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# Introduction to Checkers

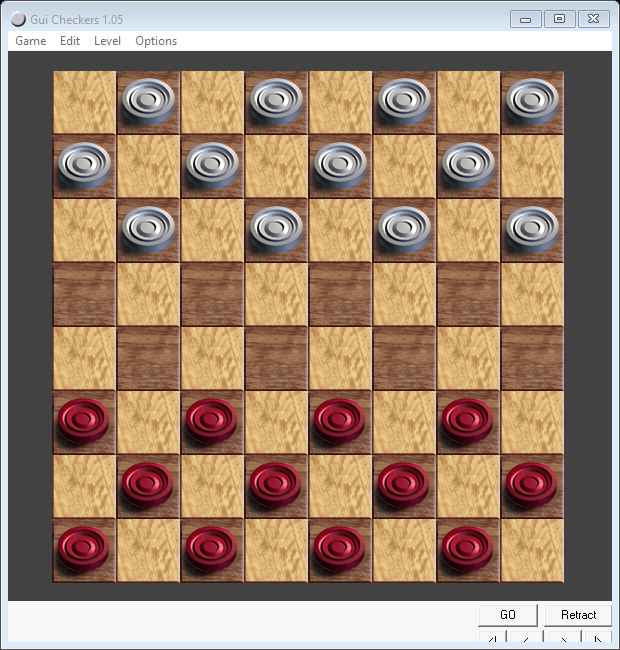


Figure 1. A normal 8 x 8 Checker board

## Explanation of the board

This is a standard 8x8 checker board with pieces on both side of the board, with black on the bottom and white on the top.

## How to play?

Each player is only allowed to move sideways on the color tiles and they must capture the opponent piece if they are close. Upon reaching the end of each of the opponent side, the piece will become a “King” in which that piece is allowed to move backwards.

## Objective of the game

The objective of this game is to capture all of your opponent pieces such that your opponent is unable to play the game. There can be a draw in the game if both players are unable to capture each other’s pieces within a certain amount of moves.

With the explanation of checkers, we will now proceed to represent the game into our project, starting with the data structure and the move generation.

# Representing checkers in solution

## Initial Draft

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
| 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 |
| 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 |

Figure 2a. Initial representation of the board

In this initial draft of the data structure, we planned to go with an array of 64 chars for both cuda and CPU but we soon realized that this might cause a lot of unnecessary memory allocation on the cuda side as there are some fields in the checker board that would not be accessed or use in the calculation of further moves, such that we decide that bit board representation for valid moves would be more preferred.

## Finalize Draft

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | 28 |  | 29 |  | 30 |  | 31 |
| 24 |  | 25 |  | 26 |  | 27 |  |
|  | 20 |  | 21 |  | 22 |  | 23 |
| 16 |  | 17 |  | 18 |  | 19 |  |
|  | 12 |  | 13 |  | 14 |  | 15 |
| 8 |  | 9 |  | 10 |  | 11 |  |
|  | 4 |  | 5 |  | 6 |  | 7 |
| 0 |  | 1 |  | 2 |  | 3 |  |

Figure 2b. Bit representation of the board (where 0 to 11 = black pieces, 12 to 19 = free movement, 20 to 31 = white pieces)

As each piece in checkers will only touch the black titles, such that it would be better to store the relevant 32 moves as compared to using an array of 64 chars where most of the time only half of the array would be referenced to perform validations of move. Also, the data representation of each pieces would be different as the starting index would be beginning on the bottom right instead of the top right for array structure. Lastly as x64 and cuda both are little endian so our bit board looks like this

## Representing pieces in terms of bit

As mentioned previously, translating the board into a 32 bit representation is slightly different as compared to array representation, rather than starting from 0 to 63 in a standard array, in the bit board version, it begins from the MSB to the LSB of each rows eg the piece at 4 starts at 0x0000 0000 0000 0000 0000 0000 1000 0000 where each corresponding 0000 representing a row

## Initializing pieces

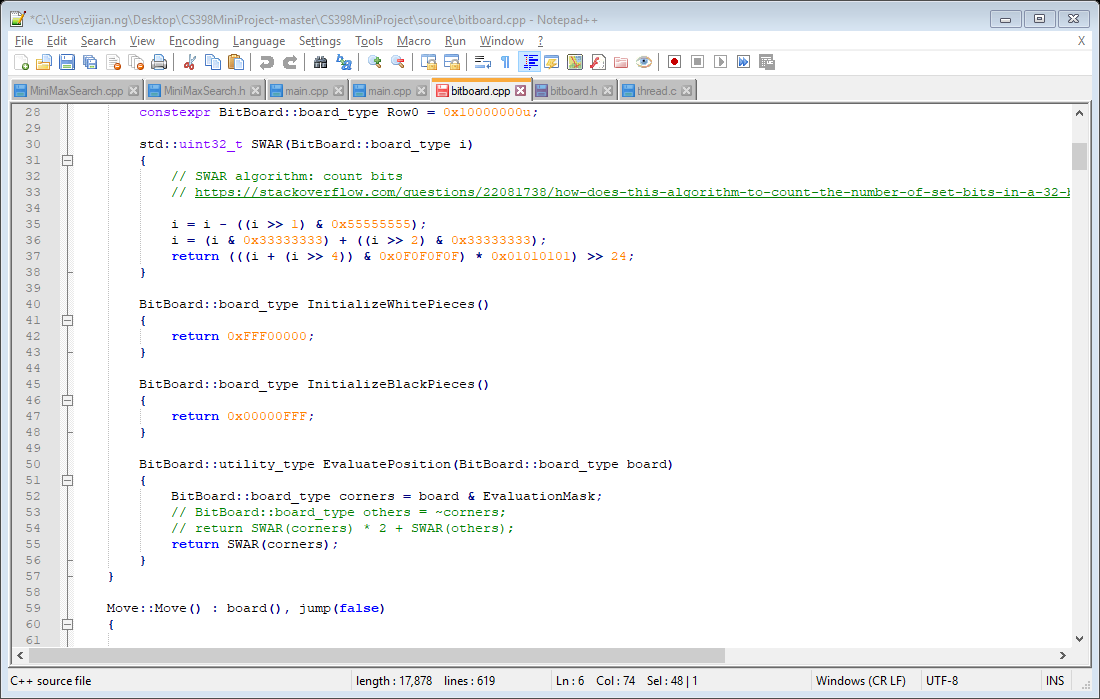


Figure 2c. Initialization of pieces.

