First Year First Semester Course

M.Tech. (CS) [Batch 2021-23]

Lecture #07

Introduction to Programming

Pointers in C

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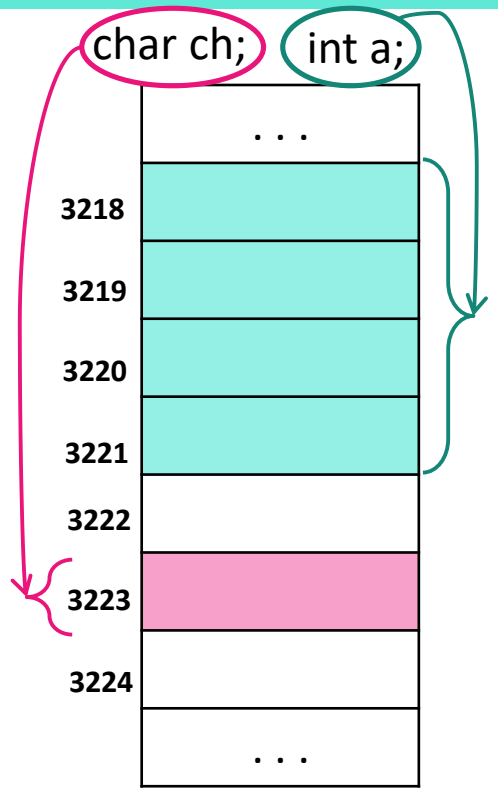
Introduction

- Every stored data item occupies one or more contiguous memory cells.
- The number of memory cells required to store a data item depends on its type (char, int, float, double, etc.).
- A **pointer** is a variable that represents the location (rather than the value) of a data item.

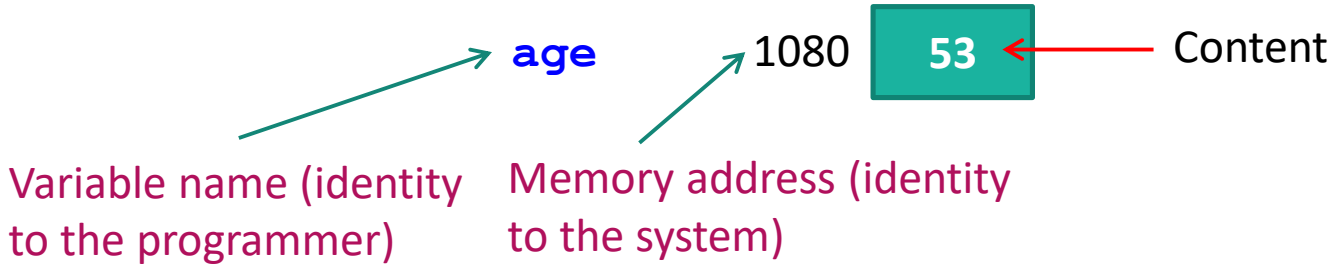


Example

- Consider the statement

```
int age = 53;
```

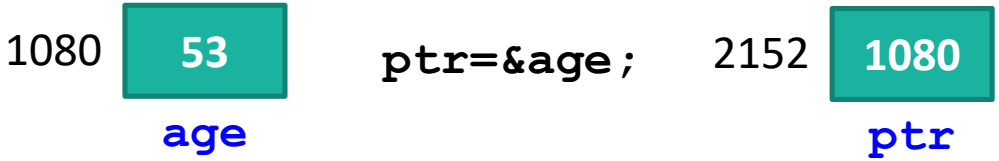
- This statement instructs the compiler to allocate a location for the integer variable *age*, and put the value 53 in that location.
- Suppose that the address location chosen is 1080.



Pointers

- Variables that hold memory addresses are called pointers.
- Since a pointer is a variable, its value is also stored in some memory location.

