CS6364 ARTIFICIAL INTELLIGENCE
PROJECT

Net ID: NXM210046

MiniMaxOpening.py:

Input and Output:

```
In [27]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxOpening.py',
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xWxBxBxWxWxBxBxWWx
Enter depth:5
Board position: xWxBxBWWxWxBxBxWWx
Positions evaluated by static estimation:184657
Minimax estimate:4
```

```
In [137]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxOpening.py',
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xxxBBBWWxWxBxBxxxx
Enter depth:6
Board position: xWxBBBWWxWxBxBxxxx
Positions evaluated by static estimation:1524596
Minimax estimate:-2
```

MiniMaxGame.py:

Input and Output:

```
In [29]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGame.py', wdir='/
Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xBBBxBWWWWBxBxBBWW
Enter depth:5
Board position: xBBBxBWWWWBxBWBBxW
Positions evaluated by static estimation:10613
Minimax estimate:-3011
```

```
In [30]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGame.py', wdir='/
Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xBBBxBWWWWBWBWBBWW
Enter depth:4
Board position: xBBBWBWWWxBWBWBBWW
Positions evaluated by static estimation:137
Minimax estimate:-1013
```

ABOpening.py:

Input and Output:

```
In [140]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/ABOpening.py', wdir='/
Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xxxWWWxWxWxBxBxxBB
Enter depth:8
Board position: xxxWWWxWxWxBxBWxxB
Positions evaluated by static estimation:1107979
Alpha_Beta estimate:2
```

```
In [141]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/ABOpening.py', wdir='/
Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:WWxWBWBWxWxBxBxxBB
Enter depth:9
Board position: WWxWBWBWxWxxxBWxBB
Positions evaluated by static estimation:6054
Alpha_Beta estimate:0
```

ABGame.py:

Input and output:

```
In [142]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/ABGame.py', wdir='/Us
trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xBWBxBWBWWBWBWBBWW
Enter depth:8
Board position: xBxBWBWBWWBWBWBBWW
Positions evaluated by static estimation:10817
Alpha_Beta estimate:-35
```

```
In [53]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/ABGame.py', wdir='/User
trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xWWWxBBxxWBWxBBxWWxx
Enter depth:7
Board position: WxWWxBBxxWBWxBBxWWxx
Positions evaluated by static estimation:31861
Alpha_Beta estimate:3970
```

MiniMaxOpeningBlack.py:

Input and output:

```
In [54]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxOpeningBlack.py'
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xWxBxBxBxWxWWWxxBB
Enter depth:5
Board position: xWxBxBxBxxxWWWBxBB
Positions evaluated by static estimation:215482
Minimax estimate:2
```

```
In [55]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxOpening
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xWWBBBxxxWxWxWxxBB
Enter depth:5
Board position: xxWBBBxxxWxWxWxBBB
Positions evaluated by static estimation:74565
Minimax estimate:2
```

MiniMaxGameBlack.py:

Input and Output:

```
In [147]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGameBlack.py',
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xWWWxBBxxWBWxBWxWWxx
Enter depth:5
Board position: xWWWBxBxxWBWxBWxWWxx
Positions evaluated by static estimation:28729
Minimax estimate:-5011
```

```
In [57]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGameBlack.py',
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xBBWxWBxxWBWxBWxWWxx
Enter depth:6
Board position: xxBWxWBxBWBWxBWxWWxx
Positions evaluated by static estimation:264944
Minimax estimate:-3022
```

MiniMaxOpeningImproved.py:

Input and Output:

```
In [149]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/
MiniMaxOpeningImproved.py', wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xWWBBWWxxWxBxWxxBB
Enter depth:5
Board position: xWWBBWWxxWxBxWWxBB
Positions evaluated by static estimation:48234
Minimax estimate:6
```

```
In [150]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/
MiniMaxOpeningImproved.py', wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xBWBWWBxxWxBxWxxWW
Enter depth:6
Board position: xBWxWWBxxWxBxWxWWW
Positions evaluated by static estimation:108
Minimax estimate:92
```

MiniMaxGameImproved.py:

Input and Output:

```
In [61]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGameImproved.py',
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xBBBxWWWxWBWBWxxWW
Enter depth:5
Board position: xBBBxWWxxWxWBWWxWW
Positions evaluated by static estimation:181271
Minimax estimate:152
```

```
In [62]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGameImproved.py',
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xWWBxBBBxWBWBWxxWW
Enter depth:6
Board position: WWxBxBBBxWBWBWxxWW
Positions evaluated by static estimation:635346
Minimax estimate:68
```

Alpha-Beta vs MiniMax:

Opening phase:

```
In [153]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxOpening.py',
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xBWBWWBxxWxBxWxxWW
Enter depth:7
Board position: WxWBWWBxxWxBxWxxWW
Positions evaluated by static estimation:108
Minimax estimate:4
```

```
In [154]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/ABOpening.py', wdir='/
Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xBWBWWBxxWxBxWxxWW
Enter depth:7
Board position: WxWBWWBxxWxBxWxxWW
Positions evaluated by static estimation:22
Alpha_Beta estimate:4
```

