# FOVEROS Chess Engine
(Modelling 2)

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**Abstract**

The FOVEROS Chess Engine project is an engine built in MATLAB that encompasses the interaction, display, legality and computer thought for a chess game. A brute force approach is taken to produce computer thought using tree-search methods, MiniMax algorithm and Alpha Beta Pruning optimisation. The optimisation has shown to reduce the time taken by 90%. A heuristic function was created to evaluate the board for the purposes of selecting the best path.

This Chess Engine successfully runs with minimal issues and demonstrates interesting characteristics such as aggression, the ability to checkmate, to castle and to evade check. The implementation of the rules of chess is near perfect and is able to execute special moves such as En Passant, Pawn Promotion and Castling.

# Contents

# 1 Introduction

The history of chess spans several centuries back to India, where it is believed to have originated in the 6th century. Chess in its current form came into being around the early 1500's. With the rise of modern technology, chess is naturally the game of choice to demonstrate the implications of increased processing power in computers.

Chess has fascinated game theorists because it is deterministic which means that there can only be 1 winning side. It is also a game of perfect information, meaning that all the information is available to the player to make the best move. This adversarial game also has well defined and rigid rules which limit movements to a relatively small number making it ideal for modelling.[1]

With the development of early computers in 1950's, the race was on to develop the ultimate chess engine that would never be beaten by a human player. Alan Turing wrote the first ever computer chess game in 1950. In 1996, Deep Blue won a match against Garry Kasparov. It was the first time a chess engine had beaten a reigning world champion.

Chess engines adopt a brute force approach. Therefore, development of chess engines tie together a broad range of topics, improve the understanding of tree searching algorithms and its optimisations, logical thought processes behind the game as well as a deeper understanding of computational thought and Artificial Intelligence(AI).

# 2 Modelling Aims

1. To create a program that displays a standard chessboard, where the user is able move the pieces legally.
2. The program should be able to generate all possible future moves up to a specified depth using the brute force approach.
3. The user must be able to specify game settings such as:
    - Difficulty - Random, Easy and Hard
    - Player choice - Player Vs Player, Player Vs AI and AI Vs AI
4. The program must incorporate an algorithm that evaluates the chessboard from a certain player's perspective to aid the AI's decision.
5. The program must display game messages, time taken to execute moves, player scores and a player performance graph.

# 3 Overview

The architecture of the system is split into 2 parts, the frontend and the backend. The frontend consists of the Mdp_Chessboard package which is the basis for the board graphics that is displayed. The frontend initialises a structured variable called $B$ which contains info about the game as well as a 16 by 16 matrix that portrays the location of the chessboard pieces as the game progresses.

The backend consists of 3 important variables that are initialised at the start of the game which are *chessboard*, *piece_colour*, *num_moves*. These are all 8 by 8 matrices that display the pieces as numbers and their relevant information. All manipulation and board calculations are carried out on the backend. The calculations of possible moves that can be made are also done in the backend.

Communication between the backend and frontend occurs through a function called *readchessboard*. This function interprets the backend variables and creates a new $B$ that represents the backend which is ready to be plotted.

The reason why the backend variables were used in calculations rather than $B$ is because $B$ is a structure and contains extra information which would be unnecessary for calculation and would slow the system down.

The game control system is linear. The player of the next turn, whether it is the user or the AI, is determined by the function called after the end of a move.

## 3.1 Starting The Chess Engine

In order to run the game, type in "ChessGame" into the MATLAB console.

During gameplay, it is possible to change Player Choice. In shifting to an AI Vs Player game, a move must be made in order to activate the AI's move process. There are some known issues with shifting player choices midway. It is also possible to change the AI settings midway and see a different characteristic. The gain values Heuristic Analysis employs can be changed to give different characteristics.

In AI Vs AI gameplay, to stop the recurring move process, any of the other 2 options can be selected. This will halt the AI's thought process.

# 4 Back-end

The back end of the chess engine works with 8x8 matrices that simulate a chessboard. This increases the speed of the engine, and reduces complexity. Only at the final stages, right before an output is generated, is the chessboard converted from its matrix form to a structure. This reduction in complexity is essential to the programming of basic movements.

| Piece | Value |
|---|---|
| Pawn | 1 |
| Knight | 3 |
| Bishop | 4 |
| Rook | 5 |
| Queen | 9 |
| King | 10 |

Figure 1: The value of each piece type

The matrix *chessboard* keeps track of the location of the pieces. Each type of piece is assigned a unique number that corresponds to its importance/value(See *Fig.* 1). Matrix *piece_colour* stores the ASCII value of the piece colours. Another matrix *num_moves* keeps track of how many moves each piece has made. Whenever a move is made, all three matrices are updated.

```
5    3    4    9   10    4    3    5
1    1    1    1    1    1    1    1
0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0
1    1    1    1    1    1    1    1
5    3    4    9   10    4    3    5
```

Figure 2: The *chessboard* matrix at game start

```
98   98   98   98   98   98   98   98
98   98   98   98   98   98   98   98
 0    0    0    0    0    0    0    0
 0    0    0    0    0    0    0    0
 0    0    0    0    0    0    0    0
 0    0    0    0    0    0    0    0
119  119  119  119  119  119  119  119
119  119  119  119  119  119  119  119
```

Figure 3: The *piece_colour* matrix at game start

## 4.1 Movement files

Each piece type has its own movement function. This function takes in the position and colour of the piece and the chessboard and generates a matrix that shows all the possible legal moves that piece can make. Empty positions into which the piece can move

are denoted by the number 1. Positions currently occupied by the opponent, where the piece can move and make a capture are denoted by the number 2. (See *Fig.* 4,5)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | 0 | 0 | 0 | 10 | 0 | 3 | 5 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 |
| 0 | 4 | 0 | 1 | 1 | 4 | 3 | 1 |
| 0 | 4 | 0 | 0 | 1 | 4 | 0 | 9 |
| 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 5 | 9 | 10 | 0 | 0 | 5 |

Figure 4: A random board with the queen highlighted

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Figure 5: Possible moves of the queen - ”1” indicates empty squares, ”2” indicates potential captures

### 4.1.1 Pawn Movement

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Figure 6: Possible moves of a pawn from the highlighted square

### 4.1.2 Knight Movement

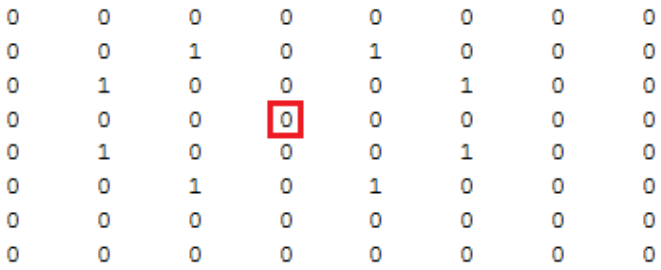



Figure 7: Possible moves of a knight from the highlighted square

### 4.1.3 Bishop Movement

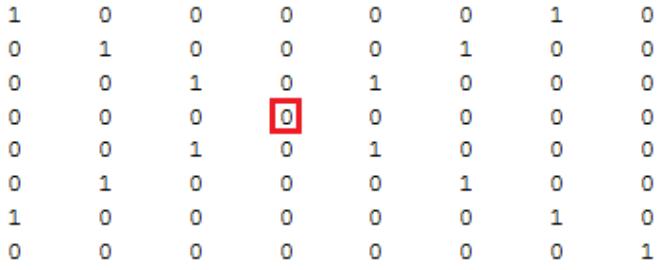



Figure 8: Possible moves of a bishop from the highlighted square

### 4.1.4 Rook Movement

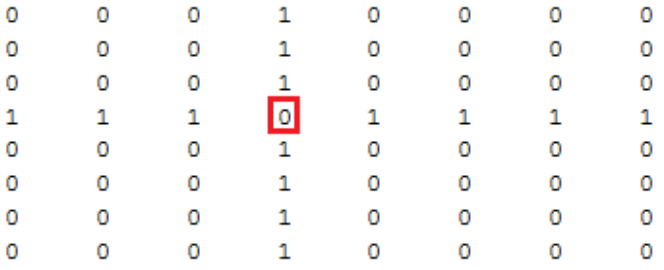



Figure 9: Possible moves of a rook from the highlighted square

### 4.1.5 Queen Movement

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |

Figure 10: Possible moves of a queen from the highlighted square

### 4.1.6 King Movement

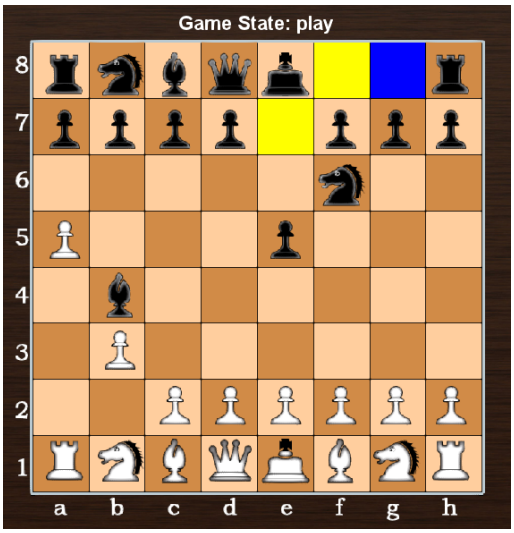
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Figure 11: Possible moves of a king from the highlighted square

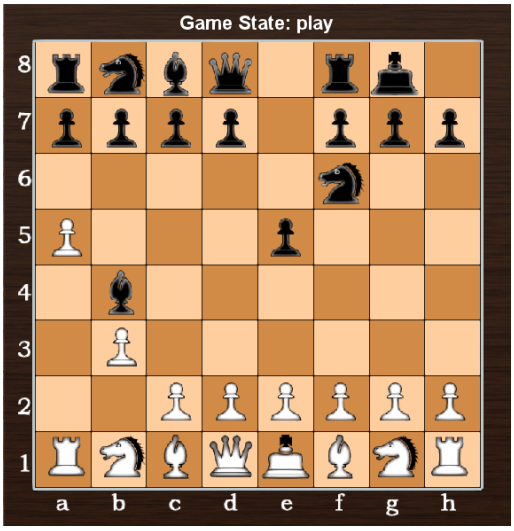
## 4.2 Special moves

The FOVEROS Chess Engine is programmed to execute special moves such as castling, en passant and pawn promotion. However in the case of en passant, the move is not restricted to the first opportunity of its execution.

### 4.2.1 Castling



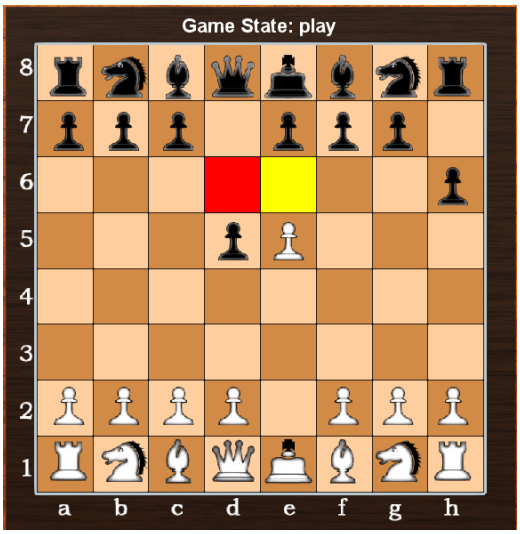

(a) Board shows the possiblity of castling




(b) Castling took place

Figure 12: Before and after Castling

### 4.2.2 En passant




(a) Board shows the possiblity of En passant


(b) En passant took place

Figure 13: Before and after En passant

### 4.2.3 Pawn promotion


(a) Board shows possiblity of Pawn promotion

(b) Pawn promotion took place

Figure 14: Before and after Pawn promotion

## 4.3 Board Analysis

### 4.3.1 Analyseboard Function

The function *analyseboard* looks at all the pieces of a specified colour and determines where every piece is able to move. This function generates the matrix *potentialmoves* containing all the possible moves that side can make and a vector *capt_index* containing the locations of possible captures. This function lends itself to the *KingCheck* and *checkmate* functions.

### 4.3.2 KingCheck Function

The function *KingCheck* uses the results of *analyseboard* to determine if the king is in check. The king is in check when its position overlaps with the opponent's potential moves. This function lends itself to the *checkmate* function.

### 4.3.3 Checkmate Function

The function *checkmate* determines if the current board is a checkmate state for the specified colour. This function generates all the possible moves while searching for any legal moves that can be made. Even if one legal move exists, then the board is determined to not be in a state of checkmate.
*checkmate* assumes that the king is already in check and hence must always be paired with the *KingCheck* function.

# 5 Front-end

## 5.1 Click Series of Functions

This section discusses the following functions:

- *ClickPiece*
- *ClickCapturePiece*
- *ClickMovePiece*
- *ClickPawnPromo*
- *ClickCastling*
- *ClickEnPassant*

The purpose of the click series of functions is to enable the user to make selections on the GUI that translate into a new board state. *ClickPiece* is embedded in the ButtonDown function of the images on the plot. When a user selects a piece, it's moves are highlighted as shown. In essence, *ClickPiece* acts like a switch to embed the other 5 functions into the right squares so that the user is able to make the corresponding move.(See *Fig.* 15)

Line 9 – 17: Determines the colour that is at play.

Line 19 - 31: Determines the coordinates of the user selection and makes the relevant coordinate conversions for the backend.

Line 34 – 51: Determines the piece that is selected and generates its possible moves.

Line 52 – 104: The squares of the board are redrawn with colours corresponding to the matrix of the possiblemoves. For example: A capture is shown in the possible moves matrix as '2' and the corresponding square is coloured red.

Lines 108 – 134: This section redraws the pieces on the board and embeds "ClickPiece" again so that the user can reselect another piece if necessary.

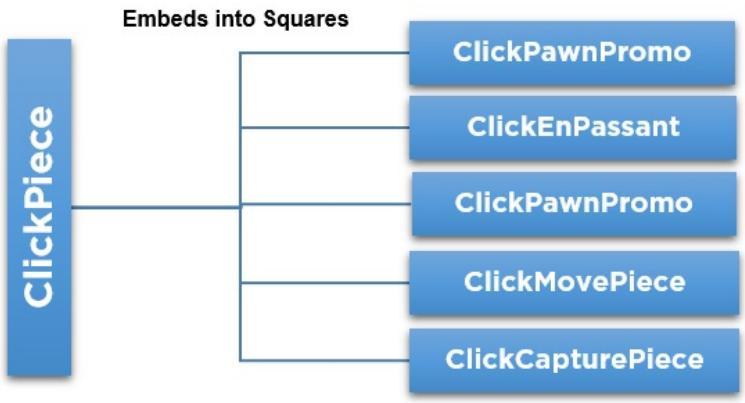



Figure 15: Flow chart showing the activation of *ClickPiece*

This section will detail the code of the 5 click functions for *ClickMovePiece*, *ClickCapturePiece*, *ClickCastling*, *ClickEnPassant* and *ClickPawnPromo*. The code for all of them are very similar, except their function specific parts. The code explanation below details the *ClickMovePiece* function:

Line 8 – 14 : Determines the colour at play

Line 17 – 32: Determines the coordinates that player has chosen to move the piece and makes the relevant coordinate conversions for the backend.

