lab_inheritance

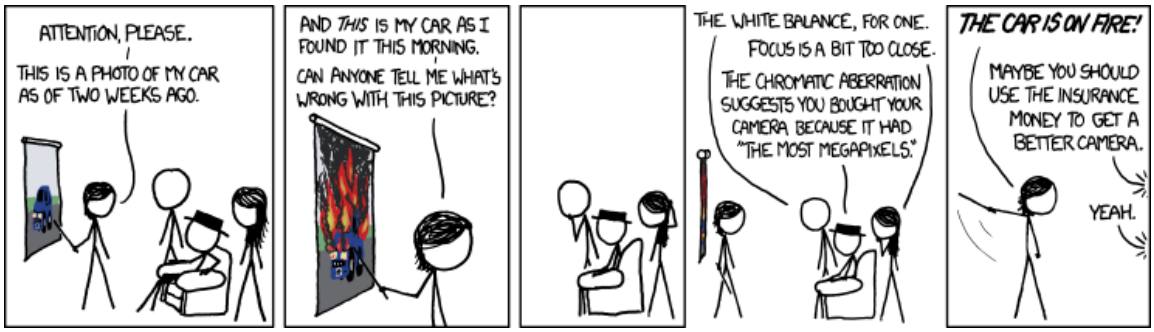
Insidious Inheritance

Due: Feb 10, 23:59 PM

Doxygen | Lab handout

Assignment Description

In this lab you will get experience with some of the implementation issues and conceptual details of inheritance. Inheritance is a mechanism for increasing the reusability and reliability of C++ code. It is worth mentioning that inheritance is a characteristic of all object oriented programming languages. Our goal is to give you a glimpse of the functionality of inheritance, so that you can make informed design decisions in the future. Please read through the entire lab before you begin.



Lab Insight

This lab teaches some of the characteristics observed in object oriented programming. These characteristics are useful in software design when building code bases for large projects, APIs, and production code bases. Some classes that further extend on these concepts include CS 427, CS 242, and CS 422. This lab will help you build clean code bases where the OOP (Object-Oriented Programming) characteristics help minimize having to rewrite redundant code as well as make use of virtual inheritance to treat custom sub-classes the same way as their base classes without losing the custom functionality of these subclasses.

Getting Set Up

From your CS 225 git directory, run the following on EWS:

```
$
```

```
git fetch release
git merge release/lab_inheritance -m "Merging initial lab_inheritance files"
```

If you're on your own machine, you may need to run:

```
$
```

```
git fetch release
git merge --allow-unrelated-histories release/lab_inheritance -m "Merging initial
lab_inheritance files"
```

Upon a successful merge, your lab_inheritance files are now in your `lab_inheritance` directory.

The code for this activity resides in the `lab_inheritance/` directory. Get there by typing this in your working directory:

```
$

   cd lab_inheritance/
```

> You will only need to modify the following files:
>
> - `shape.{cpp,h}`
> - `circle.{cpp,h}`
> - `truck.{cpp,h}`
> - `flower.{cpp,h}`
> - `drawable.h`

Class Hierarchy

To help us understand class hierarchies better here is an example of a simple class hierarchy showing that a `Dog` **is a** `Animal`.

The code would look something like the following:

```
class Animal {
   public:
      string name;

      virtual void speak() = 0;
      /* The = 0 at the end of the method means that the method is a pure virtual method
       * meaning that it does not have an implementation and it delegates the task
       * of implementing the method to the classes that is derived from it */
};

class Dog : public Animal {
   public:
      string breed;

      /* Dog inherits speak from Animal */
      void speak();

};

void Dog::speak() {
    cout << "Woof Woof" << endl;
}
```

In this example `Animals` have a `name` and can `speak` but since `speak` is a pure virtual method we CANNOT construct an `Animal` by itself. That is `Animal` is an abstract class and it can only be constructed by one of its derived classes. For example, a `Dog` is a derived class of Animal. This means that a Dog **is a** `Animal`, and, therefore, it inherits a `name` and a `speak` method from `Animal`. However, since the `Animal`'s `speak` does not have an implementation, `Dog` **must** implement the `speak` method.

Here is an example of how we could use a `Dog` object:

```
Dog* d = new Dog();

/* Like usual we can access all the public methods and member variables of a
 * Dog */
d->breed;

/* But now since a Dog is an Animal we can also do this too */
d->name;     // inherited from Animal
d->speak();  // inherited from Animal and since it is a Dog speak() will print
             // "Woof Woof"

/* Additionally we can treat our Dog only like an Animal like this */
Animal* a = d;

/* But now we can only do the following */
a->name;
a->speak();  // Still prints "Woof Woof" because speak is a virtual method.

a->breed     // ERROR! This will NOT work since we perceive it as an Animal now

/* Additionally, if we try to have our Animal pointer point back to a Dog
 * pointer this will cause a problem because an Animal Is NOT A Dog. */
Dog* d2 = a;  // ERROR!  Animal Is NOT A Dog

/* Furthermore, since Animal is abstract and has a pure virtual method
 * we CANNOT construct one! */
Animal a2;  // ERROR! Animal is an abstract class
```

Now that we can understand a simple class hierarchy, let's look at a more complex one. Here is a diagram depicting the class hierarchy that is used in this lab. (Note: This diagram is missing some information, e.g. methods, member variables, etc.., for demonstration purposes)

