Introduction to “C” Programming

Maxwell James Dunne

Spring 2016
File I/O
File I/O

- Most data on computers are stored in files
- So accessing data reads and writes to these files
- And in a Unix environment, everything is a file
  - Serial ports
  - Network connections
  - Hard drives
  - Displays
- So everything can be controlled via file access
File I/O
Standard files

• Three special files that are automatically opened and closed
  – **stdin**: standard input (keyboard/serial port)
  – **stdout**: standard output (screen)
  – **stderr**: standard error (screen)
File I/O
The standard library

• `<stdio.h>` contains functions for working with files
• Its concept of a file includes:
  – Filename
  – File access mode
  – File size
  – Current position
File I/O

Using files

- Files are opened with `fopen()`
- Files are read and written to:
  - `fprintf()`, `fscanf()` – Formatting strings
  - `fputc()`, `fgetc()` – Characters
  - `fputs()`, `fgets()` – Lines
  - `fread()`, `fwrite()` – Blocks
- Files are closed with `fclose()`
File I/O
Using files

• Only a limited number of files can be opened at a time
  – Per process
  – Also per OS
• Very large on modern Oses
  – >= 2048 usually
• For the XC32: 8

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CMPE-013/L: “C” Programming
File I/O

The standard library uses a single struct to store the metadata of the file

```c
typedef struct __iobuf {
    char * _ptr;
    int   _cnt;
    char * _base;
    unsigned short   _flag;
    short   __file;
    size_t  __size;
} FILE;
```
**File I/O**

`fopen()`

**Syntax**

```c
FILE *fopen(const char *name, const char *mode);
```

- **name** is a C string with the filename
- **mode** is the mode to open the file in
  - "r" opens for reading
  - "w" opens for writing
  - "a" opens for appending
  - "b" specifies binary

- Returns the file pointer
ascii

unicode

'a' bytes

'π' 16 bits

16 bits + 5
## File I/O

### File modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>Open a text file for reading.</td>
</tr>
<tr>
<td>w</td>
<td>Truncate to zero length or create a text file for writing.</td>
</tr>
<tr>
<td>a</td>
<td>Append; open or create a text file for writing at the end-of-file.</td>
</tr>
<tr>
<td>rb</td>
<td>Open a binary file for reading.</td>
</tr>
<tr>
<td>wb</td>
<td>Truncate to zero length or create a binary file for writing.</td>
</tr>
<tr>
<td>ab</td>
<td>Append; open or create a binary file for writing at the end-of-file.</td>
</tr>
<tr>
<td>r+</td>
<td>Open a text file for read/write.</td>
</tr>
<tr>
<td>w+</td>
<td>Truncate to zero length or create a text file for read/write.</td>
</tr>
<tr>
<td>a+</td>
<td>Append; open or create a text file for read/write. You can read data anywhere in the file, but you can write data only at the end-of-file.</td>
</tr>
<tr>
<td>r+b or rb+</td>
<td>Open a binary file for read/write.</td>
</tr>
<tr>
<td>w+b or wb+</td>
<td>Truncate to zero length or create a binary file for read/write.</td>
</tr>
<tr>
<td>a+b or ab+</td>
<td>Append; open or create a binary file for read/write. You can read data anywhere in the file, but you can write data only at the end-of-file.</td>
</tr>
</tbody>
</table>
File I/O

Syntax

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

- `ptr` - The buffer to write into
- `size` - The size of each element to read
- `count` - The number of elements to read
- `stream` - The pointer to the file
- Returns the number of elements read
  - Less than `count` indicates error or EOF
File I/O

fwrite()

**Syntax**

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

- **ptr** – The buffer to write into
- **size** – The size of each element to read
- **count** – The number of elements to read
- **stream** – The pointer to the file

- Returns the number of elements read
  - Less than count indicates error or EOF
File I/O

feof()

Syntax

```c
int feof(FILE *stream);
```

- `stream` – The pointer to the file
- Returns a non-zero value if the stream is at the end of the file, 0 otherwise
File I/O

fseek()

Syntax

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

- **stream** – The pointer to the file
- **offset** – The bytes to move from the current location
- **origin** – The reference location: either SEEK_SET, SEEK_CUR, or SEEK_END
- Returns 0 if successful, otherwise returns a non-zero value
<table>
<thead>
<tr>
<th></th>
<th></th>
<th>2</th>
<th></th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Freed (6) Freed (6)
File I/O

fclose()

