C++ References, Const, Classes
CSE 333 Winter 2024

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Administrivia

- ❖ No new exercise today – get ahead on hw2; longer exercise coming Friday, due Monday morning

- ❖ Sections this week: makefiles, then C++ classes, references, const

- ❖ Homework 2 due next Thursday (2/1)
  - ▪ Note: `libhw1.a` (yours or ours) needs to be in correct directory (`hw1/`) for hw2 to build
  - ▪ Use Ctrl-D (eof) on a line by itself to exit `searchshell`; must free all allocated memory
  - ▪ Test on directory of small self-made files where you can predict the data structures and then check them
  - ▪ Valgrind takes a *long* time on the full test_tree. Try using enron docs only or other small test data directory for quick checks.

Lecture Outline

❖ **C++ References**

❖ `const` in C++

❖ C++ Classes Intro

Pointers Reminder

❖ A **pointer** is a variable containing an address

- Modifying the pointer *doesn't* modify what it points to, but you can access/modify what it points to by *dereferencing*

- These work the same in C and C++

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

  *z += 1;
  x += 1;

  z = &y;
  *z += 1;

  return EXIT_SUCCESS;
}
```
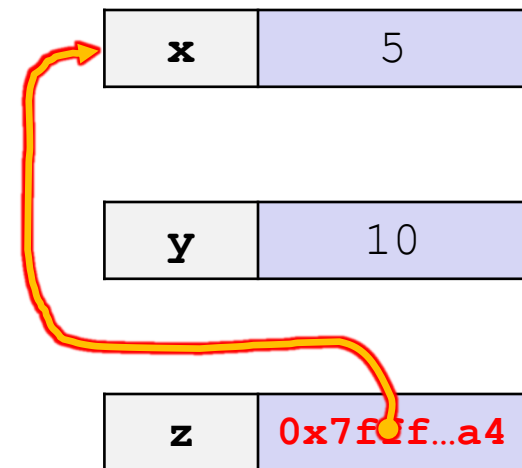
x	5

y	10

z	

pointer.cc

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

  *z += 1;
   x += 1;

   z = &y;
  *z += 1;

  return EXIT_SUCCESS;
}
```
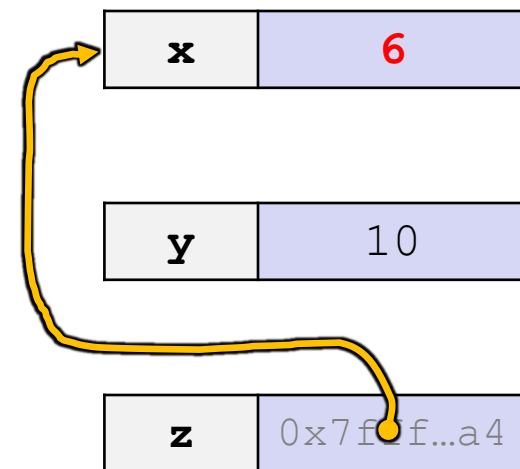
x	5

y	10

z	0x7f2f…a4

pointer.cc

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- These work the same in C and C++

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

  *z += 1;   // sets x to 6
   x += 1;

   z = &y;
  *z += 1;

  return EXIT_SUCCESS;
}
```

x	6

y	10

z	0x7f f…a4

pointer.cc
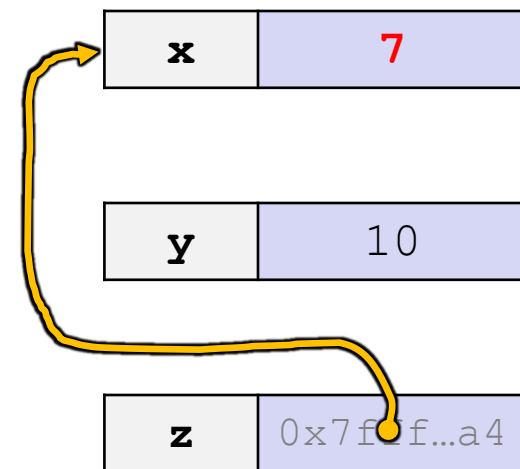
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Pointers Reminder

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  - These work the same in C and 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 *z) to 7

   z = &y;
  *z += 1;

  return EXIT_SUCCESS;
}
```

x	7

y	10

z	0x7f f...a4

pointer.cc

Pointers Reminder

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- These work the same in C and 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 *z) to 7

