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Operator Overloading

How can we repurpose common operators to write
descriptive and functional code?

CS106L - Winter 23

Attendance!

<http://bit.ly/41ark2n>



**Complete the
midquarter survey!**
<http://bit.ly/3lHamBF>
Due next Tuesday! (2/28)





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01. Recap: Classes

02. Operators and Operator Overloading





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01. Recap: Classes

02. Operators and Operator Overloading

03. ...Nap time?





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01. Recap: Classes

02. Operators and Operator Overloading



Objects and Classes

- Objects are instances of classes
- Objects encapsulate data related to a single entity
 - Define complex behavior to work with or process that data:

```
Student.printEnrollmentRecord()
```



Objects and Classes

- Objects store private state through instance variables
 - `Student::name`
- Expose private state to other through public instance methods
 - `Student::getName()`
- Allow us to expose state in a way we can control

We almost have everything we need!

Classes let you define new objects with new behavior!

- We know how to parametrize classes and functions using templates!

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- But...
- Remember maps and sets?

Unordered maps/sets

Both maps and sets in the STL have an unordered version!

- **Ordered** maps/sets require a **comparison operator** to be defined.
- **Unordered** maps/sets require a **hash function** to be defined.

Unordered maps/sets are usually faster than ordered ones!

Simple types are already natively supported; anything else will need to be defined yourself.



We almost have everything we need!

Classes let you define new objects with new behavior!

- We know how to parametrize classes and functions using templates!
- But...
- Remember maps and sets?
- And structs in streams?

A stream you've used: cout

```
// use a stream to print any primitive type!  
std::cout << 5 << std::endl; // prints 5  
// and most from the STL work!  
std::cout << "Sarah" << std::endl;  
// Mix types!  
std::cout << "Sarah is " << 21 << std::endl;  
// structs?  
Student s = {"Sarah", "CA", 21};  
std::cout << s << std::endl;
```

ERROR!

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Classes let you define new objects with new behavior!

- We know how to parametrize classes and functions using templates!
- But...
- Remember maps and sets?
- And structs in streams?
- And functors?

Aside: What the Functor?

A **functor** is any class that provides an implementation of `operator()`.

- They can create **closures** of “customized” functions!
- Lambdas are just a reskin of functors!

```
class functor {  
public:  
    int operator() (int arg) const { // parameters and function body  
        return num + arg;  
    }  
private:  
    int num; // capture clause  
};  
  
int num = 0;  
auto lambda = [&num] (int arg) { num += arg; };  
lambda(5);
```

Closure: a single instantiation of a functor object

We almost have everything we need!

Classes let you define new objects with new behavior!

- We know how to parametrize classes and functions using templates!
- But...
- Remember maps and sets?
- And structs in streams?
- And functors?

We're missing something important!



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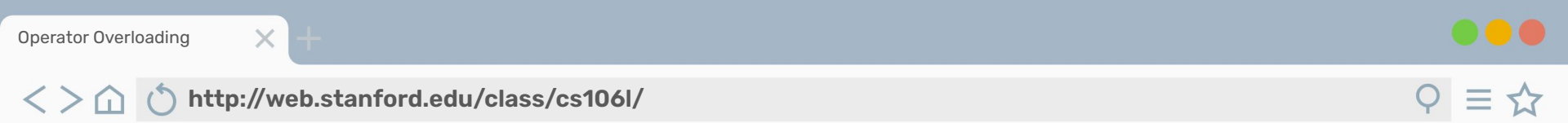


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01. Recap: Classes

02. Operators and Operator Overloading



Let's talk about it!

How do operators work with classes?

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How do operators work with classes?

- Just like declaring functions in a class, we can declare operator functionality!
- When we use that operator with our new object, it performs a custom function or operation!
- Just like in function overloading, if we give it the same name, it will override the operator's behavior!

What operators can we overload?

Most of them, actually!

```
+ - * / % ^ & | ~ ! , = < > <= >=
++ -- << >> == != && || += -= *=
/= %= ^= &= |= <<= >>= [ ] ( ) ->
->* new new[] delete delete[]
```

What can't be overloaded?

- Scope Resolution
- Ternary
- Member Access
- Pointer-to-member access
- Object size, type, and casting

```
::      ?      .      .*      sizeof()  
typeid()      cast()
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```
::      ?      .      .*      sizeof()  
typeid()  cast()
```

**We can go from
this...**

//student.h

```
class Student {  
    public:  
        std::string getName();  
        void setName(string name);  
        int getAge();  
        void setAge(int age);  
  
    private:  
        std::string name;  
        std::string state;  
        int age;  
};
```

**...to
this!**

//student.h

```
class Student {  
    public:  
        std::string getName() const;  
        void setName(string name);  
        int getAge() const;  
        void setAge(int age);  
        bool operator < (const Student& rhs) const;  
  
    private:  
        std::string name;  
        std::string state;  
        int age;  
};
```

In the
.cpp:

//student.cpp

```
#include student.h
```

```
std::string Student::getName() {
```

```
    //implementation here!
```

```
}
```

```
    /* ... */
```

```
bool operator< (const Student& rhs) const {
```

```
    return age < rhs.age;
```

```
}
```

In the .cpp:

//student.cpp

```
#include student.h
std::string Student::getName() {
    //implementation here!
}

/* ... */

bool operator< (const Student& rhs) const {
    return age < rhs.age;
}
```

We're in a member
function, so age refers to
this->age by default!



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Let's take a look!

`simple_fraction!`



We can overload operators in two ways:

Member functions

- Declare your overloaded operator within the scope of your class!
- Allows you to use member variables of `this->`

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Member functions

- Declare your overloaded operator within the scope of your class!
- Allows you to use member variables of `this->`

Non-member functions

- Declare the overloaded operator outside of any classes (main.cpp?)
- Define both left and right hand objects as parameters

What if we don't know what will be on the left-hand side?



