CS161: Introduction to Computer Science I

Week 8 – Arrays

12/2020

What is in CS161 today?

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- **Arrays in C++**
  - Introduction
  - Declaring Arrays
  - Example of using Arrays
- **Strings**
  - What is a string in C++?
  - How can I define strings?
  - How can I read and write strings?
  - Comparing and copying strings
  - Accessing single characters in a string
  - Write a program with strings

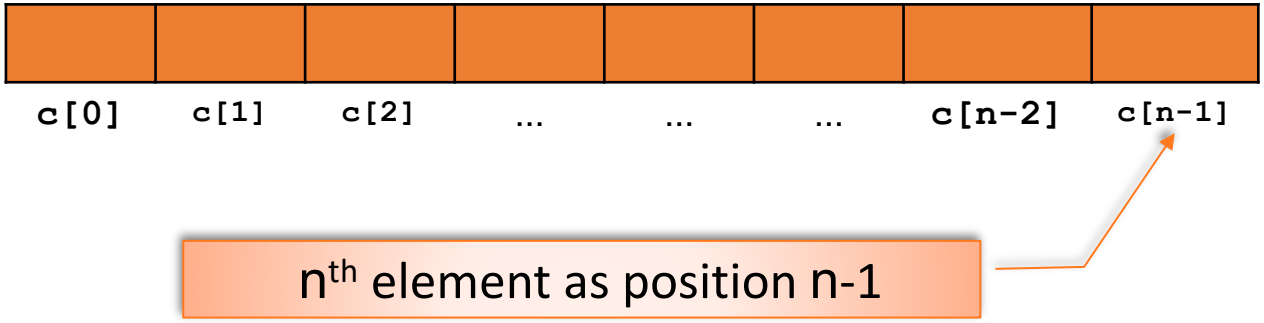
Introduction to Arrays

- Arrays
  - Structures of **related data items**
  - **Static entity** (same size throughout program)
- Array
  - Consecutive group of memory locations
  - Same name and type (`int`, `char`, etc.)

Introduction to Arrays

- To refer to an element
  - Specify array name and position number (index)
  - Format: `arrayname[position number]`
  - First element at position 0

- N-element array c



Introduction to Arrays

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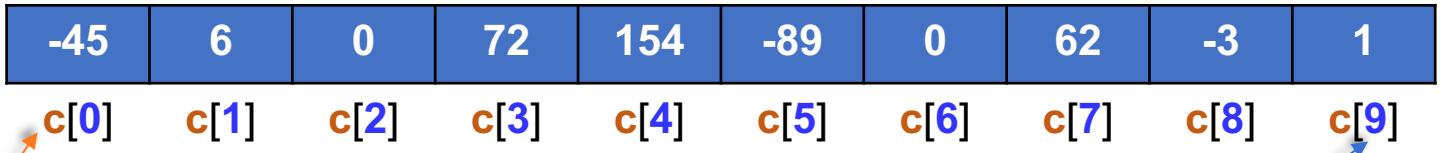
- Array elements like other variables
  - Assignment, printing for an integer array `c`

```
c[0] = 3;
cout << c[0];
```

- Can perform operations inside subscript

`c[5-2]` same as `c[3]`

Introduction to Arrays



Name of the array (note that all elements of this array have the same name, c)

Position number of the element within array c

Declaring Arrays

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- When declaring arrays, specify
  - Name
  - Type of array (Any data type)
  - Number of elements
  - `type arrayName[ arraySize ];`

```
int c[10];  // array of 10 integers
float d[3284]; // array of 3284 floats
```

- Declaring multiple arrays of same type
  - Use comma separated list, like regular variables

```
int b[100], x[27];
```

Declaring Arrays

- Initializing arrays: many ways
  1. `for` loop: set each element

```
for(int i=0; i<n; i++)
        c[i] = 0;
```

  2. Initializer list: Specify each element when array declared

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

→ If not enough initializers, rightmost elements 0

→ Listing too many will result in a syntax error

  3. To set every element to same value

```
int c[5] = { 0 };
```

  4. If array size omitted, initializers determine size

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

→ 5 initializers, therefore 5 element array

Declare & Initialize Arrays: Example

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```
// Initializing an array.
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
        int n[10];  // n is an array of 10 integers

        // initialize elements of array n to 0
        for (int i = 0; i < 10; ++i)
           n[i] = 0;   // set element at location i to 0

        cout << "Element" << setw(13) << "Value" << endl;

        // output contents of array n in tabular format
        for (int j = 0; j < 10; ++j)
           cout << setw(7) << j << setw(13) << n[j] << endl;
        return 0;
}//end main
```

Declare a 10-element array of integers.

Initialize array to **0** using a for loop. Note that the array has elements **n[0]** to **n[9]**.

Declare & Initialize Arrays: Example

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- Resulting Array:

Element	Value
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0

Declare & Initialize Arrays: Example

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```
// Initializing an array.
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
      // use initializer list to initialize array n
        int n[10] = { 32, 27, 64, 18, 95, 14, 90, 70, 60, 37
};

        cout << "Element" << setw(13) << "Value" << endl;

        // output contents of array n in tabular format
        for (int i = 0; i < 10; ++i)
           cout << setw(7) << i << setw(13) << n[i] << endl;
        return 0;
}//end main
```

Note the use of the initializer list.

