CSC 4304 - Systems Programming
Fall 2008

LECTURE - V

FILE I/O - II

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Summary of Last Class

- Advanced Structures in C
  - Local vs Global Variables
  - Dynamic Memory Management
- File I/O
  - opening and closing files
  - reading from / writing to files
  - seeking files

In Today's Class

- Buffered File I/O
  - opening and closing streams
  - reading from / writing to streams
  - Binary I/O
  - Formatted I/O

Buffered I/O

- Unbuffered I/O: each read write invokes a system call in the kernel.
  - read, write, open, close, lseek
- Buffered I/O: data is read/written in optimal-sized chunks from/to disk --> streams
  - standard I/O library written by Dennis Ritchie

Standard I/O Library

- Difference from File I/O
  - File Pointers vs File Descriptors
  - fopen vs open
    - When a file is opened/created, a *stream* is associated with the file.
    - FILE object
      - File descriptor, buffer size, # of remaining chars, an error flag, and the like.
  - stdin, sdtout, stderr defined in <stdio.h>
    - STDIO_FILENO, STDOUT_FILENO,…

Buffering

- Goal
  - Use the minimum number of read and write calls.
- Types
  - Fully Buffered
    - Actual I/O occurs when the buffer is filled up.
    - A buffer is automatically allocated when the first-time I/O is performed on a stream.
    - flush: standard I/O lib vs terminal driver

Buffering

- Line Buffered
  - Perform I/O when a newline char is encountered! – usually for terminals.
  - Caveats
    - The filling of a fixed buffer could trigger I/O.
    - The flushing of all line-buffered outputs if input is requested.
- Unbuffered
  - Expect to output asap, e.g. using write()
  - E.g., stderr

Buffering

```
#include <stdio.h>
void setbuf(FILE *fp, char *buf);
int setvbuf(FILE *fp, char *buf, int mode,
   size_t size);
```

- Full/line buffering if buf is not NULL (BUFSIZ)
  - Terminals
- mode: _IOFBF, IOLBF, _IONBF (<stdio.h>)
  - Optional size → st_blksize (stat())
- #define BUFSIZ 1024 (<stdio.h>)
- They must be called before any op is performed on the streams!

Buffering

- ANSI C Requirements
  - Fully buffered for stdin and stdout unless interactive devices are referred to.
    - SVR4/4.3+BSD – line buffered
  - Standard error is never fully buffered.

```
#include <stdio.h>
int fflush(FILE *fp);
```

  - All output streams are flushed if fp == NULL

Opening a Stream

- #include <stdio.h>
- FILE *fopen(const char *pathname, const char *type);

- opens a specified file
- types:
  - r : open for reading
  - w : create for writing or truncate to 0
  - a : open or create for writing at the end of file
  - r+ : open for reading and writing
  - w+: create for reading and writing or truncate to 0
  - a+ :open or create for reading and writing at the end of file

  - use b to differentiate text vs binary , e.g. rb, wb ..etc

Restrictions

Type	r	w	a	r+	w+	a+
File exists?	Y			Y		
Truncate		Y			Y	
R	Y			Y	Y	Y
W		Y	Y	Y	Y	Y
W only at end			Y			Y

* When a file is opened for reading and writing:

- Output cannot be directly followed by input without an intervening *fseek, fsetpos, or rewind*
- Input cannot be directly followed by output without an intervening *fseek, fsetpos, or rewind*

Closing a Stream

```
#include <stdio.h>
int fclose(FILE *fp);
```

- Flush buffered output
- Discard buffered input
- All I/O streams are closed after the process exits.

- setbuf or setvbuf to change the buffering of a file before any operation on the stream.

Reading and Writing from/to Streams

- Unformatted I/O
  - Character-at-a-time I/O, e.g., getc
    - Buffering handled by standard I/O lib
  - Line-at-a-time I/O, e.g., fgets
    - Buffer limit might need to be specified.
  - Direct I/O, e.g., fread
    - Read/write a number of objects of a specified size.
    - An ANSI C term, e.g., = object-at-a-time I/O

Reading a Char

```
#include <stdio.h>
int getc(FILE *fp);
int fgetc(FILE *fp);
int getchar(void);
```

- getchar == getc(stdin)
- Differences between getc and fgetc
  - getc could be a macro
  - Argument's side effect, exec time, passing of the function address.
- unsigned char converted to int in returning

Error/EOF Check

```
#include <stdio.h>
int ferror(FILE *fp);
int feof(FILE *fp);
void clearerr(FILE *fp);
int ungetc(int c, FILE *fp);
```

- An error flag and an EOF flag for each FILE
- No pushing back of EOF (i.e., -1)
  - No need to be the same char read!

