Practical C Issues:

Preprocessor Directives, Typedefs, Multi-file Development, and Makefiles

CS449 Spring 2016

Preprocecessor Directives

#define

- **Textual** Symbol Replacements

```
#define PI 3.1415926535
#define MAX 10

float f = PI;
for(i=0;i<MAX;i++) …
```

#define Macros

- Textual replacements with parameters:
- Good:
  - `#define MAX(a, b) (a > b) ? a : b`
- Not so good:
  - `#define SWAP(a,b) {int t=a; a=b; b=t;}`

#if

- #if <condition that can be evaluated by the preprocessor>

- What does preprocessor know?
  - Values of #defined variables
  - Constants

Example

```
#include <stdio.h>

int main()
{
   #if 0
      printf(“this is not printed\n”);
   #endif
   printf(“This is printed\n”);
   return 0;
}
```

Example 2

```
#include <stdio.h>
#define VERSION 5

int main()
{
   #if VERSION < 5
      printf(“this is not printed\n”);
   #endif
   printf(“This is printed\n”);
   return 0;
}
```

#else

```
#if
    ...
#elif
    ...
#else
    ...
#endif
```

#if defined

- #if defined
  - Checks to see if a macro has been defined, but doesn't care about the value
  - A defined macro might expand to nothing, but is still considered defined

Example

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

int main()
{
    #if defined MACRO
        printf("this is printed\n");
    #endif
    printf("This is also printed\n");
    return 0;
}
```

#undef

- Undefines a macro:

```
#include <stdio.h>
#define MACRO
#undef MACRO

int main()
{
   #if defined MACRO
      printf("this is not printed\n");
   #endif
   printf("This is printed\n");
   return 0;
}
```

Shortcuts

- #if defined → #ifdef
- #if !defined → #ifndef

Uses

- Handle System Architecture specific code
- Build program with different features
  - Debugging:

```
#ifdef DEBUG
    printf(...)
#endif
```

- Better debugging

```
#ifdef DEBUG
#define PrintDebug(args...) fprintf(stderr, args)
#else
#define PrintDebug(args...)
#endif
```

Notes

- Can define variables from the commandline with `-D`
  - `gcc -o test -DVERSION=5 test.c`
  - `gcc -o test -DMACRO test.c`

Pre-Defined Macros

Macro	Meaning
`__FILE__`	The currently compiled file
`__LINE__`	The current line number
`__DATE__`	The current date
`__TIME__`	The current time
`__STDC__`	Defined if compiler supports ANSI C
…	Many other compiler-specific flags

Other Preprocessor Details

- # - quotes a string
- ## - concatenates two things
- #pragma: Change behavior of compiler
- #warning: Emit warning message
- #error: Emit error message and exit

Pragma Example

```
#include <stdio.h>

#pragma message "Compiling " __FILE__ "
   using " __VERSION__
int main() {
  return 0;
}
```

```
>> gcc ./pragma.c
./pragma.c:3: note: #pragma message:
Compiling ./pragma.c using 4.4.7
20120313 (Red Hat 4.4.7-4)
```

- Pragma message prints a message during compilation of file
- Note use of two pre-defined macros: __FILE__ and __VERSION__
- Many more pragmas
  - To control compiler optimizations
  - To control code generation
  - To convey program semantics

Error Directive Example

```
#include <stdio.h>

#ifndef __i386__
#error "Needs i386 architecture."
#endif
int main() {
  return 0;
}
```

```
>> gcc ./error.c
./error.c:3:2: error: #error "Needs i386 architecture.
>> gcc –m32 ./error.c
```

- Tests whether hardware platform is i386 (x86) and displays error
- Initially fails because default compilation target is x86_64
- '-m32' option changes target to x86, allowing compilation to proceed
- Example of preprocessor usage for architecture specific code

Concatenation example

```
#include <stdio.h>

#define PRINT(type, x) print_##type (x)
void print_int(int x) {
  printf("%d\n", x);
}
void print_char(char x) {
  printf("%c\n", x);
}
int main() {
  PRINT(int, 5);
  PRINT(char, 'H');
  return 0;
}
```

