

Final C Details

CSE 333

Instructor: Hannah C. Tang

Teaching Assistants:

Deeksha Vatwani Hannah Jiang

Jen Xu

Leanna Nguyen Nam Nguyen

Sayuj Shahi

Tanay Vakharia Wei Wu

Yiqing Wang

Zohar Le

Lecture Outline

- ❖ **Header Guards and Preprocessor Tricks**
- ❖ Visibility of Symbols
 - `extern, static`

Administrivia

- ❖ New exercise posted today, due Monday morning
- ❖ How far we get in lecture will dictate which exercise we post:
 - Ex4 = write a multi-file program
 - Ex5 = use today's best-practices and resubmit your program

An #include Problem

- ❖ What happens when we compile `foo.c`?

```
struct pair {  
    int a, b;  
};
```

pair.h

```
#include "pair.h"
```

```
// a useful function  
struct pair* make_pair(int a, int b);
```

util.h

```
#include "pair.h"  
#include "util.h"  
  
int main(int argc, char** argv) {  
    // do stuff here  
    ...  
    return EXIT_SUCCESS;  
}
```

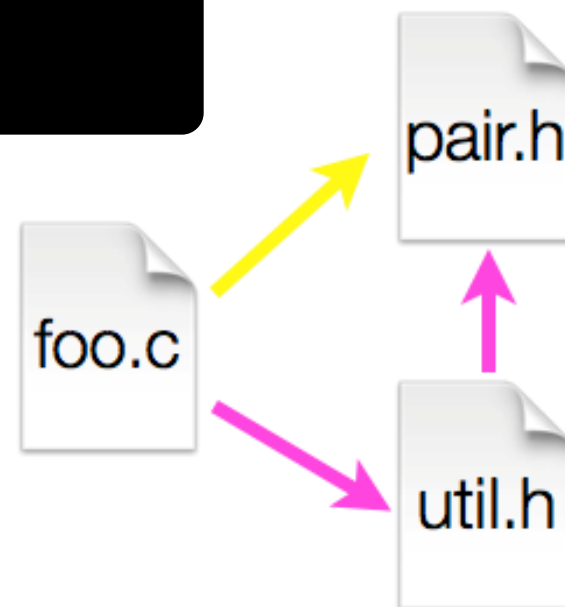
foo.c

An #include Problem

- ❖ What happens when we compile `foo.c`?

```
bash$ gcc -Wall -g -o foo foo.c
In file included from util.h:1:0,
                 from foo.c:2:
pair.h:1:8: error: redefinition of 'struct pair'
   struct pair { int a, b; };
       ^
In file included from foo.c:1:0:
pair.h:1:8: note: originally defined here
   struct pair { int a, b; };
       ^
```

- ❖ `foo.c` includes `pair.h` twice!
 - Second time is indirectly via `util.h`
 - Struct definition shows up twice
 - Can see using `cpp`



Header Guards

- ❖ A standard C Preprocessor trick to deal with this
 - Uses macro definition (`#define`) in combination with conditional compilation (`#ifndef` and `#endif`)

```
#ifndef PAIR_H_
#define PAIR_H_

struct pair {
    int a, b;
};

#endif // PAIR_H_
```

pair.h

```
#ifndef UTIL_H_
#define UTIL_H_

#include "pair.h"

// a useful function
struct pair* make_pair(int a, int b);

#endif // UTIL_H_
```

util.h

Other Preprocessor Tricks

- ❖ A way to deal with “magic numbers” (constants)

```
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)

```
#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

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

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

cpp

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

- ❖ Beware of operator precedence issues!

- Use parentheses

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

ODD(5 + 1);

WEIRD(5 + 1);
```

cpp

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

5 + 1 % 2 != 0;
```


Conditional Compilation

- ❖ You can change what gets compiled
 - In this example, `#define TRACE` before `#ifdef` to include debug `printf`s in compiled code

```
#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 as part of the `gcc` command:

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

- ❖ `assert` can be controlled the same way – defining `NDEBUG` causes `assert` to expand to “empty”
 - It’s a macro – see `assert.h`

```
bash$ gcc -Wall -g -DNDEBUG -o faster useassert.c
```

❖ What will happen when we try to compile and run?

```
bash$ gcc -Wall -DFOO -DBAR -o condcomp condcomp.c
bash$ ./condcomp
```

- A. Outputs "333"
- B. Outputs "334"
- C. Compiler message about EVEN
- D. Compiler message about BAZ
- E. We're lost...