Syntax

```c
int fclose(FILE *stream);
```

- `stream`  – The pointer to the file
- Returns 0 if successful, otherwise returns `EOF`
  - `EOF` is a macro, generally -1
```c
int main(void)
{
    // Open the file, terminating if there was an error
    FILE *pFile = fopen("/room1.txt", "rb");
    if (pFile == NULL) {
        puts("Error opening file.");
        return EXIT_FAILURE;
    }

    // Count the characters in the file.
    int n = 0;
    while (fgetc(pFile) != EOF) {
        ++n;
    }

    // Output the results, if we succeeded
    if (feof(pFile)) {
        printf("Total bytes read: %d\n", n);
        fclose(pFile);
        return EXIT_SUCCESS;
    }

    // Otherwise output an error
    puts("Error occurred before reading end of file.");
    fclose(pFile);
    return EXIT_FAILURE;
}
```
File formats
File formats

Types

• Two groups:
  – Text
  – Binary

• Text are easier to process, but larger
• Binary are harder to process, but smaller
• Many formats are now zipped text files so the data is easy to parse, but the size is small
  – .docx/.xlsx for example
File formats

**Text: XML**

```xml
<MetaData>
  <messageInfo name = "System Time" pgn = "126992" size = "8">
    <desc>Represents the current data and time</desc>
    <field
      name = "Days since epoch"
      type = "int"
      offset = "16"
      length = "16"
      signed = "no"
      units = "days"
      endian = "little"
    />
  </messageInfo>
  <messageInfo name = "Rudder" pgn = "127245" size = "6">
    <desc>Represents the current rudder position</desc>
    <field
      name = "Position"
      type = "int"
      offset = "32"
      length = "16"
      signed = "yes"
      units = "rad"
      scaling = "0.0001"
      endian = "little"
    />
  </messageInfo>
</MetaData>
```
### File formats

Text: CSV

<table>
<thead>
<tr>
<th>timestamp</th>
<th>time_usec</th>
<th>fix_type</th>
<th>lat</th>
<th>lon</th>
<th>alt</th>
<th>eph</th>
<th>epv</th>
<th>vel</th>
<th>cog</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.3000000000000004</td>
<td>57300</td>
<td>450</td>
<td>-59.0</td>
<td>-15857.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>57460000</td>
<td>3</td>
</tr>
<tr>
<td>57.5500000000000004</td>
<td>57550</td>
<td>457</td>
<td>-51.0</td>
<td>-15855.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>57760000</td>
<td>3</td>
</tr>
<tr>
<td>57.8000000000000004</td>
<td>57800</td>
<td>469</td>
<td>-42.0</td>
<td>-15854.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>57960000</td>
<td>3</td>
</tr>
<tr>
<td>58.0500000000000004</td>
<td>58050</td>
<td>474</td>
<td>-32.0</td>
<td>-15850.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>58260000</td>
<td>3</td>
</tr>
<tr>
<td>58.3000000000000004</td>
<td>58300</td>
<td>477</td>
<td>-17.0</td>
<td>-15847.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>3</td>
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<tr>
<td>58.5500000000000004</td>
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<td>474</td>
<td>-9.0</td>
<td>-15846.0</td>
<td>0.0</td>
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</tr>
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<td>58.8000000000000004</td>
<td>58800</td>
<td>469</td>
<td>-12.0</td>
<td>-15843.0</td>
<td>0.0</td>
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<td>3</td>
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<tr>
<td>59.0500000000000004</td>
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<td>468</td>
<td>-18.0</td>
<td>-15839.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>3</td>
</tr>
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<td>59.3000000000000004</td>
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<td>471</td>
<td>-14.0</td>
<td>-15841.0</td>
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<tr>
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<td>502</td>
<td>-18.0</td>
<td>-15839.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>60260000</td>
<td>3</td>
</tr>
<tr>
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<td>60300</td>
<td>507</td>
<td>-28.0</td>
<td>-15839.0</td>
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<td>0.0</td>
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</tr>
<tr>
<td>60.5500000000000004</td>
<td>60550</td>
<td>504</td>
<td>-25.0</td>
<td>-15824.0</td>
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<td>3</td>
</tr>
<tr>
<td>60.8000000000000004</td>
<td>60800</td>
<td>515</td>
<td>-20.0</td>
<td>-15824.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>60960000</td>
<td>3</td>
</tr>
<tr>
<td>61.0500000000000004</td>
<td>61050</td>
<td>524</td>
<td>-14.0</td>
<td>-15832.0</td>
<td>0.0</td>
<td>0.0</td>
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</tr>
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<td>0.0</td>
<td>0.0</td>
<td>62260000</td>
<td>3</td>
</tr>
</tbody>
</table>
File formats

