

UES103

Programming for Problem Solving

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Structures

Basic Definitions

What is a Structure?

It is a convenient construct for representing a group of logically related data items. Particularly relevant when the constituent data items are of different types.

Compare with arrays that are collections of items of the **same** type.

Better readability even when the constituent data items are of the same type.

- **Examples:**

- **Student name (string), roll number (string), height (float), and marks (int).**
- **Real part and imaginary part of a complex number (pair of double).**

Structures help in organizing composite data in a programmer-friendly way. The individual structure elements are called **members** or **fields**.

This is our first look at a **user-defined data type**.

Defining a Structure

The composition of a structure may be defined as:

```
struct  < name of structure >  {  
  
    <data type>    <member1 name> ;  
    <data type>    <member2 name> ;  
    . . .  
    <data type>    <memberk name> ;  
  
};
```

For example:

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

Example

A structure definition:

```
struct student {  
    char name[30];  
    char roll_number[12];  
    float height;  
    int total_marks;  
};
```

Defining structure variables:

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

A new data type

- **struct** is the required C keyword
- **Do not forget the ; at the end of the structure defn**
- 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 the structure

Structure Definition versus Structure Variable Declaration

Structure Definition

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

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

Structure Variable Declaration

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

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

Structure Variable 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 name for the struct
- Hence we cannot reuse the struct definition

Each structure type variable (like a, b, c) has its own copy of each member of that structure type.

Type Definitions

The *typedef* construct

The *typedef* construct can be used to give new names to (existing) data types in C.

```
typedef float kilometers_per_hour; // kilometers_per_hour is a new name for float  
                                   // Note: no variable is allocated space here
```

```
kilometers_per_hour speed; speed = 40; // Here speed is a declared variable
```

More complicated examples of *typedef*

```
typedef int intarray[50];  
intarray    A,      // A is an array of 50 integers  
            B[20],  // B is an array of 20 arrays of 50 integers (a 20 x 50 array)  
            *C;     // C is a pointer to an array of 50 integers
```

```
typedef int *intptr;  
intptr      p,      // p is an int pointer  
            q[10],  // q is an array of 10 int pointers  
            *r;     // r is a pointer to an int pointer
```

These declarations are equivalent to:

```
int A[50], B[20][50], (*C)[50];  
int *p, *q[10], **r;
```

Structures and *typedef*

Without typedef

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

```
struct complex a, b, c;
```

Here **struct complex** is a **new data type**.

With typedef

- `typedef struct {`
- `float real;`
- `float imag;`
- `} complex;`
- `complex a, b, c;`

• Here **complex** is a **new data type**. Since **struct** is not followed by a name, this data type can be addressed only by the given name **complex**.

Accessing members and using structures

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

Dot operator is used to access members of a structure, through a structure-type variable

⟨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 braces separated by commas.

An example:

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



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

Example: Addition of two complex numbers

```
#include<stdio.h>  int
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 ("a + b = %f + %f j\n",
c.real,c.imag);
```

Structure
declar as well.
This is
multiple
functio

ation can be outside
main() necessary if a
program has ns using a
structure type.

Assignment of Structure Variables

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

```
int main()  
{  
    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 variable of the same type. All the individual members get assigned / copied.

But two structure variables **CANNOT be compared for equality or inequality `if (student1 == student2) . . .` **this cannot be done****

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 !!

Assigning all the members of a structure together

```
struct student {  
    char name[50];  
    float CGPA;  
    int height;  
} s;
```

```
s = { "Foolan Barik", 8.79, 176 };  
    NOT ALLOWED
```

```
s = (struct student){ "Foolan Barik", 8.79, 176 };    ALLOWED
```

Size of a structure

```
struct student {  
    char name[50];  
    float CGPA;  
    int height;  
} s;
```

Calculation shows a total space of $50 + 4 + 4 = 58$ bytes to store all the members of struct student.

But `sizeof(struct student)` or `sizeof(s)` may be 60 (the nearest larger multiple of 4) or even 64 (the nearest larger multiple of 8).

```
struct student {  
    char *name;  
    float CGPA;  
    int height;  
} s;
```

Assume 64-bit addresses.
Then `sizeof(struct student)` or `sizeof(s)` would be $8 + 4 + 4 = 16$.

This will be true irrespective of how much memory you `malloc` to `s.name`.

Arrays of structures

Arrays of Structures

Once a structure data type 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`

name of the k^{th} student

`student[k].name[j]`

j^{th} character in the name of the k^{th} student

Ex: Store a list of students (name, CGPA), compute average CGPA

```
#include <stdio.h>

struct student{
    float cgpa;
    char name[10];
};

int main(
{
    int i; float avg;
    struct student st[5];
    printf("Enter records of 5 students\n");
    for (i=0; i<5; i++) {
        printf ("Enter Cgpa:");
        scanf ("%f",&st[i].cgpa);
        printf ("Enter Name:");
        scanf ("%s",st[i].name);
    }
```