   z = &y;   // sets z to the address of y
  *z += 1;

  return EXIT_SUCCESS;
}
```

x	7

y	10

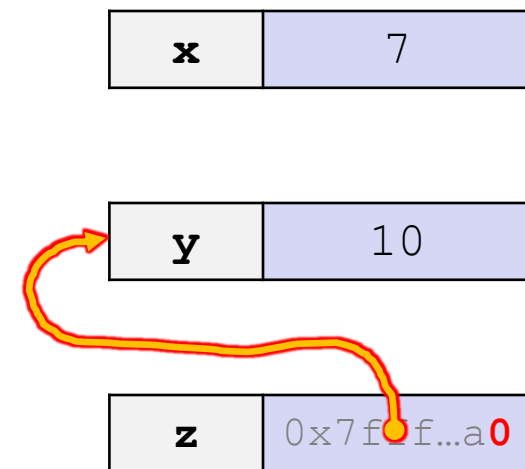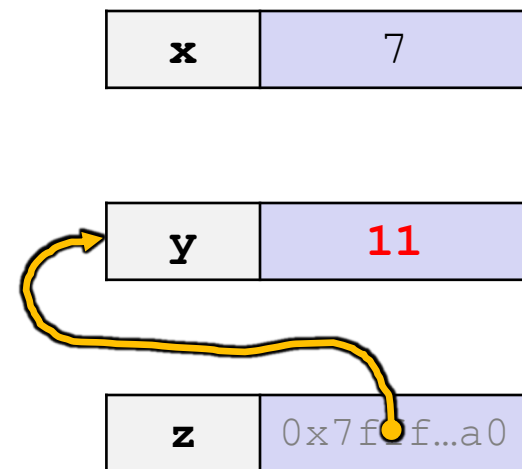| z	0x7f f…a0

pointer.cc

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Pointers Reminder

❖ A **pointer** is a variable containing an address
  ▪ Modifying the pointer *doesn't* modify what it points to, but you can access/modify what it points to by *dereferencing*
  ▪ These work the same in C and 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 *z) to 7

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

  return EXIT_SUCCESS;
}
```

x	7

y	11

z	0x7f…f…a0

pointer.cc

References

❖ A **reference** is an alias for another variable

  ▪ *Alias*: another name that is bound to the aliased variable

    • Mutating a reference *is* mutating the aliased variable

  ▪ Introduced in C++ as part of the language

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

  z += 1;
  x += 1;

  z  = y;
  z += 1;

  return EXIT_SUCCESS;
}
```

x	5

y	10

reference.cc

References

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- Introduced in C++ as part of the language

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

  z += 1;
  x += 1;

  z  = y;
  z += 1;

  return EXIT_SUCCESS;
}
```

x, **z**	5

y	10

reference.cc

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References

Note: Arrow points to *next* instruction.

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

  z  = y;
  z += 1;


  return EXIT_SUCCESS;
}
```

x, z	6

y	10

reference.cc

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

  z  = y;
  z += 1;

  return EXIT_SUCCESS;
}
```

x, z	7

y	10

reference.cc

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References

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  int x = 5, y = 10;
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  z += 1;  // sets z (and x) to 6
  x += 1;  // sets x (and z) to 7

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

  return EXIT_SUCCESS;
}
```

x, z	10

y	10

reference.cc

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References

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

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

  return EXIT_SUCCESS;
}
```

x, z	11

y	10

reference.cc

Pass-By-Reference

- ❖ C++ allows you to use real 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

passbyreference.cc

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Pass-By-Reference

❖ C++ allows you to use real 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!

```
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** (swap) **x**	5

(main) **b** (swap) **y**	10

(swap) **tmp**	

passbyreference.cc

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Pass-By-Reference

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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** (swap) **x**	5

(main) **b** (swap) **y**	10

(swap) **tmp**	**5**

passbyreference.cc

Pass-By-Reference

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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** (swap) **x**	**10**

(main) **b** (swap) **y**	10

(swap) **tmp**	5

passbyreference.cc

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Pass-By-Reference

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  ▪ Client passes in an argument with normal syntax

    • Function uses reference parameters with normal syntax

    • Modifying a reference parameter modifies the caller's argument!