```
#include <stdio.h>
#ifdef FOO
#define EVEN(x) !(x%2)
#endif
#ifndef DBAR
#define BAZ 333
#endif

int main(int argc, char** argv) {
    int i = EVEN(42) + BAZ;
    printf("%d\n", i);
    return EXIT_SUCCESS;
}
```

Lecture Outline

- ❖ Header Guards and Preprocessor Tricks
- ❖ **Visibility of Symbols**
 - `extern, static`

Namespace Problem

- ❖ If we define a global variable named “counter” in one C file, is it visible in a different C file in the same program?
 - Yes, if you use *external linkage*
 - The name “counter” refers to the same variable in both files
 - The variable is *defined* in one file and *declared* in the other(s)
 - When the program is linked, the symbol resolves to one location
 - No, if you use *internal linkage*
 - The name “counter” refers to a different variable in each file
 - The variable must be *defined* in each file
 - When the program is linked, the symbols resolve to two locations

External Linkage

- ❖ `extern` makes a *declaration* of something externally-visible

```
#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 EXIT_SUCCESS;
}
```

foo.c

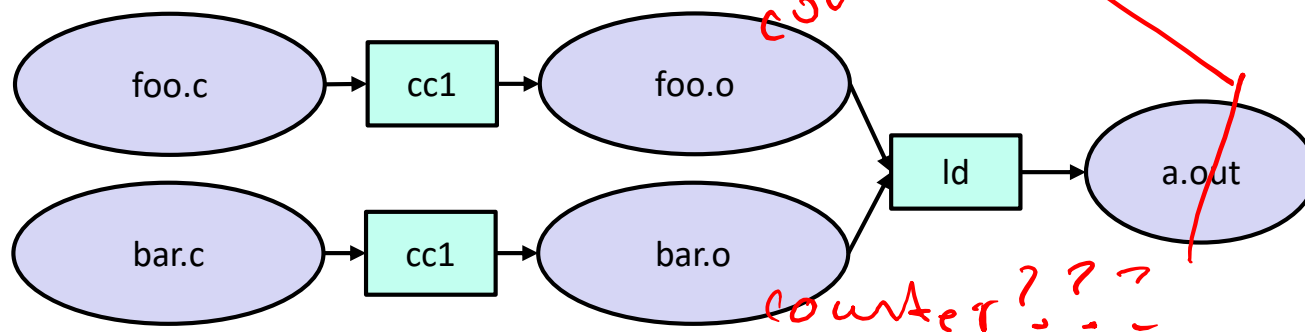
```
#include <stdio.h>

// "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() {
    counter++;
    printf("(b): counter = %d\n",
           counter);
}
```

bar.c

External Linkage



```
#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 EXIT_SUCCESS;
}
```

foo.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() {
    counter++;
    printf("(b): counter = %d\n",
           counter);
}
```

bar.c

Internal Linkage

- ❖ `static` (in the global context) restricts a definition to visibility within that file

```
#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 EXIT_SUCCESS;
}
```

foo.c

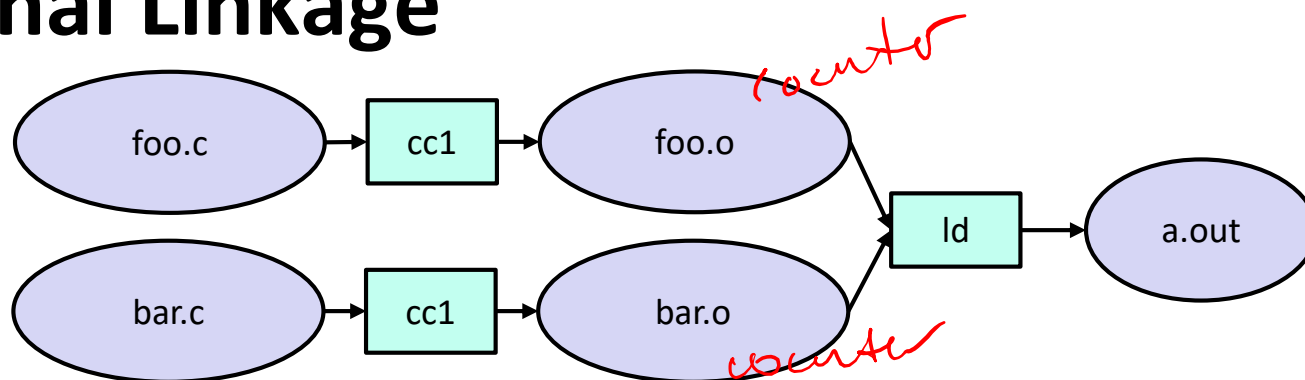
```
#include <stdio.h>

// 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() {
    counter++;
    printf("(b): counter = %d\n",
           counter);
}
```

bar.c

Internal Linkage



```
#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 EXIT_SUCCESS;
}
```

foo.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() {
    counter++;
    printf("(b): counter = %d\n",
           counter);
}
```

bar.c

- ❖ Coming back to our `NthPrime.h`, `NthPrime.c`, and `ex4.c`, example, do either of these successfully link?