Writing a Char

```
#include <stdio.h>
int putc(int c, FILE *fp);
int fputc(int c, FILE *fp);
int putchar(int c);
```

- putchar(c) == putc(c, stdout)
- Differences between putc and fputc
  - putc() can be a macro.

Example 1

```
#include <stdio.h>
main()
{
    int c;

    while ((c = getchar()) != EOF)
        putchar(c);
 }
```


Line-at-a-Time I/O

#include <stdio.h>

char *fgets(char *buf, int n, FILE *fp);

- Include '\n' and be terminated by *null*
- Could return a partial line if the line is too long.

char *gets(char *buf);

- Read from stdin.
- No buffer size is specified → overflow
- *buf does not include '\n' and is terminated by *null.*

Line-at-a-Time I/O

#include <stdio.h>

char *fputs(const char *str, FILE *fp);

- Include '\n' and be terminated by *null.*
- No need for line-at-a-time output.

char *puts(const char *str);

- *str does not include '\n' and is terminated by *null.*
- puts then writes '\n' to stdout.

Example 2

```
#include <stdio.h>
main()
{
    int bufsize = 1024;
    char buf[bufsize];

    while (fgets(buf, bufsize, stdin) != NULL)
        fputs(buf, stdout);
 }
```

Standard I/O Eficiency

- Copy stdin to stdout using:

	total time	kernel time
• fgets, fputs	2.6 sec	0.3 sec
• fgetc, fputc	5 sec	0.3 sec
• read, write	423 sec	397 sec (1 char at a time)

Example 3

```
#include ...
main()
{
    int bufsize = 1;
    char buf[bufsize];

    while (read(0, buf, bufsize) > 0)
        write (1, buf, bufsize);
 }
```

Effect of Buffer Size

- cp file1 to file2 using read/write with buffersize:
  (5 MB file)

buffersize	exec time
1	50.29
4	12.81
16	3.28
64	0.96
256	0.37
1024	0.22
4096	0.18
16384	0.18

Binary I/O

- Objectives
  - Read/write a structure at a time, which could contains null or '\n'.

```
#include <stdio.h>
size_t fread(void *ptr, size_t size, size_t nobj,
   FILE *fp);
size_t fwrite(const void *ptr, size_t size, size_t
   nobj, FILE *fp);
```

- size: size of each element
- nobj: number of elements
- return value: number of objects read/written

Binary I/O

- Not portable for programs using fread and fwrite
  1. The offset of a member in a structure can differ between compilers and systems (due to alignment).
  2. The binary formats for various data types, such as integers, could be different over different machines.

Binary I/O

- Example 1

```
float data[10];
if (fwrite(&data[2], sizeof(float), 4, fp) != 4)
    err_sys("fwrite error");
```

- Example 2

```
struct {
        short count;
        long total;
        char name[NAMESIZE];
} item;
if (fwrite(&item, sizeof(item), 1, fp) != 1)
    err_sys("fwrite error");
```

Positioning a Stream

```
#include <stdio.h>
long ftell(FILE *fp);
int fseek(FILE *fp, long offset, int whence);
void rewind(FILE *fp);
```

- Assumption: a file's position can be stored in a long (since Version 7)
- whence: same as lseek
  - Binary files: No requirements for SEEK_END under ANSI C (good under Unix, possible padding for other systems).
  - Text files: SEEK_SET only – 0 or returned value by ftell (different formats for some sys).

Positioning a Stream

```
#include <stdio.h>
long fgetpos(FILE *fp, fpos_t *pos);
int fsetpos(FILE *fp, const fpos_t *pos);
```

- ANSI C standard
- Good for non-Unix systems
- A new data type fpos_t

Formatted I/O

```
#include <stdio.h>
int printf(const char *format, …);
int fprintf(FILE *fp, const char *format, …);
int sprintf(char *buf, const char *format, …);
```

- Overflow is possible for sprintf() – '\0' appended at the end of the string.

```
int vprintf(const char *format, var_list arg);
int vfprintf(FILE *fp, const char *format, var_list
   arg);
int vsprintf(char *buf, const char *format,
   var_list arg);
```


Formatted I/O

```
#include <stdio.h>
int scanf(const char *format, …);
int fscanf(FILE *fp, const char
   *format, …);
int sscanf(char *buf, const char
   *format, …);
```

Summary

- Buffered File I/O
  - opening and closing streams
  - reading from / writing to streams
  - Binary I/O
  - Formatted I/O

- Next Lecture: Files & Directories
- Read Ch.5 from Stevens

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