CH-230-A

Programming in C and C++

C/C++

Lecture 6

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The C Preprocessor (1)

- Before compilation, C source files are being preprocessed
- The preprocessor replaces tokens by an arbitrary number of characters
- Offers possibility of:
  - Use of named constants
  - Include files
  - Conditional compilation
  - Use of macros with arguments

The C Preprocessor (2)

- The preprocessor has a different syntax from C
- All preprocessor commands start with `#`
- A preprocessor directive terminates at the end-of-line
  - Do not put `;` at the end of a directive
- It is a common programming practice to use all uppercase letters for macro names

The C Preprocessor: File Inclusion

- `#include <filename>`
  - includes file, follows implementation defined rule where to look for file, for Unix is typically `/usr/include`
  - Ex: `#include <stdio.h>`
- `#include "filename"` 
  - looks in the directory of the source file
  - Ex: `#include "myheader.h"`
- Included files may include further files
- Typically used to include prototype declarations

The C Preprocessor: Motivation for Macros (1)

- Motivation for using named constants/macros
- What if the size of arrays has to be changed?

```
1  int data[10];
2  int twice[10];
3  int main()
4  {
5    int index;
6    for(index = 0; index < 10; ++index) {
7      data[index] = index;
8      twice[index] = index * 2;
9    }
10   return 0;
11 }
```

The C Preprocessor: Motivation for Macros (2)

More generic program if using named constants/macros

```
1  #define SIZE 20
2  int data[SIZE];
3  int twice[SIZE];
4  int main()
5  {
6     int index;
7     for(index = 0; index < SIZE; ++index) {
8        data[index] = index;
9        twice[index] = index * 2;
10    }
11    return 0;
12 }
```

Works but it no type information is associated with macros, so using `const` for this problem is a better solution.

The C Preprocessor: Macro Substitution (1)

- Definition of macro
  - `#define NAME replacement_text`
- Any name may be replaced with any replacement text
  - Ex: `#define FOREVER for (;;)` defines new word FOREVER to be an infinite loop
  - Ex:

```
#define ODD(A, B) { unsigned char abit=A & 1;\
                    unsigned char bbit=B & 1; \
                    ... }
```


The C Preprocessor: Macro Substitution (2)

- Possible to define macros with arguments
  - `#define MAX(A, B) ((A) > (B) ? (A) : (B))`
- Each formal parameter (A or B) will be replaced by corresponding argument
  - `x = MAX(p+q, r+s);` will be replaced by
  - `x = ((p+q) > (r+s) ? (p+q) : (r+s));`
- It is type independent

Ternary operator: (condition) ? val1 : val2

if condition is true => val1. If false => val2

The C Preprocessor: Macro Substitution (3)

- Why are the `( )` around the variables important in the macro definition?
  - `#define SQR(A) (A)*(A)`
- Write a small program using this and see the effect without `( )` in `(A)*(A)` by calling `SQR(5+1)`
- Try also `gcc -E program.c` sends the output of the preprocessor to the standard output
- What happens if you call `SQR(++i)`?

The C Preprocessor: Macro Substitution (4)

- Spacing and syntax in macro definition is very important
- See the preprocessor output of the following source code

```
1 #include<stdio.h>
2 #define MAX =10
3 int main()
4 {
5   int counter;
6   for(counter =MAX; counter > 0; --counter)
7     printf("Hi there!\n");
8   return 0;
9 }
```

wrong_macro.c

The C Preprocessor: Macro Substitution (5)

- Defined names can be undefined using
  - `#undef NAME`
- Formal parameters are not replaced within quoted strings
- If parameter name is preceded by `#` in replacement text, the actual argument will be put inside quotes
  - `#define DPRINT(expr) printf(#expr " = %g\n", expr)`
  - `DPRINT(x/y)` will be expanded to
  - `printf("x/y" " = %g\n", x/y);`

The C Preprocessor: Conditional Inclusion (1)

- Preprocessing can be controlled by using conditional statements which will be evaluated while preprocessor runs
- Enables programmer to selectively include code, depending on conditions
- `#if`, `#endif`, `#elif` (i.e., else if), `#else`

```
1 #if defined(DEBUG)  // short: #ifdef DEBUG
2   printf("x: %d\n", x);
3 #endif
```