In Figure 2c, we create two 32 bit binary to represent both black and white where white begins from the LSB to MSB while black begins from the MSB to LSB.

## Final board output

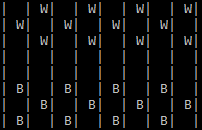


Figure 2d. A Checker board represented in console

This is the final representation of the checkers that will be seen when the program once starts up from the initialization of black and white pieces in figure 2c.

## Advantage of using bitboard

Performing bit wise operation would also be great in a sense that we do not need to perform countless of loops to get the list of possible moves. With the representation of the board done, let's move on to the processing of movement in checkers.

# Movement in checkers:

## Using array approach

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
| 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 |
| 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 |

Figure 3a. Array representation of the board

For movement in checkers, if we are using array of 64 chars then the movement will be much simpler as it will only be only dereferencing of the current pieces such as here for eg moving from a piece at 46 to 38 would be simply changing the piece in the array location of 46 to 38, this also applies for capturing of pieces.

## Using bitboard approach

### For basic movement:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | 28 |  | 29 |  | 30 |  | 31 |
| 24 |  | 25 |  | 26 |  | 27 |  |
|  | 20 |  | 21 |  | 22 |  | 23 |
| 16 |  | 17 |  | 18 |  | 19 |  |
|  | 12 |  | 13 |  | 14 |  | 15 |
| 8 |  | 9 |  | 10 |  | 11 |  |
|  | 4 |  | 5 |  | 6 |  | 7 |
| 0 |  | 1 |  | 2 |  | 3 |  |

Figure 3b. Bit representation of the board

In the case of using bit representation where each bit above represents a valid move, in order to move from 11 to 14, the program first has to move from 11 to 12 to 13 to 14 which is a total of 3 shift such that we can apply bit shift operations to move pieces to the designated direction of upper right, upper left, lower right and lower left. However, do take note that there are certain restrictions of movement on both black and white unless they have become king pieces, as well as there is a type of shift for even and odd rows which now comes into the picture.

### Table for Basic movement using bit:

|  |  |  |
| --- | --- | --- |
|  | Odd rows | Even rows |
| Moving Upper right | <<5 (left shift by 5) | <<4 (left shift by 4) |
| Moving Upper left | <<4 (left shift by 4) | <<3 (left shift by 3) |
| Moving Lower right | >>4 (right shift by 4) | >>5 (right shift by 5) |
| Moving Lower left | >>3 (right shift by 3) | >>4 (right shift by 4) |

Table 3a. Possible basic movement

The table above is the concluded possible normal move available.

### For jumping movement:

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

Figure 3c. An example of a possible scenario

For capturing of pieces in bit representation, it follows the same implementation of the array approach of checking if there are opponent pieces in the possible direction, in terms of bit represent it will be checking with the existing white location, while at it, there is also a consideration to be added such as jumping to the next possible cell with even and odd rows as well.

### Table for jumping movement using bit:

|  |  |  |
| --- | --- | --- |
|  | Odd rows to even rows | Even to odd rows |
| Moving Upper right | <<5 <<4 (left shift by 5 then left shift by 4) | <<4<<5 (left shift by 4 then left shift by 5) |
| Moving Upper left | <<4 <<3 (left shift by 4 then left shift by 3) | <<3 <<4 (left shift by 3 then left shift by 4) |
| Moving Lower right | >>4 >>5 (right shift by 4 then left shift by 5) | >>5 >>4 (right shift by 5 then right shift by 4) |
| Moving Lower left | >>3 >>4 (right shift by 3 then left shift by 4) | >>4 >>3 (right shift by 4 then right shift by 3) |

Table 3b. Possible jump movement

The table above is the concluded possible jump move available.

# Generating of pieces that can be moved

With the list of possible moves derived in Section 3, it is time to start generating list of moves to be considered in Section 5.

