

# CSE 333

## Lecture 9 - intro to C++

**Hal Perkins**

Department of Computer Science & Engineering

University of Washington



# Administrivia

New exercise posted after sections tomorrow, due Monday morning

Read a directory and open/copy text files found there

Good warmup for ...

## HW2

Writeup posted tomorrow, starter files pushed Friday

Short demo in class Friday

# Today's goals

An introduction to C++

- some shortcomings of C that C++ addresses

- give you a perspective on how to learn C++

- kick the tires and write some code

Advice: read related sections in the *C++ Primer*. It's hard to learn the “why it is done like this” from reference docs

Lectures and examples introduce main ideas, but aren't everything you'll ~~want~~ need to understand

# C

We had to work hard to mimic encapsulation, abstraction

**encapsulation:** hiding implementation details

used header file conventions and the “static” specifier to separate private functions from public functions

cast structures to (void \*) to hide implementation-specific details

**abstraction:** associating behavior with encapsulated state

the functions that operate on a LinkedList were not really tied to the linked list structure

we passed a linked list to a function, rather than invoking a method on a linked list instance

# C++

A major addition is its support for classes & objects!

classes

public, private, and protected **methods** and **instance variables**

(multiple!) inheritance

polymorphism

**static polymorphism:** multiple functions or methods with the same name, but different argument types (overloading)

Works for all functions, not just class members

**dynamic (subtype) polymorphism:** derived classes can override methods of parents, and methods will be dispatched correctly

# C

We had to emulate generic data structures

- customer passes a (void \*) as a payload to a linked list

- customer had to pass in function pointers so that the linked list could operate on payloads correctly

- comparisons, deallocation, pickling up state, etc.

# C++

Supports **templates** to facilitate generic data types!

Parametric polymorphism - same idea as Java generics, but different in details - particularly implementation

to declare that **x** is a vector of ints:

- ▶ `vector<int> x;`

to declare that x is a vector of floats:

- ▶ `vector<float> x;`

to declare that x is a vector of (vectors of floats):

- ▶ `vector<vector<float>> x;`

# C

We had to be careful about namespace collisions

C distinguishes between external and internal linkage

use “static” to prevent a name from being visible outside a source file (as close as C gets to “private”)

otherwise, a name is global -- visible everywhere

we used naming conventions to help avoid collisions in the global namespace

**LL**IteratorNext, **HT**IteratorNext, etc.



# C++

Permits a module to define its own namespace!

- the linked list module could define an “LL” namespace

- the hashtable module could define an “HT” namespace

- both modules could define an Iterator class

  - one would be globally named `LL::Iterator`

  - the other would be globally named `HT::Iterator`

Classes also allow duplicate names without collisions

- Namespaces group & isolate names in collections of classes and other “global” things (somewhat like Java packages)

# C

C does not provide any standard data structures  
we had to implement our own linked list and hash table  
as a C programmer, you often re-invent the wheel badly  
maybe if you're clever you'll use somebody else's libraries  
but, C's lack of abstraction, encapsulation, and generics means  
you'll probably have to tweak them, or tweak your code to use them

# C++

The C++ standard library is huge!

**generic containers:** bitset, queue, list, associative array (including hash table), deque, set, stack, and vector

and iterators for most of these

**a string class:** hides the implementation of strings

**streams:** allows you to stream data to and from objects, consoles, files, strings, and so on

and more...

# C

Error handling is a pain

- have to define error codes and return them

- customers have to understand error code conventions, and need to constantly test return values

- if **a**() calls **b**() calls **c**()

  - a** depends on **b** to propagate an error in **c** back to it

# C++

Supports exceptions!

try / throw / catch

if used with discipline, can simplify error processing

but, if used carelessly, can complicate memory management

consider: a( ) calls b( ) calls c( )

if c( ) throws an exception that b( ) doesn't catch, you might not get a chance to clean up resources allocated inside b( )

But much C++ code still needs to work with C & old C++ libraries, so still uses return codes, exit( ), etc.

