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Part 1 Report:

State representation scheme

There will be a n rows \times m columns board and L row of pawns on each side. A pawn can move other north or north-west or northeast. If the opponent's pawn is at north, a player cannot go there. Same with the player from north to south. If a player's pawn can reach the opponent's base, the player wins.

We need to keep track of the board size, location of all pawns, and whose turn it is right now. We also need to keep track of which pawn is whose. In our implementation, our class State will have attributes: $p1$ is a list of position tuples for the pawns of player 1, $p2$ is a list of position tuples for the the pawns of player 2, $turn$ is the number indicates which player will take the move at the current state, and $boardSize$ is a tuples of the board size.

Part 2-A Report: Evasive vs. Evasive

The evasive function seems to be a good strategy for the player to win. However, since its motive is to have as many pawns remaining as possible on current player's side, even though the player can win with one more move, it does not care but proceeds to carry out its motive until the `random()` function will finally put more weight on the pawn that has the best chance of winning.

1st turn	3rd turn	5th turn
0.000	0.00.	..00.
.0...	...0.	0..0.
.....	.0...	...X.
...X.	.X.XX	XX0.X
XXX.X	X.X..	..X..
2nd turn	4th turn	6th turn
0.00.	0.00.	..00.
.0.0.	...0.	0....
.....X.X0
.X.X.	XX0XX	X.0.X
X.X.X	..X..	..X..

7th turn	8th turn	9th turn
..00.	...0.
X....	X.O..	X.OO.
O..XO	O..XO	OX.XO
X.O.X	XXO.X	.X..X
..X..0..

In the game shown above, the game state is (5,5,1) with both sides using the evasive function. The top player is “p1” and the bottom one is “p2”. We can see that “p1” could win at the 5th turn by moving the pawn at (3,2), but the game lasted for 5 more unnecessary turns. The reason is that when the three-moves prediction happens, the player’s tree will not have any moves at the leaf node because if the player wins at the next move, that pawn will have no more moves it can make after the next move. Therefore, its utility function is not being calculated properly.

The results under the Appendix section show that the second player of the game has a better chance of winning if both players use the evasive technique. The reason might be that the second player has a better heuristic after the first player makes its first move.

Part 2-B Report: Evasive vs. Conqueror

The raw results of this part are shown in the Appendix Evasive vs. Conqueror. Used board sizes are (5 rows, 5 columns, 1 pawn row each side), (6, 3, 1), and (8, 8, 2). Each board size is played by 2 AI Evasive and Conqueror 10 or 5 times, and Evasive wins more games than Conqueror no matter who goes first (10-0, 3-2, 5-0, respectively). This pattern holds both before and after strong aversion/preference are assigned to losing/winning state.

In general, the Conqueror AI tries to move its pawns to where they can capture the Evasive AI’s pawns, while Evasive AI tries to move its pawns to avoid being captured by the Conqueror AI’s pawns and even sometimes capture them. Evasive AI ends up with more pawns on the board when the game ends most of the time no matter who wins.

The overall result is not surprising because the Evasive AI predicts correctly what the Conqueror AI wants to do, but the Conqueror AI predicts wrongly what the Evasive AI wants to do:

- P1 (Evasive AI):
 - + Wants to maximize the P1’s number of pawns

- + Thinks that P2 wants to minimize P1's number of pawns (correct)
- P2 (Conqueror AI):
 - + Wants to minimize P1's number of pawns
 - + Thinks that P1 wants to minimize P2's number of pawns (incorrect)

Part 2-C Report: Two more utilities

1. DecideBestUtility

DecideBest utility function decides between the evasive and the conqueror to use depending on the number of pawns remaining on each side of the game. If the player has more pawns than the opponent, the player will focus on having more pawns. If the player has less or equal pawns than the opponent, the player will focus on decreasing the pawns of the opponent.

This approach seems to win both the evasive and the conqueror according to the results shown in the appendix.

