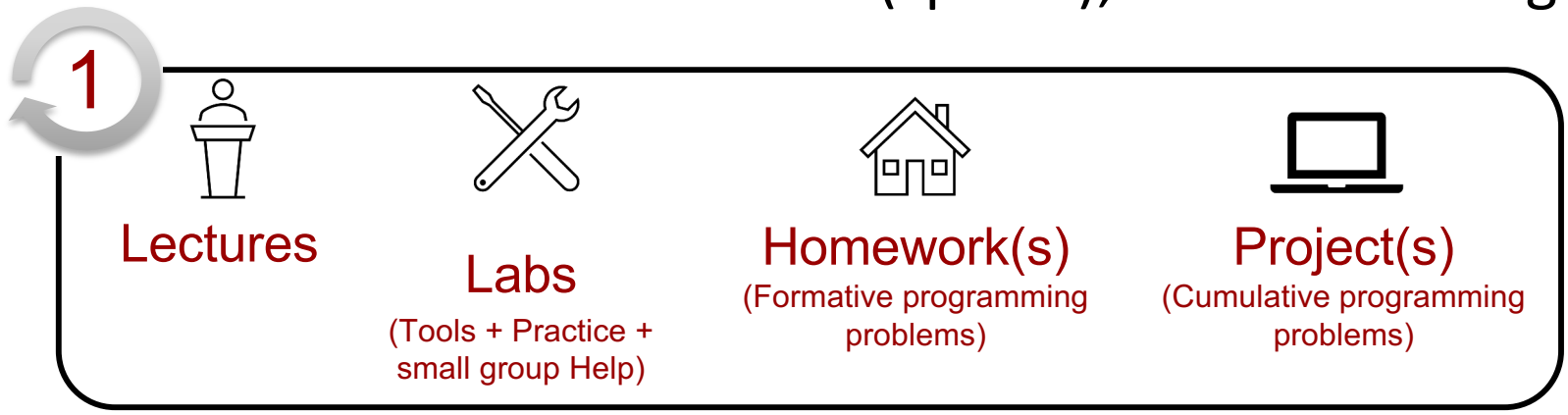
CS 103 Unit 5a – Operator Overloading

CSCI 103L Teaching Team

Unit 5 – Objects Part 2

- The course is broken into 6 units (spirals), each consisting of:



1 **C++ Language Syntax**

2 **Algorithms and Computational Thinking**

3 **Objects 1**

4 **Managing Data**

5 **Objects 2**

6 **Recursion**

Function Overloading

- What makes up a signature (uniqueness) of a function
  - name
  - number and type of arguments
- No two functions are allowed to have the same signature; the following 4 functions are unique and allowable…
  - `void f1(int);` `void f1(double, int);`
  - `void f1(double);` `void f1(int, int);`
- We say that "f1" is **overloaded** 4 times
- Notes:
- Return type does NOT make signature unique
  - int f1(); is considered the same as void f1();
- For member functions, 'const' make signature unique
  - `int& List::get()` `int const & List::get() const;`

Operator Overloading

- C++ defines operators (+,*,-,==,etc.) that work with basic data types like `int`, `char`, `double`, etc.
- C++ has no clue what classes we'll define and what those operators would mean for these "yet-to-be-defined" classes
  - ```
    class Complex {
      private:
       double real, imag;
    };
    ```
  - ```
    Complex c1,c2,c3;
    // should add component-wise
    c3 = c1 + c2;
    ```
  - ```
    class List {
     ...
    };
    List l1,l2;
    l1 = l1 + l2;  // should concatenate
                   // l2 items to l1
    ```
- **We can write custom functions to tell the compiler what to do when we use these operators! Let us learn how…**

user.h

```
class User{
 public:
   User(string n);  // Constructor
   string get_name();
 private:
   int id_;
   string name_;
};
```

user.cpp

```
#include "user.h"
User::User(string n) {
  name_ = n;
}
string User::get_name(){
  return name_;
}
```

user_test.cpp

