Tutorial 9
Pointers in C

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Content

- **Some Interview Questions**
- **Basic concept of pointers**
- **Pointer arithmetic**
- **Array of pointers**
- **Pointer to pointer**
- **Passing pointers to functions in C**
- **Return pointer from functions in C**

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Q1: What are main characteristics of C language?

- C is a *procedural* language.
- The main features of C language include low-level access to memory, simple set of keywords, and clean style.
- These features make it suitable for system programming like operating system or compiler development.

Q2: What is the use of a '\0' character?

- It is referred to as a terminating null character, and is used primarily to show the end of a string value.

Q3: What is the difference between i++ and ++i?

- The expression **i++** returns the old value and then increments i.
- The expression **++i** increments the value and returns new value.
- i = 1; j = ++i; (i is 2, j is 2)
- i = 1; j = i++; (i is 2, j is 1)

Q4: What is the difference between passed by value and passed by reference?

- **Passed By Value:** The actual arguments are **copied** to the formal arguments, hence any operation performed by function on arguments **doesn't affect** actual parameters.
- **Passed By Reference:** The **addresses** of actual arguments are passed to the formal parameters, which means any operation performed on formal parameters **affects** the value of actual parameters.
- C parameters are always **passed by value** rather than by reference. However, if you think of the **address** of an object as being a ***reference*** to that object, then you can pass that reference by value. Because you're passing **the value** of the pointer to the method and then dereferencing it to get the integer that is pointed to.
- Reference: http://stackoverflow.com/questions/2229498/passing-by-reference-in-c

Example

```
#include <stdio.h>
void Func1(int, int);  // pass by value
void Func2(int *, int *);  // pass by reference

int main( )
{
     int a = 8, b = 9;
     printf("Before Func1 is called, a = %d, b = %d\n", a, b);
     Func1(a, b);
     printf("After Func1 is called, a = %d, b = %d\n\n", a, b);

     printf("\nBefore Func2 is called, a = %d, b = %d\n", a, b);
     Func2(&a, &b);
     printf("After Func2 is called, a = %d, b = %d\n\n", a, b);
}
```

Example

```
void Func1(int a, int b)
{
     a = 0;
     b = 0;
     printf("The value inside Func1, a = %d, b = %d\n", a,
   b);
}

void Func2(int *pa, int *pb)
{
     *pa = 0;
     *pb = 0;
     printf("The value inside Func2, *pa = %d, *pb =
   %d\n", *pa, *pb);
}
```

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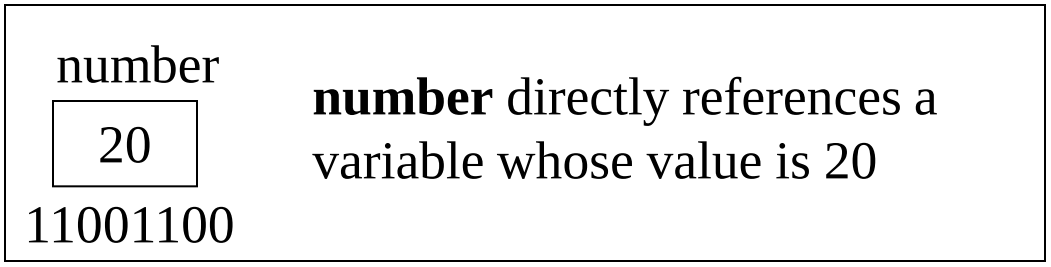
What is a pointer

- So far, we have seen that a variable is used to store a **value**.
- Variables allow the programmer to directly manipulate the data in memory.
- A pointer variable, however, does not store a value but store the **address of the memory** space which contain the value i.e. **it directly points to a specific memory address.**
- Why would we want to use pointers?
  - To call a function by reference so that the data passed to the function can be changed inside the function.
  - To create a dynamic data structure which can grow larger or smaller as necessary.

Variable declaration

- A variable declaration such as,
  - ***int number = 20***; causes the compiler to allocate a memory location for the variable *number* and store in it the integer value 20.
  - This absolute address of the memory location is readily available to our program during the run time.
  - The computer uses this address to access its content.



Pointer declaration

- General Format:

  data_type *pointer_name;

- A pointer declaration such as,

  ***int *numberPtr*;**

  - declares ***numberptr*** as a variable that **points to an integer variable**. Its content is a **memory address.**

