CSC 242 Project 1 Writeup

Part 1: 3 x 3 board

Steps to run the 3 x 3 board

1. Go to the directory project1/part1/
2. Run the following commands:
   ```
   javac Main.java
   java Main
   ```

Implementation

`Main.java`

`main()` makes an instance of the problem class and then starts the tic-tac-toe game using `startGame()`. `startGame()` asks the human agent if she wants to play as “`X`” or “`O`”. If their response is “`X`” then the following functions are executed sequentially until goal state is found: `humanMove()`, `aiMove()` and `displayBoard()`. A response of “`O`” would run the sequence `aiMove()`, `displayBoard()` and `humanMove()`.

`Problem.java`

`humanMove()` asks the human agent to enter the position of her move. If the spot is already taken, then the human agent is asked again, until a valid response is given. After the human agent’s correct response, `activeState` is set to the result of applying that response to the active state. This is implemented on line 119, shown below:

```
activeState = result(activeState, new Action(position));
```

`result()` first makes a copy of the `State` that is passed in as the first parameter and then initializes a new `State` (the successor state) with the contents of the passed in `State`. Something that I learned working on this project was that fiddling with the passed in State causes a side-effect on the original `State`. My very first implementation of the `copy()` function failed because of this very reason. I initially had the following:

```
    board = sCopy.board
```

Whereas the correct implementation is:

```
    System.arraycopy(board, 0, sCopy.board, 0, 9);
```

The lesson to learn here is that “`=`” copies the *reference* of the array rather than the value, and if we want to prevent side-effects, we must either use `System.arrayCopy`, or iterate over the elements of the array, using “`=`” to copy individual elements.

`aiMove()` is a two liner function that calls `minimaxDecision()`, which returns a `decision`. Then `aiMove()` sets the `activeState` to the result of applying `decision` on `activeState`. This is shown in the following two lines:

```
Action decision = minimaxDecision(activeState);

activeState = result(activeState, decision);
```

`minimaxDecision()` returns the most optimal action available for the AI agent. There is one conditional in this function, whose decision is dependent on the value of `aiMaximize`, which is set in `startGame()` based on the human agent’s decision to be “`X`” or “`O`”. If the human agent had chosen “`X`”, then `aiMaximize` would have been set to false, running the part of the conditional where the AI agent seeks to minimize its utility. On the other hand, if the human agent had chosen “`O`”, `aiMaximize` would be false, running the part of the conditional where the AI agent seeks to maximize its utility.

`minVal()` and `maxVal()` are the helper functions of `minimaxDecision()`.

`minimaxDecision()`, `minVal()` and `maxVal()` call `applicableActions()` while passing in a `State`. `applicableActions` returns a `HashSet` of `Actions` that are applicable at the `State` that is passed in as a parameter.

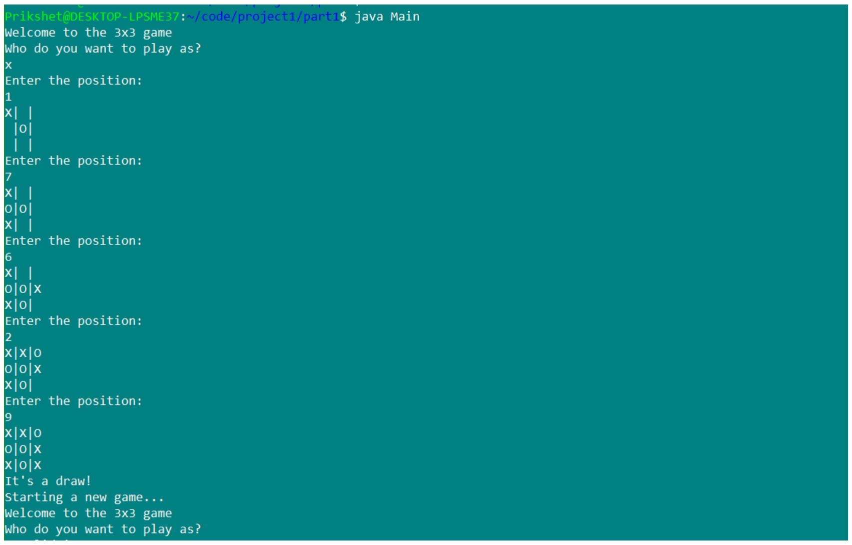
Utility function returns `1` if it finds that the state passed in is won by “`X`”, `-1` if by “`O`” and `0` if it’s a draw.

