Multi-file (larger) programs

Friday: social implications

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Motivation

- Single-file programs do not work well when code gets large
  - compilation can be slow
  - hard to collaborate between multiple programmers
  - more cumbersome to edit
- So, larger programs are split into multiple files
  - each file represents a partial program or module
  - modules can be compiled separately or together
  - a module can be shared between multiple programs

Partial programs

- A `.c` file can contain a partial program:

```
#include <stdio.h>
void f1(void) {                // part1.c
    printf("this is f1\n");
}
```

- Such a file cannot be compiled into an executable by itself:

```
$ gcc part1.c
/usr/lib/gcc/crt1.o: In function `_start':
(.text+0x18): undefined reference to `main'
collect2: ld returned 1 exit status
```


But `part2.c` wants to use `part1.c's` code?

```
#include <stdio.h>
void f2(void);            // part2.c
int main(void) {
    f1();                 // not defined!
    f2();
}
void f2(void) {
    printf("this is f2\n");
}
```

- The program will not compile
  - `$ gcc -o combined part2.c`
  - `In function `main':`
  - `part2.c:6: undefined reference to `f1'`

Including .c files (bad)

- One solution: `#include part1.c` in `part2.c`

```
#include <stdio.h>
#include "part1.c"       // note "" not <>
void f2(void);
int main(void) {
    f1();                // defined in part1.c
    f2();
}
void f2(void) {
    printf("this is f2\n");
}
```

- The program will compile successfully:

```
$ gcc -g -Wall -o combined part2.c
```


Multi-file compilation

```
#include <stdio.h>
void f2(void);            // part2.c
int main(void) {
    f1();                 // not defined?
    f2();
}
void f2(void) {
    printf("this is f2\n");
}
```

- `gcc` accepts multiple source files to combine

```
$ gcc -g -Wall -o combined part1.c part2.c
$ ./combined
this is f1
this is f2
```

Object (.o) files

- A partial program can be compiled into an object (`.o`) file with `-c`

```
$ gcc -g -Wall -c part1.c
$ ls
part1.c    part1.o    part2.c
```

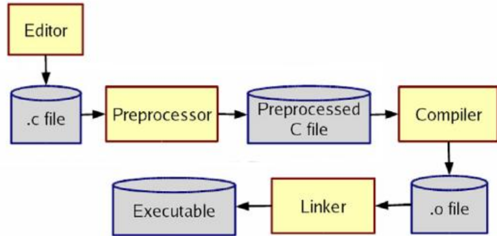
- A `.o` file is a binary blob of compiled C code that cannot be directly executed, but can be directly inserted into a larger executable later
- You can compile a mixture of `.c` and `.o` files

```
$ gcc -g -Wall -o combined part1.o part2.
```

- Avoids recompilation of unchanged partial program files

The compilation process

- Each step's output can be dumped to a file, depending on arguments passed to `gcc`



Problem

- With the previous code, we can't safely create `part2.o`

```
$ gcc -g -Wall -c part2.c
part2.c: In function `main':
part2.c:6: warning: implicit declaration of
  function `f1'
```

- The compiler is complaining because `f1` does not exist.
  - But it will exist once `part1.c/o` is added in later
- We'd like a way to be able to declare to the compiler that certain things will be defined later in the compilation process...

Header files

- Header : A file whose only purpose is to be included
  - By convention a filename with the `.h` extension
  - Holds shared variables, types, and function declarations
- Key ideas:
  - every `name.c` intended to be a module has a `name.h`
  - `name.h` declares all global functions/data of the module
  - other `.c` files that want to use the module will `#include name.h`
- Some conventions:
  - `.c` files never contain global function prototypes
  - `.h` files never contain definitions (only declarations)
  - never `#include` a `.c` file (only `.h` files)
  - any file with a `.h` file should be able to be built into a `.o` file

Multiple inclusion

- If multiple modules include the same header, the variables/functions in it will be declared twice
- Solution : use preprocessor to introduce conditional compilation
  - convention: `#ifndef/#define` with a variable named like the `.h` file
  - first time file is included, the variable won't be defined
  - on inclusions by other modules, will be defined and thus not included again

```
#ifndef _FOO_H
#define _FOO_H
... // contents of foo.h
#endif
```


Global visibility

```
// example.c
int passcode = 12345;

// example2.c
int main(void) {
  printf("Password is %d\n", passcode);
  return 0;
}
```

- By default, global variables and functions defined in one module can be seen and used by other modules it is compiled with
  - problem : `gcc` compiles each file individually before linking them
  - if `example2.c` is compiled separately into a `.o` file, its reference to `passcode` will fail as being undeclared

extern

```
// example2.c
extern int passcode;
...
printf("Password is %d\n", passcode);
```

- `extern` used on variables and functions
  - does not actually define a variable/function or allocate space for it – but promises the compiler that some other module will define it
  - allows your module to compile even with an undeclared variable/function reference, so long as eventually its `.o` object is linked to some other module that declares that variable/function
    - if `example.c` and `example2.c` are linked together, the above will work

static

```
// example.c
int passcode = 12345;                    // public
static int admin_passcode = 67890;       // private
```

- `static` used on global variables and functions
  - visible only to the current file/module (sort of like Java's `private`)
  - declare things `static` if you do not want them exposed
  - avoids potential conflicts with multiple modules that happen to declare global variables with the same names
  - `passcode` will be visible through the rest of `example.c`, but not to any other modules/files compiled with `example.c`

Function static data

- When used inside a function
  `static type name = value;`
  … declares a static local variable that will be remembered across calls

```
int nextSquare() {
    static int n = 0;
    static int increment = 1;
    n += increment;
    increment += 2;
    return n;
}
```

- `nextSquare()` returns `1`, then `4`, then `9`, then `16`, ...

Risks

- **File share leaks data on US Congress members under investigation**
- *Jeremy Epstein <jeremy.j.epstein@gmail.com> Fri, 30 Oct 2009 13:54:08 -0400* The Washington Post's Oct 30 lead article notes that "more than 30 lawmakers and several aides" are under investigation for various possible misdeeds associated with "defense lobbying and corporate influence peddling". What's technology relevant is that the information leaked because a report was (presumably accidentally) placed on an unprotected computer (not clear whether it was a web site, a file share, or something else). No word on whether the problem was a misconfiguration (i.e., mis-set file permissions, whether accidentally or intentionally) or due to a bug in software that allowed bypassing protections. No indication that the data was encrypted... perhaps this is an opportunity for Congress to learn the need for more usable security systems, including encryption, to reduce the RISK of accidental sharing?

Questions?