CSE 333 – SECTION 3

POSIX I/O Functions

Administrivia

- **Questions (?)**

- **HW1 Due Tonight**
- HW2 Due Thursday, July 19th
- Midterm on Monday, July 23th
- 10:50-11:50 in TBD

- (And regular exercises in between)

POSIX

- **Portable Operating System Interface**
- Family of standards specified by the IEEE
- Maintains compatibility across variants of Unix-like OS
- Defines API and standards for basic I/O: file, terminal and network
- Also defines a standard threading library API

Basic File Operations

- Open the file
- Read from the file
- Write to the file
- Close the file / free up resources

System I/O Calls

```
int open(char* filename, int flags, mode_t mode);
```

Returns an integer which is the file descriptor.
Returns -1 if there is a failure.

filename: A string representing the name of the file.
flags: An integer code describing the access.

- O_RDONLY -- opens file for read only
- O_WRONLY – opens file for write only
- O_RDWR – opens file for reading and writing
- O_APPEND --- opens the file for appending
- O_CREAT -- creates the file if it does not exist
- O_TRUNC -- overwrite the file if it exists

mode: File protection mode. Ignored if O_CREAT is not specified.

`[man 2 open]`

System I/O Calls

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

fd: file descriptor.

buf: address of a memory area into which the data is read.

count: the maximum amount of data to read from the stream.

The return value is the actual amount of data read from the file.

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

```
int close(int fd);
```

Returns 0 on success, -1 on failure.

```
[man 2 read]
[man 2 write]
[man 2 close]
```

- Question: Why is it important to remember to call the close() function once you have finished working on a file?

- **In order to free resources i.e. other processes can acquire locks on those files.**

Errors

- When an error occurs, the error number is stored in **errno**, which is defined under <errno.h>
- View/Print details of the error using **perror()** and **errno**.
- POSIX functions have a variety of error codes to represent different errors. Some common error conditions:
  - **EBADF -** *fd* is not a valid file descriptor or is not open for reading.
  - **EFAULT -** *buf* is outside your accessible address space.
  - **EINTR -** The call was interrupted by a signal before any data was read.
  - **EISDIR -** *fd* refers to a directory.
- errno is shared by all library functions and overwritten frequently, so you must read it right after an error to be sure of getting the right code

```
[man 3 errno]
[man 3 perror]
```

Reading a file

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

...