```
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** (swap) **x**	10

(main) **b** (swap) **y**	**5**

(swap) **tmp**	5

passbyreference.cc

Pass-By-Reference

❖ C++ allows you to use real 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**	10

(main) **b**	5

passbyreference.cc

Lecture Outline

- ❖ C++ References
- ❖ **`const` in C++**
- ❖ C++ Classes Intro

const

❖ `const`: this cannot be changed/mutated

- Used *much* more in C++ than in C

- Signal of intent to compiler; meaningless at hardware level

  - Results in compile-time errors

```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` and Pointers

- ❖ Pointers can change data in two different contexts:
  1) You can change the value of the pointer (what it points to)
  2) You can change the thing the pointer points to (via dereference)

- ❖ `const` can be used to prevent either/both of these behaviors!
  - `const` next to pointer name means you can't change the value of the pointer
  - `const` next to data type pointed to means you can't use this pointer to change the thing being pointed to
  - <u>Tip</u>: read variable declaration from *right-to-left*

const and Pointers

❖ The syntax with pointers is confusing:

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

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

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

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

  return EXIT_SUCCESS;
}
```

constmadness.cc

`const` Parameters

- A `const` parameter *cannot* be mutated inside the function
  - Therefore it does not matter if the argument can be mutated or not

- A non-`const` parameter *could* be mutated inside the function
  - It would be BAD if you could pass it a `const` var
  - Illegal regardless of whether *or not* the function actually tries to change the var

```cpp
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(&a);    // OK
  foo(&b);    // OK
  bar(&a);    // not OK – error
  bar(&b);    // OK

  return EXIT_SUCCESS;
}
```

Google Style Guide Convention

❖ Use `const` references or call-by-value for input values

  ▪ Particularly for large values, use references (no copying)

❖ Use pointers for output parameters

❖ List input parameters first, then output parameters last

```cpp
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;
}
```

ordinary int (not int&) probably better here, but shows how const ref can be used

styleguide.cc

When to Use References?

❖ A stylistic choice, not 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 struct/object instances)
  - Output parameters:
    - Use `const` pointers
      - Unchangeable pointers referencing changeable data

Lecture Outline

❖ C++ References

❖ `const` in C++

❖ **C++ Classes Intro**

Classes

❖ Class definition syntax (in a .h file):

```
class Name {
 public:
   // public member declarations & definitions go here

 private:
   // private member delarations & definitions go here
};   // class Name
```

- Members can be functions (methods) or data (variables)

❖ Class member function definition syntax (in a .cc file):

```
retType Name::MethodName(type1 param1, …, typeN paramN) {
   // body statements
}
```

- (1) *define* within the class definition or (2) *declare* within the class definition and then *define* elsewhere

Class Organization

❖ It's a little more complex than in C when modularizing with `struct` definition:

- Class definition is part of interface and should go in `.h` file
  - Private members still must be included in definition (**!**)
- Usually put member function definitions into companion `.cc` file with implementation details
  - Common exception: setter and getter methods
- These files can also include non-member functions that use the class (more about this later)

❖ Unlike Java, you can name files anything you want

- But normally `Name.cc` and `Name.h` for `class Name`

Class Definition (`.h` file)

Point.h

```cpp
#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

#endif  // _POINT_H_
```

Class Member Definitions (`.cc` file)

Point.cc

```cpp
#include <cmath>
#include "Point.h"

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

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;
}
```

Class Usage (`.cc` file)

usepoint.cc

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

using namespace std;

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

  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;
}
```

Reading Assignment

❖ Before next time, you **must *read*** the sections in *C++ Primer* covering class constructors, copy constructors, assignment (`operator=`), and destructors

▪ Ignore "move semantics" for now

▪ The table of contents and index are your friends…

▪ Should we start class with a "quiz" next time?

• Topic: if we write C x = y; or C x(y); or x=y; or C x; , which is called: (i) constructor, (ii) copy constructor, (iii) assignment operator, …

▪ Seriously – the next lecture will make a ***lot*** more sense if you've done some background reading ahead of time

• Don't worry whether it all makes sense the first time you read it – it won't! The goal is to be aware of what the main issues are….

Extra 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, and z coordinates

Extra Exercise #2

❖ Write a C++ program that:

▪ Has a class representing a 3-dimensional box

  • Use your Extra Exercise #1 class to store the coordinates of the vertices that define the box

  • Assume the box has right-angles only and its faces are parallel to the axes, so you only need 2 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