Week 10 Lecture 2

XMUT-NWEN 241 - 2024 T2

Systems Programming

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Content

- **File Stream I/O**
- Introduction to File Stream I/O
- File Stream Operations
- Opening, Flushing, and Closing
- Reading and Writing a Character

File Stream I/O

Introduction to File Input / Output

- I/O is the process of copying data between main memory and external devices, like terminals (keyboards), disk drives, networks, etc.

- In C, everything is abstracted as a *file*
  - Each file is simply a sequential stream of bytes
  - C imposes no structure on a file

- **From the program's point of view, data input and data output are made possible through files**

Accessing Files

- **A file must first be opened properly before it can be accessed for reading or writing**

- Opening a file establishes a “communication channel” between the program and the file

File Stream vs File Descriptor

- "Communication channel" can either be a **file stream** or **file descriptor**
- C provides functions for accessing files via file stream or file descriptor

	File Descriptor	File Stream
Content access	*Primitive access*: contents can be accessed as blocks of bytes	*Rich access*: contents can be formatted using format specifiers
Control operations	Allows setting of control parameters	Does not allow
Special I/O modes	Allows special access modes such as non-blocking	Does not allow
Buffering	None	Supports 3 modes of buffering

File Stream vs File Descriptor

- **File streams provide a higher-level interface, layered on top of the primitive file descriptor facilities**

- For special files (e.g. I/O devices and **sockets**), file descriptor is the recommended approach

- For **regular files** (files on disk), file stream is the recommended approach

Stream Buffering

- One of the common pitfalls when dealing with file streams is **buffering**

- More problematic in interactive I/O streams
  - Data written by program to file does not appear immediately
  - Data read by program from file does not appear immediately

Illustration

```
char str[100];
scanf ("%s", str);
```

- If user types the string

```
The quick brown fox
```

- The string str will only be assigned "The"
- What happens to the rest?

Stream Buffering Modes

Mode	Description
Unbuffered	Characters written to or read from an unbuffered stream are transmitted individually to or from the file as soon as possible.
Line buffered	Characters written to a line buffered stream are transmitted to the file in blocks when a newline character is encountered.
Fully buffered	Characters written to or read from a fully buffered stream are transmitted to or from the file in blocks of arbitrary size.

- Newly opened streams are fully buffered by default, except streams connected to interactive devices which are line buffered
- C provides functions for changing stream buffering mode

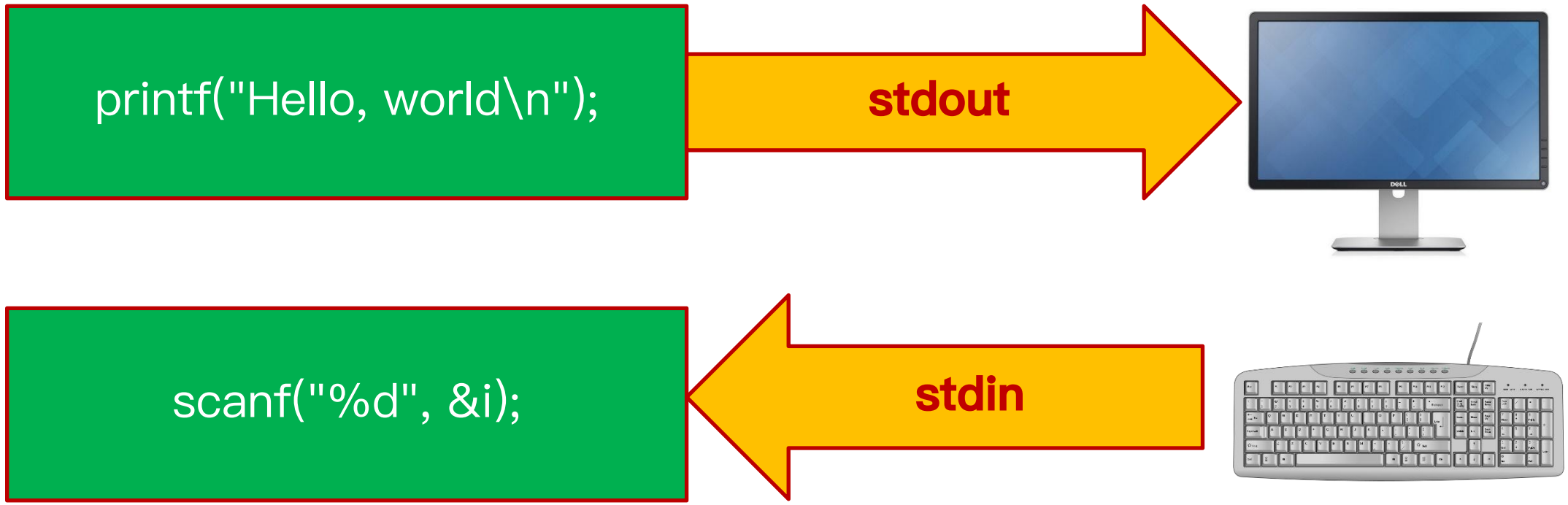
Built-in Streams (1)

