Introduction to Computing

MCS1101B

Lecture 8

User Defined Datatypes

- Sometimes basic data-types are not sufficient for describing problems conveniently, *e.g., 2D coordinates, complex numbers, student information, etc.*
- You can define your own data-type as per your requirements
- You need to use the keyword *struct* for this purpose
- *struct* is short for **structure**

```
struct my_type {
        member 1;
        …
        member n;
};
```

- struct my_type becomes your new user-defined data-type
- Member(s) can be any existing data-types or user-defined types, such as, int, float, int*, char[10], struct another_type, etc.

Structures

Example:
representing a complex number
n = x + i y

```
struct complex{
        float x;
        float y;
    };
```

```
struct complex n;
n.x = 1.0;
n.y = 2.0;
```

This^ can represent the complex number 1.0 + *i* 2.0

- struct complex n1={1,2}, n2={2,3}, n3;
    - Declare and initialize similar to any type
- n3 = n2; //copies the value of n2 into n3
- Normal operations does not work (why?), such as
    - n1+n2, n1-n2
    - n1 == n2

You need to write your own functions

```
struct complex add (struct complex num1, struct complex num2) {
    struct complex sum;
    sum.x = num1.x + num2.x;
    sum.y = num1.y + num2.y;
    return sum;
}
add (n1, n2); //function call for addition
```

Structures (contd.)

- Normal operations does not work
  - n1+n2, n1-n2
  - n1 == n2
- You need to write your own functions and define your own operations
  - Example code for addition of two complex numbers is given ⇒
  - Similarly you can write your own subtraction, multiplication, equality, conjugate, etc.

- struct complex add (struct complex n1, struct complex n2)

```
{
    struct complex ret;
    ret.x = n1.x + n2.x;
    ret.y = n1.y + n2.y;
    Return ret;
}

add (n1,n2)
```

Structures (contd.)

- You can choose to rename (create an alias) for any datatype using a keyword called typedef - it is particularly convenient for structures
- Example:
    - typedef struct complex Q;
    - Then, we could write => Q add (Q n1, Q n2) {...}
    - You can declare variables: Q n1, n2; etc.

- Another way of writing typedef

```
typedef struct complex{
        float x;
        float y;
}Q;
```

- Size of a structure variable…
    - Is sum of the sizes of all its member's sizes
    - So, sizeof (Q) = sizeof (float) + sizeof (float)

Structures and pointers

- Since structures are just another datatype - it is possible to create pointers of it’s type
- struct complex *ptr; ⇒ is able to contain the address of structure variable
  - We could also write Q *ptr; ⇒since we renamed it as Q
- So, sizeof(ptr) ⇒ ?

- How do you access the members using pointers
  - Q *ptr; Q v = {10, 20};
  - ptr = &v;
  - *ptr.real ⇒ will not work
  - You can write (*ptr).real
  - Alternatively ptr->real can be used to access the members using pointers

Structures examples

Store student record with name, roll number, height, weight, DoB, DoJ

- How do you store information about 100 students?
- What happens if one or more student joins later on?
- What happens if you do not know the number of students beforehand?

```
// A possible implementation
typedef struct _student_info{
        char *name;
        char DoB[10], DoJ[10];
        int roll_no;
        float height, weight;
}student;

// An array of structure
        variables
student st_arr[100];
```

Array and Structure

- Since structures are just another datatype - it is possible to create an array
- Q arr[5]; ⇒ is equivalent of 5 Q variables
  - We can access the variables using indexes e.g. arr[1], arr[3], etc.
  - We can also access using pointer arithmetic ← remember this?

- arr[i].x, arr[i].y ← to access member variables
- arr[i] == *(arr + i)
- So (arr+i)->x should work

– but how to create array when size is not known beforehand?

Dynamic Memory allocation (DMA)

- This is another way to allocate memory for variables
- It can allocate memory to a variable during the runtime of the program
  - So, you can read/scan the number of elements from the user
  - Then allocate necessary memory
- It works for allocating memory for
  - A single variable of any type
  - An array of any type

- We need a new include library
  - stdlib.h
- We will use two functions from this library for DMA
  - malloc - **mem**ory **alloc**ator
  - free - frees some allocated memory

Prototype: ***void* malloc (int size)***

- It allocates a memory space of the given *size*
- returns a pointer(*) (without any specific type, i.e. **void***)
- You can **typecast** it to your need

DMA (contd.)