Binary: ZIP
File formats

Binary: RPG

- Needed a format to store each room in a dungeon
- Requirements
  - Title
  - Description
  - Items in the room
  - Exits:
    - Which room
    - What direction
File formats

Binary: RPG

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
<th>Items contained</th>
<th>Exits</th>
</tr>
</thead>
</table>

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File formats
Binary: RPG

- But it would be cool if the rooms could change depending on items the player has encountered
  - Like keys
- So we want different versions of the room for:
  - Description
  - Items
  - Exits
## File formats

Binary: RPG

<table>
<thead>
<tr>
<th>Title</th>
<th>Item requirements</th>
<th>Description</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(repeated)
File formats

Binary: RPG

<table>
<thead>
<tr>
<th>size</th>
<th>ASCII data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>Item requirements</td>
</tr>
</tbody>
</table>
File formats

Binary: RPG

<table>
<thead>
<tr>
<th>size</th>
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File formats

Binary: RPG

<table>
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<th>size</th>
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</table>

| Title | Item requirements | Description | Items contained | Exits |

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File formats
Binary: RPG

<table>
<thead>
<tr>
<th>size</th>
<th>binary data</th>
</tr>
</thead>
</table>

| Title | Item requirements | Description | Items contained | Exits |
# File formats

Binary: RPG

<table>
<thead>
<tr>
<th>North</th>
<th>East</th>
<th>South</th>
<th>West</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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File formats

Binary: RPG

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<th>Exits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Version 1: Requires key, no items</td>
<td></td>
<td></td>
<td></td>
<td>Version 2: No requirements, contains key</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

/Room32.txt
# File formats

Binary: RPG

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
<th>Items contained</th>
<th>Exits</th>
<th>Item requirements</th>
<th>Description</th>
<th>Items contained</th>
<th>Exits</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 The Throne Room</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Version 1: Requires key, no items

Version 2: No requirements, contains key

/Room32.txt
# File formats

**Binary: RPG**

<table>
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<tr>
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/Room32.txt
File formats

Binary: RPG

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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Version 2: No requirements, contains key</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A large metal throne forged of swords of previous kings sits prominently here. Your dad is rarely in it, however, instead ruling the kingdom from his council's chambers.

/Room32.txt
File formats

Binary: RPG

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<th>Title</th>
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/Room32.txt
# File formats

**Binary: RPG**

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</table>

Version 1: Requires key, no items
Version 2: No requirements, contains key

/Room32.txt
File formats

Binary: RPG

A large metal throne forged of swords of previous kings sits prominently here. Your dad is rarely in it, however, instead ruling the kingdom from his council's chambers. You feel the weight of the castle key stolen earlier in your pocket.

<table>
<thead>
<tr>
<th>Title</th>
<th>Item requirements</th>
<th>Description</th>
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<td></td>
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<td>Version 1: Requires key, no items</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Version 2: No requirements, contains key</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

/Room32.txt
File formats

Binary: RPG

<table>
<thead>
<tr>
<th>Title</th>
<th>Item requirements</th>
<th>Description</th>
<th>Items contained</th>
<th>Exits</th>
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<th>Description</th>
<th>Items contained</th>
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</tr>
</thead>
<tbody>
<tr>
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/Room32.txt
## File formats

### Binary: RPG

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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Version 1: Requires key, no items

