Strings and Multiple Source Files

Comp-206 : Introduction to Software Systems
Lecture 15

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Fall 2006

String operation

- As you have probably noticed by now, C does not have a string primitive.
- This means that traditional operators, such as = or == cannot be used with strings.
  - string1 == string2 will compare the pointer addresses, not the content of the string.
- C provided functions in the <string.h> library to manipulate and compare string.

Len of String

- The strlen functions returns the length of a string, not including the terminating null character.
  - size_t strlen(const char *s);

Comparing Strings

- To compare two string, use the strcmp function.
  - int strcmp(const char *s, const char *t)
- The function does a char by char comparison:
  - If both strings are equal, the function returns a 0.
  - The function returns a negative number if s > t
  - The function returns a positive number if t > s
- The strncmp function can also be used if only the first n characters of a string need to be compared.
  - int strncmp(const char *s, const char *t, size_t n)

Concatenating String

- The strcat function appends the src string to the dest string.
  - char *strcat(char *dest, const char *src);
- Once both string have been concatenated, a terminating null character is added.
  - The original null character at the end of dest is overwritten.
- The strings may not overlap.
- The dest string must have enough space for the result.
- If only n characters from src need to be concatenated, the strncat function should be used instead.
  - char *strncat(char *dest, const char *src, size_t n);

