Pointers

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Introduction

- A pointer is a variable that represents the location (rather than the value) of a data item.
- They have a number of useful applications.
  - Enables us to access a variable that is defined outside the function.
  - Can be used to pass information back and forth between a function and its reference point.
  - More efficient in handling data tables.
  - Reduces the length and complexity of a program.
  - Sometimes also increases the execution speed.

Basic Concept

- Within the computer memory, 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, double, etc.).
- Whenever we declare a variable, the system allocates memory location(s) to hold the value of the variable.
  - Since every byte in memory has a unique address, this location will also have its own (unique) address.

Basic Concept

- Consider the statement

  int A = 10;

  – This statement instructs the compiler to allocate a location for the integer variable A and put the value 10 in that location.

  – Suppose that the address location chosen is 1000.

A	→	**variable**
10	→	**value**
1000	→	**address**

Basic Concept

- During execution of the program, the system always associates the name A with the address 1000.
  - The value 10 can be accessed by using either the name A or the address 1000.
- Since memory addresses are simply numbers, they can be assigned to some variables which can be stored in memory.
  - Such variables that hold memory addresses are called pointers.
  - Since a pointer is a variable, its value is also stored in some memory location.

Basic Concept

- Suppose we assign the address of A to a variable p.
  - p is said to point to the variable A.

Variable	Value	Address
A	10	1000
p	1000	2000

p = &A;

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:

  p = &A;
  - The address of A (1000) is assigned to p.
- The '&' operator can be used only with a simple variable or an array element.

  &distance

  &x[0]

  &x[i-2]

Example

```
#include  <stdio.h>
main()
{
   int   a;
   float  b, c;
   double  d;
   char  ch;

   a = 10;   b = 2.5;  c = 12.36;  d = 12345.66;  ch = 'A';
   printf  ("%d is stored in location %u \n",  a,  &a) ;
   printf  ("%f is stored in location %u \n",  b,  &b) ;
   printf  ("%f is stored in location %u \n",  c,  &c) ;
   printf  ("%ld is stored in location %u \n",  d,  &d) ;
   printf  ("%c is stored in location %u \n",  ch,  &ch) ;
}
```

Example

Output:

10 is stored in location 3221224908 a
2.500000 is stored in location 3221224904 b
12.360000 is stored in location 3221224900 c
12345.660000 is stored in location 3221224892 d
A is stored in location 3221224891 ch

Incidentally variables a, b, c, d and ch are allocated to contiguous memory locations.

Pointer Declarations

- Pointer variables must be declared before we use them.
- General form:

```
data_type   *pointer_name;
```

Three things are specified in the above declaration:

1. The asterisk (*) tells that the variable pointer_name is a pointer variable.
2. pointer_name needs a memory location.
3. pointer_name points to a variable of type data_type.

Pointer Declarations

- Example:

```
int     *count;
float  *speed;
```

- Once a pointer variable has been declared, it can be made to point to a variable using an assignment statement like:

```
int      *p,  xyz;
:
p = &xyz;
```

  – This is called pointer initialization.

Things to Remember

- Pointer variables must always point to a data item of the *same type*.

```
float   x;
int    *p;
:
p = &x;
```

➔ will result in erroneous output

- Assigning an absolute address to a pointer variable is prohibited.

```
int   *count;
:
count = 1268;
```

Accessing a Variable Through its Pointer

- **Once a pointer has been assigned the address of a variable, the value of the variable can be accessed using the indirection operator (*).**

```
int   a, b;
int   *p;
:
p = &a;
b = *p;
```

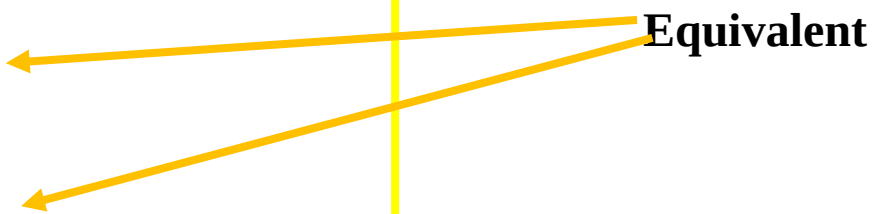
b = a

Example 1

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

   a  =  4  *  (c  +  5) ;

   p  =  &c;
   b  =  4  *  (*p  +  5) ;
   printf  (“a=%d  b=%d \n”,  a, b) ;
}
```



Example 2

```
#include  <stdio.h>
main()
{
   int  x, y;
   int  *ptr;

   x = 10 ;
   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  ("%d is stored in location %u \n",  y,  &*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);
}
```

*&x⇔x

ptr=&x;
&x⇔&*ptr

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Example 2

Output:

10 is stored in location 3221224908
10 is stored in location 3221224908
10 is stored in location 3221224908
10 is stored in location 3221224908
3221224908 is stored in location 3221224900
10 is stored in location 3221224904

Now x = 25

Address of x: 3221224908

Address of y: 3221224904

Address of ptr: 3221224900

Pointer Expressions

- Like other variables, pointer variables can be used in expressions.
- If p1 and p2 are two pointers, the following statements are valid:

```
sum  = *p1 + *p2 ;
prod = *p1 * *p2 ;
prod =  (*p1) * (*p2) ;
*p1 = *p1 + 2;
x = *p1 / *p2 + 5 ;
```

Pointer Expressions

- **What are allowed in C?**
  - **Add an integer to a pointer.**
  - **Subtract an integer from a pointer.**
  - **Subtract one pointer from another (related).**
    - **If p1 and p2 are both pointers to the same array, them p2–p1 gives the number of elements between p1 and p2.**
- **What are not allowed?**
  - **Add two pointers.**

```
p1 = p1 + p2 ;
```

  - **Multiply / divide a pointer in an expression.**

```
p1 = p2 / 5 ;
p1 = p1 – p2 * 10 ;
```

Scale Factor

- We have seen that an integer value can be added to or subtracted from a pointer variable.

```
int   *p1,  *p2 ;
int   i,  j;
:
p1  =  p1  +  1 ;
p2  =  p1  +  j ;
p2++ ;
p2  =  p2  –  (i + j) ;
```

- In reality, it is not the integer value which is added/subtracted, but rather the scale factor times the value.

Scale Factor

Data Type	Scale Factor
char	1
int	4
float	4
double	8

– If p1 is an integer pointer, then

p1++

will increment the value of p1 by 4.

Example: to find the scale factors

```
#include  <stdio.h>
main()
{
   printf ("Number of bytes occupied by int is %d \n", sizeof(int));
   printf ("Number of bytes occupied by float is %d \n", sizeof(float));
   printf ("Number of bytes occupied by double is %d \n", sizeof(double));
   printf ("Number of bytes occupied by char is %d \n", sizeof(char));
}
```

Returns no. of bytes required for data type representation

Output:

```
Number of bytes occupied by int is  4
Number of bytes occupied by float is  4
Number of bytes occupied by double is  8
Number of bytes occupied by char is  1
```

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-reference (or by address or by location).
- 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: passing arguments by value

```
#include  <stdio.h>
main()
{
      int  a, b;
      a = 5 ;   b = 20 ;
      swap (a, b) ;
      printf  ("\n a = %d,  b = %d", a, b);
}

void   swap  (int  x, int  y)
{
      int  t ;
      t = x ;
      x = y ;
      y = t ;
}
```

a and b do not swap

x and y swap

Output
a = 5, b = 20

Example: passing arguments by reference

```
#include  <stdio.h>
main()
{
      int  a, b;
      a = 5 ;   b = 20 ;
      swap (&a, &b) ;
      printf  ("\n a = %d,  b = %d", a, b);
}

void   swap  (int  *x, int  *y)
{
      int  t ;
      t = *x ;
      *x = *y ;
      *y = t ;
}
```

***(&a) and *(&b) swap**

***x and *y swap**

Output

a = 20, b = 5

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Example: Sort 3 integers

- Three-step algorithm:
  1. Read in three integers x, y and z
  2. Put smallest in x
     - Swap x, y if necessary; then swap x, z if necessary.
  3. Put second smallest in y
     - Swap y, z if necessary.

Example: Sort 3 integers

```
#include  <stdio.h>
main()
{
      int  x, y, z ;
      ……..
      scanf  (“%d %d %d”, &x, &y, &z) ;
      if  (x > y)   swap (&x, &y);
      if  (x > z)   swap (&x, &z);
      if  (y > z)   swap (&y, &z) ;
      ……..
}
```

sort3 as a function

```
#include  <stdio.h>
main()
{
     int  x, y, z ;
     ……..
     scanf  (“%d %d %d”, &x, &y, &z) ;
     sort3  (&x, &y, &z) ;
     ……..
}

void   sort3  (int *xp,  int *yp,  int *zp)
{
     if  (*xp > *yp)   swap (xp, yp);
     if  (*xp > *zp)   swap (xp, zp);
     if  (*yp > *zp)   swap (yp, zp);
}
```

xp/yp/zp are pointers

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.

Example

- Consider the declaration:

  int x[5] = {1, 2, 3, 4, 5} ;

  – Suppose that the base address of x is 2500, and each integer requires 4 bytes.

Element	Value	Address
x[0]	1	2500
x[1]	2	2504
x[2]	3	2508
x[3]	4	2512
x[4]	5	2516

Example

x ⇔ &x[0] ⇔ 2500 ;

- p = x; and p = &x[0]; are equivalent.
- We can access successive values of x by using p++ or p- - to move from one element to another.

- Relationship between p and x:

p = &x[0] = 2500
p+1 = &x[1] = 2504
p+2 = &x[2] = 2508
p+3 = &x[3] = 2512
p+4 = &x[4] = 2516

***(p+i) gives the value of x[i]**

Example: Function to find average

```
#include  <stdio.h>
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));
}
```

int *array

```
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);
}
```

p[i]

Thank You

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