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- Allows us to overload operators with classes we don't own! (ex. **vector** to a **StudentList**)

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```
bool operator< (const Student& lhs, const Student& rhs);
```

Non-member overloading

Non-member overloading is preferred by the STL!

- It allows the LHS to be a non-class type (ex. comparing **double** to a **Fraction**)
- Allows us to overload operators with classes we don't own! (ex. **vector** to a **StudentList**)

We now have to declare what is on the lefthand side of the operator!

```
bool operator< (const Student& lhs, const Student& rhs);
```




What about member variables?

With member function overloading, we have access to this->
and its private variables.



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Can we still access these with non-member operator overloading?





Everything is better with **friends**!

The **friend** keyword allows non-member functions or classes to access private information in another class!

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Everything is better with **friends**!

The **friend** keyword allows non-member functions or classes to access private information in another class!

- To use, declare the name of the function or class as a friend within the target class's header!
- If it's a class, you must say **friend class [name];**

//student.h

```
class Student {  
    public:  
    /* ... */  
    friend bool operator < (const Student& lhs, const Student& rhs)  
    const;  
  
    private:  
    /* ... */  
};  
  
bool operator < (const Student& lhs, const Student& rhs) {  
    return lhs.age < rhs.age;  
}
```

//student.h

```
class Student {  
    public:  
        /* ... */  
        friend bool operator < (const Student& lhs, const Student& rhs)  
            const;  
  
    private:  
        /* ... */  
};  
  
bool operator < (const Student& lhs, const Student& rhs) {  
    return lhs.age < rhs.age;  
}
```


Seen this before?

This happens when a custom class hasn't defined the stream operator!

```
main.cpp:23:8: error: invalid operands to binary expression ('std::__1::ostream' (aka 'basic_ostream<char>') and 'Fraction')
  cout << a << endl;
       ^ ~
/Library/Developer/CommandLineTools/usr/include/c++/v1/ostream:218:20: note: candidate function not viable: no known conversion from 'Fraction' to 'const void*' for 1st
  argument; take the address of the argument with &
  basic_ostream& operator<<(const void* __p);
                        ^
/Library/Developer/CommandLineTools/usr/include/c++/v1/ostream:194:20: note: candidate function not viable: no known conversion from 'Fraction' to 'std::__1::basic_ostream<char>
  &(*) (std::__1::basic_ostream<char> &)' for 1st argument
  basic_ostream& operator<<(basic_ostream& (*__pf)(basic_ostream&))
                        ^
/Library/Developer/CommandLineTools/usr/include/c++/v1/ostream:198:20: note: candidate function not viable: no known conversion from 'Fraction' to
  'basic_ios<std::__1::basic_ostream<char, std::__1::char_traits<char> >::char_type, std::__1::basic_ostream<char, std::__1::char_traits<char> >::traits_type>
  &(*) (std::__1::basic_ostream<char, std::__1::char_traits<char> >::char_type, std::__1::basic_ostream<char, std::__1::char_traits<char> >::traits_type> &)' (aka
  'basic_ios<char, std::__1::char_traits<char> > &(*) (basic_ios<char, std::__1::char_traits<char> > &)' for 1st argument
  basic_ostream& operator<<(basic_ios<char_type, traits_type> &
                        ^
/Library/Developer/CommandLineTools/usr/include/c++/v1/ostream:203:20: note: candidate function not viable: no known conversion from 'Fraction' to
  'std::__1::ios_base &(*) (std::__1::ios_base &)' for 1st argument
  basic_ostream& operator<<(ios_base& (*__pf)(ios_base&))
                        ^
/Library/Developer/CommandLineTools/usr/include/c++/v1/ostream:206:20: note: candidate function not viable: no known conversion from 'Fraction' to 'bool' for 1st argument
  basic_ostream& operator<<(bool __n);
                        ^
/Library/Developer/CommandLineTools/usr/include/c++/v1/ostream:207:20: note: candidate function not viable: no known conversion from 'Fraction' to 'short' for 1st argument
  basic_ostream& operator<<(short __n);
                        ^
/Library/Developer/CommandLineTools/usr/include/c++/v1/ostream:208:20: note: candidate function not viable: no known conversion from 'Fraction' to 'unsigned short' for 1st
  argument
  basic_ostream& operator<<(unsigned short __n);
                        ^
```

We can do something like this!

Operator overloading is how the STL lets cout mix types!

```
std::ostream& operator << (std::ostream& out, const Time& time) {  
    out << time.hours << ":" << time.minutes << ":" << time.seconds;  
    return out;  
}
```

Be careful with non-member overloading!

Certain operators, like `new` and `delete`, don't require a specific type.

- Overloading this outside of a class is called **global overloading** and will affect everything!

```
void* operator new(size_t size);
```



Overloading Strategies

As with everything, there's a time and a place for operator overloading!

- **Don't go overboard**; it can be confusing if overused.

Compare:

```
MyString a( "opossum" );
```

```
MyString b( "quokka" );
```

```
MyString c = a * b; // what does this even mean??
```

```
MyString a( "opossum" );
```

```
MyString b( "quokka" );
```

```
MyString c = a.charsInCommon(b); // much better!
```



Rules and Philosophy

- Meaning should be **obvious** when you see it

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- Functionality should be **reasonably similar** to corresponding arithmetic operations
 - Don't define + to mean set subtraction!



Rules and Philosophy

- Meaning should be **obvious** when you see it
- Functionality should be **reasonably similar** to corresponding arithmetic operations
 - Don't define + to mean set subtraction!
- When the meaning isn't obvious, give it a normal name instead.



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Thanks!

Next up: special member functions!