

Makefiles

Multiple Source Files (1)

- ◆ Obviously, large programs are not going to be contained within single files.
- ◆ C provides several techniques to ensure that these multiple files are managed properly.
 - These are not enforced rules but every good C programmer know how to do this.
- ◆ A large program is divided into several modules, perhaps using abstract data types.
- ◆ The header (.h) file contains function prototypes of a module.
- ◆ The (.c) file contains the function definitions of a module.
- ◆ Each module is compiled separately and they are linked to generate the executable file.

Multiple Source Files (2)

- ◆ C programs are generally broken up into two types of files.

.c files:

- ❖ contain source code (function definitions) and global variable declarations
- ❖ these are compiled once and never included

.h files:

- ❖ these are the “interface” files which “describe” the **.c** files
 - type and **struct** declarations
 - **extern const** and **#define** constant declarations
 - **#includes** of other header files that must be included
 - prototypes for functions

Example - Main Program sample.c

```
#include <stdio.h>
#include "my_stat.h"
int main()
{
    int a, b, c;
    puts("Input three numbers:");
    scanf("%d %d %d", &a, &b, &c);
    printf("The average of %d %d %d is %f.\n",
           a, b, c, average(a,b,c));
    return 0;
}
```

Example - Module my_stat

```
/* my_stat.h */  
#define PI 3.1415926  
float average(int x, int y, int z);  
float sum( int x, int y, int z);
```

```
/* my_stat.c */  
#include "my_stat.h"  
float average(int x, int y, int z)  
{  
    return sum(x,y,z)/3;  
}  
  
float sum(int x, int y, int z)  
{  
    return x+y+z;  
}
```

Example - Compile the Sample Program

- ◆ You need `my_stat.c` and `my_stat.h` to compile the `my_stat` module to object code
`cc -c my_stat.c`
- ◆ You need `my_stat.h` and `sample.c` to compile `sample.c` to object code
`cc -c sample.c`
- ◆ You need `my_stat.o` and `sample.o` to generate an executable file
`cc -o sample sample.o my_stat.o`
- ◆ Therefore, the module `my_stat` can be reused just with the `my_stat.o` and `my_stat.h`. In fact, this is how the standard libraries work. (Libraries are just collections of object code, with headers describing functions and types used in the libraries.)

The make Utility (1)

- ◆ Programs consisting of many modules are nearly impossible to maintain manually.
- ◆ This can be addressed by using the **make** utility.

Makefile for the sample

Target

sample: sample.o my_stat.o

Dependencies

These
indentation
are from a tab
(not spaces!!!)

cc -o sample sample.o my_stat.o

sample.o: sample.c my_stat.h

cc -c sample.c

my_stat.o: my_stat.c my_stat.h

cc -c my_stat.c

clean:

rm -f sample *.o core

Commands

The make Utility (2)

- ◆ Save the file with name "**Makefile**" (or "**makefile**") at the same directory.
- ◆ For every time you want to make your program, type **make**
- ◆ The **make** utility will
 - Find the **Makefile**
 - Check rules and dependencies to see if an update is necessary.
 - Re-generate the necessary files that need updating.
- ◆ For example:
 - If only sample.c is newer than sample, then only the following commands will be executed:
 - ❖ **cc -c sample.c**
 - ❖ **cc -o sample sample.o my_stat.o**

The make Utility (3)

- ◆ To clean all generated files:
`make clean`
- ◆ To re-compile, you can
 - Remove all generated files and `make` again.
 - ❖ `make clean; make`
 - Or you can:
 - ❖ `touch my_stat.h` and then `make` again
 - ❖ This changes the time stamp of `my_stat.h`, so `make` thinks it necessary to make all the files.

Using make with Several Directories

- ◆ As the number of `.c` files for a program increases, it becomes more difficult to keep track of all the parts.
- ◆ Complex programs may be easier to control if we have one `Makefile` for each major module.
- ◆ A program will be stored in a directory that has one subdirectory for each module, and one directory to store *all* the `.h` files.
- ◆ The `Makefile` for the main program will direct the creation of the executable file.
- ◆ `Makefiles` for each module will direct the creation of the corresponding `.o` files.

A Makefile Example (1)

- ◆ Consider a C program that uses a Stack ADT, a Queue ADT and a main module.
- ◆ Suppose that the program is in seven files: `StackTypes.h`, `StackInterface.h`, `QueueTypes.h`, `QueueInterface.h`, `StackImplementation.c`, `QueueImplementation.c`, and `Main.c`
- ◆ We will build the program in a directory called `Assn` that has four subdirectories: `Stack`, `Queue`, `Main`, and `Include`.
- ◆ All four `.h` files will be stored in `Include`.

A Makefile Example (2)

- ◆ **Stack** contains **StackImplementation.c** and the following **Makefile**:

```
export: StackImplementation.o
```

```
StackImplementation.o: StackImplementation.c \  
                        ../Include/StackTypes.h \  
                        ../Include/StackInterface.h
```

```
gcc -I../Include -c StackImplementation.c
```

```
# substitute a print command of your choice for lpr below  
print:
```

```
lpr StackImplementation.c
```

```
clean:
```

```
rm -f *.o
```

A Makefile Example (3)

- ◆ Queue contains QueueImplementation.c and the following Makefile:

```
export: QueueImplementation.o
```

```
QueueImplementation.o: QueueImplementation.c \  
                        ../Include/QueueTypes.h \  
                        ../Include/QueueInterface.h
```

```
gcc -I../Include -c QueueImplementation.c
```

```
# substitute a print command of your choice for lpr below  
print:
```

```
lpr QueueImplementation.c
```

```
clean:
```

```
rm -f *.o
```

A Makefile Example (4)

- ◆ Note: The `-I` option (uppercase i) for `cc` and `gcc` specifies a path on which to look to find `.h` files that are mentioned in statements of the form `#include "StackTypes.h"` in `.c` files.
- ◆ It is possible to specify a list of directories separated by commas with `-I`.
- ◆ By using `-I`, we can avoid having to put copies of a `.h` file in the subdirectories for every `.c` file that depends on the `.h` file.