```
#define NUM_PRECALC 20
static int16_t
kPrecalculated[NUM_PRECALC] =
    {2, 3, 5, 7, /* etc */ };

int16_t NthPrime(int16_t n);
```

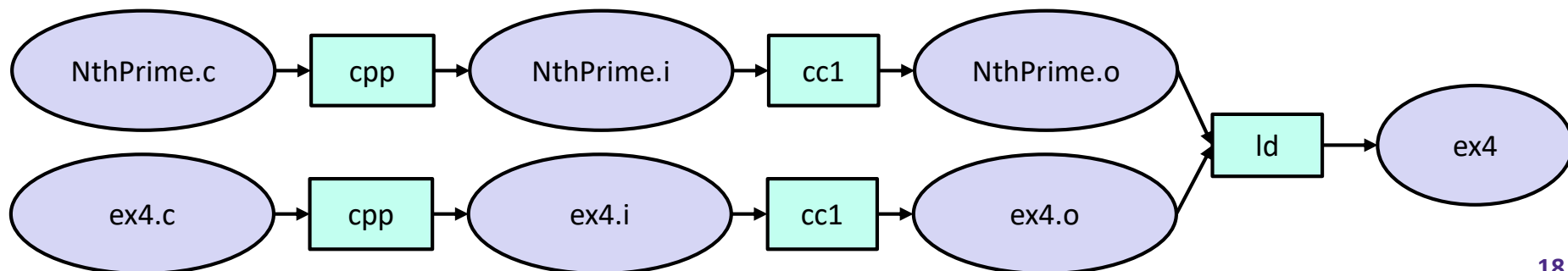
`NthPrime.static.h`

```
extern int16_t kPrecalculated[];

int16_t NthPrime(int16_t n);
```

`NthPrime.extern.h`

- ❖ (you can assume `NthPrime.c` and `ex4.c` are unchanged)



Closing Thoughts

- ❖ Don't do either of these with an unchanged NthPrime.c!

```
#define NUM_PRECALC 20
static int16_t
kPrecalculated[NUM_PRECALC] =
    {2, 3, 5, 7, /* etc */ };

int16_t NthPrime(int16_t n);
```

NthPrime.static.h

```
extern int16_t kPrecalculated[];

int16_t NthPrime(int16_t n);
```

NthPrime.extern.h

- ❖ Static variable in the header: every file that #includes the header will have its own private copy of the variable
 - Unnecessary data duplication!
- ❖ Extern variable in the header: the accompanying .c file must define the extern'ed variable for successful linkage

Function Visibility

```
// 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);  
}
```

bar.c

```
#include <stdio.h>
```

```
extern int bar(int x); // "extern" is default, usually omit.  
// should be in .h file, but effect is same
```

```
int main(int argc, char** argv) {  
    printf("%d\n", bar(5));  
    return EXIT_SUCCESS;  
}
```

main.c

Linkage Issues

- ❖ Every global (variables and functions) is `extern` by default
 - Unless you add 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 declarations in a module's header file
 - Header is the public specification



Static Confusion...

- ❖ C has a *different* use for the word “`static`”: to create a persistent *local* variable
 - The storage for that variable is allocated when the program loads, in either the `.data` or `.bss` segment
 - Retains its value across multiple function invocations
 - Confusing! Don't use!! (But you may see it ☹)

```
void foo() {
    static int count = 1; // static var, not auto!!
    printf("foo has been called %d times\n", count++);
}

void bar() {
    int count = 1;
    printf("bar has been called %d times\n", count++);
}

int main(int argc, char** argv) {
    foo(); foo(); bar(); bar(); return EXIT_SUCCESS;
}
```

static_extent.c

Additional C Topics

❖ Teach yourself!

- **man pages** are your friend!
- String library functions in the C standard library
 - `#include <string.h>`
 - `strlen()`, `strcpy()`, `strdup()`, `strcat()`, `strcmp()`, `strchr()`, `strstr()`, ...
 - `#include <stdlib.h>` or `#include <stdio.h>`
 - `atoi()`, `atof()`, `sprint()`, `sscanf()`
- How to declare, define, and use a function that accepts a variable-number of arguments (`varargs`)
- `unions` and what they are good for
- `enums` and what they are good for
- Pre- and post-increment/decrement
- Harder: the meaning of the “`volatile`” storage class

Extra 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