2. HeightisgoalUtility

HeightisgoalUtility function takes in account how far a pawn on both sides has moved away from its base and got close to the other base, combines Conqueror and Evasive, and also takes in account if a pawn is in a support position for an ally pawn. Among those components, The most important one is the first as it weighs a forward move near the opponent base more than a forward move near our own base (row height is squared) and it also tries to not lose pieces up there because they are more valuable than the piece near the base.

This utility dominates both Conqueror (5-0) and Evasive (5-0) with the detailed results being shown in the Appendix Heightisgoal vs. Evasive and Heightisgoal vs. Conqueror.

3. HeightisgoalUtility vs. DecideBestUtility

HeightisgoalUtility won 4-1 in (8,8,2) and depth 3 settings. Detailed results are in the appendix. HeightisgoalUtility is currently the best our group has so far.

Appendix

Evasive Vs. Evasive (5,5,1)

.X0..

0....

OX0.0

....X

X.X..

Number of moves p1 made: 7

Number of moves p2 made: 7

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p2

.X00.

0..0.

0....

.....

X.XXX

Number of moves p1 made: 4

Number of moves p2 made: 4

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p2

0.0..

..0.0

....X

.XXX.

..X.0

Number of moves p1 made: 6

Number of moves p2 made: 5

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

..0X.

00..0

...0.

.X...

X..XX

Number of moves p1 made: 5

Number of moves p2 made: 5

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p2

..X0.

.00..

0...0

...XX

XX...

Number of moves p1 made: 6

Number of moves p2 made: 6

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p2

Evasive Vs. Conqueror (5,5,1): 5-0

0..00

...0.

.....

X....

.0.XX

Number of moves p1 made: 5

Number of moves p2 made: 4

p1 captured 2 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

.000.

....0

..X..

.XX..

X0..X

Number of moves p1 made: 5

Number of moves p2 made: 4

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

0.000

.....

.....

.XXX.

X0..X

Number of moves p1 made: 4

Number of moves p2 made: 3

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

0.00.

....0

.....

X.X..

.XX.0

Number of moves p1 made: 5

Number of moves p2 made: 4

p1 captured 1 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

.00..

0.0..

.....

X....

.X0X.

Number of moves p1 made: 6

Number of moves p2 made: 5

p1 captured 2 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

Conqueror Vs. Evasive (5,5,1): 0-5

X....

.00..

.X.00

.....

.XX..

Number of moves p1 made: 8

Number of moves p2 made: 8

p1 captured 1 pawns of p2

p2 captured 1 pawns of p1

Winner: p2

.0.X0

0....

.0.0.

....X

XXX..

Number of moves p1 made: 5

Number of moves p2 made: 5

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p2

.0.X.

0...0

...0.

X....

X.XX.

Number of moves p1 made: 5

Number of moves p2 made: 5

p1 captured 0 pawns of p2

p2 captured 1 pawns of p1

Winner: p2

...X.

00...

.X.0.

...X.

.X...

Number of moves p1 made: 9

Number of moves p2 made: 9

p1 captured 1 pawns of p2

p2 captured 2 pawns of p1

Winner: p2

.0.X0

0..0.

.....

.....

XXX.X

Number of moves p1 made: 4

Number of moves p2 made: 4

p1 captured 0 pawns of p2

p2 captured 1 pawns of p1

Winner: p2

Conqueror vs. Evasive

(6,3,1),(8,8,2): 2-3, 0-5

board size: (6, 3)

minimax depth: 3

#p1 left: 2

#p2 left: 3

total moves: 16

X..

.0.

...

X0.

.X.

...

Evasive won

board size: (6, 3)

minimax depth: 3

#p1 left: 1

#p2 left: 3

total moves: 12

X..

..0

...

...

.X.

X..

Evasive won

board size: (6, 3)

minimax depth: 3

#p1 left: 2

#p2 left: 3

total moves: 16

.X.

..0

...

O.X

.X.

...

Evasive won

board size: (6, 3)

minimax depth: 3

#p1 left: 3

#p2 left: 2

total moves: 13

.0.

...

O..

.XX

...

.0.

Conqueror won

board size: (6, 3)

minimax depth: 3

#p1 left: 3

#p2 left: 3

total moves: 9

.00

...

