COMPOSITION AND INHERITANCE

Today

- Today we will look at:
  - Composition; and
  - Inheritance
- These are the cornerstones of object oriented programming.
- This material is taken from Pohl, Chapter 8.

An example

- Consider the program `rabbit.cpp` which you can download from the class web site (Unit IV).
- This, rather like homework 2, models a small ecosystem which holds:
  - A rabbit
  - Some carrots
- The rabbit runs around looking for carrots and eating them.
- Note that the way this is done is rather different from the way I asked you to do homework 2.
- The class definition for the `rabbit` class is as follows

```
class rabbit {

private:
  point location;
  int   consumed;

public:
  rabbit(){consumed = 0;};
  int  getX() const;
  int  getY() const;
  void set(int x, int y);
  void print() const;
  void move();
  void move(direction d);
  void eat();
  bool hungry();
};
```

Composition

- The `rabbit` class includes a member of the `point` class, which we have played with before.
- We say that `rabbit` is related to `point` by *composition*.
- This just means what we see here — one class has an instance of another as a data member.
- Another example of composition in `rabbit.cpp` is that the class `world` contains both `carrot` and `rabbit` instances.

- Several of the function members (methods) of `rabbit` look like those for `point`.
  - `getX()`
  - `getY()`
  - `set(int x, int y)`
- These data members provide a to alter the values of the attributes of the instance of `point` that is a member of `rabbit`.
- Since the data member is `private`, we can't just use the function member of `point`.

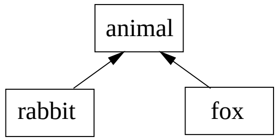
- Other methods are new:
  - `move()`
  - `eat()`
  - `hungry()`
- These give us the functionality we want from `rabbit`, allowing it to move, to report whether it is hungry, and to eat.
- If you haven't done so already, you should run the program `rabbit` and see how it works.
- Now imagine that we want to extend the program to include a fox, which runs around the world and eats rabbits.
- One way we could do this is to write a `fox` class that looks like the following.

```
class fox {

private:
  point location;
  int   consumed;

public:
  fox(){consumed = 0;};
  int  getX() const;
  int  getY() const;
  void set(int x, int y);
  void print() const;
  void move();
  void move(direction d);
  void eat();
  bool hungry();
};
```

- This is exactly like the `rabbit` class since `fox` and `rabbit` are so similar.
- Both have a location in the world, move around, and eat things.
- Since they are so similar, writing both out seems a bit repetitive, and dull with it.
- It turns out that there is an alternative to doing this.
- The alternative is to use *inheritance* and this is considered better style than having lots of classes with (more or less) the same functionality.

Inheritance

- A program that handles the `fox` and `rabbit` example using *inheritance* is `rabbit2.cpp` on the class web page.
- The relationship between the classes is summarised by:



- That is the class `rabbit` and the class `fox` are both *subclasses* of the class `animal`.
- Alternatively, every instance of a `rabbit` is an instance of `animal` and every instance of `fox` is an instance of `animal`.

- We define `fox` as:

```
class fox : public animal {

};
```

- This is the syntax for saying that `fox` has exactly the same members as `animal`.
- The keyword `public` indicates that all the `public` members of `animal` remain `public` in `fox`.
- If we replaced `public` with `private`, then all the `public` members of `animal` would become `private` in `fox`.
- We will say more about this next lecture.

- Normally we want to do more than have a subclass just be a copy of the superclass.
- What we often want to do is to have the subclass add things to the superclass.
- (In Java this is explicit. When we define a subclass it is by saying it `extends` the superclass).
- `rabbit` is an example of this.

```
class rabbit : public animal {

private:

  bool  eaten;

public:

  rabbit(){eaten = false;};
  void beEaten();
};

void rabbit::beEaten(){
  cout << "Drat that fox!" << endl;
  eaten = true;
}
```

- Here `rabbit` is extended with:
  - A `private` data member `eaten`, which records whether the `rabbit` has been eaten by the fox; and
  - A `public` function member `beEaten` that takes appropriate action when the `rabbit` is eaten.
- Thus `rabbit` has all of the data members of `animal` as well as the additional ones listed here.
- As a result we can do this:

  ```
  rabbit peter;
  peter.set(2, 3);
  ```

  which calls the `set` method on the `rabbit` `peter`.
- `rabbit` *inherits* the `set` method from `animal`.

Overriding and inheritance

- A sub-class definition can re-define a function member defined in the super-class.
- This is called *overriding*.
- We can, for example, override the definition of `move` in `fox`.
- The program `rabbit3.cpp` has:

  ```
  class fox : public animal {

  public:
    void move();
    void move(direction d);

  };
  ```

  giving new definitions for how the fox moves.

Aside: "protected"

- It turns out (as you can see in `rabbit3.cpp`) that to change the definition of `move` we have to do some more work.
- The problem is that to move the fox, we have to change its location.
- Now, location is `private` to `animal`, so `fox` cannot alter it.
- One answer is to make `location` not `private` but `protected`.
- `protected` data members sit somewhere between `public` members, which are accessible to any object, and `private` members, which are only accessible within that class.
- Roughly speaking, `protected` members are like `private` data members but are also accessible by members of derived classes.
- We will talk more about `protected` later on.

More inheritance

- Since `rabbit` is a subclass of `animal`, we can carry out any operation on a `rabbit` that we can on a `animal`.
- We already know that this is the case where the operations are function members of `animal` with simple parameters.
- Thus we can do:

```
rabbit peter;
peter.set(2, 3);
peter.move();
```

calling methods from `animal` on `rabbit`.

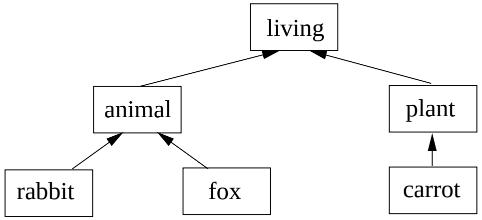
- It turns out we can go a bit further than this also.
- If we have:

```
bool animal::hungrier(animal a1, animal a2){
   if(a1.consumed < a2.consumed){
      return true;
   }
   else {
      return false;
   }
```

we can pass this two `rabbit`s, two `fox`es, or a `rabbit` and a `fox`.

Virtual functions

- The program `rabbit4.cpp` is a cleaner version of our little ecosystem.
- By defining a class `living`, we can exploit the fact that `carrot` has some aspects (to do with location) that are just like `rabbit` and `fox`,.
- We have the class hierarchy:


living
animal
plant
rabbit
fox
carrot

- Not all of the functions that exist in the sub-classes make sense in the super class.
  - For example, since plants do not move, it makes little sense to have a `move` class in `living`.
- The function `beEaten`, does apply to all living things and so could be defined in `living`.
- However, in our example, every class implements `beEaten` in its own way.
- C++ style suggests that we should define functions like `beEaten` that we know will be overridden as *virtual functions*.
- We do this by adding the keyword `virtual` before the function prototype:

```
virtual void beEaten();
```

- The virtual function `beEaten` in `living` will never be called.
- All objects are carrots, rabbits, or foxes, and these all define their own way to `beEaten`.
- In such cases we should define `beEaten` in `living` as a *pure virtual function*.
- We do this by:

```
virtual void beEaten() = 0;
```

- Any class that has at least one pure virtual function is an *abstract class*.
- You cannot create instances of abstract classes.

Summary

- This lecture has looked at a number of issues related to object oriented programming in C++.
    - Composition of classes
    - Inheritance
    - Overriding;
    - Virtual functions; and
    - Abstract classes.