Chapter 10

C - Pointers

Pointers in C are easy and fun to learn. Some C programming tasks are performed more easily with pointers, and other tasks, such as dynamic memory allocation, cannot be performed without using pointers. So it becomes necessary to learn pointers to become a perfect C programmer. Let's start learning them in simple and easy steps.

As you know, every variable is a memory location and every memory location has its address defined which can be accessed using ampersand (&) operator, which denotes an address in memory. Consider the following example, which prints the address of the variables defined –

```
#include <stdio.h>

int main () {

  int var1;
  char var2[10];

  printf("Address of var1 variable: %x\n", &var1  );
  printf("Address of var2 variable: %x\n", &var2  );

  return 0;
}
```

When the above code is compiled and executed, it produces the following result –

```
Address of var1 variable: bff5a400
Address of var2 variable: bff5a3f6
```

What are Pointers?

A **pointer** is a variable whose value is the address of another variable, i.e., direct address of the memory location. Like any variable or constant, you must declare a pointer before using it to store any variable address. The general form of a pointer variable declaration is –

type *var-name;

Here, **type** is the pointer's base type; it must be a valid C data type and **var-name** is the name of the pointer variable. The asterisk * used to declare a pointer is the same asterisk used for multiplication. However, in this statement the asterisk is being

used to designate a variable as a pointer. Take a look at some of the valid pointer declarations –

```
int   *ip;   /* pointer to an integer */
double *dp;   /* pointer to a double */
float  *fp;   /* pointer to a float */
char   *ch    /* pointer to a character */
```

The actual data type of the value of all pointers, whether integer, float, character, or otherwise, is the same, a long hexadecimal number that represents a memory address. The only difference between pointers of different data types is the data type of the variable or constant that the pointer points to.

How to Use Pointers?

There are a few important operations, which we will do with the help of pointers very frequently. **(a)** We define a pointer variable, **(b)** assign the address of a variable to a pointer and **(c)** finally access the value at the address available in the pointer variable. This is done by using unary operator * that returns the value of the variable located at the address specified by its operand. The following example makes use of these operations –

```
#include <stdio.h>

int main () {

   int  var = 20;  /* actual variable declaration */
   int  *ip;       /* pointer variable declaration */

   ip = &var;  /* store address of var in pointer variable*/

   printf("Address of var variable: %x\n", &var  );

   /* address stored in pointer variable */
   printf("Address stored in ip variable: %x\n", ip );

   /* access the value using the pointer */
   printf("Value of *ip variable: %d\n", *ip );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result –

```
Address of var variable: bffd8b3c
Address stored in ip variable: bffd8b3c
Value of *ip variable: 20
```

NULL Pointers

It is always a good practice to assign a NULL value to a pointer variable in case you do not have an exact address to be assigned. This is done at the time of variable declaration. A pointer that is assigned NULL is called a **null**pointer.

The NULL pointer is a constant with a value of zero defined in several standard libraries. Consider the following program –

```
#include <stdio.h>

int main () {

  int  *ptr = NULL;

  printf("The value of ptr is : %x\n", ptr  );

  return 0;
}
```

When the above code is compiled and executed, it produces the following result –

```
The value of ptr is 0
```

In most of the operating systems, programs are not permitted to access memory at address 0 because that memory is reserved by the operating system. However, the memory address 0 has special significance; it signals that the pointer is not intended to point to an accessible memory location. But by convention, if a pointer contains the null (zero) value, it is assumed to point to nothing.

To check for a null pointer, you can use an 'if' statement as follows –

```
if(ptr)    /* succeeds if p is not null */
if(!ptr)   /* succeeds if p is null */
```

Pointers in Detail

Pointers have many but easy concepts and they are very important to C programming. The following important pointer concepts should be clear to any C programmer –

Sr.No.	Concept & Description
1	**Pointer arithmetic**

	There are four arithmetic operators that can be used in pointers: ++, --, +, -
2	**Array of pointers** You can define arrays to hold a number of pointers.
3	**Pointer to pointer** C allows you to have pointer on a pointer and so on.
4	**Passing pointers to functions in C** Passing an argument by reference or by address enable the passed argument to be changed in the calling function by the called function.
5	**Return pointer from functions in C** C allows a function to return a pointer to the local variable, static variable, and dynamically allocated memory as well.

C - Pointer arithmetic

A pointer in c is an address, which is a numeric value. Therefore, you can perform arithmetic operations on a pointer just as you can on a numeric value. There are four arithmetic operators that can be used on pointers: ++, --, +, and -

To understand pointer arithmetic, let us consider that **ptr** is an integer pointer which points to the address 1000. Assuming 32-bit integers, let us perform the following arithmetic operation on the pointer –