# Some tasks still hurt in C++

## Memory management

C++ has no garbage collector

you have to manage memory allocation and deallocation, and track ownership of memory

it's still possible to have leaks, double frees, and so on

but, there are some things that help

“smart pointers”

classes that encapsulate pointers and track reference counts

deallocate memory when the reference count goes to zero

# Some tasks still hurt in C++

C++ doesn't guarantee type or memory safety

You can still...

- forcibly cast pointers between incompatible types

- walk off the end of an array and smash the stack (or heap)

- have dangling pointers

- conjure up a pointer to an address of your choosing

# C++ has many, many features.

## Operator overloading

your class can define methods for handling “+”, “->”, etc!

## Object constructors, destructors

particularly handy for stack-allocated objects

## Reference types

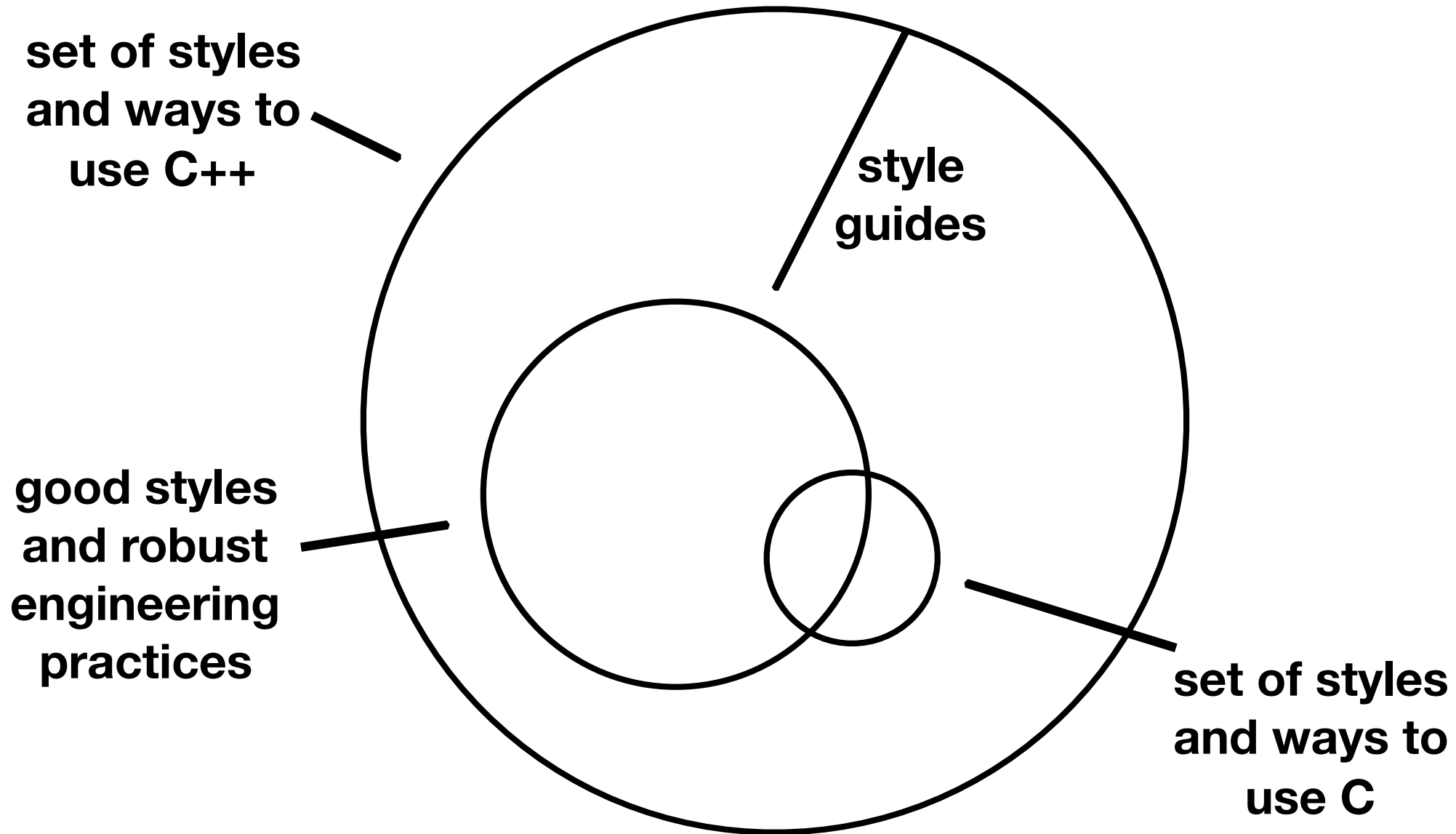
truly pass-by-reference instead of pass-by-value