## Creating the pieces that can move in CPU

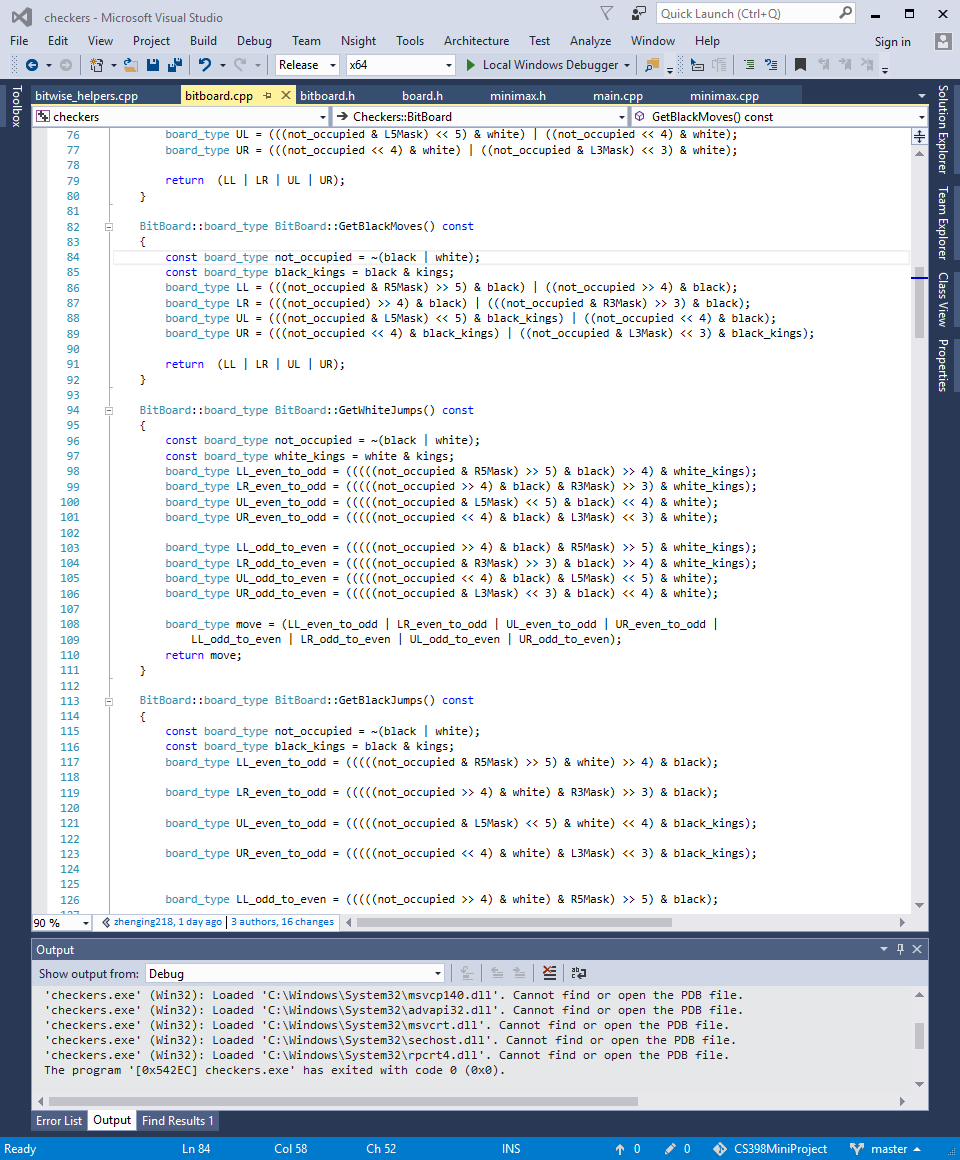


Figure 4a. An implementation of creating normal moves in CPU

As seen in Section 3, there is a possibility of a piece being able to move in 4 directions if there is nothing in the adjacent titles such that there will be lower left, lower right, upper left and upper right for both even and odd titles. Since we are going with bit implementation, we are constantly keep track of where the black and the white pieces are, to retrieve the empty cells for the moves considerations. While checking for the possible moves, it is also important to check if the moves are valid via the masks.

## Creating the pieces that can jump in CPU

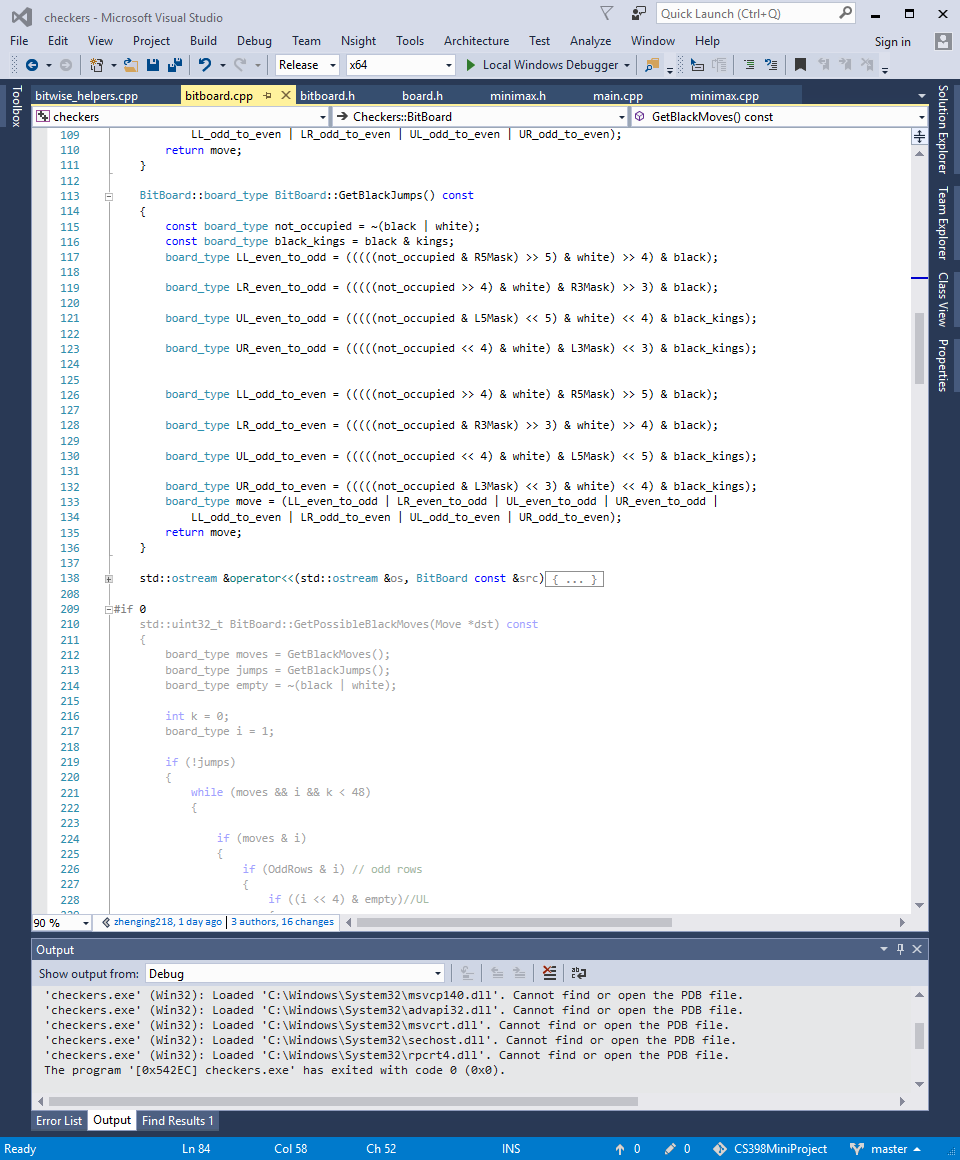


Figure 4b. An implementation of creating jump moves in CPU

With some implementation similar to creation of normal moves in Section 4.1, this time there is a need to check if the piece that is in the adjacent tiles are the opponent pieces. If the piece that is moving to any adjacent pieces has opponent tiles, the piece is then moved to the next tile after the opponent piece with their shifting based on the piece current position.