...

..X

.XX

O..

Conqueror won

board size: (8, 8)

minimax depth: 3

#p1 left: 11

#p2 left: 14

total moves: 46

O.X.O.O.

00.00.0.

O.....0.

..X.....

...X....

XO....XX

.....X

XXX.XXXX

Evasive won

```

board size: (8, 8)
minimax depth: 3
#p1 left: 12
#p2 left: 15
total moves: 42
0.00.X..
000.0..0
.0.X0.00
.....
.X.....
X.X...XX
...X....
XXXXXXX.
Evasive won

```

```

-----
board size: (8, 8)
minimax depth: 3
#p1 left: 15
#p2 left: 16
total moves: 14
00000.X0
0000000.
.....0
.....
.....0..
...X....
XX.XXX.X
XXXXXXXXX
Evasive won

```

```

board size: (8, 8)
minimax depth: 3
#p1 left: 10
#p2 left: 11
total moves: 62
.0.X0000
0.0..0..
....0...
.X.....
.X0.X..X
..X...X.
.X....X.
...XX...
Evasive won

```

```

-----
board size: (8, 8)
minimax depth: 3
#p1 left: 13
#p2 left: 16
total moves: 26
0.0.X000
0000..0.
.....000
.....
.X.....
X.X.XX..
....X.XX
XXX.XXXX
Evasive won

```


Conqueror Vs. DecideBest: 3-2

...X0

0.00.

.0...

..X..

XX.X.

Number of moves p1 made: 5

Number of moves p2 made: 5

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p2

.00.X

0.0..

.....

.....

XXX.X

Number of moves p1 made: 4

Number of moves p2 made: 4

p1 captured 0 pawns of p2

p2 captured 1 pawns of p1

Winner: p2

.0000

.....

.....

X..XX

X0..X

Number of moves p1 made: 4

Number of moves p2 made: 3

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

00.00

.....

.....

.XX.X

..X0X

Number of moves p1 made: 4

Number of moves p2 made: 3

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

0.000

.....

X....

.X...

0.XXX

Number of moves p1 made: 4

Number of moves p2 made: 3

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

DecideBest Vs. Conqueror: 5-0

0..0.

.0...

.X...

.XX..

...0X

Number of moves p1 made: 7

Number of moves p2 made: 6

p1 captured 1 pawns of p2

p2 captured 1 pawns of p1

Winner: p1

000..

...0.

.....

X.X..

.XX.0

Number of moves p1 made: 5

Number of moves p2 made: 4

p1 captured 1 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

...00

.00..

....X

X.X..

.X.0.

Number of moves p1 made: 6

Number of moves p2 made: 5

p1 captured 1 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

..000

0....

.....

.XXXX

0..X.

Number of moves p1 made: 5

Number of moves p2 made: 4

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

0...0

...00

.....

.XX..

0..XX

Number of moves p1 made: 6

Number of moves p2 made: 5

p1 captured 1 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

DecideBest Vs. Evasive: 4-1

.000.

.0...

.X...

.X.X.

..X0X

Number of moves p1 made: 5

Number of moves p2 made: 4

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

..00.

00...

...X.

XX..X

.0X..

Number of moves p1 made: 6

Number of moves p2 made: 5

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

0..0.

0..0.

...X.

X.X.X

X..0.

Number of moves p1 made: 6

Number of moves p2 made: 5

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

.X...

0....

.00X.

...0X

...X.

Number of moves p1 made: 10

Number of moves p2 made: 10

p1 captured 1 pawns of p2

p2 captured 1 pawns of p1

Winner: p2

..0..

.00.0

..X.X

X...X

0X...

Number of moves p1 made: 7

Number of moves p2 made: 6

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

Evasive Vs. DecideBest: 2-3

0..X.

0....

..000

XX.X.

....X

Number of moves p1 made: 7

Number of moves p2 made: 7

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p2

.X0..

00.0.

....0

X....

..XXX

Number of moves p1 made: 5

Number of moves p2 made: 5

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p2

.00.0

.....

.0XX.

.X...

