cis15
advanced programming techniques, using c++
fall 2007
lecture # IV.1

topics:

- inheritance
- composition of classes

resources:

- Pohl, chapters 8 and 11

an example

- consider the program `robot.cpp` (posted on the class web page)
- this program models a world in which there is a robot and some spots of dirt
- the robot wanders around looking for spots of dirt and vacuuming them up
- this is kind of like the assignment from unit II, where you had a robot running around looking for coins; but as we go through this example, you'll see where the code becomes more sophisticated and more *object-oriented*
- the class definition for the `robot` class is as follows


```
class robot {

private:
  point location;
  int   num_vacuumed;

public:
  robot() { num_vacuumed = 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 `robot` class includes a member of the `point` class, which we have used before (many times!)
- we say that the `robot` class is related to the `point` class by *composition*
- *composition* means that one class contains a data member that is an *instance* of another class, i.e., a data member that is a variable whose data type is another class
- another example of composition in `robot.cpp` is that the class `world` contains both `robot` and `dirt` instances

privacy

- note that several of the function members (methods) of `robot` look like those for `point`
  - `getX()`
  - `getY()`
  - `set( int x, int y )`
  - `print()`
- these function members provide a way to access the values of the data members of the instance of `point`, which is a data member of `robot`
- since the data members (`x` and `y`) are `private`, we cannot access them directly in `robot` — we have to refer to them indirectly by using the public function members of `point`

overloading

- the rest of the methods in the `robot` class give us the functionality we want from `robot`, allowing it to move, to vacuum up spots of dirt and to report whether it is busy (i.e., if there are still spots of dirt in the world for it to vacuum)
  - `move()`
  - `move( direction d )`
  - `vacuum()`
  - `busy()`
- note that we have two versions of the `move()` function: one that takes no arguments and one that takes one argument
- creating two versions of the same function, distinguished by their different argument lists, is called *overloading*
- we used overloading when talking earlier in the term about different kinds of constructors


```
void robot::move(){
  direction d;
  d = static_cast<direction>( rand() % 4 );
  move( d );
}

// overloaded function
void robot::move( direction d ){
  int x = location.getX();
  int y = location.getY();
  switch( d ) {
  case north: y = (y + 1) % WORLD_SIZE;
              break;
  case south: y = (y - 1);
              if ( y < 0 ) y = WORLD_SIZE;
              break;
  case east:  x = (x + 1) % WORLD_SIZE;
              break;
  case west:  x = (x - 1) % WORLD_SIZE;
              if ( x < 0 ) x = WORLD_SIZE;
              break;
  }
  location.set( x, y );
}
```


extending classes

- since we are inherently lazy, we can create a class that is an *extension* of another class—instead of creating a whole new class (like `dirt` or `robot`) that contains all the functionality of one class (like `point`) and then adds functionality to it
- the class being extended is called the *super* (or *parent*) class, and the resulting classes that are derived from extending the parent are called *subclasses* or *children* classes
- look at `robot2.cpp`, which is a modified version of `robot.cpp` in which the `dirt` and `robot` classes are redefined as subclasses of the `point` class

```
class dirt : public point {
private:
  bool gone;
public:
  dirt() { gone = false; }
  void disappear();
};

void dirt::disappear(){
  cout << "poof!" << endl;
  gone = true;
}

class robot : public point {
private:
  int num_vacuumed;
public:
  robot() { num_vacuumed = 0; }
  void move();
  void move( direction d );
  void vacuum();
  bool busy();
};
```



```
void robot::move(){
  direction d;
  d = static_cast<direction>( rand() % 4 );
  move( d );
}

// overloaded function
void robot::move( direction d ){
  int x = getX();
  int y = getY();
  switch( d ) {
  case north: y = (y + 1) % WORLD_SIZE;
              break;
  case south: y = (y - 1);
              if ( y < 0 ) y = WORLD_SIZE;
              break;
  case east:  x = (x + 1) % WORLD_SIZE;
              break;
  case west:  x = (x - 1) % WORLD_SIZE;
              if ( x < 0 ) x = WORLD_SIZE;
              break;
  }
  set( x, y );
}
```

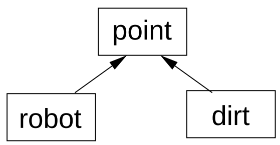


