### Recitation 11: I/O Problems

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# Logistics

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- Office hours
  - NSH 2504
  - Permanently moving to Tuesday 2–3
- What's left
  - Lab 6 Malloc: due on Thursday, 21 Nov
  - Lab 7 Proxy: due on Thursday, 5 Dec
  - Final Exam: 8:30am on Tuesday, 17 Dec, in Porter Hall 100

# Today's Plan

- Robust I/O
- Chapter 11 Practice Problems

# Why Use Robust I/O

- Handles interrupted system calls
  - Signal handlers
- Handles short counts
  - Encountering end-of-file (EOF) on reads (disk files)
  - Reading text lines from a terminal
  - Reading and writing network sockets or Unix pipes
- Useful in network programs
  - Subject to short counts
  - Internal buffering constraints
  - Long network delays
  - Unreliable

### Rio: Unbuffered Input/Output

- Transfer data directly between memory and a file
- No application level buffering
- Useful for reading/writing binary data to/from networks
  - (Though text strings **are** binary data.)

ssize\_t rio\_readn(int fd, void\* usrbuf, size\_t n)

- Reads n bytes from fd into usrbuf
- Only returns short on EOF

ssize\_t rio\_writen(int fd, void\* usrbuf, size\_t n)

- Writes n bytes from usrbuf to file fd
- Never returns short count

# **Rio: Buffered Input**

### void rio\_readinitb(rio\_t\* rp, int fd);

- Called only once per open file descriptor
- Associates fd with a read buffer rp

### ssize\_t rio\_readlineb(rio\_t\* rp, void\* usrbuf, size\_t maxlen);

- For reading lines from a text file only
- Read a line (stop on `\n') or maxlen-1 chars from file rp to usrbuf
- Terminate the text line with null (zero) character
- Returns number of chars read

#### ssize\_t rio\_readnb(rio\_t\* rp, void\* usrbuf, size\_t n);

- For both text and binary files
- Reads n bytes from rp into usrbuf
- Result string is NOT null-terminated!
- Returns number of chars read

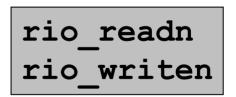
### rio\_readlineb

```
ssize t rio readlineb(rio t *rp, void *usrbuf, size t maxlen)
{
    int n, rc;
    char c, *bufp = usrbuf;
    for (n = 1; n < maxlen; n++) {
         if ((rc = rio read(rp, &c, 1)) == 1) {
             *bufp++ = c;
             if (c == ' \setminus n')
                 break;
         } else if (rc == 0) {
             if (n == 1)
                 return 0; /* EOF, no data read */
             else
                 break; /* EOF, some data was read */
        } else
             return -1; /* error */
    }
    *bufp = 0;
    return n;
}
```

## Do not interleave

- Do not interleave calls on the same file descriptor to these two sets of functions
- Why?

rio\_readinitb rio\_readlineb rio\_readnb



# **Rio Error Checking**

- All functions have upper case equivalents (Rio\_readn ...), which call unix\_error if the function encounters an error
  - Short reads are not errors
  - Also handles interrupted system calls
  - But does **not** ignore EPIPE errors, which are not fatal errors for Lab 7

# Problems from Chapter 11

- 11.1-11.5
- Handout contains the problems

# What is the output of the following program?

```
#include "csapp.h"
int main()
{
    int fd1, fd2;
    fd1 = Open("foo.txt", O_RDONLY, 0);
    Close(fd1);
    fd2 = Open("baz.txt", O_RDONLY, 0);
    printf("fd2 = %d\n", fd2);
    exit(0);
}
```

- Default file descriptors:
  - stdin (descriptor 0)
  - stdout (descriptor 1)
  - stderr (descriptor 2)
- open always returns *lowest, unopened* descriptor
- First open returns 3. close frees it.
- So second open also returns 3.
- Program prints:

fd2 = 3

### Kernel Structure for Open Files

- Descriptor table
  - One per process
  - Children inherit from parents
- File Table
  - The set of all open files
  - Shared by all processes
  - Reference count of number of file descriptors pointing to each entry
- V-node table
  - Contains information in the stat structure
  - Shared by all processes

Suppose that the disk file foobar.txt consists of the 6 ASCII characters "foobar". Then what is the output of the following program?

```
#include "csapp.h"
int main()
{
    int fd1, fd2;
    char c;
    fd1 = Open("foobar.txt", O RDONLY, 0);
    fd2 = Open("foobar.txt", O RDONLY, 0);
    Read(fd1, &c, 1);
    Read(fd2, &c, 1);
    printf("c = c n", c);
    exit(0);
```

- Two descriptors fd1 and fd2
- Two open file table entries, each with their own file positions for foobar.txt
- The read from fd2 also reads the first byte of foobar.txt
- So, the output is

c = f

and not

c = 0

As before, suppose the disk file foobar.txt consists of 6 ASCII characters "foobar". Then what is the output of the following program?

```
#include "csapp.h"
int main()
{
    int fd;
    char c;
    fd = Open("foobar.txt", O_RDONLY, 0);
    if(Fork() == 0) {
        Read(fd, &c, 1);
        exit(0);
    }
    Wait(NULL);
    Read(fd, &c, 1);
    printf("c = %c\n", c);
    exit(0);
}
```

- Child inherits the parent's descriptor table.
- Child and parent share an open file table entry (refcount == 2).
- Hence they share a file position!

• The output is

c = o

• How would you use dup2 to redirect standard input to descriptor 5?

- int dup2(int oldfd, int newfd);
  - Copies descriptor table entry oldfd to descriptor table entry newfd

dup2(5,0);

or

dup2(5,STDIN FILENO);

Assuming that the disk file foobar.txt consists of 6 ASCII characters "foobar". Then what is the output of the following program?

```
#include "csapp.h"
int main()
{
    int fd1, fd2;
    char c;
    fd1 = Open("foobar.txt", O_RDONLY, 0);
    fd2 = Open("foobar.txt", O_RDONLY, 0);
    Read(fd2, &c, 1);
    Dup2(fd2, fd1);
    Read(fd1, &c, 1);
    printf("c = %c\n", c);
    exit(0);
}
```

 We are redirecting fd1 to fd2. So the second Read uses the file position offset of fd2.

### $\mathbf{c} = \mathbf{o}$