```
#include<iostream>
#include “user.h”

int main(int argc, char *argv[]) {
  User u1("Bill"), u2("Jane");
  // see if same username
  // Option 1:
  if(u1 == u2) cout << "Same";
  // Option 2:
  if(u1.get_name() == u2.get_name())
    {   cout << "Same" << endl; }
  return 0:
  }
```
```

Two Approaches

- There are two ways to specify an operator overload function
  - 1. Global level function (not a member of any class)
  - 2. As a member function of the class on which it will operate
- Which should we choose?
  - It depends on the **left-hand side** operand
  - Ex 1: `iostream << Complex`
  - Ex 2: `Complex + int`

Method 1: Global Functions

- Can define global functions with name "operator{+-…}" taking two arguments
  - LHS = Left Hand side is 1st arg
  - RTH = Right Hand side is 2nd arg
- When compiler encounters an operator with objects of specific types it will look for an "operator" function to match and call it
- But what if we need to access private data of some object to implement our operation?
  - A global (non-member) function will not work. We need method 2

```
int main()
{
  int hour = 9;
  string suffix = "p.m.";

  string time = hour + suffix;
  // WON'T COMPILE…doesn't know how to
  //  add an int and a string
  return 0;
}
```

```
string operator+(int time, string suf)
{
  string res = to_string(time); // conv int to str
  res += suf;  // strings already support +
  return res;
}
int main()
{
  int hour = 9;
  string suffix = "p.m.";


  string time = hour + suffix;
  // WILL COMPILE TO:
  // string time = operator+(hour, suffix);

  return 0;
}
```

Method 2: Class Members

- C++ allows users to write class member functions that define what an operator should do for a class
- Same naming convention: function name starts with '**operator**' and then the actual operator
- Important: **Left-hand side** is the implied calling object for which the member function is called and **Right-hand side** is passed as the argument
  - `LHS-arg.operator+(RHS-arg);`

```
class Complex
{ public:
  Complex();
  Complex(double r, double i);
  Complex operator+(const Complex &rhs) const;

 private:
  double real, imag;
};

Complex Complex::operator+(const Complex &rhs) const
{
   Complex temp;
   temp.real = real + rhs.real;
   temp.imag = imag + rhs.imag;
   return temp;
}
int main()
{
  Complex c1(2,3);
  Complex c2(4,5);
  Complex c3 = c1 + c2;
  // Same as c3 = c1.operator+(c2);
  cout << c3.real << "," << c3.imag << endl;
  // can overload '<<' so we can write:
  // cout << c3 << endl;
  return 0;
}
```

Overloading Notes

- You can overload any operator except the member operator (.), the scope operator (::), and the ternary operator (? :)
  - **Binary operators**: `+`, `-`, `*`, `/`, `++`, `--`
  - **Comparison operators**: `==`, `!=`, `<`, `>`, `<=`, `>=`
  - **Assignment**: `=`, `+=`, `-=`, `*=`, `/=`, etc.
  - **I/O stream operators**: `<<`, `>>`
- You cannot change the operator's precedence
  - Multiply must always come before addition
- More questions: **https://isocpp.org/wiki/faq/operator-overloading**

Binary Operator Overloading

- For binary operators, do the operation on a new object's data members and return that object
  - Don’t want to affect the input operands data members
    - Difference between: `x = y + z;` vs. `x = x + z;`
- Normal order of operations and associativity apply (can’t be changed)
- Can overload each operator with various RHS types…
  - See next slide

Binary Operator Overloading

```
class Complex
{
 public:
  Complex();
  Complex(double r, double i);
  Complex operator+(const Complex &rhs) const;
  Complex operator+(int real) const;
 private:
  double real, imag;
};
Complex Complex::operator+(const Complex &rhs) const
{
   Complex temp;
   temp.real = real + rhs.real;
   temp.imag = imag + rhs.imag;
   return temp;
}

Complex Complex::operator+( int real ) const
{
   Complex temp = *this;
   temp.real += real;
   return temp;
}
```