Line 40 – 60: The move is done on a future board state to validate that the King will not be left in check as a result of the move, which constitutes an illegal move. This is where the different click functions will have function specific coordinate transformations to facilitate their purpose.

Line 73 – 75: If the move is valid, the future board state is saved as the accepted board state.

Line 77 – 94: Validates if the opposing King is in check as a result of the move and also validates if checkmate or stalemate has taken place.

Line 99 – 128: The board is redrawn to reflect the new board state.

Line 131 – 138: Based on the user's player choice, the next move is passed to the relevant control function.

## 5.2 Graphical User Interface

The GUI is designed to show the relevant board stats and game messages. The user is able to select from different settings for the GUI. It also plots the scores on a graph to show the progression of both players with each turn.


Figure 16: The FOVEROS Chess Engine GUI

# 6 Artificial Intelligence

## 6.1 Brute Force Approach

The approach to implementing computer thought is through brute force calculations. The strength in computer systems lies in its ability to perform large amounts of computation in a short period of time. Therefore, it has the ability to generate all future board states up to a certain depth. Depth is the number of turns ahead of the current board state that is generated.

### 6.1.1 Minimax Algorithm

The generation of board states must be aided by an algorithm to evaluate and save the best board states. This is an adversarial search problem where only 2 players are competing. In order to make the optimal decision for a certain player, the MiniMax strategy is used. The idea is that, from a certain player's perspective, the objective is to maximise his advantage and to minimise the opponent's advantage. The generation starts from the "Initial State" and branches out until it reaches the "Leaf Nodes" or "Terminal Nodes" where the board is evaluated and the results backed up the tree as the recursion unwinds.[1]

Generation of board states however is a computationally expensive task especially at greater depths. The branching factor can be defined as the number of children per node. The average branching factor for chess positions is 35 to 38 moves per position. Therefore, $38^2$ (1,444) game states need to be evaluated at depth 2, $38^3$ (54,872) game states need to be evaluated at depth 3, $38^4$ (2,085,136) game states need to be evaluated at depth 4. It is clear that the number of game states will continue to grow at an exponential rate.[2]

### 6.1.2 Alpha-Beta Pruning

An algorithm that "prunes" the search tree needs to eliminate parts of the tree that have no effect on the final result of the tree. Alpha Beta pruning is one of the methods used to prune the search tree. Alpha is the maximum lower bound of the possible solutions and Beta is the minimum upper bound of the possible solutions. The search proceeds down to the first terminal node of the tree, the board score is backed up the tree and becomes either the alpha or beta value of the node above it depending on whether it is a minimum or maximum player.


Figure 17: Figure shows $\alpha$-$\beta$ pruning criteria

The search then proceeds and references back to the alpha and beta value before it. If the values are found to be lower than the maximum lower bound or higher than the minimum upper bound, the values of alpha and beta are reassigned to the new values. However, pruning occurs when alpha is greater than beta and the branches leading from the selected node are not evaluated because it will not change the overall result of the tree. It will not change it because there is no overlap between the maximum lower bound and the minimum upper bound as shown in the figure.[3]

By implementing Alpha Beta pruning with random move ordering, the average number of nodes to be evaluated will be dropped to $b^{3d/4}$ from $b^d$. This means that Alpha Beta pruning is able to perform a depth 4 calculation at roughly the same speed as a depth 3 without Alpha Beta pruning.[4]

## 6.2 Generation of Moves

The function $AI\_GenerateAllMoves$ generates all nodes up to a certain depth, implements the MiniMax Algorithm and the Alpha Beta pruning. The function does this via the recursion method where the function calls itself within its body. This is useful because in the MiniMax algorithm we require the values to be backed up the tree and recursion does that inherently.

Line 1 – 15: Determines the colour at play

Line 20 – 26: At Terminal Node, the board is evaluated

Line 29 – 122: Implementation for the Maximum Player

Line 126 – 222: Implementation for the Minimum Player

The implementation for the Maximum and Minimum player are the same but with slightly different parameters. The general structure is discussed below for the Maximum Player.

Line 33 – 36: The coordinates of the current colour pieces are found. The arrangement of the pieces in the vector is randomly permutated.

Line 42 – 57: For each of the pieces, the individual possible moves are generated

Line 63 – 67: The coordinates of the possible moves are randomly permutated

Line 70 – 87: The potential future board state is generated.

Line 89 – 116: The board is evaluated for legality, if found to be illegal it will be ignored. If it is valid, the function calls itself again. The new node is passed as a parameter and the depth is decreased. The alpha-beta pruning condition is also implemented here.

### 6.3 Heuristic Analysis

The function *heuristicanalysis* examines the board from a given player's point of view. The goal of this function is to assign a numerical value(boardscore) to each board depending on a given set of conditions. These conditions determine if a move is good or bad.[5][6]

A move is judged to be good:

- If it opens up possibilities to capture opponent's pieces
- If it increases the number of pieces captured
- If it opens up space for other pieces to move
- If it increases control of the centre of the board
- If it enables the king to castle
- If it brings the pawns closer to the end of the board for promotion
- If it leads to checks and checkmates on the opponent

A move is judged to be bad:

- If it causes threats to its own pieces
- If it decreases the number of its own pieces
- If it leads to the opponent's pawns being promoted
- If it leads to its own king being checked or checkmated

Each of these conditions is assigned a specific $gainfactor$. The more important the condition, the higher the numerical value of it's $gainfactor$. Good moves have positive $gainfactor$ which encourages the AI to make those moves, while bad moves have negative $gainfactor$, discouraging the AI.
For example, a move that leads to the opponent king being checkmated is assigned the highest possible score of 99999, while a move that leads to its own checkmate is assigned the lowest possible score of -99999.

The values of the $gainfactor$ depend on the level of difficulty the player has chosen. In a 'Random' game the gains are all set to 0 and have no influence on the moves. In an 'Easy' game, the gains are such that it's easy for the player to make threats and capture pieces. In a 'Hard' game, the gains ensure that the AI plays aggressively.

### 6.4 AI Control

The function $AIControl$ sets the depth parameters for $AI\_GenerateAllMoves$, plots the board scores as seen on the GUI and validates check/checkmate/stalemate for both colours.

# 7 Results

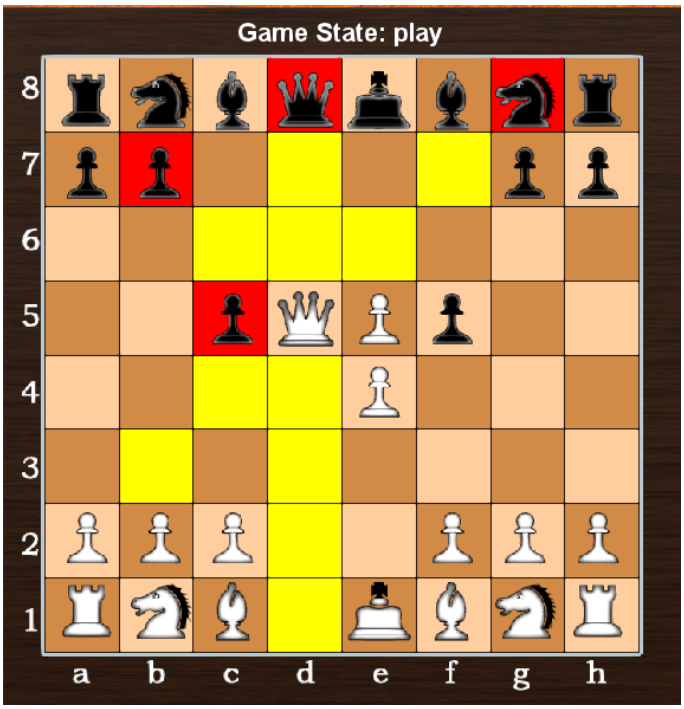



Figure 18: Possible moves of Queen in game

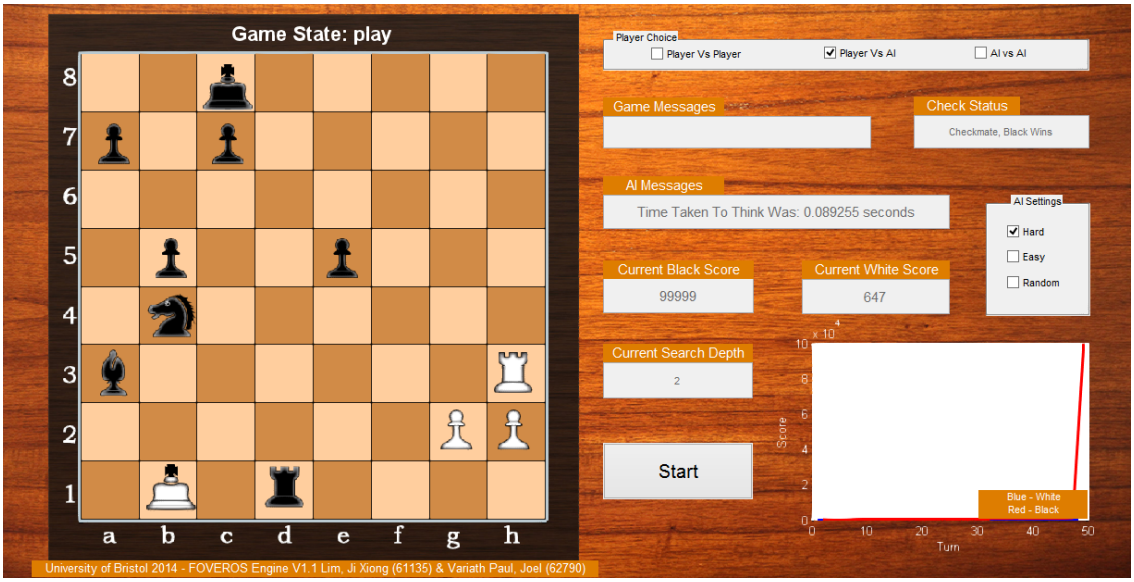



Figure 19: Checkmate by Black


Figure 20: AI has Castled

| Depth | Without Alpha Beta Pruning | | With Alpha Beta Pruning | | Percentage Reduction Between With and Without Pruning | |
|---|---|---|---|---|---|---|
| | Time/s | Nodes | Time/s | Nodes | Time | Node |
| 1 | 0.046 | 20 | 0.05 | 20 | 8.70 | 0 |
| 2 | 1.45 | 620 | 0.31 | 136 | -78.6 | -78.1 |
| 3 | 46.7 | 13928 | 1.98 | 832 | -95.8 | -94.0 |
| 4 | 1365 | 420180 | 23.4 | 8535 | -98.3 | -98.0 |
| 5 | >2400 | >720000 | 96 | 33022 | - | - |

Table 1: Performance results of $\alpha$-$\beta$ pruning

# 8 Discussions

## 8.1 Tuning

Tuning is the process of finding the optimum gains for the different scenarios in the Heuristics Analysis function. The different gains increase or decrease the effect of different parameters on the board score. Tuning is a difficult process because the values are relative and therefore trial and error is to be used to determine the optimum value. By comparison, the programmers of the legendary Deep Blue machine had made plausible initial guesses for values but there still was a lot of uncertainty as to what the correct values should be.[7]

The first objective for optimum tuning was to reach a high level of aggressiveness for the AI as that is the most noticeable feature. This would be demonstrated by the AI making captures whenever the opportunity presents itself. The second objective was to prevent moves that would jeopardise its own pieces and that also includes encouraging castling to shield the King. The third objective was to increase the likelihood of checks and checkmate.

The current gains are set based on the results of a few trial and error runs. In the results, some of the features have demonstrated itself rather obviously. *Fig.* 19 shows the situation of Player Vs AI where the AI has successfully checkmated the player in a rather creative arrangement that involves 3 different pieces. The graph also shows that the boardscore has been maximised for that colour which is the correct output from the Heuristics Analysis.

*Fig.* 20 shows the AI using Castling to its advantage in the late game by allowing the rook to come out and the King to seek shelter behind the pawns thus increasing its boardscore as a result of the move.

A deficiency that is quite common in the AI was that the AI tended to make captures that would lead to its own piece being captured. The pay off would sometimes be less than the value of the piece being sacrificed. The AI would also pass off captures sometimes though it is rare.

## 8.2 Alpha Beta Pruning Efficiency

*Table* 1 shows the time and number of nodes at a certain depth for different cases. The results is as expected, the number of nodes that need to be evaluated at a certain depth have an exponential relationship with the depth itself. The Alpha Beta Pruning implementation cuts down the time taken by a very substantial amount. This is also expected, as discussed in the Artificial Intelligence section. This enable the system to go 1 depth deeper with Alpha Beta Pruning at the same speed as without the Alpha Beta Pruning.

# 9 Conclusions

The FOVEROS Chess Engine which means “Awesome” in Greek employs basic understanding of the tree search algorithm, the MiniMax Theory, and the Alpha Beta pruning optimisation. It has also met the design aim of being a functional chessboard that has inbuilt rules and is able to execute all the special moves without problems.

There are further improvements that can be made to this engine. The first is the integration of a database of opening moves. This will enable the engine to have greater flexibility in its opening moves and open up more possibilities for the engine. This can be done by setting the AI to respond with predefined moves for the first 3 rounds based on the response of the opponent.

Further optimisations to the tree-search algorithm can be looked into. The first is Iterative Deepening which encourages deeper searches until the pre-allocated time is exhausted. It is a time management strategy in depth-first searches and has benefits for move ordering and pruning.[8]

FOVEROS employs random move ordering in the algorithm and so dynamic move ordering techniques should be looked into. The benefits of Alpha Beta pruning are only tangible if the best move is presented as soon as possible so that pruning can take place immediately.[9]

## References

[1] Russell, Stuart J. and Norvig, Peter, *Artificial Intelligence - A Modern Approach*. Upper Saddle River, New Jersey: Pearson Education, 2010.

[2] *Chess Programming*. 2014. `https://chessprogramming.wikispaces.com/Branching+Factor` [Online; last accessed 20-Nov-2014].

