Operator Overloading

Programming Fundamentals

Dr Kevin Chalmers

School of Computing
Edinburgh Napier University
Edinburgh

k.chalmers@napier.ac.uk

Edinburgh Napier UNIVERSITY

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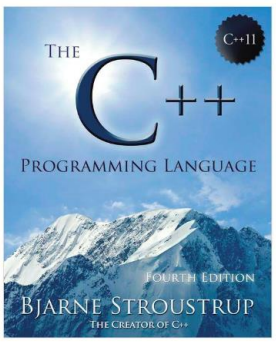
References

- Stroustrup (2011), *The C++ Programming Language, 4th Edition*
  - The inventor of C++
- Also look at the official C++ documentation coming with your development environment



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Operator Overloading

- C++ implements a powerful feature, *operator overloading*.
- Operator overloading allows developers to redefine the behaviour of classes when they are being used with standard operators (e.g., +, -, *, etc.).
  - This is also known as ad-hoc polymorphism.
- Some other languages implement this feature (e.g. C#, Python etc) whilst some others don't (e.g. Java), making it an often overlooked feature.

Notes

Using Operators

- You have already been using operator overloading, e.g.
  - When using a vector type you can access values by using a function (e.g. `vec.at(4)`) or an operator overload (`vec[4]`).
  - Similarly, `cout << "Hello"` is also using an operator. This can be overloaded for different classes.
- Operator overloading uses the `operator` keyword, e.g.
  - `type operator+(const type &lhs, const type &rhs)`

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Examples of Operators

Type	Function	Example
Arithmetic	Based on arithmetic operations	`+, -, *, /`
Assignment	What happens when you assign a value to an object	`=`
Increment, decrement	Both pre and post-fix	`variable++`, `++variable`
Logical	And, or, not, equals	`&&, ||, !`
Comparison	Greater than, less than	`<, >, ++, !=`
Member access	As used in `vector`	`[ ]`
Other	Casting, `new`, `delete`, etc.	

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Examples of Applications

Arithmetics you can create classes for vector or matrices and the regular operators to perform

Object descriptions you can print an object description in the form of a `string` to `std::cout` or another file by using the << syntax.

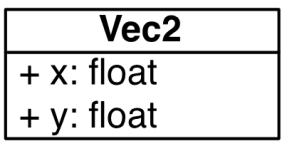
Object comparisons Easily compare two objects to see if they are "equal" (under the programmer's definition)

- Other definitions uses also exist

Notes

Case Study - vec2

- This lecture the practical will use the same case study: vec2
- vec2 is a 2-dimensional vector, in the mathematical definition, it can be a 2D point in space.



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Comparison : Equality

- We can implement the comparison == operator in a class as a *member function* in the following way:

Equality Operator

```
bool operator==(const vec2 &rhs)
{
  return (this->x == rhs.x) && (this->y == rhs.y);
}
```

- If we compare two vec2 objects with identical x and y values, it will return true, other it will return false.

Notes

Comparison : Inequality

- Similarly, we can implement the negative comparison != operator in the following way:

Inequality Operator

```
bool operator!=(const vec2 &rhs)
{
  return !(*this == rhs);
}
```

- We can use the syntax above because we already redefined the == operator, which is a handy shortcut *in this situation*.

Notes

Comparison : Greater / Less Than

- For our example, we will define less based on Pythagoras (there is no such thing as a vec2 being more or less than another):

$$length^2 = x^2 + y^2$$

Less Than Operator

```
bool operator<(const vec2 &rhs)
{
  float my_len = (this->x * this->x) + (this->y * this
      ->y);
  float rhs_len = (rhs.x * rhs.x) + (rhs.y * rhs.y);
  return my_len < rhs_len;
}
```

- In this example, the operator will return true or false based on the squared length of our vector.

Notes

Comparison : Caution!

- You need to be consistent. If you decided to apply Pythagoras to the *less than* operator, the same needs to apply to the *more than* operator. It is technically possible to implement anything, however you need to keep it logical, especially if others will use your class.
- Greater than or equal, and less than or equal need to be defined separately. You will need to implement all the logical cases individually.

