

Software Engineering 2

(C++)

CSY2006
(Week 6)

Pointers

Why? Benefits?

See NILE → Useful Resources → Benefits of Pointers

Benefits of Using Pointers

- Pointers can handle arrays and data table efficiently.
- Pointers support dynamic memory management.
- Pointer helps to return multiple values from a function through function argument.
- Pointer increases program execution speed.
- Pointer is an efficient tool for manipulating structures, linked lists, queues, stacks etc.
- Pointers permit references to functions and thereby facilitating passing of functions as arguments to other functions.

Benefits of Using Pointers(contd.)

- The use of pointer arrays for character strings results in saving of data storage space in memory.
- Provides an alternate way to access array elements.
- Pointers can implement sharing without copying.
- Pointers can simulate Call by Reference.
- Pointers allow modifications by a function that is not the creator of the memory i.e. function A can allocate the memory and function C can modify it, without using global variables.
- Control tables used to control program flow, usually make extensive use of pointers.

Disadvantages of Pointers

- If a pointer contains an incorrect value it can lead to memory corruption and huge disasters.
- Pointers can lead to memory leaks.
- A dereferenced null pointer can cause a program to crash.
- A memory overrun (or "buffer overflow") occurs when memory allocated by a pointer is not large enough for the input it receives.
- Pointers are confusing to learn for programmers.
- Debugging programs using pointers is difficult.

Getting the Address of a Variable

- Each variable in program is stored at a unique address
- Use address operator `&` to get address of a variable:

```
int num = -99;  
cout << &num; // prints address  
               // in hexadecimal
```

Pointer Variables

Pointer Variables

- Pointer variable : Often just called a pointer, it's a variable that holds an address
- Because a pointer variable holds the address of another piece of data, it "points" to the data

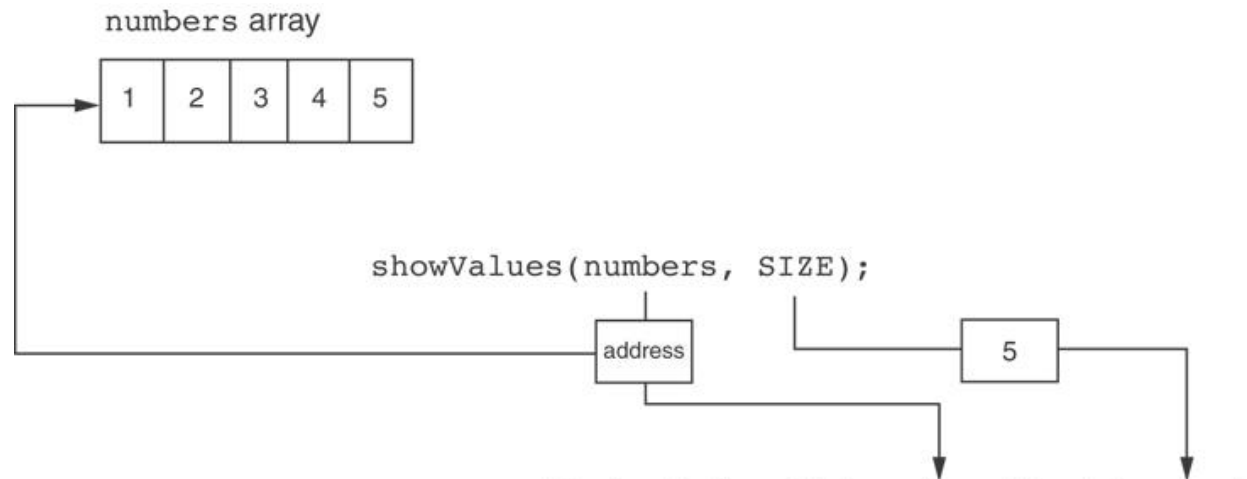
Something Like Pointers: Arrays

- We have already worked with something similar to pointers, when we learned to pass arrays as arguments to functions.
- For example, suppose we use this statement to pass the array `numbers` to the `showValues` function:

```
showValues (numbers, SIZE) ;
```

Something Like Pointers : Arrays

The `values` parameter, in the `showValues` function, points to the `numbers` array.