- Every C program has access to 3 file streams: stdin, stdout, stderr

File	Description	Default	Buffering
stdin	Standard input stream	Connected to the keyboard	Line buffered
stdout	Standard output stream	Connected to the screen	Line buffered
stderr	Standard error stream	Connected to the screen	Unbuffered

Built-in Streams (2)

- You have already been using these streams without you knowing it!



File Stream (Stream for Short)

- The <stdio.h> header file provides types and functions for accessing streams
- **FILE** structure: a structure that holds information about a stream
- **FILE** facilitates stream I/O: C functions use **FILE pointer** to access files

Stream I/O Functions (1)

- **fopen** – open or create a file and associate a stream
- **fclose** – close a stream
- **fflush** – force to write all buffered data to file
- **fgetc** – read a single character from a stream
- **fputc** – write a single character to a stream

Stream I/O Functions (2)

- **fscanf** – read formatted input from stream
- **fprintf** – write formatted output to stream
- **fread** – read in binary mode from stream
- **fwrite** – write in binary mode to stream
- **fseek/rewind** – change position in stream
- **ftell** – determine position in stream

Opening a File

A file must be “opened” before it can be used

```
FILE *fp; // pointer to stream
          :::
fp = fopen (filename, mode);
```

“string” specifying the file name

"r" – open the file for reading only
"w" – open the file for writing only
"a" – open the file for appending data to it

returns a pointer to FILE (FILE *); used in all subsequent file operations.

Examples

- Open a file named mydata for reading:

```
FILE *fp;
fp = fopen ("mydata", "r");
```

- File is opened for reading only – file must exist
- File reading is positioned at the start of file

- Open or **create** a file named file.csv for writing:

```
FILE *fp;
fp = fopen ("file.csv", "w");
```

- Creates a new file for writing
- If file exists, contents (if any) are deleted
- File writing is positioned at the start of file

Examples

- Open or **create** a file named sample.txt for appending:

```
FILE *fp;
fp = fopen ("sample.txt", "a");
```

- Creates a new file for writing if does not exist
- File writing is positioned at the end of file

Did fopen() Succeed?

- If the file was not able to be opened, then the value returned by the fopen() is NULL
- Always check return value of fopen()

```
FILE *fp;
fp = fopen ("mydata", "r");
if (fp == NULL) {
    printf ("File open failed.\n");
    return 0;
}
```

Reasons for opening failure:

- File does not exist
- File is already open
- File cannot be created
- File cannot be accessed (insufficient permissions)

Closing a File

- After completing all operations on a file, it must be closed to ensure that all file data stored in the buffer are written to the file
- General format:

```
fclose (file_pointer);
```

```
FILE *fp; // pointer to data type FILE
          :::
fp = fopen (filename, mode);
          :::
fclose (fp); // close the file
```

Flushing Buffer Contents

- To force writing of buffer content to file without closing it, call the fflush() function
- General format:

```
fflush (file_pointer);
```

```
FILE *fp; // pointer to data type FILE
          :::
fp = fopen (filename, mode);
          :::
fflush (fp); // write buffer to file
          :::
```

Read/Write Operations on Files

- Simplest file input-output (I/O) function: fgetc() & fputc()

```
char ch;
FILE *fp;
    :::
ch = fgetc(fp);
```

- **fgetc()** reads one character from stream
- **fgetc()** return an end-of-file marker EOF, when the end of the file has been reached

getchar() -> fgetc(stdin)

Read/Write Operations on Files

```
char ch;
FILE *fp;
    :::
fputc(ch, fp);
```