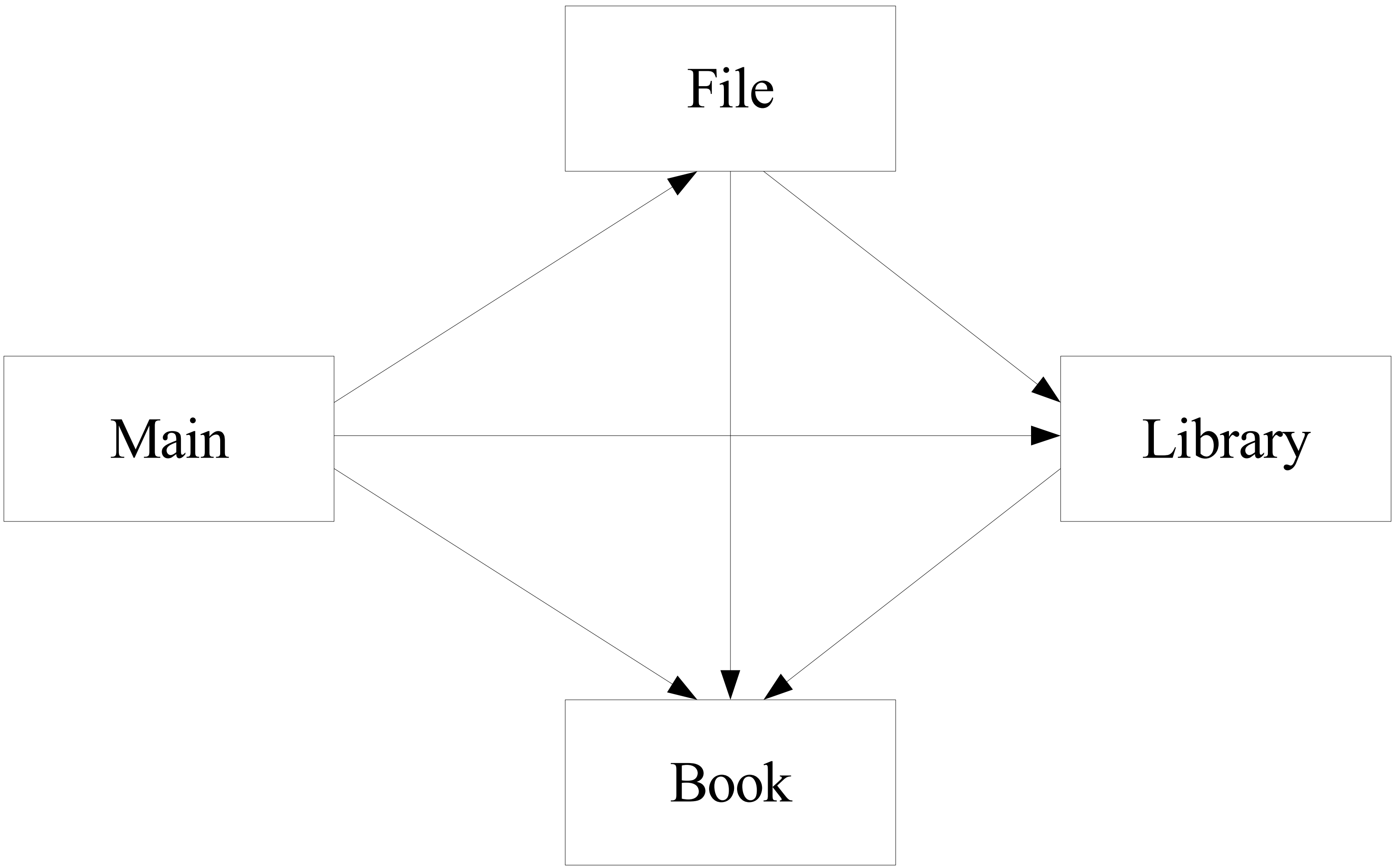
Copying Strings

- The strcpy() function copies the string pointed to by src to the array pointed to by dest.
  - char *strcpy(char *dest, const char *src);
- The terminating `\0' character is also copied.
- The strings may not overlap.
- The destination string dest must be large enough to receive the copy.
- In only n characterns need to be copied, the strncpy function should be used instead.
  - char *strncpy(char *dest, const char *src, size_t n);
- Note that if no null byte among the first n bytes of src, the result will not be null-terminated.

Library Example

- Small example application to manage a book list.
- Striking similarity to assignment 2.
- For modules:
  - Book : Structure to hold book information.
  - Library : Structure to hold collection of books.
  - File : Utilities to save/load books.
  - Main : Runs the application.