```
ptr++
```

After the above operation, the **ptr** will point to the location 1004 because each time ptr is incremented, it will point to the next integer location which is 4 bytes next to the current location. This operation will move the pointer to the next memory location without impacting the actual value at the memory location. If **ptr** points to a character whose address is 1000, then the above operation will point to the location 1001 because the next character will be available at 1001.

Incrementing a Pointer

We prefer using a pointer in our program instead of an array because the variable pointer can be incremented, unlike the array name which cannot be incremented

because it is a constant pointer. The following program increments the variable pointer to access each succeeding element of the array –

```
#include <stdio.h>

const int MAX = 3;

int main () {

  int  var[] = {10, 100, 200};
  int  i, *ptr;

  /* let us have array address in pointer */
  ptr = var;

  for ( i = 0; i < MAX; i++) {

    printf("Address of var[%d] = %x\n", i, ptr );
    printf("Value of var[%d] = %d\n", i, *ptr );

    /* move to the next location */
    ptr++;
  }

  return 0;
}
```

When the above code is compiled and executed, it produces the following result –

```
Address of var[0] = bf882b30
Value of var[0] = 10
Address of var[1] = bf882b34
Value of var[1] = 100
Address of var[2] = bf882b38
Value of var[2] = 200
```

Decrementing a Pointer

The same considerations apply to decrementing a pointer, which decreases its value by the number of bytes of its data type as shown below –

```
#include <stdio.h>

const int MAX = 3;

int main () {

  int  var[] = {10, 100, 200};
  int  i, *ptr;
```

```
  /* let us have array address in pointer */
  ptr = &var[MAX-1];

  for ( i = MAX; i > 0; i--) {

    printf("Address of var[%d] = %x\n", i-1, ptr );
    printf("Value of var[%d] = %d\n", i-1, *ptr );

    /* move to the previous location */
    ptr--;
  }

  return 0;
}
```

When the above code is compiled and executed, it produces the following result –

```
Address of var[2] = bfedbcd8
Value of var[2] = 200
Address of var[1] = bfedbcd4
Value of var[1] = 100
Address of var[0] = bfedbcd0
Value of var[0] = 10
```

Pointer Comparisons

Pointers may be compared by using relational operators, such as ==, <, and >. If p1 and p2 point to variables that are related to each other, such as elements of the same array, then p1 and p2 can be meaningfully compared.

The following program modifies the previous example – one by incrementing the variable pointer so long as the address to which it points is either less than or equal to the address of the last element of the array, which is &var[MAX - 1] –

```
#include <stdio.h>

const int MAX = 3;

int main () {

  int  var[] = {10, 100, 200};
  int  i, *ptr;

  /* let us have address of the first element in pointer */
  ptr = var;
  i = 0;

  while ( ptr <= &var[MAX - 1] ) {
```

```
  printf("Address of var[%d] = %x\n", i, ptr );
  printf("Value of var[%d] = %d\n", i, *ptr );

  /* point to the previous location */
  ptr++;
  i++;
 }

 return 0;
}
```

When the above code is compiled and executed, it produces the following result –

```
Address of var[0] = bfdbcb20
Value of var[0] = 10
Address of var[1] = bfdbcb24
Value of var[1] = 100
Address of var[2] = bfdbcb28
Value of var[2] = 200
```

C - Array of pointers

Before we understand the concept of arrays of pointers, let us consider the following example, which uses an array of 3 integers –

```
#include <stdio.h>

const int MAX = 3;

int main () {

 int  var[] = {10, 100, 200};
 int i;

 for (i = 0; i < MAX; i++) {
   printf("Value of var[%d] = %d\n", i, var[i] );
 }

 return 0;
}
```

When the above code is compiled and executed, it produces the following result –

```
Value of var[0] = 10
Value of var[1] = 100
Value of var[2] = 200
```

There may be a situation when we want to maintain an array, which can store pointers to an int or char or any other data type available. Following is the declaration of an array of pointers to an integer –

```
int *ptr[MAX];
```

It declares **ptr** as an array of MAX integer pointers. Thus, each element in ptr, holds a pointer to an int value. The following example uses three integers, which are stored in an array of pointers, as follows –

```
#include <stdio.h>

const int MAX = 3;

int main () {

  int  var[] = {10, 100, 200};
  int i, *ptr[MAX];

  for ( i = 0; i < MAX; i++) {
    ptr[i] = &var[i]; /* assign the address of integer. */
  }

  for ( i = 0; i < MAX; i++) {
    printf("Value of var[%d] = %d\n", i, *ptr[i] );
  }

  return 0;
}
```

When the above code is compiled and executed, it produces the following result –

