CS 241: Systems Programming
Lecture 20. File I/O in C

Fall 2019
Prof. Stephen Checkoway

Announcement

Winter Term organizational meeting this Thursday at 12:15 in King 105
- ‣ You need to register in advance with Jackie in the CS office

Streams

C's view of Input/Output

Sequence of bytes

Implications about buffering

Physical I/O characteristics are concealed

Unix I/O

Unix treats all I/O as reading or writing a file

- ‣ mice
- ‣ printer
- ‣ keyboard
- ‣ networking
- ‣ screen
- ‣ disk files

Lower level I/O will be covered later (file descriptors)

File pointers

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Treat as opaque

‣   don't manipulate manually, use routines

Buffering

Output data is stored in a buffer (an array) when writing until there is "enough" data to write to the device

Buffering types
- ‣ Unbuffered: data is written to device immediately
- ‣ Line buffered: data is written after each newline
- ‣ Fully (or block) buffered: data is written in blocks once the block is full

```
int fflush(FILE *file);
```

Standard file pointers in Unix

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`stdout` — Line buffered if connected to a terminal; otherwise fully buffered

`stderr` — Unbuffered

Recall redirection and pipelines
- `./a.out < input.txt > output.txt`
- `./a.out | filter1 | filter2 > output.txt`

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‣ "a"   write, create, always at end

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‣ `"a+"`   read/write, create, always at end

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  ‣ "`a+`"   read/write, create, always at end

  ‣ In addition to +, there are also modifiers b for binary streams and x for eXclusive (`fopen(path, "wx")` fails if path already exists)

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If we want to read the contents of a text file into memory, modify it, and then write it back to the same file, which call to fopen() should we use?

A. `FILE *fp = fopen(path, "r+");`

B. `FILE *fp = fopen(path, "w+");`

C. `FILE *fp = fopen(path, "a+");`

D. `FILE *fp = fopen(path, "rb");`

E. `FILE *fp = fopen(path, "wx");`

Stream I/O single char

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char *fgets(char *str, size_t size, FILE *stream);


// Writes str to stdout and appends a newline

int puts(char const *str);

// Writes str to file but does not append a newline

int fputs(char const *str, FILE *stream);
```

Analogous to puts() vs. fputs(), there's a function
`char *gets(char *str);`
that reads a line from `stdin` and stores it in `str`.

This function should never be used under any circumstance!

Why not?

A. Including the function was a mistake by the C designers

B. There's no bounds checking on the input

C. A too-long line may crash the program

D. A too-long line may let an attacker take control of the program

E. All of the above

Checking for EOF/error

```
int feof(FILE *stream); // returns nonzero if stream is at the end

int ferror(FILE *stream); // returns nonzero if stream had an error
```

```c
#include <stdio.h>

int main(int argc, char *argv[argc]) {
  FILE *input = fopen(argv[1], "r");
  FILE *output = fopen(argv[2], "w");
  char str[1024];

  while (fgets(str, sizeof str, input)) {
    if (fputs(str, output) == EOF)
      break;
  }
  if (ferror(input) || ferror(output))
    return 1;
  return 0;
}
```

Error information

```c
#include <stdio.h>
#include <errno.h>

extern int errno; // libc funcs set this on failure
char *strerror(int errnum); // human-readable error string
void perror(char const *str); // prints error on stderr
```

perror(str) is (essentially)
```c
if (str && str[0])
  fprintf(stderr, "%s: %s\n", str, strerror(errno));
else
  fprintf(stderr, "%s\n", strerror(errno));
```

Exit values

When errors occur, may want to terminate program

```
void exit(int status);
  EXIT_SUCCESS    — value 0, c99 standard
  EXIT_FAILURE    — some value other than 0, (usually 1) c99 standard
```

BSD has tried to standardize other values

‣ `/usr/include/sysexits.h`

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 ‣ `EOF` on error (see `errno`)

Can close `stdin`, `stdout`, `stderr` if unneeded
 ‣ limit to the number of files allowed to be open

```c
#include <errno.h>
#include <stdio.h>
#include <stdlib.h>

int main(int argc, char *argv[argc]) {
  if (argc != 2) {
    fprintf(stderr, "Usage: %s FILE\n", argv[0]);
    exit(EXIT_FAILURE);
  }
  FILE *fp = fopen(argv[1], "w");
  if (!fp) {
    perror(argv[1]);
    exit(EXIT_FAILURE);
  }
  fputs("Created for CS 241\n", fp);
  fclose(fp);
  return EXIT_SUCCESS;
}
```

In-class exercise

https://checkoway.net/teaching/cs241/2019-fall/exercises/Lecture-20.html

Grab a laptop and a partner and try to get as much of that done as you can!