /* automatic, local to block, initialized
                        each time the block is entered */
    printf ("m = %i\n", m);
  }
}
```


What's Wrong?

```
int *func (void)
 {
 static int x;
 ...
 return &x;
}
int *x;
x = func();
x[0]++;
```

```
int *func (void)
 {
 int x;
 ...
 return &x;
}
int *x;
x = func();
x[0]++;
```

Warning: function returns address of local variable.

Overview

- Declarations and Definitions
- Memory Allocation
- **Pointer and Arrays**
- Lexical Pitfalls
- Syntactic Pitfalls
- Semantic Pitfalls

Pointers and Arrays

- The C notions of pointers and arrays are inseparably joined
- C has only one dimensional arrays, and the size of an array must be fixed as a constant in compilation time.
- However, an element of an array may be an object of any type.

Pointers and Arrays

- Only 2 things can be done to an array:
  - Determine size
  - Obtain a pointer to element 0 of the array.
- All other array operations are actually done with pointers even if they are written with what look like subscripts.

Pointers and Arrays some examples

- **`int a[3];`** /* says that a is an array of three `int` elements*/
- **`struct {`** /*says that b is an array of 17 elements of type struct*/

```
  int p[4];
   double x;
 } b[17];
```

- **`int calendar[12][31];`** /*array of 12 arrays of 31 int
  We note that sizeof(calendar) is 372 (=31*12) */
- **`int *ip;`** /* a pointer to int */
  `int i;` /* we can assign the address of i to ip by saying */
  `ip = &i;`
  and then we can change the value of i by assigning to *ip : */
  /* **`*ip = 17;`**

Pointers Arithmetic

- If a pointer happens to point to an element of an array, we can add/subtract an integer to that pointer to obtain a pointer to the next element of that array.
- But very different from integer arithmetic!
  `ip+1` does <u>NOT</u> point to the next memory location.
- If we have written
  `int *q = p + i;`
  then we should be able to obtain **`i`** from writing **`q-p`**.
- There is no way to guarantee even that the distance between **p** and **q** is an integral multiple of an array element!

Pointers Arithmetic

- `int a[3];`
  `p=a;`
  // a pointer to the first element of the array
  `p=&a;`
  // wrong! A pointer to an array assign to a pointer to int
- Does `sizeof(p)` equal to the `sizeof(a)`?
- `*a = 84;` sets the element 0 to 84
- `*(a+i)` is no different `a[i]`
- Since `a+i` equals `i+a` then `a[i]` and `[i]a` is the same. Also, `calendar[4][7]` <=> `*(calendar[4]+7)` <=> `*(*(calendar+4) +7)`

Overview

- Declarations and Definitions
- Memory Allocation
- Pointer and Arrays
- **Lexical Pitfalls**
- Syntactic Pitfalls
- Semantic Pitfalls

Lexical Pitfalls

- & and | are not && or ||
- = is not ==

```
if (x = y)
    foo();
```

```
while (c == ' ' || c = '\t' || c == '\n')
    c = getc (f);
```


Lexical Pitfalls

Instead of:

```
if (x = y)
    foo();
```

write:

```
if ((x = y) != 0)
    foo();
```

Avoiding C compiler's warning messages:

Assignment of y to x first and then checking its value, whether equals to 0 or not.

Lexical Pitfalls

Multi-character Tokens

- The next token of the input stream is taken to be the longest string of characters.
  - If a / is the first character of a token, and the / is immediately followed by a *, the two characters begin a comment, regardless of any other context.

Note: A token is a sequence of one or more characters that have a (relatively) uniform meaning in the language being compiled.

Lexical Pitfalls

`y = x/*p` /* p is a pointer to the divisor */;

Rewriting this statement as

`y = x / *p` /* p is a pointer to the divisor */;

or even

`y = x/(*p)` /* p is a pointer to the divisor */;

Lexical Pitfalls

- Older versions of C use =+ to mean what present versions mean by +=.
- Programmer intend to assign -1 to a:

`a=-1;` → as meaning the same thing as **`a =- 1;`** or **`a = a - 1;`**

Strings and Characters are Different!

- **Single** and **double quotes** mean very things in C language.
  - A character enclosed in single quotes is just another way of writing an integer.
    - The integer that corresponds to the given character in the implementation's collating sequence.
  - Thus, in an ASCII implementation, `'a'` means exactly the same thing as `0141` or `97`.

Strings and Characters are Different!

- A string enclosed in double quotes, is a short-hand way of writing a pointer to a nameless array.
- This array will be initialized with the characters between the quotes and an extra character whose binary value is zero.

