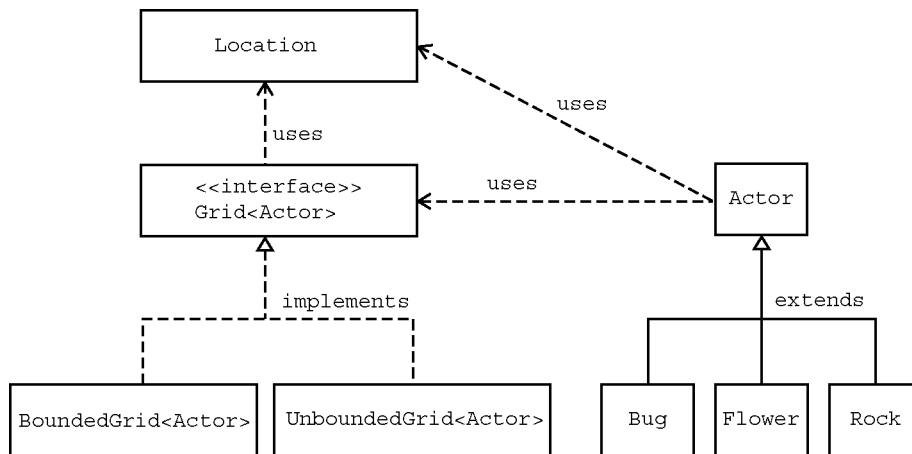


# GridWorld Case Study

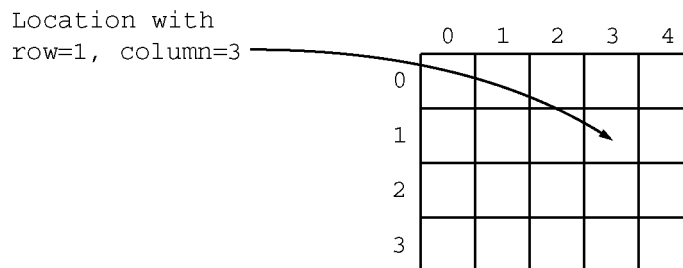
## Part 3: GridWorld Classes and Interfaces

In our example programs, a grid contains actors that are instances of classes that extend the `Actor` class. There are two classes that implement the `Grid` interface: `BoundedGrid` and `UnboundedGrid`. Locations in a grid are represented by objects of the `Location` class. An actor knows the grid in which it is located as well as its current location in the grid. The relationships among these classes are shown in the following figure.



### The Location Class

Every actor that appears has a location in the grid. The `Location` class encapsulates the coordinates for an actor's position in a grid. It also provides methods that determine relationships between locations and compass directions.



Every actor in the grid also has a direction. Directions are represented by compass directions measured in degrees: 0 degrees is north, 45 degrees is northeast, 90 degrees is east, etc. The `Location` class provides eight constants that specify the compass directions.

```
public static final int NORTH = 0;
public static final int EAST = 90;
public static final int SOUTH = 180;
public static final int WEST = 270;
public static final int NORTHEAST = 45;
public static final int SOUTHEAST = 135;
public static final int SOUTHWEST = 225;
public static final int NORTHWEST = 315;
```

In addition, the `Location` class specifies constants for commonly used turn angles. For example, `Location.HALF_RIGHT` denotes a turn by 45 degrees. Here are the constants for the turn angles.

```
public static final int LEFT = -90;
public static final int RIGHT = 90;
public static final int HALF_LEFT = -45;
public static final int HALF_RIGHT = 45;
public static final int FULL_CIRCLE = 360;
public static final int HALF_CIRCLE = 180;
public static final int AHEAD = 0;
```

To make an actor turn by a given angle, set its direction to the sum of the current direction and the turn angle. For example, the `turn` method of the `Bug` class makes this call.

```
setDirection(getDirection() + Location.HALF_RIGHT);
```

A location in a grid has a row and a column. These values are parameters of the `Location` constructor.

```
public Location(int r, int c)
```

Two accessor methods are provided to return the row and column for a location.

```
public int getRow()
public int getCol()
```

Two other `Location` methods give information about the relationships between locations and directions.

```
public Location getAdjacentLocation(int direction)
    returns the adjacent location in the compass direction that is closest to direction

public int getDirectionToward(Location target)
    returns the closest compass direction from this location toward target
```

For example, assume you have the statement below.

```
Location loc1 = new Location(5, 7);
```

The following statements will result in the values indicated by the comments.

```
Location loc2 = loc1.getAdjacentLocation(Location.WEST);
// loc2 has row 5, column 6

Location loc3 = loc1.getAdjacentLocation(Location.NORTHEAST);
// loc3 has row 4, column 8

int dir = loc1.directionToward(new Location(6, 8));
// dir has value 135 (degrees)
```

Note that the row values increase as you go south (down the screen) and the column values increase as you go east (to the right on the screen).

