

Nine Men Morris Project Report

We go over all the cases one by one.

Command to run the code:

```
python <file_name.py> <input_board.txt> <output_board_path.txt> <depth>
```

1. Running MiniMaxOpening.py

Console output 1: python MiniMaxOpening.py board.txt board1.txt 5

Input position: BBxxxxWBWWWxxxxxxxxxx

Output position: BBxWxxWBWWWxxxxxxxxxx

Positions evaluated by static estimation: 612636

MINIMAX estimate: 3

Console output 2: python MiniMaxOpening.py board2.txt board1.txt 5

Input position: BBBxWxWBWWWBBBxWxxxxW

Output position: BBBxWxWBWWWBBBWWxxxxW

Positions evaluated by static estimation: 59912

MINIMAX estimate: 2

2. Running ABOpening.py

Console output 1: python ABOpening.py board.txt board1.txt 5

Input position: BBxxxxWBWWWxxxxxxxxxx

Output position: BBxWxxWBWWWxxxxxxxxxx

Positions evaluated by static estimation: 7771

MINIMAX estimate: 3

Console output 2: python ABOpening.py board2.txt board1.txt 5

Input position: BBBxWxWBWWWBBBxWxxxxW

Output position: BBBxWxWBWWWBBBWWxxxxW

Positions evaluated by static estimation: 1614

MINIMAX estimate: 2

Savings using Alpha-Beta pruning method:

As we can see in the above ABOpening and MiniMaxOpening consoles output

Comparing console output 1:

Positions evaluated = 612636 (MiniMaxOpening)

Positions evaluated = 7771 (ABOpening)

Comparing console output 1:

Positions evaluated = 59912 (MiniMaxOpening)

Positions evaluated = 1614 (ABOpening)

Savings are 90% on an average for Alpha-beta pruning over MiniMax Algorithm

3. Running MiniMaxGame.py

Console output 1: python MiniMaxGame.py board.txt board1.txt 6

Input position: BBBxxxWBWWWBxxxxxxxxxW

Output position: BBBxWxWBxWWBxxxxxxxxxW

Positions evaluated by static estimation: 88186

MINIMAX estimate: -7

Console output 2: python MiniMaxGame.py board2.txt board1.txt 6

Input position: WBWxBxBWWWxxBxxBWBWxx

Output position: WBWxBxBWWWxWxBxxBWBWxx

Positions evaluated by static estimation: 82833

MINIMAX estimate: 994

4. Running ABGame.py

Console output 1: python ABGame.py board1.txt board1.txt 6

Input position: BBBxxxWBWWWBxxxxxxxxxW

Output position: BBBxWxWBxWWBxxxxxxxxxW

Positions evaluated by static estimation: 3765

MINIMAX estimate: -7

Console output 1: python ABGame.py board2.txt board1.txt 6

Input position: WBWxBxBWWWxxBxxBWBWxx

Output position: WBWxBxBWWxWxBxxBWBWxx

Positions evaluated by static estimation: 3167

MINIMAX estimate: 994

Savings using Alpha-Beta pruning method:

As we can see in the above ABOpening and MiniMaxOpening consoles output

Comparing console output 1:

Positions evaluated = 88186 (MiniMaxOpening)

Positions evaluated = 3765 (ABOpening)

Comparing console output 1:

Positions evaluated = 82833 (MiniMaxOpening)

Positions evaluated = 3167 (ABOpening)

Savings are 90% on an average for Alpha-beta pruning over MiniMax Algorithm and varies as per the board and moves combinations and remaining pieces on the board.

5. Running MiniMaxOpeningBlack.py

Console output 1: python MiniMaxOpeningBlack.py board2.txt board1.txt 6

Input position: WBWxBxBWxxxxxxxxxxWxx

Output position: WBWxBxBWxxxxxxxxBxxWxx

Positions evaluated by static estimation: 514028

MINIMAX estimate: 0

--- As we can see the program is playing as a Black piece and adding a black piece to the board

