Low-Level I/O – the POSIX Layer
CSE 333 Spring 2022

Instructor: Hal Perkins

Teaching Assistants:

Esau Abraham	Nour Ayad	Ramya Challa
Cleo Chen	Sanjana Chintalapati	Dylan Hartono
Kenzie Mihardja	Brenden Page	Aakash bin Srazali
Justin Tysdal	Julia Wang	Timmy Yang

Administrivia

- ❖ HW1 due tomorrow night
    - ▪ Any last-minute surprises? Questions?

- ❖ No exercise due Friday morning!

- ❖ Sections tomorrow: POSIX I/O and reading directories
- ❖ Next exercise: find text files in directory and print contents
    - ▪ Includes section stuff and is a warmup for hw2
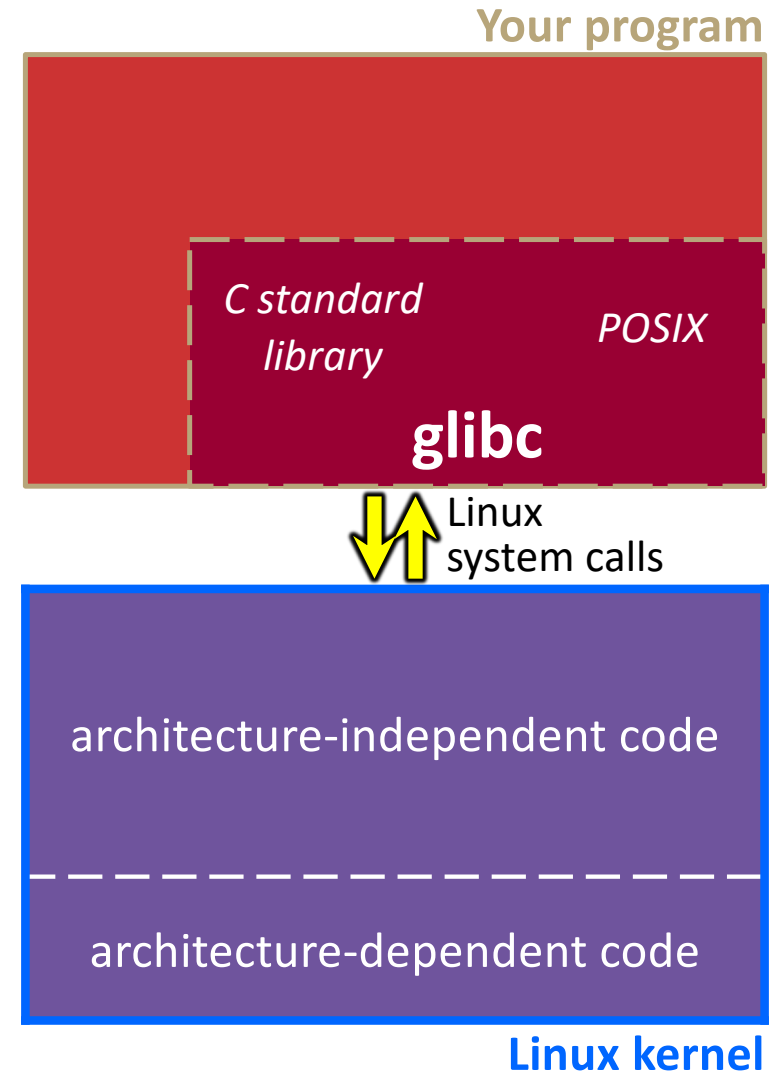   - ▪ Out tomorrow after sections; due Monday morning

- ❖ Friday: HW2 out; demo in class, starter code pushed to repos after class

Lecture Outline

❖ **POSIX Lower-Level I/O**

Remember This Picture?

Your program

❖ Your program can access many layers of APIs:

- C standard library
  - Some are just ordinary functions (<string.h>, for example)
  - Some also call OS-level (POSIX) functions (<stdio.h>, for example)
- POSIX compatibility API
  - C-language interface to OS system calls (fork(), read(), etc.)
- Underlying OS system calls
  - Assembly language ☺

C standard library   *POSIX*

glibc

Linux system calls

architecture-independent code

- -

architecture-dependent code

Linux kernel

C Standard Library File I/O

❖ So far you've used the C standard library to access files

▪ Use a provided `FILE*` *stream* abstraction

▪ **fopen(), fread(), fwrite(), fclose(), fseek()**

❖ These are convenient and portable

▪ They are buffered

▪ They are implemented using lower-level OS calls

Lower-Level File Access

❖ Most UNIX-en support a common set of lower-level file access APIs: POSIX – Portable Operating System Interface

  ▪ **open()**, **read()**, **write()**, **close()**, **lseek()**

    • Similar in spirit to their f*() counterparts from C std lib

    • Lower-level and unbuffered compared to their counterparts

    • Also less convenient

  ▪ We will have to use these to read file system directories and 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 FILE* from **fopen**(), but is just an int

  - Defaults: 0 is stdin, 1 is stdout, 2 is stderr

```c
#include <fcntl.h>    // for open()
#include <unistd.h>   // for close()
  ...
  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 number of bytes read
  - Might be fewer bytes than you requested (**!!!**)
  - Returns **0** if you're already at the end-of-file
  - Returns **−1** on error

- **read** has some surprising error modes…

Read error modes

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

- On error, `read` returns -1 and sets the global **errno** variable

- You need to check **errno** to see what kind of error happened

  - `EBADF:`   bad file descriptor
  - `EFAULT:`   output buffer is not a valid address
  - `EINTR:`   read was interrupted, please try again (ARGH!!!! 😤😠)
  - And many others…

One way to `read()` n bytes

```c
int fd = open(filename, O_RDONLY);
char* buf = ...;  // buffer of appropriate size
int bytes_left = n;
int result;

while (bytes_left > 0) {
  result = read(fd, buf + (n - bytes_left), bytes_left);
  if (result == -1) {
    if (errno != EINTR) {
      // a real error happened, so return an error result
    }
    // EINTR happened, so do nothing and try again
    continue;
  } else if (result == 0) {
    // EOF reached, so stop reading
    break;
  }
  bytes_left -= result;
}

close(fd);
```

readN.c

Other Low-Level Functions

❖ Read man pages to learn about:

- **`write()`** – write data

- **`fsync()`** – flush data to the underlying device

- **`opendir()`, `readdir()`, `closedir()`** – deal with directory listings

  - Make sure you read the section 3 version (*e.g.* `man 3 opendir`)

❖ A useful shortcut sheet (from CMU):

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

❖ More in sections this week….