Week 8: Arrays

Gaddis: 7.1-4,6

CS 1428
Fall 2015

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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 definition statement in C++:

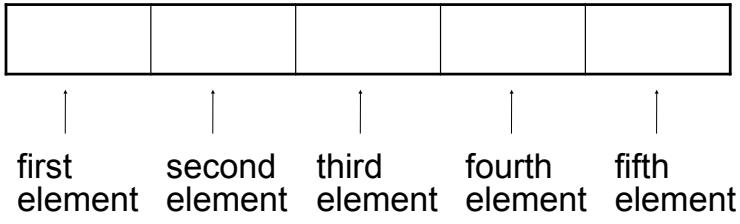
```
int numbers[5];
```

- 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)



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

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)

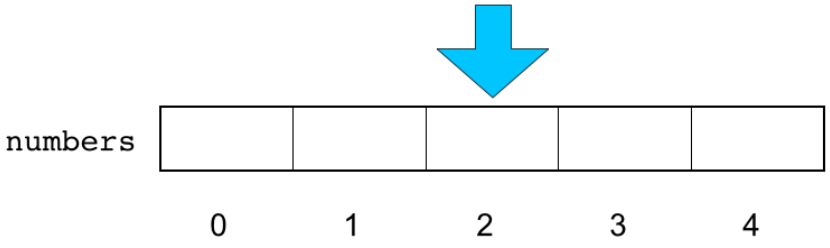
the last element's subscript is n-1 where n is the number of elements in the array

Accessing Array Elements

- Syntax to access one element:

```
numbers[2]  //the third element of numbers array
```

- Called "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 `numbers[2]`
  - variable: i `numbers[i]`
  - expression: (i+2)/2 `numbers[(i+2)/2]`

Array subscripts

- Given the following array definition:

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

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

```
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;
```


7.4 Array initialization

- You can initialize arrays when they are defined.

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

- Values are assigned in order:

  scores[0] = 86.5

  scores[1] = 92.1

  scores[2] = 77.5

- NOTE: uninitialized arrays have unknown values stored in them (not necessarily 0).

Implicit array sizing

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

```
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.

7.5 Processing Array Contents

- 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
```


Operations over arrays

- Most array operations must be done one element at a time.
- Input the 7 programming assignment grades for 1 student in CS1428:

```
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 a variable

```
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];
}
```


Array output using a loop

- We can use a for loop to **output** the elements of the array

```
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;
```


Q1

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];
}
```

How do you get the average programming assignment score?

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++) { //start i at 1
   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.

```
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];
}
```


Q2,3,4,5

Partially filled arrays

- The programmer does not always know ahead of time how many elements there will be in the array (i.e. reading from a file).
- If it is unknown how much data an array will be holding during a given execution of the program:
  - Make the array large enough to hold the largest expected number of elements.
  - Use a counter variable to keep track of the number of items currently stored in the array.
  - Change the counter when elements are added/removed.

Partially filled arrays

```
const int MAX_STUDENTS = 100;
int scores[MAX_STUDENTS];

ifstream infile;
infile.open("students.txt");

int count = 0;
while (count<MAX_STUDENTS && infile >> scores[count]){
   count++;
}

int total = 0;
for (int x = 0; x < count; x++)  //not MAX_STUDENTS
   total = total + scores[i];
```


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.

```
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).

Finding the maximum value in an array **and its position**

- Keep track of the minimum value, AND what its position is:

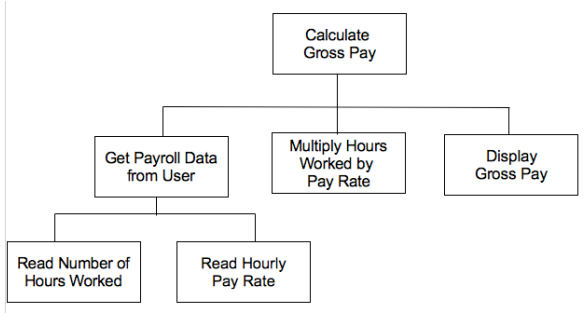
```
const int NUM_SCORES = 7;
int scores[NUM_SCORES];
// input code goes here

int indexOfMax = 0;   //init indexOfMax to first
int maximum = scores[0]; //init max to first elem
for (int i=1; i < NUM_SCORES; i++) { //start i at 1
   if (scores[i] > maximum) {
      maximum = scores[i];
      indexOfMax = i;
   }
}
cout << "The highest score was " << maximum
     << " and it was PA# " << indexOfMax+1
     << endl;
```


Top Down Design

- Design: plan the structure of your program before you write the code for it.
- Top Down Design process:
  - Break the main problem into a sequence of (about 5) smaller tasks.
  - Break each of the sub-tasks into a sequence of (about 5 or less) smaller tasks.
  - Soon, each of the tasks will be easy to code.
- Top down design usually results in a hierarchy chart that describes the tasks to be accomplished.

Top Down Design

- Problem: design a program to calculate an hourly worker's gross pay for one week (based on their hours and pay rate):



Incremental Development

- Do not attempt to write all the code for an entire program all at once.
- Implement a very small, but workable, part:
- Compile, fix syntax errors, test (run program over sample data), debug (fix code if test failed)
- Add another small part, refine the code.
- Compile + test again. Any new errors are (probably) due to newly added code.
- Repeat until complete.

This is how experienced programmers code.