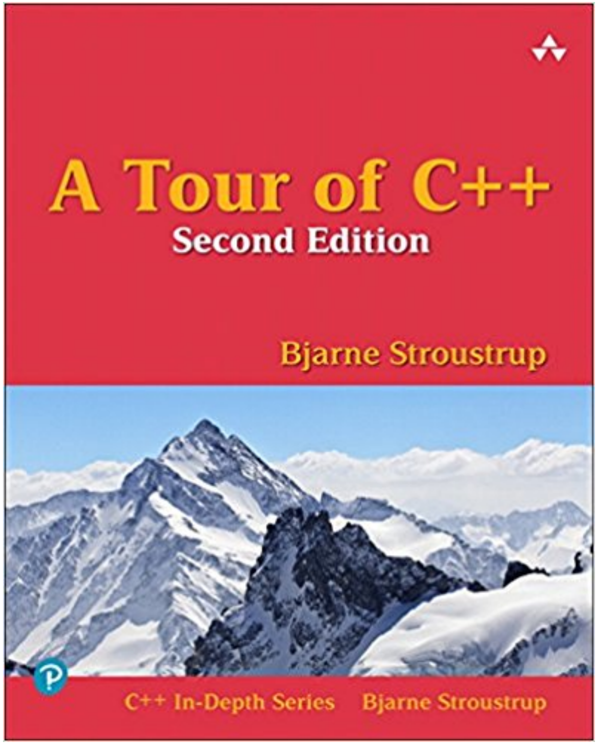
CS11 Intro C++

Spring 2018 – Lecture 1

Welcome to CS11 Intro C++!

- An introduction to the C++ programming language and tools
- Prerequisites:
  - CS11 C track, or equivalent experience with a curly-brace language, is encouraged but not required
- No books are required for this course
  - Lecture slides and assignments are sufficient
  - Lecture recordings will also be available
- If you want some reference books:
- A Tour of C++, 2nd Edition
  - An overview and survey of C++, by its creator
  - Contains good advice on proper C++ usage and recommended idioms
  - Better for more experienced programmers



Welcome to CS11 Intro C++! (2)

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- Prerequisites:
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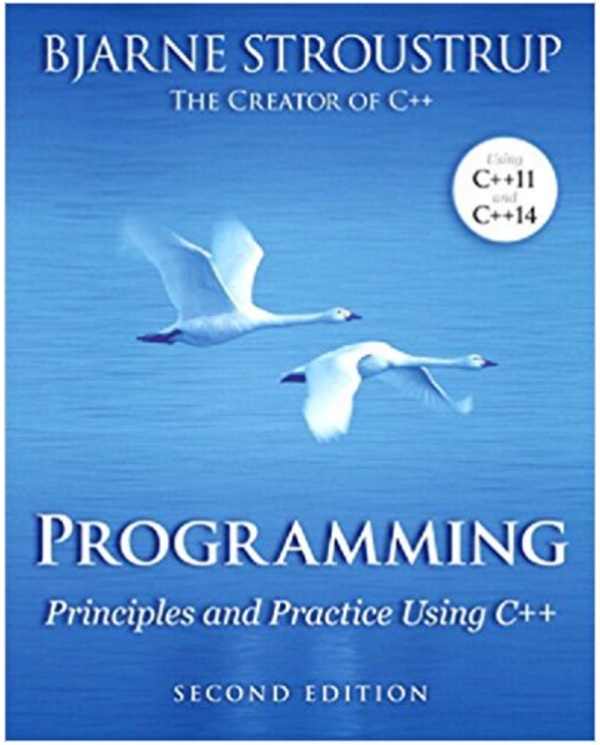
- No books are required for this course
  - Lecture slides and assignments are sufficient
  - Lecture recordings will also be available
- If you want some reference books:
- Programming, 2nd Edition
  - Learning to program, using C++, by its creator
  - A much expanded version of the previous book
  - Good for novice programmers