```
Value of var[0] = 10
Value of var[1] = 100
Value of var[2] = 200
```

You can also use an array of pointers to character to store a list of strings as follows –

```
#include <stdio.h>

const int MAX = 4;

int main () {

  char *names[] = {
    "Zara Ali",
    "Hina Ali",
    "Nuha Ali",
```

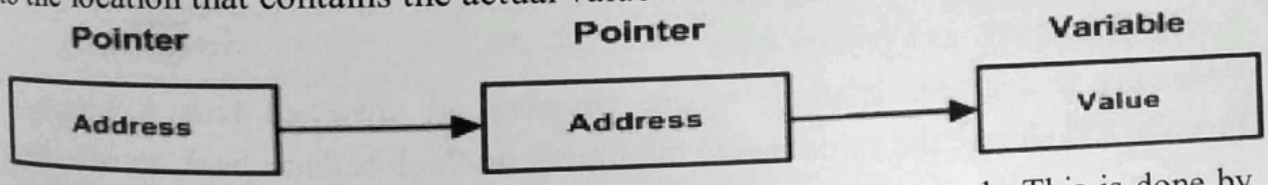
```
  "Sara Ali"
};

int i = 0;

for ( i = 0; i < MAX; i++) {
  printf("Value of names[%d] = %s\n", i, names[i] );
}

return 0;
}
```

When the above code is compiled and executed, it produces the following result –

```
Value of names[0] = Zara Ali
Value of names[1] = Hina Ali
Value of names[2] = Nuha Ali
Value of names[3] = Sara Ali
```

C - Pointer to Pointer

A pointer to a pointer is a form of multiple indirection, or a chain of pointers. Normally, a pointer contains the address of a variable. When we define a pointer to a pointer, the first pointer contains the address of the second pointer, which points to the location that contains the actual value as shown below.



A variable that is a pointer to a pointer must be declared as such. This is done by placing an additional asterisk in front of its name. For example, the following declaration declares a pointer to a pointer of type int –

```
int **var;
```

When a target value is indirectly pointed to by a pointer to a pointer, accessing that value requires that the asterisk operator be applied twice, as is shown below in the example –

```
#include <stdio.h>

int main () {

   int  var;
   int  *ptr;
   int  **pptr;
```

```
  var = 3000;

  /* take the address of var */
  ptr = &var;

  /* take the address of ptr using address of operator & */
  pptr = &ptr;

  /* take the value using pptr */
  printf("Value of var = %d\n", var );
  printf("Value available at *ptr = %d\n", *ptr );
  printf("Value available at **pptr = %d\n", **pptr);

  return 0;
}
```

When the above code is compiled and executed, it produces the following result –

```
Value of var = 3000
Value available at *ptr = 3000
Value available at **pptr = 3000
```

Passing pointers to functions in C

C programming allows passing a pointer to a function. To do so, simply declare the function parameter as a pointer type.

Following is a simple example where we pass an unsigned long pointer to a function and change the value inside the function which reflects back in the calling function –

```
#include <stdio.h>
#include <time.h>

void getSeconds(unsigned long *par);

int main () {

  unsigned long sec;
  getSeconds( &sec );

  /* print the actual value */
  printf("Number of seconds: %ld\n", sec );

  return 0;
}
```

```
void getSeconds(unsigned long *par) {
 /* get the current number of seconds */
 *par = time( NULL );
 return;
}
```

When the above code is compiled and executed, it produces the following result –

```
Number of seconds :1294450468
```

The function, which can accept a pointer, can also accept an array as shown in the following example –

```
#include <stdio.h>

/* function declaration */
double getAverage(int *arr, int size);

int main () {

  /* an int array with 5 elements */
  int balance[5] = {1000, 2, 3, 17, 50};
  double avg;

  /* pass pointer to the array as an argument */
  avg = getAverage( balance, 5 ) ;

  /* output the returned value  */
  printf("Average value is: %f\n", avg );
  return 0;
}

double getAverage(int *arr, int size) {

  int  i, sum = 0;
  double avg;

  for (i = 0; i < size; ++i) {
    sum += arr[i];
  }

  avg = (double)sum / size;
  return avg;
}
```

When the above code is compiled together and executed, it produces the following result –

```
Average value is: 214.40000
```

Return pointer from functions in C

We have seen in the last chapter how C programming allows to return an array from a function. Similarly, C also allows to return a pointer from a function. To do so, you would have to declare a function returning a pointer as in the following example –

```
int * myFunction() {
  .
  .
  .
}
```

Second point to remember is that, it is not a good idea to return the address of a local variable outside the function, so you would have to define the local variable as **static** variable.

Now, consider the following function which will generate 10 random numbers and return them using an array name which represents a pointer, i.e., address of first array element.