Version 2: No requirements, contains key

/Room32.txt
Battle Boats

1) due Thursday
2) partnered

3) Late hours max(p1, p2)
4) RPG no late hours
5) Quizzes 30% Labs: 70%
Protocol

User input

HumanAgent

Provided code

BattleBoats

Provided code

BattleBoats

ArtificialAgent

Protocol

Field

UART

Protocol

Field

UART
<table>
<thead>
<tr>
<th>Character</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>$</code></td>
<td>The start-of-message identifier, always a dollar-sign</td>
</tr>
<tr>
<td>MESSAGE_ID</td>
<td>A 3-character string identifying the type of message.</td>
</tr>
<tr>
<td>,</td>
<td>A comma separates the MESSAGE_ID from the subsequent data</td>
</tr>
<tr>
<td>DATA1,DATA2,DATA3,...</td>
<td>A comma-separated list of data, all encoded as ASCII characters</td>
</tr>
<tr>
<td>*</td>
<td>A message ends with an asterisk and then a checksum byte encoded as two separate ASCII hexadecimal characters (like '0A'). This checksum is calculated from ALL bytes between the <code>$</code> and the <code>*</code>.</td>
</tr>
<tr>
<td>\n</td>
<td>A newline character actually ends the string.</td>
</tr>
</tbody>
</table>
• Agent A generates a random 16-bit number that is its "guess" along with another 16-bit number that is used as the encryption key.

• Agent A then transmits a checksum of both its guess and key (which is an 8-bit XOR of all of their bytes) along with an encrypted version of its guess (which is a 16-bit XOR of the guess with the encryption key).

• During this time Agent B is doing the same thing.
guess 16
Ekey 16

\[
\begin{array}{c|c}
16 & 16 \\
\end{array}
\]

checksum

\[\text{guess XOR Ekey}\]

\[\text{unencryp}\]
• Once Agent A has received Agent B's encrypted guess and checksum, it transmits the unencrypted guess and the encryption key (and Agent B does the same).

• 5. Agent B can now verify Agent A's information by verifying both the checksum and the encryption key (and Agent A does the same).

• 6. Now both can agree on who should go first by having either guessed higher or lower than the other agent depending on if the XOR of the LSB of their guesses is 1 or 0.
<table>
<thead>
<tr>
<th>Negotiation Data Set 1</th>
<th>$CHA, 37348, 117*46</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$DET, 9578, 46222*66</td>
</tr>
<tr>
<td>Negotiation Data Set 2</td>
<td>$CHA, 54104, 139*45</td>
</tr>
<tr>
<td></td>
<td>$DET, 32990, 21382*5e</td>
</tr>
<tr>
<td>Negotiation Data Set 3</td>
<td>$CHA, 62132, 70*79</td>
</tr>
<tr>
<td></td>
<td>$DET, 52343, 16067*50</td>
</tr>
<tr>
<td>Negotiation Data Set 4</td>
<td>$CHA, 36027, 55*7a</td>
</tr>
<tr>
<td></td>
<td>$DET, 7321, 36898*6e</td>
</tr>
<tr>
<td>HIT messages</td>
<td>$HIT, 3, 8, 1*43</td>
</tr>
<tr>
<td></td>
<td>$HIT, 0, 2, 0*4b</td>
</tr>
<tr>
<td></td>
<td>$HIT, 2, 3, 1*49</td>
</tr>
<tr>
<td></td>
<td>$HIT, 5, 6, 4*4e</td>
</tr>
<tr>
<td></td>
<td>$HIT, 0, 3, 0*4a</td>
</tr>
<tr>
<td></td>
<td>$HIT, 1, 7, 1*4e</td>
</tr>
<tr>
<td></td>
<td>$HIT, 4, 8, 0*45</td>
</tr>
<tr>
<td></td>
<td>$HIT, 5, 3, 3*4c</td>
</tr>
<tr>
<td></td>
<td>$HIT, 0, 5, 0*4c</td>
</tr>
<tr>
<td></td>
<td>$HIT, 5, 6, 1*4b</td>
</tr>
<tr>
<td></td>
<td>$HIT, 1, 1, 1*48</td>
</tr>
<tr>
<td></td>
<td>$HIT, 1, 0, 0*48</td>
</tr>
<tr>
<td></td>
<td>$HIT, 5, 2, 2*4b</td>
</tr>
<tr>
<td></td>
<td>$HIT, 2, 8, 0*43</td>
</tr>
<tr>
<td></td>
<td>$HIT, 0, 6, 0*4f</td>
</tr>
<tr>
<td></td>
<td>$HIT, 5, 9, 0*45</td>
</tr>
<tr>
<td></td>
<td>$HIT, 2, 8, 2*41</td>
</tr>
</tbody>
</table>
while(FIELD).addBoat((rand, rand))
70\% < 62\%

IAIBI < 1

LEDS, h