Managing Large Programs

The “make” program

Managing Large Programs

- large programs can be *very* large: thousands or even millions of lines in hundreds of files
- a C program can have many .c and .h files
- whenever we change one of the files (.c or .h) we have to recompile all of the unchanged ones as well
- this is very time consuming

Example

- we have C files:

```
labels.c readml.c printml.c util.c
```

- we make a change to util.c and then recompile by:

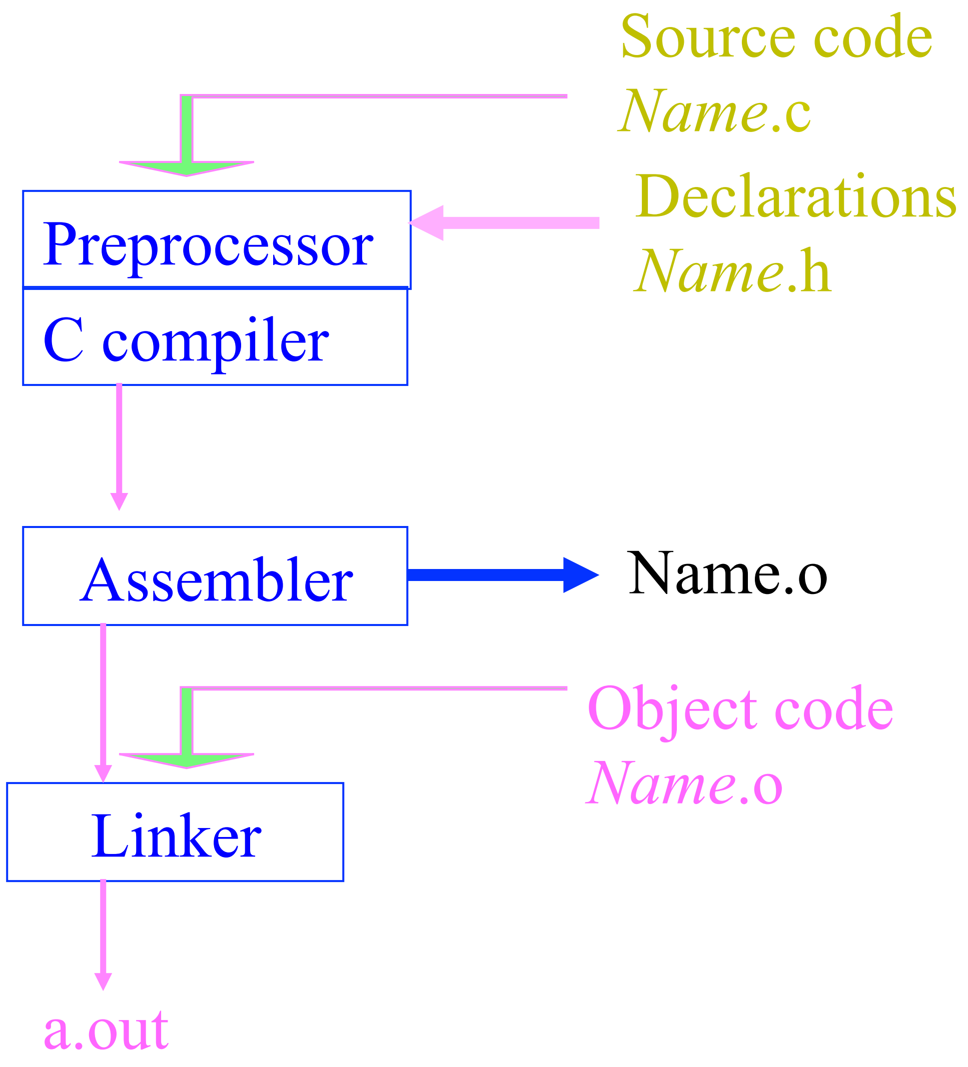
```
gcc labels.c readml.c printml.c util.c -o labels
```