Positions evaluated by AlphaBeta = 20% Positions evaluated by MiniMax

```
In [65]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxOpening.py',
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xBWxxWBxxxxBxWxxWW
Enter depth:4
Board position: WBWxxWBxxxxBxWxxWW
Positions evaluated by static estimation:14742
Minimax estimate:3

In [66]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/ABOpening.py', wdir='/
Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xBWxxWBxxxxBxWxxWW
Enter depth:4
Board position: WBWxxWBxxxxBxWxxWW
Positions evaluated by static estimation:1175
Alpha_Beta estimate:3
```

Positions evaluated by AlphaBeta = 8% Positions evaluated by MiniMax

MidGame-EndGame:

```
In [67]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/ABGame.py', wdir='/Users/
trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xWWBxBBBxWBWBWxxWW
Enter depth:5
Board position: xWWBWBBBxxBWBWxxWW
Positions evaluated by static estimation:5783
Alpha_Beta estimate:2995

In [68]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGame.py', wdir='/
Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xWWBxBBBxWBWBWxxWW
Enter depth:5
Board position: xWWBWBBBxxBWBWxxWW
Positions evaluated by static estimation:87591
Minimax estimate:2995
```

Positions evaluated by AlphaBeta = 6.6% Positions evaluated by MiniMax

```
In [70]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/ABGame.py', wdir='/Users/
trinath/Desktop/CS6364_AI/Morris/src')
Given input position:BWBxBBBxxBBBWxxWWW
Enter depth:6
Board position: BWBxBBBxxBBBWWxWxW
Positions evaluated by static estimation:9660
Alpha_Beta estimate:-3011

In [71]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGame.py', wdir='/
Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:BWBxBBBxxBBBWxxWWW
Enter depth:6
Board position: BWBxBBBxxBBBWWxWxW
Positions evaluated by static estimation:142988
Minimax estimate:-3011
```

Positions evaluated by AlphaBeta = 6.7% Positions evaluated by MiniMax

Improved Static Estimation:

Opening Phase:

The estimation function provided is "number of white pieces - number of black pieces" which only depends on the number of pieces but improved function included configurations such as 2 piece, 3 piece, closed mill, number of blocked pieces and different weights are given for all of them. So, the estimation function depends on a lot of factors and board positions can be distinguished easily.

MidGame EndGame:
The given estimation function is the same for Midgame and end-game phases but in the improved static estimation different functions are used for midgame and endgame.
For Midgame factors such as 2-piece configuration, closed mill, a number of blocked pieces, and double mills are added along with given factors, and for endgame factors such as 2-piece configuration, closed mill, 3-piece configurations are considered.

By including extra factors we can easily distinguish and choose better board positions.

Opening phase examples:

Normal vs improved

```
In [162]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxOpening.py',
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xWBxWWBBxxBWxxWWBx
Enter depth:5
Board position: xWBWWWxBxxBWxxWWBx
Positions evaluated by static estimation:88729
Minimax estimate:3

In [163]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/
MiniMaxOpeningImproved.py', wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:xWBxWWBBxxBWxxWWBx
Enter depth:5
Board position: xWBxWWxBxxBWxxWWBW
Positions evaluated by static estimation:88729
Minimax estimate:75
```

Normal vs Improved

```
In [164]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxOpening.py',
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:WBxBBWxBxWxxxWWWBB
Enter depth:5
Board position: WBxBBWWBxWxxxWWWBB
Positions evaluated by static estimation:18595
Minimax estimate:1

In [165]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/
MiniMaxOpeningImproved.py', wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:WBxBBWxBxWxxxWWWBB
Enter depth:5
Board position: WBxBBWxBxWxxWWWWBx
Positions evaluated by static estimation:18595
Minimax estimate:57
```

Midgame-Endgame phase examples:

Normal vs Improved

```
In [85]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGame.py', wdir='/
Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:BWBxWWWBBxWBBBWBWW
Enter depth:5
Board position: BWBWWxWBBxWBBBWBWW
Positions evaluated by static estimation:2614
Minimax estimate:996

In [86]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGameImproved.py',
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:BWBxWWWBBxWBBBWBWW
Enter depth:5
Board position: BWBxWWWBBWxBBBWBWW
Positions evaluated by static estimation:2614
Minimax estimate:24
```

Normal vs Improved

```
In [168]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGame.py', wdir=
Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:BWBxxWxxWxBxxxBxxB
Enter depth:4
Board position: BWBWxWxxxxxxxBxxB
Positions evaluated by static estimation:128784
Minimax estimate:-1011

In [169]: runfile('/Users/trinath/Desktop/CS6364_AI/Morris/src/MiniMaxGameImproved.py
wdir='/Users/trinath/Desktop/CS6364_AI/Morris/src')
Given input position:BWBxxWxxWxBxxxBxxB
Enter depth:4
Board position: BxBxxWxxWxBWxxBxxB
Positions evaluated by static estimation:128784
Minimax estimate:-3
```