CSE 333

Lecture 10 - references, const, classes

Hal Perkins

Department of Computer Science & Engineering

University of Washington
Administrivia

Yet another exercise out today, due Friday morning

Section this week: C++, const / references / classes

Additional new office hours on Tue. and Wed. afternoons

See web front page and calendar for details
Today’s goals

Useful C++ features
  references, const

Introducing C++ classes
  defining, using them
Reminder: pointers

C: a pointer is a variable containing an address
you can change its value to change what it is pointing to
a pointer can contain the address of a different variable

```c
int main(int argc, char **argv) {
    int x = 5, y = 10;
    int *z = &x;

    *z += 1;    // sets x to 6
    x += 1;    // sets x (and therefore *z) to 7

    z = &y;    // sets z to the address of y
    *z += 1;    // sets y (and therefore *z) to 11

    return EXIT_SUCCESS;
}
```

```
int | 5
---|---
char| ?
```
Reminder: pointers

C: a pointer is a variable containing an address

you can change its value to change what it is pointing to

a pointer can contain the address of a different variable

```cpp
int main(int argc, char **argv) {
    int x = 5, y = 10;
    int *z = &x;

    *z += 1; // sets x to 6
    x += 1; // sets x (and therefore *z) to 7

    z = &y; // sets z to the address of y
    *z += 1; // sets y (and therefore *z) to 11

    return EXIT_SUCCESS;
}
```

```plaintext
x | 5
y | 10
z | 0xbfff2d4
```
Reminder: pointers

C: a pointer is a variable containing an address

you can change its value to change what it is pointing to

a pointer can contain the address of a different variable

```c
int main(int argc, char **argv) {
    int x = 5, y = 10;
    int *z = &x;

    *z += 1;  // sets x to 6
    x += 1;   // sets x (and therefore *z) to 7

    z = &y;   // sets z to the address of y
    *z += 1;  // sets y (and therefore *z) to 11

    return EXIT_SUCCESS;
}
```

```c
x | 6
y | 10
z | 0xbfff2d4
```
Reminder: pointers

C: a pointer is a variable containing an address

you can change its value to change what it is pointing to

a pointer can contain the address of a different variable

```cpp
int main(int argc, char **argv) {
    int x = 5, y = 10;
    int *z = &x;

    *z += 1; // sets x to 6
    x += 1;  // sets x (and therefore *z) to 7

    z = &y;  // sets z to the address of y
    *z += 1; // sets y (and therefore *z) to 11

    return EXIT_SUCCESS;
}
```

x 7
y 10
z 0xbfff2d4
Reminder: pointers

C: a pointer is a variable containing an address

you can change its value to change what it is pointing to

a pointer can contain the address of a different variable

```c
int main(int argc, char **argv) {
    int x = 5, y = 10;
    int *z = &x;

    *z += 1;  // sets x to 6
    x += 1;   // sets x (and therefore *z) to 7

    z = &y;   // sets z to the address of y
    *z += 1;  // sets y (and therefore *z) to 11

    return EXIT_SUCCESS;
}
```

```c
int x = 7
int y = 10
int *z = 0xbff1f2d0
```
Reminder: pointers

C: a pointer is a variable containing an address

you can change its value to change what it is pointing to

a pointer can contain the address of a different variable

```cpp
int main(int argc, char **argv) {
  int x = 5, y = 10;
  int *z = &x;

  *z += 1;  // sets *z (and therefore x) to 6
  x += 1;   // sets x (and therefore *z) to 7

  z = &y;   // sets z to the address of y
  *z += 1;  // sets *z (and therefore y) to 11

  return EXIT_SUCCESS;
}
```
References

C++: introduces references as part of the language

a reference is an alias for some other variable

alias: another name that is bound to the aliased variable

mutating a reference is mutating the referenced variable

```c
int main(int argc, char **argv) {
    int x = 5, y = 10;
    int &z = x;  // binds the name "z" to variable x
    z += 1;     // sets z (and thus x) to 6
    x += 1;     // sets x (and thus z) to 7
    z = y;      // sets z (and thus x) to the value of y
    z += 1;     // sets z (and thus x) to 11
    return EXIT_SUCCESS;
}
```
References

