

Heuristic Analysis

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March 2017

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Abstract

Minimax alpha-beta pruning with iterative deepening uses a heuristic in order to determine which branches should be kept and which should be pruned. four different strategies are explored with the hope that a heuristic that outperforms the ID Improved default heuristic can be found.

1 Primarily Follow The Opponent

Favor moves where the player encroaches on the opponents final move. Otherwise, follow the opponent around the board.

```
playerMoves = game.get_legal_moves(player)
opponentMoves = game.get_legal_moves(game.get_opponent(player))
if len(opponentMoves) == 1:
    for o in opponentMoves:
        for p in playerMoves:
            if o == p:
                return float("+inf")

playerAt = game.get_player_location(player)
opponentAt = game.get_player_location(game.get_opponent(player))

xDiff = playerAt[0] - opponentAt[0]
yDiff = playerAt[1] - opponentAt[1]
denom = float(xDiff*xDiff + yDiff*yDiff)
if denom == 0:
```

```

        return float("+inf")
    return float(1.0/denom)

```

```

*****
Evaluating: ID_Improved
*****

```

Playing Matches:

```

-----
Match 1: ID_Improved vs Random      Result: 186 to 14
Match 2: ID_Improved vs MM_Null     Result: 172 to 28
Match 3: ID_Improved vs MM_Open     Result: 148 to 52
Match 4: ID_Improved vs MM_Improved Result: 156 to 44
Match 5: ID_Improved vs AB_Null     Result: 156 to 44
Match 6: ID_Improved vs AB_Open     Result: 131 to 69
Match 7: ID_Improved vs AB_Improved Result: 137 to 63

```

Results:

```

-----
ID_Improved      77.57%

```

```

*****
Evaluating: Student
*****

```

Playing Matches:

```

-----
Match 1: Student vs Random      Result: 191 to 9
Match 2: Student vs MM_Null     Result: 172 to 28
Match 3: Student vs MM_Open     Result: 149 to 51
Match 4: Student vs MM_Improved Result: 133 to 67
Match 5: Student vs AB_Null     Result: 160 to 40
Match 6: Student vs AB_Open     Result: 129 to 71
Match 7: Student vs AB_Improved Result: 119 to 81

```

Results:

```

-----
Student          75.21%

```

This strategy appears to be roughly equivalent to the default ID Improved heuristic.

2 Consume The Opponent's Movement Space

Favor moves where the player encroaches on the opponent's moves or follow them around the board. Also uses the idea of trying to stop an opponent that suddenly has limited movement.

```

playerMoves = game.get_legal_moves(player)
opponentMoves = game.get_legal_moves(game.get_opponent(player))
if len(opponentMoves) == 1:
    for o in opponentMoves:
        for p in playerMoves:
            if o == p:
                return float("+inf")

matchedMoves = 0
centerAt = board_center(game)
for o in opponentMoves:
    for p in playerMoves:
        if o == p:
            matchedMoves += 10
if matchedMoves > 0:
    return float(matchedMoves)

playerAt = game.get_player_location(player)
opponentAt = game.get_player_location(game.get_opponent(player))

xDiff = playerAt[0] - opponentAt[0]
yDiff = playerAt[1] - opponentAt[1]
denom = float(xDiff*xDiff + yDiff*yDiff)
if denom == 0:
    return float("+inf")
return float(1.0/denom)

```

```

*****
Evaluating: ID_Improved
*****

```

Playing Matches:

```

-----
Match 1: ID_Improved vs   Random      Result: 184 to 16
Match 2: ID_Improved vs   MM_Null     Result: 174 to 26
Match 3: ID_Improved vs   MM_Open     Result: 157 to 43
Match 4: ID_Improved vs   MM_Improved Result: 141 to 59
Match 5: ID_Improved vs   AB_Null     Result: 161 to 39
Match 6: ID_Improved vs   AB_Open     Result: 136 to 64
Match 7: ID_Improved vs   AB_Improved Result: 123 to 77

```

Results:

```

-----
ID_Improved          76.86%

```

```

*****
Evaluating: Student
*****

```

Playing Matches:

```
-----
Match 1: Student vs Random Result: 181 to 19
Match 2: Student vs MM_Null Result: 168 to 32
Match 3: Student vs MM_Open Result: 146 to 54
Match 4: Student vs MM_Improved Result: 138 to 62
Match 5: Student vs AB_Null Result: 156 to 44
Match 6: Student vs AB_Open Result: 127 to 73
Match 7: Student vs AB_Improved Result: 121 to 79
```

Results:

```
-----
Student 74.07%
```

Seeing that the value drops below 75% is not encouraging.

3 Remain Near The Center

Favor moves that position the player closer to the center of the board.

```
centerAt = board_center(game)
playerAt = game.get_player_location(player)

xDiff = playerAt[0] - centerAt[0]
yDiff = playerAt[1] - centerAt[1]
denom = float(xDiff*xDiff + yDiff*yDiff)
if denom == 0:
    return float("+inf")
return float(1.0/denom)
```

```
*****
Evaluating: ID_Improved
*****
```

Playing Matches:

```
-----
Match 1: ID_Improved vs Random Result: 179 to 21
Match 2: ID_Improved vs MM_Null Result: 176 to 24
Match 3: ID_Improved vs MM_Open Result: 148 to 52
Match 4: ID_Improved vs MM_Improved Result: 146 to 54
Match 5: ID_Improved vs AB_Null Result: 154 to 46
Match 6: ID_Improved vs AB_Open Result: 127 to 73
Match 7: ID_Improved vs AB_Improved Result: 126 to 74
```

Results:

```
-----
ID_Improved 75.43%
```

```
*****
Evaluating: Student
*****
```

Playing Matches:

```
-----
Match 1:  Student  vs  Random    Result: 180 to 20
Match 2:  Student  vs  MM_Null   Result: 162 to 38
Match 3:  Student  vs  MM_Open   Result: 138 to 62
Match 4:  Student  vs  MM_Improved Result: 131 to 69
Match 5:  Student  vs  AB_Null    Result: 142 to 58
Match 6:  Student  vs  AB_Open    Result: 138 to 62
Match 7:  Student  vs  AB_Improved Result: 127 to 73
```

Results:

```
-----
Student              72.71%
```

This ends up being the most disappointing set of results. This is clearly not a winning strategy.

