Homework 5: Generalized Tic Tac Toe

For this assignment, you will write a program that given an $n \times n$ tic-tac-toe board, determines which player will win, or if the game will be a draw. You're going to make significant use of Scala collections and learn the the *Minimax algorithm*, which is a form of backtracking search.

The template for this assignment is available here¹.

1 Representing a Tic Tac Toe Board

We assume you know how to play Tic Tac Toe. This section talks about the representation of tic-tac-toe boards that you will use. All the types mentioned below are in the file src/main/scala/Provided.scala in the template code.

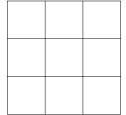
The sealed trait Player has two constructors, 0 and X, that represent the two players. A typical 3×3 board can be thought of as a 3×3 matrix, where (0,0) is the coordinate of the top-left corner and (2,2) is the coordinate of the bottom-right corner:

(0,0)	(1,0)	(2,0)
(0,1)	(1, 1)	(2,1)
(0,2)	(1, 2)	(2, 2)

The Solution.createGame function, which you need to implement, takes as input the player who makes the first move, the value n that specifies the dimensions of the board, and a map from coordinates to Players that indicates where the pieces are.

For example:

• In generalized tic-tac-toe, either play may make the first move. Therefore, given an empty board:

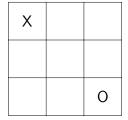


¹https://www.cs.umass.edu/~arjun/courses/cmpsci220-spring2016/hw/tictactoe.zip

We can call the function in two ways:

```
Solution.createGame(0, 3, Map())
Solution.createGame(X, 3, Map())
```

• This board:

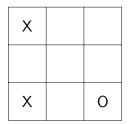


Can be represented as:

```
Solution.createGame(X, 3, Map((0, 0) \rightarrow X, (2, 2) \rightarrow 0))
```

Alternatively, we could have O make the next move.

• This board:

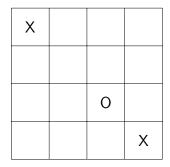


Can be represented as:

```
Solution.createGame(X, 3, Map((0, 0) \rightarrow X, (0, 2) \rightarrow X, (2, 2) \rightarrow 0))
```

Alternatively, we could have O make the next move.

• This board, which is 4×4 :



Can be represented as:

```
Solution.createGame(0, 4, Map((0, 0) \rightarrow X, (2, 2) \rightarrow 0, (3, 3) \rightarrow X))
```

Alternatively, we could have X start first too.

2 The Minimax Algorithm

Minimax is an algorithm to to determine who will win (or draw) a two-player game, if both players are playing perfectly. To do so, Minimax searches all possible game-states that are reachable from a given inital state. Here is an outline of a recursive implementation of Minimax:

You can find several other descriptions of Minimax on the Web. But, Minimax is a very straightforward function to write, if you follow the programming directions below and implement (and test) everything leading up to Minimax.

3 Programming Task

Your task is to implement a representation of boards, by implementing the GameLike trait, provided in the template code. Your code must be able to implement arbitrary $n \times n$ boards for all n > 2. However, your implementation of the Minimax algorithm (the MinimaxLike trait) only needs to be fast enough for n < 4.

I recommend proceeding in the following way, using Solution.scala as a template:

- 1. Add fields to the Game class to represent the state of the game and fill in the body of the Solution.createGame(turn, dim, board) function. You may assume that dim >= 2 and that all the pieces described in board are within bounds. However, The board may be in an arbitrary, even illegal state. For example, the board may have seven Xs. Similarly, the turn could be either X or O.
- 2. Implement the Game.isFinished method. Human players often end a game early, when the outcome is inevitable. However, you may find it easier to write a program that plays until every single square is filled.
- 3. Implement the getWinner method.

Provided.scala has a class called Matrix that has some useful methods. You may find it easier to use a matrix to represent a board, instead of an arbitrary map or two-dimensional array.

²If you want to do better, lookup *alpha-beta pruning* on the web.

4. Implement the nextBoards method, which returns a list of boards that represent all the moves the next player could make.

For example, if the current board looks like this:

X	Χ	
	0	
Х	0	0

And if it is O's turn, then these are the three possible next boards:

X	Χ	
0	0	
X	0	0

X	Χ	
	0	0
X	0	0

X	X	0
	0	
X	0	0

As you implement each successive step, you may need to revisit design decisions you made earlier.

4 Hand In

From sbt, run the command submit. The command will create a file called submission.tar.gz in your assignment directory. Submit this file using Moodle.

For example, if the command runs successfully, you will see output similar to this:

```
Created submission.tar.gz. Upload this file to Moodle. [success] Total time: 0 s, completed Jan 17, 2016 12:55:55 PM \,
```

Note: The command will not allow you to submit code that does not compile. If your code doesn't compile, you will receive no credit for the assignment.