```
void robot::vacuum(){
  cout << "shrooooop...";
  num_vacuumed++;
}

// the robot is busy until all the dirt has been found and vacuumed
bool robot::busy() {
  if ( num_vacuumed < NUM_SPOTS ){
    return true;
  }
  else {
    return false;
  }
}
```


inheritance

- the relationship between the classes is illustrated by:



- that is the class `robot` and the class `dirt` are both *subclasses* of the class `point`
- put another way, every instance of a `robot` is an instance of `point` and every instance of `dirt` is an instance of `point`
- an instance of a subclass *inherits* all the members of its parent class
- which means that `dirt` and `robot` inherit `x`, `y`, `getX()`, `getY()`, `set()` and `print()` from `point`
- note that `x` and `y` are `private`, which means that they cannot even be accessed directly by the subclasses of `point` (later we'll explain how they could be)

- normally we want to do more than have a subclass just be a copy of the superclass—like we do with `dirt` and `robot`
- 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).
- in our example `robot2`, the classes `dirt` and `robot` are examples of this

- here `dirt` is extended with:
  - a `private` data member `gone`, which records whether the dirt instance has been vacuumed up yet
  - a `public` function member `disappear` that sets the `gone` flag to `true` when a dirt instance has been vacuumed up
- thus `dirt` has all of the data members of `point` as well as the additional ones listed here
- as a result we can do this:

```
dirt spot;
spot.set( 2, 3 );
```

  which calls the `set` method on the `dirt` object named `spot`
- `dirt` *inherits* the `set` method from `point`

overriding and inheritance

- a subclass definition can re-define a function member defined in the superclass
- this is called *overriding*
- (don't confuse it with *overloading*!)
- we can, for example, override the definition of `move` in `robot`
- the program `robot3.cpp` has:

```
class creature : public point {
public:
  void move();
  void move(direction d);
};
```

  which has two subclasses:

```
class robot : public creature {
private:
  int num_vacuumed;
```



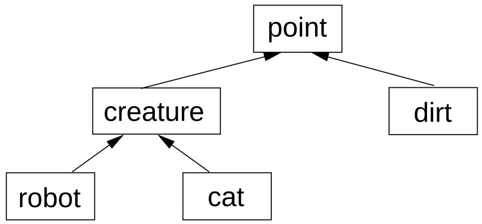
```
public:
  robot() { num_vacuumed = 0; }
  void vacuum();
  bool busy( int num_spots );
};
```

and

```
class cat : public creature {
public:
  void move();
  void move( direction d );
};
```

- the `robot` class uses the default `move()` functions, but the `cat` class *overrides* the default definitions by providing its own (see the code, but the main difference is that the `cat`'s `move()` function moves 2 spaces at a time instead of 1)

- a picture of this new hierarchy is shown below:



protected

- earlier we mentioned that we could not directly access a superclass' private data members in a subclass, but instead had to use the superclass' public function members to get access to the private data members
- however, if we really wanted access to the superclass' data members, we could declare them as `protected` instead of `private`
- `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 on inheritance

- since `robot` is a subclass of `creature`, we can carry out any operation on a `robot` that we can on a `creature` and on a `point`
- we already know that this is the case where the operations are function members of `creature` with simple parameters
- thus we can do:

```
robot rosie;
rosie.set( 2, 3 );
rosie.move();
```

calling methods from `point` and `creature` on `robot`

comparing objects

- we can compare two instances of an object:

```
bool robot::busier( robot r ) {
  if ( this->num_vacuumed > r.num_vacuumed )
    return true;
  else
    return false;
}
```

- we can pass this function an instance of a `robot` and get the result that compares the current instance (referenced by the pointer `this->`) to its argument instance

comparing objects using inheritance

- we can also do this with a superclass but pass an instance of a subclass
- for example, suppose we have a function that compares if one point is more to the west than another point:

```
bool point::moreWest( point p ) {
  if ( this->getX() < p.getX() )
    return true;
  else
    return false;
}
```

- this could be called on two `point` objects:

```
point p1, p2;
p1.set( 1, 2 );
p2.set( 3, 4 );
if ( p1.moreWest( p2 )) ...
```


- and it could also be called on two subclasses of `point`:

```
robot r1, r2;
r1.set( 1, 2 );
r2.set( 3, 4 );
if ( r1.moreWest( r2 )) ...
```


virtual functions and abstract classes

- the program `robot4.cpp` is another version of our world in which we define something called a `virtual` function
- this is the function `speak()` in the example
- notice that this function is first defined in the `creature`
- but the function definition is preceded by the keyword `virtual` and has a funny prototype:

```
class creature : public point {
public:
  void move();
  void move( direction d );
  virtual void speak() = 0;
};
```

- because we have defined a virtual function, the class `creature` is now called *abstract*
- we do this when we know we will want to define a function (e.g., `speak()`) but we don't want to give it any default behavior in the superclass

- the virtual function `speak()` in `creature` will never be called
- because an abstract class can never be instantiated
- it can only be extended, to create other classes
- the other classes, e.g., `robot` and `cat`, define their own versions of `speak()` and then these are not abstract classes but instead can be instantiated
- any class that has at least one pure virtual function is an *abstract class*
- you cannot create instances of abstract classes! (i.e., you cannot declare variables whose data type is an abstract class)

summary

- this lecture has looked at a number of issues related to object oriented programming in C++:
  - composition of classes
  - function overloading
  - inheritance
  - function overriding
  - comparing objects
  - virtual functions
  - abstract classes