`State.java`

`State.java` contains the variables for the board as an array of Strings and the `activePlayer` (either “`X`” or “`O`”). It also contains the `displayBoard` function, that is called when we display the tic-tac-toe board.

Gameplay

The gameplay is very simple. First, we tell the program if we want to play as “`X`” or “`O`”, and then enter a number for each move, which specifies the location of the move.



```
Prikshet@DESKTOP-LPSME37:~/code/project1/part1$ java Main
Welcome to the 3x3 game
Who do you want to play as?
x
Enter the position:
1
x| |
 |o|
 | |
Enter the position:
7
x| |
o|o|
x| |
Enter the position:
6
x| |
o|o|x
x|o|
Enter the position:
2
x|x|o
o|o|x
x|o|
Enter the position:
9
x|x|o
o|o|x
x|o|x
It's a draw!
Starting a new game...
Welcome to the 3x3 game
Who do you want to play as?
```

Figure 1: 3x3 board gameplay

Part 2: 9 x 9 board

Steps to run the 9 x 9 board

1. Go to the directory project1/part2/
2. Run the following commands:
   javac Main.java
   java Main

Implementation

`Main.java`

Similar to the 3 x 3 board, `main()` makes an instance of the problem class and then initializes the game using `startGame`(). `startGame()` asks the human agent if they want to play as “`X`” or “`O`”.

`Problem.java`

If their response is “`X`” then the following functions are executed sequentially until goal state is found: `humanMove()`, `aiMove()` and `displayBoard()`. A response of “`O`” would run the sequence `aiMove()`, `displayBoard()` and `humanMove()`.

`humanMove()` first checks if the human agent has a choice as to what board she should play on. If board has the value of `0` in `humanMove()`, then the human agent is free to choose the board position. If `board` has any other value, then that value refers to the board where the human agent must to play her next move. If the human agent inputs any other board number, she would be prompted to input the value again, until the correct value is entered.

`aiMove()` first sets the depth of the `activeState` to `0`. This is important because we are implementing a depth limited search with a depth of `10`. So each time `hMinimaxDecision()` is called by `aiMove()`, setting the depth of activeState to zero makes sure that sure `hMinimaxDecision()` always searches ten levels deeper than the current state. `hMinimimaxDecision()` returns the best action as far as the AI agent can tell based on the heuristic, so we set the new `activeState` to `result(activeState, hMinimaxDecision(activeState))`.

`result()` function does four things:

1. Adds the move on the board.
2. Changes the `activePlayer` from "`O`" to "`X`", or from "`X`" to "`O`"
3. Sets the cost of the successor state one more than the cost of previous state
4. Sets the depth of the successor state one more than the cost of previous state