- To create a int variable using malloc, declare a int pointer variable
  - int *ptr;
- Allocate memory using malloc
  - ptr = (int*) malloc(sizeof(int));
- Access the values using *ptr
  - *ptr = 10;
  - printf (“%d”, *ptr); // →prints 10

- **Caution**: if you try to access *ptr before allocating memory, the behaviour is undefined
- So, for the structure Q, we can do the same
  - Q *ptr;
  - ptr = (Q*) malloc (sizeof(Q));
  - Access: ptr->x, ptr->y

Array and DMA

- To create an array using DMA
- We need to specify the total memory size (in bytes) required for the array

e.g., to get an integer array of size 10, we can write the following code

```
int *arr;
arr = (int*) malloc (sizeof(int) * 10);
```

Access as arr[i] or *(arr+i)

If you need to take the size from the user, you can do the following

```
int n;
int *ptr;
scanf (“%d”, &n);
ptr = (int*) malloc (sizeof(int) * n);
```

To release an allocated memory, you can write

```
free (ptr);
```

- Make sure the ptr is a valid one
- Otherwise, it may result in error

Adding an element in array

- Array has a fixed size
  - Be it allocated using DMA or statically
- Assume you have an array of 10 elements
  - You have inserted 5 elements from 0 to 4 indexes, then you want to insert another element in position 2
  - You have already inserted 10 elements, then you want to add another element

A better solution for such issues:

Linked list

- A clever solution using structures, DMA and pointers
- It requires more space than an array to store the same amount of data

It's a beautiful testimony to the power of C language

- *If time permits, we will talk about it at the end of this course*

Storage issues

- Single variable
  - Can only store a value
- Array of variables
  - Can store multiple values, but size allocation needs to be known first
- Array using DMA - can be allocated later, based on requirements
  - But insertion, deletion, resizing is still an issue
- Linked list is used to alleviate such problems
  - However, it uses more memory compared to arrays to store the same information

← All of these solution works only until program is running, once it is closed all data are lost.

- The solution to this problem is usage of persistent storage (you know these as pen drive, ssd, hard disk, etc.)
- But how do you write in such devices

— We create files.

File

- Stored as sequence of bytes, logically contiguous
    - May not be physically contiguous on disk, but you don't need to worry about that
- Two types of files
    - Text - can only contain ASCII characters
    - Binary - can contain non-ASCII characters
        - Example: image, video, executable, audio, etc.

- Basic operations on file (stdio.h)
    - Open
    - Read
    - Write
    - Close
- A file needs to be open before you can do read or write operations
- Once the works are done on file you need to close the file
- In case, close is not done, some/all contents of the file may be lost

File (contd)

- **FILE*** is a datatype used to represent a pointer to a file
- To open a file we use a function called **fopen**
  - It takes two parameters
    - Name of the file
    - Mode in which it is to be opened
  - It returns a pointer to the file if the file is opened successfully, otherwise it returns NULL

Example of a file creation for writing

```
FILE *fp;
char filename[] = “a_file.dat”
fp = fopen (filename, “w”);
if (fp == NULL)
{
        printf (“unable to create file”);
        /* DO SOMETHING */
}
/* WRITE SOMETHING IN FILE */
fclose (fp);
```

File (contd)

Modes of opening a file

- “r” – Opens a file for reading
  - Error if the file does not already exist
  - “r+” allows write also
- “w” – Opens a file for writing
  - If file does not already exist, it creates a new file
  - If file already exists, all the previous contents of the file will be overwritten
  - “w+” allows read also
- “a” – Opens a file for appending (write at the end of the file)
  - “a+” allows read also

- When error occurs, e.g. file failed to open, the rest of your program may not work properly
  - In such case, you may want to exit the program on emergency basis
  - The function **exit**() from stdlib.h allows you to do so
  - If can be called from anywhere in the c program and it will terminate the program at once

File (contd)

```
FILE *fp;
char filename[] = “a_file.dat”
fp = fopen (filename, “w”);
if (fp == NULL)
{
        printf (“unable to create file”);
        /* DO SOMETHING */
        exit(-1);
}
/* WRITE SOMETHING IN FILE */
fclose (fp);
```

- You can pass any integer in the exit function
- This value will be returned as the output of the program
    - Recall that a c function is a collection of functions and functions must return something
    - A negative value (by convention) is treated as some error has happened

Next Class…

- Python preliminaries