CMPE-013/L

Introduction to “C” Programming

Maxwell James Dunne
Adjudicate
Dynamic Memory

\[ \text{malloc()} \]

\[ \text{free()} \]
Dynamic Memory

Memory leaks

• If pointers returned by \texttt{malloc()} are lost, that memory is then "lost"

• Easy to do because this may not crash your program, possibly only causing errors over long periods of time

\begin{verbatim}
void MyFunc(void)
{
    Complex *x = malloc(sizeof(Complex));
    ...
}
\end{verbatim}
Dynamic Memory

Memory leaks

- So for every pointer obtained from `malloc()`, there should be an equivalent `free()` at some point

Example

```c
void MyFunc(void)
{
    Complex *x = malloc(sizeof(Complex));
    ...
    free(x);
}
```
Dynamic Memory

When to use the Heap

- For unknown amounts of data
  - Arrays are always fixed-length at compile time
- When data needs to be accessible outside of the scope it was created in
  - Pointers need to be passed around
Pointers

Pointers to pointers
Pointers
Pointers to pointers

• Since pointers can point to any valid datatype, they can also point to other pointers

• No limit on levels of indirection
Pointers

Pointers to pointers

Example

```c
{ 
    int x = 6;
    int *y = &x;
    int **z = &y;
    printf("%d\n", **z);
}
```

32-bit Data Memory (RAM)

<table>
<thead>
<tr>
<th>Address</th>
<th>0x3F50</th>
<th>0x3F54</th>
<th>0x3F58</th>
<th>0x3F5C</th>
<th>0x3F60</th>
<th>0x3F64</th>
<th>0x3F68</th>
<th>0x3F6C</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>0006</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
</tr>
<tr>
<td>y</td>
<td>03F4</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
</tr>
<tr>
<td>z</td>
<td>03F8</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
<td>0000</td>
</tr>
</tbody>
</table>

Output

6
Pointers
Passing by reference, again

- Passing by reference only allows persistently changing the value 1 level of indirection from the pointer and further
  - If a pointer is passed to a function, the data it points to can be altered.
  - If a pointer-to-a-pointer is passed, the pointer it points to and the data that pointer points to can be altered.
Pointers
Passing by reference, again

Example interrupt

```c
void MyFunc(int *x)
{
    *x = 6;
    x = &malloc();
}

int main(void)
{
    int myInt;
    int *myIntPtr = &myInt;
    MyFunc(myIntPtr);
}
```
My func(x);

* x = 3;

My Func

Main

A0030

A0030
My func(x);

X = 3;
Example interrupt

```c
void MyFunc(int **x)
{
    *x = malloc(sizeof(int));
    if (*x)
    {
        **x = 6;
    }
}

int main(void)
{
    int *myInt;
    MyFunc(&myInt);
}
```

My func takes an int pointer
```c
int *y
MyFunc(&y)
```
Enums
Enumerations are integer data types that you can create with a limited range of values. Each value is represented by a symbolic constant that may be used in conjunction with variables of the same enumerated type.

- **Enumerations:**
  - Are unique integer data types
  - May only contain a specified list of values
  - Values are specified as symbolic constants
Enumerations
How to Create an Enumeration Type

- Creates an ordered list of constants
- If unspecified, each label’s value is one greater than the previous label

Syntax

```c
enum typeName {label_0, label_1, ..., label_n}
```

Where compiler sets $label_0 = 0, label_1 = 1, label_n = n$

Example

```c
enum weekday {SUN, MON, TUE, WED, THR, FRI, SAT};
```

Label Values:

- SUN = 0
- MON = 1
- TUE = 2
- WED = 3
- THR = 4
- FRI = 5
- SAT = 6
Enumerations
How to Create an Enumeration Type

- Any label may be assigned a specific value
- The following labels will increment from that value

Syntax:

```c
enum typeName { label_0 = const_0, ..., label_n }
```

Where compiler sets `label_0 = const_0, label_1 = (const_0 + 1), ...

Example:

```c
enum people { Rob, Steve, Paul = 7, Bill, Gary };
```

Label Values:

- Rob = 0, Steve = 1, Paul = 7, Bill = 8, Gary = 9
Enumerations
How to Create an Enumeration Type

- Any label may be assigned a specific value
- The following labels will increment from that value

**Syntax**

```c
enum typeName {label₀ = const₀,...,labelₙ}
```

Where compiler sets \( label₀ = const₀, label₁ = (const₀ + 1), \ldots \)

**Example**

```c
enum people {Rob = 'a', Steve, Paul, Bill, Gary};
```

Label Values:

- Rob = 'a'
- Steve = 'b'
- Paul = 'c'
- Bill = 'd'
- Gary = 'e'
Enumerations
How to Create an Enumeration Type

• Any label may be assigned a specific value
• The following labels will increment from that value

Syntax

```c
enum typeName {label_0 = const_0, ..., label_n}
```
Where compiler sets label_0 = const_0, label_1 = (const_0 + 1), ...