Dependencies



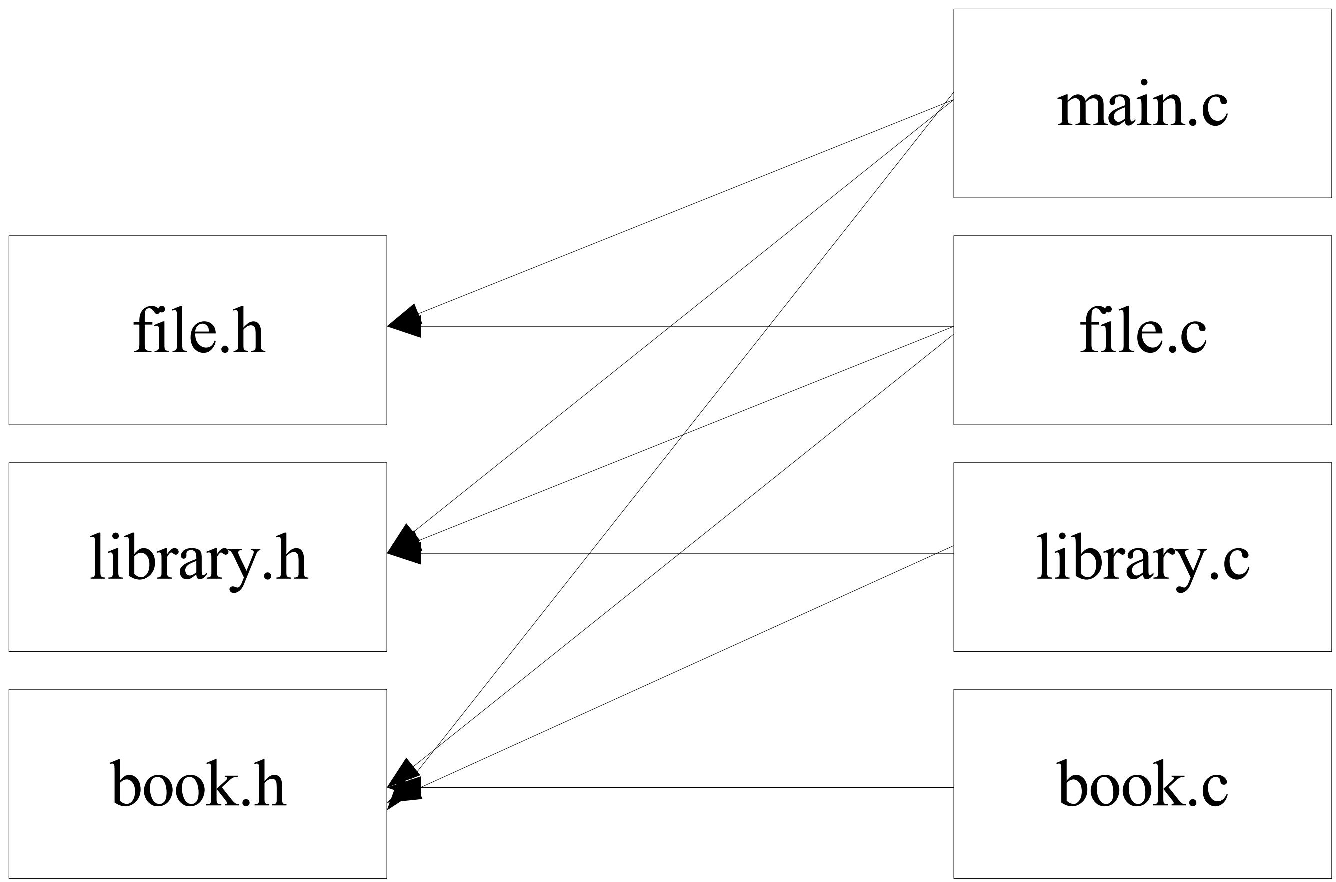
Using Multiple Files

- As mentioned before, functions and types in C need to be defined before they can be used.
- For functions, we can solve this problems by declaring the functions before we use them (function prototype).
- But what happens when we want to use a function defined inside another file?
- C allows us to include a file inside another.
  - We will take a look at this latter in the lecture.

Using Header Files

- When programming in C, code is usually separated in two types of file:
  - Header files (.h)
  - Code files (.c)
- All the preprocessor commands, type declarations, global variable declaration and function prototypes are usually stored in the header file.
  - Header files have the .h extension.
- The actual code is store in the code file.
  - Code files have the .c extension.

Dependency Tree



book.h

```
#if !defined(BOOK)
#define BOOK

#include <stdio.h>
#include <stdlib.h>
#include <string.h>

typedef struct {
        char * title;
        char * author;
        int pages;
} book;

book * createBook(char* title, char* author, int pages);
void printBook(book* myBook);
void unallocateBook(book* myBook);

#endif
```

book.c

```c
#include "book.h"

book * createBook(char* title, char* author, int pages) {

        book* newBook;

        newBook = (book *)malloc(sizeof(book));
        newBook->title = (char *)malloc(strlen(title)+1);
        newBook->author = (char *)malloc(strlen(title)+1);
        newBook->pages = pages;
        strcpy(newBook->title, title);
        strcpy(newBook->author, author);

        return newBook;
}

void printBook(book* myBook) {
...
```

main.c

```
#include "book.h"
#include "library.h"
#include "file.h"

int main (int argc, char **argv) {

        library* mylibrary = createLibrary(20);

        loadLibrary("lib.txt", mylibrary);

        addBookToLibrary(mylibrary, createBook(
              "Lotr", "Tolkien", 300));
        addBookToLibrary(mylibrary, createBook(
              "Harry Potter", "Rowing", 50));
        addBookToLibrary(mylibrary, createBook(
              "C Prog", "Kerning", 100));

        printLibrary(mylibrary);
...
```

Preprocessor

- The preprocessor processes a file before it is compiled.
  - It removes comments from source files.
  - It executes preprocessor commands (#define, #include).
- Preprocessor commands (or directives) are most often found in the beginning of the source file.

#include

- Any instance of the #include directive is replace by the content of the filename attached to the directive.
- #include directive come in two formats:
  - #include <filename>
  - #include “filename”
- When using the include statement with the < >, the preprocessor searches for filename in the library directories of the operating system.
- When using the include statement with the “ “, the preprocessor searches for filename in the same directory as the source file.