```
>> gcc ./concat.c
>> ./a.out
5
H
```

- ## concatenates two tokens into one token
- Useful when generating long identifiers with multiple components that can be given as arguments

Typedefs

typedef

```
typedef type-declaration synonym;
```

Examples:

```
typedef int * int_pointer;
typedef int * int_array;
```

Typedefs for Type Clarity

```
void takes_int(int_pointer x)
{
    *x = 3;
}
```

```
void takes_array(int_array x,
   int n)
{
    int i;
    for(i=0; i<n; i++)
        printf("%d\n", x[i]);
}
```

Typedefs for Structures

Typedef

```
typedef struct node {
   int i;
   struct node *next;
} Node;

Node *head;
```

Struct with Instance

```
struct node {
   int i;
   struct node *next;
} Node;
```

Typedefs for Function Pointers

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

typedef void (*FP)(int, int);

void f(int a, int b) {
    printf("%d\n", a+b)
}

void g(int a, int b) {
    printf("%d\n", a*b)
}

int main() {
        FP ar1 = f;
        FP ar2 = g;

        ar1(2,3);
        ar2(2,3);
        return 0;
}
```

Function Pointers As Parameters

- In <stdlib.h>,

```
typedef int (*compar_fn_t) (const void *, const void *);

void qsort (
    void *base ,
    size_t num ,
    size_t size ,
    compar_fn_t comparator
);
```

Function Pointers As Parameters

```
int compare_ints(const void *a, const void *b)
{
    int *x = (int *)a;
    int *y = (int *)b;
    return *x - *y;
}
int main()
{
  int a[100];
  qsort(a, 100, sizeof(int), compare_ints);
}
```

- A function passed as a parameter is also called a *callback* function

Multi-file Development

Multi-file Development

- Multi-file development breaks up a program into multiple files
  - Multiple authors
  - Quicker compilation
  - Modularity
  - Encapsulation
- Use scoping to enforce encapsulation
  - Avoids polluting global namespace
  - Makes programs easier to maintain

Local Scope

- Scope: **Local** (e.g. within a function)
- Lifetime: **Automatic** (duration of function)

```
void f(…) {
   int x;
   …
}
```

Static Local Scope

- Scope: **Local** (e.g. within a function)
- Lifetime: **Static** (life of program)

```
void f(…) {
   static int
  x;
   …
}
```

Static Global Scope

- Scope: **File**
- Lifetime: **Static** (life of program)

```
static int x;
void f(…) {
   …
}
```

Global Scope

- Scope: **Program**
- Lifetime: **Static** (life of program)
- extern maybe be used to import variables from other files

File A

```
int x;
```

File B

```
extern int x;
```

Will refer to the same memory location

Example

a.c

```
int x = 0;

int f(int y)
{
        return x+y;
}
```

b.c

```
#include <stdio.h>

extern int x;
int f(int);

int main()
{
        x = 5;
        printf("%d", f(0));

        return 0;
}
```

Compiling

```
gcc a.c b.c

./a.out
5
```

Static

a.c

```
static int x = 0;

static int f(int y)
{
        return x+y;
}
```

b.c

```
#include <stdio.h>

extern int x;
int f(int);

int main()
{
        x = 5;
        printf("%d", f(0));

        return 0;
}
```

Compiling

```
gcc a.c b.c

/tmp/cccyUCUA.o(.text+0x6): In
  function `main':
: undefined reference to `x'
/tmp/cccyUCUA.o(.text+0x19): In
  function `main':
: undefined reference to `f'
collect2: ld returned 1 exit status
```

Header Files

- Declarations that need to be shared across multiple C files are put into header files
  - Type declarations and typedefs
  - #define's (macro declarations)
  - Functions (prototype declarations)
  - Variables (extern declarations)
  - Other header files
- Usually paired with an implementation file that has the definitions