## Advanced OO

multiple inheritance, virtual base classes, dynamic dispatch



# How to think about C++



Or...



**in the hands of a  
disciplined programmer,  
C++ is a powerful weapon**



**but, if you're not so  
disciplined about how  
you use C++...**

# Hello, world!

```
#include <iostream>
#include <cstdlib>
```

helloworld.cc

```
int main(int argc, char **argv) {
    std::cout << "Hello, World!" << std::endl;
    return EXIT_SUCCESS;
}
```

Looks simple enough...

compile with g++ instead of gcc:

```
g++ -Wall -g -std=c++11 -o helloworld helloworld.cc
```

let's walk through the program step by step

# Hello, world!

```
#include <iostream>
```

helloworld.cc

```
#include <cstdlib>
```

```
int main(int argc, char **argv) {  
    std::cout << "Hello, World!" << std::endl;  
    return EXIT_SUCCESS;  
}
```

iostream is part of the C++ standard library

note you don't include a ".h" when you include C++ standard library headers

but you do for local headers (e.g., #include "ll.h")

iostream declares stream object instances, including std::cin, std::cout, std::cerr, in the "std" namespace

# Hello, world!

```
#include <iostream>
```

helloworld.cc

```
#include <cstdlib>
```

```
int main(int argc, char **argv) {  
    std::cout << "Hello, World!" << std::endl;  
    return EXIT_SUCCESS;  
}
```

cstdlib is the C standard library's stdlib.h header

(nearly) all C standard library functions are available to you

for header <foo.h>, you should `#include <cfoo>`

we need it for EXIT\_SUCCESS, as usual

# Hello, world!

```
helloworld.cc
#include <iostream>
#include <cstdlib>

int main(int argc, char **argv) {
    std::cout << "Hello, World!" << std::endl;
    return EXIT_SUCCESS;
}
```

std::cout is the “cout” object instance declared by iostream, living within the “std” namespace (C++’s name for stdout)

std::cout is an object of class ostream

<http://www.cplusplus.com/reference/iostream/ostream/>

used to format and write output to the console

the entire standard library is in namespace std

# Hello, world!

```
#include <iostream>
#include <cstdlib>
```

helloworld.cc

```
int main(int argc, char **argv) {
    std::cout << "Hello, World!" << std::endl;
    return EXIT_SUCCESS;
}
```

C++ distinguishes between objects and primitive types

- primitive types include all the familiar ones from C
  - ▶ char, short, int, unsigned long, float, double, long double, etc.
  - ▶ and, C++ defines “bool” as a primitive type (woohoo!)