Declare & Initialize Arrays: Example

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- Resulting Array:

Element	Value
0	32
1	27
2	64
3	18
4	95
5	14
6	90
7	70
8	60
9	37

Introduction to Strings

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- There is NO such thing as a string data type build into the language of C++
  - Although there is a string "class" that provides a standardized string type
- When I use the term "string" I mean some ***sequence of characters*** (such as a name, address, description, etc.)
- Strings are represented in C and C++ by arrays of characters
- We all know what a character is (a single byte), so what's an array of characters?
  - a sequence of character stored sequentially in memory

How do I define an Array of Characters?

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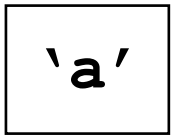
- We know how to define a single character:

```
char ch='a';
```



- But what about an array of characters?

```
char str[5];
```

- Since these are just characters stored sequentially in memory, we use a special character to indicate the end of a string: `'\0'`

How do I read in a string?

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- There are **two ways** to read in strings
- If the string is a sequence of characters without any whitespace, then you can say:

```
cin >> str;
```

- If I enter "hi", this is what is stored:

'h'	'i'	'\0'		

What does `cin >> array_of_characters` do?

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```
char str[5];
cin >> str;
```

- When reading in an array of characters, **`cin`** and the extraction operator (`>>`) skip leading whitespace and read characters until a whitespace character is encountered.
- Then, it automatically stores a `'\0'` after the last character read in.

What do we need to be careful about?

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- We need to be careful when working with arrays of characters...
- If we have an array of size 5
  - that means there are 5 bytes of memory allocated for our variable sequentially in memory
- This means that we can store four characters at most, since one spot needs to be reserved for the **terminating null**

So, What could happen???

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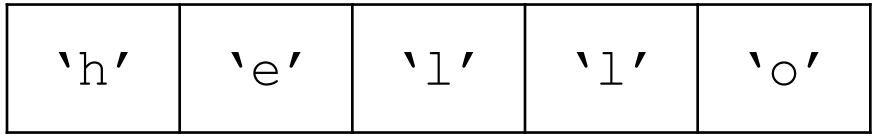
- Using `cin >> str;`
- If I enter “hello”, this is what is stored:



- Notice we ended up storing the `'\0'` in memory that is **not allocated** for our variable
  - *this is extremely dangerous and can cause our programs to bomb! (segmentation fault or core dump when running...)*

What do we need to be careful about?

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- What this means is that C++ does not check to make sure we stay within the bounds of our arrays
- C++ assumes that we know what we are doing!
- It is a powerful language...one that can even be used to design operating systems
- Therefore, if there is a chance that the user may type in too many characters, we need to read in our strings using a different approach

How do I read in a string safely?

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- There is a **`cin.get`** function that is useful
- There are three ways to use this function:
  - it can be used to read a single character

```
char ch;
ch = cin.get();
Or cin.get(ch);
```

→ *this reads in the next character from the input buffer, even if that next character is whitespace!*

How do I read in a string safely?

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- Or, we can use this function to read in a string using 2 or 3 arguments:

```
char str[5];
cin.get(str,5);
Or cin.get(str,5, '\n');
```

→ this reads in the next sequence of characters up until (size-1) characters are read or the delimiting character is encountered (`'\n'` by default)

How do I read in a string safely?

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- The three argument version of cin.get has the following form:

```
cin.get(array_name, max_size, delimiting_character);
```

- A side benefit of this function is that it will allow us to read in sentences, our entire first/last name, a paragraph, etc. This is because the delimiting character need not be white space!

How do I read in a string safely?

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- There is one "gotcha" with this function.
- While the three argument version of cin.get won't read in too many characters (so it will *never* store characters outside your array bounds),
  - it will NOT read in the delimiting character!
- Therefore, we must always "eat" the delimiting character, using either:

`cin.get();` or `while(cin.get()!= '\n');`

Let's read another string, using cin.get:

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- Using `cin.get(str, 5);`
- If I enter "`hi !`", this is what is stored:

'h'	'i'	' '	'!'	'0'

- Notice that room is left to store the `'\0'` at the end of the array, and there is no danger of writing outside of our array bounds.
- But, what is left in the input buffer? `'\n'`
- How do we "flush" this?

```
cin.get();
```

Let's read another string, using cin.get:

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- Using `cin.get(str, 5);`
- If I enter "`hello`", this is what is stored:

'h'	'e'	'l'	'l'	'0'

- Notice that room is left to store the `'\0'` at the end of the array, and there is no danger of writing outside of our array bounds.
- But, what is left in the input buffer? `'o\n'`
- How do we "flush" this?

```
while(cin.get() !='\n');
```

How do I display a string?

- Luckily, displaying strings isn't as complicated.