- fputc() is used to write a character to a stream

putchar(ch) -> fputc(ch,stdout)

Example with fgetc() and fputc()

```
int main(void)
{
    FILE  *ifp, *ofp;
    char  c;

    ifp = fopen ("ifile.dat","r");
    ofp = fopen ("ofile.dat","w");

    while ((c = fgetc (ifp)) != EOF)
        fputc (toupper(c), ofp);
    fclose (ifp);
    fclose (ofp);
}
```

ifile.dat:

```
Hello nwen241!
```

ofile.dat:

```
HELLO NWEN241!
```

fgetc() vs getc()

- Both routines read a character from a stream
- `fgetc()` is implemented as a function while `getc()` **is implemented as a function-like macro**
- **Argument to** `getc()` **should not be an expression with side effects**
- Example: `fgetc(*p++)` works but `getc(*p++)` fails

fputc() vs putc()

- Both routines write a character to a FILE stream
- fputc() is implemented as a function while putc() **is implemented as a function-like macro**
- Same considerations as fgetc() and getc()

Recall: scanf()

- Reads user input from keyboard (stdin stream)

- Consider:

```
int a, b;
scanf("%d %d", &a, &b);
```

scanf() [and printf()] are **variadic** functions: the number of arguments they accept is not fixed

Format specifier expects 2 integers in decimal

2 numbers entered by user on keyboard will be stored here

fscanf()

- Same as scanf() except need stream (FILE *) as an argument
  - scanf() reads formatted input from stdin stream
  - fscanf() reads formatted input from specified stream
- Example:

```
int a, b;
FILE *fp;
fp = fopen ("datafile", "r");
fscanf(fp, "%d %d", &a, &b);
```

fscanf() would read values from the stream pointed by fp and assign those values to a and b

scanf("%d", &a) -> fscanf(stdin, "%d", &a)

Example (1)

- Consider:

```
int a, b;
FILE *fp;
fp = fopen ("datafile", "r");
fscanf(fp, "%d %d", &a, &b);
```

- Contents of datafile:

```
100 200
```

- What is the value assigned to a and b?

  a = 100, b = 200

Example (2)

- Consider:

```
int a, b;
FILE *fp;
fp = fopen ("datafile", "r");
fscanf(fp, "%d %x", &a, &b);
```

- Contents of datafile:

```
100 200
```

200 is taken as a hexadecimal number

- What is the value assigned to a and b? a = 100, **b = 512**

Detecting End of File using EOF

- **End-of-file indicator** EOF informs the program when there are no more data (no more bytes) to be processed
- fscanf() returns EOF if end-of-file is reached, or errors were encountered when reading from stream
- Example:

```
int ret, var;
ret = fscanf (fp, "%d", &var) ;
if (ret == EOF) {
        printf ("End-of-file encountered.\n");
}
```

Detecting End of File using feof()

- Use the feof() function which returns a non-zero value (true) or zero (false) condition
  - *True* if EOF is reached, or errors were encountered during read operation
  - *False* otherwise
- Example:

```
int var;
fscanf (fp, "%d", &var) ;
if (feof(fp)) {
        printf ("End-of-file happened.\n");
}
```

Recall: printf()

- Writes to screen (stdout stream)

- Consider:

```
int a = 1, b = 2;
printf("%d %d", a, b);
```

Format specifier will write 2 integers in decimal

2 numbers to be written to screen

fprintf()

- Same as prinf() except need stream (FILE *) as an argument
  - printf() writes formatted output to stdout stream
  - fprintf() writes formatted output to specified stream
- Example:

```
int a = 100, b = 200;
FILE *fp;
fp = fopen ("datafile", "w");
fprintf(fp, "%d %d", a, b);
```

fprintf() would write the values stored in a and b to the stream pointed to by fp

printf("%d", a) -> fprintf(stdout, "%d", a)

Example (1)

```
int a = 100, b = 200;
FILE *fp;
fp = fopen ("datafile", "w");
fprintf(fp, "%d %d", a, b);
```

- What will be the contents of datafile after running this code?

```
100 200
```

Example (2)

```
int a = 100, b = 200;
FILE *fp;
fp = fopen ("datafile", "w");
fprintf(fp, "%d %x", a, b);
```