Variable	Value	Address
age	53	1080
ptr	1080	2152



NOTE

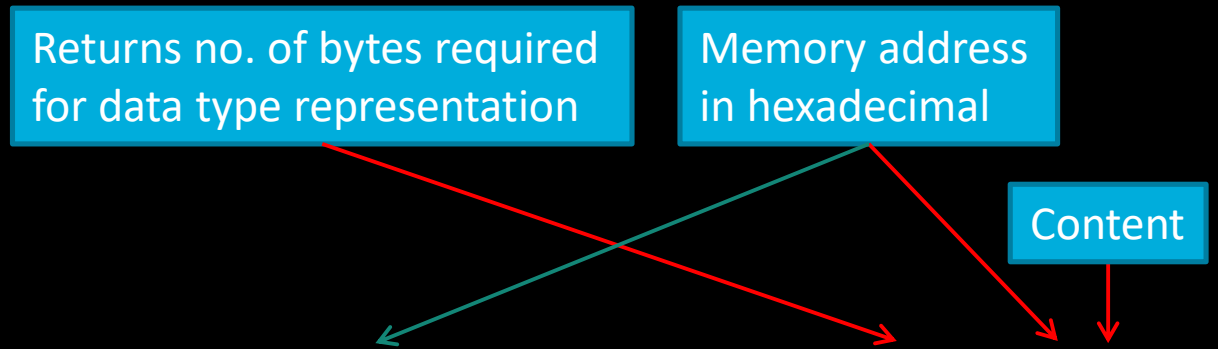
Pointer constants→ Memory Addresses; We cannot change these;

Pointer value→ Value of the memory address of a variable;

Pointer variable→ Variable that contains a pointer value.

Example


```
#include <stdio.h>
int main()
{
        char a='1';
        int b=1;
        long int c=1;
        float d=1.0;
        double e=1.0;

        printf("a: size is %dB, address is %X and content is %c\n", sizeof(a), &a,a);
        printf("b: size is %dB, address is %X and content is %d\n", sizeof(b), &b,b);
        printf("c: size is %dB, address is %X and content is %ld\n", sizeof(c), &c, c);
        printf("d: size is %dB, address is %X and content is %f\n", sizeof(d), &d, d);
        printf("e: size is %dB, address is %X and content is %lf\n", sizeof(e), &e, e);
        return 0;
}
```



Accessing the Address of a Variable

- The address of a variable can be determined using the '&' operator.
  - The operator '&' immediately preceding a variable returns the address of the variable.

- Example:

```
int age;
ptr = &age;     // the address of age is assigned to ptr.
```

What is the data type of ptr?

Data Type

- Pointer must have a data type. That is the data type of the variable whose address will be stored.

```
int *p;          // p is the pointer to data of type int.
float *p1;       // p1 is the pointer to data of type float.
long int *p2;    // p2 is the pointer to data of type long int.
```

NOTE

int *ptr and int* ptr are the same. However the first one helps you to declare in one statement:

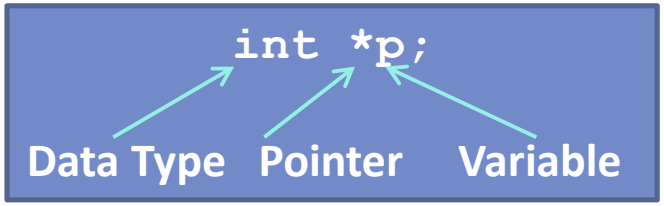
int *ptr, var1;

REMEMBER

int x;
float *a;
a=&x; // NOT ALLOWED

Declaration and Initialization of Pointer


```
int age;
int *ptr;      //declaration
ptr=&age;   //initialization
```



- printf("%d",age); is equivalent to printf("%d",*ptr);
- So **age** and ***ptr** can be used for the same purpose.
- Declaration of a pointer variable can also be made in a single statement along with other normal variables: int age, *ptr;
- Declaration and initialization can be combined: int *ptr=&age;
- Pointers can be initialized with NULL and 0 (zero). However, no other constant value can be assigned to a pointer: int *p= 2186; //wrong

Dereferencing Pointers

- Dereferencing is an operation performed to access and manipulate data contained in the memory location.
- A pointer variable is said to be dereferenced when the unary operator *, in this case called the ***indirection operator***, is used like a prefix to the pointer variable or pointer expression.
- An operation performed on the dereferenced pointer directly affects the value of the variable it points to.