The `Location` class defines the `equals` method so that `loc.equals(other)` returns true if `other` is a `Location` object with the same row and column values as `loc` and returns false otherwise.

The `compareTo` method compares two `Location` objects. The method call `loc.compareTo(other)` returns a negative integer if `loc` has a smaller row coordinate than `other`, or if they have the same row and `loc` has a smaller column coordinate than `other`. The call returns 0 if `loc` and `other` have the same row and column values. Otherwise, the call returns a positive integer.



### Do You Know? Set 3

The API for the `Location` class is in Appendix B.

Assume the following statements when answering the following questions.

```
Location loc1 = new Location(4, 3);  
Location loc2 = new Location(3, 4);
```

1. How would you access the row value for `loc1`?
2. What is the value of `b` after the following statement is executed?

```
boolean b = loc1.equals(loc2);
```

3. What is the value of `loc3` after the following statement is executed?

```
Location loc3 = loc2.getAdjacentLocation(Location.SOUTH);
```

4. What is the value of `dir` after the following statement is executed?

```
int dir = loc1.getDirectionToward(new Location(6, 5));
```

5. How does the `getAdjacentLocation` method know which adjacent location to return?

## The Grid Interface

The interface `Grid<E>` specifies the methods for any grid that contains objects of the type `E`. Two classes, `BoundedGrid<E>` and `UnboundedGrid<E>` implement the interface.

You can check whether a given location is within a grid with this method.

```
boolean isValid(Location loc)
    returns true if loc is valid in this grid, false otherwise
Precondition: loc is not null
```



All methods in this case study have the implied precondition that their parameters are not `null`. The precondition is emphasized in this method to eliminate any doubt whether `null` is a valid or invalid location. The `null` reference does not refer to any location, and you must not pass `null` to the `isValid` method.

The following three methods allow us to put objects into a grid, remove objects from a grid, and get a reference to an object in a grid.

```
E put(Location loc, E obj)
    puts obj at location loc in this grid and returns the object previously at that
    location (or null if the location was previously unoccupied)
Precondition: (1) loc is valid in this grid (2) obj is not null
```

```
E remove(Location loc)
    removes the object at location loc and returns it (or null if the location is
    unoccupied)
Precondition: loc is valid in this grid
```

```
E get(Location loc)
    returns the object at location loc (or null if the location is unoccupied)
Precondition: loc is valid in this grid
```

An additional method returns all occupied locations in a grid.

```
ArrayList<Location> getOccupiedLocations()
```

Four methods are used to collect adjacent locations or neighbor elements of a given location in a grid. The use of these methods is demonstrated by the examples in Part 4.

```
ArrayList<Location> getValidAdjacentLocations(Location loc)
    returns all valid locations adjacent to loc in this grid
```

**Precondition:** loc is valid in this grid

```
ArrayList<Location> getEmptyAdjacentLocations(Location loc)
    returns all valid empty locations adjacent to loc in this grid
```

**Precondition:** loc is valid in this grid

```
ArrayList<Location> getOccupiedAdjacentLocations(Location loc)
    returns all valid occupied locations adjacent to loc in this grid
```

**Precondition:** loc is valid in this grid

```
ArrayList<E> getNeighbors(Location loc)
```

returns all objects in the occupied locations adjacent to loc in this grid

**Precondition:** loc is valid in this grid

Finally, you can get the number of rows and columns of a grid.

```
int getNumRows();
int getNumCols();
```

For unbounded grids, these methods return -1.



### Do You Know? Set 4

The API for the `Grid` interface is in Appendix B.

1. How can you obtain a count of the objects in a grid? How can you obtain a count of the empty locations in a bounded grid?
2. How can you check if location (10,10) is in a grid?
3. `Grid` contains method declarations, but no code is supplied in the methods. Why? Where can you find the implementations of these methods?
4. All methods that return multiple objects return them in an `ArrayList`. Do you think it would be a better design to return the objects in an array? Explain your answer.