C++: introduces references as part of the language

a reference is **an alias** for some other variable

**alias:** another name that is bound to the aliased variable

mutating a reference **is** mutating the referenced variable

```cpp
int main(int argc, char **argv) {
    int x = 5, y = 10;
    int &z = x; // binds the name "z" to variable x
    
z += 1; // sets z (and thus x) to 6
x += 1; // sets x (and thus z) to 7
    
z = y; // sets z (and thus x) to the value of y
z += 1; // sets z (and thus x) to 11
    
    return EXIT_SUCCESS;
}
```

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>5</td>
</tr>
<tr>
<td>z</td>
<td></td>
</tr>
<tr>
<td>y</td>
<td>10</td>
</tr>
</tbody>
</table>

reference1.cc
References

C++: introduces references as part of the language

a reference is an alias for some other variable

alias: another name that is bound to the aliased variable

mutating a reference is mutating the referenced variable

```cpp
int main(int argc, char **argv) {
    int x = 5, y = 10;
    int &z = x;  // binds the name "z" to variable x
    z += 1;    // sets z (and thus x) to 6
    x += 1;    // sets x (and thus z) to 7
    z = y;     // sets z (and thus x) to the value of y
    z += 1;    // sets z (and thus x) to 11
    return EXIT_SUCCESS;
}
```

x, z | 6
---|--
y | 10

reference1.cc
References

C++: introduces references as part of the language

a reference is **an alias** for some other variable

**alias:** another name that is bound to the aliased variable

mutating a reference **is** mutating the referenced variable

```c
int main(int argc, char **argv) {
    int x = 5, y = 10;
    int &z = x;  // binds the name "z" to variable x
    z += 1;     // sets z (and thus x) to 6
    x += 1;     // sets x (and thus z) to 7
    z = y;      // sets z (and thus x) to the value of y
    z += 1;     // sets z (and thus x) to 11
    return EXIT_SUCCESS;
}
```

x, z | 7
--- | ---
y   | 10

reference1.cc
References

C++: introduces references as part of the language

a reference is an alias for some other variable

alias: another name that is bound to the aliased variable

mutating a reference is mutating the referenced variable

```cpp
int main(int argc, char **argv) {
    int x = 5, y = 10;
    int &z = x;  // binds the name "z" to variable x

    z += 1;     // sets z (and thus x) to 6
    x += 1;     // sets x (and thus z) to 7

    z = y;      // sets z (and thus x) to the value of y
    z += 1;     // sets z (and thus x) to 11

    return EXIT_SUCCESS;
}
```

x, z | 10
---|---
y | 10

reference1.cc
References

C++: introduces references as part of the language

a reference is **an alias** for some other variable

**alias:** another name that is bound to the aliased variable

mutating a reference **is** mutating the referenced variable

```c
int main(int argc, char **argv) {
    int x = 5, y = 10;
    int &z = x;  // binds the name "z" to variable x
    z += 1;     // sets z (and thus x) to 6
    x += 1;     // sets x (and thus z) to 7
    z = y;      // sets z (and thus x) to the value of y
    z += 1;     // sets z (and thus x) to 11
    return EXIT_SUCCESS;
}
```

```
\begin{tabular}{|c|c|}
\hline
x, z & 11 \\
\hline
y & 10 \\
\hline
\end{tabular}
```
Pass by reference

C++ allows you to truly pass-by-reference

client passes in an argument with normal syntax

function uses reference parameters with normal syntax

modifying a reference parameter modifies the caller’s argument

```cpp
void swap(int &x, int &y) {
    int tmp = x;
    x = y;
    y = tmp;
}

int main(int argc, char **argv) {
    int a = 5, b = 10;

    swap(a, b);
    cout << "a: " << a << "; b: " << b << endl;
    return EXIT_SUCCESS;
}
```

```
(main) a  5
(main) b  10
```
Pass by reference

C++ allows you to truly pass-by-reference

client passes in an argument with normal syntax

function uses reference parameters with normal syntax

modifying a reference parameter modifies the caller’s argument

```cpp
#include <iostream>

void swap(int &x, int &y) {
    int tmp = x;
    x = y;
    y = tmp;
}

int main(int argc, char **argv) {
    int a = 5, b = 10;
    swap(a, b);
    cout << "a: " << a << " b: " << b << endl;
    return EXIT_SUCCESS;
}
```

```bash
CSE333 lec 10 C++2 // 04-19-17 // Perkins
```

```
(main) a
5

(main) b
10
```
Pass by reference