```
        // compute average cgpa
        avg = 0.0;
        for (i=0;i<5;i++)
            avg += st[i].cgpa;

        avg = avg / 5.0;
        printf ("Avg cgpa:%f",
avg);

        return 0;
```

Note: `&st[i].cgpa` is to be interpreted as `&(st[i].cgpa)`, not as `(&st[i]).cgpa` (an address cannot have a member).

A structure may contain other structures

```
typedef struct {  
    double x, y;  
} point;  
  
typedef struct {  
    point A, B, C;  
    double area;  
} triangle;  
  
triangle T = { {1.0, 2.0}, {-4.0, 5.0}, {3.0, -6.0}, -1 };  
  
T.area =      T.A.x * (T.B.y - T.C.y) +  
              T.B.x * (T.C.y - T.A.y) +  
              T.C.x * (T.A.y - T.B.y);  
T.area /= 2;  
if (T.area < 0) T.area = -T.area;  
printf("Area of T = %lf\n", T.area);
```

Output

Area of T = 17.000000

Structure containment cannot be recursive

It is **not allowed** that `struct a` contains `struct a` members.

It is **not allowed** that `struct a` contains `struct b`, and `struct b` contains `struct a`.

It is **allowed** that a structure contains a **pointer** to a structure of the same type.

These are called **self-referencing pointers**.

Such pointers are used extensively to create chains and other types of linked data structures.

```
typedef struct _student {                                // A name after struct is
mandatory
    char name[50];
    float CGPA;
    struct _student *next;                               // A self-referencing pointer
} student;
```


Structures and functions

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)
```

No swapping takes place actually, similar to what we saw for integers, floats, and so on.

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

Pointers to Structures

Pointers and Structures

```
struct class {  
    int roll;  
    char name[20];  
    float marks;  
};  
  
struct class *ptr;
```

Once **ptr** points to a structure variable, the members can be accessed as:

```
ptr -> roll;  
ptr -> name;  
ptr -> marks;
```

- The symbol “->” is called the **arrow** operator.

Arrow operator used to access members of a structure, through a structure-type pointer.

`ptr -> member` is a shortcut for `(*ptr).member`.

Use of pointers to structures

```
#include <stdio.h>

struct complex {
    float  real;
    float  imag;
};

main( )
{
    struct complex a, b, c;
    scanf ("%f %f", &a.real, &a.imag );
    scanf ("%f %f", &b.real, &b.imag );
    add( &a, &b, &c ) ;
    printf ("%f %f\n", c.real, c.imag );
}
```

```
void add (    struct complex *x,
             struct complex *y, struct complex *t)
{
    t->real = x->real + y->real;
    t->imag = x->imag + y->imag;
}
```

A Warning

When using structure pointers, we should take care of operator precedence.

- Member operator “.” has higher precedence than the dereferencing operator “*”

`ptr -> roll` and `(*ptr).roll` mean the same thing.

`*ptr.roll` will lead to error.

- The operator “->” enjoys the highest priority among operators.

`++ptr -> roll` will increment roll, not ptr.

`(++ptr) -> roll` will increment the pointer (to the next structure in an array) and access roll in the next structure.

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 coordinate system. Using this structure for a point, do the following.**
 - a. **Write a function to return the distance between two given points**
 - b. **Write a function to return the middle point of the line segment joining two given points**
 - c. **Write a function to compute the area of a triangle formed by three given points**
 - d. **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
- a. 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
 - b. 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')
 - c. Write a function to search the array for a student by roll no.
 - d. Write a function to print the details of all students with $\text{CGPA} > x$ for a given *x*
 - e. Call the functions from the main after reading in name/roll no/CGPA to search

Unions

Unions

- 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 that we wish to store the height of a student in one of the following formats.

- In the FPS system, it is a string like 5'10" (let us use a character array of size 8).
- In the CGS system, it is an integer like 178 (4 bytes are needed).
- In the MKS system, it is a floating-point number like 1.78 (4 bytes are needed).
- If we use a structure with all these members, we need $8 + 4 + 4 = 16$ bytes of space.
- A union will use only $\max(8, 4, 4) = 8$ bytes of space.
- You need to store an additional flag to tell which representation it is.

Union example

```
typedef struct {  
    char name[50];  
    float CGPA;  
    char htype;  
    union {  
        char fps[8];  
        int cgs;  
        float mks;  
    } height;  
} student;
```

```
int main ()  
{  
    student S;  
    printf("size of the union is %lu\n", sizeof(S.height));  
    printf("Enter type of height (f/c/m): ");  
    scanf("%c", &S.htype);  
    printf("Enter height: ");  
    if (S.htype == 'f') scanf("%s", S.height.fps);  
    else if (S.htype == 'c') scanf("%d", &S.height.cgs);  
    else if (S.htype == 'm') scanf("%f", &S.height.mks);  
    switch (S.htype) {  
        case 'f' : printf("%s\n", S.height.fps); break;  
        case 'c' : printf("%d\n", S.height.cgs); break;  
        case 'm' : printf("%.2f\n", S.height.mks); break;  
        default: printf("Unknown height type\n");  
    }  
}
```

Output

```
size of the union is 8  
Enter type of height (f/c/m): f  
Enter height: 6'5''  
6'5''
```