## The mask used for verification in CPU

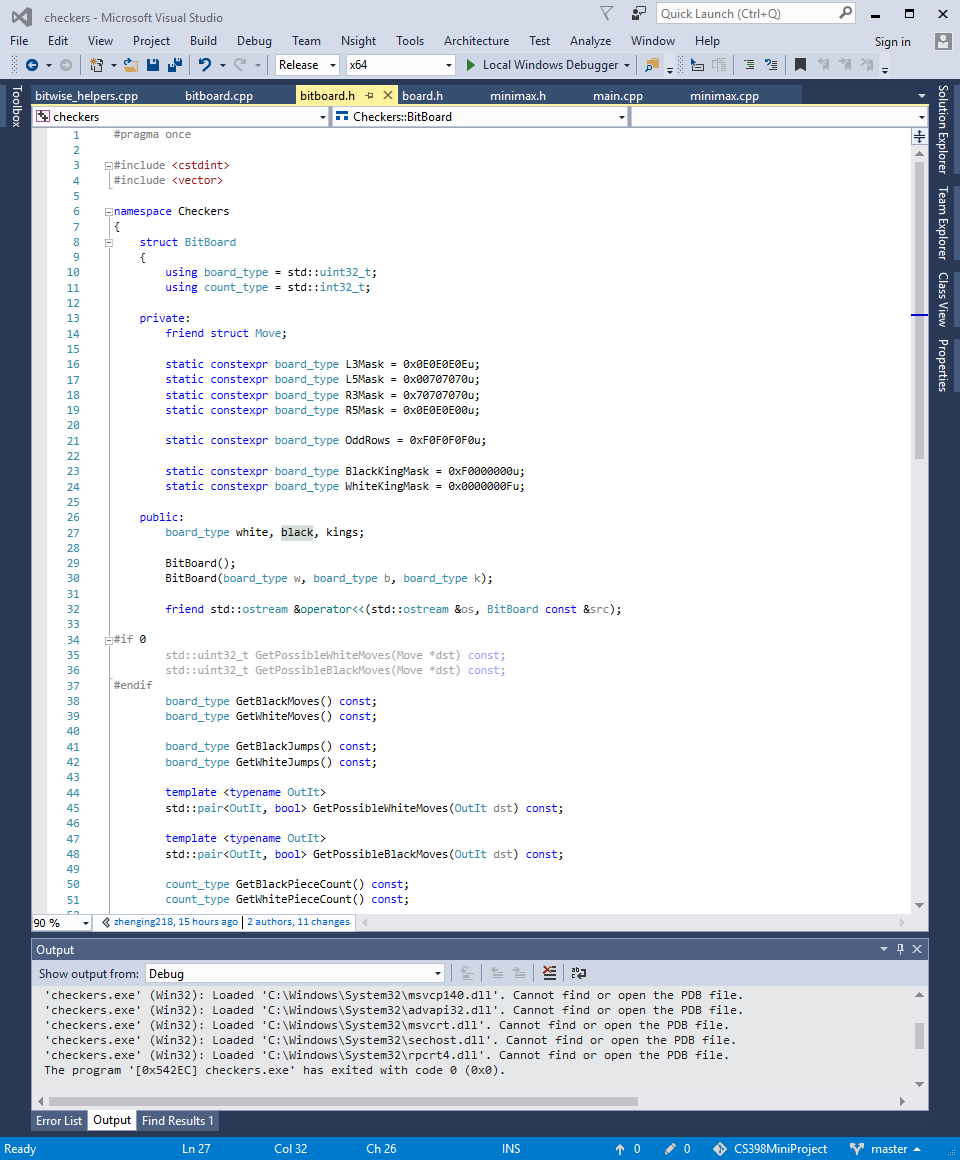


Figure 4c. The masks for checking valid moves

The L3,L5,R3,R5 masks are what is used to make a comparison with to see if the pieces can move to the corresponding even or odds tiles, as the king pieces in this case black could move additionally in the opposite direction thus the check of UL and UR is catered to the king pieces and for white pieces LL and LR. There is no need for if statements if we are using bit wise operations. Finally, after getting the possible moves in the 4 directions, all that is left is to return the bit results of those pieces that can be moved.

## Creating the list of moves in GPU

* + 1. Creating the list of normal moves in GPU
    2. Creating the list of jump moves in GPU

