CS 106B
Lecture 3: C++ Strings

Friday, September 30, 2016

Programming Abstractions
Fall 2016
Stanford University
Computer Science Department

Lecturer: Chris Gregg

reading:
Programming Abstractions in C++, Chapter 3 - 4

Today's Topics

- Logistics:
  - TreeHacks Organizing Team Info Session, Tuesday Oct. 4th
  - Lathrop 298, 6-7pm. Link: tinyurl.com/treehacks
- Homework 1:
  - Library Bug, input/output, general comments
- Reference Semantics review
  - Mystery Function example
- Strings
  - C++ strings vs C strings
  - Characters
  - Member Functions
  - Stanford Library extensions
  - Char and <cctype>
- Reading Assignment: Chapter 3

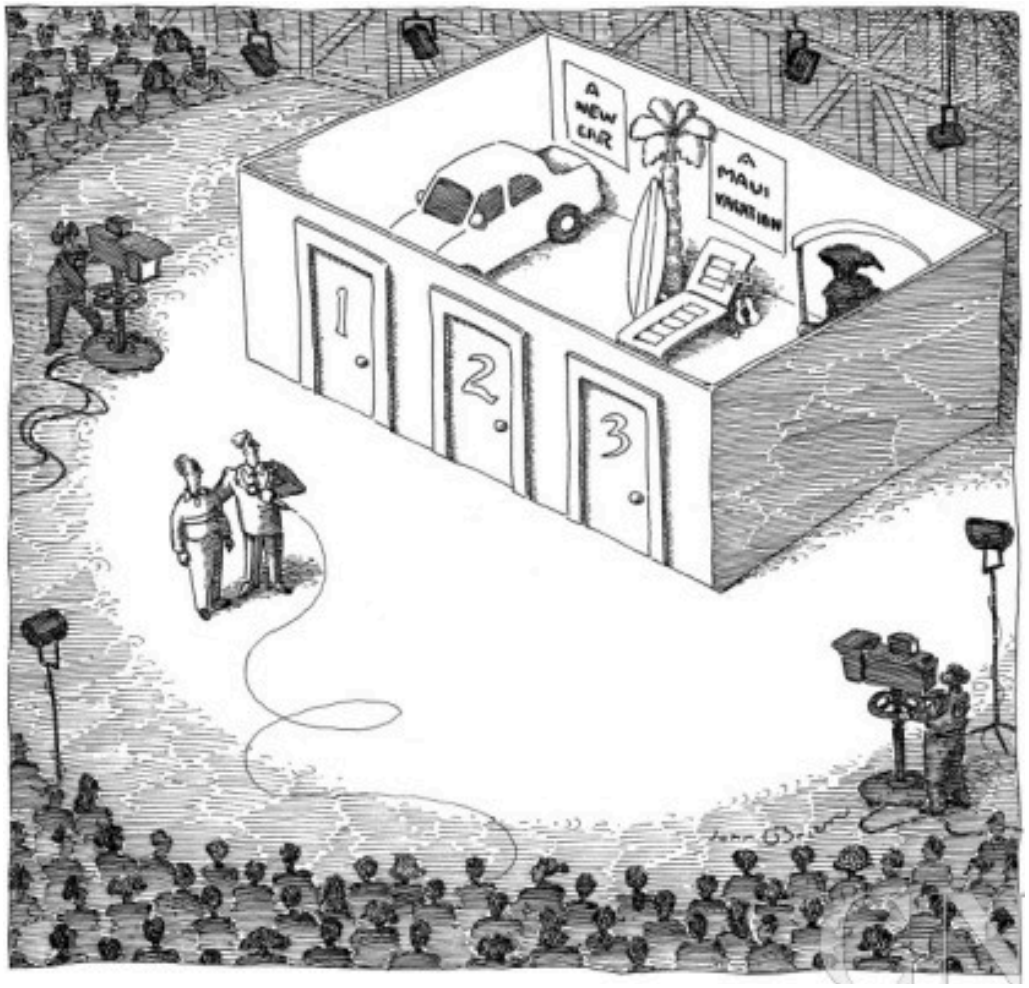
HW1 Notes

- Homework 1: Fauxtoshop
- There is a very annoying bug in the Fauxtoshop project that you cannot control (we may have found a fix -- see Piazza post @35). Sometimes, when you load an image, the program simply stops and doesn't load the image. If this happens, you must re-start your program (I know -- not fun!). Please apply the fix!
- For input, you should be using the Stanford library function **`getLine()`** and **`getInteger()`** as follows (we will talk about strings next!):

```
string filename = getLine("Enter name of image file to open (or blank to quit): ");
int myInteger = getInteger("Enter degree of scatter [1-100]: ");
```

- You should start to get familiar with the Stanford Library
- Remember, procedural decomposition is **super important**. Your functions should be short (less than 30 lines!) and should each perform a single, coherent task.
- The functions for each part of this assignment do not need to be long -- think about what you are trying to accomplish, decide on an algorithm, and plan what you want the function to do. *Then* write the code.

CS 106 Game Show!



Gameshow idea and implementation by Chris Piech

Helper Function (see CS 106B website for full code)

```
int getChoice() {
    string prompt = "Which door would you like to open (1
    while(true) {
        int choice = getInteger(prompt);
        if(choice < 1 || choice > 3) {
            cout << "Illegal door. Try again." << endl;
        } else {
            return choice;
        }
    }
}
```

Helper Function (see CS 106B website for full code)

Function that returns an integer

```
int getChoice() {
