Administrivia

New exercise posted yesterday, due before class Wed.
   Exercise not due until then because…

No class Monday - UW closed for MLK day

Keep working on hw1 - due a week from Tuesday
Agenda

Today’s topics:

a few final C details

header guards and other preprocessor tricks

extern, static and visibility of symbols

some topics for you to research on your own
an include problem

What happens when we compile foo.c?

typedef void *LinkedList;
// more declarations below

#include "ll.h"

typedef void *HashTable;

#include "ht.h"

int main(int argc, char **argv) {
    // ... do stuff here ... 
    return 0;
}

#include "ll.h"
#include "ht.h"

#include "ll.h"

/*
 * A hypothetical function
 */

LinkedList HTKeyList(HashTable t);

foo.c
an `#include` problem

What happens when we compile foo.c?

```
bash$ gcc -Wall -g -o foo foo.c
```

In file included from ht.h:1,
    from foo.c:2:
ll.h:1: error: redefinition of typedef ‘LinkedList’
ll.h:1: note: previous declaration of ‘LinkedList’ was here

**foo.c** includes **ll.h** twice!

2nd time is indirectly via **ht.h**

so, typedef shows up twice!

*try using cpp to see this*
header guards

A commonly used C preprocessor trick to deal with this

uses macro definition (#define)

uses conditional compilation (#ifndef and #endif)

```c
#ifndef _LL_H_
#define _LL_H_

typedef void *LinkedList;

// more definitions below
#endif // _LL_H_
```

```c
#ifndef _HT_H_
#define _HT_H_

#include "ll.h"

typedef void *HashTable;

// A hypothetical function
LinkedList HTKeyList(HashTable t);

#endif // _HT_H_
```
Other preprocessor tricks

A way to deal with “magic constants”

```c
int globalbuffer[1000];
void circalc(float rad,
    float *circumf,
    float *area) {
    *circumf = rad * 2.0 * 3.1415;
    *area = rad * 3.1415 * 3.1415;
}
```

bad code
(littered with magic constants)

```c
#define BUFSIZE 1000
#define PI 3.14159265359
int globalbuffer[BUFSIZE];
void circalc(float rad,
    float *circumf,
    float *area) {
    *circumf = rad * 2.0 * PI;
    *area = rad * PI * PI;
}
```

better code
Macros

You can pass arguments to macros

```cpp
#define ODD(x) ((x) % 2 != 0)

void foo(void) {
    if ( ODD(5) )
        printf("5 is odd!\n");
}
```

Be careful of precedence issues; use parenthesis:

```cpp
#define ODD(x) ((x) % 2 != 0)
#define BAD(x) x % 2 != 0

ODD(5 + 1);
BAD(5 + 1);
```

```cpp
void foo(void) {
    if ( ((5) % 2 != 0) )
        printf("5 is odd!\n");
}

((5 + 1) % 2 != 0);
5 + 1 % 2 != 0;
```
Conditional Compilation

You can change what gets compiled

```c
#ifdef TRACE
#define ENTER(f) printf("Entering %s\n", f);
#define EXIT(f) printf("Exiting %s\n", f);
#else
#define ENTER(f)
#define EXIT(f)
#endif

// print n
void pr(int n) {
    ENTER("pr");
    printf("n = %d\n", n);
    EXIT("pr");
}
```

ifdef.c
Defining Symbols

Besides #defines in the code, preprocessor values can be given on the gcc command

```
bash$ gcc -Wall -g -DTRACE -o ifdef ifdef.c
```

assert is controlled the same way - #define NDEBUG and asserts expand to “empty” (it’s a macro - see assert.h)

```
bash$ gcc -Wall -g -DNDEBUG -o faster usesassert assert.c
```
Namespace problem

If I define a global variable named “counter” in foo.c, is it visible in bar.c?