  char *buf = ...;      // buffer has size n
  int bytes_left = n;   // where n is the length of file in bytes
  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;
  }
```

Again, why are we learning POSIX functions?

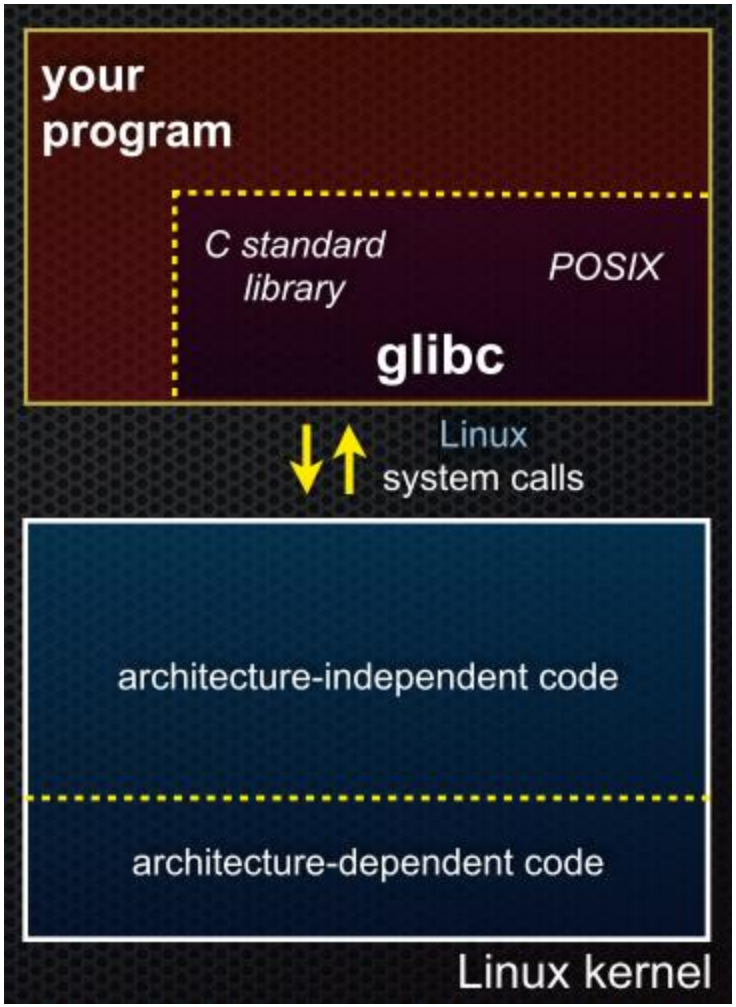
- They are unbuffered. You can implement different buffering/caching strategies on top of read/write.
- More explicit control since read and write functions are system calls and you can directly access system resources.
- There is no standard higher level API for network and other I/O devices.

STDIO vs. POSIX Functions

- User mode vs. Kernel mode.

- STDIO library functions
  - fopen, fread, fwrite, fclose, etc.
    use FILE* pointers.

- POSIX functions
  - open, read, write, close, etc.
    use integer file descriptors.



Exercise 1

- **Given the name of a file as a command-line argument, write a C program that is analogous to *`cat`*, i.e. one that prints the contents of the file to `stdout`. Handle any errors!**

- int main(int argc, char** argv) {
- /* 1. Check to make sure we have a valid command line arguments */
-
- /* 2. Open the file, use O_RDONLY flag */
-
- /* 3. Read from the file and write it to standard out. Try doing
- this without using printf() and instead have write() pipe to
- Stdout. It might be helpful to initialize a buffer variable
- (of size 1024 bytes should be fine) to pass in to read() and
- write().
-
- /*4. Clean up */
- }

Directories

- Accessing directories:
  - Open a directory
  - Iterate through its contents
  - Close the directory
- Opening a directory:

  DIR *opendir(const char* name);

  - Opens a directory given by **name** and provides a pointer **DIR*** to access files within the directory.
- Don’t forget to close the directory when done:

  int closedir(DIR *dirp);

```
[man 0P dirent.h]
[man 3 opendir]
[man 3 closedir]
```

Directories

- Reading a directory file.

```
struct dirent *readdir(DIR *dirp);

struct dirent {
  ino_t          d_ino;    /* inode number for the dir entry */
  off_t          d_off;    /* not necessarily an offset */
  unsigned short d_reclen; /* length (in bytes) of this record */
  unsigned char  d_type;   /* type of file (not what you think);
                              not supported by all file system types */
  char           d_name[NAME_MAX+1] ; /* directory entry name, null terminated */
};
```