    string prompt = "Which door would you like to open (1
    while(true) {
        int choice = getInteger(prompt);
        if(choice < 1 || choice > 3) {
            cout << "Illegal door. Try again." << endl;
        } else {
            return choice;
        }
    }
}
```

Helper Function (see CS 106B website for full code)

```
int getChoice() {
    string prompt = "W                                    (1
    while(true) {
        int choice = getInteger(prompt);
        if(choice < 1 || choice > 3) {
            cout << "Illegal door. Try again." << endl;
        } else {
            return choice;
        }
    }
}
```

Useful Stanford Library function -- where to I find these?? The website! http://stanford.edu/~stepp/cppdoc/

Welcome Message in a File

welcome.txt
Located in the res folder in the project.

```
6
Welcome to the CS106B game show!
You stand in front of three doors
and behind each door is a special prize.
Will you be brave?
Will you be wise?
Step right up and try your luck.
```

Another Helper Function

```
void setUpGame() {
    ifstream fileStream;
    openFile(fileStream, "welcome.txt");

    // get first line
    string numLinesStr;
    getline(fileStream, numLinesStr);
    int numLines = stringToInteger(numLinesStr);

    // output the welcome message
    for(int i = 0; i < numLines; i++) {
        string line;
        getline(fileStream, line);
        cout << line << endl;
    }
}
```

Another Helper Function

creates a file stream variable

```
void setUpGame() {
    ifstream fileStream;
    openFile(fileStream, "welcome.txt");

    // get first line
    string numLinesStr;
    getline(fileStream, numLinesStr);
    int numLines = stringToInteger(numLinesStr);

    // output the welcome message
    for(int i = 0; i < numLines; i++) {
        string line;
        getline(fileStream, line);
        cout << line << endl;
    }
}
```

Another Helper Function

```
void setUpGame() {
    ifstream fileStream;
    openFile(fileStream, "welcome.txt");

    // get first line
    string numLinesStr;
    getline(fileStream, numLinesStr);
    int numLines = stringToInteger(numLinesStr);

    // output the welcome message
    for(int i = 0; i < numLines; i++) {
        string line;
        getline(fileStream, line);
        cout << line << endl;
    }
}
```

opens the file "welcome.txt"