`eval()` returns the sum of `cost()` and `heuristic().`

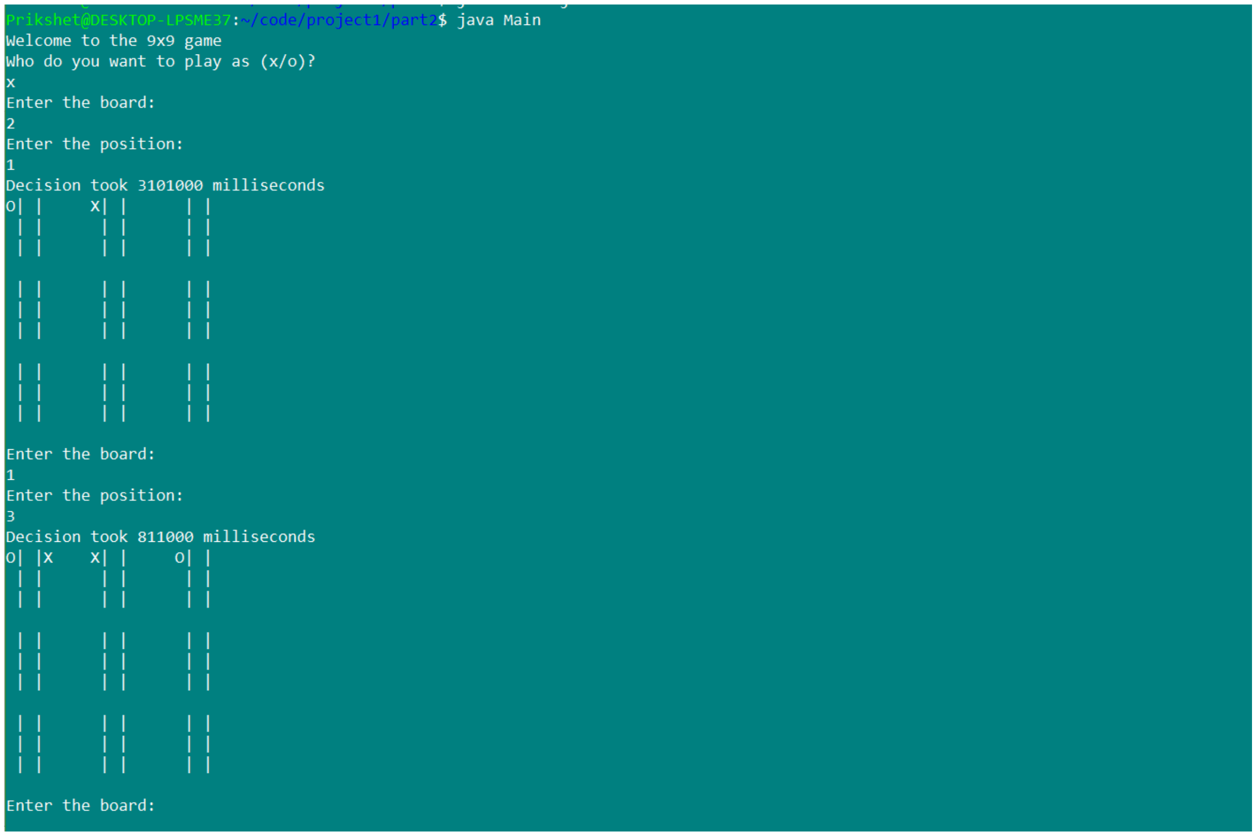
`State.java`

`cost()` is the cost of reaching that node.

`heuristic()` is implemented to check how many times we can find two X's or O's horizontally, vertically or diagonally, given that the third space is empty.

Gameplay

The gameplay for the 9 x 9 board is a little more engaging. First the human agent inputs if she wants to play as "`X`" or "`O`". Then they first input the board which they want to play on, and then the position on that board.



```
Prikshet@DESKTOP-LPSME37:~/code/project1/part2$ java Main
Welcome to the 9x9 game
Who do you want to play as (x/o)?
x
Enter the board:
2
Enter the position:
1
Decision took 3101000 milliseconds
O| |     X| |      | |
 | |      | |      | |
 | |      | |      | |

 | |      | |      | |
 | |      | |      | |
 | |      | |      | |

 | |      | |      | |
 | |      | |      | |
 | |      | |      | |

Enter the board:
1
Enter the position:
3
Decision took 811000 milliseconds
O| |X    X| |     O| |
 | |      | |      | |
 | |      | |      | |

 | |      | |      | |
 | |      | |      | |
 | |      | |      | |

 | |      | |      | |
 | |      | |      | |
 | |      | |      | |

Enter the board:
```

