Which concept did you find the most difficult in the context of HW1?

A. Pointers
B. Output parameters
C. Dynamic memory allocation
D. Structs
E. GDB
F. Style considerations
G. Prefer not to say
C++ References, Const, Classes
CSE 333 Spring 2023

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Relevant Course Information

- Exercise 4 due next Thursday @ 11 am
  - Hardest exercise (Rating: 5)
- Exercise 5 due next Friday @ 11 am
  - “Lighter” exercise in C++ (Rating: 1)

- Homework 2 due April 27
  - File system crawler, indexer, and search engine
  - **Note:** libhw1.a (yours or ours) and the .h files from hw1 need to be in right directory (~yourgit/hw1/)
  - **Note:** use Ctrl-D to exit searchshell, test on directory of small self-made files
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.
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;
}
```

- `x` initially points to 5, after dereferencing and incrementing it points to an unknown address.
- `y` initially points to 10, after dereferencing and incrementing it points to an unknown address.
- `z` initially points to `&x`, after assignment it points to `&y`.

Note: Arrow points to next instruction.
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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;

    z = &y;
    *z += 1;

    return EXIT_SUCCESS;
}
```

Note: Arrow points to *next* instruction.
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;  // 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.
Pointers 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++

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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;

    return EXIT_SUCCESS;
}
```

Note: Arrow points to next instruction.
# 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; // 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;
}
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Note: Arrow points to *next* instruction.

---

- 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; // 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;
}
```
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
```
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;  // binds the name "z" to x

    z += 1;
    x += 1;

    z = y;
    z += 1;

    return EXIT_SUCCESS;
}
```

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

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

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    z = y;
    z += 1;
    return EXIT_SUCCESS;
}
```

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

Note: Arrow points to *next* instruction.
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;  // binds the name "z" to x

    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; // sets z (and x) to 11

    return EXIT_SUCCESS;
}
```

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

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

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

Note: Arrow points to *next* instruction.

`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!

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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;
}
```

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

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

**Note:** Arrow points to next instruction.
What will happen when we try to compile and run this code?

A. Output "(1,2,3)"
B. Output "(3,2,3)"
C. Compiler error about arguments to Foo (in main)
D. Compiler error about body of Foo
E. We’re lost...

```cpp
void Foo(int& x, int* y, int z) {
    z = *y;
    x += 2;
    y = &x;
}

int main(int argc, char** argv) {
    int a = 1;
    int b = 2;
    int& c = a;

    Foo(a, &b, c);
    std::cout << "(" << a << ", " << b << ", " << c << ")" << std::endl;

    return EXIT_SUCCESS;
}
```
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++;

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

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

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

    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
  - Compiler won’t let you pass in const parameters

```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;
}
```
What will happen when we try to compile and run this code?

A. Output "(2,4,0)"
B. Output "(2,4,3)"
C. Compiler error about arguments to Foo (in main)
D. Compiler error about body of Foo
E. We’re lost…

define poll2.cc

void Foo(int* const x, int& y, int z) {
    *x += 1;
    y *= 2;
    z -= 3;
}

int main(int argc, char** argv) {
    const int a = 1;
    int b = 2, c = 3;

    Foo(&a, b, c);
    std::cout << "(" << a << "," << b << "," << c << ")" << std::endl;

    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
  - Ordering:
    - List input parameters first, then output parameters last

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

styleguide.cc
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`
Const & Classes

- Like other data types, objects can be declared as const:
  - Once a const object has been constructed, its member variables can’t be changed
  - Can only invoke member functions that are labeled const

- You can declare a member function of a class as const
  - This means that if cannot modify the object it was called on
    - The compiler will treat member variables as const inside the function at compile time
  - If a member function doesn’t modify the object, mark it const!
#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;
}
#include <iostream>
#include <cstdlib>
#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 EXIT_SUCCESS;
}
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...