Another Helper Function

```
void setUpGame() {
    ifstream fileStream;
    openFile(fileStream, "welcome.txt");

    // get first line
    string numLinesStr;
    getline(fileStream, numLinesStr);
    int numLines = stringToInteger(numLinesStr);

    // output the welcome message
    for(int i = 0; i < numLines; i++) {
        string line;
        getline(fileStream, line);
        cout << line << endl;
    }
}
```

declares a string

Another Helper Function

```
void setUpGame() {
    ifstream fileStream;
    openFile(fileStream, "welcome.txt");

    // get first line
    string numLinesStr;
    getline(fileStream, numLinesStr);
    int numLines = stringToInteger(numLinesStr);

    // output the welcome message
    for(int i = 0; i < numLines; i++) {
        string line;
        getline(fileStream, line);
        cout << line << endl;
    }
}
```

Puts the next line in the file into the string (which is the number of lines of text to read)

Another Helper Function

```
void setUpGame() {
    ifstream fileStream;
    openFile(fileStream, "welcome.txt");

    // get first line
    string numLinesStr;
    getline(fileStream, numLinesStr);
    int numLines = stringToInteger(numLinesStr);

    // output the welcome message
    for(int i = 0; i < numLines; i++) {
        string line;
        getline(fileStream, line);
        cout << line << endl;
    }
}
```

Loops to read all the lines and print them to the screen.

Another Helper Function

```
void suspense() {
    cout << endl << "Dumroll!" << endl;
    for(int i = 0; i < 10; i++) {
        string line = "";
        for(int j = 0; j < (10 - i); j++) {
            line += ".";
        }
        cout << line << endl;
        pause(200);
    }
}
```

CS 106B Game Show

```
int main() {
    setUpGame();
    string prize = "some candy";

    int choice = getChoice();
    if(choice == 1) {
        doorOne(prize);
    } else if(choice == 2) {
        doorTwo(prize);
    } else if(choice == 3) {
        doorThree(prize);
    }

    suspense();
    cout << "You win " << prize << endl;
    return 0;
}
```

The Doors

```
void doorOne(string & prize) {
    int dollars = 1 / 5 * 100;
    prize = "$" + integerToString(dollars);
}

void doorTwo(string prize) {
    prize = "a Maasai rungu";
}

void doorThree(string & prize) {
    prize = "a pineapple";
}
```

Volunteer!

The Doors

```
void doorOne(string & prize) {
    int dollars = 1 / 5 * 100;
    prize = "$" + integerToString(dollars);
}

void doorTwo(string prize) {
    prize = "a Maasai rungu";
}

void doorThree(string & prize) {
    prize = "a pineapple";
}
```

The Doors

```
void doorOne(string & prize) {
    int dollars = 1 / 5 * 100;
    prize = "$" + integerToString(dollars);
}

void doorTwo(string prize) {
    prize = "a Maasai rungu";
}

void doorThree(string & prize) {
    prize = "a pineapple";
}
```

Integer division produces an integer!

Not passed by reference! Change does not propagate back to calling function!

Pineapples are delicious and healthy

Tricky Reference Mystery Example (from Wed.)

What is the output of this code? Talk to your neighbor! (and this is a good example for *writing down the variables and keeping track on paper!*

```
void mystery(int& b, int c, int& a) {
    a++;
    b--;
    c += a;
}

int main() {
    int a = 5;
    int b = 2;
    int c = 8;
    mystery(c, a, b);
    cout << a << " " << b << " " << c << endl;
    return 0;
}
```

```
// A. 5 2 8
// B. 5 3 7
// C. 6 1 8
// D. 61 13
// E. other
```