Headers and Implementation

mymalloc.h

```
void *my_buddy_malloc(int size);

void my_free(void *ptr);
```

mymalloc.c

```
static void *base;

void *my_buddy_malloc(int size)
{
    ...
}

void my_free(void *ptr)
{
    ...
}
```

#include

- Copies the contents of the specified file into the current file
- < > means: look in a known location for includes
- “ “ means: look in the current directory or specified path (using –I option)
  - E.g. gcc –I ~/local/include main.c

```
#include <stdio.h>
#include “myheader.h”
```

Driver

- Driver program:

  #include “mymalloc.h”

- Can now use those functions

- Compile:

```
gcc -o malloctest mymalloc.c mallocdriver.c
```

Including a Header File Once

```
#ifndef _MYHEADER_H_
#define _MYHEADER_H_

…Definitions of header to only be included
  once


#endif
```

Makefiles

- Used with the GNU Make utility to build projects containing multiple files
- Goal: if any source files are modified, build smallest set required
- Express what files depend upon others
- Composed of a collection of *rules* which look like

target: dependencies

action

- Action must be preceded by <tab>, not spaces

Makefile

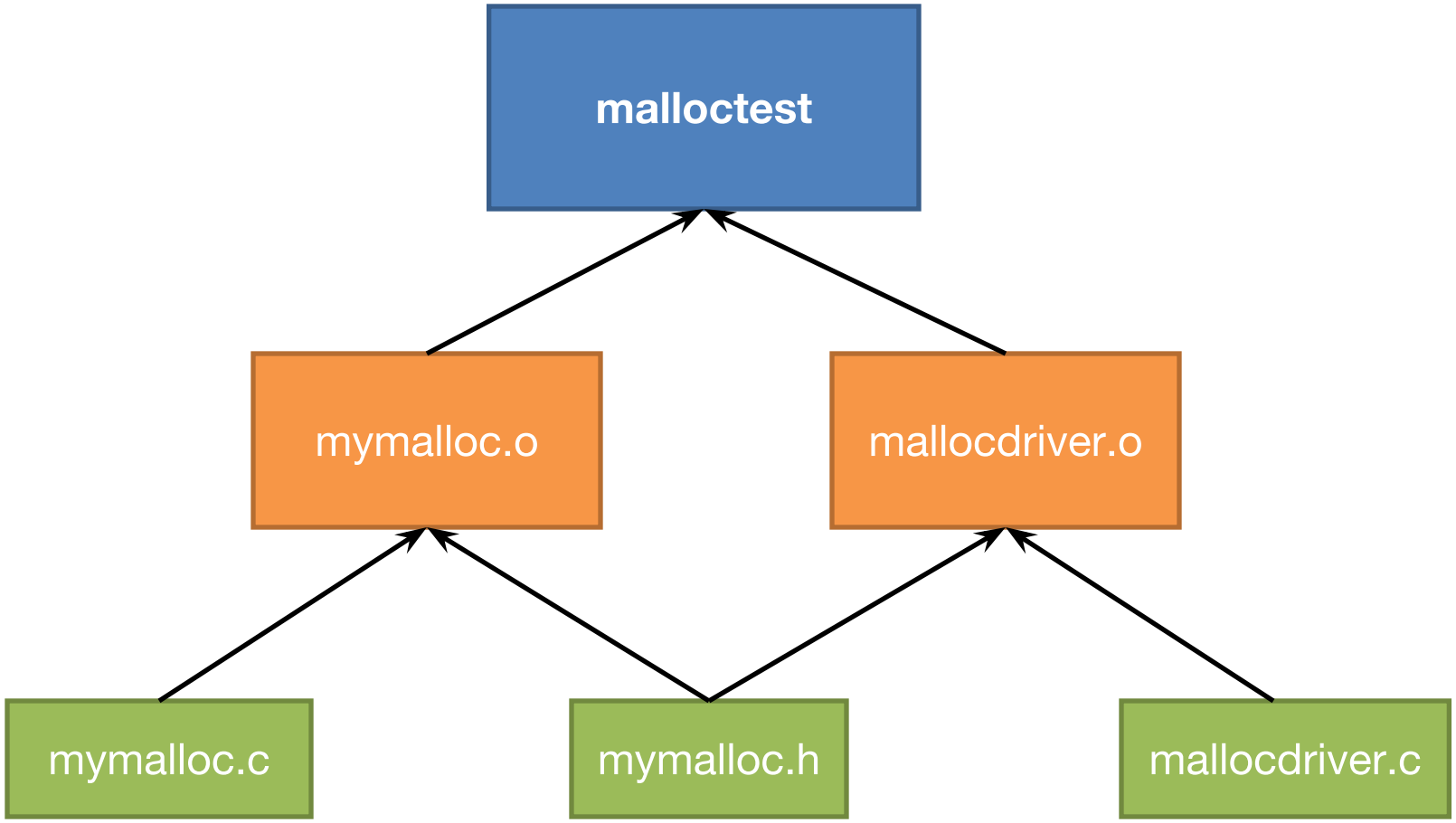
```
malloctest: mymalloc.o mallocdriver.o
    gcc -o malloctest mymalloc.o mallocdriver.o

mymalloc.o: mymalloc.c mymalloc.h
    gcc -c mymalloc.c

mallocdriver.o: mallocdriver.c mymalloc.h
    gcc -c mallocdriver.c

clean:
    rm -f *.o malloctest
```