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[6] zaifrun, Chess.com, *Creating a Chess Engine*. 2014. `http://www.chess.com/blog/zaifrun/creating-a-chess-engine-part-4---position-evaluation` [Online; last accessed 12-Nov-2014].

[7] Furnkranz, Johannes and Kubat, Miroslav, *Machines That Learn To Play Games*. Huntington, New York: Nova Science Publishers, 2001.

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[9] Cornell University, *Minimax search and Alpha-Beta Pruning*. 2014. `https://www.cs.cornell.edu/courses/cs312/2002sp/lectures/rec21.htm` [Online; last accessed 13-Nov-2014].

# A Appendix: The Code

## A.1 Back-end

### A.1.1 MovementRook.m

```
1
2  function [possiblemoves] = MovementRook(chessboard,piece_colour,p_x,p_y)
3
4  %Initialisation values ------------------------------------------------
5  r_colour = piece_colour(p_x,p_y);
6  possiblemoves = zeros(8,8);
7
8  %This section allows movement in vertical direction -----------------------
9  i = 1;
10 while(p_x+i<9)
11     if(piece_colour(p_x+i,p_y)== r_colour)
12         break
13     end
14     if(piece_colour(p_x+i,p_y)≠ r_colour && chessboard(p_x+i,p_y)≠0)
15         possiblemoves(p_x+i,p_y) = 2;
16         break
17     end
18     possiblemoves(p_x+i,p_y) = 1;
19     i = i+1;
20 end
21
22 i = 1;
23 while(p_x-i>0)
24     if(piece_colour(p_x-i,p_y)== r_colour)
25         break
26     end
27      if(piece_colour(p_x-i,p_y)≠ r_colour && chessboard(p_x-i,p_y)≠0)
28         possiblemoves(p_x-i,p_y) = 2;
29         break
30     end
31     possiblemoves(p_x-i,p_y) = 1;
32     i = i+1;
33 end
34
35 %This section allows movement in the horizontal direction
36 i = 1;
37 while(p_y+i<9)
38     if(piece_colour(p_x,p_y+i)== r_colour)
39         break
40     end
41     if(piece_colour(p_x,p_y+i)≠ r_colour && chessboard(p_x,p_y+i)≠0)
42         possiblemoves(p_x,p_y+i) = 2;
43         break
44     end
45     possiblemoves(p_x,p_y+i) = 1;
46     i = i+1;
47 end
48
49 i = 1;
50 while(p_y-i>0)
51     if(piece_colour(p_x,p_y-i)== r_colour)
52         break
```

```
53      end
54      if(piece_colour(p_x,p_y-i)≠ r_colour && chessboard(p_x,p_y-i)≠0)
55          possiblemoves(p_x,p_y-i) = 2;
56          break
57      end
58      possiblemoves(p_x,p_y-i) = 1;
59      i = i+1;
60  end
61
62  %-------------------------------------------------------------------------
63
64  end
```

### A.1.2 MovementQueen.m

```
1   function [possiblemoves] = MovementQueen(chessboard,piece_colour,p_x,p_y)
2
3   %Initialisation values ----------------------------------------------------
4   possiblemoves = zeros(8,8);
5   r_colour = piece_colour(p_x,p_y);
6
7   %This section allows movement in / direction ------------------------------
8   i=1;
9   while(p_x+i<9 && p_y+i<9)
10      if(piece_colour(p_x+i,p_y+i)== r_colour)
11          break
12      end
13      if(piece_colour(p_x+i,p_y+i)≠ r_colour && chessboard(p_x+i,p_y+i)≠0)
14          possiblemoves(p_x+i,p_y+i) = 2;
15          break
16      end
17      possiblemoves(p_x+i,p_y+i) = 1;
18      i = i+1;
19  end
20
21  i=1;
22  while(p_x-i>0 && p_y-i>0)
23      if(piece_colour(p_x-i,p_y-i)== r_colour)
24          break
25      end
26      if(piece_colour(p_x-i,p_y-i)≠ r_colour && chessboard(p_x-i,p_y-i)≠0)
27          possiblemoves(p_x-i,p_y-i) = 2;
28          break
29      end
30      possiblemoves(p_x-i,p_y-i) = 1;
31      i = i+1;
32  end
33
34  %This section allows movement in the \ direction--------------------------
35  i=1;
36  while(p_x+i<9 && p_y-i>0)
37      if(piece_colour(p_x+i,p_y-i)== r_colour)
38          break
39      end
40      if(piece_colour(p_x+i,p_y-i)≠ r_colour && chessboard(p_x+i,p_y-i)≠0)
41          possiblemoves(p_x+i,p_y-i) = 2;
42          break
43      end
```

```
44      possiblemoves(p_x+i,p_y-i) = 1;
45      i = i+1;
46  end
47
48  i=1;
49  while(p_x-i>0 && p_y+i<9)
50      if(piece_colour(p_x-i,p_y+i)== r_colour)
51          break
52      end
53      if(piece_colour(p_x-i,p_y+i)≠ r_colour && chessboard(p_x-i,p_y+i)≠0)
54          possiblemoves(p_x-i,p_y+i) = 2;
55          break
56      end
57      possiblemoves(p_x-i,p_y+i) = 1;
58      i = i+1;
59  end
60
61  %This section allows movement in vertical direction ----------------------------
62  i = 1;
63  while(p_x+i<9)
64      if(piece_colour(p_x+i,p_y)== r_colour)
65          break
66      end
67      if(piece_colour(p_x+i,p_y)≠ r_colour && chessboard(p_x+i,p_y)≠0)
68          possiblemoves(p_x+i,p_y) = 2;
69          break
70      end
71      possiblemoves(p_x+i,p_y) = 1;
72      i = i+1;
73  end
74
75  i = 1;
76  while(p_x-i>0)
77      if(piece_colour(p_x-i,p_y)== r_colour)
78          break
79      end
80       if(piece_colour(p_x-i,p_y)≠ r_colour && chessboard(p_x-i,p_y)≠0)
81          possiblemoves(p_x-i,p_y) = 2;
82          break
83      end
84      possiblemoves(p_x-i,p_y) = 1;
85      i = i+1;
86  end
87
88  %This section allows movement in the horizontal direction-------------------------
89  i = 1;
90  while(p_y+i<9)
91      if(piece_colour(p_x,p_y+i)== r_colour)
92          break
93      end
94      if(piece_colour(p_x,p_y+i)≠ r_colour && chessboard(p_x,p_y+i)≠0)
95          possiblemoves(p_x,p_y+i) = 2;
96          break
97      end
98      possiblemoves(p_x,p_y+i) = 1;
99      i = i+1;
100 end
101
102 i = 1;
103 while(p_y-i>0)
104     if(piece_colour(p_x,p_y-i)== r_colour)
105         break
```

```
    end
    if(piece_colour(p_x,p_y-i)≠ r_colour && chessboard(p_x,p_y-i)≠0)
        possiblemoves(p_x,p_y-i) = 2;
        break
    end
    possiblemoves(p_x,p_y-i) = 1;
    i = i+1;
end
%--------------------------------------------------------------------------

end
```

### A.1.3 MovementPawn.m

```
function [possiblemoves] = MovementPawn(chessboard,piece_colour,num_moves,p_x,p_y)

%Initialisation values ---------------------------------------------------
r_colour = piece_colour(p_x,p_y);
possiblemoves = zeros(8,8);

%This section allows all movements after checking whether it exceeds the board or not ------
switch r_colour
    case 119 %White case
        %En passant-------------------------------------------------------
        if (p_x==4)

            if(p_x-1>0 && p_y-1 >0) %Capture left
                if(piece_colour(p_x,p_y-1)≠r_colour && chessboard(p_x,p_y-1)==1 && num_moves
                    possiblemoves(p_x-1,p_y-1) = 3;
                end
            end

            if(p_x-1>0 && p_y+1<9) %Capture right
                if(piece_colour(p_x,p_y+1)≠r_colour && chessboard(p_x,p_y+1)==1 && num_moves
                    possiblemoves(p_x-1,p_y+1) = 3;
                end
            end

        end

        if(p_x-1>0) %Forward movement
            if(chessboard(p_x-1,p_y)==0)
                possiblemoves(p_x-1,p_y) = 1;
            end
        end

        %Initial forward movement
        if(p_x==7 && chessboard(p_x-2,p_y)==0 && chessboard(p_x-1,p_y)==0)
        possiblemoves(p_x-2,p_y) = 1;
        end

        if(p_x-1>0 && p_y-1 >0) %Capture left
            if(piece_colour(p_x-1,p_y-1)≠r_colour && chessboard(p_x-1,p_y-1)≠0)
                possiblemoves(p_x-1,p_y-1) = 2;
                if(p_x==2) %Capture and pawn promotion
                    possiblemoves(p_x-1,p_y-1) = 5;
                end
            end
```

```
45          end
46
47          if(p_x-1>0 && p_y+1<9) %Capture right
48              if(piece_colour(p_x-1,p_y+1)≠r_colour && chessboard(p_x-1,p_y+1)≠0)
49                  possiblemoves(p_x-1,p_y+1) = 2;
50                     if(p_x==2) %Capture and pawn promotion
51                        possiblemoves(p_x-1,p_y+1) = 5;
52                     end
53              end
54          end
55
56          %Pawn promotion-----------------------------------------------------
57          if(p_x==2)
58              if(chessboard(p_x-1,p_y)==0)
59                  possiblemoves(p_x-1,p_y) = 5;
60              end
61          end
62
63      case 98 %Black Case
64
65          %En passant---------------------------------------------------------
66          if (p_x==5)
67
68              if(p_x-1>0 && p_y-1 >0) %Capture left
69                  if(piece_colour(p_x,p_y-1)≠r_colour && chessboard(p_x,p_y-1)==1 && num_moves
70                      possiblemoves(p_x+1,p_y-1) = 3;
71                  end
72              end
73
74              if(p_x-1>0 && p_y+1<9) %Capture right
75                  if(piece_colour(p_x,p_y+1)≠r_colour && chessboard(p_x,p_y+1)==1 && num_moves
76                      possiblemoves(p_x+1,p_y+1) = 3;
77                  end
78              end
79
80          end
81
82          if(p_x+1<9) %Forward movement
83              if(chessboard(p_x+1,p_y)==0)
84                  possiblemoves(p_x+1,p_y) = 1;
85              end
86          end
87
88          %Initial Forward movement
89          if(p_x==2 && chessboard(p_x+2,p_y)==0 && chessboard(p_x+1,p_y)==0)
90              possiblemoves(p_x+2,p_y) = 1;
91          end
92
93          if(p_x+1<9 && p_y-1>0) %Capture left
94              if(piece_colour(p_x+1,p_y-1)≠r_colour && chessboard(p_x+1,p_y-1)≠0)
95                  possiblemoves(p_x+1,p_y-1) = 2;
96                    if(p_x==7) %Capture and pawn promotion
97                        possiblemoves(p_x+1,p_y-1) = 5;
98                     end
99              end
100         end
101
102         if(p_x+1<9 && p_y+1<9) %Capture right
103             if(piece_colour(p_x+1,p_y+1)≠r_colour && chessboard(p_x+1,p_y+1)≠0)
104                 possiblemoves(p_x+1,p_y+1) = 2;
105                    if(p_x==7) %Capture and pawn promotion
106                       possiblemoves(p_x+1,p_y+1) = 5;
```

```
                    end
                end
            end

            %Pawn promotion-----------------------------------------------------
            if(p_x==7)
                if(chessboard(p_x+1,p_y)==0)
                    possiblemoves(p_x+1,p_y) = 5;
                end
            end

    end
    %-------------------------------------------------------------------------
    end
```

### A.1.4 MovementKnight.m

```
function [possiblemoves] = MovementKnight(chessboard,piece_colour,p_x,p_y)

%Initialisation values ----------------------------------------------------
r_colour = piece_colour(p_x,p_y);
possiblemoves = zeros(8,8);

%This sections allows L shaped movements for knight
if(p_x-2>0 & p_y-1>0)
    if (piece_colour(p_x-2,p_y-1)≠ r_colour && chessboard(p_x-2,p_y-1)≠0)
        possiblemoves(p_x-2,p_y-1) = 2;
    elseif (piece_colour(p_x-2,p_y-1)== r_colour)
        ;
    else
        possiblemoves(p_x-2,p_y-1) = 1;
    end
end

if(p_x-2>0 & p_y+1<9)
    if (piece_colour(p_x-2,p_y+1)≠ r_colour && chessboard(p_x-2,p_y+1)≠0)
        possiblemoves(p_x-2,p_y+1) = 2;
    elseif (piece_colour(p_x-2,p_y+1)== r_colour)
        ;
    else
        possiblemoves(p_x-2,p_y+1) = 1;
    end
end

if(p_x-1>0 & p_y-2>0)
    if (piece_colour(p_x-1,p_y-2)≠ r_colour && chessboard(p_x-1,p_y-2)≠0)
        possiblemoves(p_x-1,p_y-2) = 2;
    elseif (piece_colour(p_x-1,p_y-2)== r_colour)
        ;
    else
        possiblemoves(p_x-1,p_y-2) = 1;
    end
end

if(p_x-1>0 & p_y+2<9)
    if (piece_colour(p_x-1,p_y+2)≠ r_colour && chessboard(p_x-1,p_y+2)≠0)
        possiblemoves(p_x-1,p_y+2) = 2;
    elseif (piece_colour(p_x-1,p_y+2)== r_colour)
```

```
        ;
    else
        possiblemoves(p_x-1,p_y+2) = 1;
    end
end

if(p_x+1<9 & p_y-2>0)
    if (piece_colour(p_x+1,p_y-2)≠ r_colour && chessboard(p_x+1,p_y-2)≠0)
        possiblemoves(p_x+1,p_y-2) = 2;
    elseif (piece_colour(p_x+1,p_y-2)== r_colour)
        ;
    else
        possiblemoves(p_x+1,p_y-2) = 1;
    end
end

if(p_x+1<9 & p_y+2<9)
    if (piece_colour(p_x+1,p_y+2)≠ r_colour && chessboard(p_x+1,p_y+2)≠0)
        possiblemoves(p_x+1,p_y+2) = 2;
    elseif (piece_colour(p_x+1,p_y+2)== r_colour)
        ;
    else
        possiblemoves(p_x+1,p_y+2) = 1;
    end
end

if(p_x+2<9 & p_y-1>0)
    if (piece_colour(p_x+2,p_y-1)≠ r_colour && chessboard(p_x+2,p_y-1)≠0)
        possiblemoves(p_x+2,p_y-1) = 2;
    elseif (piece_colour(p_x+2,p_y-1)== r_colour)
        ;
    else
        possiblemoves(p_x+2,p_y-1) = 1;
    end
end

if(p_x+2<9 & p_y+1<9)
    if (piece_colour(p_x+2,p_y+1)≠ r_colour && chessboard(p_x+2,p_y+1)≠0)
        possiblemoves(p_x+2,p_y+1) = 2;
    elseif (piece_colour(p_x+2,p_y+1)== r_colour)
        ;
    else
        possiblemoves(p_x+2,p_y+1) = 1;
    end
end

%-------------------------------------------------------------------------

end
```