Console output 1: python MiniMaxOpeningBlack.py board.txt board1.txt 5

Input position: WBWxBxBWxxxxxxxxxxWxx

Output position: WBWxBxBWxxxxxxxxBxxWxx

Positions evaluated by static estimation: 514028

MINIMAX estimate: 0

Console output 2: python MiniMaxOpeningBlack.py board2.txt board1.txt 5

Input position: Wxxxxxxxxxxxxxxxxxxxxxx

Output position: WBxxxxxxxxxxxxxxxxxxxxxx

Positions evaluated by static estimation: 1917984

MINIMAX estimate: 0

6. Running MiniMaxGameBlack.py

Console output 1: python MiniMaxGameBlack.py board.txt board1.txt 6

Input position: WBWxBxBWWWxxBxxBWBWxx

Output position: WxWxBxBWWWxBBxxBWBWxx

Positions evaluated by static estimation: 98217

MINIMAX estimate: -1010

--- As we can see the program is playing as Black and moving a black piece on the board

Console output 1: python MiniMaxGameBlack.py board2.txt board1.txt 6

Input position: WBWxBxBWWWxxxBxxBxxWxx

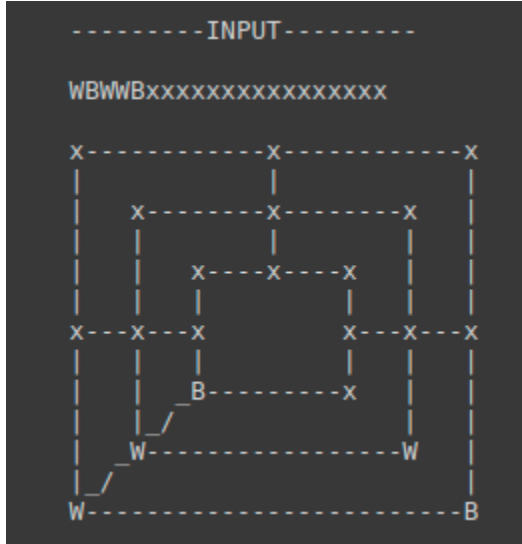
Output position: WxWxBxBWWWxBBxxBxxWxx

Positions evaluated by static estimation: 37275

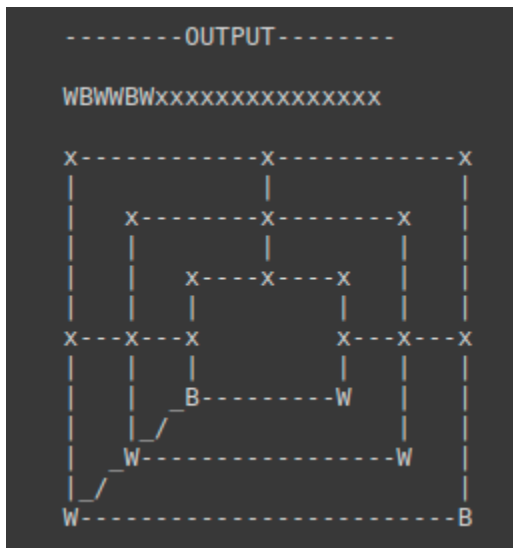
MINIMAX estimate: -7

7. Opening on given static estimation:

When given the input: **WBWWBxxxxxxxxxxxxxxxxxx** to MiniMaxOpening with depth 3



Using the given static estimation the output which we get is:



Input position: WBWWBxxxxxxxxxxxxxxxxxx Output position: WBWWBWxxxxxxxxxxxxxxxxxx
Positions evaluated by static estimation: 3528
MINIMAX estimate: 2

As we can see from the output that the next move for white is to place **W** in the **6th position**.

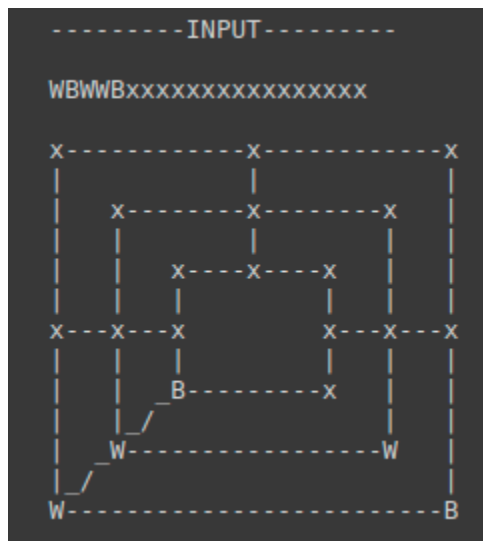
This does not seem to be a good choice. By placing W in the 6th position white is not getting any advantage. At least white should try forming a mill instead of wasting the move by placing W in the 6th position. This is because the static estimation given to us is very basic and just subtracts white pieces with black pieces which are currently on the board.

