AP Computer Science
Curriculum Module: Flocking Birds

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Flocking Birds

In this lesson, we will focus on the `Actor` class in the GridWorld Case Study. As you know, the case study is a large body of code designed to simulate the movement of creatures, known as actors, in a grid environment. The world containing the grid allows for many ways of interacting with the actors in the grid. `Actor` is very loosely defined, but provides the core methods that will be needed in order to provide a rich and interesting set of behaviors to the various actors in the world.

Specifically, the `Actor` class defines the following methods:

```
    public Actor()
    public Color getColor()
    public void setColor(Color newColor)
    public int getDirection()
    public void setDirection(int newDirection)
    public Grid<Actor> getGrid()
    public Location getLocation()
    public void putSelfInGrid(Grid<Actor> gr, Location loc)
    public void removeSelfFromGrid()
    public void moveTo(Location newLocation)
    public void act()
    public String toString()
```

The case study is designed so that any class that you wish to build (e.g., `Bug`, `Flower`, `Critter`) will extend the behavior of an `Actor`. In the case study narrative, students are introduced right away to the `Bug` class, which is a class that inherits from `Actor`. For this exercise we will concentrate on creating a `Bird` class which inherits from `Actor`, but exhibits behavior typical of birds. Specifically, we would like to get our `Bird` objects to flock together.

The `Bird` class

We will introduce the `Bird` class by inheriting from class `Actor` and adding the following methods:

```
public Bird()
public void move()
public void turn()
public boolean canMove()
```

We will also override the `act` method inherited from the `Actor` class:

```
public void act() {
  if (Math.random() > TURNPCT) {
    turn();
  }
  if (canMove()) {
    move();
  }
}
```

This makes for an interesting-looking world. Rather than copying the `Bug` behavior by turning whenever it encounters an obstacle, the bird will randomly turn fairly regularly based on the value we assign to the constant `TURNPCT`. If a bird cannot move, it will simply stop. This is like having the bird alight on a branch for a brief rest.

The `Flockable` interface

This is interesting behavior, but we would like to enhance the behavior of the bird by giving it the ability to flock to another object. For this we will create the `Flockable` interface:

```
public interface Flockable {

    public void setLeader(Actor flockLeader);

    public void stopFollowing();

    public boolean isFollowing();
}
```

The `Flockable` interface gives an object the ability to acquire and follow any `Actor` given as its leader. The interface is quite simple, but provides for the implementation of some powerful behavior.

Exercise A:
Option 1: Modify the `Bird` class so that it implements the methods in the `Flockable` interface. Observe that you will need to create a private data member of class `Actor` in order to store state relevant to the flocking behavior of the `Bird`s.

Option 2: Consider adding the following private data member to class `Bird`:

```
private Actor myLeader = null;
```

Use `myLeader` to implement the methods required to get class `Bird` to implement the `Flockable` interface. In implementing these methods, write your code in a way that takes advantage of the initialization of `myLeader` to `null`:

```
/**
 *  Provide this Flockable object with a leader that it can follow.
 *  Subsequent actions by this Flockable object should cause it to
 *  behave in a manner that causes it to follow flockLeader
 *  @param  flockLeader The Flockable that this Flockable will follow
**/
public void follow(Actor leader) {




}
/**
 *  Instruct this Flockable to permanently stop following its leader
**/
public void stopFollowing() {



}
/**
 *  Return true if this Flockable has a leader that it is following
 *  @return true if this Flockable has a leader, false otherwise
**/

public boolean isFollowing() {



}
```

Now that the `Bird` class implements the `Flockable` interface, we would like to modify its behavior so that it is capable of following its leader. The following method is essential in making the changes to `Bird` behavior:

```
/** Given a Location, turn to face that Location
 * @param   loc The location this Bird should face
**/
private void turnToFace(Location loc) {
  if (loc.equals(this.getLocation())) return;
    int xDist = this.getLocation().getCol() - loc.getCol();
    int yDist = this.getLocation().getRow() - loc.getRow();
    double turn = Math.atan2(yDist, xDist);
    setDirection((int)Math.toDegrees(turn) - 90);
  }
}
```

Do not be scared off by the use of `Math.atan2` in this method. This simply gives us a direction to face, in radians. This direction is then converted to degrees and transposed to fit the `setDirection` method.