```
#include <stdio.h>
#include <time.h>

/* function to generate and return random numbers. */
int * getRandom( ) {

  static int  r[10];
  int i;

  /* set the seed */
  srand( (unsigned)time( NULL ) );

  for ( i = 0; i < 10; ++i) {
    r[i] = rand();
    printf("%d\n", r[i] );
  }

  return r;
}

/* main function to call above defined function */
int main () {

  /* a pointer to an int */
```

```
int *p;
int i;

p = getRandom();

for ( i = 0; i < 10; i++ ) {
  printf("*(p + [%d]) : %d\n", i, *(p + i) );
}

return 0;
}
```

When the above code is compiled together and executed, it produces the following result –

```
1523198053
1187214107
1108300978
430494959
1421301276
930971084
123250484
106932140
1604461820
149169022
*(p + [0]) : 1523198053
*(p + [1]) : 1187214107
*(p + [2]) : 1108300978
*(p + [3]) : 430494959
*(p + [4]) : 1421301276
*(p + [5]) : 930971084
*(p + [6]) : 123250484
*(p + [7]) : 106932140
*(p + [8]) : 1604461820
*(p + [9]) : 149169022
```

Programming Exercises

1. Write a program in C to show the basic declaration of pointer

Expected Output:

Pointer : Show the basic declaration of pointer :

Here is m=10, n and o are two integer variable and *z is an integer

z stores the address of m = 0x7ffd40630d44

*z stores the value of m = 10

&m is the address of m = 0x7ffd40630d44

&n stores the address of n = 0x7ffd40630d48

&o stores the address of o = 0x7ffd40630d4c

&z stores the address of z = 0x7ffd40630d50

2. Write a program in C to demonstrate how to handle the pointers in the program

Expected Output :

Address of m : 0x7ffcc3ad291c
Value of m : 29

Now ab is assigned with the address of m.
Address of pointer ab : 0x7ffcc3ad291c
Content of pointer ab : 29

The value of m assigned to 34 now.
Address of pointer ab : 0x7ffcc3ad291c
Content of pointer ab : 34

The pointer variable ab is assigned with the value 7 now.
Address of m : 0x7ffcc3ad291c
Value of m : 7

3. Write a program in C to demonstrate the use of &(address of) and *(value at address) operator.

Expected Output :

Pointer : Demonstrate the use of & and * operator :
---
m = 300
fx = 300.600006
cht = z

Using & operator :
---
address of m = 0x7ffda2eeeec8

address of fx = 0x7ffda2eeeecc
address of cht = 0x7ffda2eeeec7

Using & and * operator :
---
value at address of m = 300
value at address of fx = 300.600006
value at address of cht = z

Using only pointer variable :
---
address of m = 0x7ffda2eeeec8
address of fx = 0x7ffda2eeeecc
address of cht = 0x7ffda2eeeec7

Using only pointer operator :
---
value at address of m = 300
value at address of fx= 300.600006
value at address of cht= z

4. Write a program in C to add two numbers using pointers.
Test Data :
Input the first number : 5
Input the second number : 6
Expected Output :
The sum of the entered numbers is : 11

5. Write a program in C to add numbers using call by reference. Go to the editor
Test Data :
Input the first number : 5
Input the second number : 6
Expected Output :
The sum of 5 and 6 is 11

6. Write a program in C to find the maximum number between two numbers using a pointer.

Test Data :
Input the first number : 5
Input the second number : 6
Expected Output :
6 is the maximum number.

7. Write a program in C to store n elements in an array and print the elements using pointer. Test Data :

```
Input the number of elements to store in the array :5
Input 5 number of elements in the array :
element - 0 : 5
element - 1 : 7
element - 2 : 2
element - 3 : 9
element - 4 : 8
```

Expected Output :
The elements you entered are :
element - 0 : 5
element - 1 : 7
element - 2 : 2
element - 3 : 9
element - 4 : 8

8. Write a program in C to swap elements using call by reference.
Test Data :
Input the value of 1st element : 5
Input the value of 2nd element : 6
Input the value of 3rd element : 7

Expected Output :
The value before swapping are :
element 1 = 5
element 2 = 6
element 3 = 7

The value after swapping are :
element 1 = 7
element 2 = 5
element 3 = 6