C++ allows you to truly pass-by-reference

client passes in an argument with normal syntax

function uses reference parameters with normal syntax

modifying a reference parameter modifies the caller’s argument

```cpp
void swap(int &x, int &y) {
    int tmp = x;
    x = y;
    y = tmp;
}

int main(int argc, char **argv) {
    int a = 5, b = 10;

    swap(a, b);
    cout << "a: " << a << " b: " << b << endl;
    return EXIT_SUCCESS;
}
```

passbyreference.cc
Pass by reference

C++ allows you to truly pass-by-reference

client passes in an argument with normal syntax

function uses reference parameters with normal syntax

modifying a reference parameter modifies the caller’s argument

```cpp
void swap(int &x, int &y) {
    int tmp = x;
    x = y;
    y = tmp;
}

int main(int argc, char **argv) {
    int a = 5, b = 10;
    swap(a, b);
    cout << "a: " << a << "; b: " << b << endl;
    return EXIT_SUCCESS;
}
```

```
(swap) tmp  5
(main) a  5
(swap) x  5
(main) b  10
(swap) y  10
```
Pass by reference

C++ allows you to truly pass-by-reference

client passes in an argument with normal syntax

function uses reference parameters with normal syntax

modifying a reference parameter modifies the caller’s argument

```cpp
void swap(int &x, int &y) {
    int tmp = x;
    x = y;
    y = tmp;
}

int main(int argc, char **argv) {
    int a = 5, b = 10;

    swap(a, b);
    cout << "a: " << a << "; b: " << b << endl;
    return EXIT_SUCCESS;
}
```

passbyreference.cc

CSE333 lec 10 C++.2 // 04-19-17 // Perkins
Pass by reference

C++ allows you to truly pass-by-reference

client passes in an argument with normal syntax

function uses reference parameters with normal syntax

modifying a reference parameter modifies the caller’s argument

```cpp
void swap(int &x, int &y) {
    int tmp = x;
    x = y;
    y = tmp;
}

int main(int argc, char **argv) {
    int a = 5, b = 10;

    swap(a, b);
    cout << "a: " << a << " b: " << b << endl;
    return EXIT_SUCCESS;
}
```

passbyreference.cc
Pass by reference

C++ allows you to truly pass-by-reference

client passes in an argument with normal syntax

function uses reference parameters with normal syntax

modifying a reference parameter modifies the caller’s argument

```cpp
void swap(int &x, int &y) {
    int tmp = x;
    x = y;
    y = tmp;
}

int main(int argc, char **argv) {
    int a = 5, b = 10;

    swap(a, b);
    cout << "a: " << a << "; b: " << b << endl;
    return EXIT_SUCCESS;
}
```

<table>
<thead>
<tr>
<th>(main) a</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>(main) b</td>
<td>5</td>
</tr>
</tbody>
</table>
**const**: cannot be changed

used much more in C++ than in C

```cpp
void BrokenPrintSquare(const int &i) {
    i = i*i;  // Compiler error here!
    std::cout << i << std::endl;
}

int main(int argc, char **argv) {
    int j = 2;
    BrokenPrintSquare(j);
    return EXIT_SUCCESS;
}
```

brokenpassbyrefconst.cc
const

const’s syntax is confusing

```c
int main(int argc, char **argv) {
    int x = 5;       // x is an int
    const int y = 6; // y is a (const int)
    y++;            // compiler error

    const int *z = &y;  // z is a (variable pointer) to a (const int)
    *z += 1;         // compiler error
    z++;             // ok

    int *const w = &x; // w is a (const pointer) to a (variable int)
    *w += 1;         // ok
    w++;             // compiler error

    const int *const v = &x; // v is a (const pointer) to a (const int)
    *v += 1;         // compiler error
    v++;             // compiler error

    return EXIT_SUCCESS;
}
```

constmadness.cc
style guide tip

use const reference parameters for input values
particularly for large values

use pointers for output parameters

input parameters first, then output parameters last

```c
#include <cstdlib>

void CalcArea(const int &width, const int &height, int *const area) {
    *area = width * height;
}

int main(int argc, char **argv) {
    int w = 10, h = 20, a;

    CalcArea(w, h, &a);
    return EXIT_SUCCESS;
}
```

styleguide.cc
When to use references?

