CSE 333

Lecture 8 - low-level I/O

Hal Perkins

Department of Computer Science & Engineering

University of Washington

Administrivia

HW1 due Thursday night

- Some good stuff on the discussion board
- Watch that hashtable.c doesn't violate the modularity of ll.h
- Watch for pointers to local (stack-allocated) variables - don't store them in persistent data structures
- Extra credit: if you add unit tests, it would help if they were in a new file and you adjusted the makefile accordingly.
- Quiz: what is the late day policy?
- Quiz: what happens if you re-submit the project after first turnin?

Administrivia 2

HW2 out Thursday or Friday

- Sections tomorrow: POSIX I/O (needed for hw2)

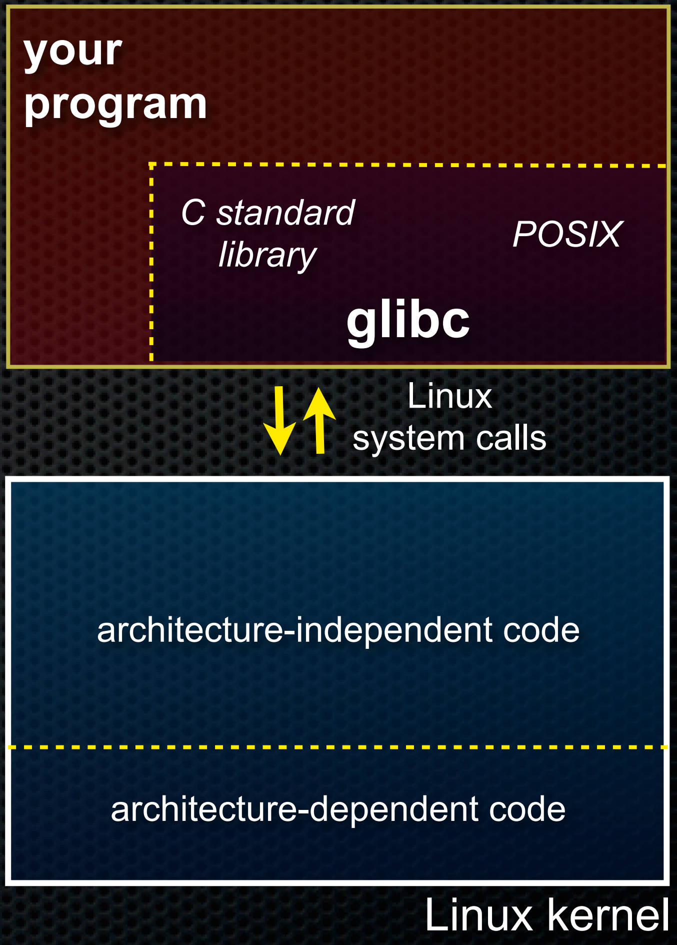
Next exercise won’t be due until Monday (HW2 warmup)

Next lectures: Start C++ (!!)

Lower-level file access

Remember this picture?

- your program can access many layers of APIs
  - C standard library
  - POSIX compatibility API
  - underlying OS system calls



So far...

You’ve used the C standard library to access files

- specifically, fopen, fread, fwrite, fclose, fseek
  - these provide a (FILE *) stream abstraction

These are convenient and portable...

- but, they are *buffered*
- and, they are implemented by using lower-level OS calls

Lower-level file access

Most UNIX-en support a common set of lower-level file access APIs

- open, read, write, close, fseek
  - similar in spirit to their fopen (etc.) counterparts
  - but, lower-level and unbuffered
    - (well, unbuffered from user's perspective; OS does its own buffering at least for disk blocks)
  - and, less convenient
- you will have to use these for network I/O, so we might as well learn them now

open / close

To open a file...

- pass in the filename and access mode, similar to fopen
- get back a “file descriptor”
  - similar to a (FILE *) from fopen, but is just an int

```
#include <fcntl.h>

...

 int fd = open("foo.txt",
               O_RDONLY);
 if (fd == -1) {
   perror("open failed");
   exit(EXIT_FAILURE);
 }

...

 close(fd);
```

Reading from a file

```
ssize_t read(int fd, void *buf, size_t count);
```

- returns the # of bytes read
    - might be fewer bytes than you requested (!!!)
    - returns 0 if you're at end-of-file
    - return -1 on error
- warning: read has some very surprising error modes!

read( ) error modes

On error, the “errno” global variable is set

- you need to check it to see what kind of error happened

What errors might read( ) encounter?

- EBADF -- bad file descriptor
- EFAULT -- output buffer is not a valid address
- EINTR -- read was interrupted, please try again
  - argh!!!
- and many others

How to read( ) n bytes

```
#include <errno.h>
#include <unistd.h>

...

  char *buf = ...;
  int bytes_left = n;
  int result = 0;

  while (bytes_left > 0) {
     result = read(fd, buf + (n-bytes_left), bytes_left);
     if (result == -1) {
       if (errno != EINTR)) {
        // a real error happened, return an error result
       }
       // EINTR happened, do nothing and loop back around
       continue;
     }
     bytes_left -= result;
  }
```

Other low-level functions

Read the man pages to learn about:

- **write**( ) -- write data
- **fsync**( ) -- flush data to the underlying device
- **opendir**( ), **readdir**( ), **closedir**( ) -- get a directory listing
  - make sure you read the section 3 version, e.g.:
    - man 3 opendir
  - kind of painful to use

A useful cheat-sheet

From a CMU systems programming course:

http://www.cs.cmu.edu/~guna/15-123S11/Lectures/Lecture24.pdf

See you on Friday!