Assignments and Grading

- Each lecture has a corresponding assignment for exploring the material
- Labs are due approximately one week later, at noon
  - e.g. this term labs will be due on Fridays at noon
  - Submit on csman
- Labs are given a 0..3 grade, meaning:
  - 3 = excellent (masters all important parts)
  - 2 = good (demonstrates mastery of key idea; a few minor issues)
  - 1 = insufficient (not passing quality; significant bugs that must be addressed)
  - 0 = incorrect (worthy of no credit)
- Must receive at least 75% of all possible points to pass the track
- Can submit up to 2 reworks of assignments to improve grade
- Not uncommon for initial submission to get a 0!
  - Don’t take it personally; it’s really not a big deal in CS11 tracks

C++ Compilers

- Two main C++ compilers in use these days
- GNU g++
  - Most widely used on Linux systems
  - Typically used in cygwin on Windows systems
- LLVM clang++
  - The default compiler on Apple MacOSX
  - clang++ emulates some basic g++ functionality, but also leaves out many options
- If unsure, you can find out what you are using:
  - "`g++ --version`" outputs the compiler version
- Example output on a Mac:
  - LLVM: "Apple LLVM version 6.0 (clang-600.0.57)"
  - GNU: "g++ (MacPorts gcc49 4.9.3_0) 4.9.3"

C++ Compilers (2)

- As long as we can compile and run your code with either GNU g++ or LLVM clang++, you're fine
- Can specify the version of C++ to use
  - `g++ -std=c++14 ...`
  - `clang++ -std=c++14 ...`
  - (or use `-std=c++11` if your compiler doesn't support C++14)
- Most annoying difference between g++ and clang++ is that the debuggers are very different
  - g++ provides gdb
  - clang++ provides lldb
  - The debugger commands are significantly different
- If you are on a Mac and want to use g++/gdb, use Homebrew or MacPorts to install them
  - Make sure your path is set up to find GNU g++, and not clang's "fake g++"

C++ Origins

- Original designer: Bjarne Stroustrup, AT&T Bell Labs
- First versions called “C with Classes” – 1979
  - Most language concepts taken from C
    - “C with Classes” code was translated into C code, then compiled with the C compiler
  - Class system conceptually derived from Simula67
- Name changed to “C++” in 1983
- Continuous evolution of language features
  - (as usual)
  - Renewed development recently, with C++11, C++14 and upcoming C++17 standard updates

C++ Philosophy

“Close to the problem to be solved”

- Elegant, powerful abstractions
- Strong focus on modularity

“Close to the machine”

- Retains C’s focus on performance, and ability to manipulate hardware and data at a low level
  - Good language e.g. for games programming, systems programming, etc.
- “You don’t pay for what you don’t use.”
  - Some features have additional cost (e.g. classes, exceptions, runtime type information)
  - If you don’t use them, you don’t incur the cost

C++ Components

C++ Core Language

- Syntax, data types, variables, flow control, …
- Functions, classes, templates, …

C++ Standard Library

- Many useful classes and functions written using the core language
- Generic strings, IO streams, exceptions
- Generic containers and algorithms
  - The Standard Template Library (STL)
- Multithreading support
- Several other useful facilities

Example C++ Program

- Hello, world!

```
#include <iostream>

using namespace std;

int main() {
    cout << "Hello, world!\n";
    return 0;
}
```

- `main()` function is program's entry point
    - Every C++ program must have exactly one `main()` function
- Returns 0 to indicate successful completion, nonzero (typically 1..63) to indicate that an error occurred

Compilation

- Save your program in `hello.cpp`
  - Typical C++ extensions are `.cpp`, `.cc`, `.cxx`
  - Typical C++ header files are `.h`, `.hpp`, `.hh`, `.hxx`
- Compile your C++ program

```
> g++ -std=c++14 -Wall hello.cpp -o hello
> ./hello
Hello, world!
```

- Typical arguments:
  - `-Wall` Reports all compiler warnings. **<u>Always</u> fix these!!!**
  - `-o` *`file`* Specifies filename output by the compiler
    - Defaults to `a.out`, which isn't very useful…

Console IO in C++

- C uses `printf()`, `scanf()`, etc.
  - Defined in the C standard header stdio.h
  - `#include <stdio.h>` (or `<cstdio>` in C++)
- C++ introduces "Stream IO"
  - Defined in the C++ standard header `iostream`
  - `#include <iostream>`
- In this class, we will use C++ stream IO
  - printf/scanf can be useful in C++ programs, but we are here to learn C++!