```
[man 3 readdir]
[man readdir]
```

Read the man pages

- **man, section 2: Linux system calls**
- `man 2 intro`
- `man 2 syscalls`
- `man 2 open`
- `man 2 read`
- …
- **man, section 3: glibc / libc library functions**
- `man 3 intro`
- `man 3 fopen`
- `man 3 fread`
- `man 3 stdio` for a full list of functions declared in `<stdio.h>`
- …

Exercise 2

- **Given the name of a directory, write a C program that is analogous to ls, *i.e.* prints the names of the entries of the directory to stdout. Handle any errors!**

- int main(int argc, char** argv) {
- /* 1. Check to make sure we have a valid command line arguments */

- /* 2. Open the directory, look at opendir() */

- /* 3. Read through/parse the directory and print out file names. Look at readdir() and struct dirent */

- /* 4. Clean up */
- }

Makefile & DAG (= Directed Acyclic Graph)

- **Given the snippets of the following files, draw out the DAG and write a suitable Makefile.**
  It should produce the executables UsePoint, UseThing, and Alone and have ‘all’ and ‘clean’ phony targets.

Point.h	`class Point { … };`	Point.c	`#include "Point.h"` `// defs of methods`

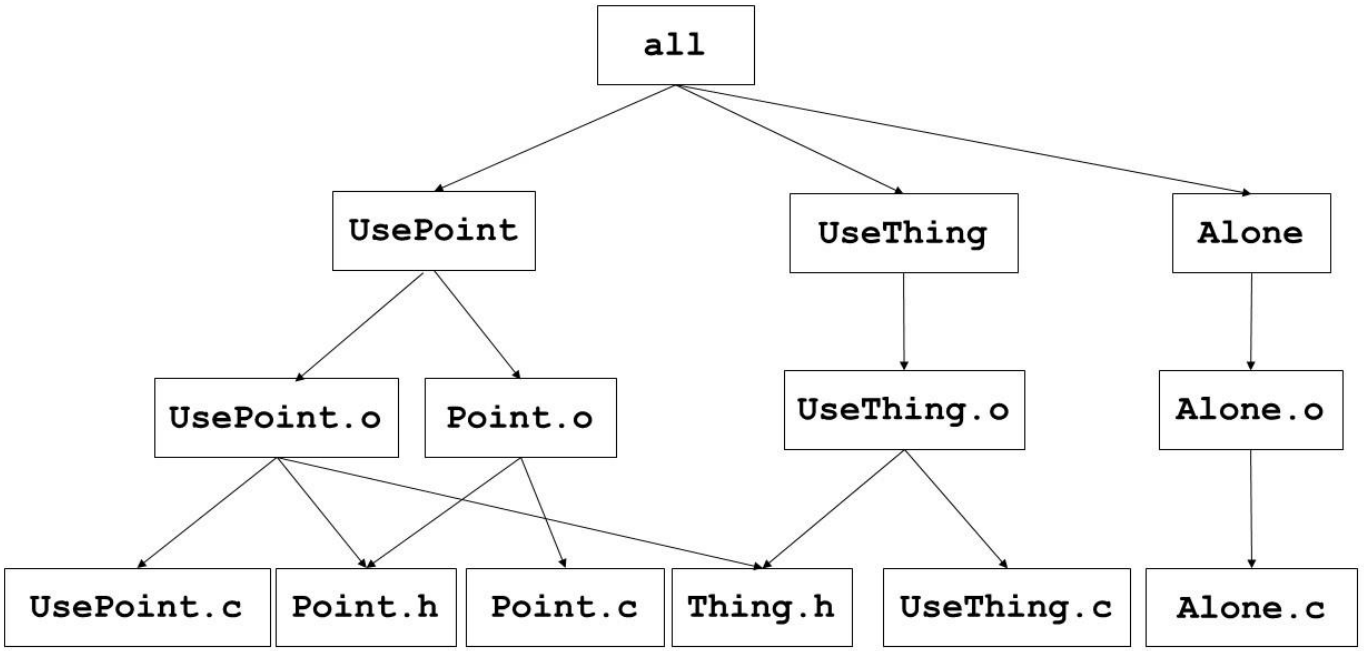
UsePoint.c	`#include "Point.h"`
	`#include "Thing.h"`
	`int main( … ) { … }`
		Thing.h	`struct Thing { … };`
			`// full struct def here`

UseThing.c	`#include "Thing.h"` `int main( … ) { … }`	Alone.c	`int main( … ) { … }`

Point.h	`class Point { … };`	Point.c	`#include "Point.h"` `// defs of methods`

UsePoint.c	`#include "Point.h"`
	`#include "Thing.h"`
	`int main( … ) { … }`
		Thing.h	`struct Thing { … };`
			`// full struct def here`

UseThing.c	`#include "Thing.h"` `int main( … ) { … }`	Alone.c	`int main( … ) { … }`



```
CFLAGS = -Wall -g -std=c11
all: UsePoint UseThing Alone
UsePoint: UsePoint.o Point.o
	gcc $(CFLAGS) -o UsePoint UsePoint.o Point.o
UseThing: UseThing.o
	gcc $(CFLAGS) -o UseThing UseThing.o
Alone: Alone.o
	gcc $(CFLAGS) -o Alone Alone.o
UsePoint.o: UsePoint.c Point.h Thing.h
	gcc $(CFLAGS) -c UsePoint.c
Point.o: Point.c Point.h
	gcc $(CFLAGS) -c Point.c
UseThing.o: UseThing.c Thing.h
	gcc $(CFLAGS) -c UseThing.c
Alone.o: Alone.c
	gcc $(CFLAGS) -c Alone.c
clean:
	rm UsePoint UseThing Alone *.o *~
```