- we are recompiling ALL the C files when only one has been changed

Object Code Files

- the C compiler can produce an *object code* version of a .c file that is machine language but not linked with other parts of your program
- these *object code* files end in .o

Compiling multi-file programs



Compiling and Linking

- the C compiler can be instructed to produce the .o file from the .c using the -c flag, eg:

```
gcc -c util.c
```

- several .c or .o files can be combined to produce an executable program:

```
gcc myprog.c util.o -o myprog
```

- the *object code* files are linked together to form the final executable program

- after changing a .c file we only need to recompile the affected file into its object code (.o) form and then relink all the .o files to produce the executable

Example using .o files

- we initially compile the C files to .o:

```
gcc -c labels.c readml.c printml.c util.c
```

- we make a change to util.c and then recompile by:

```
gcc -c utils.c
gcc labels.o readml.o printml.o util.o -o labels
```

- we are recompiling the file that has been changed and then relinking with the other .o files

- BUT if we have a large number of files and make many changes, how do we remember which files we’ve changed and recompile them?

Problem: what happens if we change a .c file and forget to recompile it?

Problem: what happens if we change a .h file and forget to recompile *some* of the files that #include it?

Answer: your program fails!

or gives the wrong answer!

The real answer: use the *make* program to recompile and relink your files

Why does the program fail?

- if changes are made to data structures but code that refers to it is not recompiled, the references may now go to the wrong place

```
struct {
        int     a;
        char    b;
} X;
```

$$\xrightarrow{\text{change}}$$

```
struct {
        int     a;
        char    q;
        char    b;
} X;
```

- a function that referred to X.b would not get the correct value if it wasn't recompiled after the change

Make

- the *make* program will automate the process of recompiling and recompile all the files that have been changed
- *make* interprets a set of rules and will run the C compiler and the linker as necessary to make your program
- the rules are normally stored in a file called `Makefile` or `makefile`

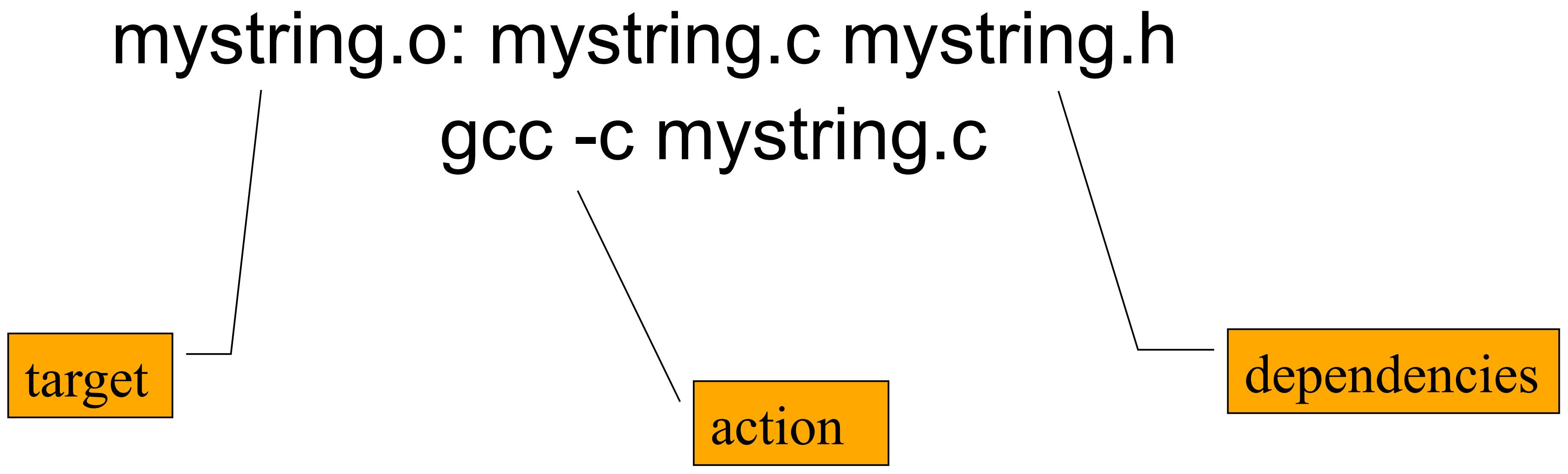
Make rules

- in general, make rules have:

- a *target:* the name of the file you want to make
- one or more *dependencies:* files the target depends on
- an *action:* a shell command that creates the target

Example rule

- to make mystring.o from mystring.c we might use the rule:



```
mystring.o: mystring.c mystring.h
        gcc -c mystring.c
```

Example rule

- if mystring.c or mystring.h have changed since mystring.o was created then the action is performed to recreate mystring.o

- how does the make program know that a file has been changed?

```
# first version of makefile for labels program
labels: labels.o util.o
        gcc labels.o util.o -o labels

labels.o: labels.c ml.h
        gcc -c labels.c

util.o: util.c ml.h
        gcc -c util.c
```

- To remake the labels program just type:

```
make
```

Default rules

- these rules are very repetitive: every action is the same except for the file name
- make provides a set of default rules for common situations
- these defaults can be overidden and rules for new file types can be entered

Default rules

- for example, there is a default rule that specifies how to make a .o file from a .c file:

filename.o : *filename.c*

gcc -c *filename.c*

```
# second version of makefile for labels program
#   (using default rules)
labels: labels.o util.o
        gcc labels.o util.o -o labels

labels.o: ml.h

util.o: ml.h
```

- make knows the default rule for labels.o and util.o
- still have to specify a rule for the case where ml.h changes

Combining rules

- you can combine rules when the targets have common dependencies and actions:

```
labels:     labels.o util.o
            gcc labels.o util.o -o labels

labels.o util.o: ml.h
```

Rules without dependencies

- it is often useful to create rules that don't have dependencies and *always* activate
- for example, a rule to cleanup the file space:

```
labels:        labels.o util.o
               gcc labels.o util.o -o labels
labels.o util.o: ml.h
clean:
               rm *.o
```

Make variables

- sometimes you need to refer to a list of files at several places in the make file
- if you retype the list in each place you can introduce errors if you leave out a file in one or more places
- make has a variable or macro facility that lets you type the list in one place and refer to it using the variable name

Make variables

- assignments have the form:
  variable_name = any character sequence

- the value of the variable is substituted with:
  $(variable_name)

```
# makefile for labels program

OBJECTS = labels.o util.o

labels: $(OBJECTS)
        gcc $(OBJECTS) -o labels

$(OBJECTS):ml.h

clean:
        rm $(OBJECTS)
```

Predefined variables

- make has a number of predefined variables:

CC	the default C compiler
CFLAGS	flags passed to the compiler

- you can change the value of these variables:

```
CFLAGS = -DDEBUG -W -Wall -pedantic -ansi
```

this would cause the DEBUG symbol to be defined

Libraries

- a large system might consist of several programs that share a number of functions
- libraries give you the ability to store the object code versions of the functions in one place and have them linked into your program
- there are many libraries of functions provided by the system
- the standard C library has the standard I/O functions, system functions, sort function, etc
- the standard library is automatically searched when your program is linked

Libraries

- you can use functions from other libraries by using the -l flag when linking, eg

```
gcc -lm myprog.o -o myprog
```

- this will search the standard maths function library for functions such as sin, cos etc
- the C compiler will search for the library in standard directories: /lib, /usr/lib

Making your own libraries

- you make your own libraries using the “ar” command on the .o files:

```
ar c mylib.a readit.o util.o
```

- the library will be called mylib.a and will contain your .o files
- you can use the library with a command like:

```
gcc myprog.o mylib.a -o myprog
```

Summary

- C programs very quickly get to a size where they require several files
- large programs can have hundreds of .c and .h files that depend on each other
- the make tool helps you maintain an up-to-date version of your program
- libraries can also help maintain large systems