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Arithmetic : Addition

- Intuitively the + operator can be used for arithmetic additions.
  - This is how we have been conditioned to use it from years and years of math classes.
- However, in programming, it is often used to *abstractly* add two things together. For example stings:
  - `string3 = string1 + string2;`
- The example above would conventionally perform an operation similar to the C `strcat` function, which is not an arithmetic operation.

Notes

Artihmetic : Addition

- In our example, we can add two vectors by adding their components. For example if `w` were the addition of two vectors `v` and `u`:

$$w_x = v_x + u_x$$
$$w_y = v_y + u_y$$

Adding Two Vectors

```
vec2 operator+(const vec2 &rhs)
{
  // Assuming the correct constructor exists
  return vec2(this->x + rhs.x, this->y + rhs.y);
}
```

Notes

Arithmetic : Multiplication

- Note in the last example, we actually create a new vector and return it to the parent function.
- C++ allows you to define different types of arguments for operators, e.g. you could multiply two vectors together:
  - `vec2 operator*(const vec2 &rhs) {...}`
- Or perform a scalar multiplication:
  - `vec2 operator*(float scale) {...}`

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Assignment

- You can assign a vector to another using the = operator:

Assignment Operator

```
vec2& operator=(const vec2 &rhs)
{
  this->x = rhs.x;
  this->y = rhs.y;
  return *this;
}
```

- Note that we return a *reference* to vec2. This is to ensure we return the original object and not a copy. In this case, we need to use the dereference operator.

Notes

Assignment

- Other assignment operators (+=, -=, *=, /=) work in a similar manner:

Addition-Assignment Operator

```
vec2& operator+=(const vec2 &rhs)
{
  this->x = this->x + rhs.x;
  this->y = this->y + rhs.y;
  return *this;
}
```

- These operators are shortcuts for assignment and arithmetic operations. They are widely used in C-like languages.

Notes

Member Access

- Our vec2 class contains two member floats. We can use the [] operator to access both members.
  - e.g. vec[0] or vec[1].

Member Access Operator

```
float& operator[](int index)
{
  assert(index >= 0 && index <= 1);
  if (index == 0)
    return x;
  else
    return y;
}
```

Notes

Input and Output

- The >> and << operators for input and output can also be overloaded.
- This is useful if we want to control the way an object is printed or read from an I/O stream.
- Other languages provide similar features for their object types, like `toString()` in Java or `description` in Objective-C.

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Input and Output

- To redefine the input to a stream, we proceed this way:

Input Operator

```
friend istream& operator>>(istream &in, vec2 &value)
{
  in >> value.x >> value.y;
  return in;
}
```

- Note the `friend` keyword, which alters the public/private visibility of class members. This function is defined outside the class scope. `friend` is outside the scope of this module but is required in this scenario.

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Example - Input

- The last example would allow the manual creation of a vec2 using the console:

Reading in a vec2

```
// Create object
vec2 v;
// Read from console
cin >> v;
```

- In the example above, a user would be prompted to enter two float values on the keyboard, thus creating a 2D vector with those values as x and y.

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Example - Output

- The output to a stream is similar. Note that you can format the output to be easily understandable in logs and debugging consoles:

Output Operator

```
friend ostream& operator<<(ostream &out, const vec2 &
    value)
{
  out << "{" << value.x << ", " << value.y << "}";
  return out;
}
```

- This overload would allow us to output the x and y values of a vec2 by passing an object to a stream, like std::cout.

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Summary

- Operator overloading is useful to redefine the behaviours of primitive C++ operators.
- This enables a higher level abstraction, where we can manipulate objects with operators as if they were primitive data types.
- This can make classes "feel" easier and more natural to uase than only using these methods:
  - `vec3 = vec1 + vec2`
  - `vec3 = vec1.add(vec2)`

Notes

To do...

- In the lab - lots of work with operator overloading. This is useful for coursework 2.
  - Speaking of which, you should all be making progress through this now.
- Coursework 2 - any queries contact Kevin ASAP.
- Next time - data structures using pointers. Helps your thinking for coursework 2.

Notes