### A.1.5 MovementKing.m

```
function [possiblemoves] = MovementKing(chessboard,piece_colour,num_moves,potential_moves,p

%Initialisation values ---------------------------------------------------
r_colour = piece_colour(p_x,p_y);
possiblemoves = zeros(8,8);

```

```
%This section allows all movements after checking whether it exceeds the board or not
%and ensures that the king is not moving into square that is in check ----------------

%-------------------------------------------------------------------------
%                          Movement (8 Directions)
%-------------------------------------------------------------------------


    if(p_x+1<9)
        if (piece_colour(p_x+1,p_y)≠ r_colour && chessboard(p_x+1,p_y)≠0)
            possiblemoves(p_x+1,p_y) = 2;
        elseif (piece_colour(p_x+1,p_y)== r_colour)
            ;
        else
            possiblemoves(p_x+1,p_y) = 1;
        end
    end


    if(p_x+1<9 && p_y+1<9)
        if (piece_colour(p_x+1,p_y+1)≠ r_colour && chessboard(p_x+1,p_y+1)≠0)
            possiblemoves(p_x+1,p_y+1) = 2;
        elseif (piece_colour(p_x+1,p_y+1)== r_colour)
            ;
        else
            possiblemoves(p_x+1,p_y+1) = 1;
        end
    end


    if(p_x+1<9 && p_y-1>0)
        if (piece_colour(p_x+1,p_y-1)≠ r_colour && chessboard(p_x+1,p_y-1)≠0)
            possiblemoves(p_x+1,p_y-1) = 2;
        elseif (piece_colour(p_x+1,p_y-1)== r_colour)
            ;
        else
            possiblemoves(p_x+1,p_y-1) = 1;
        end
    end


    if(p_y+1<9)
        if (piece_colour(p_x,p_y+1)≠ r_colour && chessboard(p_x,p_y+1)≠0)
            possiblemoves(p_x,p_y+1) = 2;
        elseif (piece_colour(p_x,p_y+1)== r_colour)
            ;
        else
            possiblemoves(p_x,p_y+1) = 1;
        end
    end


    if(p_y-1>0)
        if (piece_colour(p_x,p_y-1)≠ r_colour && chessboard(p_x,p_y-1)≠0)
            possiblemoves(p_x,p_y-1) = 2;
        elseif (piece_colour(p_x,p_y-1)== r_colour)
            ;
        else
            possiblemoves(p_x,p_y-1) = 1;
        end
    end

```

```
69
70      if(p_x-1>0)
71          if (piece_colour(p_x-1,p_y)≠ r_colour && chessboard(p_x-1,p_y)≠0)
72              possiblemoves(p_x-1,p_y) = 2;
73          elseif (piece_colour(p_x-1,p_y)== r_colour)
74              ;
75          else
76              possiblemoves(p_x-1,p_y) = 1;
77          end
78      end
79
80
81      if(p_x-1>0 && p_y+1<9)
82          if (piece_colour(p_x-1,p_y+1)≠ r_colour && chessboard(p_x-1,p_y+1)≠0)
83              possiblemoves(p_x-1,p_y+1) = 2;
84          elseif (piece_colour(p_x-1,p_y+1)== r_colour)
85              ;
86          else
87              possiblemoves(p_x-1,p_y+1) = 1;
88          end
89      end
90
91
92      if(p_x-1>0 && p_y-1>0)
93          if (piece_colour(p_x-1,p_y-1)≠ r_colour && chessboard(p_x-1,p_y-1)≠0)
94              possiblemoves(p_x-1,p_y-1) = 2;
95          elseif (piece_colour(p_x-1,p_y-1)== r_colour)
96              ;
97          else
98              possiblemoves(p_x-1,p_y-1) = 1;
99          end
100     end
101
102 %-------------------------------------------------------------------------
103 %                                  Castling
104 %-------------------------------------------------------------------------
105
106
107 %---------------------------- For white king ----------------------------
108
109 possiblemoves(p_x,p_y)=0;
110 %-------------------------------------------------------------------------
111 end
```

### A.1.6 MovementBishop.m

```
1  function [possiblemoves] = MovementBishop(chessboard,piece_colour,p_x,p_y)
2
3  %Initialisation values ---------------------------------------------------
4  r_colour = piece_colour(p_x,p_y);
5  possiblemoves = zeros(8,8);
6
7  %This section allows movement in / direction ------------------------------
8  i=1;
9  while(p_x+i<9 && p_y+i<9)
10     if(piece_colour(p_x+i,p_y+i)== r_colour)
11         break
12     end
```

```
13      if(piece_colour(p_x+i,p_y+i)≠ r_colour && chessboard(p_x+i,p_y+i)≠0)
14          possiblemoves(p_x+i,p_y+i) = 2;
15          break
16      end
17      possiblemoves(p_x+i,p_y+i) = 1;
18      i = i+1;
19  end
20
21  i=1;
22  while(p_x-i>0 && p_y-i>0)
23      if(piece_colour(p_x-i,p_y-i)== r_colour)
24          break
25      end
26      if(piece_colour(p_x-i,p_y-i)≠ r_colour && chessboard(p_x-i,p_y-i)≠0)
27          possiblemoves(p_x-i,p_y-i) = 2;
28          break
29      end
30      possiblemoves(p_x-i,p_y-i) = 1;
31      i = i+1;
32  end
33
34  %This section allows movement in the \ direction-------------------------
35  i=1;
36  while(p_x+i<9 && p_y-i>0)
37      if(piece_colour(p_x+i,p_y-i)== r_colour)
38          break
39      end
40      if(piece_colour(p_x+i,p_y-i)≠ r_colour && chessboard(p_x+i,p_y-i)≠0)
41          possiblemoves(p_x+i,p_y-i) = 2;
42          break
43      end
44      possiblemoves(p_x+i,p_y-i) = 1;
45      i = i+1;
46  end
47
48  i=1;
49  while(p_x-i>0 && p_y+i<9)
50      if(piece_colour(p_x-i,p_y+i)== r_colour)
51          break
52      end
53      if(piece_colour(p_x-i,p_y+i)≠ r_colour && chessboard(p_x-i,p_y+i)≠0)
54          possiblemoves(p_x-i,p_y+i) = 2;
55          break
56      end
57      possiblemoves(p_x-i,p_y+i) = 1;
58      i = i+1;
59  end
60
61  %--------------------------------------------------------------------------
62
63  end
```

## A.2 Front-end

### A.2.1 ClickPiece.m

```
1  %ClickPiece Obtains all the data from a user's click, highlights possible
```

```
%moves and allows the user to make that move.
function [varargout]=ClickPiece(var1,var2,B,piece_colour,chessboard,...
    num_moves,parameters,potentialmoves,handles,varargin )

set(handles.gameconsole,'String','')

%----------Determines which colour is able to be selected-----------------
if(mod(B.info.turn,2)==1)
    colourturn = 119;
    oppositecolour = 98;
else
    colourturn = 98;
    oppositecolour = 119;
end

onlyAIoption = 0;
%-------------------------------------------------------------------------
 clickP = get(gca,'CurrentPoint');
      x = ceil(clickP(1,2));
      y = ceil(clickP(1,1));
%---- Conversion from Graph Grid to B.top grid --------------------------
      x = 13-x;
      y = y + 4;
%-------------------------------------------------------------------------
%This is the board
      piecetype = B.top(x,y).name;

%--------Conversion from B.Top grid to Chessboard grid-------------------
      p_x = x - 4;
      p_y = y - 4;

if(piece_colour(p_x,p_y) == colourturn)
%----------------------Generates Possible Moves--------------------------

switch piecetype
    case 'pawn'
        [possiblemoves] = MovementPawn(chessboard,piece_colour,num_moves,p_x,p_y);
    case 'rook'
        [possiblemoves] = MovementRook(chessboard,piece_colour,p_x,p_y);
    case 'knight'
        [possiblemoves] = MovementKnight(chessboard,piece_colour,p_x,p_y);
    case 'bishop'
        [possiblemoves] = MovementBishop(chessboard,piece_colour,p_x,p_y);
    case 'queen'
        [possiblemoves] = MovementQueen(chessboard,piece_colour,p_x,p_y);
    case 'king'
        [possiblemoves] = MovementKing(chessboard,piece_colour,num_moves,...
            potentialmoves,p_x,p_y);
end

%-------------------------------------------------------------------------
%             REDRAWS THE BOARD BUT HIGHLIGHTS POSSIBLE MOVES
%-------------------------------------------------------------------------
%------------------------------Draws Rectangles---------------------------
icount=0;
for i=1:71
         icount=icount+1;
         if mod(i,2)==1
             rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
                 parameters.dx ,parameters.dx],'Curvature',[0,0],...
                 'FaceColor',[0.82 0.545 0.278])
         else
```

```
64              rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
65                  parameters.dx ,parameters.dx],...
66                  'Curvature',[0,0],'FaceColor',[1 0.808 0.62])
67          end
68  end
69
70  %----------- Highlights possible moves-----------------------------------
71  for r=1:parameters.rows
72      for c=1:parameters.cols
73          switch possiblemoves(r,c)
74  %---------------------Highlights movable squares----------------------
75              case 1
76               rectangle('Position',[parameters.xx(9-r,c),parameters.yy(9-r,c),...
77                   parameters.dx ,parameters.dx],'Curvature',[0,0],'FaceColor','y',...
78                   'ButtonDownFcn',{@ClickMovePiece,x,y,B,piece_colour,chessboard...
79                   ,num_moves,parameters,possiblemoves,handles,onlyAIoption,0,0})
80  %---------------------Highlights capturable squares-------------------
81              case 2
82               rectangle('Position',[parameters.xx(9-r,c),parameters.yy(9-r,c),...
83                   parameters.dx ,parameters.dx],'Curvature',[0,0],'FaceColor','r')
84  %---------------------Highlights Enpassant Squares---------------------
85              case 3
86               rectangle('Position',[parameters.xx(9-r,c),parameters.yy(9-r,c),...
87                   parameters.dx ,parameters.dx],'Curvature',[0,0],'FaceColor','r',...
88                   'ButtonDownFcn',{@ClickEnpassant,x,y,B,piece_colour,chessboard...
89                   ,num_moves,parameters,possiblemoves,handles,onlyAIoption,0,0})
90  %---------------------Highlights Castling Squares---------------------
91              case 4
92               rectangle('Position',[parameters.xx(9-r,c),parameters.yy(9-r,c),...
93                   parameters.dx ,parameters.dx],'Curvature',[0,0],'FaceColor','b',...
94                   'ButtonDownFcn',{@ClickCastling,x,y,B,piece_colour,chessboard...
95                   ,num_moves,parameters,possiblemoves,handles,onlyAIoption,0,0})
96  %---------------------Highlights Pawn Promotion Square-----------------
97              case 5
98               rectangle('Position',[parameters.xx(9-r,c),parameters.yy(9-r,c),...
99                   parameters.dx ,parameters.dx],'Curvature',[0,0],'FaceColor','c',...
100                  'ButtonDownFcn',{@ClickPawnPromo,x,y,B,piece_colour,chessboard...
101                  ,num_moves,parameters,possiblemoves,handles,onlyAIoption,0,0,0})
102         end
103     end
104 end
105 %-------------------------------------------------------------------------
106 %                             Redraws images
107 %-------------------------------------------------------------------------
108 for r=1:parameters.rows
109     for c=1:parameters.cols
110         if ¬isempty(B.top(r+B.info.pad/2,c+B.info.pad/2).image)
111             % load the image
112             [X, map, alpha]  = imread(B.top(r+B.info.pad/2,c+B.info.pad/2).image);
113             % draw the image
114             %If Statement enables capture move
115             if possiblemoves(r,c) == 2
116                 imHdls(r,c) = image(c+[0 1]-1,[parameters.rows-1 parameters.rows]-r+1,...
117                 mirrorImage(X),'AlphaData',mirrorImage(alpha),...
118                 'ButtonDownFcn',{@ClickCapturePiece,x,y,B,piece_colour,chessboard...
119                  ,num_moves,parameters,possiblemoves,handles,onlyAIoption,0,0});
120              %Enables Pawn Promotion
121             elseif possiblemoves(r,c) == 5 && chessboard(r,c)≠0
122                 imHdls(r,c) = image(c+[0 1]-1,[parameters.rows-1 parameters.rows]-r+1,...
123                 mirrorImage(X),'AlphaData',mirrorImage(alpha),...
124                 'ButtonDownFcn',{@ClickPawnPromo,x,y,B,piece_colour,chessboard...
125                  ,num_moves,parameters,possiblemoves,handles,onlyAIoption,0,0});
```

```
126              %Else enable click piece
127             else
128             imHdls(r,c) = image(c+[0 1]-1,[parameters.rows-1 parameters.rows]-r+1,...
129                 mirrorImage(X),'AlphaData',mirrorImage(alpha),...
130                 'ButtonDownFcn',{@ClickPiece,B,piece_colour,chessboard,...
131                 num_moves,parameters,potentialmoves,handles,onlyAIoption,0,0});
132             end
133         end
134     end
135 end
136 drawnow;
137 end
138 end
139 %--------------------------------------------------------------------------
140 %--------------------------------------------------------------------------
```

