Assignment Two

Question 1:

```
{3,4,5,7,5,3,4},
{4,6,8,10,8,6,4},
{5,8,11,13,11,8,5},
{5,8,11,13,11,8,5},
{4,6,8,10,8,6,4},
{3,4,5,7,5,4,3}
```

This matrix pre-determines the value of every position on the connect 4 board. The integer value at each position is simply the total possible ways that one could connect 4 tiles using that particular position. For instance, let's take the bottom left corner(it's position would be (0,0))
Different number of ways to connect 4:

1) (0,0) to (0,3)
2) (0,0) to (3,0)
3) (0,0) to (3,3)

Hence, there are 3 possible ways to make connect 4 with tile (0,0). Thus, its value is 3. We can also notice that the values of the tiles increase as we get closer to the centre.

For evaluating a given position, we iterate through the board summing up the value of any tile belonging to the AI player and subtracting the value of any tile belonging to the opponent. This calculation gives us the AI's utility. Keep in mind that the starting value of our utility variable is 0. Also if we stumble upon a tile not belonging to either player, its value is 0.

1) If utility<0 : losing position(opponent winning)
2) If utility=0 : draw position
3) If utility>0 : winning position(AI winning)

Thus, we will follow the route that gives us the highest utility.

Evaluation example:

```
{ , , , , , , },
{ , , , , , , },
{ , , , , , , },
{ , , ,x, , , },
{ , , ,o, , , },
{ , , ,x,o, , },
```

Let's assume that the AI is player one, playing with X, and the opponent is playing with O. The evaluation function iterates from the top row to

the bottom, from the left column to the right. The first it stumbles upon, belonging to either player is tile (3,2). Since it belongs to player one, utility=+13. Next, tile (3,1) which belongs to opponent. Hence, utility=13-10=+3. Next, tile (3,0) which belongs to player 1: utility=3+7=+10. Next, tile (4,0) which belongs to player 2: utility=10-5=+5.
Thus, our utility for this position is +5. However, if we were the player 2, our utility would have been -5.

Successor function:

For ordering moves such that the best-case scenario for pruning occurs, we must check each player's best moves first. However, there is no certain way to tell what the player's best move might be unless we look down the tree. But looking too far down the tree could deceive the purpose of pruning.

My successor function orders the successor moves in descending order based on the value of the tile that would immediately be occupied by making each of the moves. As an example, consider the matrix:

```
{ , , , , , , },
{ , , , , , , },
{ , , , , , , },
{ , , ,x, , , },
{ , , ,o, , , },
{ , , ,x,o, , },
```

In this state, X has seven immediate moves available. Now, we map each of the moves to the immediate value associated with the move. For example: dropping at 0 would occupy the tile (0,0) which has a value of 3.

Map={0=3, 1=4, 2=5, 3=13 ,4=8 ,5=4 ,6=3}.

Next we sort it in descending order of the value:

sortedMap={3=13, 4=8, 2=5, 1=4, 5=4, 0=3, 6=3}

Now that we have decided the order of the successors, we iterate through each of them in this very order.
Though we cannot guarantee that the first move is going to continue to be the best move as we go further down the tree, we have good reason to believe that the best move will be closer to the beginning of the map than at the end: since we know that capturing an important tile on the board only makes the player's position better.

MiniMax Games(games won:40/40)

Opponent: StupidAI

Player 1: MiniMax
Player 2: MonteCarloAI

```
          xxx....
          ooo....
Game 1:   xoo....      Player 1 wins!
          ooxo...
          oxxxx..
          ooxxx..

          xxx....
          ooo....
Game 2:   xoo....      Player 1 wins!
          ooxo...
          oxxxx..
          ooxxx..

          xxx....
          ooo....
Game 3:   xoo....      Player 1 wins!
          ooxo...
          oxxxx..
          ooxxx..

          xxx....
          ooo....
Game 4:   xoo....      Player 1 wins!
          ooxo...
          oxxxx..
          ooxxx..

          xxx....
          ooo....
Game 5:   xoo....      Player 1 wins!
          ooxo...
          oxxxx..
          ooxxx..
```