- `cin` – console input, from "stdin"
- `cout` – console output, to "stdout"
- Also `cerr`, which is "stderr," for error-reporting.

Stream Output

- The << operator is **overloaded** for stream-output
  - Compiler figures out when you mean “shift left” and when you mean “output to stream,” from the context
  - Supports all primitive types and some standard classes, e.g. C++ strings

- Example:

```
string name = "series";
int n = 15;
double sum = 35.2;
cout << "name = " << name << "\n"
     << "n = " << n << "\n"
     << "sum = " << sum << "\n";
```

  - Note: Line up << operators to improve code readability

Stream Input

- The >> operator is overloaded for stream-input
  - Also supports primitive types and C++ strings.
- Example:

```
float x, y;
cout << "Enter x and y coordinates:  ";
cin >> x >> y;
```

- Input values are whitespace-delimited.

```
Enter x and y coordinates:  3.2       -5.6

Enter x and y coordinates:  4
35
```

C++ Namespaces

- **Namespaces** are used to group related items
- All C++ Standard Library code is in the `std` namespace
  - `string`, `cin`, `cout` are part of Standard Library
- Can either write `namespace::name` everywhere…

```
std::string name;
std::cin >> name;
std::cout << "Hello, " << name << "\n";
```

- Or, declare that you are using the namespace!

```
using namespace std;
string name;
cin >> name;
cout << "Hello, " << name << "\n";
```

- `namespace::name` form is called a **qualified name**

C++ Classes

- C++ classes are made up of **members**

- **Data members** are variables that appear in objects of the class' type
  - They store the object's state
  - Also called **member variables** or **fields**

- **Member functions** are operations that can be performed on objects of the class' type
  - These functions usually involve the data members

- Several different categories of member functions

Member Function Types

- **Constructors** initialize new instances of a class
  - Can take arguments, but not required. No return value.
  - Every class has at least one constructor
  - No-argument constructor is called **default constructor**
  - Several other special kinds of constructors too

- **Destructors** clean up an instance of a class
  - This is where an instance's *dynamically-allocated* resources are released
    - (The compiler knows how to clean up everything else)
  - No arguments, no return value
  - Every class has <u>exactly one</u> destructor

Member Function Types

- **Accessors** allow internal state to be retrieved
  - Provide control over when and how data is exposed
- **Mutators** allow internal state to be modified
  - Provide control over when and how changes can be made

- Accessors and mutators guard access to (and mutation of) an object’s internal state values
- Generally don’t want to expose internal state!
  - Instead, provide accessors and mutators to govern when and how internal state is exposed and manipulated

Abstraction and Encapsulation

- **Abstraction**:
  - Present a clean, simplified interface
  - Hide unnecessary detail from users of the class (e.g. implementation details)
  - They usually don’t care about these details!
  - Let them concentrate on the problem they are solving.
- **Encapsulation**:
  - Allow an object to protect its internal state from external access and modification
  - The object itself governs all internal state-changes
  - Methods can ensure only valid state changes

Declarations and Definitions

- C++ distinguishes between the declaration of a class, and its definition.
- The **declaration** describes member variables and functions, and their access constraints.
  - This is put in the "header" file, e.g. `point.h`
- The **definition** specifies the behavior – the actual code of the member functions.
  - This is put in a corresponding `.cpp` file, e.g. `point.cpp`
- Users of our classes include only the declarations
  - `#include "point.h"`
  - People usually don't care how the types work internally; just how to use them to solve other problems

C++ Access Modifiers

- The class declaration states what is exposed and what is hidden.
- Three access-modifiers in C++
  - `public` – Anybody can access it
  - `private` – Only the class itself can access it
  - `protected` – We'll get to this later…

- **The default access-level for classes is `private`.**
- In general, other code can only access the public parts of your classes.