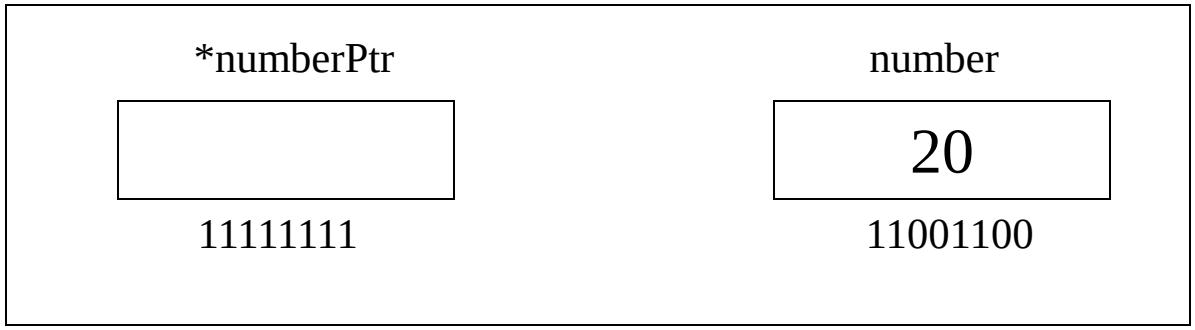
- The asterisk * indicates that the variable being declared is a pointer variable instead of a normal variable.

Pointer declaration (cont.)

- Consider the following declaration

  int *numberPtr, number = 20;

- In this case, two memory address have been reserved in the memory, namely the ***numberPtr*** and ***number***.
- The value in variable ***number*** is of type integer, and the value in variable ***numberPtr*** is an address for another memory.



Pointer Initialization

- To prevent the pointer from pointing to a random memory address, it is advisable that the pointer is initialized to ***0***, ***NULL*** or **an address before being used.**
- A pointer with the value ***NULL***, points to nothing.
- Initializing a pointer to ***0*** is equivalent to initializing a pointer to ***NULL***, but ***NULL*** is preferred.

Pointer Operator (& and *)

- When a pointer is created, it is not pointing to any valid memory address. Therefore, we need to assign it to a variable's address by using the ampersand **&** operator. This operator is called a **reference operator**.
- Look at this example:

```
int number = 20;
int *numberPtr; //(a) We define a pointer variable
numberPtr = &number; //(b) assign the address of a variable to a pointer
printf("number = %d", *numberPtr); //(c) finally access the value at the address available in the pointer variable.
```

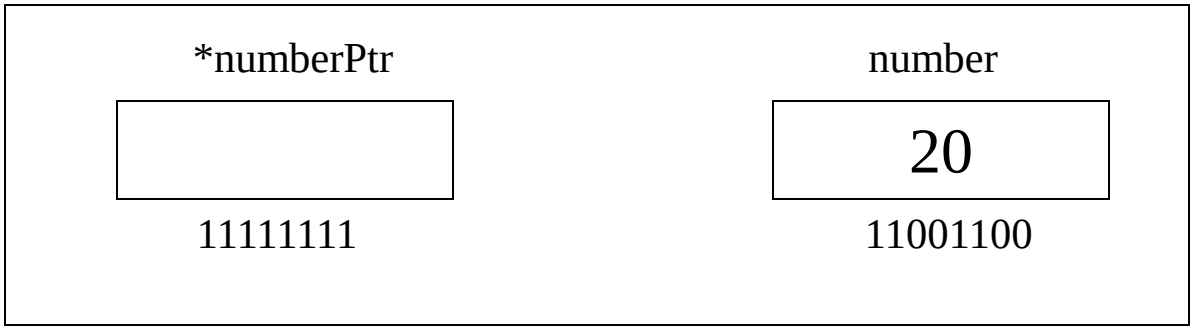
Output:

number = 20

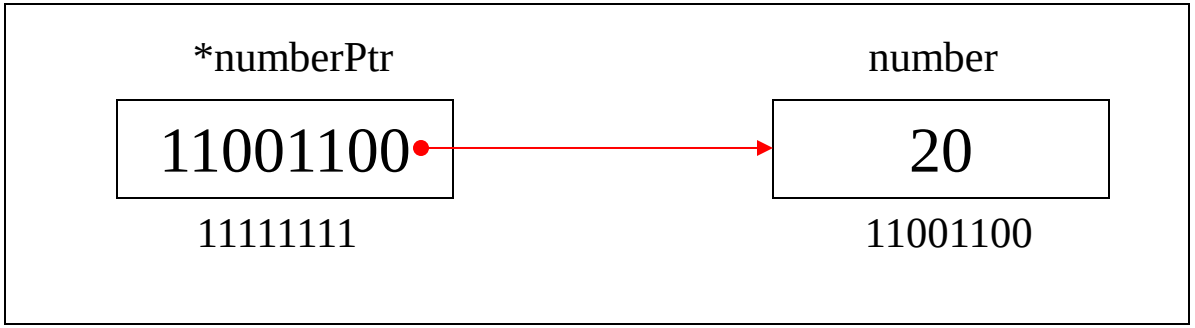
- The statement **numberPtr = &number** assigns the address of the variable number to a pointer variable numberPtr.
- Variable numberPtr is then said as to "**point to**" variable number.

Graphical representation

- int *numberPtr, number = 20;



- numberPtr = &number;



Pointer Operator (& and *) (cont.)