C++ automatically stores the address of `numbers` in the `values` parameter.

Something Like Pointers: Reference Variables

- We have also worked with something like pointers when we learned to use reference variables. Suppose we have this function:

```
void getOrder(int &donuts)
{
    cout << "How many doughnuts do you want? ";
    cin >> donuts;
}
```

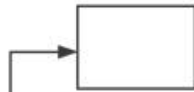
- And we call it with this code:

```
int jellyDonuts;
getOrder(jellyDonuts);
```

Something Like Pointers: Reference Variables

The donuts parameter, in the getOrder function, points to the jellyDonuts variable.

jellyDonuts variable



`getOrder(jellyDonuts);`

address

```
void getOrder(int &donuts)
{
    cout << "How many doughnuts do you want? ";
    cin >> donuts;
}
```

C++ automatically stores
the address of
jellyDonuts in the
donuts parameter.

Pointer Variables

- Pointer variables are yet another way using a memory address to work with a piece of data.
- Pointers are more "low-level" than arrays and reference variables.
- This means you are responsible for finding the address you want to store in the pointer and correctly using it.

Pointer Variables

- Definition:

```
int *intptr;
```

- Read as:

“intptr can hold the address of an int”

- Spacing in definition does not matter:

```
int * intptr;    // same as above
```

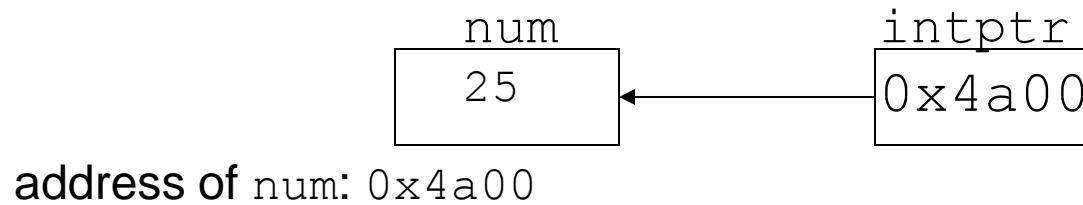
```
int*  intptr;    // same as above
```

Pointer Variables

- Assigning an address to a pointer variable:

```
int *intptr;  
intptr = &num;
```

- Memory layout:



Program 9-2

```
1  // This program stores the address of a variable in a pointer.
2  #include <iostream>
3  using namespace std;
4
5  int main()
6  {
7      int x = 25;      // int variable
8      int *ptr;        // Pointer variable, can point to an int
9
10     ptr = &x;        // Store the address of x in ptr
11     cout << "The value in x is " << x << endl;
12     cout << "The address of x is " << ptr << endl;
13     return 0;
14 }
```

Program Output

The value in x is 25

The address of x is 0x7e00

The Indirection Operator

- The indirection operator (*) dereferences a pointer.
- It allows you to access the item that the pointer points to.

```
int x = 25;  
int *intptr = &x;  
cout << *intptr << endl;
```



This prints 25.

Program 9-3

```
1 // This program demonstrates the use of the indirection operator.
2 #include <iostream>
3 using namespace std;
4
5 int main()
6 {
7     int x = 25;    // int variable
8     int *ptr;      // Pointer variable, can point to an int
9
10    ptr = &x;       // Store the address of x in ptr
11
12    // Use both x and ptr to display the value in x.
13    cout << "Here is the value in x, printed twice:\n";
14    cout << x << endl;    // Displays the contents of x
15    cout << *ptr << endl; // Displays the contents of x
16
17    // Assign 100 to the location pointed to by ptr. This
18    // will actually assign 100 to x.
19    *ptr = 100;
20
21    // Use both x and ptr to display the value in x.
22    cout << "Once again, here is the value in x:\n";
23    cout << x << endl;    // Displays the contents of x
24    cout << *ptr << endl; // Displays the contents of x
25    return 0;
26 }
```

Program 9-3 *(continued)*

Program Output

Here is the value in x, printed twice:

25

25

Once again, here is the value in x:

100

100

The Relationship Between Arrays and Pointers

The Relationship Between Arrays and Pointers

- Array name is starting address of array

```
int vals[] = {4, 7, 11};
```

4	7	11
---	---	----

starting address of `vals`: 0x4a00

```
cout << vals;           // displays
```

```
                        // 0x4a00
```

```
cout << vals[0];        // displays 4
```

The Relationship Between Arrays and Pointers

- Array name can be used as a pointer constant:

```
int vals[] = {4, 7, 11};  
cout << *vals;      // displays 4
```

- Pointer can be used as an array name:

```
int *valptr = vals;  
cout << valptr[1]; // displays 7
```

Program 9-5

```
1  // This program shows an array name being dereferenced with the *
2  // operator.
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8      short numbers[] = {10, 20, 30, 40, 50};
9
10     cout << "The first element of the array is ";
11     cout << *numbers << endl;
12     return 0;
13 }
```

Program Output

The first element of the array is 10

Pointers in Expressions

Given:

```
int vals[]={4,7,11}, *valptr;  
valptr = vals;
```

What is `valptr + 1`? It means (address in
`valptr`) + (1 * size of an int)

```
cout << *(valptr+1); //displays 7  
cout << *(valptr+2); //displays 11
```

Must use () as shown in the expressions

Array Access

- Array elements can be accessed in many ways:

Array access method	Example
array name and []	<code>vals[2] = 17;</code>
pointer to array and []	<code>valptr[2] = 17;</code>
array name and subscript arithmetic	<code>*(vals + 2) = 17;</code>
pointer to array and subscript arithmetic	<code>*(valptr + 2) = 17;</code>

Array Access

- Conversion: `vals[i]` is equivalent to `*(vals + i)`
- No bounds checking performed on array access, whether using array name or a pointer

From Program 9-7

```
9      const int NUM_COINS = 5;
10     double coins[NUM_COINS] = {0.05, 0.1, 0.25, 0.5, 1.0};
11     double *doublePtr;    // Pointer to a double
12     int count;            // Array index
13
14     // Assign the address of the coins array to doublePtr.
15     doublePtr = coins;
16
17     // Display the contents of the coins array. Use subscripts
18     // with the pointer!
19     cout << "Here are the values in the coins array:\n";
20     for (count = 0; count < NUM_COINS; count++)
21         cout << doublePtr[count] << " ";
22
23     // Display the contents of the array again, but this time
24     // use pointer notation with the array name!
25     cout << "\nAnd here they are again:\n";
26     for (count = 0; count < NUM_COINS; count++)
27         cout << *(coins + count) << " ";
28     cout << endl;
```

Program Output

```
Here are the values in the coins array:
0.05 0.1 0.25 0.5 1
And here they are again:
0.05 0.1 0.25 0.5 1
```

Pointer Arithmetic

Pointer Arithmetic

- Operations on pointer variables:

Operation	Example
	<pre>int vals[]={4,7,11}; int *valptr = vals;</pre>
<code>++, --</code>	<pre>valptr++; // points at 7 valptr--; // now points at 4</pre>
<code>+, - (pointer and int)</code>	<pre>cout << *(valptr + 2); // 11</pre>
<code>+=, -= (pointer and int)</code>	<pre>valptr = vals; // points at 4 valptr += 2; // points at 11</pre>
<code>- (pointer from pointer)</code>	<pre>cout << valptr-val; // difference // (number of ints) between valptr // and val</pre>

From Program 9-9

```
7     const int SIZE = 8;
8     int set[SIZE] = {5, 10, 15, 20, 25, 30, 35, 40};
9     int *numPtr;    // Pointer
10    int count;      // Counter variable for loops
11
12    // Make numPtr point to the set array.
13    numPtr = set;
14
15    // Use the pointer to display the array contents.
16    cout << "The numbers in set are:\n";
17    for (count = 0; count < SIZE; count++)
18    {
19        cout << *numPtr << " ";
20        numPtr++;
21    }
22
23    // Display the array contents in reverse order.
24    cout << "\nThe numbers in set backward are:\n";
25    for (count = 0; count < SIZE; count++)
26    {
27        numPtr--;
28        cout << *numPtr << " ";
29    }
```

Program Output

```
The numbers in set are:
5 10 15 20 25 30 35 40
The numbers in set backward are:
40 35 30 25 20 15 10 5
```