Opening Improved static estimation:

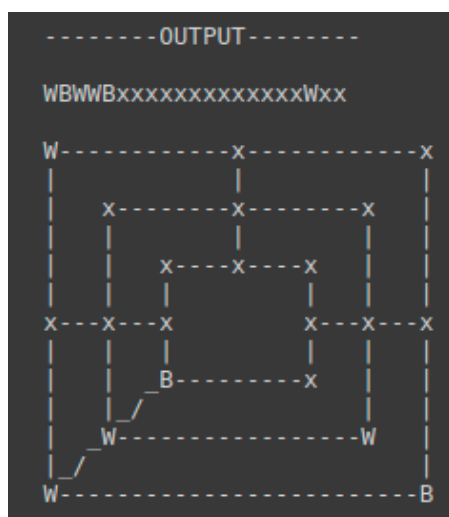
My improved static estimation takes into account DoubleMill forming, number of white pieces blocked, number of black pieces blocked and number of white and black pieces

Example 1:

When given the input: **WBWWBxxxxxxxxxxxxxxxxxx** to MiniMaxOpeningImproved with depth 3



Using the improved static estimation the output which we get is:



```

Input position: WBWWBxxxxxxxxxxxxxxxxx Output position: WBWWBxxxxxxxxxxxxxxxxWxx
Positions evaluated by static estimation: 3528
MINIMAX estimate: 12

```

As we can see from the output that the next move for white using the improved static estimation is to place **W** in the **19th position**.

Placing W in the 19th position seems to be a better choice rather than the 6th since it provides white with the opportunity to form a mill or use that position to form two mills instead of the 6th position where you can form only one mill using that position.

Example 2:

When given the input: **WBWWBxxxxxxxxxxxxxxxxx** to MiniMaxOpening with depth 4. The output is closing a mill on position 6th and removing B from position 3.

```

-----INPUT-----
Wx BxxxxxBxxxxBBxWxx

W-----x-----x
|         |         |
|  B-----B-----x
|         |         |
|   x---x---x
|         |         |
x---x---x         x---B---x
|         |         |
|   x---x---x
|         |         |
|  x-----x-----B
|         |         |
W-----W-----W

-----OUTPUT-----
WWxxxxWxxxxBxxxxBBxWxx

W-----x-----x
|         |         |
|  B-----B-----x
|         |         |
|   x---x---x
|         |         |
W---x---x         x---B---x
|         |         |
|   x---x---x
|         |         |
|  x-----x-----x
|         |         |
W-----W-----W

Input position: Wx BxxxxxBxxxxBBxWxx Output position: WWxxxxWxxxxBxxxxBBxWxx
Positions evaluated by static estimation: 57530
MINIMAX estimate: -1

```


This is a good move but we have a better move which leads us close to winning positions and prepares the white to be equipped with better moves when the game commences to midgame

Improved: Same input to ImprovedMiniMaxOpening

```

-----INPUT-----
WWxBxxxxxBxxxxBBxWxx

W-----x-----x
|           |           |
|   B-----B-----x   |
|   |           |           |
|   x---x---x---x   |
|   |           |           |
x---x---x           x---B---x
|   |           |           |
|   x---x---x           |
|   |           |           |
|   x-----B           |
W-----W

-----OUTPUT-----
WWxBxxxxxBxxxxBBxWxx

W-----x-----x
|           |           |
|   B-----B-----W   |
|   |           |           |
|   x---x---x---x   |
|   |           |           |
x---x---x           x---B---x
|   |           |           |
|   x---x---x           |
|   |           |           |
|   x-----B           |
W-----W

Input position: WWxBxxxxxBxxxxBBxWxx Output position: WWxBxxxxxBxxxxBBxWxx
Positions evaluated by static estimation: 57530
MINIMAX estimate: -1

```

In an improved static estimation case we can see that the white is blocking the formation of two mills. This case is crucial because if white would not have intervened and blocked the two mills there are high chances that during the midgame the black could move a black piece(from the double mill) back and forth and constantly form a mill which is a big disadvantage for White hence it first blocks the double mill formation by black so as not to be in a state where it has a disadvantage.