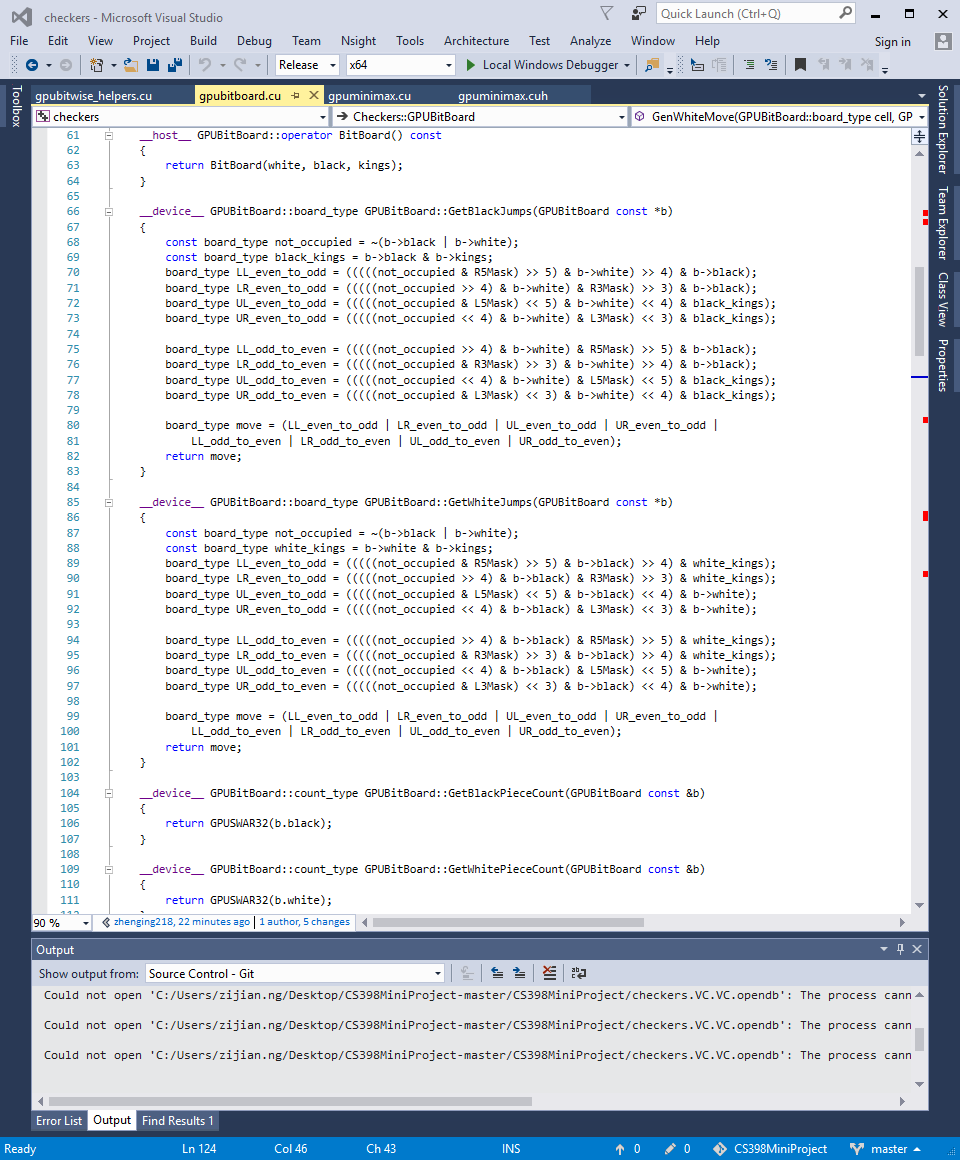


Figure 4d. An implementation of creating normal moves in CPU

In the GPU version of generating of moves, the implementation is almost identical to the version in CPU except this time, we need to input a parameter for GPU to be able to calculate.