- What will be the contents of datafile after running this code?

```
100 c8
```

c8 is the hexadecimal representation of 200

Handling Binary Files

- Same as dealing with text files **except in the opening step**

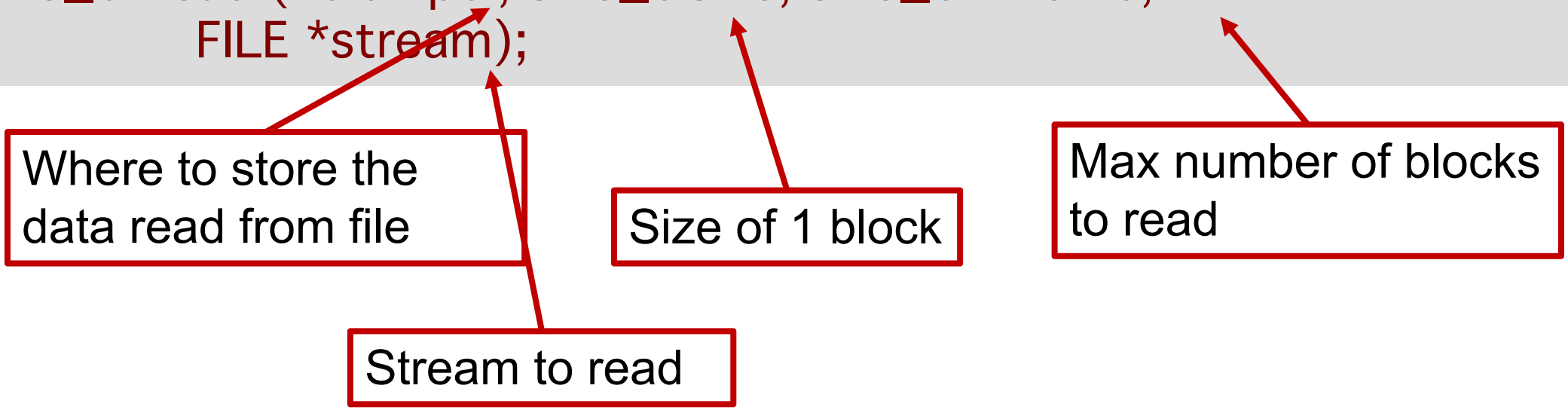
```
FILE *fp; // pointer to stream

        :::
        :::
fp = fopen (filename, mode);
```

"rb" – open the file in binary mode for reading only
"wb" – open the file in binary mode for writing only
"ab" – open the file in binary mode fo r appending data to it

Reading Binary Files

- Read blocks of binary data from stream

```
size_t fread (void *ptr, size_t size, size_t nmemb,
              FILE *stream);
```



- fread() returns the actual number of elements read

Example

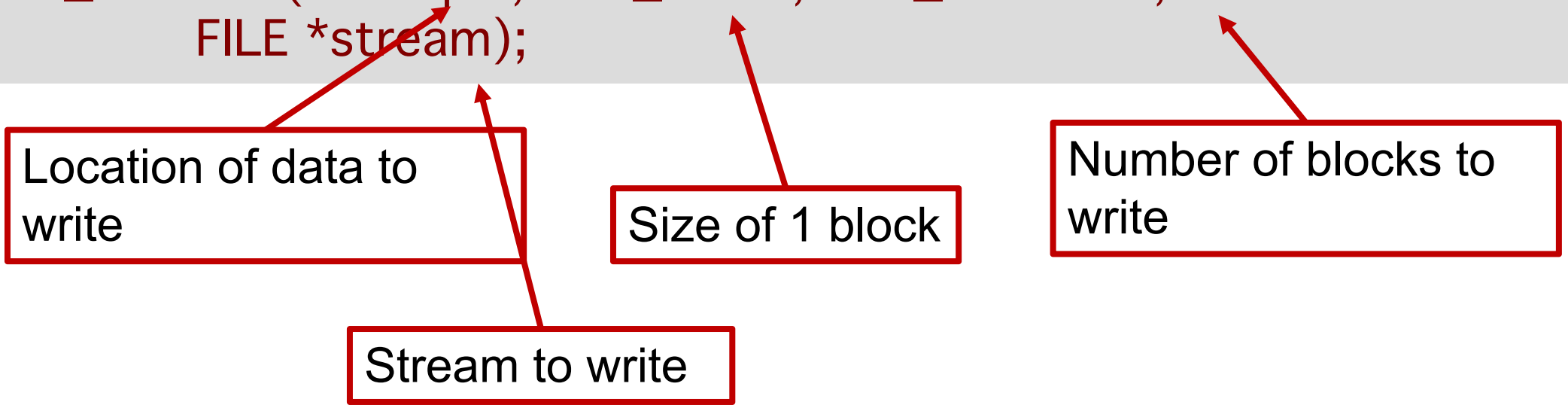
```
FILE *fp;
unsigned char buffer[10];

fp = fopen("file1.exe", "rb");
fread (buffer, sizeof(buffer), 1, fp);
```