Point Class Declaration – `point.h`

```
// A 2D point class
class Point {
    double x, y;                // Data-members

public:
    Point();                    // Constructors
    Point(double x, double y);

    ~Point();                   // Destructor

    double get_x();             // Accessors
    double get_y();
    void set_x(double x);       // Mutators
    void set_y(double y);
};
```

Defining Point Behavior – `point.cpp` (1)

```
#include ”point.h"

// Default (aka no-argument) constructor
Point::Point() {
    x = 0;
    y = 0;
}

// Two-argument constructor - sets point to (x, y)
Point::Point(double x, double y) {
    this->x = x;
    this->y = y;
}

// Cleans up a Point object.
Point::~Point() {
    // No dynamically allocated resources; nothing to do!
}
```

Variable Shadowing

- A somewhat confusing situation:

```
Point::Point() {
    x = 0;
    y = 0;
}

Point::Point(double x, double y) {
    this->x = x;
    this->y = y;
}
```

- In C++, variables in an inner scope can *shadow* a variable in an outer scope
  - The data-members x and y are defined at the object scope
  - Additionally, function arguments x and y are arguments to the constructor, and these shadow the data-members
  - Consequence: If you say “x” or “y” by itself, compiler assumes you mean the function argument, not the data-member
  - (In general, compiler uses the variable at the narrowest scope)

Variable Shadowing (2)

- A somewhat confusing situation:

```
Point::Point() {
    x = 0;
    y = 0;
}

Point::Point(double x, double y) {
    this->x = x;
    this->y = y;
}
```

- A simple solution: use `this` to resolve the ambiguity, when needed
  - “`this`” is a pointer to the object that member function is being invoked on
  - Built into the C++ language, available in *member-functions*, but not regular functions (exactly like Java “`this`” or Python “`self`”)
  - In this example, “`this`” has the type `Point*`, because the member function is part of the Point class.

Defining Point Behavior – `point.cpp` (2)

```
// Returns X-coordinate of a Point
double Point::get_x() {
    return x;
}

// Returns Y-coordinate of a Point
double Point::get_y() {
    return y;
}

// Sets X-coordinate of a Point
void Point::set_x(double x) {
    this->x = x;
}

// Sets Y-coordinate of a Point
void Point::set_y(double y) {
    this->y = y;
}
```

Using the `Point` Type

- Now we have a new type to use!

```
#include "point.h"

Point p1;                    // Calls default constructor
Point p2{3, 5};              // Calls 2-arg constructor
cout << "P2 = (" << p2.get_x()
     << "," << p2.get_y() << ")\n";
p1.set_x(210);
p1.set_y(154);
```

- Point’s private members cannot be accessed directly.
  - `p1.x = 452;                  // Compiler reports an error!`
  - `cout << p2.y;                // Compiler reports an error!`

The C++ `std::string` Class

- C++ retains the C notion of `char*` as a "string"
  - An array of `char` values, terminated with a 0 value (a.k.a. "the null character" or "NUL")
- Typically difficult / bug-prone to manipulate in complex ways…
  - Have to manually allocate and reallocate space to hold string data
  - Can easily write past end of string (buffer overflows, exploits!)
  - Can easily forget to free memory used by C strings
- C++ also introduces a new `std::string` type
  - Resizable string that keeps data in heap memory
  - `#include <string>`
- Provides <u>many</u> features over `char*` strings
  - Can manipulate strings easily, without manual memory management
  - Supports stream IO with >> and << operators
- Prefer `string` to `char*`, wherever possible!!!

The C++ `std::string` Class (2)

- Usage of std::string is very intuitive

```
string name;
cout << "What is your name?  ";
cin >> name;
cout << "Hello " << name << "!\n";
```

- Setting initial values, or mutating string values, is also easy

```
string favorite_color{"green"};
string mood = "happy";
mood = "cheery";
```

- Will cover C++ string functionality in much more detail in the future!

This Week's Homework

- For the next few weeks, we will build a simple units-conversion utility
- When finished, it will be quite powerful

- This week:
  - Start practicing the basic concepts of C++ class declaration, and start creating the machinery for our utility
  - Focus on good coding style and commenting
  - Figure out what C++ compiler you have, and how to invoke it
  - Figure out how to compile your program on your computer
  - Test your program's correctness