No special code is needed to add 3 or more operands. The compiler chains multiple calls to the binary operator in sequence.

```
int main()
{
 Complex c1(2,3), c2(4,5), c3(6,7);

  Complex c4 = c1 + c2 + c3;
  // (c1 + c2) + c3
  // c4 = c1.operator+(c2).operator+(c3)
  //    = anonymous-ret-val.operator+(c3)


  c3 = c1 + c2;
  c3 = c3 + 5;

}
```

Adding different types (`Complex + Complex` vs. `Complex + int`) requires different overloads

Relational Operator Overloading

- Can overload
  ==, !=, <, <=, >, >=
- Should return bool

```
class Complex
{
 public:
  Complex();
  Complex(double r, double i);
  Complex operator+(const Complex &rhs) const;
  bool operator==(const Complex &rhs) const;
  double real, imag;
};

bool Complex::operator==(const Complex &rhs) const
{
  return (real == rhs.real && imag == rhs.imag);
}

int main()
{
  Complex c1(2,3);
  Complex c2(4,5);
  // equiv. to c1.operator==(c2);
  if(c1 == c2)
    cout << "C1 & C2 are equal!" << endl;

  return 0;
}
```

Nothing will be displayed

Non-Member Functions

- What if the user changes the order?
  - int on LHS & Complex on RHS
  - No match to a member function b/c to call a member function the LHS has to be an instance of that class
- We can define a non-member function (global scope function) that takes in two parameters (both the LHS & RHS)
  - May need to declare it as a friend

```
int main()
{
  Complex c1(2,3);
  Complex c2(4,5);
  Complex c3 = 5 + c1;
              // ?? 5.operator+(c1) ??
              // ?? int.operator+(c1) ??
              // there is no int class we can
              //  change or write

  return 0;
}
```

Doesn't work without a new operator+ overload

```
Complex operator+(const int& lhs, const Complex &rhs)
{
  Complex temp;
  temp.real = lhs + rhs.real;   temp.imag = rhs.imag;
  return temp;
}
int main()
{
  Complex c1(2,3);
  Complex c2(4,5);
  Complex c3 = 5 + c1;   // Calls operator+(5,c1)
  return 0;
}
```

Still a problem with this code
Can operator+(…) access Complex's private data?

Friend Functions

- A friend function is a function that is not a member of the class but has access to the private data members of instances of that class
- Put keyword '**friend**' in function prototype in class definition
- Don't add scope to function definition

```
class Silly
{
  public:
    Silly(int d) { dat = d };
    friend int inc_my_data(Silly &s);
  private:
    int dat;
};

// don't put Silly:: in front of inc_my_data(...)
//  since it isn't a member of Silly
int inc_my_data(Silly &a)
{
   s.dat++;
   return s.dat;
}

int main()
{
   Silly cat(5);
   //cat.dat = 8
   // WON'T COMPILE since dat is private

   int x = inc_my_data(cat);
   cout << x << endl;
}
```

Notice inc_my_data is NOT a member function of Silly. It's a global scope function but it now can access the private class members.

Non-Member Functions

- Revisiting the previous problem

```
class Complex
{
 public:
  Complex();
  Complex(double r, double i);
  // this is not a member function
  friend Complex operator+(const int&, const Complex& );
 private:
  double real, imag;
};

Complex operator+(const int& lhs, const Complex &rhs)
{
  Complex temp;
  temp.real = lhs + rhs.real;   temp.imag = rhs.imag;
  return temp;
}
int main()
{
  Complex c1(2,3);
  Complex c2(4,5);
  Complex c3 = 5 + c1;   // Calls operator+(5,c1)
  return 0;
}
```

Now things work!

Why Friend Functions?