# Extraction of moves

## In CPU implementation

## Getting the results

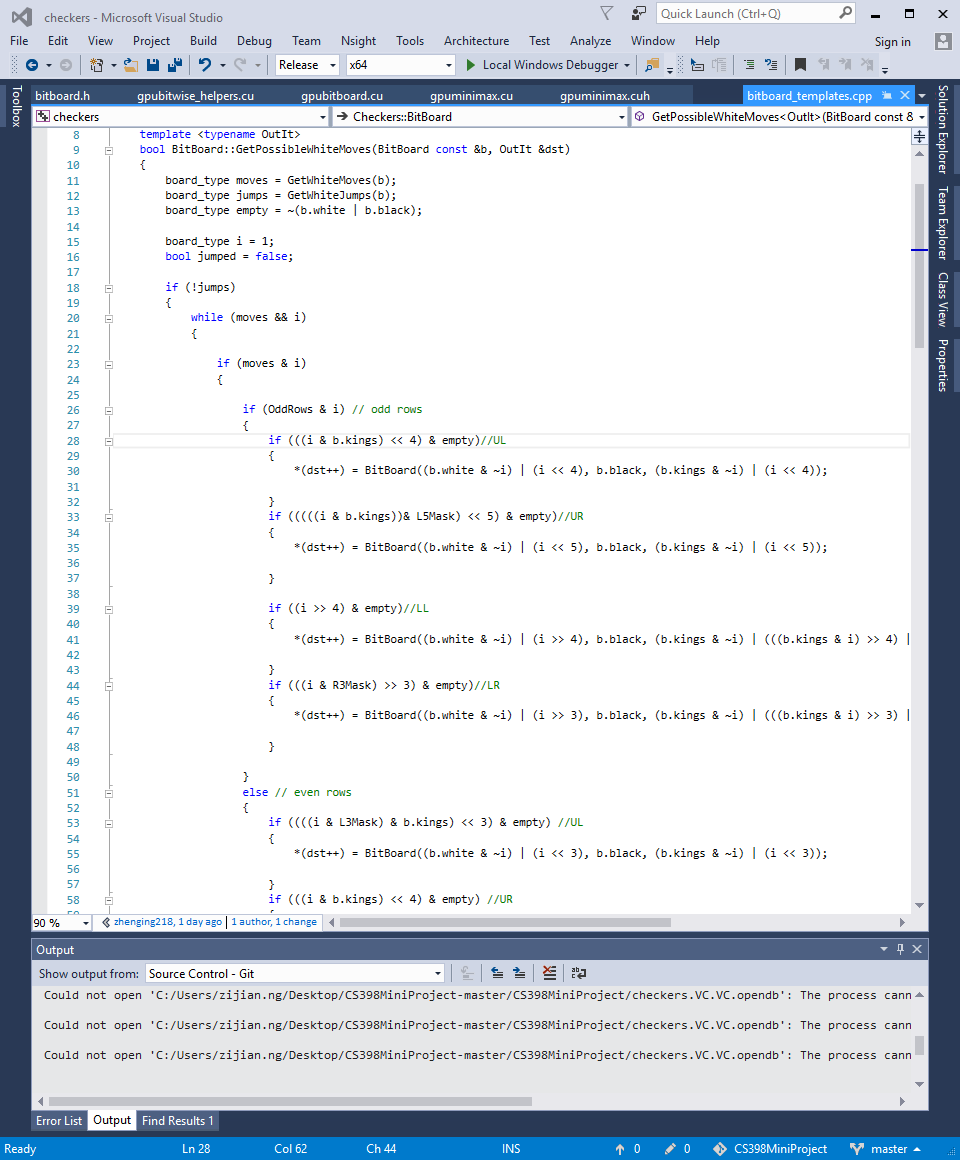


Figure 5a. Extraction of possible moves

In section 4, after the extraction of all the possible pieces that can move or jump, we would proceed to do some bitwise operation to create the list of possible move. In the game of checkers, the rule is that jump must be performed if there is two different color at adjacent tiles, such that jump movement would be performed immediately (refer to Section 5.1.2), the loop is done 32 as it is the list of possible cell that could be moved to and from.

## Extracting of possible odd normal moves

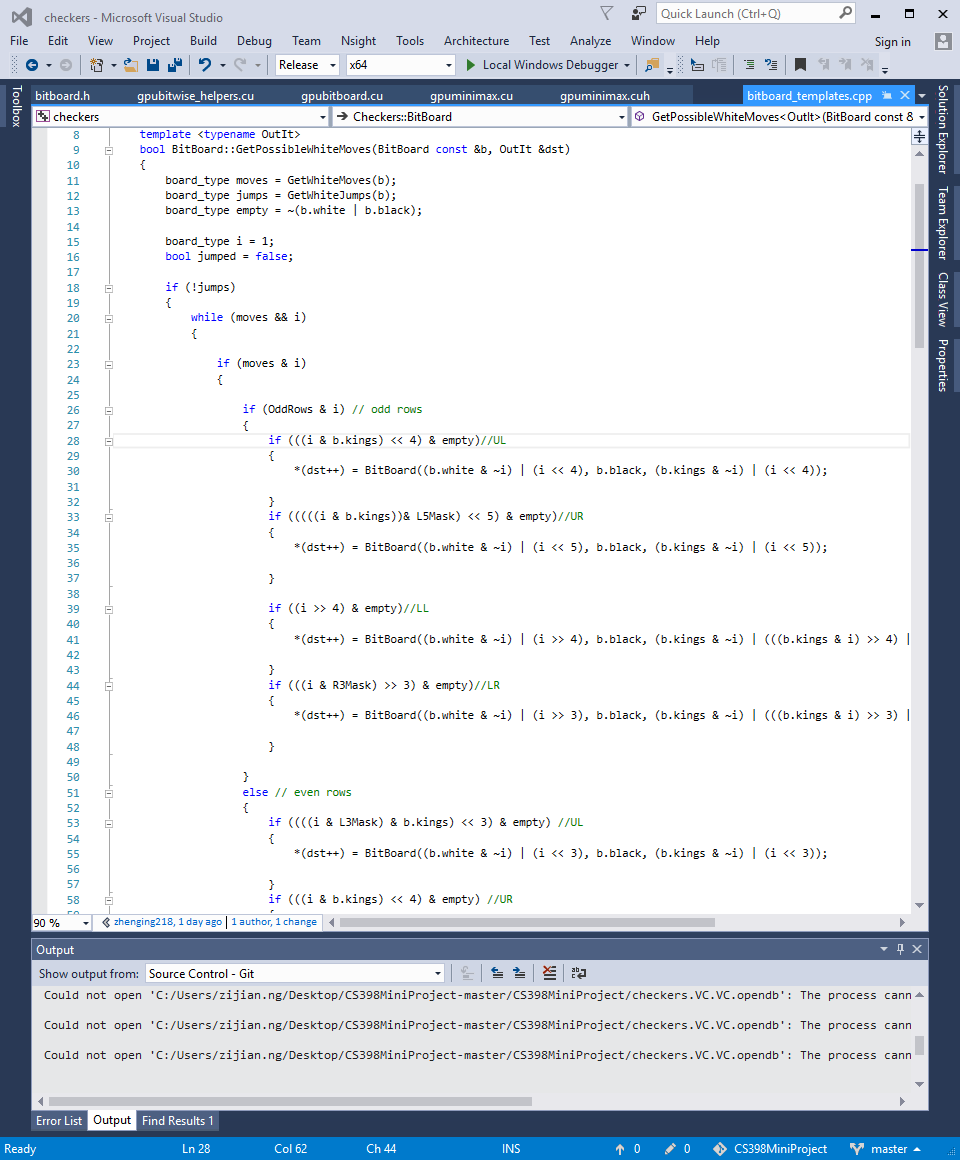


Figure 5b. An implementation of extracting odd moves

Since there could be 2 possible direction and 4 for a king, there needs to be a check for each possible direction. For the UL and UR moves, this is only exclusive to the king pieces. In the sample of the UL of king, we check that if the king piece could backtrack or is becoming a king, if it could, we would call for BitBoard constructor to make that piece into a king if it isn’t at the end of the other end. As both normal pieces and king share the LL and LR, moving in those tiles shares the same implementation as UR and UL.