Exercise B:
Modify the `act` method so that if a `Bird` is following a leader, it will turn to face the leader before moving. If the `Bird` is not following a leader, allow it to continue acting like a normal `Bird`. In both cases, the `move` method should be called.

```
public void act() {
// Before turning, see if you have a leader.  If so, turn to face that
// leader

  if (Math.random() > turnPct) {
    turn();
  }
  if (canMove()) {
    move();
  }
}
```

The `Flock` class

A `Flock` is a group of `Flockable` objects stored together in a common class. The underlying data structure of this class is a `List` of `Flockable` objects:

```
List <Flockable> theFlock = new ArrayList<Flockable>();
```

The `List` is defined as holding objects of class `Flockable`. However, you will observe that `Flockable` is an interface, not a class. This restricts the `List` such that it can only hold objects of a class that implement the `Flockable` interface. Since the `Flock` class requires behaviors supported by the `Flockable` interface in order to create a `Flock`, we put in this restriction.

The definition of `theFlock`, above, guarantees that our `Flock` will only contain objects that implement the `Flockable` interface. The leader of this `Flock`, however, can be any `Actor` object. The `addLeader` method accepts a leader of class `Actor`, and stores it in a private data member `theLeader`. All of the `Flockable` objects in `theFlock` are instructed to set that `Actor` as their leader.

```
public void addLeader(Actor leader) {
  theLeader = leader;
  Iterator <Flockable> flockIter = iterator();
  while (flockIter.hasNext()) {
    Flockable nextFlockObject = flockIter.next();
    nextFlockObject.setLeader(leader);
   }
}
```

Observe that the `Iterator flockIter` is used to instruct each `Flockable` object in the `List` to follow the leader given. We do not care if the leader is a `Bird`, a `Fish`, a `Bug`, or any other object, so long as it is an `Actor`.

This ability of the Java programming language (and all object-oriented programming languages, for that matter) to handle objects of different classes through an interface is a common and powerful feature. We use the interface to define the behaviors we want, and then we use a class to implement those behaviors. This ability to deal with objects of many different classes through a common interface is known as **polymorphism**.

Exercise C:
Observe that after running the `FlockRunner` sample for some time, the leader `Bird` inevitably becomes stuck in some position. This generally happens when the leader goes into a corner, and its flock traps it there. Come up with a solution to ensure that the leader will not become stuck in this manner. You may use one of these suggested methods, or come up with one of your own:

1. Tag! After a certain number of steps, the `Flock` picks a new leader.
2. Survival: After a certain number of steps without moving, the whole `Flock` becomes hungry and stops following its leader.
3. Darwin: After a certain number of steps without moving, the `Flock` picks a new leader within its `Flock`.
4. AI: The leader learns how to lead and avoids getting trapped in corners.

Appendix A: The complete `Flockable` interface

```
/*
 * Flockable.java
*/

import info.gridworld.actor.Actor;

/**
 * @author Christian Day
 * @version June 5, 2007
 */
public interface Flockable {

    public void setLeader(Actor flockLeader);

    public void stopFollowing();

    public boolean isFollowing();
}
```

Appendix B: the complete `Bird` class

```
/*
 * Bird.java
 */

import info.gridworld.actor.Actor;
import info.gridworld.grid.Grid;
import info.gridworld.grid.Location;

/**
 * @author Christian Day
 * @version June 4, 2007
 */
public class Bird extends Actor implements Flockable {

    private final double TURNPCT = 0.75;
    private Actor myLeader = null;

    public void move() {
        Grid<Actor> gr = getGrid();
        if (gr == null)
            return;
        Location loc = getLocation();
        Location next = loc.getAdjacentLocation(getDirection());
        if (gr.isValid(next))
            moveTo(next);
        else
            removeSelfFromGrid();
    }

    public void act() {
        if (isFollowing()) {
            turnToFace(myLeader.getLocation());
        } else if (Math.random() > TURNPCT) {
            turn();
        }
        if (canMove()) {
            move();
        }
    }

    public void turn() {
        setDirection(getDirection() + Location.HALF_LEFT);
    }

    /** Given a Location, turn to face that Location
     * @param   loc The location this Bird should face
     **/
    private void turnToFace(Location loc) {
        if (loc.equals(this.getLocation())) return;
        int xDist = this.getLocation().getCol() - loc.getCol();
        int yDist = this.getLocation().getRow() - loc.getRow();
        double turn = Math.atan2(yDist, xDist);
        setDirection((int)Math.toDegrees(turn) - 90);
```

```
    }

    public boolean canMove() {
        Grid<Actor> gr = getGrid();
        if (gr == null)
            return false;
        Location loc = getLocation();
        Location next = loc.getAdjacentLocation(getDirection());
        if (!gr.isValid(next))
            return false;
        Actor neighbor = gr.get(next);
        return (neighbor == null);

    }

    public void stopFollowing() {
        myLeader = null;
    }

    public boolean isFollowing() {
        return myLeader != null;
    }

    public void setLeader(Actor leader) {
        myLeader = leader;
    }
}
```

