C++ References, Const, Classes
CSE 333 Summer 2018

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Administrivia

- Exercise 9 released today, due Friday

- Homework 2 due next Thursday (7/19)
  - File system crawler, indexer, and search engine
  - **Note**: `libhw1.a` (yours or ours) needs to be in right directory
  - **Demo**: use Ctrl-D to exit `searchshell`, test on directory of small self-made files
  - Valgrind takes a *long* time on the full test_tree. Try using enron docs only or other small test data directory
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++

```c
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;
}
```

**Note**: Arrow points to *next* instruction.
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```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;
}
```

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```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;
}
```

**Note:** Arrow points to next instruction.
Points Reminder

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  - 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++

```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;
}
```

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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;
}
```

**Note:** Arrow points to next instruction.

```
x 7
y 11
z 0x7f...a0
```
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

```c
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;
}
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```c
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;
}
```

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

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

**Note**: Arrow points to next instruction.
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!

```c++
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;
}
```

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    int tmp = x;
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    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;
}
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Note: Arrow points to next instruction.

Pass-By-Reference.cc
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    cout << "a: " << a << " b: " << b << endl;
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int main(int argc, char** argv) {
    int a = 5, b = 10;

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

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    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;
}
```

**Note:** Arrow points to next instruction.

```plaintext
(main) a         10
(swap) x         10
(main) b         5
(swap) y         5
(swap) tmp       5
```
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;
}
```

Note: Arrow points to next instruction.
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
  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
  - **Tip:** read variable declaration from *right-to-left*
const and Pointers

- The syntax with pointers is confusing:

```c
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;
}
```
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 *may* be mutated inside the function
  - It would be BAD if you passed it a `const` variable

```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
    bar(&b);    // OK

    return EXIT_SUCCESS;
}
```
Style Guide Tip

- Use `const` reference parameters for input values
  - Particularly for large values (no copying)
- Use pointers for output parameters
  - Input parameters first, then output parameters last

```c
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;
}
```
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):

```cpp
class Name {
  public:
    // public member definitions & declarations go here
  private:
    // private member definitions & declarations go here
}; // class Name
```

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

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

```cpp
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

- Unlike Java, you can name files anything you want
  - Typically `Name.cc` and `Name.h` for class `Name`
**Class Definition (.h file)**

```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_
```
#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)

```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, 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?
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