Arrays

Unit 5
Gaddis: 7.1-3,5
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Array Data Type

- **Array**: a variable that contains multiple values of the same type.
- Values are stored consecutively in memory.
- An array variable declaration statement in C++:
  ```
  int numbers[5];
  ```
- This creates an array called *numbers* which contains 5 integer values (ints).

Array - Memory Layout

- The definition: `int numbers[5];`
- Allocates the following memory:
  (values are stored consecutively in memory)
- `first` `second` `third` `fourth` `fifth`
- `element` `element` `element` `element` `element`

Array Terminology

- Given the following array definition:
  ```
  int numbers[5];
  ```
- *numbers* is the **name** of the array
- `int` is the data type of the array **elements**
- 5 is the **size declarator**: the number of elements (values) in the array.
Size Declarator

• The size declarator must be an integer and a constant.
  ‣ it must be greater than 0
  ‣ IT CANNOT BE A VARIABLE!
• It can be a literal or a named constant.
  
  ```
  const int SIZE = 40;
  double grades[SIZE];
  ```
• Named constants ease program maintenance when the size of the array must be changed.
  
  *Unless you are using a special compiler (mine is not special).*

7.2 Accessing Array Elements

• Each element of the array has a unique subscript (or index) that indicates its position in the array.
• The subscripts are 0-based
  ‣ the first element has subscript 0
  ‣ the second element has subscript 1
  ‣ . . .
  ‣ the last element has subscript (size -1)
  
  the last element’s subscript is n-1 where n is the number of elements in the array

Accessing Array Elements

• Given this array declaration: int numbers[5];
• The syntax to access one element is:
  ```
  numbers[2] //the third element of numbers array
  ```
• Pronounced “numbers at 2” or “numbers sub 2”

Array subscripts

• The subscript is ALWAYS an integer
  ‣ regardless of the type of the array elements.
• the subscript can be ANY integer expression
  ‣ literal: 2
  ‣ variable: i
  ‣ expression: (i+2)/2
  ```
  numbers[2]  numbers[i]  numbers[(i+2)/2]
  ```
Inputting array contents

• Most array operations must be done **one element at a time**.
• Input programming assignment grades for a student in CS1428:

```cpp
const int NUM_SCORES = 7;
int scores[NUM_SCORES];
cout << "Enter the " << NUM_SCORES << " programming assignment scores: " << endl;
cin >> scores[0];
cin >> scores[1];
cin >> scores[2];
cin >> scores[3];
cin >> scores[4];
cin >> scores[5];
cin >> scores[6];
```

• Is there a better way?

Array input using a loop

• We can use a for loop to **input** into the array
• The subscript/index can be the loop variable:

```cpp
const int NUM_SCORES = 7;
int scores[NUM_SCORES];
cout << "Enter the " << NUM_SCORES << " programming assignment scores: " << endl;
for (int i=0; i < NUM_SCORES; i++) {
    cin >> scores[i];
}
```

• i starts at 0, the first valid subscript
• loop ends when i is 7, the first invalid subscript
• This code is equivalent to the code on the previous slide.

Array output using a loop

• We can also use a for loop to **output** the elements of the array:

```cpp
const int NUM_SCORES = 7;
int scores[NUM_SCORES];
cout << "Enter the " << NUM_SCORES << " programming assignment scores: " << endl;
for (int i=0; i < NUM_SCORES; i++) {
    cin >> scores[i];
}
cout << "You entered these values: ";
for (int i=0; i < NUM_SCORES; i++) {
    cout << scores[i] << " ";
}
cout << endl;
```

Array initialization

• You can initialize arrays when they are defined.

```cpp
const int NUM_SCORES = 3;
float scores[NUM_SCORES] = {86.5, 92.1, 77.5};
```

• Values are assigned in order:

```cpp
scores[0] = 86.5
scores[1] = 92.1
scores[2] = 77.5
```

• **NOTE**: uninitialized arrays have **GARBAGE** values stored in them (not necessarily 0).
Partial Array Initialization

- When you initialize, you don’t need to specify a value for every position.

```c
float scores[7] = {86.5, 92.1, 77.5};
```

- In this case, the first 3 elements are initialized to the specified values.
- The uninitialized values WILL be set to 0!!!!

```
| 86.5 | 92.1 | 77.5 | 0   | 0   | 0   | 0   |
```

Implicit array sizing

- When you initialize, you don’t need to specify the size declarator.

```c
float scores[] = {86.5, 92.1, 77.5};
```

- In this case, the compiler determines the size of the array from the number of elements listed.

```
| 86.5 | 92.1 | 77.5 |
```

7.3 C++: No bounds checking

- C++ does not check it to make sure an array subscript is valid (between 0 and size-1)
- If you use a subscript that is outside the bounds of the array you **may not** get a warning or error.
- You may unintentionally change memory allocated to other variables.

```c
const int SIZE = 3;
int values[SIZE];
for (int i=0; i < 5; i++) {
    values[i] = 100;
}
```

This code defines a three-element array and then writes five values to it (changing the memory after the array).

7.5 Processing Array Contents

- Given the following array definition:

  ```c
double tests[10];
  ```

  the expression `tests[i]` may be used exactly like **any** variable of type double.

  ```c
tests[0] = 79;
cout << tests[0];
cin >> tests[1];
tests[4] = tests[0] + tests[1];
```
Using array elements:

double values[3]; //array definition
values[0] = 22.3; //assignment to array element
values[1] = 11.1;

cout << "Enter a number: ";
cin >> values[2];

double sum = values[0] + values[1] + values[2];
double avg = sum/3.0;

cout << "Values at zero: " << values[0] << endl;

int i=2;
if (values[i] > 32.0)
cout << "Above freezing" << endl;

Operations over Entire Arrays

• Generally there are NO operations that you can perform over an entire array.
• Some operations may appear to work (no errors) but you don’t get the desired results.

int numbers1[] = {1, 2, 3};
int numbers2[] = {4, 5, 6};

cin >> numbers1; //input, won’t work
cout << numbers1 << endl; //output, won’t work
numbers1 = numbers2; //assignment, won’t work
if (numbers1==numbers2) //comparison, won’t work
...
numbers3 = numbers1 + numbers2; //addition, won’t work

Summing values in an array

• We can use a for loop to sum the elements of the array (the running total)

const int NUM_SCORES = 7;
int scores[NUM_SCORES];
cout << "Enter the " << NUM_SCORES " programming assignment scores: " << endl;
for (int i=0; i < NUM_SCORES; i++) {
cin >> scores[i];
}

int total = 0; //initialize accumulator
for (int i=0; i < NUM_SCORES; i++) {
total = total + scores[i];
}

Finding the maximum value in an array

• We can use a for loop to find the max value:
• Note: keep track of the maximum value encountered so far (the running maximum)

const int NUM_SCORES = 7;
int scores[NUM_SCORES];
cout << "Enter the " << NUM_SCORES " programming assignment scores: " << endl;
for (int i=0; i < NUM_SCORES; i++) {
cin >> scores[i];
}

int maximum = scores[0]; //init max to first elem
for (int i=1; i < NUM_SCORES; i++) {
if (scores[i] > maximum)
maximum = scores[i]; //save the new maximum
} // no else needed
Array assignment

• To **copy/assign** one array to another, you must assign element by element.

```c
const int SIZE = 4;
int values1[SIZE] = {100, 200, 300, 400};
int values2[SIZE];

// values2 = values1;  WRONG, won’t work correctly
for (int i = 0; i < SIZE; i++) {
    values2[i] = values1[i];
}
```

• Note: this also does not work:

```c
values2 = {3,6,9,27};
//only works for initialization
```