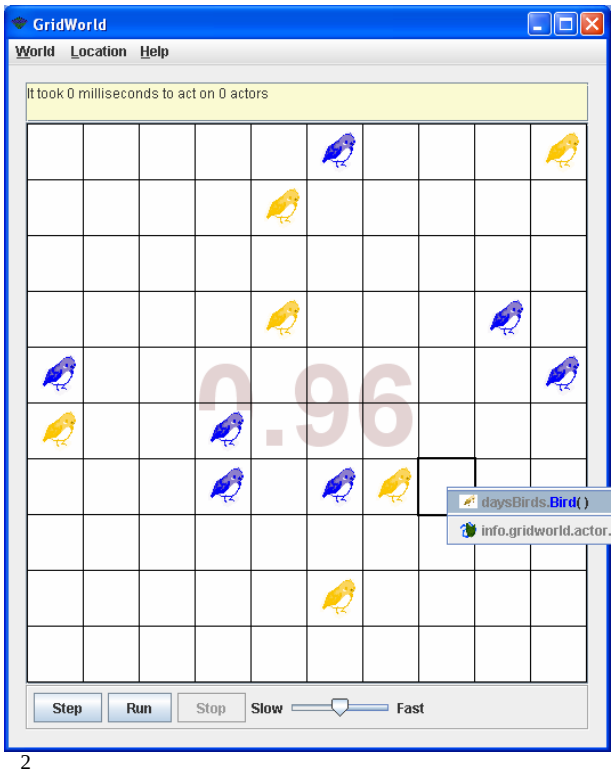
Appendix C: The `Flock` class

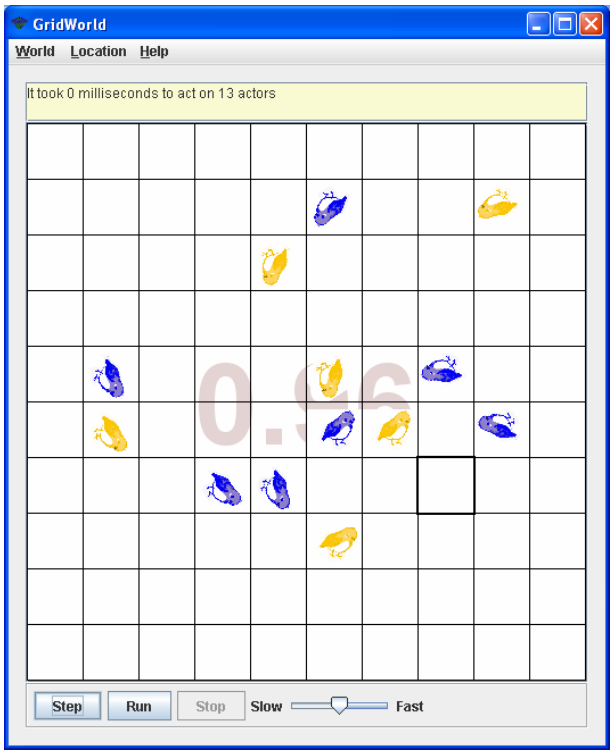
```
/*
 * Flock.java
*/
import info.gridworld.actor.Actor;
import java.util.*;

/**
 *
 * @author Christian Day
 * @version June 5, 2007
 */
 public class Flock {
    List <Flockable> theFlock = new ArrayList<Flockable>();
    Actor theLeader;

    public void add(Flockable f) {
        theFlock.add(f);
    }

    public Iterator <Flockable> iterator() {
        return theFlock.iterator();
    }

    public void addLeader(Actor leader) {
        theLeader = leader;
        Iterator <Flockable> flockIter = iterator();
        while (flockIter.hasNext()) {
            Flockable nextFlockObject = flockIter.next();
            nextFlockObject.setLeader(leader);
        }
    }

    public void removeLeader() {
        theLeader = null;
        Iterator <Flockable> flockIter = iterator();
        while (flockIter.hasNext()) {
            flockIter.next().stopFollowing();
        }
    }
}
```