Example


```
#include <stdio.h>
int main()
{
        int a, b;
        int c = 5;
        int *p;

        a = 10 * (c + 8);
        p = &c;
        b = 10 * (*p + 8);

        printf ("a=%d b=%d \n", a, b);
        return 0;
}
```

Equivalent

Example


```
#include<stdio.h>
int main() {
        int *iptr, var1, var2;
        iptr=&var1;
        *iptr=32;
        *iptr += 10;
        printf("variable var1 contains %d\n",var1);
        var2=*iptr;
        printf("variable var2 contains %d\n",var2);
        iptr=&var2;
        *iptr += 20;
        printf("variable var2 now contains %d\n",var2);
        return 0;
}
```

Example [contd.]

Output

```
variable var1 contains 42
variable var2 contains 42
variable var2 now contains 62
```

- Thus the two uses of * are to be noted.
  - int *p for declaring a pointer variable
  - *p=10 is for indirection to the value in the address pointed by the variable p.
- This power of pointers is often useful, where direct access via variables is not possible.

Example


```
#include <stdio.h>
int main()
{
        int x, y;
        int *ptr;
        x = 50 ;
        ptr = &x ;
        y = *ptr ;
        printf ("%d is stored in location %u \n", x, &x) ;
        printf ("%d is stored in location %u \n", *&x, &x) ;
        printf ("%d is stored in location %u \n", *ptr, ptr) ;
        printf ("%u is stored in location %u \n", ptr, &ptr) ;
        printf ("%d is stored in location %u \n", y, &y) ;
        *ptr = 25;
        printf ("\nNow x = %d \n", x);
        return 0;
}
```

Output:

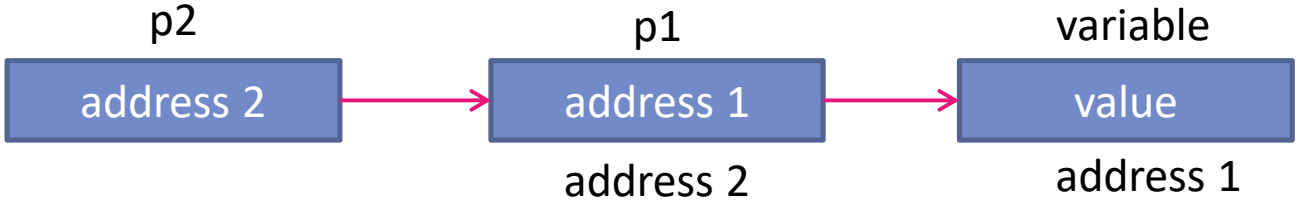
```
50 is stored in location 2293436
50 is stored in location 2293436
50 is stored in location 2293436
2293436 is stored in location 2293428
50 is stored in location 2293432

Now x = 25
```

*&x ⟺ x

ptr=&x;
&x ⟺ &*ptr

Chain of Pointers

- It is possible to make a pointer to point to another pointer, thus creating a chain of pointers



- A variable which is a pointer to a pointer must be declared using additional indirection operator symbols in front of the name.

```
int **p2;
```

- The target value, indirectly pointed to by pointer to a pointer can be accessed by applying indirection operator twice

Example


```
#include <stdio.h>
int main()
{
        int x, *p1, **p2;
        x=400;
        p1=&x;
        p2=&p1;

        printf("%d %d %d", x,*p1,**p2);
        return 0;
}
```