#define

- #define directives are used to define symbolic names or values.
- Similar to constant variables, #define can be used to insert hard-coded values.
- However, #define commands are executed by the preprocessor, before the code is compiled.
- The directive will replace the defined keyword by the defined value.
  - #define STEP 20
  - In this case, all occurrence of the string STEP will be replaced by the number 20

#define vs const

- #define is more efficient
  - Const is a variable and requires memory.
  - #define is a text replacement and requires no additional memory
- const is safer
  - Since the constant is a variable, the compiler can safely type check it.
  - #define can have some weird interaction (next slide).
- My rule of thumb: unless you have a specific reason for using #define, use const.
- Good reasons for using #define include:
  - Memory is a concern
  - Performance is a concern
  - You need the constant in another preprocessor command.

Dangers of define

```
#define C1 10/5
float const C2 = 10/5;

float C3 = 23.0 / C1;   // C3 = 11
float C4 = 23.0 / C2;  // C4 = 11.5
```

- Why? Because C3 gets preprocessed to

```
float C3 = 23.0 / 10/5;
```

- Because of the presence of 10 and 5, we get integer division.
- This example is pretty simple, but in large applications (hundreds of source files), this can be difficult to find.

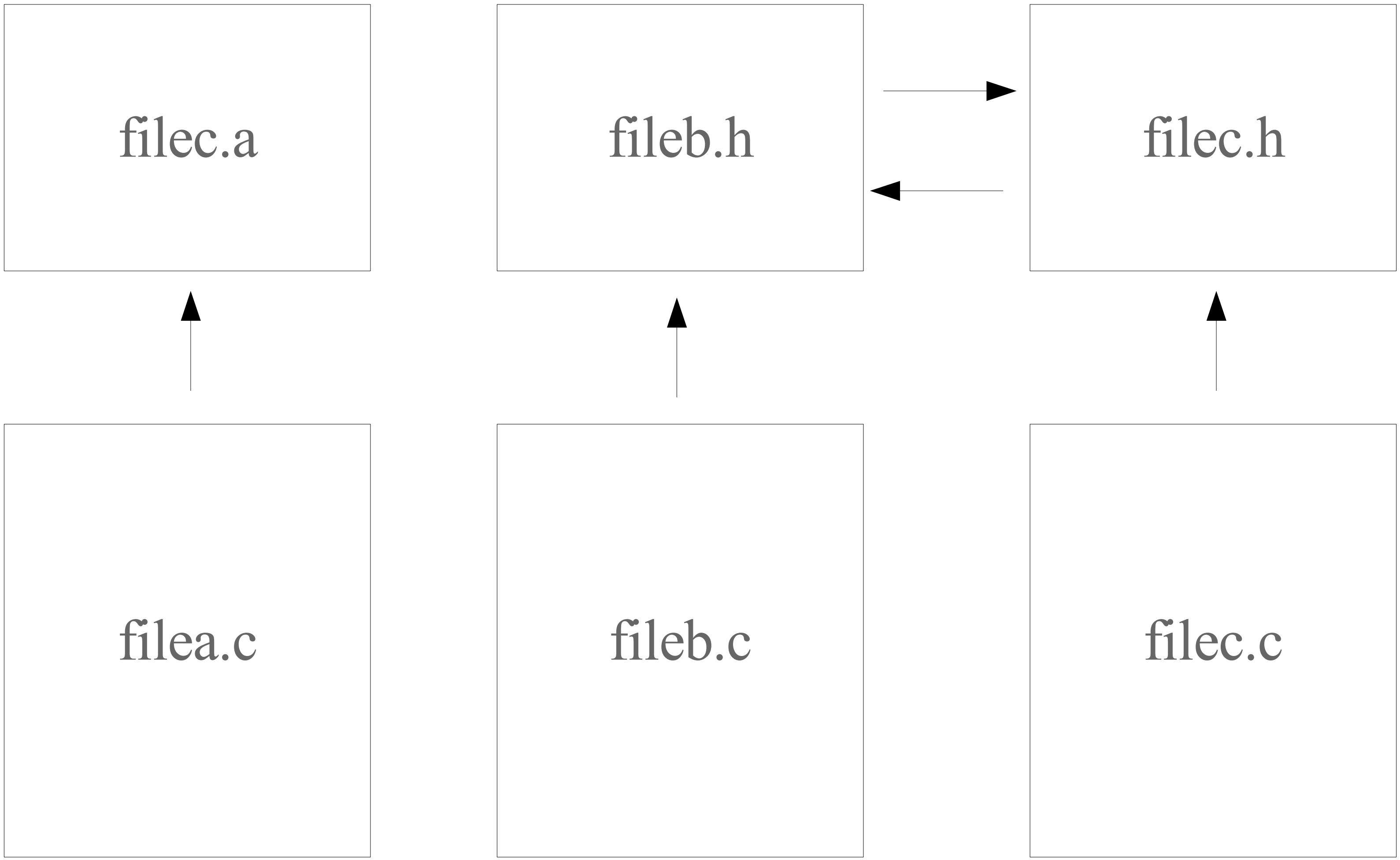
Macro Substitution

- Macros exploit the substitution power of #define directive to embedded small functions in the code.