- After a pointer is assigned to a particular address, the value in the pointed address can be accessed/modified using the asterisk * operator.
- This operator is commonly called as the ***indirection operator*** or ***dereferencing operator***.
- The * operator returns the value of the object to which its operand points. For example, the statement
  - printf("number = %d", *numberPtr);
    //prints the value of variable number, namely as 20.
    //Using * in this manner is called dereferencing operator.

Example: & and *

```
#include <stdio.h>
int main( )
{
     int var = 10;
     int *ptrvar = &var;

     printf("The address of the variable var is: %d\n", &var);
     printf("The value of the pointer ptrvar is: %d\n", ptrvar);
     printf("Both values are the same\n\n");

     printf("The value of the variable var is: %d\n", var);
     printf("The value of *ptrvar is: %d\n", *ptrvar);
     printf("Both values are the same\n\n");

     printf("The address of the value pointed by ptrvar is: %d\n", &*ptrvar);
     printf("The value inside the address of ptrvar is: %d\n", *&ptrvar);
     printf("Both values are the same\n\n");
}
```

Example: & and *

```
/*Sample Output */

The address of the variable var is: 1245052
The value of the pointer ptrvar is: 1245052
Both values are the same

The value of the variable var is: 10
The value of *ptrvar is: 10
Both values are the same

The address of the value pointed by ptrvar is: 1245052
The value inside the address of ptrvar is: 1245052
Both values are the same

Press any key to continue
```

&* and *&

- & and * are inverse operations.
- &* acts equivalent to *& and this leads back to the original value.
- Example: (Assume that the address of num is 1245052)

```
#include <stdio.h>
int main()
{
  int num = 5;
  int *numPtr = &num;
  printf("%d \n", numPtr);
  printf("%d \n", &*numPtr);
  printf("%d \n", *&numPtr);
}
```

```
Output:
1245052
1245052
1245052
```

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Pointer arithmetic

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

`int *ptr = 1000;`	`char *ptr = 1000;`
`ptr++`	`ptr++`
ptr = 1004	ptr = 1001

Example

```
#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;
}
```

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Array of pointers

- 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.

Example

```
#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;
}
```

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Pointer to Pointer

- 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.

- Declare a pointer to a pointer of type int

int **var;

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;
}
```

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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.
  - Declare the variable that is meant to return a value to the calling function as a pointer variable in the formal parameter list of the function.

    void function_name(int *varPtr);
  - When to call the function, use a variable together with address operator (&)

    function_name(&var);

Parameter Passing by Reference/Pointer

- This way of passing the argument can realize the purpose of passing by reference. However, there is no “passed by reference” in C.
- Just because you're passing **the value** of the pointer to the method and then dereferencing it to get the integer that is pointed to.
- When the value referenced by the pointer is changed inside the function, the value in the actual variable will also change.
- When a pointer is passed to a function, we are actually passing the address of a variable to the function.
- Since we have the address, we can directly manipulate the data in the address.

Example

```
#include <stdio.h>
void Func1(int, int);  // pass by value
void Func2(int *, int *);  // pass by reference

int main( )
{
     int a = 8, b = 9;
     printf("Before Func1 is called, a = %d, b = %d\n", a, b);
     Func1(a, b);
     printf("After Func1 is called, a = %d, b = %d\n\n", a, b);

     printf("\nBefore Func2 is called, a = %d, b = %d\n", a, b);
     Func2(&a, &b);
     printf("After Func2 is called, a = %d, b = %d\n\n", a, b);
}
```

Example

```
void Func1(int a, int b)
{
     a = 0;
     b = 0;
     printf("The value inside Func1, a = %d, b = %d\n", a,
   b);
}

void Func2(int *pa, int *pb)
{
     *pa = 0;
     *pb = 0;
     printf("The value inside Func2, *pa = %d, *pb =
   %d\n", *pa, *pb);
}
```

Result

```
/* output */

Before Func1 is called, a = 8, b = 9
The value inside Func1, a = 0, b = 0
After Func1 is called, a = 8, b = 9

Before Func2 is called, a = 8, b = 9
The value inside Func2, *pa = 0, *pb = 0

After Func2 is called, a = 0, b = 0
Press any key to continue
```

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Return pointer from functions in C

- Declare a function returning a pointer:

  int * myFunction() { . . . }

- 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.

Example

```
#include <stdio.h>
#include <time.h>
/* function to generate and retrun 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;
}
```

Summary

- **Some Interview Questions**
- **Basic concept of pointers**
- **Pointer arithmetic**
  - **ptr++**
- **Array of pointers**
  - **int *ptr[MAX];**
- **Pointer to pointer**
  - **int **var;**
- **Passing pointers to functions in C**
  - **void function_name(int *varPtr);**
- **Return pointer from functions in C**
  - **int * myFunction() { . . . }**

Thank you!