CHAPTER 11
INHERITANCE AND POLYMORPHISM

CMPS 148

This week

- Lab Solution – Anagrams
  - To be posted
- Memory Management - Destructors
- Inheritance
  - Base Class, Sub-Class
- Polymorphism
  - Flexibility through pointers
- Abstract Classes

Example Problem

- Lets create a new "container" class called Collection
  - Stores integers
  - Constructor specifies the maximum size
  - Add
  - Resize (new size)

  - ***Recall – we've done something similar to this before…***

Problem: Memory Leak?

- We have a problem - when we construct our Collection we allocated using new
- This memory will **never** be reclaimed
  - If we are just using in main, no big deal…
  - If we had collections in other functions, this is a **major** problem

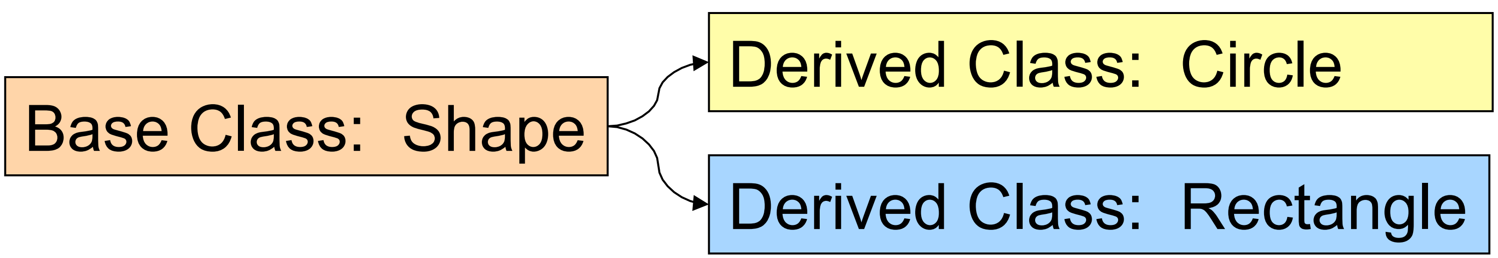
Solution: Destructor

- A *constructor* is automatically called when an instance of your class is being created
- A *destructor* is automatically called when an instance is being reclaimed:
  - Stack instances going out of scope
  - Delete called on heap instances

```
~List() {
    if ( contents != NULL ) delete contents;
}
```

Inheritance

- Object-Oriented programming allows for classes to *extend* other classes
  - Other terminology:
    - **Derived** classes extend base classes
    - Derived classes extend **parent** classes
    - Inheritance allows **is a** relationships



Derived Classes

- Derived classes *extend* base classes by adding properties and/or functions.
  - Example: Shape
    - Property: Color [string]
    - Property: Filled [bool] (for drawing)
    - String getColor(), void setColor(string)
    - Bool isFilled(), void setFilled(bool)
    - String toString() -> "A solid red shape"
  - Circle extends Shape (Circle **is a** Shape)
    - Property: Radius
    - Double get/set Radius, getArea(), getPerimeter()

Derived Classes

```
class Shape {
public:
  Shape();
  Shape(string color, bool filled);
  string getColor();
  void setColor(string c);
  bool isFilled();
  void setFilled(bool f);
  string toString();
private:
  string color;
  bool filled;
};
```

```
class Circle : public Shape {
public:
  Circle();
  Circle(double radius);
  Circle(double radius, string color, bool filled);
  double getRadius();
  void setRadius(double r);
  double getArea();
  double getPerimeter();
  double getDiameter();
private:
  double radius;
}
```

```
int main() {
  Circle c(5, "white", true);
  cout << c.getColor() << endl;
}
```

Derived Classes

- Many classes can extend a common base

If applicable, you could make another class that extends Rectangle too… (3D rectangle…?)

```
class Rectangle : public Shape {
public:
  Rectangle();
  Rectangle(double width, height);
  double getWidth();
  void setWidth();
  double getHeight();
  void setWidth();
  double getArea();
  double getPerimeter();
private:
  double width;
  double height;
}
```

Constructors

- A Circle **is a** Shape, so it makes sense that when you create a Circle, you also create a Shape…
  - By default, the default Constructor of the **base** class is called right before the code in the derived class

```
class Shape {
public:
  Shape() {
    color = "white";
    filled = false;
  }
  ...
```

+

```
class Circle : public Shape {
public:
  Circle(double r) {
    radius = r;
  }
  . . .
```

=

```
color = "white";
filled = false;
radius = r;
```

If shape doesn't have a default constructor… compiler error!!!

Constructors

- You can call *specific* base constructors using very special syntax…

```
Circle(double radius, string color, bool filled) : Shape( color, filled ) {
    radius = 1;
}
```

Destructors

- Base Class constructors are **always** called before their sub-classes

- Base Class **destructors** are **always** called **after** their sub-classes

Power of "Generic" Programming

- Object inheritance allows us to write functions that accept "generic" base classes

```
void printShape(Shape s) {
  cout << s.toString() << endl;
}

int main() {
  Shape s;
  Circle c(1, "black", false);
  Rectangle(r(3, 4, "red", true);
  printShape(s);
  printShape(c);
  printShape(r);
}
```