```
printf ("Hello world\n");
```

Same as

```
char hello[] =
{'H', 'e', 'l', 'l', 'o', ' ',
'w', 'o', 'r', 'l', 'd', '\n', 0};
printf (hello);
```


Strings and Characters are Different!

Saying

```
printf('\n');
```

instead of

```
printf ("\n");
```

Is not the same

- Using a pointer instead of an integer (or vice versa) will often cause a warning message.

Strings and Characters are Different!

- Writing `'yes'` instead of `"yes"` is not the same!

- **`"yes"`** means "the address of the first of four consecutive memory locations containing y, e, s, and a `null` character, respectively."
- **`'yes'`** means "an integer that is composed of the values of the characters y, e, and s."

Strings and Characters are Different!

What are the following in C?

- `'0'`
- `"0"`
- `0`
- `NULL`
- `'\0'`

Strings and Characters are Different!

What are the following in C?

- `'0'` an integer value of a character
- `"0"` a string that encodes zero
- `0` the integer 0
- `NULL (#define NULL ((void *)0))`
- `'\0'` the first character of ASCII table, NULL

Overview

- Declarations and Definitions
- Memory Allocation
- Pointer and Arrays
- Lexical Pitfalls
- **<u>Syntactic Pitfalls</u>**
- Semantic Pitfalls

Syntactic Pitfalls – Type Cast

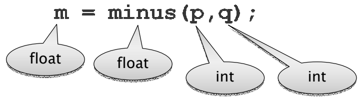
Is the following piece of code correct?

```
…
float minus(float a, float b){return a-b;}
…
int p,q;
float m;
…
p = 1;
q = 2;
m = minus(p,q);
```


Syntactic Pitfalls – Type Cast

- All variables and expressions in one statement should be of the same type.

```
m = minus(p,q);
```



- Although it may work, but the results may be unexpected.
- So, we need a type cast:

```
m = minus((float)p,(float)q);
```

Syntactic Pitfalls - Declarations

- **`float f, g;`**
  The expressions **f** and **g**, when evaluated, will be of type **`float`**.
- Parentheses may be used freely:
  `float ((f));`
  means that **`((f))`** evaluates to a **`float`** and therefore, by inference, that **f** is also a **`float`**.
- Similar logic applies to function and pointer types.
  `float ff();`
  means that the expression **`ff()`** is a **`float`**, and therefore that **`ff`** is a function that returns a **`float`**.

Syntactic Pitfalls - Declarations

- **`float *pf;`**

`*pf` is a **`float`** and therefore **`pf`** is a pointer to a **`float`**.

- **`float *g(), (*h)();`**

Says **`*g()`** and **`(*h)()`** are **`float`** expressions.

note:
`()` binds more tightly than `*`, `*g()` means the same thing as `*(g())`:
- **g** is a function that returns a pointer to a **`float`**.
- **h** is a pointer to a function that returns a **`float`**.

Syntactic Pitfalls - Declarations

- Knowing variable declaration allows us to write a cast for that type
- Remove the *variable name* and the *semicolon* from the declaration and enclose the whole thing in parentheses.
- **`float *g();`** declares `g` to be a function returning a pointer to a `float`
- **`(float *())`** is a cast to this type.

Overview

- Declarations and Definitions
- Memory Allocation
- Pointer and Arrays
- Lexical Pitfalls
- Syntactic Pitfalls
- **<u>Semantic Pitfalls</u>**

Operators Precedence

- Constant FLAG is an integer with exactly one bit turned on in its binary representation (in other words, a power of two),
- We want to test whether the integer variable flags has that bit turned on.