Pointer Expressions

- Let p1, p2, p3 are properly declared and initialized pointers. Then, following statements are valid.

```
y=*p1 * *p2     //same as (*p1) * (*p2)
sum=sum + *p1;
Z= 6* - *p2/ *p1;  //same as (6* (-(*p2)))/(*p1)
```

- A few more valid expressions:

```
p2=p1 + 4;
p2= p1 - 2;
p3= p2 - p1;
p1++;
sum += *p3;
```

Pointer can also be used in relational expressions:

```
p1 > p2     //valid
p1 == p2    //valid
p1 != p2    //valid
```

Invalid Pointer Arithmetic

- Following are illegal:

  p1 / p2

  p1 * p2

  p1 / 3

  p1 + p2

Pointer Increment and Scale Factor

- When we increment a pointer, its value is incremented by the length of the data type that it points to.

- This length is called as the ***scale factor***

- Let p1 be an integer pointer and the initial value of p1 is 5140

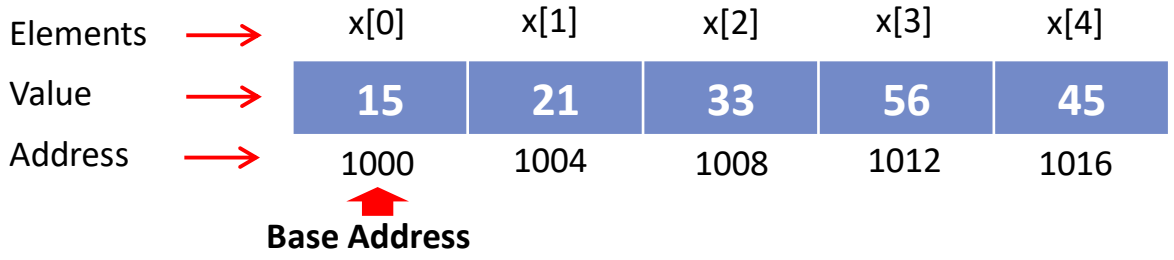
  Then, p1 = p1 + 1 causes p1 to become 5144; **not 5141**

Pointers and Arrays

- When an array is declared,
  - The ***compiler allocates a base address*** and ***sufficient amount of storage*** to contain all the elements of the array in ***contiguous*** memory locations.
  - The ***base address*** is the ***location of the first element*** (index 0) of the array.
  - The compiler also defines the ***array name as a constant pointer to the first element***.

```
int x[5]={15,21,33,56,45};
```

x = &x[0] = 1000



Pointers and Arrays

- The elements of an array can be efficiently accessed by using a pointer.
- Consider an array of integers and an int pointer:

```
#define MAXSIZE 10
int A[MAXSIZE], *p;
```

- The ***following are legal assignments*** for the pointer p:

```
p = A; /* p point to the 0-th location of the array A */
p = &A[0]; /* p point to the 0-th location of the array A */
p = &A[1]; /* p point to the 1-st location of the array A */
p = &A[i]; /* p point to the i-th location of the array A */
```

- Whenever p is assigned the value &A[i], the value *p refers to the array element A[i].

Pointers and Arrays

- **Pointers can be incremented and decremented by integral values**.
- After the assignment p = &A[i]; the increment p++ (or ++p) lets p one element down the array, whereas the decrement p-- (or --p) lets p move by one element up the array. (Here "up" means one index less, and "down" means one index more.)
- Incrementing or decrementing p by an integer value n lets p move forward or backward in the array by n locations.

```
p = A; /* p point to the 0-th location of the array A */
p++; /* Now p points to the 1-st location of A */
p = p + 6; /* Now p points to the 8-th location of A */
p += 2; /* Now p points to the 10-th location of A */
--p; /* Now p points to the 9-th location of A */
p -= 5; /* Now p points to the 4-th location of A */
p -= 5; /* Now p points to the (-1)-th location of A */
```

Remember:

Increment/ Decrement is by data type not by bytes.