Opponent: StupidAI

```
Player 1: MonteCarloAI
Player 2: MiniMax

          x......
          x......
Game 1:   o......     Player 2 wins!
          x......
          x......
          xoooo..

          x......
          x......
Game2:    o......     Player 2 wins!
          x......
          x......
          xoooo..

          x......
          x......
Game 3:   o......     Player 2 wins!
          x......
          x......
          xoooo..

          x......
          x......
Game 4:   o......     Player 2 wins!
          x......
          x......
          xoooo..

          x......
          x......
Game 5:   o......     Player 2 wins!
          x......
          x......
          xoooo..

Opponent: RandomAI

Player 1: MiniMax
Player 2: RandomAI

          .......
          .......
Game 1    .......     Player 1 wins!
          .......
          ..o....
          xxxxoo.
```

```
          .......
          .......
Game 2:   ..x....     Player 1 wins!
          ..x....
          ..x....
          ..xooo.

          ..x....
          ..x....
Game 3:   ..x....     Player 1 wins!
          ..x....
          ..o....
          o.xxooo

          .......
          .......
Game 4:   .......     Player 1 wins!
          .o.o...
          xxxx...
          ooxx..o

          .......
          .......
Game 5:   ..x....     Player 1 wins!
          ..x....
          ..x....
          .oxoo..

Opponent: RandomAI

Player 1: RandomAI
Player 2: MiniMax

          .......
          .......
Game 1:   .......     Player 2 wins!
          .......
          ....x..
          Ooooxxx




          .......
Game 2:   .......
          ...o...     Player 2 wins!
```

```
          ...o...
          o.xo...
          xxooxxx

          .......
          .......
Game 3:   ...o...      Player 2 wins!
          .x.o...
          .x.o...
          .x.ox..

          .......
          .......
Game 4:   .......      Player 2 wins!
          .......
          x......
          xooooxx


          o......
          ooo....
Game 5:   oxox...      Player 2 wins!
          xxxo...
          xooo.x.
          xxxooxx

Opponent: MonteCarloAI

Player 1: MiniMax
Player 2: MonteCarloAI


          ...o.o.
          .xxx.o.
Game 1:   .oxx.xx      Player 1 wins!
          oxox.oo
          oxxoxoo
          xxxoxoo

          ...o.o.
          .xxx.o.
Game 2:   .oxx.xx      Player 1 wins!
          oxox.oo
          oxxoxoo
          xxxoxoo
```

```
          ...o.o.
          .xxx.o.
Game 3:   .oxx.xx      Player 1 wins!
          oxox.oo
          oxxoxoo
          xxxoxoo

          ...o.o.
          .xxx.o.
Game 4:   .oxx.xx      Player 1 wins!
          oxox.oo
          oxxoxoo
          xxxoxoo

          ...o.o.
          .xxx.o.
Game 5:   .oxx.xx      Player 1 wins!
          oxox.oo
          oxxoxoo
          xxxoxoo

          ...o.o.
          .xxx.o.
Game 6:   .oxx.xx      Player 1 wins!
          oxox.oo
          oxxoxoo
          xxxoxoo



          ...o.o.
          .xxx.o.
Game 7:   .oxx.xx      Player 1 wins!
          oxox.oo
          oxxoxoo
          xxxoxoo

          ...o.o.
          .xxx.o.
Game 8:   .oxx.xx      Player 1 wins!
          oxox.oo
          oxxoxoo
          xxxoxoo

          ...o.o.
          .xxx.o.
Game 9:   .oxx.xx      Player 1 wins!
          oxox.oo
          oxxoxoo
          xxxoxoo
```

```
          ...o.o.
          .xxx.o.
Game 10:  .oxx.xx      Player 1 wins!
          oxox.oo
          oxxoxoo
          xxxoxoo

Opponent: MonteCarloAI

Player 1: MonteCarloAI
Player 2: MiniMax



          o.x....
          o.oo...
Game 1:   ooox..o      Player 2 wins!
          xoox..x
          xoxo.xx
          xoxxoxx

          o.x....
          o.oo...
Game 2:   ooox..o      Player 2 wins!
          xoox..x
          xoxo.xx
          xoxxoxx

          o.x....
          o.oo...
Game 3:   ooox..o      Player 2 wins!
          xoox..x
          xoxo.xx
          xoxxoxx

          ....x..
          ...oo..
Game 4:   ...xo.o      Player 2 wins!
          ..xxo.x
          ooooxox
          xxoxxox


          ....x..
          ...oo..
Game 5:   ...xo.o      Player 2 wins!
          ..xxo.x
          ooooxox
```

```
          xxoxxox


          o.x....
          o.oo...
Game 6:   ooox..o      Player 2 wins!
          xoox..x
          xoxo.xx
          xoxxoxx

          ....x..
          ...oo..
Game 7:   ...xo.o      Player 2 wins!
          ..xxo.x
          ooooxox
          xxoxxox

          o.x....
          o.oo...
Game 8:   ooox..o      Player 2 wins!
          xoox..x
          xoxo.xx
          xoxxoxx

          o.x....
          o.oo...
Game 9:   ooox..o      Player 2 wins!
          xoox..x
          xoxo.xx
          xoxxoxx

          o.x....
          o.oo...
Game 10:  ooox..o      Player 2 wins!
          xoox..x
          xoxo.xx
          xoxxoxx
```