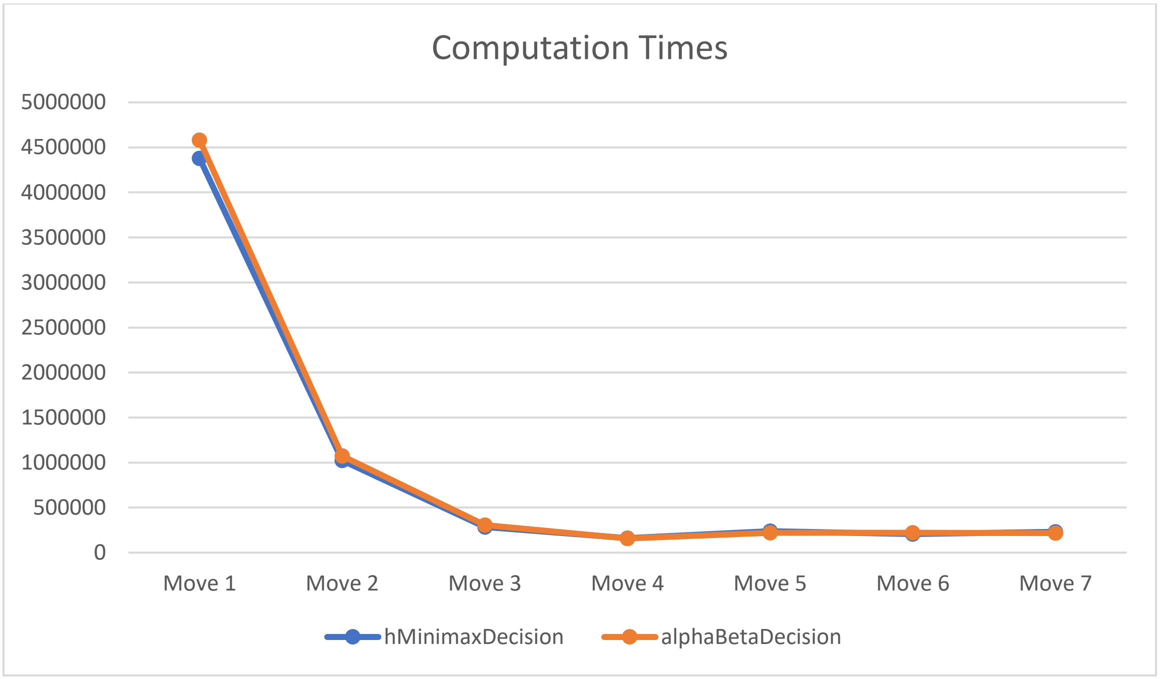
Figure 2: 9x9 board gameplay

Effects of Alpha Beta Pruning

Here we compare the computation times for `alphaBetaDecision()` versus the `hMinimaxDecision()`

These times were computed by sandwiching these two functions between two `System.nanoTime()` statements who value we store in two different variables. The difference of those two variables gives the time it took to compute the functions.

Computation times								
	`hMinimaxDecison (ms)`				`alphaBetaDecision (ms)`			
Move	Trial 1	Trial 2	Trial 3	Average	Trial 1	Trial 2	Trial3	Average
1	4E+06	4561000	4151000	4378000	4759000	4627000	4357000	4581000
2	976000	1024000	1066000	1022000	831000	953000	1435000	1073000
3	330000	208000	314000	284000	311000	398000	211000	306666.7
4	195000	158000	131000	161333.3	158000	185000	130000	157666.7
5	267000	250000	193000	236666.7	282000	167000	214000	221000
6	176000	280000	166000	207333.3	256000	188000	222000	222000
7	288000	218000	185000	230333.3	219000	157000	271000	215666.7



Result: In the 9x9 state space search, `hMinimaxDecision()` fared as well as `alphaBetaDecision()`

Problems and Proposed Solution

Although the 3 x 3 board never loses, the 9 x 9 board unfortunately tends to lose sometimes. That means that either something in our implementation is causing this problem, or that the heuristic is not effective. A way to make the AI agent play better games would be to use a better heuristic.