Note: please don't obfuscate your code like this! :(

See the International Obfuscated C Contest for much, much worse examples

Tricky Reference Mystery Example

What is the output of this code? Talk to your neighbor! (and this is a good example for *writing down the variables and keeping track on paper!*

```
void mystery(int& b, int c, int& a) {
    a++;
    b--;
    c += a;
}

int main() {
    int a = 5;
    int b = 2;
    int c = 8;
    mystery(c, a, b);
    cout << a << " " << b << " " << c << endl;
    return 0;
}
```

```
// A. 5 2 8
// B. 5 3 7
// C. 6 1 8
// D. 61 13
// E. other
```

Note: please don't obfuscate your code like this! :(
See the International Obfuscated C Contest for much, much worse examples

Strings (3.1)

(not this type of string)

(or this one)


```
#include<string>
...
string s = "hello";
```

- A string is a sequence of characters, and can be the empty string: ""
- In C++, a string has "double quotes", not single quotes:

```
"this is a string"
'this is not a string'
```

- Strings are similar to Java strings, although the functions have different names and in some cases different behavior.
- The biggest difference between a Java string and a C++ string is that C++ strings are *mutable* (changeable).
- The second biggest difference is that in C++, we actually have two types of strings (more on that in a bit)

Strings and Characters

- Strings are made up of *characters* of type **`char`**, and the characters of a string can be accessed by the index in the string:

```
string s = "Fear the Tree";
```

index	0	1	2	3	4	5	6	7	8	9	10	11	12
`character`	`'F'`	`'e'`	`'a'`	`'r'`	`' '`	`'t'`	`'h'`	`'e'`	`' '`	`'T'`	`'r'`	`'e'`	`'e'`

```
char c1 = s[3]    // 'r'
char c2 = s.at(2) // 'a'
```

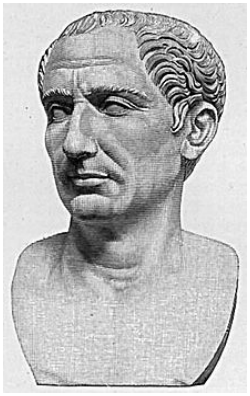
- Notice that **`char`**s have *single quotes* and are limited to one ASCII character. A space char is `' '`, not `''` (in fact, `''` is not a valid char at all. It is hard to see on the slide, but there is an actual space character between the single quotes in a valid space **`char`**, and there is no space in the not-valid example)

ASCII

- Characters have a numerical representation,

```
cout << (int) 'A' << endl; // 65
```

- This means you can perform math on characters, but you need to be careful:



Char	Value	Char	Value	Char	Value
(sp)	32	@	64	`	96
!	33	A	65	a	97
"	34	B	66	b	98
#	35	C	67	c	99
$	36	D	68	d	100
%	37	E	69	e	101
&	38	F	70	f	102
'	39	G	71	g	103
(	40	H	72	h	104
)	41	I	73	i	105
*	42	J	74	j	106
+	43	K	75	k	107
,	44	L	76	l	108
-	45	M	77	m	109
.	46	N	78	n	110
/	47	O	79	o	111
0	48	P	80	p	112
1	49	Q	81	q	113
2	50	R	82	r	114
3	51	S	83	s	115
4	52	T	84	t	116
5	53	U	85	u	117
6	54	V	86	v	118
7	55	W	87	w	119
8	56	X	88	x	120
9	57	Y	89	y	121
:	58	Z	90	z	122
;	59	[	91	{	123
<	60	\	92	|	124
=	61	]	93	}	125
>	62	^	94	~	126
?	63	_	95	(del)	127

```
string plainText = "ATTACK AT DAWN";
string cipherText = "";
int key = 5; // caesar shift by five

// only works for uppercase!
for (int i=0;i<(int)plainText.length();i++) {
    char plainChar = plainText[i];
    char cipherChar;
    if (plainChar >= 'A' && plainChar <= 'Z') {
        cipherChar = plainText[i] + key;
        if (cipherChar > 'Z') {
            cipherChar -= 26; // wrap back around
        }
    } else {
        cipherChar = plainChar;
    }
    cipherText += cipherChar;
}
cout << "Plain text:  " << plainText << endl;
cout << "Cipher text: " << cipherText << endl;
```