A stylistic choice

not something mandated by the C++ language

Google C++ style guide suggests:

input parameters:

either use values (for primitive types like int or small structs/objects)

or use const references (for complex structs / object instances)

output parameters

use const pointers (i.e., unchangeable pointers referencing changeable data – see previous slide)
virality of const

**OK to pass**
- a pointer to non-const
to a function that expects
  a pointer to const

**not OK to pass**
- a pointer to a const
to a function that expects
  a pointer to a non-const

```cpp
#include <iostream>

void foo(const int *y) {
    std::cout << *y << std::endl;
}

void bar(int *y) {
    std::cout << *y << std::endl;
}

int main(int argc, char **argv) {
    const int a = 10;
    int b = 20;

    foo(&b);    // OK
    bar(&a);    // not OK

    return 0;
}
```
Classes

class declaration syntax  (in a .h file)

```cpp
class Name {
    public:
        members;
    private:
        members;
};
```

class member definition syntax  (in a .cc file)

```cpp
returntype classname::methodname(parameters) {
    statements;
}
```

You can name your .cc, .h file anything (unlike Java)
- typically name them Classname.cc, Classname.h
#ifndef _POINT_H_
define _POINT_H_

class Point {
  public:
    Point(const int x, const int y); // constructor
    int get_x() const { return x_; } // inline member function
    int get_y() const { return y_; } // inline member function
    double Distance(const Point &p) const; // member function
    void SetLocation(const int x, const int y); // member function

  private:
    int x_; // data member
    int y_; // data member
}; // class Point

#undef _POINT_H_
}
```cpp
#include <cmath>
#include "Point.h"

Point::Point(const int x, const int y) {
    x_ = x;
    this->y_ = y;  // "this->" is optional, unless names conflict
}

double Point::Distance(const Point &p) const {
    // We can access p’s x_ and y_ variables either through the
    // get_x(), get_y() accessor functions, or the x_, y_ private
    // member variables directly, since we’re in a member
    // function of the same class.
    double distance = (x_ - p.get_x()) * (x_ - p.get_x());
    distance += (y_ - p.y_) * (y_ - p.y_);
    return sqrt(distance);
}

void Point::SetLocation(const int x, const int y) {
    x_ = x;
    y_ = y;
}
```

#include <iostream>
#include "Point.h"

using namespace std;

int main(int argc, char **argv){
    Point p1(1, 2);  // stack allocate a new Point
    Point p2(4, 6);  // stack allocate a new Point

    cout << "p1 is: (" << p1.get_x() << ", ";
    cout << p1.get_y() << ")" << endl;

    cout << "p2 is: (" << p2.get_x() << ", ";
    cout << p2.get_y() << ")" << endl;

    cout << "dist : " << p1.Distance(p2) << endl;
    return 0;
}
struct vs. class

in C

- a struct contains only fields
  - cannot contain methods
  - does not have public vs. private vs. protected

in C++

- struct and class are (nearly) the same
  - both can contain methods
  - both can have public vs. private vs. protected

struct: default public, class: default private

common style convention: structs for simple bundles of data (maybe with convenience constructors); classes for abstractions with data + functions
Reading Assignment

Before next class: read sections in C++ *Primer* covering constructors, copy constructors, assignment (operator=), and destructors

Ignore “move semantics” for now

The table of contents and index are your friends…
Exercise 1

Write a C++ program that:

- has a class representing a 3-dimensional point
- has the following methods:
  - return the inner product of two 3d points
  - return the distance between two 3d points
  - accessors and mutators for the x, y, z coordinates
Exercise 2

Write a C++ program that:

has a class representing a 3-dimensional box

use your exercise 1 class representing 3d points to store the coordinates of the vertices that define it

assume the box has right-angles only and its faces are parallel to the axes, so you only need two vertices to define it

has the following methods:

test if one box is inside another box

return the volume of a box

handles "<<", "=" , and a copy constructor

uses const in all the right places
See you on Friday!