if you use **external linkage**: yes

  - the name “counter” refers to the same variable in both files
  - the variable is defined in one file, declared in the other(s)
  - when the program is linked, the symbol resolves to one location

if you use **internal linkage**: no

  - the name “counter” refers to different variables in each file
  - the variable must be defined in each file
  - when the program is linked, the symbols resolve to two locations
External linkage

```c
#include <stdio.h>

// A global variable, defined and initialized here in foo.c.
// It has external linkage by default.
int counter = 1;

int main(int argc, char **argv) {
    printf("%d\n", counter);
    bar();
    printf("%d\n", counter);
    return 0;
}
```

```c
#include <stdio.h>

// "counter" is defined and initialized in foo.c.
// Here, we declare it, and specify external linkage by using the extern specifier.
extern int counter;

void bar(void) {
    counter++;
    printf("(b): counter %d\n", counter);
}
```
Internal linkage

```c
#include <stdio.h>

// A global variable, defined and initialized here in foo.c.
// We force internal linkage by using the static specifier.
static int counter = 1;

int main(int argc, char **argv) {
    printf("%d\n", counter);
    bar();
    printf("%d\n", counter);
    return 0;
}
```

```c
#include <stdio.h>

// A global variable, defined and initialized here in bar.c.
// We force internal linkage by using the static specifier.
static int counter = 100;

void bar(void) {
    counter++;
    printf("(b): counter %d\n", counter);
}
```
Some gotchas

Every global (variables and functions) is extern by default unless you write the static specifier, if some other module uses the same name, you’ll end up with a collision!

- best case: compiler (or linker) error
- worst case: stomp all over each other

It’s good practice to:

- use static to defend your globals (hide your private stuff!)
- place external (i.e., global) declarations in a module’s header file
**Extern, static functions**

// By using the static specifier, we are indicating
// that foo() should have internal linkage. Other
// .c files cannot see or invoke foo().
static int foo(int x) {
    return x*3 + 1;
}

// Bar is "extern" by default. Thus, other .c files
// could declare our bar() and invoke it.
int bar(int x) {
    return 2*foo(x);
}

#include <stdio.h>

extern int bar(int);

int main(int argc, char **argv) {
    printf("%d\n", bar(5));
    return 0;
}
Somebody should get fired

C has a second, different use for the word “static”

- to declare the extent of a local variable

if you declare a static local variable, then:

‣ the storage for that variable is allocated when the program loads, in either the program’s .data or .bss segment

‣ the variable retains its value across multiple function invocations

(see static_extent.c for an example)
Additional C topics

Teach yourself

- bit-level manipulation in C (cf CSE 351): ~ | & << >>

- string library functions provided by the C standard library

  ```
  #include <string.h>
  `strlen()`, `strcp()`, `strdup()`, `strcat()`, `strcmp()`, `strchr()`, `strstr()`, ...
  ```

  learn why `strncat` is safer (in the security sense) than `strcat`, etc.

  ```
  #include <stdlib.h>  or  #include <stdio.h>
  `atoi()`, `atof()`, `sprintf()`, `sscanf()`
  ```

  `man` pages are your friend!
Additional C topics

Teach yourself

- the syntax for function pointers, including passing as args
- how to declare, define, and use a function that accepts a variable-lengthed number of arguments (varargs)
- unions and what they are good for
- what argc and argv are for in main

```c
#include <stdio.h>

int main(int argc, char **argv) {
    int i;
    for (i = 0; i < argc, i++) {
        printf("%d: %s\n", i, argv[i]);
    }
    return 0;
}
```

```bash
bash$ gcc -o argv argv.c
bash$ ./argv
0: ./argv
bash$ ./argv foo bar
0: ./argv
1: foo
2: bar
bash$
```
Additional C topics

Teach yourself:

- the difference between pre-increment (++v) and post-increment (v++)

- the meaning of the “register” storage class

  Might see it in code, but compilers often ignore it these days since they can often do a better job without it

- harder: the meaning of the “volatile” storage class

  pages 91, 92 of CARM, much more precise in C11
Exercise 1

Write a program that:

- prompts the user to input a string (use fgets( ))
  - assume the string is a sequence of whitespace-separated integers
  - e.g., “5555 1234 4 5543”
- converts the string into an array of integers
- converts an array of integers into an array of strings
  - where each element of the string array is the binary representation of the associated integer
- prints out the array of strings
Exercise 2

Modify the linked list code from last lecture / exercise 1

- add static declarations to any internal functions you implemented in linkedlist.h

- add a header guard to the header file

- write a Makefile

  use Google to figure out how to add rules to the Makefile to produce a library (liblinkedlist.a) that contains the linked list code
See you on Wednesday!