Structures

.... and other user-defined data types

Basic Definitions

What is a Structure?

It is a convenient construct for representing a group of logically related data items.

- Examples:
  - Student name, roll number, and marks.
  - Real part and complex part of a complex number.

This is our first look at a non-trivial data structure.

- Helps in organizing complex data in a more meaningful way.

The individual structure elements are called *members*.

Defining a Structure

The composition of a structure may be defined as:

```
struct 〈 name of structure 〉{
        〈 data-type 〉〈 member-name1〉;
        〈 data-type 〉〈 member-name2〉;
        :
        〈 data-type 〉〈 member-namek〉;
};
```

For example:

```
struct point  {
        float xcoord;
        float ycoord;
};
```

Example

A structure definition

```
struct student {
        char name[30];
        int  roll_number;
        int  total_marks;
        char dob[10];
      };
```

Defining structure variables:

```
struct student  a1, a2, a3;
```

A new data-type

Important

- **struct** is the required C keyword
- Do not forget the ; at the end!
- The individual members can be ordinary variables, pointers, arrays, or other structures (any data type)
- The member names within a particular structure must be distinct from one another
- A member name can be the same as the name of a variable defined outside of the structure

Structure Definition versus Structure Declaration

Structure Definition

```
struct point  {
        float xcoord;
        float ycoord;
};
```

- No memory is allocated
- Like defining a new data type

Structure Declaration

```
struct point a, b, c;
```

- Here a, b, c are variables of the type struct point
- Memory is allocated for a, b, c.
- Declaration is possible *after* definition

Structure Declaration can be clubbed with Definition

Separately:

```
struct point  {
        float xcoord;
        float ycoord;
};

struct point  a, b, c;
```

Together:

```
struct point  {
        float xcoord;
        float ycoord;
} a, b, c;
```

- The struct definition can be reused elsewhere
- Like:

```
struct point p, q;
```

Another way:

```
struct  {
        float xcoord;
        float ycoord;
} a, b, c;
```

- In this case we do not have a name for the struct
- Hence we cannot reuse the struct definition

Accessing the members of a structure

- The members of a structure are accessed individually, as separate entities.

- A structure member can be accessed by writing

  ⟨variable-name⟩.⟨member-name⟩

  where *variable* refers to the name of a structure-type variable, and *member* refers to the name of a member within the structure.

```
struct point  {
        float xcoord;
        float ycoord;
} a, b;
a.xcoord = 2.5;    a.ycoord = 3.2;
b.xcoord = b.ycoord = 0;
```

Structure initialization

Structure variables may be initialized following similar rules of an array. The values are provided within the second braces separated by commas

An example:

```
struct complex a={1.0,2.0}, b={-3.0,4.0};
```

```
a.real=1.0;   a.img=2.0;
b.real=-3.0;  b.img=4.0;
```

Example: Addition of two complex numbers

```
#include <stdio.h>
main( )
{
        struct complex
        {
                float real;
                float imag;
        } a, b, c;

        scanf ("%f %f", &a.real, &a.imag);
        scanf ("%f %f", &b.real, &b.imag);

        c.real = a.real + b.real;
        c.imag = a.imag + b.imag;
        printf ("\n %f + %f j", c.real, c.imag);
}
```

Assignment of Structure Variables

```
struct class
{
    int  number;
    char name[20];
    float marks;
};
```

```
main()
  {
    int  x;
    struct class student1 = {111, "Rao", 72.50};
    struct class student2 = {222, "Reddy", 67.00};
    struct class student3;

    student3 = student2;
  }
```

A structure variable can be directly assigned to another

Two structure variables can not be compared for equality or inequality

if (student1 == student2)…… this cannot be done

Arrays of Structures

Once a structure has been defined, we can declare an array of structures.

```
struct class
{
    int  number;
    char name[20];
    float marks;
};
struct class student[50];
```

- The individual members can be accessed as:

  `student[ k ].marks` — *marks of the k^{th} student*

  `student[ k ].name[ j ]` — *j^{th} character in the name of the k^{th} student*

An interesting observation

```
int a[5] = { 10, 20, 30, 40, 50 };
int b[5];

b = a;
```

X This is not allowed

```
struct list {
    int x[5];
};

struct list a, b;
a.x[0] = 10;   a.x[1] = 20;
a.x[2] = 30;   a.x[3] = 40;
a.x[4] = 50;

b = a;
```

This is allowed !!

Structures can be copied directly – even if they contain arrays !!