Output:

```
Plain text:  ATTACK AT DAWN
Cipher text: FYYFHP FY IFBS
```

String Operators (3.2)

- As in Java, you can concatenate strings using + or +=

```
string s1 = "Chris";
string sSq = s1 += "Squared"; // sSq == ChrisSquared
```

- Unlike in Java, you can compare strings using relational operators:

```
string s2 = "Zebra";
if ((s1 > s2) && (s2 != "Walrus")) { // true
   ...
}
```

- Unlike in Java, strings are mutable and can be changed (!):

```
•s2.append("Giraffe"); // s2 is now "ZebraGiraffe"
•s2.erase(4,3); // s2 is now "Zebrraffe" (which would be a very cool animal)
•s2[5] = 'i'; // s2 is now "Zebrriffe"
•s2[9] = 'e'; // BAD!!!1! PROGRAM MAY CRASH! POSSIBLE BUFFER OVERFLOW! NO NO NO!
```

- Unlike in Java, C++ does not bounds check for you! The compiler doesn't check for you, and Qt Creator won't warn you about this. We have entered the scary territory of "you must know what you are doing". Buffer overflows are a critical way for viruses and hackers to do their dirty work, and they can also cause hard to track down bugs.

String Member Functions

Function	Description
s.append(***str***)	add text to the end of a string
s.compare(***str***)	return -1, 0, or 1 depending on relative ordering
s.erase(***index, length***)	delete text from a string starting at given index
s.find(***str***) **s**.rfind(***str***)	first or last index where the start of ***str*** appears in this string (returns **string::npos** if not found)
s.insert(***index, str***)	add text into a string at a given index
s.length() or **s**.size()	number of characters in this string
s.replace(***index, len, str***)	replaces *len* chars at given index with new text
s.substr(***start, length***) or **s**.substr(***start***)	the next *length* characters beginning at *start* (inclusive); if *length* omitted, grabs till end of string

```
string name = "Donald Knuth";
if (name.find("Knu") != string::npos) {
    name.erase(7, 5); // "Donald"
}
```

C++ vs C strings

- C++ has (confusingly) two kinds of strings:
  - **C strings** (**`char`** arrays), inherited from the C language
  - **C++ strings** (string objects), which is part of the standard C++ library.
  - When possible, declare C++ strings for better usability (you will get plenty of C strings in CS 107!)
- Any string *literal* such as **`"hi there"`** is a C string.
  - C strings don't have member functions, and you must manipulate them through regular functions. *You also must manage the memory properly -- this is SUPER IMPORTANT and involves making sure you have allocated the correct memory -- again, this will be covered in detail in CS 107.*
  - E.g., C strings do not have a **`.length()`** function (there are no member functions, as C strings are not part of a class.
- You can convert between string types:
  - **`string("text")`** converts C string into C++ string
  - **`string.c_str()`** returns a C string out of a C++ string

C string issues

```
string s1 = "hi" + "there";
```

- Does not compile; C strings can't be concatenated with +.

```
string s2 = string("hi") + "there";
string s3 = "hi"; // "hi" is auto-converted to string
s += "there";
```

- These all compile and work properly.

```
int n = (int) "42";
```

- Bug; sets **n** to the memory address of the C string **"42"** (ack!). Qt Creator will produce an error, too

```
int n = stringToInteger("42");
```

- Works, because of explicit conversion of "42" to a C++ string (and **stringToInteger()** is part of the Stanford C++ library)

C string issues

```
string s = "hi" + '?'; // C-string + char
string s = "hi" + 41;  // C-string + int
```

- Both bugs. Produces garbage, not **"hi?"** or **"hi42"**. (memory address stuff)

```
string s = string("") + "hi" + '?'
```

- does work because of the empty C++ string at the beginning

```
string s = "hi"; // char '?' is concatenated to string
s += '?'; // "hi?"
```

- Works, because of auto-conversion.