- Can I do the following?
- error: no match for 'operator<<' in 'std::cout << c1'
- /usr/include/c++/4.4/ostream:108: note: candidates are: /usr/include/c++/4.4/ostream:165: note: std::basic_ostream<_CharT, _Traits>& std::basic_ostream<_CharT, _Traits>::operator<<(**long int**) [with _CharT = char, _Traits = std::char_traits<char>]
- /usr/include/c++/4.4/ostream:169: note: std::basic_ostream<_CharT, _Traits>& std::basic_ostream<_CharT, _Traits>::operator<<(**long unsigned int**) [with _CharT = char, _Traits = std::char_traits<char>]
- /usr/include/c++/4.4/ostream:173: note: std::basic_ostream<_CharT, _Traits>& std::basic_ostream<_CharT, _Traits>::operator<<(**bool**) [with _CharT = char, _Traits = std::char_traits<char>]
- /usr/include/c++/4.4/bits/ostream.tcc:91: note: std::basic_ostream<_CharT, _Traits>& std::basic_ostream<_CharT, _Traits>::operator<<(**short int**) [with _CharT = char, _Traits = std::char_traits<char>]

```
class Complex
{
 public:
   Complex();
   Complex(double r, double i);
   Complex operator+(const Complex &rhs) const;
 private:
   double real, imag;
};

int main()
{
   Complex c1(2,3);
   cout << c1;  // equiv. to cout.operator<<(c1);
   cout << endl;
   return 0;
}
```

Why Friend Functions?

- cout is an object of type 'ostream'
- << is just an operator
- But we call it with cout on the LHS which would make operator<< a member function of class ostream
- Ostream class can't define these member functions to print out user defined classes because they haven't been created
- Similarly, ostream class doesn't have access to private members of Complex

```
class Complex
{
 public:
  Complex();
  Complex(double r, double i);
  Complex operator+(const Complex &rhs) const;
 private:
  double real, imag;
};

int main()
{
  Complex c1(2,3);
  cout << "c1 = " << c1;
  // cout.operator<<("c1 = ").operator<<(c1);

  // ostream::operator<<(const char *str);
  // ostream::operator<<(Complex &src);

  // Using global scope (friend) functions
  // operator<<(operator<<(cout,"c1 = "), c1);

  cout << endl;
  // operator<<(cout,endl);
  return 0;
}
```

Ostream Overloading

- Can define operator functions as friend functions
- LHS is 1st arg.
- RHS is 2nd arg.
- Use friend function so LHS can be different type but still access private data
- Return the ostream& (i.e. os which is really cout) so you can chain calls to 'operator<<' and because cout/os object has changed

```
class Complex
{
 public:
  Complex();
  Complex(double r, double i);
  Complex operator+(const Complex &rhs) const;
  friend ostream& operator<<(ostream&, const Complex &c);
 private:
  int real, imag;
};

ostream& operator<<(ostream &os, const Complex &c)
{
  os << c.real << "," << c.imag << "j";
  //cout.operater<<(c.real).operator<<(",").operator<<...
  return os;
}

int main()
{
  Complex c1(2,3), c2(4,5);
  cout << c1 << c2;
  // operator<<( operator<<(cout, c1), c2);
  cout << endl;
  return 0;
}
```

Implicit Type Conversion

- Would the following if condition make sense?
- No! If statements want Boolean variables

```
class Student {
  private:  int id; double gpa;
};
int main()
{
  Student s1;
  if(s1){  cout << "Hi" << endl; }
  return 0;
}
```

- But you've done things like this before
  - Operator>> returns an ifstream&
- So how does ifstream do it?
  - With an "implicit type conversion operator overload"
  - Student::operator bool()
    - Code to specify how to convert a Student to a bool
  - Student::operator int()
    - Code to specify how to convert a Student to an int

```
ifstream ifile(filename);
...
while( ifile >> x )
{  ...  }
```

```
class Student {
  private:
   int id; double gpa;
  public:
   operator bool() { return gpa>= 2.0;}
   operator int() { return id; }
};

Student s1;
if(s1)          // calls operator bool() and
   int x = s1; // calls operator int()
```

Member or Friend?