- Will read the first 10 bytes of file1.exe and store them in buffer

Writing Binary Files

- Writes blocks of binary data to stream

```
size_t fwrite (void *ptr, size_t size, size_t nmemb,
               FILE *stream);
```



- fwrite() returns the actual number of elements written

Example

```
FILE *fp;
int data[4] = {15, 31, 63, 127};

fp = fopen("datafile", "wb");
fwrite (data, sizeof(int), 4, fp);
```

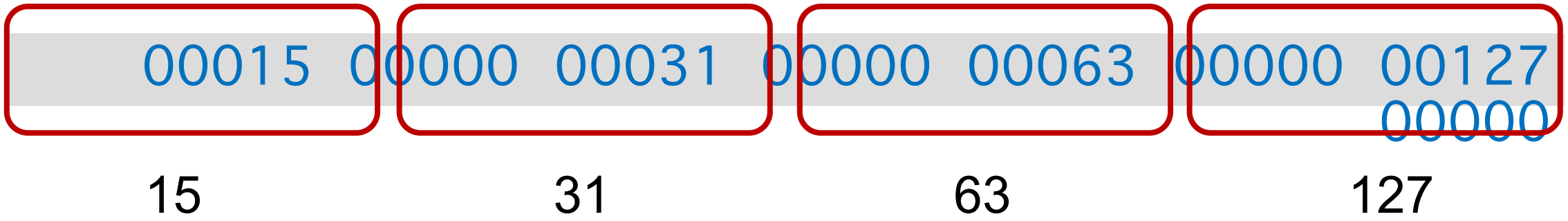
- Will write the data array to datafile

Example

- In Linux, you can use hexdump to view contents of binary file

- hexdump –d datafile will display the contents of datafile in decimal

datafile:



Random Access

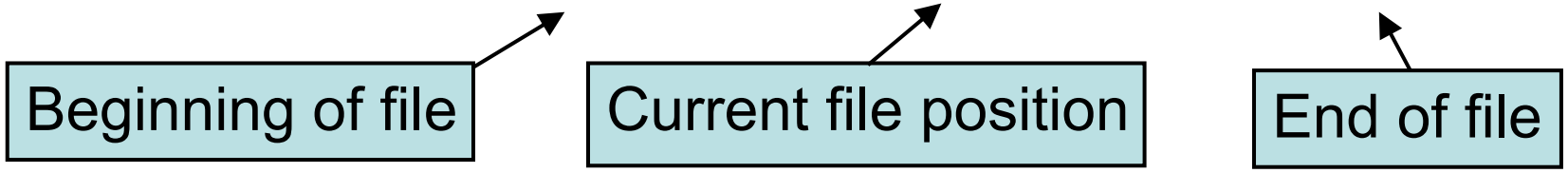
- After opening a file, **read/write position** is either at start or end of file
- To change position, use either fseek() or rewind()
- To know current position, use ftell()

fseek()

- fseek() allows repositioning within a file

```
int fseek(FILE *stream, long int offset, int startpoint);
```

- New position in the file is determined by:
  - offset – byte count (possibly -ve) relative to the position specified by startpoint where
    - startpoint: {SEEK_SET, SEEK_CUR, SEEK_END}



ftell()

- ftell() returns the current file position:

```
long ftell(FILE *stream);
```

- This may be saved and later passed to fseek():

```
long file_pos;
file_pos = ftell(fp);
...
fseek(fp, file_pos, SEEK_SET);
/* return to previous position */
```

rewind()

- Reposition reading/writing to start of file

- rewind(fp) is equivalent to:

```
fseek(fp, 0, SEEK_SET)
```