- Macros have the following syntax:
  - #define name function
- A common example of macro is the maximum value macro.
  - #define max(A, B) ((A) > (B) ? (A) : (B))
- Not that macros are even more dangerous then #define statements.
  - By themselves, they are usually ok.
  - However, if you start mixing them, you might get some unexpected behavior.

Conditional Inclusion

- It is possible to control preprocessing itself with conditional statements that are evaluated during preprocessing.
- This provides a way to include code selectively, depending on the value of conditions evaluated during compilation.
- The two most common uses of conditional inclusions are:
  - Making sure that a header is included only once.
  - Adapting code to different OS.

Mixed an matched headers



Headers only Once

- To make sure that the contents of a file are included only once, the contents of the file are surrounded with a conditional like this:

```
#if !defined(UNIQUE_KEYWORD)
#define UNIQUE_KEYWORD
/* contents of header go here */
#endif
```

- Note that the defined variable should be unique to the file (unless you know exactly what you are doing).

Introduction to Make

- Make is an automated build utility.
- It automatically determines which pieces of a large program need to be recompiled, and issues commands to recompile them.
- Although all our examples will be based on C programming, Make can be used with any language.
- These slides are based on the excellent Make Tutorial at http://theory.uwinnipeg.ca/gnu/make/make_toc.html