## The Actor Class

The following accessor methods of the `Actor` class provide information about the state of the actor.

```
public Color getColor()
public int getDirection()
public Grid<Actor> getGrid()
public Location getLocation()
```

One method enables an actor to add itself to a grid; another enables the actor to remove itself from the grid.

```
public void putSelfInGrid(Grid<Actor> gr, Location loc)
public void removeSelfFromGrid()
```

The `putSelfInGrid` method establishes the actor's location as well as the grid in which it is placed. The `removeSelfFromGrid` method removes the actor from its grid and makes the actor's grid and location both `null`.



When adding or removing actors, do *not* use the `put` and `remove` methods of the `Grid` interface. Those methods do not update the `location` and `grid` instance variables of the actor. That is a problem since most actors behave incorrectly if they do not know their location. To ensure correct actor behavior, always use the `putSelfInGrid` and `removeSelfFromGrid` methods of the `Actor` class.

To move an actor to a different location, use the following method.

```
public void moveTo(Location loc)
```

The `moveTo` method allows the actor to move to any valid location. If the actor calls `moveTo` for a location that contains another actor, the other one removes itself from the grid and this actor moves into that location.

You can change the direction or color of an actor with the methods below.

```
public void setColor(Color newColor)
public void setDirection(int newDirection)
```

These `Actor` methods provide the tools to implement behavior for an actor. Any class that extends `Actor` defines its behavior by overriding the `act` method.

```
public void act()
```

The `act` method of the `Actor` class reverses the direction of the actor. You override this method in subclasses of `Actor` to define actors with different behavior. If you extend `Actor` without specifying an `act` method in the subclass, or if you add an `Actor` object to the grid, you can observe that the actor flips back and forth with every step.

The `Bug`, `Flower`, and `Rock` classes provide examples of overriding the `act` method.

The API for the `Grid` interface and the `Location` and `Actor` classes is provided in Appendix B. The following questions help analyze the code for `Actor`.



### Do You Know? Set 5

The API for the `Actor` class is in Appendix B.

1. Name three properties of every actor.
2. When an actor is constructed, what is its direction and color?
3. Why do you think that the `Actor` class was created as a class instead of an interface?
4. Can an actor put itself into a grid twice without first removing itself? Can an actor remove itself from a grid twice? Can an actor be placed into a grid, remove itself, and then put itself back? Try it out. What happens?
5. How can an actor turn 90 degrees to the right?

## Extending the `Actor` Class

The `Rock`, `Flower`, and `Bug` classes extend `Actor` in different ways. Their behavior is specified by how they override the `act` method.

### The `Rock` Class

A rock acts by doing nothing at all. The `act` method of the `Rock` class has an empty body.

### The `Flower` Class

A flower acts by darkening its color, without moving. The `act` method of the `Flower` class reduces the values of the red, green, and blue components of the color by a constant factor.



## The Bug Class

A bug acts by moving forward and leaving behind a flower. A bug cannot move into a location occupied by a rock, but it can move into a location that is occupied by a flower, which is then removed. If a bug cannot move forward because the location in front is occupied by a rock or is out of the grid, then it turns right 45 degrees.

In Part 2, exercises were given to extend the `Bug` class. All of the exercises required the `act` method of the `Bug` class to be overridden to implement the desired behavior. The `act` method uses the three auxiliary methods in the `Bug` class: `canMove`, `move` and `turn`. These auxiliary methods call methods from `Actor`, the superclass.

The `canMove` method determines whether it is possible for this `Bug` to move. It uses a Java operator called `instanceof` (not part of the AP CS Java subset). This operator is used as in the following way.

```
expr instanceof Name
```

Here, `expr` is an expression whose value is an object and `Name` is the name of a class or interface type. The `instanceof` operator returns `true` if the object has the specified type. If `Name` is a class name, then the object must be an instance of that class itself or one of its subclasses. If `Name` is an interface name, then the object must belong to a class that implements the interface.

This statement in the `canMove` method checks whether the object in the adjacent location is `null` or if it is a `Flower`.

```
return (neighbor == null) || (neighbor instanceof Flower);
```

The following statement in the `canMove` method checks that the bug is actually in a grid—it would be possible for the bug not to be in a grid if some other actor removed it.

```
if (gr == null) return false;
```

The other code for `canMove` is explored in the questions at the end of this section.