### A.2.2 ClickCapturePiece.m

```
1  %CapturePiece Part of the Click Series of Functions - Enables capture
2  function [chessboard,piece_colour, num_moves,allowscheck]=ClickCapturePiece(v1,v2,x_ori,y_or
3      num_moves,parameters,PM,handles,onlyAIoption,move_x,move_y,varargin)
4
5  %--------------------------------------------------------------------------
6  %                   Init values,conversions and click location
7  %--------------------------------------------------------------------------
8  if(mod(B.info.turn,2)==1)
9      colourturn = 119;
10     oppositecolour = 98;
11 else
12     colourturn = 98;
13     oppositecolour = 119;
14 end
15
16 if onlyAIoption == 0
17 clickP = get(gca,'CurrentPoint');
18       x = ceil(clickP(1,2));
19       y = ceil(clickP(1,1));
20 %---- Conversion from Graph grid to B.top grid ----------------------------
21       x = 13-x;
22       y = y + 4;
23 %--------Conversion from B.Top grid to Chessboard grid--------------------
24       p_x = x - 4; %p_x is necessary because it is the current clicked position
25       p_y = y - 4;
26       ori_x = x_ori - 4; %The difference is that ori_x is for chessboard,
27       ori_y = y_ori - 4; %x_ori is for B.top
28 else
29     p_x = move_x;   %Where is it moving to
30     p_y = move_y;
31     ori_x = x_ori;   %Where was it originally
32     ori_y = y_ori;
33 end
34
35 %--------------------------------------------------------------------------
36 %            Checks if King is exposed to check in any way
37 %--------------------------------------------------------------------------
38 %The method used is to create a future chessboard based on the move
39 %requested
40
```

```
fboard = chessboard;
f_p_colour= piece_colour;
f_num_moves = num_moves;
%This step officially moves the piece
fboard(p_x,p_y) = chessboard(ori_x,ori_y);
f_p_colour(p_x,p_y) = piece_colour(ori_x,ori_y);
f_num_moves(p_x,p_y) = num_moves(ori_x,ori_y) + 1;
%This step empties the previous box
fboard(ori_x,ori_y) = 0;
f_p_colour(ori_x,ori_y) = 0;
f_num_moves(ori_x,ori_y) = 0;

%Analyses the future board
[potentialfuturemoves,capt_index_future] = analyseboard(fboard,...
    f_p_colour,f_num_moves,oppositecolour);
[allowscheck]=KingCheck(fboard,f_p_colour,colourturn,...
    capt_index_future,potentialfuturemoves);
if allowscheck==1 && onlyAIoption == 0
    set(handles.gameconsole,'String','King will be left in check, move invalid')
end
%--------------------------------------------------------------------------
%Ensures it can only move legally
if PM(p_x,p_y)==2 && chessboard(p_x,p_y) ≠ 10 && allowscheck==0

B.info.turn = B.info.turn + 1;
%--------------------------------------------------------------------------
%              This is to edit the backend chessboard matrix
%--------------------------------------------------------------------------
%This step officially moves the piece
chessboard = fboard;
piece_colour = f_p_colour;
num_moves = f_num_moves;


%-------------To Check Opposing Side ------------------------------------
[potentialmoves,capt_index] = analyseboard(chessboard,piece_colour,num_moves,colourturn);
[checkopp]=KingCheck(chessboard,piece_colour,oppositecolour,capt_index,potentialmoves);
if checkopp == 1 && onlyAIoption == 0
   set(handles.checkstat,'String','Check')
    [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
    if ischeckmate
        set(handles.checkstat,'String','Checkmate, White Wins')
    end
elseif checkopp == 0 && onlyAIoption ==0
    [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
    if ischeckmate
        set(handles.checkstat,'String','Stalemate')
    else
        set(handles.checkstat,'String','')
    end
end

if onlyAIoption == 0
    [B] = readchessboard(B,chessboard,piece_colour);
%--------------------------------------------------------------------------
%                           Redraws the Board
%--------------------------------------------------------------------------
icount=0;
for i=1:71
         icount=icount+1;
         if mod(i,2)==1
             rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
```

```
                    parameters.dx ,parameters.dx],'Curvature',[0,0],...
                    'FaceColor',[0.82 0.545 0.278])
            else
                rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
                    parameters.dx ,parameters.dx],...
                    'Curvature',[0,0],'FaceColor',[1 0.808 0.62])
            end
end

for r=1:parameters.rows
    for c=1:parameters.cols
        if ¬isempty(B.top(r+B.info.pad/2,c+B.info.pad/2).image)
            % load the image
            [X, map, alpha]  = imread(B.top(r+B.info.pad/2,c+B.info.pad/2).image);
            % draw the image
            imHdls(r,c) = image(c+[0 1]-1,[parameters.rows-1 parameters.rows]-r+1,...
                mirrorImage(X),'AlphaData',mirrorImage(alpha),...
                'ButtonDownFcn',{@ClickPiece,B,piece_colour,chessboard,...
                num_moves,parameters,potentialmoves,handles});
        end
    end
end
drawnow;
if(get(handles.choice2,'Value')==1)
    AIControl(B,piece_colour,chessboard,num_moves,parameters, handles);
end
if(get(handles.choice3,'Value')==1)
    AIvsAI(B,piece_colour,chessboard,num_moves,parameters, handles)
end
if(get(handles.choice1,'Value')==1)
    PlayerVsPlayer( B,piece_colour,chessboard,num_moves,parameters, handles )
end
end
%-------------------------------------------------------------------------------------------
end
end
```

### A.2.3 ClickCastling.m

```
%Castling Enables frontend implementation of castling
function [chessboard,piece_colour, num_moves,allowscheck]=ClickCastling(v1,v2,x_ori,y_ori,B,
    num_moves,parameters,PM,handles,onlyAIoption,move_x,move_y,varargin)

%-------------------------------------------------------------------------
%                  Init values,conversions and click location
%-------------------------------------------------------------------------
if(mod(B.info.turn,2)==1)
    colourturn = 119;
    oppositecolour = 98;
else
    colourturn = 98;
    oppositecolour = 119;
end

if onlyAIoption == 0
clickP = get(gca,'CurrentPoint');
      x = ceil(clickP(1,2));
      y = ceil(clickP(1,1));
```

```
%---- Conversion from Graph grid to B.top grid ---------------------------
      x = 13-x;
      y = y + 4;
%--------Conversion from B.Top grid to Chessboard grid--------------------
      p_x = x - 4; %p_x is necessary because it is the current clicked position
      p_y = y - 4;
      ori_x = x_ori - 4; %The difference is that ori_x is for chessboard,
      ori_y = y_ori - 4; %x_ori is for B.top
else
    p_x = move_x;   %Where is it moving to
    p_y = move_y;
    ori_x = x_ori;   %Where was it originally
    ori_y = y_ori;
end

%-------------------------------------------------------------------------
%            Checks if King is exposed to check in any way
%-------------------------------------------------------------------------
%The method used is to create a future chessboard based on the move
%requested

fboard = chessboard;
f_p_colour= piece_colour;
f_num_moves = num_moves;
%This step officially moves the piece
fboard(p_x,p_y) = chessboard(ori_x,ori_y);
f_p_colour(p_x,p_y) = piece_colour(ori_x,ori_y);
f_num_moves(p_x,p_y) = num_moves(ori_x,ori_y) + 1;
%This step empties the previous box
fboard(ori_x,ori_y) = 0;
f_p_colour(ori_x,ori_y) = 0;
f_num_moves(ori_x,ori_y) = 0;

%Analyses the future board
[potentialfuturemoves,capt_index_future] = analyseboard(fboard,...
    f_p_colour,f_num_moves,oppositecolour);
[allowscheck]=KingCheck(fboard,f_p_colour,colourturn,...
    capt_index_future,potentialfuturemoves);
if allowscheck ==1 && onlyAIoption == 0
    set(handles.gameconsole,'String','King will be left in check, move invalid')
end
%-------------------------------------------------------------------------
%Ensures it can only move legally
if PM(p_x,p_y)==4 && allowscheck==0

%-------------------------------------------------------------------------
%                   B.top
%-------------------------------------------------------------------------
%Coordinate system is X_rook = [B.top Chessboard]
if ( p_x == 8 && p_y == 7)
    x_rook = [12 8]; %Initial Rook Position
    y_rook = [12 8];
    move_x = [12 8]; %Final Rook Position
    move_y = [10 6];
elseif ( p_x == 8 && p_y == 3 )
    x_rook = [12 8];
    y_rook = [5 1];
    move_x = [12 8];
    move_y = [8 4];
elseif ( p_x == 1 && p_y == 7)
    x_rook = [5 1];
    y_rook = [12 8];
```

```
82      move_x = [5 1];
83      move_y = [10 6];
84  elseif ( p_x == 1 && p_y == 3)
85      x_rook = [5 1];
86      y_rook = [5 1];
87      move_x = [5 1];
88      move_y = [8 4];
89  end
90
91  B.info.turn = B.info.turn + 1;
92  %------------------------------------------------------------------------
93  %               This is to edit the backend chessboard matrix
94  %------------------------------------------------------------------------
95  %--------------------------------King--------------------------------------
96  %This step officially moves the piece
97  chessboard(p_x,p_y) = chessboard(ori_x,ori_y);
98  piece_colour(p_x,p_y) = piece_colour(ori_x,ori_y);
99  num_moves(p_x,p_y) = num_moves(ori_x,ori_y) + 1;
100
101 %This step empties the previous box
102 chessboard(ori_x,ori_y) = 0;
103 piece_colour(ori_x,ori_y) = 0;
104 num_moves(ori_x,ori_y) = 0;
105
106 %-------------------------------Rook---------------------------------------
107 %This step officially moves the piece
108 chessboard(move_x(2),move_y(2)) = chessboard(x_rook(2),y_rook(2));
109 piece_colour(move_x(2),move_y(2)) = piece_colour(x_rook(2),y_rook(2));
110 num_moves(move_x(2),move_y(2)) = num_moves(x_rook(2),y_rook(2)) + 1;
111
112 %This step empties the previous box
113 chessboard(x_rook(2),y_rook(2)) = 0;
114 piece_colour(x_rook(2),y_rook(2)) = 0;
115 num_moves(x_rook(2),y_rook(2)) = 0;
116
117 %-------------Analyses for potential checks & provides game stats---------
118 [potentialmoves,capt_index] = analyseboard(chessboard,piece_colour,num_moves,colourturn);
119 [checkopp]=KingCheck(chessboard,piece_colour,oppositecolour,capt_index,potentialmoves);
120 if checkopp == 1 && onlyAIoption == 0
121     set(handles.checkstat,'String','Check')
122     [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
123     if ischeckmate
124         set(handles.checkstat,'String','Checkmate, White Wins')
125     end
126     elseif checkopp == 0 && onlyAIoption ==0
127     [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
128     if ischeckmate
129         set(handles.checkstat,'String','Stalemate')
130     else
131         set(handles.checkstat,'String','')
132     end
133 end
134
135 if onlyAIoption ==0
136     [B] = readchessboard(B,chessboard,piece_colour);
137 %------------------------------------------------------------------------
138 %                           Redraws the Board
139 %------------------------------------------------------------------------
140 icount=0;
141 for i=1:71
142          icount=icount+1;
143          if mod(i,2)==1
```

```
144                 rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
145                     parameters.dx ,parameters.dx],'Curvature',[0,0],...
146                     'FaceColor',[0.82 0.545 0.278])
147             else
148                 rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
149                     parameters.dx ,parameters.dx],...
150                     'Curvature',[0,0],'FaceColor',[1 0.808 0.62])
151             end
152 end
153
154 for r=1:parameters.rows
155     for c=1:parameters.cols
156         if ¬isempty(B.top(r+B.info.pad/2,c+B.info.pad/2).image)
157             % load the image
158             [X, map, alpha]  = imread(B.top(r+B.info.pad/2,c+B.info.pad/2).image);
159             % draw the image
160             imHdls(r,c) = image(c+[0 1]-1,[parameters.rows-1 parameters.rows]-r+1,...
161                 mirrorImage(X),'AlphaData',mirrorImage(alpha),...
162                 'ButtonDownFcn',{@ClickPiece,B,piece_colour,chessboard,...
163                 num_moves,parameters,potentialmoves,handles});
164         end
165     end
166 end
167 drawnow;
168 if(get(handles.choice2,'Value')==1)
169     AIControl(B,piece_colour,chessboard,num_moves,parameters, handles);
170 end
171 if(get(handles.choice3,'Value')==1)
172     AIvsAI(B,piece_colour,chessboard,num_moves,parameters, handles)
173 end
174 if(get(handles.choice1,'Value')==1)
175     PlayerVsPlayer( B,piece_colour,chessboard,num_moves,parameters, handles )
176 end
177 end
178 %-------------------------------------------------------------------------------------------
179 end
180 end
```

### A.2.4 ClickEnpassant.m

```
1  %Enpassant Enables frontend implementation of En Passant
2  function [chessboard,piece_colour, num_moves,allowscheck]=ClickEnpassant(v1,v2,x_ori,y_ori,P
3      num_moves,parameters,PM, handles,onlyAIoption,move_x,move_y,varargin)
4
5  %-------------------------------------------------------------------------
6  %                  Init values,conversions and click location
7  %-------------------------------------------------------------------------
8  if(mod(B.info.turn,2)==1)
9      colourturn = 119;
10     oppositecolour = 98;
11 else
12     colourturn = 98;
13     oppositecolour = 119;
14 end
15
16 if onlyAIoption == 0
17 clickP = get(gca,'CurrentPoint');
18       x = ceil(clickP(1,2));
```

```
19        y = ceil(clickP(1,1));
20  %---- Conversion from Graph grid to B.top grid ---------------------------
21        x = 13-x;
22        y = y + 4;
23  %--------Conversion from B.Top grid to Chessboard grid--------------------
24        p_x = x - 4; %p_x is necessary because it is the current clicked position
25        p_y = y - 4;
26        ori_x = x_ori - 4; %The difference is that ori_x is for chessboard,
27        ori_y = y_ori - 4; %x_ori is for B.top
28  else
29      p_x = move_x;   %Where is it moving to
30      p_y = move_y;
31      ori_x = x_ori;   %Where was it originally
32      ori_y = y_ori;
33  end
34
35  %-------------------------------------------------------------------------
36  %        Checks if King is exposed to check in any way due to move
37  %-------------------------------------------------------------------------
38  %The method used is to create a future chessboard based on the move
39  %requested
40
41  fboard = chessboard;
42  f_p_colour= piece_colour;
43  f_num_moves = num_moves;
44  %This step officially moves the piece
45  fboard(p_x,p_y) = chessboard(ori_x,ori_y);
46  f_p_colour(p_x,p_y) = piece_colour(ori_x,ori_y);
47  f_num_moves(p_x,p_y) = num_moves(ori_x,ori_y) + 1;
48  %This step empties the previous box
49  fboard(ori_x,ori_y) = 0;
50  f_p_colour(ori_x,ori_y) = 0;
51  f_num_moves(ori_x,ori_y) = 0;
52
53  %Analyses the future board
54  [potentialfuturemoves,capt_index_future] = analyseboard(fboard,...
55      f_p_colour,f_num_moves,oppositecolour);
56  [allowscheck]=KingCheck(fboard,f_p_colour,colourturn,...
57      capt_index_future,potentialfuturemoves);
58  if allowscheck==1 && onlyAIoption == 0
59      set(handles.gameconsole,'String','King will be left in check, move invalid')
60  end
61  %-------------------------------------------------------------------------
62  %Ensures it can only move legally
63  if PM(p_x,p_y)==3 && allowscheck==0
64  %-------------------------------------------------------------------------
65  %                Moves Data in B.TOP & deletes previous cell
66  %-------------------------------------------------------------------------
67  %Coordinates of the captured piece
68  if (piece_colour(ori_x,ori_y)==98)
69     del_x = [p_x+3 p_x-1];
70     del_y = [p_y+4 p_y];
71  end
72
73  if (piece_colour(ori_x,ori_y)==119)
74     del_x = [p_x+5 p_x+1];
75     del_y = [p_y+4 p_y];
76  end
77
78  B.info.turn = B.info.turn + 1;
79  %-------------------------------------------------------------------------
80  %              This is to edit the backend chessboard matrix
```

```
%-------------------------------------------------------------------------
%This step officially moves the piece
chessboard(p_x,p_y) = chessboard(ori_x,ori_y);
piece_colour(p_x,p_y) = piece_colour(ori_x,ori_y);
num_moves(p_x,p_y) = num_moves(ori_x,ori_y) + 1;

%This step empties the previous box
chessboard(ori_x,ori_y) = 0;
piece_colour(ori_x,ori_y) = 0;
num_moves(ori_x,ori_y) = 0;

%This step deletes the capured piece
chessboard(del_x(2),del_y(2)) = 0;
piece_colour(del_x(2),del_y(2)) = 0;
num_moves(del_x(2),del_y(2)) = 0;


%-------------Analyses for potential checks & provides game stats---------
[potentialmoves,capt_index] = analyseboard(chessboard,piece_colour,num_moves,colourturn);
[checkopp]=KingCheck(chessboard,piece_colour,oppositecolour,capt_index,potentialmoves);
if checkopp == 1 && onlyAIoption == 0
    set(handles.checkstat,'String','Check')
    [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
    if ischeckmate
        set(handles.checkstat,'String','Checkmate, White Wins')
    end
    elseif checkopp == 0 && onlyAIoption ==0
    [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
    if ischeckmate
        set(handles.checkstat,'String','Stalemate')
    else
        set(handles.checkstat,'String','')
    end
end

if onlyAIoption == 0
    [B] = readchessboard(B,chessboard,piece_colour);
%-------------------------------------------------------------------------
%                           Redraws the Board
%-------------------------------------------------------------------------
icount=0;
for i=1:71
         icount=icount+1;
         if mod(i,2)==1
             rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
                 parameters.dx ,parameters.dx],'Curvature',[0,0],...
                 'FaceColor',[0.82 0.545 0.278])
         else
            rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
                parameters.dx ,parameters.dx],...
                'Curvature',[0,0],'FaceColor',[1 0.808 0.62])
         end
end
end
end
```