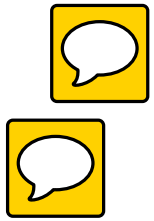
The C Preprocessor: Conditional Inclusion (2)

- `#ifdef`, `#ifndef` are special constructs that test whether name is (not) defined
- `gcc` allows to define names using the `-D` switch
- Ex: `gcc -DDEBUG -c program.c`
- Previous line is equivalent to `#define DEBUG`

The C Preprocessor: Conditional Inclusion (3)

- Write a small program in which you illustrate the use of conditional inclusion for debugging purposes
- Ex: If the name `DEBUG` is defined then print on the screen the message "This is a test version of the program"
- If `DEBUG` is not defined then print on the screen the message "This is the production version of the program"
- Also experiment with `gcc -D`

The Structure of a Header File with Conditional Inclusion



```
1  /* Student.h */
2  #ifndef _LIST_H
3  #define _LIST_H
4  struct list {
5    int info;
6    struct list *next;
7  };
8  void printList(struct list *);
9  struct list * push_front(struct list *, int);
10 ...
11 #endif // this matches the initial #ifndef
```

Bit Operations

- The bit is the smallest unit of information
  - Represented by `0` or `1`
- Eight bits form one byte
  - Which data type could be used for representation?
- Low-level coding like writing device drivers or graphic programming require bit operations
- Data representation
  - Octal (format %o), hexadecimal (format %x, representation prefix `0x`)
- In C you can manipulate individual bits within a variable

Bitwise Operators (1)

Power	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Decimal	128	64	32	16	8	4	2	1
Binary number	0	1	0	1	1	1	0	1

- Allow you to store and manipulate multiple states in one variable
- Allows to set and test individual bits in a variable

Bitwise Operators (2)

Operator	Function	Use
~	bitwise NOT	~expr
<<	left shift	expr1 << expr2
>>	right shift	expr1 >> expr2
&	bitwise AND	expr1 & expr2
^	bitwise XOR	expr1 ^ expr2
|	bitwise OR	expr1 | expr2
&=	bitwise AND assign	expr1 &= expr2
^=	bitwise XOR assign	expr1 ^= expr2
|=	bitwise OR assign	expr1 |= expr2

Bitwise and Logical AND

```
1  #include <stdio.h>
2  int main()
3  {
4     int i1, i2;
5     i1 = 6; // set to 4 and suddenly check 3 fails
6     i2 = 2;
7     if ((i1 != 0) && (i2 != 0))
8        printf("1: Both are not zero!\n");
9     if (i1 && i2)
10       printf("2: Both are not zero!\n");
11    // wrong check
12    if (i1 & i2)
13       printf("3: Both are not zero!\n");
14    return 0;
15 }
```