This means everything is a `Drawable` and will have a `draw` method. Code like the following is perfectly acceptable:

```
Drawable* triangle  = new Triangle(....);
Drawable* circle    = new Circle(...);
Drawable* rectangle = new Rectangle(....);
Drawable* truck     = new Truck(...);
Drawable* flower    = new Flower(....);

/* Now the only thing we can use on triangle, circle, rectangle, truck, and
 * flower is draw but what gets drawn will change depending on what type the
 * pointer is actually pointing to. This is called polymorphism, the behavior
 * changes depending on the actual type of the object being pointed to. */

PNG canvas;
triangle->draw(&canvas);   // draws a Triangle even though triangle is a Drawable*
circle->draw(&canvas);     // draws a Circle even though circle is a Drawable*
rectangle->draw(&canvas);  // draws a Rectangle even though rectangle is a Drawable*
truck->draw(&canvas);      // draws a Truck even though truck is a Drawable*
flower->draw(&canvas);     // draws a Flower even though flower is a Drawable*
```

Look at `main.cpp` for a working example executable in action. `main.cpp` gets compiled and linked into an executable named `lab_inheritance`. Follow the instructions below to build, run, and view the output:

The `Makefile` provided for this MP will create an executable when you run `make`. It will generate `lab_inheritance`.

For example when you run

```
$
```

```
./lab_inheritance
```

You could also run `Valgrind` on the normal executable:

```
$
```

```
valgrind --leak-check=full ./lab_inheritance
```

This lab will use all of these objects in interesting ways but as you will quickly see they are not working the way the should. Your objective for this lab is to go through the 5 test executables and fix the code to work correctly by modifying how the classes in the hierarchy declare and implement their methods.

Once you have fixed all the Valgrind errors, you can test your program output following the directions below.

Exercise 1: Fix the Virtual Methods

Please build and run `test_virtual`:

```
$
```

```
make test_virtual                   # compile to produce test_virtual executeble
valgrind ./test_virtual             # run test_virtual with valgrind
```

As you will see when you run `test_virtual`, the output will say:

```
The Perimeters are NOT the same.
The Areas are NOT the same.
```

However, if you look closely at the code they should be the same because both of the pointers in `test_virtual.cpp` point to the same object!

Exercise

- Investigate and fix the code so that the areas and the perimeters are the same.
- To fix this problem you should only need to modify `shape.cpp` and/or `shape.h`.

Exercise 2: Fix the Destructor

Please build and run `test_destructor`:

$

```
make test_destructor                          # compile to produce test_destructor
executeble
valgrind --leak-check=full ./test_destructor # run test_destructor in valgrind
```

When you run `test_destructor` in Valgrind you will see that `test_destructor` is leaking memory. However, if you look closely, `Triangle` does have a valid destructor and it is being called in `test_destructor`!

> **Exercise**
>
> - Investigate and fix the code so that the there is no more memory leak inside of `test_destructor`.
> - To fix this problem you should only need to modify `drawable.h` and `shape.h`.

Exercise 3: Fix the Constructor

Please build and run `test_constructor`:

$

```
make test_constructor # make test_constructor
./test_constructor    # run test_constructor
```

When you run `test_constructor` you will see the following output:

```
Circle's color is NOT correct!
Circle's center is NOT correct!
```

If you look closely, we are constructing a `Circle` with a valid center and color. However, when it is being drawn and when we ask for the `Circle`'s center and color they are not the same!

> **Exercise**
>
> - Investigate and fix the code so that the `Circle` is being constructed with the proper center and color.
> - To fix this problem you should only need to modify `circle.cpp`
> - The correct `test_constructor.png` should look like the following:
>
> 

Exercise 4: Fix the Pure Virtual Method

Please build and run `test_pure_virtual`.

$

```
make test_pure_virtual # make test_pure_virtual
./test_pure_virtual    # run test_pure_virtual
```

When you try to make `test_pure_virtual` you will see that it does not compile.

However, if you look at the `truck.{h,cpp}` it is a fully featured class! Why is it not compiling?

Exercise

- Investigate and fix the code so that `test_pure_virtual` compiles, runs, and outputs a `Truck`.
- To fix this problem you should only need to modify `truck.h` and `truck.cpp`.
- In order to have the `Truck` draw properly you will first need to have Exercise 3 completed.
- The correct `test_pure_virtual.png` should look like the following:

Exercise 5: Fix the Slicing

Please build and run `test_slicing` with:

$

```
make test_slicing # make test_slicing
./test_slicing    # run test_slicing
```

After you run `test_slicing` open up its output `test_slicing.png`. You will see that a `Flower` has NOT been drawn. For some reason just a bunch of X's has been drawn and a red circle.

If you look at `flower.h` and `flower.cpp`, we have all of the proper member variables set up. However, when we try to draw them they are drawn incorrectly.

Exercise

- Investigate and fix the code so that `test_slicing` outputs a `Flower`.
- To fix this problem you should only need to modify `flower.h` and `flower.cpp`.
- You must use polymorphism!
- The correct `test_slicing.png` output should look like the following:

Testing Your Code

Run the Catch tests as follows (this requires your code to compile when run simply as `make`):

$

```
make test
./test
```

Cleaning up files

To clean up your working repository and remove the test images produced by your program, you can type the following command:

$

```
make clean
```

Submitting Your Work

The following files are used to grade this assignment:

- `shape.cpp`
- `shape.h`
- `circle.cpp`
- `circle.h`
- `truck.cpp`
- `truck.h`
- `flower.cpp`
- `flower.h`
- `drawable.h`

All other files including any testing files you have added will not be used for grading.

Guide: How to submit CS 225 work using git