Initializing Pointers

Initializing Pointers

- Can initialize at definition time:

```
int num, *numptr = &num;  
int val[3], *valptr = val;
```

- Cannot mix data types:

```
double cost;  
int *ptr = &cost; // won't work
```

- Can test for an invalid address for `ptr` with:

```
if (!ptr) ...
```


Comparing Pointers

Comparing Pointers

- Relational operators (<, >=, etc.) can be used to compare addresses in pointers
- Comparing addresses in pointers is not the same as comparing contents pointed at by pointers:

```
if (ptr1 == ptr2)    // compares
                     // addresses
if (*ptr1 == *ptr2)  // compares
                     // contents
```

Pointers as Function Parameters

Pointers as Function Parameters

- A pointer can be a parameter
- Works like reference variable to allow change to argument from within function
- Requires:
 - 1) asterisk * on parameter in prototype and heading
`void getNum(int *ptr); // ptr is pointer to an int`
 - 2) asterisk * in body to dereference the pointer
`cin >> *ptr;`
 - 3) address as argument to the function
`getNum(&num); // pass address of num to getNum`

Example

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

```
int num1 = 2, num2 = -3;
swap(&num1, &num2);
```

Program 9-11

```
1  // This program uses two functions that accept addresses of
2  // variables as arguments.
3  #include <iostream>
4  using namespace std;
5
6  // Function prototypes
7  void getNumber(int *);
8  void doubleValue(int *);
9
10 int main()
11 {
12     int number;
13
14     // Call getNumber and pass the address of number.
15     getNumber(&number);
16
17     // Call doubleValue and pass the address of number.
18     doubleValue(&number);
19
20     // Display the value in number.
21     cout << "That value doubled is " << number << endl;
22     return 0;
23 }
24
```

(Program Continues)

Program 9-11 *(continued)*

```
25  //*****
26  // Definition of getNumber. The parameter, input, is a pointer. *
27  // This function asks the user for a number. The value entered  *
28  // is stored in the variable pointed to by input.                *
29  //*****
30
31  void getNumber(int *input)
32  {
33      cout << "Enter an integer number: ";
34      cin >> *input;
35  }
36
37  //*****
38  // Definition of doubleValue. The parameter, val, is a pointer. *
39  // This function multiplies the variable pointed to by val by    *
40  // two.                                                            *
41  //*****
42
43  void doubleValue(int *val)
44  {
45      *val *= 2;
46  }
```

Program Output with Example Input Shown in Bold

Enter an integer number: **10** [Enter]
That value doubled is 20

Pointers to Constants

- If we want to store the address of a constant in a pointer, then we need to store it in a pointer-to-const.

Pointers to Constants

- Example: Suppose we have the following definitions:

```
const int SIZE = 6;  
const double payRates[SIZE] =  
    { 18.55, 17.45, 12.85,  
      14.97, 10.35, 18.89 };
```

- In this code, `payRates` is an array of constant doubles.

Pointers to Constants

- Suppose we wish to pass the `payRates` array to a function? Here's an example of how we can do it.

```
void displayPayRates(const double *rates, int size)
{
    for (int count = 0; count < size; count++)
    {
        cout << "Pay rate for employee " << (count + 1)
              << " is $" << *(rates + count) << endl;
    }
}
```

The parameter, `rates`, is a pointer to `const double`.

Declaration of a Pointer to Constant

The asterisk indicates that
rates is a pointer.

`const double *rates`

This is what rates points to.

Constant Pointers

- A constant pointer is a pointer that is initialized with an address, and cannot point to anything else.
- Example

```
int value = 22;  
int * const ptr = &value;
```

Constant Pointers

* const indicates that
ptr is a constant pointer.

`int * const ptr`

This is what ptr points to.

Constant Pointers to Constants

- A constant pointer to a constant is:
 - a pointer that points to a constant
 - a pointer that cannot point to anything except what it is pointing to
- Example:

```
int value = 22;  
const int * const ptr = &value;
```

Constant Pointers to Constants

* const indicates that
ptr is a constant pointer.

`const int` * `const ptr`

This is what ptr points to.