```
if (flags & FLAG) …
/*  if statement tests whether the expression in the parentheses
    evaluates to 0 or not. */
```

- More explicit if statement:

```
if (flags & FLAG != 0) …
```

- The statement is now easier to understand, however it is wrong!! because != binds more tightly than &, so the interpretation is now:

```
if (flags & (FLAG != 0)) …
```


Operators Precedence

- We have two integer variables, h and l, whose values are between 0 and 15,
- We want to set r to an 8-bit value whose low-order bits are those of l and whose high-order bits are those of h.

```
r = h<<4 + l;
```

- Unfortunately, this is wrong.
- Addition binds more tightly than shifting

```
r = h << (4 + l);
```

- Here are two ways to get it right:

```
r = (h << 4) + l;
r = h << 4 | l;
```


Operators Precedence

- To avoid these problems
  - Parenthesize everything
    - Problem! expressions with too many parentheses are hard to understand.
  - Try to remember the precedence levels in C!
  - Unfortunately, there are fifteen of them, so this is not always easy to do.
    - Classify operators into groups; subscripting, function calls, unary operators, etc.
    - *The C Programming Language*, Kernighan, Richie

Watch Those Semicolons!

```
if (x[i] > big);
   big = x[i];
```

The semicolon on the first line will not upset the compiler, but the code fragment means something quite different from:

```
if (x[i] > big)
   big = x[i];
```

The first one is equivalent to:

```
if (x[i] > big) { }
   big = x[i];
```

which is, of course, equivalent to:

```
big = x[i];
```

(unless x, i, or big is a macro with side effects).

Watch Those Semicolons!

- Forgotten semicolons!

```
struct foo {
    int x;
}
f()
{
 ...
}
```

- Semicolon missing between the first } and `f`
- The effect of this is to declare that the function `f` returns a `struct foo`, which is defined as part of this declaration.
- If the semicolon were present, `f` would be defined by default as returning an integer.

The Switch Statement

```
switch (color) {
case 1: printf ("red");
case 2: printf ("yellow");
case 3: printf ("blue");
}
```

Labels in C behave as true labels. Control can flow through a case label.

redyellowblue, yellowblue, blue

The Switch Statement

```
switch (color) {
case 1: printf ("red");
break;
case 2: printf ("yellow");
break;
case 3: printf ("blue");
break;
}
red, yellow, blue
```


The Dangling `else` Problem

```
if (x == 0) {
   if (y == 0) error();
else {
      z = x + y;
      f (&z);
   }
}
```

- The programmer's intention:
  - There should be two main cases: *x* = 0 and *x*<>0.
  - ***x* = 0 :** the fragment should do nothing at all unless *y* = 0, in which case it should call `error`.
  - ***x*<>0 :** the program should set *z* = *x* + *y* and then call *f* with the address of *z* as its argument.

The Dangling `else` Problem

- However, the program fragment actually does something quite different. Nothing at all will happen if `(x != 0)`.
- The reason is the rule that an `else` is always associated with the closest unmatched `if`.

```
if (x == 0) {
   if (y == 0)
      error();
   else {
      z = x + y;
      f (&z);
   }
}
```


The Dangling `else` Problem

- To get the effect implied by the indentation of the original example, we need to write:

```
if (x == 0) {
   if (y == 0)
      error();
  }
else
  {
      z = x + y;
      f (&z);
   }
```


Conclusion

- We discussed:
  - Declarations and Definitions
  - Memory Allocation
  - Pointer and Arrays
  - Lexical Pitfalls
  - Syntactic Pitfalls
  - Semantic Pitfalls
- Only some of C's pitfalls were discussed here.
- Now it's your turn!

Conclusion

- Study "*C Traps and Pitfalls*", Andrew Koenig, Addison-Wesley 1989 (link at course's webpage)
  - Contains many more pitfalls!
- If still uncertain, study "*The C Programming Language*", Dennis M. Richie, Brian W. Kernighan
  - In conjunction with some C code.
  - Google Code Search is a nice tool.
- Look for more tutorial at course's webpage.