Should I make my operator overload be a member of a class, C1?

Ask yourself: *Is the LHS an instance of C1?*

YES

```
C1 objA;
objA << objB  // or
objA + int
```

YES the operator overload function can be a **member function** of the C1 class since it will be translate to objA.operator<<(…)

NO

```
C1 objA;
objB << objA // or
int + objA
```

NO the operator overload function should be a **global level (maybe friend) function** such as operator<<(cout, objA). It cannot be a member function since it will be translate to objB.operator<<(…).

Summary

- If the left hand side of the operator is an instance of that class
  - Make the operator a member function of a class…
  - The member function should only take in one argument which is the RHS object
- If the left hand side of the operator is an instance of a different class
  - Make the operator a friend function of a class…
  - This function requires two arguments, first is the LHS object and second is the RHS object

OPERATOR OVERLOADING REVIEW

Operator Overloading Review

Member or Non-member?

- How do you decide if you can make the operator overload function a member function of the class?
- When do you have to use a non-member operator function?

```
// arbitrary precision integer class
class BigInt {
  ...
};
int main(){
  BigInt x, y, z;
  x = y + 5;
}
```

Arguments

- For member function operator overloads, how many input arguments are needed for operator+? For operator! ?

```
// arbitrary precision integer class
class BigInt {
  ____ operator+(                 );
  ____ operator!(                 );
};
int main(){
  BigInt w, x, y, z;
  w = x + y;
  bool flag = !w;
}
```

Operator Overloading Review

Return types

- For class BigInt which models an arbitrary precision integer, what should the return type be for:
  - Operator+
  - Operator==

```
class BigInt {
 public:
   _________ operator+(const BigInt&);
   _________ operator==(const BigInt&);
};
int main(){
  BigInt w, x, y, z;
  w = x + y;
}
```

Chaining

- Do we need operator overload functions with 2-, 3-, 4-inputs, etc. to handle various use cases?

```
class BigInt {
  ...
};
int main(){
  BigInt w, x, y, z;
  w = x + y + z;
  cout << w << " is a bigint!" << endl;
}
```

SOLUTION

Operator Overloading Review

Member or Non-member?

- How do you decide if you can make the operator overload function a member function of the class?
  - If the left-hand side operand is a class instance
- When do you have to use a non-member operator function?
  - If the left operand of an operator is NOT an instance of the class, you cannot use a member function

```
// arbitrary precision integer class
class BigInt {
  ...
};
int main(){
  BigInt x, y, z;
  x = y + 5;
}
```

Arguments

- For member function operator overloads, how many input arguments are needed for operator+?
  - Only 1, the left side operand is 'this'
- for operator!
  - None, the left side operand is 'this'

```
// arbitrary precision integer class
class BigInt {
  ____ operator+(const BigInt& rhs);
  ____ operator!();
};
int main(){
  BigInt w, x, y, z;
  w = x + y;
  bool flag = !w;
}
```

Operator Overloading Review

Return types

- For class BigInt which models an arbitrary precision integer, what should the return type be for:
  - Operator+: BigInt (by value)
  - Operator==: bool

```
class BigInt {
 public:
   BigInt operator+(const BigInt&);
   bool operator==(const BigInt&);
};
int main(){
  BigInt w, x, y, z;
  w = x + y;
}
```

Chaining

- Do we need operator overload functions with 2-, 3-, 4-inputs, etc. to handle various use cases?
  - No, this is why the return type should be BigInt to allow for chaining: x.operator+(y).operator+(z), etc.

```
// arbitrary precision integer class
class BigInt {
  ...
};
int main(){
  BigInt w, x, y, z;
  w = x + y + z;
  cout << w << " is a bigint!" << endl;
}
```