Example

```c
enum people {Rob = -4, Steve, Paul, Bill, Gary};
```

Label Values:
Rob = -4, Steve = -3, Paul = -2, Bill = -1, Gary = 0
Enumerations

How to Declare an Enumeration Type Variable

- Declared along with type:

Syntax

```c
enum typeName {const-list} varname_1,...;
```

- Declared independently:

Syntax

```c
enum typeName varName_1,...,varName_n;
```

Example

```c
enum weekday {SUN, MON, TUE, WED, THR, FRI, SAT} today;

enum weekday day;  // day is a variable of type weekday
```
Enumerations

How to Declare a ‘Tagless’ Enumeration Variable

- No type name specified:

  **Syntax**

  ```c
  enum {const-list} varName1,...,varName_n;
  ```

- Only variables specified as part of the `enum` declaration may be of that type

- No type name is available to declare additional variables of the `enum` type later in code

**Example**

```c
enum {SUN, MON, TUE, WED, THR, FRI, SAT} Today;
```
Enumerations
How to Declare an Enumeration Type with `typedef`

- Variables may be declared as type `typeName` without needing the `enum` keyword

**Syntax**

```c
typedef enum {const-list} typeName;
```

- The enumeration may now be used as an ordinary data type (compatible with `int`)

**Example**

```c
typedef enum {SUN, MON, TUE, WED, THR, FRI, SAT} Weekday;

Weekday day; // Variable of type weekday
```
Enumerations
How to Use an Enumeration Type Variable

If enumeration and variable have already been defined:

**Syntax**

\[ \text{varName} = \text{label}_n; \]

- The labels may be used as any other symbolic constant
- Variables defined as enumeration types must be used in conjunction with the type’s labels or equivalent integer

**Example**

```c
enum weekday {SUN, MON, TUE, WED, THR, FRI, SAT};
enum weekday day;

day = WED;
day = 6;  // May only use values from 0 to 6
if (day == WED) {
    ...
```
Enumerations

Proper formatting

Example

typedef enum {
    SUN,  // comments
    MON,
    TUE,
    WED,
    THR,
    FRI,
    SAT
} Weekday;

Weekday day = WED;
Enumerations
Proper formatting

Example

typedef enum {
    SUN,
    MON,
    TUE,
    WED,
    THR,
    FRI,
    SAT
} Weekday;

Weekday day = 3; // No compilation warning/error
Enumerations
Datatype usage

Example

```c
typedef enum {
    SUN,
    MON,
    TUE,
    WED,
    THR,
    FRI,
    SAT
} Weekday;

void PrintDayName(Weekday d)
{
    if (d == SUN) {
        printf("Sun\n");
    }
    ...
}

PrintDayName(WED); // No compilation warning/error
```
Enumerations

Why enumerations?

• Enumerations are a proper datatype as well as the possible values for them
• Some compile-time checking
• Doesn't do text replacement, done during the compiler stage
• Use for a group of related values
Interrupts
Interrupts

- High-priority alerts that an event requires immediate attention
- Generally interrupts can be assigned priorities
- Event is handled by an Interrupt Service Routine (ISR)
Interrupts

• ISR is a special function that is written by the developer, but called directly by the processor
• ISRs have no inputs or outputs
  – All processing through global/module-level variables
• ISRs are written a specific way and the processor is told they have been implemented by the compiler/developer
Interrupts

Traps

- Software interrupts are generally referred to as **exceptions** or **traps**
- Examples:
  - Division by zero
  - Invalid address dereference
  - Debugging breakpoint
  - Stack overflow

NULL Pointer
Interrupts
Standard form

Example interrupt

```c
void __ISR IsrName(void)
{
    // Process data from the interrupt
    // Store results in global/module variable
    // Clear interrupt flag
}

__ISR(_TIMER_1_VECTOR, IPL4AUTO)
```
void _ISR Uart1TxInterrupt(void)
{
    // Stall until transmission finishes
    while (!U1STAbits.TRMT);

    // Continue transmitting next batch of data
    Uart1StartTransmission();

    // Clear interrupt flag
    IFS0bits.U1TXIF = 0;
}
Interrupts

Example program

```c
int main(void) {
    int x = 20;
    int y;
    y = x / 2;
}
```

Interrupt: UART1 Post-transmission

```c
void __ISR __U1TXInt(void) {
    IFS0bits.U1TXIF = 0;
}
```
Interrupts

Calling

Example program

```c
int main(void)
{
    int x = 20;
    int y;
    _U1TXInt();
    y = x / 2;
}
```

Interrupt: UART1 Post-transmission

```c
void __ISR _U1TXInt(void)
{
    IFS0bits.U1TXIF = 0;
}
```
Interrupts

- Interrupts are important events that happen in real-time.
- ISRs are the functions that handle these events.
- ISRs are called outside of regular program execution order.