### A.2.5 ClickPawnPromo.m

```
%PawnPromo Enables Front End Implementation of Pawn Promo
function [chessboard,piece_colour, num_moves,allowscheck]=ClickPawnPromo(v1,v2,x_ori,y_ori,P
    num_moves,parameters,PM,handles,onlyAIoption,move_x,move_y,promo,varargin)

%--------------------------------------------------------------------------
%                  Init values,conversions and click location
%--------------------------------------------------------------------------
if(mod(B.info.turn,2)==1)
    colourturn = 119;
    oppositecolour = 98;
else
    colourturn = 98;
    oppositecolour = 119;
end

if onlyAIoption == 0
clickP = get(gca,'CurrentPoint');
      x = ceil(clickP(1,2));
      y = ceil(clickP(1,1));
%---- Conversion from Graph grid to B.top grid ---------------------------
      x = 13-x;
      y = y + 4;
%--------Conversion from B.Top grid to Chessboard grid--------------------
      p_x = x - 4; %p_x is necessary because it is the current clicked position
      p_y = y - 4;
      ori_x = x_ori - 4; %The difference is that ori_x is for chessboard,
      ori_y = y_ori - 4; %x_ori is for B.top
else
    p_x = move_x;   %Where is it moving to
    p_y = move_y;
    ori_x = x_ori;   %Where was it originally
    ori_y = y_ori;
end

%--------------------------------------------------------------------------
%            Checks if King is exposed to check in any way
%--------------------------------------------------------------------------
%The method used is to create a future chessboard based on the move
%requested

fboard = chessboard;
f_p_colour= piece_colour;
f_num_moves = num_moves;
%This step officially moves the piece
fboard(p_x,p_y) = chessboard(ori_x,ori_y);
f_p_colour(p_x,p_y) = piece_colour(ori_x,ori_y);
f_num_moves(p_x,p_y) = num_moves(ori_x,ori_y) + 1;
%This step empties the previous box
fboard(ori_x,ori_y) = 0;
f_p_colour(ori_x,ori_y) = 0;
f_num_moves(ori_x,ori_y) = 0;

%Analyses the future board
[potentialfuturemoves,capt_index_future] = analyseboard(fboard,...
    f_p_colour,f_num_moves,oppositecolour);
[allowscheck]=KingCheck(fboard,f_p_colour,colourturn,...
    capt_index_future,potentialfuturemoves);
if allowscheck==1 && onlyAIoption == 0
    set(handles.gameconsole,'String','King will be left in check, move invalid')
end
%--------------------------------------------------------------------------
%Ensures it can only move legally
```

```
63 if PM(p_x,p_y)==5 && allowscheck==0
64 %-------------------------------------------------------------------------
65 %                 Moves Data in B.TOP & deletes previous cell
66 %-------------------------------------------------------------------------
67 %Allows user to input desired piece. Checks legality.
68 if ¬onlyAIoption
69 set(handles.gameconsole,'String','Pawn has been promoted');
70             flags=0;
71           while(flags==0)
72               flags=1;
73               v=0;
74               while v == 0
75               [pawn_prom,v] = listdlg('PromptString','Select a piece:',...
76                 'SelectionMode','single',...
77                 'ListString',{'Rook','Queen','Knight','Bishop'});
78               end
79             switch pawn_prom
80                 case 1
81                     chessboard(p_x,p_y)= 5;
82                 case 2
83                     chessboard(p_x,p_y)= 9;
84                 case 3
85                     chessboard(p_x,p_y)= 3;
86                 case 4
87                     chessboard(p_x,p_y)= 4;
88                 otherwise
89                     disp('Invalid input');
90                     flags=0;
91             end
92           end
93 else
94             switch promo
95                         case 'rook'
96                             chessboard(p_x,p_y)= 5;
97                         case 'queen'
98                             chessboard(p_x,p_y)= 9;
99                         case 'knight'
100                            chessboard(p_x,p_y)= 3;
101                        case 'bishop'
102                            chessboard(p_x,p_y)= 4;
103            end
104 end
105
106 B.info.turn = B.info.turn + 1;
107
108 %-------------------------------------------------------------------------
109 %              This is to edit the backend chessboard matrix
110 %-------------------------------------------------------------------------
111 %This step officially moves the piece
112 num_moves(p_x,p_y) = num_moves(ori_x,ori_y) + 1;
113 piece_colour(p_x,p_y)= colourturn;
114
115 %This step empties the previous box
116 chessboard(ori_x,ori_y) = 0;
117 piece_colour(ori_x,ori_y) = 0;
118 num_moves(ori_x,ori_y) = 0;
119
120 %-------------Analyses for potential checks & provides game stats---------
121 [potentialmoves,capt_index] = analyseboard(chessboard,piece_colour,num_moves,colourturn);
122 [checkopp]=KingCheck(chessboard,piece_colour,oppositecolour,capt_index,potentialmoves);
123 if checkopp == 1 && onlyAIoption == 0
124    set(handles.checkstat,'String','Check')
```

```
    [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
    if ischeckmate
        set(handles.checkstat,'String','Checkmate, White Wins')
    end
elseif checkopp == 0 && onlyAIoption ==0
    [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
    if ischeckmate
        set(handles.checkstat,'String','Stalemate')
    else
        set(handles.checkstat,'String','')
    end
end

if onlyAIoption == 0
    [B] = readchessboard(B,chessboard,piece_colour);
%-------------------------------------------------------------------------
%                           Redraws the Board
%-------------------------------------------------------------------------
icount=0;
for i=1:71
         icount=icount+1;
         if mod(i,2)==1
             rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
                 parameters.dx ,parameters.dx],'Curvature',[0,0],...
                 'FaceColor',[0.82 0.545 0.278])
         else
            rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
                parameters.dx ,parameters.dx],...
                'Curvature',[0,0],'FaceColor',[1 0.808 0.62])
         end
end

for r=1:parameters.rows
    for c=1:parameters.cols
        if ¬isempty(B.top(r+B.info.pad/2,c+B.info.pad/2).image)
            % load the image
            [X, map, alpha]  = imread(B.top(r+B.info.pad/2,c+B.info.pad/2).image);
            % draw the image
end
```

### A.2.6 ClickMovePiece.m

```
%Movepiece Part of the Click Series of Functions - Enables movement
function [chessboard,piece_colour, num_moves,allowscheck]=ClickMovePiece(v1,v2,x_ori,y_ori,
    num_moves,parameters,PM,handles,onlyAIoption,move_x,move_y,varargin)

%-------------------------------------------------------------------------
%                  Init values,conversions and click location
%-------------------------------------------------------------------------
if(mod(B.info.turn,2)==1)
    colourturn = 119;
    oppositecolour = 98;
else
    colourturn = 98;
    oppositecolour = 119;
end

if onlyAIoption == 0
```

```
clickP = get(gca,'CurrentPoint');
      x = ceil(clickP(1,2));
      y = ceil(clickP(1,1));
%---- Conversion from Graph grid to B.top grid ----------------------------
      x = 13-x;
      y = y + 4;
%--------Conversion from B.Top grid to Chessboard grid--------------------
      p_x = x - 4; %p_x is necessary because it is the current clicked position
      p_y = y - 4;
      ori_x = x_ori - 4; %The difference is that ori_x is for chessboard,
      ori_y = y_ori - 4; %x_ori is for B.top
else
    p_x = move_x;   %Where is it moving to
    p_y = move_y;
    ori_x = x_ori;   %Where was it originally
    ori_y = y_ori;
end

%-------------------------------------------------------------------------
%            Checks if King is exposed to check in any way
%-------------------------------------------------------------------------
%The method used is to create a future chessboard based on the move
%requested

fboard = chessboard;
f_p_colour= piece_colour;
f_num_moves = num_moves;
%This step officially moves the piece
fboard(p_x,p_y) = chessboard(ori_x,ori_y);
f_p_colour(p_x,p_y) = piece_colour(ori_x,ori_y);
f_num_moves(p_x,p_y) = num_moves(ori_x,ori_y) + 1;
%This step empties the previous box
fboard(ori_x,ori_y) = 0;
f_p_colour(ori_x,ori_y) = 0;
f_num_moves(ori_x,ori_y) = 0;

%Analyses the future board
[potentialfuturemoves,capt_index_future] = analyseboard(fboard,...
    f_p_colour,f_num_moves,oppositecolour);
[allowscheck]=KingCheck(fboard,f_p_colour,colourturn,...
    capt_index_future,potentialfuturemoves);
if allowscheck ==1 && onlyAIoption == 0
    set(handles.gameconsole,'String','King will be left in check, move invalid')
end
%-------------------------------------------------------------------------
%-------------------------------------------------------------------------

if PM(p_x,p_y)==1 && allowscheck==0 %Ensures it can only move legally

%Iterates the turn
B.info.turn = B.info.turn + 1;

%-------------------------------------------------------------------------
%              This is to edit the backend chessboard matrix
%-------------------------------------------------------------------------
%This step officially moves the piece
chessboard = fboard;
piece_colour = f_p_colour;
num_moves = f_num_moves;

%-------------Analyses for potential checks & provides game stats---------
[potentialmoves,capt_index] = analyseboard(chessboard,piece_colour,num_moves,colourturn);
```

```
[checkopp]=KingCheck(chessboard,piece_colour,oppositecolour,capt_index,potentialmoves);

if checkopp == 1 && onlyAIoption ==0
    set(handles.checkstat,'String','Check')
    [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
    if ischeckmate
        set(handles.checkstat,'String','Checkmate, White Wins')
    end
elseif checkopp == 0 && onlyAIoption ==0
    [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
    if ischeckmate
        set(handles.checkstat,'String','Stalemate')
    else
        set(handles.checkstat,'String','')
    end
end

%--------------------------------------------------------------------------
if onlyAIoption == 0
    [B] = readchessboard(B,chessboard,piece_colour);
%--------------------------------------------------------------------------
%                           Redraws the Board
%--------------------------------------------------------------------------
icount=0;
for i=1:71
         icount=icount+1;
         if mod(i,2)==1
             rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
                 parameters.dx ,parameters.dx],'Curvature',[0,0],...
                 'FaceColor',[0.82 0.545 0.278])
         else
            rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
                parameters.dx ,parameters.dx],...
                'Curvature',[0,0],'FaceColor',[1 0.808 0.62])
         end
end

%--------------------------------------------------------------------------
for r=1:parameters.rows
    for c=1:parameters.cols
        if ¬isempty(B.top(r+B.info.pad/2,c+B.info.pad/2).image)
            % load the image
            [X, map, alpha]  = imread(B.top(r+B.info.pad/2,c+B.info.pad/2).image);
            % draw the image
            imHdls(r,c) = image(c+[0 1]-1,[parameters.rows-1 parameters.rows]-r+1,...
                mirrorImage(X),'AlphaData',mirrorImage(alpha),...
                'ButtonDownFcn',{@ClickPiece,B,piece_colour,chessboard,...
                num_moves,parameters,potentialmoves,handles});
        end
    end
end
drawnow;
if(get(handles.choice2,'Value')==1)
    AIControl(B,piece_colour,chessboard,num_moves,parameters, handles);
end
if(get(handles.choice3,'Value')==1)
    AIvsAI(B,piece_colour,chessboard,num_moves,parameters, handles)
end
if(get(handles.choice1,'Value')==1)
    PlayerVsPlayer( B,piece_colour,chessboard,num_moves,parameters, handles )
end
end
```

```
141 %--------------------------------------------------------------------------
142 end
143 end
```