Type Definitions

The *typedef* construct

The *typedef* construct can be used to define new (derived) data types in C.

```
typedef  float  kilometers_per_hour;          // kilometers_per_hour is a new data type
                                              // Note that no variable is allocated space here

typedef  char roll_number[ 10 ];
        // roll_number is a data type representing  array of 10 characters
        // No array has been allocated yet – only the type has been defined

kilometers_per_hour speed;                    // Here speed is a variable
roll_number p = "11AG10015";                  // Here variable p is defined and initialized
speed = 40;
```

Structures and *typedef*

Without *tyedef*

```
struct  complex
{
    float  real;
    float  imag;
} ;

struct complex a, b, c;
```

Here struct complex is like a new data type.

With *tyedef*

```
typedef  struct
{
    float  real;
    float  imag;
} complex ;

complex a, b, c;
```

Here complex is a new data type

…typedef : An example

Note: typedef is not restricted to just structures, can define new types from any existing type

Example:

- **typedef int INTEGER**
- **Defines a new type named INTEGER from the known type int**
- **Can now define variables of type INTEGER which will have all properties of the int type**

```
INTEGER a, b, c;
```

Structures are passed by value to functions

```
#include <stdio.h>

typedef struct {
        float real;
        float imag;
} _COMPLEX;

void swap ( _COMPLEX a,  _COMPLEX b)
{
   _COMPLEX tmp;

   tmp = a;   a = b;   b = tmp;
 }
```

```
void print ( _COMPLEX a)
{
    printf("(%f, %f) ", a.real, a.imag);
}

main( )
{
    _COMPLEX x = { 4.0, 5.0 }, y = { 10.0, 15.0 };

    print(x); print(y); printf("\n");
    swap(x, y);
    print(x); print(y); printf("\n");
}
```

Program output:

```
(4.000000, 5.000000) (10.000000, 15.000000)
(4.000000, 5.000000) (10.000000, 15.000000)
```

Structures can be returned from functions

```
#include <stdio.h>

typedef struct {
        float real;
        float imag;
} _COMPLEX;


_COMPLEX add ( _COMPLEX a,  _COMPLEX b)
{
   _COMPLEX tmp;
   tmp.real = a.real + b.real;
   tmp.imag = a.imag + b.imag;
   return tmp;
 }
```

```
main( )
{
    _COMPLEX x = { 4.0, 5.0 }, y = { 10.0, 15.0 };
    _COMPLEX z;

    z = add(x, y);
    printf(" %f, %f \n", z.real, z.imag);
}
```

Program output:

14.000000, 20.000000

Union

- In a struct, space is allocated as the sum of the space required by its members.
- In a union, space is allocated as the union of the space required by its members.
  - We use union when we want only one of the members, but don't know which one.

Suppose we wish to store an ID for each employee.

- Some employees may provide passport ID (8 characters)
- Other employees may provide Aadhar Card Number (12 digit integer)
- If we use a structure with both these fields, we will waste space

Union example

```
typedef  union {
    char passport[9];
    int aadhar;
 }  id ;

struct employee {
    char empname[20];
    int empcode;
    int idtype;
    id idnumber;
};
```

```
main ( )
{
    struct employee x;
    … read employee name and employee code here …
    printf("What is your ID type: \n 1. Passport, 2. Aadhar\n");
    scanf("%d", x.idtype);

    if (idtype == 1) {
            printf(" Enter passport number: ");
            scanf( "%8s", x.id.passport ) ;
    }
    if (idtype == 2) {
            printf("Enter Aadhar card number:");
            scanf("%12d", x.id.aadhar );
    }
}
```

Practice problems

1. Extend the complex number program to include functions for addition, subtraction, multiplication, and division
2. Define a structure for representing a point in two-dimensional Cartesian co-ordinate system. Using this structure for a point
   i. Write a function to return the distance between two given points
   ii. Write a function to return the middle point of the line segment joining two given points
   iii. Write a function to compute the area of a triangle formed by three given points
   iv. Write a main function and call the functions from there after reading in appropriate inputs (the points) from the keyboard

3. Define a structure STUDENT to store the following data for a student: name (null-terminated string of length at most 20 chars), roll no. (integer), CGPA (float). Then
    1. In main, declare an array of 100 STUDENT structures. Read an integer n and then read in the details of n students in this array
    2. Write a function to search the array for a student by name. Returns the structure for the student if found. If not found, return a special structure with the name field set to empty string (just a '\0')
    3. Write a function to search the array for a student by roll no.
    4. Write a function to print the details of all students with CGPA > x for a given x
    5. Call the functions from the main after reading in name/roll no/CGPA to search