8. Midgame on given static estimation:

Example1: Basic static estimation

When given input: **WBxBxWxWWWxxxxxxxxxBxB** to MiniMaxMidgame with depth 3

```
-----INPUT-----
WBxBxWxWWWxxxxxxxxxBxB

B-----X-----B
|               |
|   x-----x-----x   |
|   |               |   | |
|   |   x-----x-----x   |
|   |   |               |   |
x---W---W           W---x---x
|   |   |               |   |
|   |   x-----W       |   |
|   |   |               |   |
|   |   x-----B       |   |
|   |   |               |   |
W---|---|               B
|   |   |               |

-----OUTPUT-----
WBxBWxxWWWxxxxxxxxxBxB

B-----X-----B
|               |
|   x-----x-----x   |
|   |               |   | |
|   |   x-----x-----x   |
|   |   |               |   |
x---W---W           W---x---x
|   |   |               |   |
|   |   W-----x       |   |
|   |   |               |   |
|   |   x-----B       |   |
|   |   |               |   |
W---|---|               B
|   |   |               |

Input position: WBxBxWxWWWxxxxxxxxxBxB Output position: WBxBWxxWWWxxxxxxxxxBxB
Positions evaluated by static estimation: 1963
MINIMAX estimate: 1961
```

We get output where white moves its piece from 5th position to 4th. Which isn't doing anything given the board. And does not form a mill which is possible in this case.

Improved Midgame on given static estimation:

The improved static estimation takes into account number of mills formed by white and black pieces and number of white and black pieces blocked and remaining white and black pieces

Example 1:

When given input: **WBxBxWxWWWxxxxxxxxBxB** to MiniMaxMidgameImproved with depth 3

-----INPUT-----

WBxBxWxWWWxxxxxxxxBxB

```
B-----x-----B
|
|   x-----x-----x
|   |   |   |
|   |   x-----x-----x
|   |   |   |
x---W---W           W---x---x
|   |   |   |   |
|   |   x-----W
|   |   |   |
|   x-----B
|   |   |
W---x-----B
```

-----OUTPUT-----

xBxBxWWWxxxxxxxxBxx

```
B-----x-----x
|
|   x-----x-----x
|   |   |   |
|   |   x-----x-----x
|   |   |   |
W---W---W           W---x---x
|   |   |   |   |
|   |   x-----W
|   |   |   |
|   x-----B
|   |   |
x---x-----B
```

Input position: WBxBxWxWWWxxxxxxxxBxB Output position: xBxBxWWWxxxxxxxxBxx

Positions evaluated by static estimation: 1963

MINIMAX estimate: 150

When given input: **xBxBWxWWWWxxxBxWxxBxB** to MiniMaxMidgameImproved with depth 3

```

-----INPUT-----

xBxBWxWWWxxxBxWxxBxB

B-----x-----B
|           |
|   W-----x-----x   |
|   |           |       | |
|   |   x-----B-----x   |
|   |   |           |       |
W---W---W           W---x---x
|   |           |       | |
|   |   W-----x       |
|   |   |           |       |
|   |   x-----B       |
|   |   |           |       |
x-----B-----B

-----OUTPUT-----

xxWBxxWWWxxxBxWxxBxB

B-----x-----B
|           |
|   W-----x-----x   |
|   |           |       | |
|   |   x-----B-----x   |
|   |   |           |       |
W---W---W           W---x---x
|   |           |       | |
|   |   x-----x       |
|   |   |           |       |
|   |   W-----B       |
|   |   |           |       |
x-----x-----x

```

Input position: xBxBWxWWWxxxBxWxxBxB Output position: xxWBxxWWWxxxBxWxxBxB
Positions evaluated by static estimation: 1557
MINIMAX estimate: 280

We can see that the white moves to our desired position where it closes the mill instead of doing a move from 9th to 13th which was done previously when using basic static estimation. Here in this case the white moves its pieces from 5th position to 3rd position and thus closing the mill and removing black piece from position 2.

Most of the cases my improved static estimation gives same output as the given static estimation but there are some cases where basic static estimation does not take into consideration mill forming which is addressed in my static estimation