## A.3 AI

### A.3.1 AIControl

```
1  function [B,piece_colour,chessboard,num_moves,parameters, handles]=AIControl(B,piece_colour,
2                  num_moves,parameters, handles)
3  %AIControl Enables AI to be in action
4
5  %--------------------------------------------------------------------------
6  %                       Init Values
7  %--------------------------------------------------------------------------
8  if(mod(B.info.turn-1,2)==1)
9      colourturn = 119;
10     oppositecolour = 98;
11 else
12     colourturn = 98;
13     oppositecolour = 119;
14 end
15
16 [userboardscore] = heuristicanalysis(B,chessboard, piece_colour,num_moves,119,handles);
17 set(handles.UPS,'String',userboardscore)
18 handles.userboardscore = [handles.userboardscore userboardscore];
19 depth = 2;
20 set(handles.depth,'String',depth)
21
22 %------------------ Stops Game Execution if White Wins -------------------
23 % [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
24 % if ischeckmate
25 %     return
26 % end
27
28 [oppcolourpotentialmoves,oppcolourcapt_index] = analyseboard(chessboard, piece_colour,num_mo
29
30 [ischeck]=KingCheck(chessboard,piece_colour,oppositecolour, oppcolourcapt_index,oppcolourpot
31 if ischeck == 1
32     set(handles.checkstat,'String','Check')
33     [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
34     if ischeckmate
35         set(handles.checkstat,'String','Checkmate, White Wins')
36     end
37 elseif ischeck == 0
38     [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
39     if ischeckmate
40         set(handles.checkstat,'String','Stalemate')
41     else
42         set(handles.checkstat,'String','')
43     end
44 end
45 %--------------------Plot UserBoardScore----------------------------------
46
47  handles.turnforwhite = [handles.turnforwhite B.info.turn];
48  plot(handles.graph,handles.turnforwhite,handles.userboardscore,'-b',...
49      handles.turnforblack,handles.AIBoardscore,'-r','LineWidth',2)
```

```
 set(handles.graph,'XColor','w','YColor','w')
 xlabel(handles.graph,'Turn')
 ylabel(handles.graph,'Score')

%--------------------------------------------------------------------------
set(handles.AIMsgs,'String','Thinking Really Hard')

%Produces AI's decision
tic
[boardscore,chessboard,piece_colour,num_moves]=...
    AI_GenerateAllMoves(B,chessboard,piece_colour,num_moves,depth,1,-99999,99999,handles);
time =toc;

set(handles.AIMsgs,'String',['Time Taken To Think Was: ' num2str(time) ' seconds'])

%Translates the results into B.top
[B] = readchessboard(B,chessboard,piece_colour);
%Iterates turn
B.info.turn = B.info.turn + 1;

%---------------------- Shows AI Board Score------------------------------
[AIBoardScore] = heuristicanalysis(B,chessboard, piece_colour,num_moves,98,handles);
set(handles.APS,'String',AIBoardScore)
handles.AIBoardscore = [handles.AIBoardscore AIBoardScore];

%---------------------Plots AI Board Score--------------------------------

 handles.turnforblack = [handles.turnforblack B.info.turn];
 plot(handles.graph,handles.turnforwhite,handles.userboardscore,'-b',...
     handles.turnforblack,handles.AIBoardscore,'-r','LineWidth',2)
 set(handles.graph,'XColor','w','YColor','w')
 xlabel(handles.graph,'Turn')
 ylabel(handles.graph,'Score')

%------------------------ Checks if AI has checkmated User ---------------
[oppcolourpotentialmoves,oppcolourcapt_index] = analyseboard(chessboard, piece_colour,num_mo

[ischeck]=KingCheck(chessboard,piece_colour,colourturn, oppcolourcapt_index,oppcolourpotenti
if ischeck == 1
    set(handles.checkstat,'String','Check')
    [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
    if ischeckmate
        set(handles.checkstat,'String','Checkmate, Black Wins')
    end
elseif ischeck == 0
    [ischeckmate]=checkmate(B,chessboard,piece_colour, num_moves);
    if ischeckmate
        set(handles.checkstat,'String','Stalemate')
    else
        set(handles.checkstat,'String','')
    end
end
%--------------------------------------------------------------------------

%--------------------------------------------------------------------------
%                            Redraws the Board
%--------------------------------------------------------------------------
icount=0;
for i=1:71
          icount=icount+1;
          if mod(i,2)==1
              rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
```

```
                    parameters.dx ,parameters.dx],'Curvature',[0,0],...
                    'FaceColor',[0.82 0.545 0.278])
            else
                rectangle('Position',[parameters.xx(icount),parameters.yy(icount),...
                    parameters.dx ,parameters.dx],...
                    'Curvature',[0,0],'FaceColor',[1 0.808 0.62])
            end
end

%------------------------------------------------------------------------
for r=1:parameters.rows
    for c=1:parameters.cols
        if ¬isempty(B.top(r+B.info.pad/2,c+B.info.pad/2).image)
            % load the image
            [X, map, alpha]  = imread(B.top(r+B.info.pad/2,c+B.info.pad/2).image);
            % draw the image
            imHdls(r,c) = image(c+[0 1]-1,[parameters.rows-1 parameters.rows]-r+1,...
                mirrorImage(X),'AlphaData',mirrorImage(alpha),...
                'ButtonDownFcn',{@ClickPiece,B,piece_colour,chessboard,...
                num_moves,parameters,oppcolourpotentialmoves,handles});
        end
    end
end
drawnow;
%------------------------------------------------------------------------
end
```

### A.3.2 AI_GenerateAllMoves.m

```
%AI - Generates moves and stores them for 1 PLY (Only for DATA Tree)
function [boardscore,bchessboard,bpiece_colour,bnum_moves,handles]=...
    AI_GenerateAllMoves(B,chessboard,piece_colour,num_moves,depth,maxormin,alpha,beta,handle
%------------------------------------------------------------------------
%                           Init Values
%------------------------------------------------------------------------
TmpB = B;

if(mod(TmpB.info.turn,2)==1)
    colour = 119;
    oppcolour = 98;
else
    colour = 98;
    oppcolour = 119;
end

TmpB.info.turn = TmpB.info.turn +1;
%------------------------------------------------------------------------

if depth == 0
   TmpB.info.turn = TmpB.info.turn-1;
  [boardscore] = heuristicanalysis(TmpB,chessboard, piece_colour,num_moves,colour,handles);
  bchessboard = chessboard;
  bpiece_colour = piece_colour;
  bnum_moves = num_moves;
else

if maxormin == 1  %Maximizing Player
%==================== Generates Future Nodes or Leafs ====================
```

```
%-------------------------------------------------------------------------
%        Loop that generates all possible moves
%-------------------------------------------------------------------------
[p_x,p_y] = find(piece_colour == colour);
perm_index = randperm(length(p_x));
p_x = p_x(perm_index);
p_y = p_y(perm_index);
n_remaining = length(p_x);
[potentialmoves] = analyseboard(chessboard, piece_colour,num_moves,oppcolour);
previousboardscore = -99999;
%In essence, we are going through each piece, looking at it's possible
%moves, make those possible moves, evaluate, save bestboard.
for i=1:n_remaining
    p_type = chessboard(p_x(i),p_y(i));
    switch p_type
        case 1
            [move] = MovementPawn(chessboard,piece_colour,num_moves,p_x(i),p_y(i));
        case 5
            [move] = MovementRook(chessboard,piece_colour,p_x(i),p_y(i));
        case 4
            [move] = MovementBishop(chessboard,piece_colour,p_x(i),p_y(i));
        case 3
            [move] = MovementKnight(chessboard,piece_colour,p_x(i),p_y(i));
        case 9
            [move] = MovementQueen(chessboard,piece_colour,p_x(i),p_y(i));
        case 10
            [move] = MovementKing(chessboard,piece_colour,num_moves,potentialmoves,p_x(i),p
    end

%-------------------------------------------------------------------------
%            Individual Piece Moves That Generate New Game States
%                    Recursion is also added in each loop
%-------------------------------------------------------------------------
     [move_x,move_y] = find(move ≠ 0);
     perm_index2 = randperm(length(move_x));
     move_x = move_x(perm_index2);
     move_y = move_y(perm_index2);
     n_move = length(move_x);
     pruneflag = 0;
%This loop generates all the game states from 1 piece
     for j = 1:n_move
         switch move(move_x(j),move_y(j))
             case 1
                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickMovePiece(0,0,p_x
                     num_moves,0,move,0,1,move_x(j),move_y(j));
             case 2
                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickCapturePiece(0,0,
                     num_moves,0,move,0,1,move_x(j),move_y(j));
             case 3
                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickEnpassant(0,0,p_x
                     num_moves,0,move, 0,1,move_x(j),move_y(j));
             case 4
                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickCastling(0,0,p_x
                     num_moves,0,move,0,1,move_x(j),move_y(j));
             case 5
                 [pchessboard,ppiece_colour, pnum_moves,kingincheck]=ClickPawnPromo(0,0,p_x
                     num_moves,0,move,0,1,move_x(j),move_y(j),'queen');
         end
%--------A node has been generated, what do you want to do with it?--------
         if kingincheck
             %ignore because move not valid
             if ¬exist('boardscore','var')
```

```
92              boardscore = -99999;
93              bchessboard = 0;
94              bpiece_colour =0;
95              bnum_moves =0;
96              end
97          else
98                  %Generate another layer with recursive parameters
99                  [boardscore,¬,¬,¬,handles]=...
100             AI_GenerateAllMoves(TmpB,pchessboard,ppiece_colour,pnum_moves,depth-1,-maxormin,
101
102                     if boardscore > previousboardscore
103                         previousboardscore = boardscore;
104                         bchessboard = pchessboard;
105                         bpiece_colour = ppiece_colour;
106                         bnum_moves = pnum_moves;
107                     end
108                     if boardscore>alpha
109                         alpha = boardscore;
110                     end
111 %              disp([depth alpha beta boardscore previousboardscore i j n_remaining n_move])
112                     if alpha>beta
113                         pruneflag = 1;
114                         break
115                     end
116         end
117 %-------------------------------------------------------------------------
118     end
119     if pruneflag
120         break
121     end
122 end
123 %=========================================================================
124
125
126 elseif maxormin == -1 %Minimizing Player
127 %====================== Generates Future Nodes or Leafs ====================
128 %-------------------------------------------------------------------------
129 %        Loop that generates all possible moves
130 %-------------------------------------------------------------------------
131 [p_x,p_y] = find(piece_colour == colour);
132 perm_index = randperm(length(p_x));
133 p_x = p_x(perm_index);
134 p_y = p_y(perm_index);
135 n_remaining = length(p_x);
136 [potentialmoves] = analyseboard(chessboard, piece_colour,num_moves,oppcolour);
137 previousboardscore = 99999;
138 %In essence, we are going through each piece, looking at it's possible
139 %moves, make those possible moves, evaluate, save bestboard.
140 for i=1:n_remaining
141     p_type = chessboard(p_x(i),p_y(i));
142     switch p_type
143         case 1
144             [move] = MovementPawn(chessboard,piece_colour,num_moves,p_x(i),p_y(i));
145         case 5
146             [move] = MovementRook(chessboard,piece_colour,p_x(i),p_y(i));
147         case 4
148             [move] = MovementBishop(chessboard,piece_colour,p_x(i),p_y(i));
149         case 3
150             [move] = MovementKnight(chessboard,piece_colour,p_x(i),p_y(i));
151         case 9
152             [move] = MovementQueen(chessboard,piece_colour,p_x(i),p_y(i));
153         case 10
```

```
154             [move] = MovementKing(chessboard,piece_colour,num_moves,potentialmoves,p_x(i),p
155     end
156
157 %-------------------------------------------------------------------------
158 %             Individual Piece Moves That Generate New Game States
159 %                     Recursion is also added in each loop
160 %-------------------------------------------------------------------------
161     [move_x,move_y] = find(move ≠ 0);
162     perm_index2 = randperm(length(move_x));
163     move_x = move_x(perm_index2);
164     move_y = move_y(perm_index2);
165     n_move = length(move_x);
166     pruneflag = 0;
167 %This loop generates all the game states from 1 piece
168     for j = 1:n_move
169         switch move(move_x(j),move_y(j))
170             case 1
171                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickMovePiece(0,0,p_x
172                     num_moves,0,move,0,1,move_x(j),move_y(j));
173             case 2
174                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickCapturePiece(0,0,
175                     num_moves,0,move,0,1,move_x(j),move_y(j));
176             case 3
177                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickEnpassant(0,0,p_x
178                     num_moves,0,move, 0,1,move_x(j),move_y(j));
179             case 4
180                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickCastling(0,0,p_x
181                     num_moves,0,move,0,1,move_x(j),move_y(j));
182             case 5
183                 [pchessboard,ppiece_colour, pnum_moves,kingincheck]=ClickPawnPromo(0,0,p_x
184                     num_moves,0,move,0,1,move_x(j),move_y(j),'queen');
185         end
186 %--------A node has been generated, what do you want to do with it?--------
187         if kingincheck
188             %ignore because move not valid
189             if ¬exist('boardscore','var')
190             boardscore = 99999;
191             bchessboard = 0;
192             bpiece_colour =0;
193             bnum_moves =0;
194             end
195         else
196                 %Generate another layer with recursive parameters
197                 [boardscore,¬,¬,¬,handles]=...
198            AI_GenerateAllMoves(TmpB,pchessboard,ppiece_colour,pnum_moves,depth-1,-maxormin,
199
200                 if boardscore < previousboardscore
201                     previousboardscore = boardscore;
202                     bchessboard = pchessboard;
203                     bpiece_colour = ppiece_colour;
204                     bnum_moves = pnum_moves;
205                 end
206                 if boardscore<beta
207                     beta = boardscore;
208                 end
209
210 % disp([depth alpha beta boardscore previousboardscore i j n_remaining n_move])
211                 if alpha>beta
212                     pruneflag = 1;
213                     break
214                 end
215         end
```

```
216       end
217        if pruneflag
218           break
219       end
220   %-------------------------------------------------------------------------
221   end
222   %=========================================================================
223   end % For if maxormin
224   end % For DEPTH if condition
225   end %For Function
```