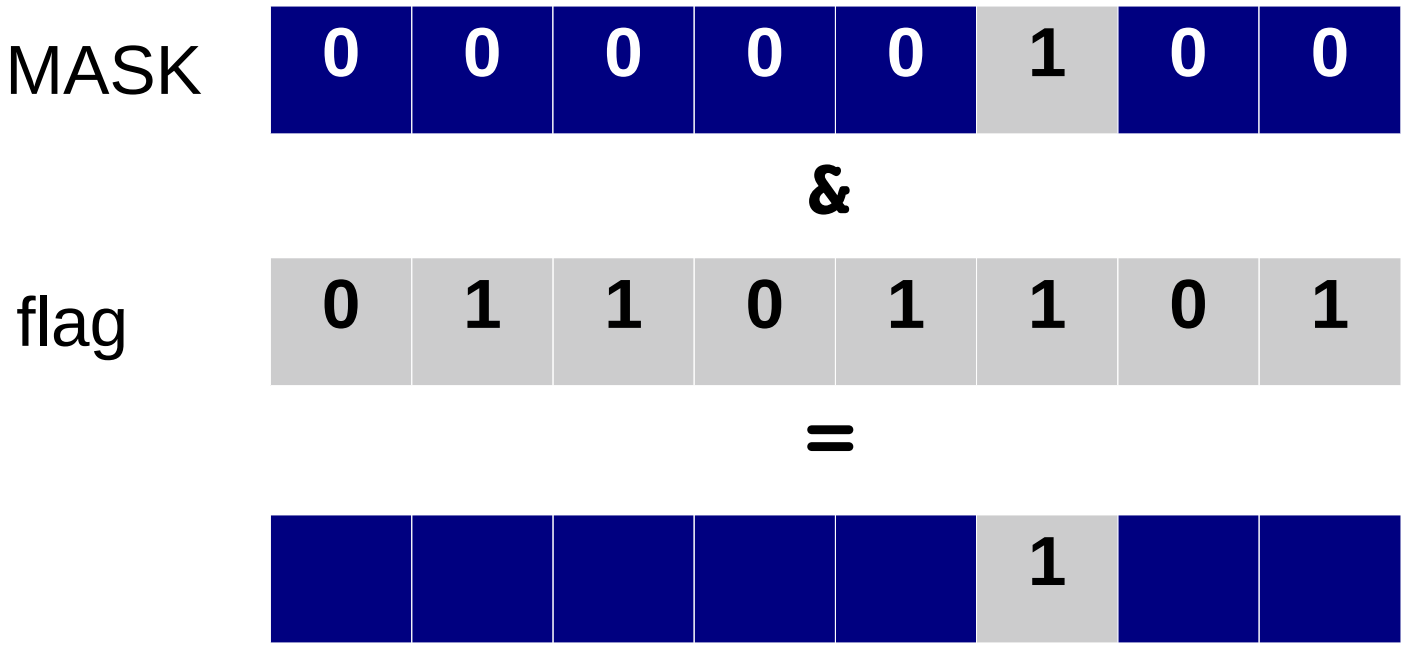
The Left-Shift Operator

- Moves the data to the left a specified number of bits
- Shifted out bits disappear
- New bits coming from the right are `0`'s
- Ex: `10101101 << 3` results in `01101000`

The Right-Shift Operator

- Moves the data to the right a specified number of bits
- Shifted out bits disappear
- New bits coming from the right are:
  - 0's if variable is unsigned
  - Value of the sign bit if variable is signed
- Ex:
  - `7 = 00000111 >> 2` results in `00000001`
  - `-7 = 11111001 >> 2` results in `11111110`

Using Masks to Identify Bits



Using Masks

- Bitwise AND often used with a mask
- A mask is a bit pattern with one (or possibly more) bit(s) set
- Think of `0`'s as opaque and the `1`'s being transparent, only the mask `1`'s are visible
- If `result > 0` then at least one bit of mask is set
- If `result == MASK` then the bits of the mask are set

binary.c

```
1  #include <stdio.h>
2  char str[sizeof(int) * 8 + 1];
3  const int maxbit = sizeof(int) * 8 - 1;
4  char* itobin(int n, char* binstr) {
5    int i;
6    for (i = 0; i <= maxbit; i++) {
7      if (n & 1 << i) {
8        binstr[maxbit - i] = '1';
9      }
10     else {
11       binstr[maxbit - i] = '0';
12     }
13   }
14   binstr[maxbit + 1] = '\0';
15   return binstr;
16 }
17 int main()
18 {
19   int n;
20   while (1) {
21     scanf("%i", &n);
22     if (n < 0) break;
23     printf("%6d: %s\n", n, itobin(n, str));
24   }
25   return 0;
26 }
```

How to Turn on a Particular Bit

- To turn on bit `1` (second bit from the right), why does `flags += 2` not work?
  - If `flags = 2` = $00000010_{(2)}$
  - Then `flags` +=2 will result in
  - `flags = 4` = $00000100_{(2)}$ which "unsets" bit `1`
- Correct usage:
  - `flags = flags | 2` is equivalent to
  - `flags |= 2` and turns on bit `1`

How to Toggle a Particular Bit

- To toggle bit `1`
  - `flags = flags ^ 2;`
  - `flags ^= 2;` toggles on bit `1`
- General form
  - `flags ^= MASK;`

How to Test a Particular Bit

- To test bit `1`, why does `flags == 2` not work?
- Testing whether any bit of `MASK` are set:
  - `if (flags & MASK) ...`
- Testing whether all bits of `MASK` are set:
  - `if ((flags & MASK) == MASK) ...`