## Extracting of possible even normal moves

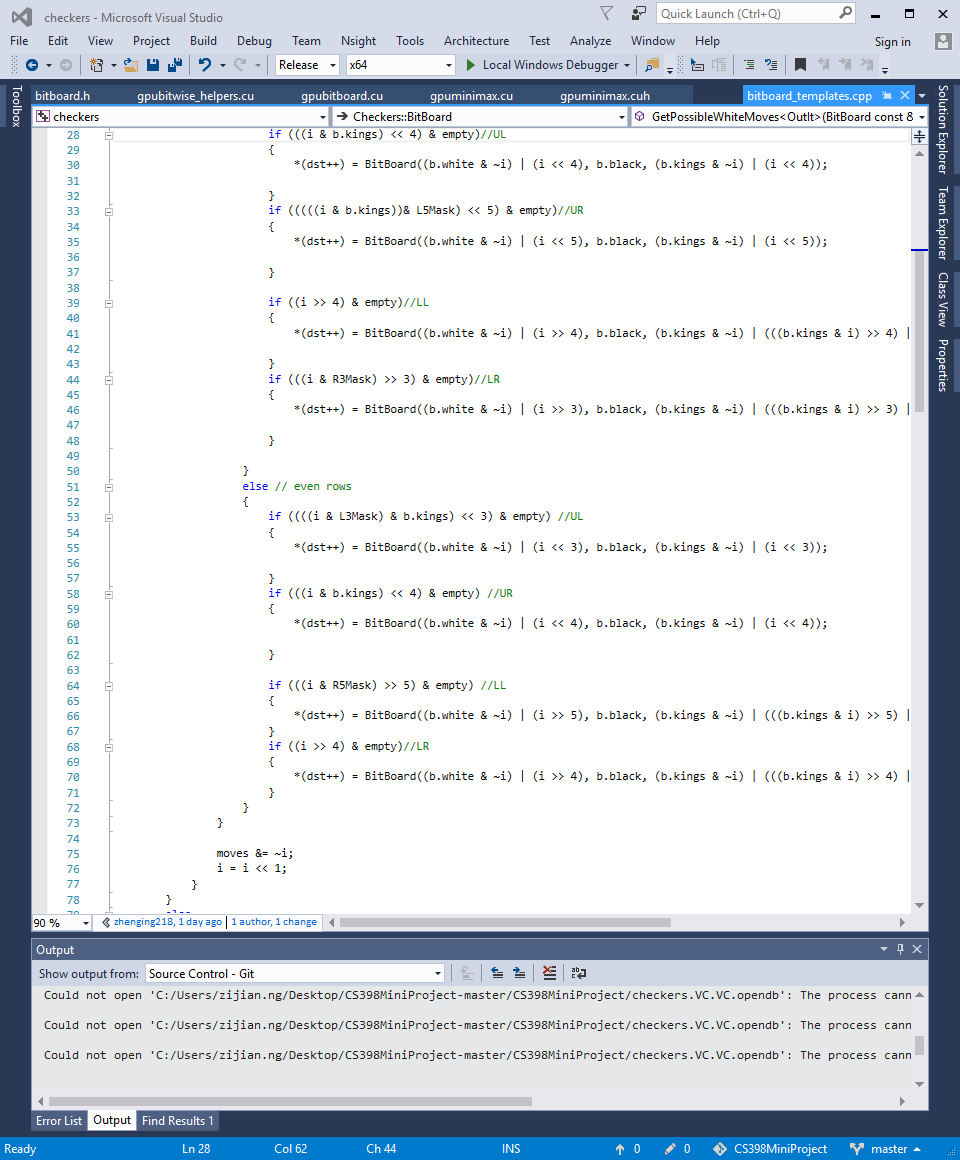


Figure 5c. An implementation of extracting even moves

Extraction of possible even normal moves follows the same implementation as the one in 5.1.1.1 except all the checks are now used with even movements.

## Extracting of jump moves

Extraction of jump moves now factors in if the adjacent pieces could be captured and if there is no piece on the next diagonal tile.