A Makefile Example (5)

- ◆ Main contains Main.c and the following Makefile:

```
export: Main
```

```
Main: Main.o StackDir QueueDir
```

```
    gcc -o Main Main.o ../Stack/StackImplementation.o \
        ../Queue/QueueImplementation.o
```

```
Main.o: Main.c ../Include/*.h
```

```
    gcc -I../Include -c Main.c
```

```
StackDir:
```

```
    (cd ../Stack; make export)
```

```
QueueDir:
```

```
    (cd ../Queue; make export)
```

#continued on next page...

A Makefile Example (6)

print:

lpr Main.c

printall:

lpr Main.c

(cd ../Stack; make print)

(cd ../Queue; make print)

clean:

rm -f *.o Main core

cleanall:

rm -f *.o Main core

(cd ../Stack; make clean)

(cd ../Queue; make clean)

A Makefile Example (7)

- ◆ Note: When a sequence of Unix commands is placed inside parentheses (), a new subprocess is created, and the commands are executed as part of that subprocess.
- ◆ For example, when `(cd ../Stack; make export)` is executed, the subprocess switches to the `Stack` directory and executes the `make` command; when the subprocess terminates, the parent process resumes in the original directory. No additional `cd` command is needed.

Using Macros in Makefiles

- ◆ Macros can be used in **Makefiles** to reduce file size by providing (shorter) names for long or repeated sequences of text.
- ◆ Example: The definition **name = text string** creates a macro called **name** whose value is **text string**.
- ◆ Subsequent references to **\$(name)** or **\${name}** are replaced by **text string** when the **Makefile** is processed.
- ◆ Macros make it easier to change **Makefiles** without introducing inconsistencies.

Makefile Example Revisited (1)

- ◆ The Makefile for **Stack** can become:

```
CC = gcc
```

```
HDIR = ../Include
```

```
INCPATH = -I$(HDIR)
```

```
DEPH = $(HDIR)/StackTypes.h $(HDIR)/StackInterface.h
```

```
SOURCE = StackImplementation
```

```
export: $(SOURCE).o
```

```
$(SOURCE).o: $(SOURCE).c $(DEPH)
```

```
    $(CC) $(INCPATH) -c $(SOURCE).c
```

```
print:
```

```
    lpr $(SOURCE).c
```

```
clean:
```

```
    rm -f *.o
```

Makefile Example Revisited (2)

- ◆ The **Makefile** for **Queue** can become:

```
CC = gcc
```

```
HDIR = ../Include
```

```
INCPATH = -I$(HDIR)
```

```
DEPH = $(HDIR)/QueueTypes.h $(HDIR)/QueueInterface.h
```

```
SOURCE = QueueImplementation
```

```
export: $(SOURCE).o
```

```
$(SOURCE).o: $(SOURCE).c $(DEPH)
```

```
    $(CC) $(INCPATH) -c $(SOURCE).c
```

```
print:
```

```
    lpr $(SOURCE).c
```

```
clean:
```

```
    rm -f *.o
```

Makefile Example Revisited (3)

- ◆ The **Makefile** for **Main.c** can become:

```
CC = gcc
```

```
HDIR = ../Include
```

```
INCPATH = -I$(HDIR)
```

```
OBJ = ../Stack/StackImplementation.o \
      ../Queue/QueueImplementation.o
```

```
export: Main
```

```
Main: Main.o StackDir QueueDir
```

```
$(CC) -o Main Main.o $(OBJ)
```

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Makefile Example Revisited (4)

```
Main.o: Main.c $(HDIR)/*.h
    $(CC) $(INCPATH) -c Main.c
StackDir:
    (cd ../Stack; make export)
QueueDir:
    (cd ../Queue; make export)
print:
    lpr Main.c
printall:
    lpr Main.c
    (cd ../Stack; make print)
    (cd ../Queue; make print)
```

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Makefile Example Revisited (5)

clean:

```
rm -f *.o Main core
```

cleanall:

```
rm -f *.o Main core
```

```
(cd ../Stack; make clean)
```

```
(cd ../Queue; make clean)
```

A Makefile Exercise

- ◆ Rewrite the **Makefiles** for the previous example so that the command **make debug** will generate an executable **Maingdb** that can be run using the debugger **gdb**.

More Advanced Makefiles

- ◆ Many newer versions of **make**, including the one with Solaris and GNU make program **gmake** include other powerful features.
 - Control structures such as conditional statements and loops.
 - Implicit rules that act as defaults when more explicit rules are not given in the Makefile.
 - Simple function support for transforming text.
 - Automatic variables to refer to various elements of a Makefile, such as targets and dependencies.
- ◆ See the following web page for more details on **gmake**:
<http://www.gnu.org/software/make/manual/make.html>

How Targets are Made: a recursive procedure

tagt:

commands

(base case:)

If tagt is not a file, execute commands

tagt: dep₁ dep₂ ... dep_n

commands

(general case:)

for i from 1 to n

if dep_i is a target, make dep_i

If tagt is not a file, execute commands

else if at least one of dep_i is not a file, execute commands

else if at least one of dep_i is newer than tagt, execute commands