CSE 333

Lecture 9 - intro to C++

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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 is it done like this" from reference docs

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

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 rich!

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 and 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

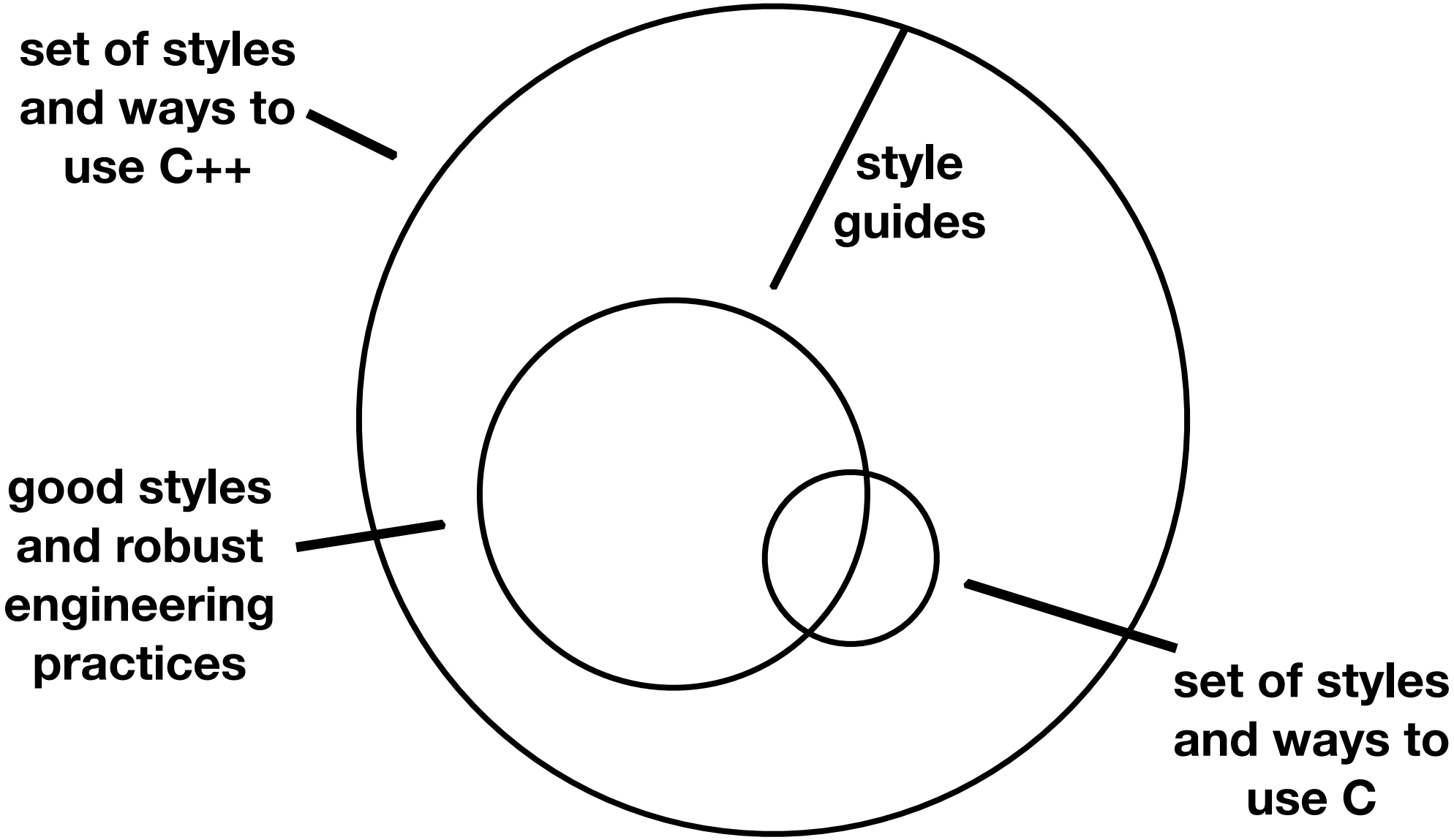
Reference types

- 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!

helloworld.cc

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

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!

helloworld.cc

```
#include <iostream>
#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!

helloworld.cc

```
#include <iostream>
#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!

helloworld.cc

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

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!

helloworld.cc

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

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

"<<" 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 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 methods to handle <<

the methods differ in the type of the RHS of <<

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

C++ invokes cout's method 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 methods that handle "<<" return (a reference to) themselves

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

a method 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!

helloworld.cc

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

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

next, a method 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...

helloworld.cc

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

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...

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;
}
```

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...

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 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<</

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

concat.cc

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

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

concat.cc

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

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

helloworld3.cc

```
#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;
}
```

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

helloworld3.cc

```
#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;
}
```

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

- only affects the next thing sent to the output stream

stream manipulators

helloworld3.cc

```
#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;
}
```

`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 <cstdio>
#include <cstdlib>

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

helloworld5.cc

```
#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;
}
```

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 Wednesday!