Dynamic Memory Allocation

Dynamic Memory Allocation

- Can allocate storage for a variable while program is running
- Computer returns address of newly allocated variable
- Uses `new` operator to allocate memory:

```
double *dptr;  
dptr = new double;
```
- `new` returns address of memory location

Dynamic Memory Allocation

- Can also use `new` to allocate array:

```
const int SIZE = 25;  
arrayPtr = new double[SIZE];
```

- Can then use `[]` or pointer arithmetic to access array:

```
for(i = 0; i < SIZE; i++)  
    *arrayptr[i] = i * i;
```

or

```
for(i = 0; i < SIZE; i++)  
    *(arrayptr + i) = i * i;
```

- Program will terminate if not enough memory available to allocate

Releasing Dynamic Memory

- Use `delete` to free dynamic memory:
`delete fptr;`
- Use `[]` to free dynamic array:
`delete [] arrayptr;`
- Only use `delete` with dynamic memory!

Program 9-14

```
1  // This program totals and averages the sales figures for any
2  // number of days. The figures are stored in a dynamically
3  // allocated array.
4  #include <iostream>
5  #include <iomanip>
6  using namespace std;
7
8  int main()
9  {
10     double *sales,      // To dynamically allocate an array
11           total = 0.0,  // Accumulator
12           average;      // To hold average sales
```

Program 9-14 *(continued)*

```
13      int numDays,          // To hold the number of days of sales
14          count;           // Counter variable
15
16      // Get the number of days of sales.
17      cout << "How many days of sales figures do you wish ";
18      cout << "to process? ";
19      cin >> numDays;
20
21      // Dynamically allocate an array large enough to hold
22      // that many days of sales amounts.
23      sales = new double[numDays];
24
25      // Get the sales figures for each day.
26      cout << "Enter the sales figures below.\n";
27      for (count = 0; count < numDays; count++)
28      {
29          cout << "Day " << (count + 1) << ": ";
30          cin >> sales[count];
31      }
32
```

Program 9-14 (Continued)

```
33     // Calculate the total sales
34     for (count = 0; count < numDays; count++)
35     {
36         total += sales[count];
37     }
38
39     // Calculate the average sales per day
40     average = total / numDays;
41
42     // Display the results
43     cout << fixed << showpoint << setprecision(2);
44     cout << "\n\nTotal Sales: $" << total << endl;
45     cout << "Average Sales: $" << average << endl;
46
47     // Free dynamically allocated memory
48     delete [] sales;
49     sales = 0;          // Make sales point to null.
50
51     return 0;
52 }
```

Program Output with Example Input Shown in Bold

How many days of sales figures do you wish to process? **5 [Enter]**

Enter the sales figures below.

Day 1: **898.63 [Enter]**

Day 2: **652.32 [Enter]**

Day 3: **741.85 [Enter]**

Day 4: **852.96 [Enter]**

Day 5: **921.37 [Enter]**

Total Sales: \$4067.13

Average Sales: \$813.43

Notice that in line 49 the value 0 is assigned to the `sales` pointer. It is a good practice to store 0 in a pointer variable after using `delete` on it. First, it prevents code from inadvertently using the pointer to access the area of memory that was freed. Second, it prevents errors from occurring if `delete` is accidentally called on the pointer again. The `delete` operator is designed to have no effect when used on a null pointer.

Returning Pointers from Functions

Returning Pointers from Functions

- Pointer can be the return type of a function:

```
int* newNum();
```

- The function must not return a pointer to a local variable in the function.
- A function should only return a pointer:
 - to data that was passed to the function as an argument, or
 - to dynamically allocated memory

From Program 9-15

```
34 int *getRandomNumbers(int num)
35 {
36     int *array;    // Array to hold the numbers
37
38     // Return null if num is zero or negative.
39     if (num <= 0)
40         return NULL;
41
42     // Dynamically allocate the array.
43     array = new int[num];
44
45     // Seed the random number generator by passing
46     // the return value of time(0) to srand.
47     srand( time(0) );
48
49     // Populate the array with random numbers.
50     for (int count = 0; count < num; count++)
51         array[count] = rand();
52
53     // Return a pointer to the array.
54     return array;
55 }
```