```
cout << str;
```

- Simply by using cout followed by the insertion operator (<<), we can display as many characters as have been stored in the array until the terminating null (`'\0'`) is encountered.
- Notice, the `'\0'` is important so that we don't display "garbage" characters (i.e., memory that has not been set or used yet!)

More about strings

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- Comparing and copying strings
- Accessing single characters in a string
- Write a program with strings

Operations on Strings

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- There are very few operations that can be performed on array of characters (i.e., strings)
- We can read in string using:

```
cin >> array_of_characters;
cin.get(array, size, delimiter);
```

- We display strings using:

```
cout << array_of_characters;
```

- But, there are no others...

Operations on Strings

- For example, we cannot compare two strings by saying:

```
char str1[10], str2[10];
if (str1 == str2)
```

- This is because an array is really *the address of the first element in a sequentially allocated set of memory*.
- So, the == or != operators would simply be comparing the memory addresses!
- Oops!

Comparing Strings

- Instead, to compare two strings we must include another library: **<cstring>**
- And, call the string compare function:

```
strcmp(first_array, second_array);
```

- The strcmp function returns:
  - 0 if first_array is equal to second_array
  - <0 if first_array is less than second_array
  - >0 if first_array is greater than second_array

Copying Strings

- We also cannot copy strings using the assignment operator:

```
char str1[10], str2[10];
str1 = str2;
```

- This is illegal because an array is really *the constant address of the first element of the array*.

  → *We can't change the location in memory where your array is located!!!! And…that is what this assignment statement is attempting to do…*

- Instead, we call strcpy from cstring

```
strcpy(str1, str2);//str1=str2
```

Passing Arrays to Functions

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- Specify name without brackets
  - To pass array `myArray` to `myFunction`

```
int myArray[ 24 ];
myFunction( myArray );
```

Passing Arrays to Functions

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- Arrays passed-by-reference
  - Functions can modify original array data
  - Value of name of array is address of first element
    - ✓Function knows where the array is stored
    - ✓Can change original memory locations
- Individual array elements passed-by-value
  - Like regular variables

```
square( myArray [ 3 ]);
```

Passing Arrays to Functions

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- Functions taking arrays as parameters
  - Function prototype

```
void modifyArray( int b[], int arraySize );
```

```
void modifyArray( int [], int );
```

→ Names are optional in prototype
→ Both take an integer array and a single integer
→ No need for array size between brackets
→ Ignored by compiler

For example:

- Let's now put this to use by writing a function to read in two strings and displaying them in alphabetical order
- First, write the algorithm:
  - Get two strings (prompt, input, echo)
  - If the first string is less than the second
    - display the first string followed by the second
  - If the first string is greater or equal to the second
    - display the second string followed by the first

Writing a function to work with strings

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```
#include <cstring>
void sort_two() {
    char first[20], second[20];
    cout << "Please enter two words: ";
    cin.get(first,20, '\n');
    cin.get(); //don't forget this part!
    cin.get(second,20, '\n');
    cin.get(); //eat the carriage return;
    if (strcmp(first, second) < 0)
      cout << first << ' ' << second << endl;
    else
      cout << second << ' ' << first << endl;
}
```

Change the function to have args

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```
#include <cstring>
void sort_two(char first[], char second[]) {
    cout << "Please enter two words: ";
    cin.get(first,20, '\n');
    cin.get();
    cin.get(second,20, '\n');
    cin.get(); //eat the carriage return;
    if (strcmp(first, second) > 0) {
      char temp[20];
      strcpy(temp, first);
      strcpy(first, second);
      strcpy(second, temp);
    }
}
```

We'd call the function by saying:

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```
#include <cstring>
void sort_two(char first[], char second[]);
int main() {
    char str1[20], str2[20];

    sort_two(str1, str2);
    cout << str1 << ' ' << str2 << endl;

    //what would happen if we then said:
    sort_two(str2, str1);
    cout << str1 << ' ' << str2 << endl;
    return 0;
}
```

Working with arrays, character at a time

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- We can also work with strings an element at a time,
  - by indexing through the array
  - we begin by using subscripts that start at zero and then progress until the array size-1
- For example, we can read in a string by:
  - Read a character
  - If that character is not a carriage return
    - save the character in the array

Reading a Character at a time:

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```
char str[20];
char ch;
int index = 0;

ch = cin.get();
while (ch != '\n') {
      str[index] = ch;   //str[index] is a char
      ++index;
      ch = cin.get();
}
str[index] = '\0';       //why is this important?
```

- But, what if they type in too many characters?

A Better Approach?

```
const int MAX = 20;
char str[MAX];      char ch;
int index = 0;

ch = cin.get();
while (index < MAX-1 && ch != '\n') {
    str[index] = ch;    //str[index] is a char
    ++index;
    ch = cin.get();
}
str[index] = '\0';      //why is this important?
```

The Same Thing...Just Condensed:

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```
const int MAX = 20;
char str[MAX];
int index = 0;

while (index < MAX-1 && (ch= cin.get()) != '\n'))
   str[index++] = ch;  //Remember postfix????

str[index] = '\0';     //Still important
```

Or, going to an extreme!

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```
const int MAX = 20;
char str[MAX];
int index = 0;

while (index < MAX-1 &&
     (str[index++]= cin.get()) != '\n'));

str[index] = '\0';
```