4 Central Hover Followed By Most Moves

Favor moves that position the player closer to the center of the board until the game board is 40% full. Otherwise, simply move as ID Improved would giving heavy weight on a set of moves that can pinch an opponent.

```
blanks = game.get_blank_spaces()
if len(blanks) > (3*game.width*game.height/5):
    centerAt = board_center(game)
    playerAt = game.get_player_location(player)
    xDiff = playerAt[0] - centerAt[0]
    yDiff = playerAt[1] - centerAt[1]
    denom = float(xDiff*xDiff + yDiff*yDiff)
    if denom == 0:
        return float("+inf")
    return float(1.0/denom)

playerMoves = game.get_legal_moves(player)
opponentMoves = game.get_legal_moves(game.get_opponent(player))
if len(opponentMoves) == 1:
    for o in opponentMoves:
        for p in playerMoves:
            if o == p:
                return float("+inf")

return float(len(game.get_legal_moves(player))-len(game.get_legal_moves(game.get_opponent(player))))
```

```
*****
```

Evaluating: ID_Improved

Playing Matches:

Match 1: ID_Improved vs Random Result: 180 to 20
Match 2: ID_Improved vs MM_Null Result: 175 to 25
Match 3: ID_Improved vs MM_Open Result: 155 to 45
Match 4: ID_Improved vs MM_Improved Result: 148 to 52
Match 5: ID_Improved vs AB_Null Result: 164 to 36
Match 6: ID_Improved vs AB_Open Result: 134 to 66
Match 7: ID_Improved vs AB_Improved Result: 126 to 74

Results:

ID_Improved 77.29%

Evaluating: Student

Playing Matches:

Match 1: Student vs Random Result: 189 to 11
Match 2: Student vs MM_Null Result: 177 to 23
Match 3: Student vs MM_Open Result: 159 to 41
Match 4: Student vs MM_Improved Result: 149 to 51
Match 5: Student vs AB_Null Result: 162 to 38
Match 6: Student vs AB_Open Result: 136 to 64
Match 7: Student vs AB_Improved Result: 133 to 67

Results:

Student 78.93%

This is the first time one of my heuristics has outperformed ID Improved. Considering that this is a variation of ID Improved's heuristic, perhaps I shouldn't be surprised that it is highly competitive.

5 Results

The ID Improved heuristic consistently achieves scores from 75-78% based on testing.

Among all four contenders, "Central Hover Followed by Most Moves" appears to be the best option. By initially remaining near the center of the board, it seems that this should allow for more available moves, permitting more possibility for finding a winning branch. I like the idea of coming up with strategies

that highly favor being able to see "horizon" results before they happen, unfortunately I am not sure how to do that in an isolation scenario with chess-like knight movement. As such, highly favoring a single move that includes the possibility of taking the opponents final move is where my strategy stopped in that regard. Naturally, given that the original ID Improved heuristic was difficult for me to overcome, incorporating it into a more detailed strategy felt like a good approach.

6 Beyond Project Scope - Breaking Changes

The following results were obtained by changing the way that the iterative deepening evaluates layers above depth == 1. If one makes the changes below so that greater than and less than comparisons become strictly greater or strictly less than, the search space is expanded but the win percentages increase. Doing this will result in the agent_test.py failing so I have not included it in my final result, but this was an interesting accidental discovery. This version seems superior particularly since it gives one of the highest win percentages that any of my testing has yet seen. Both agents ran with the default ID Improved heuristic.

```
# evaluate all branches and return the highest/lowest scoring tuple
for m in legal_moves:
    if current_move == (-1, -1):
        current_move = m

    if maximizing_player:
        ...
        # CHANGED if score >= beta:
        if score > beta:
            ...
    else:
        ...
        # CHANGED if score <= alpha:
        if score < alpha:
            ...

*****
Evaluating: ID_Improved
*****

Playing Matches:
-----
Match 1: ID_Improved vs Random Result: 184 to 16
Match 2: ID_Improved vs MM_Null Result: 174 to 26
Match 3: ID_Improved vs MM_Open Result: 158 to 42
Match 4: ID_Improved vs MM_Improved Result: 142 to 58
Match 5: ID_Improved vs AB_Null Result: 162 to 38
Match 6: ID_Improved vs AB_Open Result: 146 to 54
Match 7: ID_Improved vs AB_Improved Result: 140 to 60
```

Results:

ID_Improved 79.00%

Evaluating: Student

Playing Matches:

Match 1:	Student	vs	Random	Result: 185 to 15
Match 2:	Student	vs	MM_Null	Result: 178 to 22
Match 3:	Student	vs	MM_Open	Result: 159 to 41
Match 4:	Student	vs	MM_Improved	Result: 139 to 61
Match 5:	Student	vs	AB_Null	Result: 157 to 43
Match 6:	Student	vs	AB_Open	Result: 138 to 62
Match 7:	Student	vs	AB_Improved	Result: 128 to 72

Results:

Student 77.43%