Dependency Graph



Defining Variables in Makefiles

- Works like macros (text replacement)
- Syntax: <name> := ... or <name> = ...
- Example:
  - Instead of:

```
malloctest: mymalloc.o mallocdriver.o
    gcc -o malloctest mymalloc.o mallocdriver.o
```

  - Can do:

```
OBJECTS = mymalloc.o mallocdriver.o
malloctest: $(OBJECTS)
    gcc -o malloctest $(OBJECTS)
```

Automatic Variables

- $@: The file name of the target. E.g.:

```
malloctest: $(OBJECTS)
    gcc -o $@ $(OBJECTS)
```

- $<: The name of the first prerequisite. E.g.:

```
mymalloc.o: mymalloc.c mymalloc.h
    gcc -c $<
```

- $^: The names of all prerequisites. E.g.:

```
malloctest: $(OBJECTS)
    gcc -o $@ $^
```

Pattern Matching

- Character ‘%’ can stand for a pattern
- Example:

```
%.o: %.c
	gcc -c $< -o $@
```

Concise Makefile

```
malloctest: mymalloc.o mallocdriver.o
	gcc -o $@ $^

%.o: %.c
	gcc -c $< -o $@

mymalloc.o: mymalloc.h
mallocdriver.o: mymalloc.h

clean:
	rm -f *.o malloctest
```

Make Utility Options

- Usage:

  `make [-f makefile] [options] [targets]`
- `-f makefile`: Can specify a different makefile
- `targets`: Can specify targets you want to build
- `Options`:

  –`<name> = <value>`: Define a variable.

  –`-C <dir>`: Change to directory dir before building.

  –`-n`: Dry run. Just print commands and don't execute.

  –`-d`: Debug mode. Print verbose information.

Device Driver Makefile

```
obj-m := hello_dev.o

KDIR  := /u/SysLab/shared/linux-2.6.23.1
PWD   := $(shell pwd)

default:
	$(MAKE) -C $(KDIR) M=$(PWD) modules
```

- Default target of ‘make’ is ‘default:’
- -C option uses specified directory as root of Makefile
- Invokes Makefile with variable ‘M’ defined as ‘PWD’ to build target ‘modules:’

Problem 1

- Write a macro that returns TRUE if its parameter is divisible by 10

Problem 2

- Write a macro ***is_digit*** that returns TRUE if its argument is a decimal digit

Problem 3

- Write a second macro ***is_hex*** that returns TRUE if its argument is a hex digit (0-9, A-F, a-f). The second macro should reference the first.

Problem 4

- Write a preprocessor macro that swaps two variables of any type.