- **`s += 41; // "hi?)"`**
- Adds character with ASCII value 41, **`')'`**, doesn't produce **"hi?41"**.

```
s += integerToString(41); // "hi?41"
```

- Works, because of conversion from int to string.

What's the Output? (Talk to your neighbor!)

```
void mystery(string a, string &b) {
    a.erase(0,1);
    b += a[0];
    b.insert(3, "FOO");
}

int main() {
    string a = "Stanford";
    string b = "Tree";
    mystery(a,b);
    cout << a << " " << b << endl;
    return 0;
}
```

Answer:
Stanford TreFOOet

Stanford String Library (3.7)

```
#include "strlib.h"
```

These are *not* string class functions.

Function	Description
endsWith(***str, suffix***) startsWith(***str, prefix***)	returns **true** if the given string begins or ends with the given prefix/suffix text
integerToString(***int***) realToString(***double***) stringToInteger(***str***) stringToReal(***str***)	returns a conversion between numbers and strings
equalsIgnoreCase(***s1, s2***)	**true** if s1 and s2 have same chars, ignoring casing
toLowerCase(***str***) toUpperCase(***str***)	returns an upper/lowercase version of a string
trim(***str***)	returns string with surrounding whitespace removed

```
if (startsWith(nextString, "Age: ")) {
    name += integerToString(age) + " years old";
}
```

Recap

- **Fauxtoshop**
  - Sorry about the bug! Loading images sometimes doesn't work (though hopefully the fix works!) ಠ_ಠ
  - Use **`getLine()`** and **`getInteger()`** to read values.

- **Strings**
  - C++ has both C strings and C++ strings. Both are, under the covers, simply arrays of characters. C++ strings handle details for you automatically, C-strings *do not*.
    - C++ strings are much more functional and easier to use
    - Many times (but not always), C-strings auto-convert to C++ strings when necessary
    - Characters are single-quoted, single-character ASCII numerical values (be careful when applying arithmetic to them)
    - C++ strings have many functions you can use, e.g., **`s.length()`** and **`s.compare()`**
    - The Stanford library also has some extra string functions, which are not part of the string class, but are helpful (e.g.,

References and Advanced Reading

- **References (in general, not the C++ references!):**
  - Textbook Chapter 3
  - <cctype> functions: http://en.cppreference.com/w/cpp/header/cctype
  - Code from class: see class website (https://cs106b.stanford.edu)
  - Caesar Cipher: https://en.wikipedia.org/wiki/Caesar_cipher

- **Advanced Reading:**
  - C++ strings vs C strings: http://cs.stmarys.ca/~porter/csc/ref/c_cpp_strings.html
  - String handling in C++: https://en.wikipedia.org/wiki/C%2B%2B_string_handling
  - Stackoverflow: Difference between string and char[] types in C++: http://stackoverflow.com/questions/1287306/difference-between-string-and-char-types-in-c

Extra Slides

String Exercise (work with your neighbor)

Write a function called **`nameDiamond`** that accepts a string as a parameter and prints it in a "diamond" format as shown below.

- For example, nameDiamond("CHRIS") should print:

```
C
CH
CHR
CHRI
CHRIS
 HRIS
  RIS
   IS
    S
```

String Exercise Possible Solution

One possible solution (break into two parts!)

```
void nameDiamond(string s) {
    int len = (int)s.length(); // cast length to int to avoid warning
    // print top half of diamond
    for (int i = 1; i <= len; i++) {
        cout << s.substr(0, i) << endl;
    }

    // print bottom half of diamond
    for (int i = 1; i < len; i++) {
        for (int j = 0; j < i; j++) { // indent
            cout << " ";              // with spaces
        }
        cout << s.substr(i, len - i) << endl;
    }
}
```