The `move` method for `Bug` moves it to the location immediately in front and puts a flower in its previous location. The `turn` method for `Bug` turns it 45 degrees to the right. The code for these methods is explored in the following questions.



## Do You Know? Set 6

The source code for the `Bug` class is in Appendix C.

1. Which statement in the `canMove` method ensures that a bug does not try to move out of its grid?
2. Which statement in the `canMove` method determines that a bug will not walk into a rock?
3. Which methods of the `Grid` interface are invoked by the `canMove` method and why?
4. Which method of the `Location` class is invoked by the `canMove` method and why?
5. Which methods inherited from the `Actor` class are invoked in the `canMove` method?
6. What happens in the `move` method when the location immediately in front of the bug is out of the grid?
7. Is the variable `loc` needed in the `move` method, or could it be avoided by calling `getLocation()` multiple times?
8. Why do you think the flowers that are dropped by a bug have the same color as the bug?
9. When a bug removes itself from the grid, will it place a flower in its previous location?
10. Which statement in the `move` method places the flower in the grid in the bug's previous location?
11. If a bug needs to turn 180 degrees, how many times should it call the `turn` method?

## Group Activity

Organize groups of 3–5 students.

1. Specify: Each group creates a class called `Jumper`. This actor can move forward two cells in each move. It “jumps” over rocks and flowers. It does not leave anything behind it when it jumps.

In the small groups, discuss and clarify the details of the problem:

- a. What will a jumper do if the location in front of it is empty, but the location two cells in front contains a flower or a rock?
- b. What will a jumper do if the location two cells in front of the jumper is out of the grid?
- c. What will a jumper do if it is facing an edge of the grid?
- d. What will a jumper do if another actor (not a flower or a rock) is in the cell that is two cells in front of the jumper?

- e. What will a jumper do if it encounters another jumper in its path?
  - f. Are there any other tests the jumper needs to make?
2. Design: Groups address important design decisions to solve the problem:
    - a. Which class should `Jumper` extend?
    - b. Is there an existing class that is similar to the `Jumper` class?
    - c. Should there be a constructor? If yes, what parameters should be specified for the constructor?
    - d. Which methods should be overridden?
    - e. What methods, if any, should be added?
    - f. What is the plan for testing the class?
  3. Code: Implement the `Jumper` and `JumperRunner` classes.
  4. Test: Carry out the test plan to verify that the `Jumper` class meets the specification.

### What Makes It Run? (Optional)

A graphical user interface (GUI) has been provided for running GridWorld programs. The `World` class makes the connection between the GUI and the classes already described. The GUI asks the world for its grid, locates the grid occupants, and draws them. The GUI allows the user to invoke the `step` method of the world, either taking one step at a time or running continuously. After each step, the GUI redisplay the grid.

For our actors, a subclass of the `World` class called `ActorWorld` is provided. `ActorWorld` defines a `step` method that invokes `act` on each actor.

The `World` and `ActorWorld` classes are not tested in the AP CS exam.

Other worlds can be defined that contain occupants other than actors. By providing different implementations of the `step` method and other methods of the `World` class, one can produce simulations, games, and so on. This is not tested on the AP CS exam.

In order to display the GUI, a runner program constructs a world, adds occupants to it, and invokes the `show` method on the world. That method causes the GUI to launch.

The `ActorWorld` class has a constructor with a `Grid<Actor>` parameter. Use that constructor to explore worlds with grids other than the default 10 x 10 grid.

The `ActorWorld` has two methods for adding an actor.

```
public void add(Location loc, Actor occupant)
public void add(Actor occupant)
```

The `add` method without a `Location` parameter adds an actor at a random location.

When adding actors to a world, be sure to use the `add` method of the `ActorWorld` class and not the `put` method of the `Grid` interface. The `add` method calls the `Actor` method `putSelfInGrid`. As explained previously, the `putSelfInGrid` method sets the actor's references to its grid and location and calls the grid method `put`, giving the grid a reference to the actor.

The `remove` method removes an actor from a given location and returns the `Actor` that has been removed.

```
public Actor remove(Location loc)
```

The relationship between the GUI, world, and actor classes is shown in the following figure. Note that the GUI has no knowledge of actors. It can show occupants in any world. Conversely, actors have no knowledge of the GUI.