*It works because Circle **is a** Shape and Rectangle **is a** Shape*

Refining Methods

- The Shape class' s toString doesn' t have any dimensions (radius, width, etc.)
  - You can declare toString methods in the derive class to "override" the default behavior

```
class Shape {
public:
   ...
  string toString() {
    stringstream ss;
    ss << "A " << getColor();
    if ( isFilled() ) ss << " solid ";
    else ss << " outlined ";
    ss << "shape.";
    return ss.str();
  }
```

```
class Circle : public Shape {
public:
 string toString() {
   stringstream ss;
   ss << "A " << getColor();
   if ( isFilled() ) ss << " solid ";
   else ss << " outlined ";
   ss << "circle with radius = " << getRadius();
   return ss.str();
}
```

```
Shape s;
Circle c(2);
cout << s.toString() << " " << c.toString() << endl;
```

Keyword: `protected`

- When a derived class extends a base type, it has access only to the public functions and methods of its base

```
class Circle : public Shape {
public:
 string toString() {
   stringstream ss;
   ss << "A " << color;
   if ( isFilled() ) ss << " solid ";
   else ss << " outlined ";
   ss << "circle with radius = " << getRadius();
   return ss.str();
}
```

Compiler error: Circle cannot access private data within Shape

Keyword: `protected`

- There are some situations where the base class has good reason to limit access to its data
- However often children (derived classes) should be allowed…
- To resolve this, we use "protected" rather than "private".
- Protected data is still hidden from code outside of the class, but it is accessible within derived classes.

Limitations to Refinement

- When using base classes in functions, C++ can only do so much:

```
void printShape(Shape s) {
  cout << s.toString() << endl;
}

int main() {
  Shape s;
  Circle c(1, "black", false);
  Rectangle(r(3, 4, "red", true);
  printShape(s);
  printShape(c);
  printShape(r);
}
```

- At runtime, **printShape** will think s, c, and r are just ordinary "shapes", and use Shape's toString()

- C++ lacks "dynamic" type checking in this situation

Polymorphism

- The concept of polymorphism takes "refinement" to a more powerful level.
- Polymorphism will allow a **reference/pointer** to a base class to work intelligently when pointing to **derived** types.
- We will need some additional syntax however…

Keyword: `virtual`

- For a method to participate in polymorphism, it must be marked as *virtual* in the **base** class' s definition

```
class Shape {
public:
...
 virtual string toString() {
   stringstream ss;
   ss << "A " << getColor();
   if ( isFilled() ) ss << " solid ";
   else ss << " outlined ";
   ss << "shape.";
   return ss.ToString();
 }
```

```
class Cicle {
public:
 ...
  string toString() {
   stringstream ss;
   ss << "A " << getColor();
   if ( isFilled() ) ss << " solid ";
   else ss << " outlined ";
   ss << "circle with radius = " << getRadius();
   return ss.ToString();
}
```

Polymorphism with Pointers

- Polymorphism works when using pass-by-reference or pointers.
- When a function takes a reference to a base type as a parameter, calls on the passed object will map to the **derived** type

```
void printShape(Shape & s) {
  cout << ,toString() << endl;
}

int main() {
  Shape s;
  Circle c(1, "black", false);
  Rectangle(r(3, 4, "red", true);
  printShape(s);
  printShape(c);
  printShape(r);
}
```

- At runtime, **printShape** call the toString function on Shape for s, Circle for c, and Rectangle for r.

More abstraction

- Notice that Rectangle and Circle have some common methods (behaviors)
  - getArea()
  - getPerimeter()

- While all shapes have areas and perimeters, we cannot move those functions into the Shape class… why?

More abstraction

- Thinking carefully - it might not even make much sense to ever instantiate a "Shape"… there is no such thing!
  - Shape is a "generic" term for a set of real things.
  - Shape is considered "abstract" - its not "real"
- Although one cannot calculate the area or perimeter of a "shape", we know that it should be possible to do so…

```
void printAreaToPerimeterRatio(Shape * s) {
  cout << "The ratio of area to perimeter is"
       << s->getArea() / s->getPerimeter() << endl;
}
```

Abstract Classes

- An abstract class represents a "generic" thing, that cannot be used directly:
  - It defines "pure" virtual functions, with no implementation
  - All classes that derive from the abstract class **must** provide a full implementation of all pure virtual functions
  - Your abstract class defines an **interface** for using a bunch of different types of objects…
- Example: A shape must have an area and perimeter, but its up to Circle and Rectangle to figure it out…

Abstract Classes

```
class Shape {
public:
   ...
   virtual double getPerimeter() = 0;
   virtual double getArea() = 0;
   ...
```

```
class Circle : public Shape {
public:
   double getPerimeter() {
     return 2 * PI * radius;
   }
   double getArea() {
     return PI * radius * radius;
   }
};
```

```
class Rectangle : public Shape {
public:
   double getPerimeter() {
     return 2 * height * width;
   }
   double getArea() {
     return height * width;
   }
};
```

Abstract Classes

```
void printAreaToPerimeterRatio(Shape & s) {
  cout << "The ratio of area to perimeter is"
       << s.getArea() / s.getPerimeter() << endl;
}
```

```
int main() {
  Shape s;
  Circle c(2);
  Rectangle r(4, 5);
  printAreaToPerimeterRatio(c);
  printAreaToPerimeterRatio(r);
}
```

X - compiler error, cannot instantiate abstract class

Lab 8 – Complete at home

- Create a Triangle class which extends Shape
- Use the same functions as in main
  - make sure you can create instances
  - call the print shape method

- *Triangle can be assumed to be a* ***right triangle, which means the area = ½ base * height.***