Appendix D: A main class for creating a running two `Flocks`

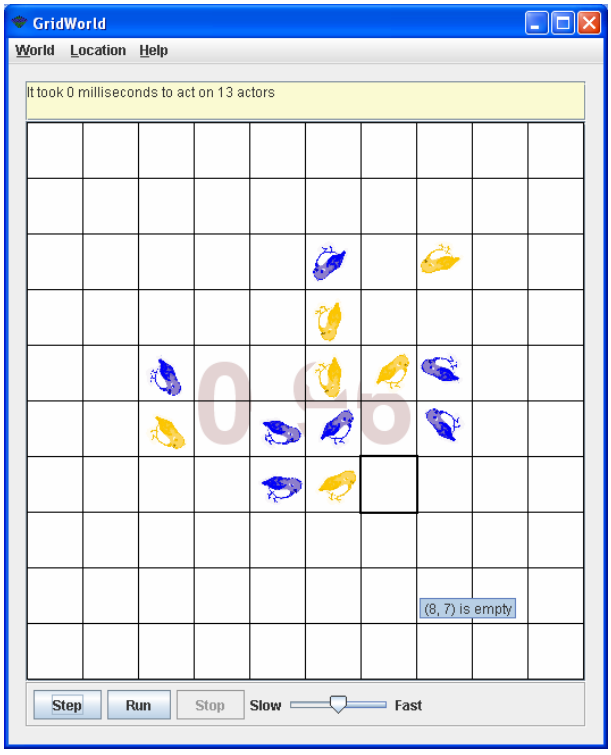
```
/*
 * FlockRunner.java
 */
import info.gridworld.actor.Actor;
import info.gridworld.actor.ActorWorld;
import info.gridworld.grid.*;
import java.util.Iterator;

/**
 *  @author Christian Day
 *  @version June 5, 2007
 **/
public class FlockRunner {
    public static void main (String[] args) {
        Flock robins = new Flock();
        Flock jays = new Flock();

        ActorWorld world = new ActorWorld();

        for (int r = 0 ; r < 5 ; r++) {
            Bird robin = new Bird();
            robin.setColor(java.awt.Color.ORANGE);
            robins.add(robin);
        }
        Bird robinLeader = new Bird();
        robinLeader.setColor(java.awt.Color.ORANGE);
        robins.addLeader(robinLeader);

        for (int j = 0 ; j < 6 ; j++) {
            jays.add(new Bird());
        }
        Bird jayLeader = new Bird();
        jays.addLeader(jayLeader);

        Iterator flockIter = robins.iterator();
        while (flockIter.hasNext()) {
            Bird b = (Bird)flockIter.next();
            world.add(world.getRandomEmptyLocation(), b);
        }
        world.add(world.getRandomEmptyLocation(), robinLeader);

        flockIter = jays.iterator();
        while (flockIter.hasNext()) {
            Bird b = (Bird)flockIter.next();
            world.add(world.getRandomEmptyLocation(), b);
        }
        world.add(world.getRandomEmptyLocation(), jayLeader);

        world.show();
    }

}
```

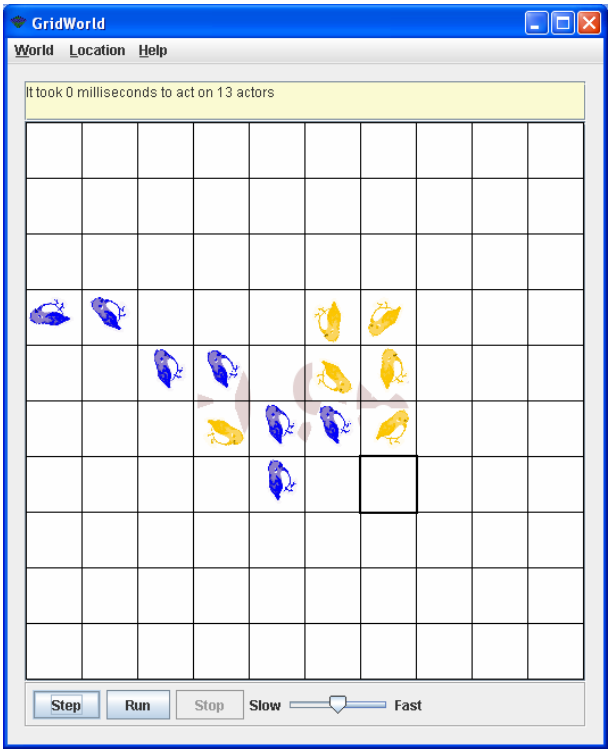
Screen Shots:





[2]





See FlockingBirds_ProgramFiles_Day.zip file containing java files and images.

[2] Bird Images by Ji Mi Lee, Emma Willard School class of 2008