Example

- Consider the declaration:

```
int *p;
int x[5] = {10, 22, 34, 46, 58} ;
```

Suppose that the base address of x is 1500, and each integer requires 4 bytes.

Element	Value	Address
x[0]	10	1500
x[1]	22	1504
x[2]	34	1508
x[3]	46	1512
x[4]	58	1516

Relationship between p and x:

```
p = &x[0]  (= 1500)     /* Equivalent to  p=x;
p+1 = &x[1] (= 1504)
p+2 = &x[2] (= 1508)
p+3 = &x[3] (= 1512)
p+4 = &x[4] (= 1516)
```

Accessing Array elements


```
#include<stdio.h>
int main()
{
        int iarray[5]={1,2,3,4,5};
        int i, *ptr;
        ptr=iarray;
        for(i=0;i<5;i++) {
                printf("iarray[%d] (%x): %d\n",i,ptr,*ptr);
                ptr++;
        }
        printf("====================\n");
        for(i=0;i<5;i++) {
                printf("iarray[%d] (%x): %d\n",i, (iarray+i),*(iarray+i));
        }
        return 0;
}
```

Output

```
iarray[0] (22fea4): 1
iarray[1] (22fea8): 2
iarray[2] (22feac): 3
iarray[3] (22feb0): 4
iarray[4] (22feb4): 5
================
iarray[0] (22fea4): 1
iarray[1] (22fea8): 2
iarray[2] (22feac): 3
iarray[3] (22feb0): 4
iarray[4] (22feb4): 5
```

NOTE : The name of the array can be used as a normal pointer, to access the other elements in the array.

More examples


```
#include<stdio.h>
int main()
{
        int i;
        int a[5]={1,2,3,4,5}, *p = a;
        for(i=0;i<5;i++,p++) {
                printf("%d %d",a[i],*(a+i));
                printf(" %d %d %d\n",*(i+a),i[a],*p);
        }
        return 0;
}
```

Output

1 1 1 1 1
2 2 2 2 2
3 3 3 3 3
4 4 4 4 4
5 5 5 5 5

Passing Pointers to a Function

- Pointers are often passed to a function as arguments.
  - ***Allows*** data items within the calling program ***to be accessed*** by the function, ***altered***, and then ***returned*** to the calling program ***in altered form***.
  - Called call-by-pointers (or pass-by-pointers).

- Normally, arguments are passed to a function by value.
  - The data items are copied to the function.
  - Changes are not reflected in the calling program.

Example: Swapping two numbers


```
void swap(int *a, int *b)
{
        int temp = *a;
        *a = *b;
        *b = temp;
}
```

```
void swap(int a, int b)
{
        int temp = a;
        a = b;
        b = temp;
}
```

```
int main( )
{
        int i, j;
        scanf("%d %d", &i, &j);
        printf("Before swap: i=%d j=%d\n",i,j);
        swap(&i,&j);
        printf("After swap: i=%d j=%d",i,j);
}
```

Passing Arrays to a Function

- An array name can be used as an argument to a function.
  - Permits the entire array to be passed to the function.
  - Array name is passed as the parameter, which is effectively the address of the first element.

- Rules:
  - The array name must appear by itself as argument, without brackets or subscripts.
  - The corresponding formal argument is written in the same manner.
    - Declared by writing the array name with a pair of empty brackets.
    - Dimension or required number of elements to be passed as a separate parameter.

Example: Function to find average


```
#include <stdio.h>
int main()
{
          int x[100], k, n ;
          scanf ("%d", &n) ;
          for (k=0; k<n; k++)
                    scanf ("%d", &x[k]) ;
          printf ("\nAverage is %f", avg (x, n));
          return 0;
}
```

```
float avg (int array[ ],int size)
{
          int *p, i , sum = 0;
          p = array ;
          for (i=0; i<size; i++)
                    sum = sum + *(p+i);
          return ((float) sum / size);
}
```

int *array

p[i]

Questions?