Makefile

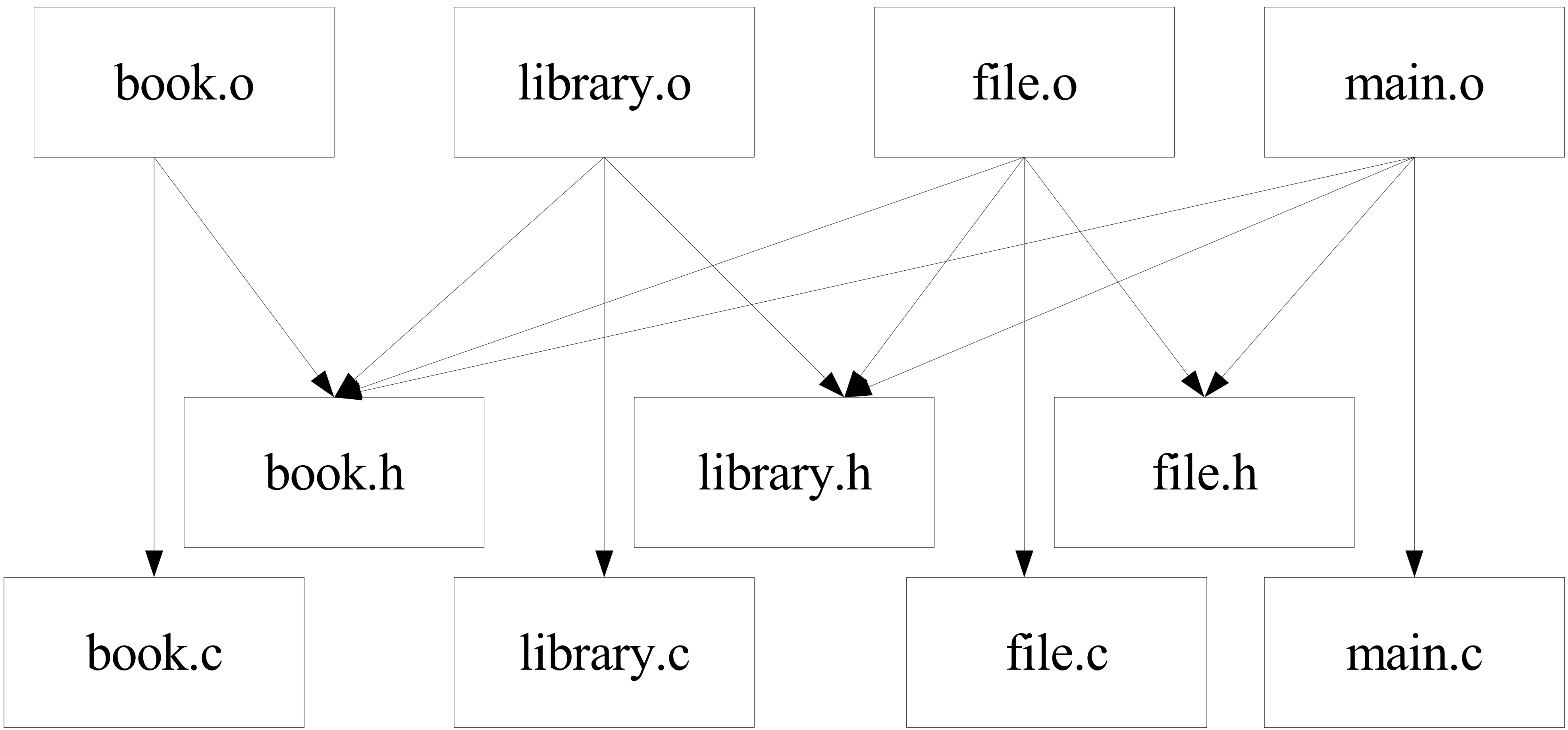
- Make gets its instruction for “Makefile” file.
- It's a collection of rules and instruction which explain how to compile your program.
- The first rule in your make file is your default rule.
- If you make a mistake building your rule, your application will not compile properly.
- You just need to type “make” at the command to run make. This will run the default rule.

```
make
```

  - makefile is the default instruction file and is automatically used.
  - To execute a specific action, specify that action as an argument.

```
make clean
```

Dependency Tree



Anatomy of a Rule

```
target ... : dependencies ...
        command
        ...
```

- Target : either the name of the file you want to compile or the name of an action you want to perform.
- Dependencies : name of files needed to execute the rule.
- Command : Action that needs to be carried out.
  - A rule can have more than one command, one on each line.
  - You **need** to put a tab character at the beginning of every command line!

Example makefile

```
librarydemo : main.o library.o file.o book.o
        gcc -Wall -g -ggdb -o library main.o library.o file.o book.o

main.o : main.c file.h library.h book.h
        gcc -c -Wall -g -ggdb main.c

file.o : file.c file.h library.h book.h
        gcc -c -Wall -g -ggdb file.c

library.o : library.c library.h book.h
        gcc -c -Wall -g -ggdb library.c

book.o : book.c book.h
        gcc -c -Wall -g -ggdb book.c

clean :
        rm -f library main.o library.o file.o book.o
```

Using Variables

```
objects = main.o library.o file.o book.o
coptions = -Wall -g -ggdb

librarydemo : ${objects}
	gcc ${coptions} -o library ${objects}

main.o : main.c file.h library.h book.h
	gcc -c ${coptions} main.c

file.o : file.c file.h library.h book.h
	gcc -c ${coptions} file.c

library.o : library.c library.h book.h
	gcc -c ${coptions} library.c

book.o : book.c book.h
	gcc -c ${coptions} book.c

clean :
	rm -f library ${objects}
```

Implicit rule

- Make has an implicit rule for updating a “.o” file from a correspondingly named “.c” file.
- Although I don't recommend you using it, I'm showing them to because will see them used frequently.

```
objects = main.o library.o file.o book.o

diskdemo : ${objects}
        gcc ${coptions} -o library ${objects}

main.o : file.h library.h book.h
file.o : file.h library.h book.h
library.o : library.h book.h
book.o : book.h

clean :
        rm -f library ${objects}
```