0..XX

Number of moves p1 made: 6

Number of moves p2 made: 5

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

X.0..

.00..

...00

XX...

...XX

Number of moves p1 made: 6

Number of moves p2 made: 6

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p2

..000

0....

...X.

.XX..

X0..X

Number of moves p1 made: 5

Number of moves p2 made: 4

p1 captured 0 pawns of p2

p2 captured 0 pawns of p1

Winner: p1

Heightisgoal vs. Evasive: 5-0

board size: (8, 8)
minimax depth: 3
#p1 left: 16
#p2 left: 14
total moves: 21
00000000
00..000.
.....
....0...
..X...0.
XX....X.
..XXXXX
OX..XXXX
p1won

board size: (8, 8)
minimax depth: 3
#p1 left: 16
#p2 left: 15
total moves: 19
00000000
.000000.
.....
.....
.XXX....
O.X...XX
...X..X.
XXXXOXXX
P1won

board size: (8, 8)
minimax depth: 3
#p1 left: 16
#p2 left: 14
total moves: 35
0.000000
0...000.
..0.....
.....X.
X.00X.X.
..X....0
...X.X.X
X0XXXXX.
p1won

board size: (8, 8)
minimax depth: 3
#p1 left: 16
#p2 left: 15
total moves: 19
00000000
.0000..0
.....0..
....X...
..0.....
X...X...
.XXX.X.X
XXXXX0XX
p1won

board size: (8, 8)
minimax depth: 3
#p1 left: 16
#p2 left: 15
total moves: 19
00000000
..00000.
.0.....
..X.....
O...X...
X.X....X
.XX..X.X
X.X0XXXX
p1won

Heightisgoal vs. Conqueror: 5-0

board size: (8, 8)
minimax depth: 3
#p1 left: 14
#p2 left: 13
total moves: 23
00000000
.0000.0.
.....
.....X.
.....
X.X.....
..X.XX..
XXXXXXOX
p1won

board size: (8, 8)
minimax depth: 3
#p1 left: 15
#p2 left: 13
total moves: 19
00000000
.000000.
.....
.....
.....
.....
X...X.X.
.X..X..X
XXXXX0XX
p1won

board size: (8, 8)
minimax depth: 3
#p1 left: 16
#p2 left: 13
total moves: 19
00000000
.00000.0
.....
.....
.....
.....
XXXOX..X
..X...X.
OX.XXXXX
p1won

board size: (8, 8)
minimax depth: 3
#p1 left: 16
#p2 left: 15
total moves: 11
00000000
.0000000
.....
.....
.....
..X.....
XX.....X
..XX.XX.
OXXXXXXX
p1won

board size: (8, 8)
minimax depth: 3
#p1 left: 15
#p2 left: 12
total moves: 19
00000000
.000000.
.....
.....
.....X.
X..XX..X
X.....
XXXXOX.X
p1won

DecideBest vs. Heightisgoal: 1-4

board size: (8, 8)
minimax depth: 3
#p1 left: 15
#p2 left: 13
total moves: 43
0...0000
0...000.
.....
.0.00...
OX.....0
....XXXX
X.X...XX
OX.X.XX.
P1won

board size: (8, 8)
minimax depth: 3
#p1 left: 16
#p2 left: 15
total moves: 19
00000000
.000000.
.....
.....
..X.X..X
X..X..0.
.X..X.X.
X0XXXXXX
p1won

board size: (8, 8)
minimax depth: 3
#p1 left: 15
#p2 left: 15
total moves: 34
.000X000
0000..0.
.....
.....X..
X.....
00X0X0X.
...X....
XXXXXXXX
p2won

board size: (8, 8)
minimax depth: 3
#p1 left: 16
#p2 left: 15
total moves: 15
00000000
.000000.
.....
..0.....
X.....
XX..X.XX
...X..X.
XXXX0XXX
P1won

board size: (8, 8)
minimax depth: 3
#p1 left: 16
#p2 left: 15
total moves: 35
0000.0.0
.00...0.
.....00.
X...0000
X.....
..XXX.XX
X....XXX
OXXX..X.
p1won