# Hello, world!

```
#include <iostream>
#include <cstdlib>

int main(int argc, char **argv) {
    std::cout << "Hello, World!" << std::endl;
    return EXIT_SUCCESS;
}
```

helloworld.cc

“<<” is an operator defined by the C++ language

it’s defined by C as well; in C/C++, it bitshifts integers

but, C++ allows **classes** to overload operators

the ostream class overloads “<<”

i.e., it defines *member functions* (methods) that are invoked when an ostream is the LHS of the << operator



# Hello, world!

```
helloworld.cc
#include <iostream>
#include <cstdlib>

int main(int argc, char **argv) {
    std::cout << "Hello, World!" << std::endl;
    return EXIT_SUCCESS;
}
```

ostream has many different functions to handle <<

the functions differ in the type of the RHS of <<

if you do `std::cout << "foo";`

C++ invokes cout's function to handle "<<" with RHS "char \*"

# Hello, world!

```
helloworld.cc
#include <iostream>
#include <cstdlib>

int main(int argc, char **argv) {
    std::cout << "Hello, World!" << std::endl;
    return EXIT_SUCCESS;
}
```

the ostream class's member functions that handle "<<" return (a reference to) themselves

so, when (std::cout << "Hello, World!") is evaluated:

a member function of the std::cout object is invoked

it buffers the string "Hello, World!" for the console

and, it returns (a reference to) std::cout

# Hello, world!

```
#include <iostream>
#include <cstdlib>
```

helloworld.cc

```
int main(int argc, char **argv) {
    std::cout << "Hello, World!" << std::endl;
    return EXIT_SUCCESS;
}
```

next, a member function on `std::cout` to handle “<<” is invoked

this time, the RHS is `std::endl`

turns out this is a pointer to a “manipulator” function

this manipulator function writes newline to the ostream it is invoked on, and then flushes the ostream’s buffer

so, something is printed on the console at this point

# Wow...

```
#include <iostream>
#include <cstdlib>
```

helloworld.cc

```
int main(int argc, char **argv) {
    std::cout << "Hello, World!" << std::endl;
    return EXIT_SUCCESS;
}
```

You should be surprised and scared at this point

C++ makes it easy to hide a significant amount of complexity

it's powerful, but really dangerous

once you mix together templates, operator overloading, method overloading, generics, and multiple inheritance, it gets really hard to know what's actually happening!

# Refining it a bit...

```
helloworld2.cc
#include <iostream>
#include <cstdlib>
#include <string>

using namespace std;

int main(int argc, char **argv) {
    string hello("Hello, World!");
    cout << hello << endl;
    return EXIT_SUCCESS;
}
```

C++'s standard library has a `std::string` class!

include the `<string>` header to use it

- <http://www.cplusplus.com/reference/string/>

# Refining it a bit...

```
helloworld2.cc
#include <iostream>
#include <cstdlib>
#include <string>
using namespace std;

int main(int argc, char **argv) {
    string hello("Hello, World!");
    cout << hello << endl;
    return EXIT_SUCCESS;
}
```

The “using” keyword introduces part of a namespace, or an entire namespace, into the current region

`using namespace std;` -- imports all names from `std::`

`using std::cout;` -- imports only `std::cout`

# Refining it a bit...

```
#include <iostream>                                helloworld2.cc
#include <cstdlib>
#include <string>

using namespace std;

int main(int argc, char **argv) {
    string hello("Hello, World!");
    cout << hello << endl;
    return EXIT_SUCCESS;
}
```

We're instantiating a `std::string` object *on the stack*  
passing the C string "Hello, World!" to its constructor method  
**hello** is deallocated (and its destructor invoked) when main returns

# Refining it a bit...

```
#include <iostream>                                helloworld2.cc
#include <cstdlib>
#include <string>

using namespace std;

int main(int argc, char **argv) {
    string hello("Hello, World!");
    cout << hello << endl;
    return EXIT_SUCCESS;
}
```

The C++ string library overloads the << operator as well

defines a function (not an object method) that is invoked when the LHS is an ostream and the RHS is a std::string

- ▶ [http://www.cplusplus.com/reference/string/operator<</a>](http://www.cplusplus.com/reference/string/operator<</)



