CSE 374
Programming Concepts & Tools

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Lecture 19 – Introduction to C++

C++

C++ is an enormous language:

- All of C
- Classes and objects (kind of like Java, some crucial differences)
- Many more little conveniences (I/O, new/delete, function overloading, pass-by-reference, bigger standard library)
- Namespaces (kind of like Java packages)
- Stuff we won't do: const, different kinds of casts, exceptions, templates, multiple inheritance, …
- We will focus on a couple themes rather than just a "big bag of new features to memorize" …

Our focus

Object-oriented programming in a C-like language may help you understand C and Java better?

- We can put objects on the stack or the heap; an object is not a pointer to an object
- Still have to manage memory manually
- Still lots of ways to HCBWKMSCOD*
- Still distinguish header files from implementation files
- Allocation and initialization still separate concepts, but easier to “construct” and “destruct”
- Programmer has more control on how method-calls work (different defaults from Java)

*hopefully crash, but who knows – might silently corrupt other data

Hello World

```
#include <iostream>
int main() {
   // Use standard output stream cout
   // and operator << to send "Hello World"
   // and an end line to stdout
   std::cout << "Hello World" << std::endl;
   return 0;
}
```

- Differences from C: “new-style” headers (no .h), namespace access (::), I/O via stream operators, …
- Differences from Java: not everything is in a class, any code can go in any file, …
  - Can write procedural programs if that’s what you want

Compiling

- Need a different compiler than for C; use g++ on Linux. Example:

  g++ -Wall -o hello hello.cc

- The .cc extension is a convention (just like .c for C), but less universal (also see .cpp, .cxx, .C).
- Uses the C preprocessor (no change there).
- Now: A few “niceties” before our real focus (classes and objects).

I/O

- Operator << takes a “ostream” and (various things) and outputs it; returns the stream, which is why this works:

  std::cout << 3 << "hi" << f(x) << ’\n’;

  – Easier and safer than printf (type safe)
- Operator >> takes “istream” and (various things) and inputs into it.
  – Easier and safer than scanf. Do not use pointers; e.g.,

    int x; std::cin >> x;
- Can “think of” >> and << as keywords, but they are not:
  – Operator overloading redefines them for different pairs of types.
    - In C and core C++ they mean “left-shift” and “right-shift” (of bits); undefined for non-numeric types.
  – Lack of address-of for input done with call-by-reference (coming soon).

Namespaces

- In C, all non-static functions in the program need different names
  - Even operating systems with tens of millions of lines.
- Namespaces (cf. Java packages) let you group top-level names:

  namespace thespace { ... definitions ... }
  - Of course, then different namespaces can have the same function names and they are totally different functions.
  - Can nest them
  - Can reuse the same namespace in multiple places
    - Particularly common: in the .h and the .cc
- Example, the whole C++ standard library is in namespace std.
- To use a function/variable/etc. in another namespace, do

  thespace::someFun() (not . like in Java)

Using

- To avoid having to always write namespaces and :: use a *using declaration*
- Example:

```
#include <iostream>
using namespace std;
int main() {
  cout << "Hello World" << endl;
  return 0;
}
```

Onto Classes and Objects

Like Java:

- Fields vs. methods, static vs. instance, constructors
- Method overloading (functions, operators, and constructors too)

Not quite like Java:

- access-modifier (e.g., private) syntax and default
- declaration separate from implementation (like C)
- funny constructor syntax, default parameters (e.g., ... = 0)

Nothing like Java:

- Objects vs. pointers to objects
- Destructors and copy-constructors
- virtual vs. non-virtual (to be discussed)

Stack vs. heap

- Java: cannot stack-allocate an object (only a pointer to one; all objects are dynamically allocated on the heap).
- C: can stack-allocate a struct, then initialize it.
- C++: stack-allocate and call a constructor (where *this* is the object's address, as always, except *this* is a pointer)

  Thing t(10000);
- Java: new Thing(...) calls constructor, returns heap-allocated pointer.
- C: Use malloc and then initialized, must free exactly once later, untyped pointers.
- C++: Like Java, new Thing(…), but can also do new int(42). Like C must deallocate, but must use delete instead of free.

Destructors

- An object's destructor is called just before the space for it is reclaimed.
- A common use: Reclaim space for heap-allocated things pointed to (first calling their destructors).
  - But not if there are other pointers to it (aliases)?!
- Meaning of delete x: call the destructor of pointed-to heap object, then reclaim space.
- Destructors also get called for stack-objects (when they leave scope).
- Advice: Always make destructors virtual (learn why soon)

Arrays

Create a heap-allocated array of objects: new A[10];

- Calls *default* (zero-argument) constructor for each element.
- Convenient if there's a good default initialization.

Create a heap-allocated array of pointers to objects: new A*[10]

- More like Java (but not initialized?)
- As in C, new A() and new A[10] have type A*.
- new A* and new A*[10] both have type A**.
- Unlike C, to delete a non-array, you must write delete e
- Unlike C, to delete an array, you must write delete [ ] e
- Else HYCSBWK – the deleter must know somehow what is an array.

Digression: Call-by-reference

- In C, we know function arguments are copies
  - But copying a pointer means you still point to the same (uncopied) thing
- Same in C++, but a “reference parameter” (the & character after it) is different.
- Callee writes: void f(int& x) { x = x + 1; }
- Caller writes: f(y)
- But it’s as though the caller wrote f(&y) and everywhere the callee said x they really said *x.
- So that little & has a big meaning.

Copy Constructors

- In C, we know x=y or f(y) copies y (if a struct, then member-wise copy).
- Same in C++, unless a copy-constructor is defined, then do whatever the copy-constructor says.
- A copy-constructor by definition takes a reference parameter (else we'd need to copy, but that's what we're defining) of the same type.
- Let's not talk about the const.
  - OK, well maybe a little

const

- const can appear in many places in C++ code
  - Basically means “doesn’t change” or “won’t change”, but there are subtleties
  - Good reference for const and much other C++ : *Effective C++*, Scott Meyers, A-W, 3rd ed, 2005
- Examples:

```
const int default_length = 125;  // don’t use #define
void examine (const thing &t);   // won’t change t
```

- “const correctness” is important in real C++ code
  - Learn it if you do any non-trivial C++

Still to come

- So far we have classes and objects (class instances)
  - Enough for many interesting types, particularly small concrete types like strings, complex, date, time, etc.
- For full object-oriented programming we still need (and have) subclassing, inheritance, and related things
  - Many similarities with Java, but more options and different defaults