### A.3.3 heuristicanalysis.m

```
1   function [boardscore] = heuristicanalysis(B,chessboard, piece_colour,num_moves,currentcolour
2   %Colour should be the side in which it is being analysed for
3
4   %-------------------------------------------------------------------------
5   %                         Init Values
6   %-------------------------------------------------------------------------
7   if currentcolour == 119
8       oppcolour = 98;
9   else
10      oppcolour = 119;
11  end
12  %Generates potential moves of the currently investigated game state colour
13  [potentialmoves,capt_index] = analyseboard(chessboard, piece_colour,num_moves,currentcolour)
14  %Generates potential moves of the opponent
15  [oppcolourpotentialmoves, oppcolourcapt_index] = analyseboard(chessboard, piece_colour,num_m
16
17  %Finds the locations of own pieces and opponent's pieces
18  piece_index = find(piece_colour==currentcolour);
19  opp_piece_index = find(piece_colour==oppcolour);
20
21  %-------------------------------------------------------------------------
22
23  %-------------------Capture Analysis--------------------------------------
24  %A move is good because it opens up capture possibilities
25  num_pot_capture = length(capt_index); %Number of potential Captures
26  capt_value_sum = sum(chessboard(capt_index)); %The total capture value
27
28  %A move is good if it increases the number of capture
29  capt_value_diff = 51 - sum(chessboard(opp_piece_index));
30
31  %------------------ Moves Analysis ---------------------------------------
32  %A move is good because it opens up space for other pieces to move
33  nocapture = potentialmoves;
34  nocapture(capt_index) = 0;
35  num_moves_available = sum(sum(nocapture));
36
37  %------------------ Threats ----------------------------------------------
38  %If the move causes other pieces to be under threat, the move is worse.
39  opp_num_pot_capture = length(oppcolourcapt_index);
40  opp_capt_value_sum = sum(chessboard(oppcolourcapt_index));
41
42  %------------------ Number of own pieces ---------------------------------
43  %A move is good if it prevents the number of own pieces from decreasing.
44  own_piece_sum_diff = 51 - sum(chessboard(piece_index));
45
```

```
46
47 %------------------- Control of centre space -----------------------------
48 %A move is good if it increases control of the centre of the board
49 centre_piece=zeros(8,8);
50 centre_piece([28 29 36 37])=chessboard([28 29 36 37]);
51 centre_piece = centre_piece≠0;
52 centre_space_sum =  sum(centre_piece(piece_index));
53
54
55 %------------------- Own King Checked? -----------------------------------
56 %Checks if own king is in check. If in check, also checks if its a checkmate
57 own_ischeck = KingCheck(chessboard,piece_colour,currentcolour,oppcolourcapt_index,oppcolourp
58 if own_ischeck==1
59     own_ischeckmate = checkmate(B,chessboard,piece_colour,num_moves);
60     else own_ischeckmate = 0;
61 end
62
63 %--------------------------- Castling? -----------------------------------
64 %Checks if castling has taken place
65 rook_pos = find(chessboard==5 & piece_colour==currentcolour);
66 king_pos = find(chessboard==10 & piece_colour==currentcolour);
67 castle = 0;
68
69 if currentcolour == 98 %Black case
70     if (king_pos==49 && ismember(41,rook_pos) && num_moves(41)==1 && num_moves(49)==1)
71         castle = 1;
72     elseif (king_pos==17 && ismember(25,rook_pos) && num_moves(25)==1 && num_moves(17)==1)
73             castle = 1;
74     end
75
76 else %White case
77     if (king_pos==56 && ismember(48,rook_pos) && num_moves(48)==1 && num_moves(56)==1)
78         castle = 1;
79     elseif (king_pos==24 && ismember(32,rook_pos) && num_moves(32)==1 && num_moves(24)==1)
80             castle = 1;
81     end
82 end
83
84 %--------------------- Opponent Checkmate?--------------------------------
85 %Checks if opponent king is in check. If in check, also checks if its a checkmate
86 opp_ischeck = KingCheck(chessboard,piece_colour,oppcolour,capt_index,potentialmoves);
87 if opp_ischeck==1
88     opp_ischeckmate = checkmate(B,chessboard,piece_colour,num_moves);
89 else opp_ischeckmate = 0;
90 end
91
92 %------------------- Possibility of opponenet's promotion? ---------------
93 %A move is bad if it brings opponent's pawn closer to the end of the board for promotion.
94 pawn_index = find(chessboard==1 & piece_colour==oppcolour);
95 if oppcolour == 98 %Black case
96     end_dist = 8-rem(pawn_index,8);
97     sum_opp_pawn_dist = sum(end_dist==0) + 0.5*sum(end_dist==1);
98 else %White case
99     end_dist = rem(pawn_index,8)-1;
100    sum_opp_pawn_dist = sum(end_dist==0) + 0.5*sum(end_dist==1);
101 end
102
103 %--------------------- Possibility of own promotion? ---------------------
104 %A move is good if it brings own pawn closer to the end of the board for promotion.
105 pawn_index = find(chessboard==1 & piece_colour==currentcolour);
106 if currentcolour == 98 %Black case
107     end_dist = 8-rem(pawn_index,8);
```

```
108     sum_own_pawn_dist = sum(end_dist==0) + 0.5*sum(end_dist==1);
109 else %White case
110     end_dist = rem(pawn_index,8)-1;
111     sum_own_pawn_dist = sum(end_dist==0) + 0.5*sum(end_dist==1);
112 end
113 
114 %------------------ Gain Factor for Hard-------------------------------------
115 if(get(handles.setHard,'Value')==1)
116 gainCapture = 3;  %Encourages AI to position a piece such that it can capture more pieces in
117 gainMoves = 10; %Encourages AI to position such that it opens space for other pieces
118 gainThreats = -4; %Discourages AI to make moves that will lead to threats
119 gainOpppieces = 25; %Encourages to make moves that decrease opponents pieces
120 gainOwnpieces = -5; %Discourages AI from making moves that decrease own pieces
121 gainCentre = 1; %Encourages AI to increase control of centre space
122 gainOwnprom = 1; %Encourages AI to promote own pawns close to the end of the board
123 gainOppprom = -10; %Discourages AI to promote opponent's pawns
124 end
125 %--------------------Gain Factor for Easy --------------------------------
126 if(get(handles.setEasy,'Value')==1)
127 gainCapture = 2;  %Encourages AI to position a piece such that it can capture more pieces in
128 gainMoves = 10; %Encourages AI to position such that it opens space for other pieces
129 gainThreats = -2; %Discourages AI to make moves that will lead to threats
130 gainOpppieces = 3.5; %Encourages to make moves that decrease opponents pieces
131 gainOwnpieces = 1; %Discourages AI from making moves that decrease own pieces
132 gainCentre = 10; %Encourages AI to increase control of centre space
133 gainOwnprom = 10; %Encourages AI to promote own pawns close to the end of the board
134 gainOppprom = -1; %Discourages AI to promote opponent's pawns
135 end
136 %--------------------- Gain Factor for Random ----------------------------
137 if(get(handles.setRandom,'Value')==1)
138 gainCapture = 0;  %Encourages AI to position a piece such that it can capture more pieces in
139 gainMoves = 0; %Encourages AI to position such that it opens space for other pieces
140 gainThreats = 0; %Discourages AI to make moves that will lead to threats
141 gainOpppieces = 0; %Encourages to make moves that decrease opponents pieces
142 gainOwnpieces = 0; %Discourages AI from making moves that decrease own pieces
143 gainCentre = 0; %Encourages AI to increase control of centre space
144 gainOwnprom = 0; %Encourages AI to promote own pawns close to the end of the board
145 gainOppprom = 0; %Discourages AI to promote opponent's pawns
146 end
147 %----------------- Final Score Calculation -----------------------------
148 boardscore =  gainCapture * capt_value_sum...
149          + gainMoves * num_moves_available...
150          + gainThreats * opp_capt_value_sum...
151          + gainOpppieces * capt_value_diff...
152          + gainOwnpieces * own_piece_sum_diff...
153          + gainCentre * centre_space_sum...
154          + gainOwnprom * sum_own_pawn_dist...
155          + gainOppprom * sum_opp_pawn_dist;
156 %Checks if castling has occured
157     if castle == 1
158         boardscore = boardscore + 250;
159     end
160 %If a checkmate has occured, new boadscores are assigned
161 if(get(handles.setHard,'Value')==1 || get(handles.setEasy,'Value')==1 )
162     if opp_ischeckmate == 1
163         boardscore = 99999;
164     end
165 
166     if own_ischeckmate == 1
167         boardscore = -99999;
168     end
169 end
```

```
170
171 if(get(handles.setRandom,'Value')==1)
172     boardscore=rand* 2000;
173 end
174 end
```

## A.4 Board analysis

### A.4.1 analyseboard.m

```
1  %Analyseboard Looks at one colour, sees where each piece is able to
2  %move. This is to allow for the Check function and castling.
3  %Colour in this case can be either current one or opposing one
4  %Use oppositecolour to generate threats and threat captures
5  function [potentialmoves,capt_index] = analyseboard(chessboard, piece_colour,num_moves,colou
6
7  %Initialisation ------------------------------------------------------------
8  [p_x, p_y] = find(piece_colour == colour);
9  n_remaining = length(p_x);
10 potentialmoves = zeros(8,8);
11
12 %Loop to look at every piece's moves ---------------------------------------
13 for i=1:n_remaining
14     %Determines what piece is selected
15     p_type = chessboard(p_x(i),p_y(i));
16
17     %Based on the type of piece, its movement is calculated
18     switch p_type
19         case 1
20             [move] = MovementPawn(chessboard,piece_colour,num_moves,p_x(i),p_y(i));
21             %disp('Pawn');
22         case 5
23             [move] = MovementRook(chessboard,piece_colour,p_x(i),p_y(i));
24             %disp('Rook');
25         case 4
26             [move] = MovementBishop(chessboard,piece_colour,p_x(i),p_y(i));
27             %disp('Bishop');
28         case 3
29             [move] = MovementKnight(chessboard,piece_colour,p_x(i),p_y(i));
30             %disp('Knight');
31         case 9
32             [move] = MovementQueen(chessboard,piece_colour,p_x(i),p_y(i));
33             %disp('Queen');
34         case 10
35             [move] = MovementKing(chessboard,piece_colour,num_moves,potentialmoves,p_x(i),p
36             %disp('King');
37     end
38
39     %Sums up all possible moves of 1 colour.
40     potentialmoves = potentialmoves+move;
41 end
42 %-------------------------------------------------------------------------
43 %                     Analysis of potentialmoves
44 %-------------------------------------------------------------------------
45 %-------------------Capture Analysis--------------------------------------
46 potentialcaptures = potentialmoves ≠ 0 & chessboard≠ 0;
47 capt_index = find(potentialcaptures==1);
```

```
48 %num_pot_capture = length(capt_index);
49 %capt_value_sum = sum(chessboard(capt_index));
50
51 %------------------ Moves Analysis ---------------------------------------
52 %nocapture = potentialmoves;
53 %nocapture(capt_index) = 0;
54 %num_moves_available = sum(sum(nocapture));
55
56 end
```

### A.4.2 KingCheck.m

```
1  %KingCheck Checks if the king is in check, checkmate or stalemate
2  %Colour in this case must be the current colour
3  %King Colour must be contrary to CAPT_INDEX & POTENTIAL MOVES
4  function [value]=KingCheck(chessboard,piece_colour,ownkingcolour, oppcolourcapt_index,oppcol
5
6  %-------------------- King In Check ----------------------------------------
7  king_index = find(chessboard == 10 & piece_colour == ownkingcolour);
8  kingincheck = ismember(king_index,oppcolourcapt_index);
9  if(kingincheck)
10     value = 1;
11 %Otherwise not in check
12 else
13     value = 0;
14 end
15 end
```

### A.4.3 checkmate.m

```
1  %Checkmate Determines if the currentboard is a checkmate state for
2  %specified colour
3  %Gives 1 for Checkmate, 0 for not checkmate
4  function [result]=checkmate(B,chessboard,piece_colour, num_moves)
5
6  if(mod(B.info.turn,2)==1)
7      colour = 119;
8      oppcolour = 98;
9  else
10     colour = 98;
11     oppcolour = 119;
12 end
13 result = 1;
14 %-------------------------------------------------------------------------
15 %        Loop that generates all possible moves
16 %-------------------------------------------------------------------------
17 [p_x,p_y] = find(piece_colour == colour);
18 n_remaining = length(p_x);
19 [potentialmoves] = analyseboard(chessboard, piece_colour,num_moves,oppcolour);
20
21 %In essence, we are going through each piece, looking at it's possible
22 %moves, make those possible moves, evaluate, save bestboard.
23 for i=1:n_remaining
24     p_type = chessboard(p_x(i),p_y(i));
```

```
    switch p_type
        case 1
            [move] = MovementPawn(chessboard,piece_colour,num_moves,p_x(i),p_y(i));
        case 5
            [move] = MovementRook(chessboard,piece_colour,p_x(i),p_y(i));
        case 4
            [move] = MovementBishop(chessboard,piece_colour,p_x(i),p_y(i));
        case 3
            [move] = MovementKnight(chessboard,piece_colour,p_x(i),p_y(i));
        case 9
            [move] = MovementQueen(chessboard,piece_colour,p_x(i),p_y(i));
        case 10
            [move] = MovementKing(chessboard,piece_colour,num_moves,potentialmoves,p_x(i),p
    end

%-------------------------------------------------------------------------
%             Individual Piece Moves That Generate New Game States
%                     Recursion is also added in each loop
%-------------------------------------------------------------------------
     [move_x,move_y] = find(move ~= 0);
     n_move = length(move_x);
%This loop generates all the game states from 1 piece
     for j = 1:n_move
         switch move(move_x(j),move_y(j))
             case 1
                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickMovePiece(0,0,p_x
                     num_moves,0,move,0,1,move_x(j),move_y(j));
             case 2
                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickCapturePiece(0,0,
                     num_moves,0,move,0,1,move_x(j),move_y(j));
             case 3
                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickEnpassant(0,0,p_x
                     num_moves,0,move, 0,1,move_x(j),move_y(j));
             case 4
                 [pchessboard, ppiece_colour, pnum_moves,kingincheck]=ClickCastling(0,0,p_x
                     num_moves,0,move,0,1,move_x(j),move_y(j));
             case 5
                 [pchessboard,ppiece_colour, pnum_moves,kingincheck]=ClickPawnPromo(0,0,p_x
                     num_moves,0,move,0,1,move_x(j),move_y(j),'queen');
         end

         result = min(kingincheck, result);
         if result == 0
             break
         end

     end
     if result == 0
         break
     end
end
```

### A.4.4 readchessboard.m

```
%readchessboard takes in chessboard and creates B
function [B] = readchessboard(B,chessboard,piece_colour)

X = struct(NewPiece([]));
```

```
% build the initial board with everything non-playable at first
% add paddings to the non-playable areas of 4 squares and place pieces
for i=1:size(chessboard,1)+B.info.pad
    for j=1:size(chessboard,2)+B.info.pad
        X(i,j) = NewPiece([]);
    end
end


% now place pieces and playable areas
for i=1:size(chessboard,1)
    for j=1:size(chessboard,2)
        if chessboard(i,j) == 0
            pName = []; pColour = 0;
        else
            switch chessboard(i,j)
                case 1
                    pName = 'pawn';
                case 3
                    pName = 'knight';
                case 4
                    pName = 'bishop';
                case 5
                    pName = 'rook';
                case 9
                    pName = 'queen';
                case 10
                    pName = 'king';
            end

            switch piece_colour(i,j)
                case 119
                    pColour = 1;
                case 98
                    pColour = -1;
        end
        X(i+B.info.pad/2,j+B.info.pad/2) = NewPiece(pName,pColour);
    end
end
end

B.top = X;
end
```