# Refining it a bit...

```
helloworld2.cc
#include <iostream>
#include <cstdlib>
#include <string>

using namespace std;

int main(int argc, char **argv) {
    string hello("Hello, World!");
    cout << hello << endl;
    return EXIT_SUCCESS;
}
```

Note the side-effect of `using namespace std;`

can now refer to `std::string` by `string`, `std::cout` by `cout`, and `std::endl` by `endl`

# string concatenation

```
#include <iostream>
#include <cstdlib>
#include <string>
```

concat.cc

```
using namespace std;
```

```
int main(int argc, char **argv) {
    string hello("Hello");
    hello = hello + " there";
    cout << hello << endl;
    return EXIT_SUCCESS;
```

The string class overloads the “+” operator

creates and returns a new string that is the concatenation of LHS and RHS

# string assignment

```
#include <iostream>
#include <cstdlib>
#include <string>
```

concat.cc

```
using namespace std;
```

```
int main(int argc, char **argv) {
    string hello("Hello");
    hello = hello + " there";
    cout << hello << endl;
    return EXIT_SUCCESS;
}
```

The string class overloads the “=” operator

copies the RHS and replaces the string’s contents with it

so, the full statement (i) “+” creates a string that is the concatenation of hello’s current contents and “ there”, and (ii) “=” creates a copy of the concatenation to store in hello. Without the syntactic sugar it is:

```
hello.operator=(hello.operator+(" there"));
```

# stream manipulators

```
#include <iostream>
#include <cstdlib>
#include <iomanip>

using namespace std;

int main(int argc, char **argv) {
    cout << "Hi! " << setw(4) << 5 << " " << 5 << endl;
    cout << hex << 16 << " " << 13 << endl;
    cout << dec << 16 << " " << 13 << endl;
    return EXIT_SUCCESS;
}
```

helloworld3.cc

iomanip defines a set of stream manipulator functions

pass them to a stream to affect formatting

- ▶ <http://www.cplusplus.com/reference/iostream/manipulators/>

# stream manipulators

```
#include <iostream>
#include <cstdlib>
#include <iomanip>

using namespace std;

int main(int argc, char **argv) {
    cout << "Hi! " << setw(4) << 5 << " " << 5 << endl;
    cout << hex << 16 << " " << 13 << endl;
    cout << dec << 16 << " " << 13 << endl;
    return EXIT_SUCCESS;
}
```

helloworld3.cc

setw(x) sets the width of the next field to x

only affects the next thing sent to the output stream

# stream manipulators

```
#include <iostream>
#include <cstdlib>
#include <iomanip>

using namespace std;

int main(int argc, char **argv) {
    cout << "Hi! " << setw(4) << 5 << " " << 5 << endl;
    cout << hex << 16 << " " << 13 << endl;
    cout << dec << 16 << " " << 13 << endl;
    return EXIT_SUCCESS;
}
```

helloworld3.cc

hex sets the stream to output integers in hexadecimal

stays in effect until you set the stream to some other base

hex, dec, oct are your choices

# You can still use printf, though

helloworld4.cc

```
#include <stdio>
#include <stdlib>

int main(int argc, char **argv) {
    printf("hello from C\n");
    return EXIT_SUCCESS;
}
```

C is (roughly) a subset of C++

Can mix C and C++ idioms if needed to work with existing code, but avoid mixing if you can - use C++(11)

# Reading

```
#include <iostream>
#include <cstdlib>

using namespace std;

int main(int argc, char **argv) {
    int num;
    cout << "Type a number: ";
    cin >> num;
    cout << "You typed: " << num << endl;
    return EXIT_SUCCESS;
}
```

helloworld5.cc

std::cin is an object instance of class istream

supports the >> operator for “extraction”

cin also has a getline( ) method



# Exercise 1

Write a C++ program that:

- uses streams to:

  - prompts the user to type in 5 floats

  - prints them out in opposite order

  - with 4 digits of precision

See you on Monday!