Alphabeta Games(games won:20/20)

Opponent: MontCarloAI

Player 1: alphabeta
Player 2: MonteCarloAI

```
          ..ox...
          ..xo.x.
Game1:    o.xxxx.      Player 1 wins!
          x.xxoo.
          o.ooxxo
          o.oxxoo

          ...xo..
          .x.ox..
Game 2:   .xxxx.o      Player 1 wins!
          .ooxx.x
          oxxoo.o
          ooxxo.o

          ...xo..
          .x.ox..
Game 3:   .xxxx.o      Player 1 wins!
          .ooxx.x
          oxxoo.o
          ooxxo.o

          o.xx...
          o.xx.ox
Game 4:   x.oxxxo      Player 1 wins!
          ooxooxx
          oxoxxox
          oooxoox

          ...xo..
          .x.ox.o
Game 5:   xx.xxxx      Player 1 wins!
          oo.xxox
          ox.ooxo
          ooxxooo


          ..ox...
          ..xo.x.
Game 6:   o.xxxx.      Player 1 wins!
          x.xxoo.
          o.ooxxo
          o.oxxoo


          ..ox...
          ..xo.xo
Game 7:   o.xxxxx      Player 1 wins!
          xoxxoox
          oxooxxo
```

```
         oooxxoo

         ...xo..
         .x.ox.o
Game 8:  xx.xxxx      Player 1 wins!
         oo.xxox
         ox.ooxo
         ooxxooo

         o.xx...
         o.xx.ox
Game 9:  x.oxxxo      Player 1 wins!
         ooxooxx
         oxoxxox
         oooxoox

         ..ox...
         ..xo.x.
Game 10: o.xxxx.      Player 1 wins!
         x.xxoo.
         o.ooxxo
         o.oxxoo
```

Opponent: MontCarloAI

Player 1: MonteCarloAI
Player 2: alphabeta

```
         ..x....
         ..oo...
Game 1:  oooxo..      Player 2 wins!
         xooxx.x
         xoxoo.x
         xoxxo.x


         ..x....
         ..oo...
Game 2:  oooxo..      Player 2 wins!
         xooxx.x
         xoxoo.x
         xoxxo.x

         ..x....
         ..oo...
Game 3:  oooxo..      Player 2 wins!
```

```
         xooxx.x
         xoxoo.x
         xoxxo.x

         ..x....
         ..oo...
Game 4:  oooxo..       Player 2 wins!
         xooxx.x
         xoxoo.x
         xoxxo.x

         ..x....
         ..oo...
Game 5:  oooxo..       Player 2 wins!
         xooxx.x
         xoxoo.x
         xoxxo.x

         ..x....
         ..oo...
Game 6:  oooxo..       Player 2 wins!
         xooxx.x
         xoxoo.x
         xoxxo.x

         ..x....
         ..oo...
Game 7:  oooxo..       Player 2 wins!
         xooxx.x
         xoxoo.x
         xoxxo.x


         ..o.x..
         ..xooox
Game 8:  ..oxoxo       Player 2 wins!
         ..xxoox
         ..ooxox
         x.oxxox

         ..o.x..
         ..xooox
Game 9:  ..oxoxo       Player 2 wins!
         ..xxoox
         ..ooxox
         x.oxxox

          ..x....
          ..oo...
Game 10: oooxo..       Player 2 wins!
```

```
xooxx.x
xoxoo.x
xoxxo.x
```