## Extracting of odd jump moves

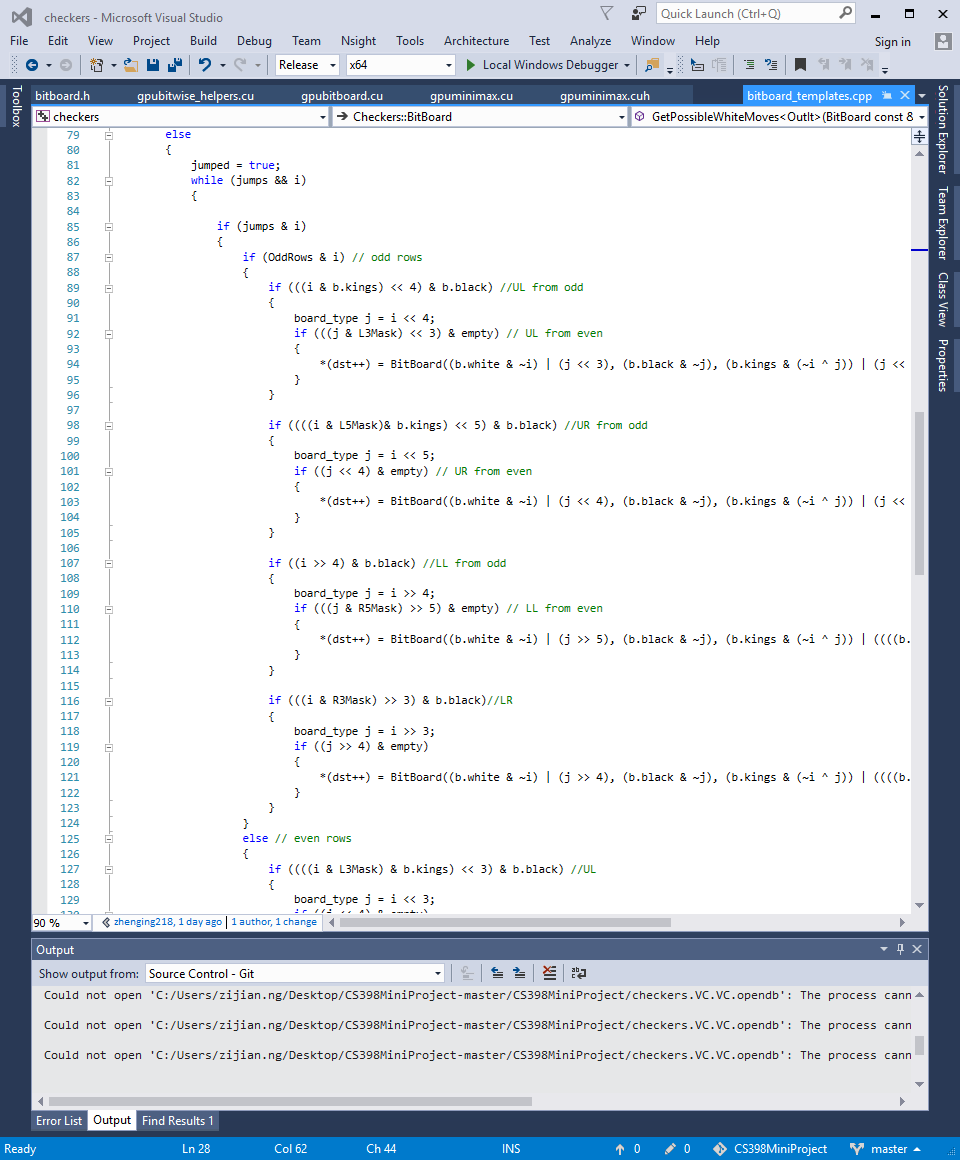
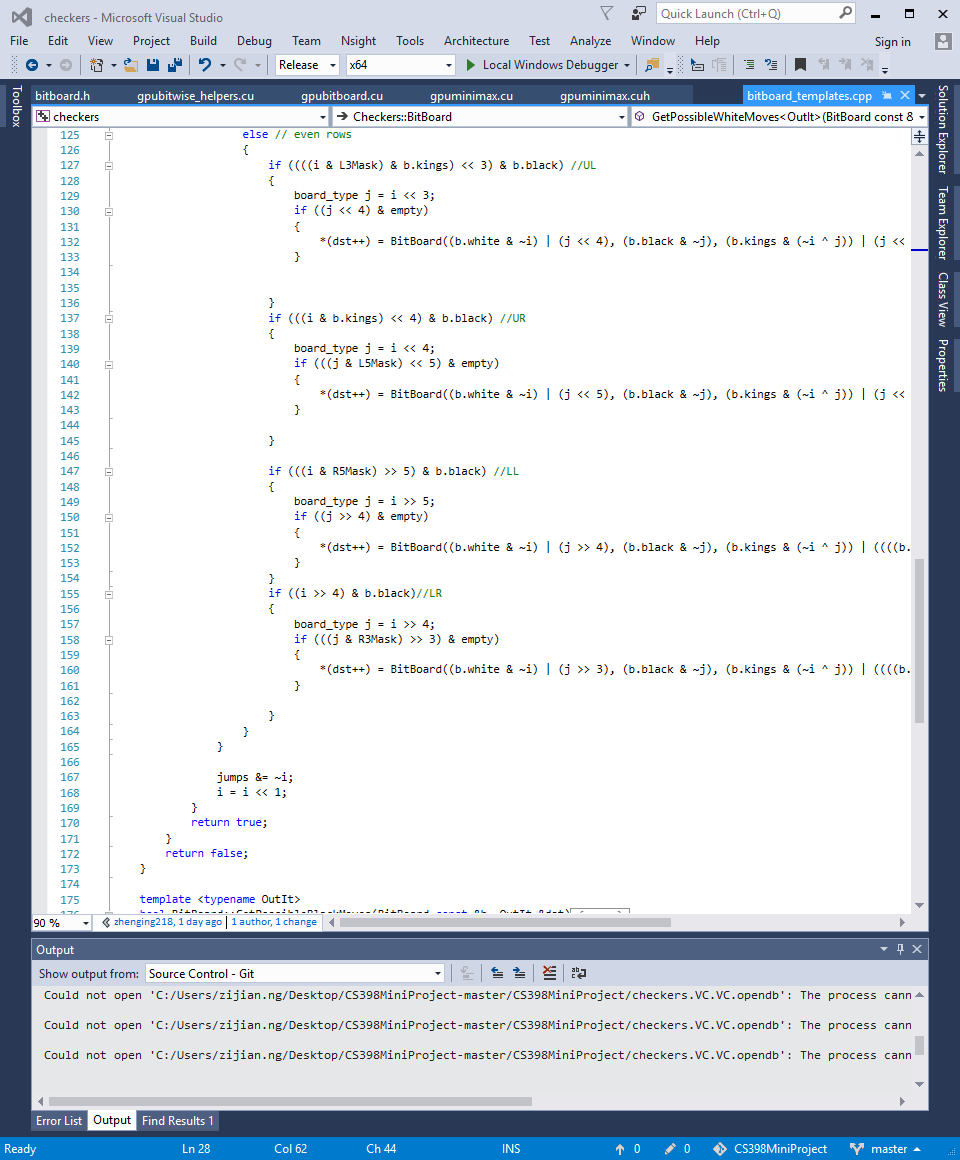


Figure 5d. An implementation of extracting odd jump moves

Taking an example in UL, the check in the move i << 4, gets whether is there any opponent piece and the operation (j & L3Mask) <<3 )& empty, checks if the current piece could jump to the next diagonal tile.

## Extracting of even jump moves



Extraction of possible even jump moves follows the same implementation as the one in 5.1.2.1 except all the checks are now used with even movements.

## In GPU implementation

# Getting the best move set available

## Using minimax algorithm

We are using minimax algorithm to determine the best moves that is derived from section 4 in both CPU and GPU. What minimax does is to get the best possible moves from a series of nodes that might have been created from each tree.



Figure 5a. An illustration of minimax algorithm

How minimax works, it perform a recursive iteration down the main node to the terminal node on the left and works its way up the node while comparing with its siblings’ nodes applying the condition of who has min or max value on that specific depth and it keeps comparing until it has reached the top node.

## Using CPU minimax

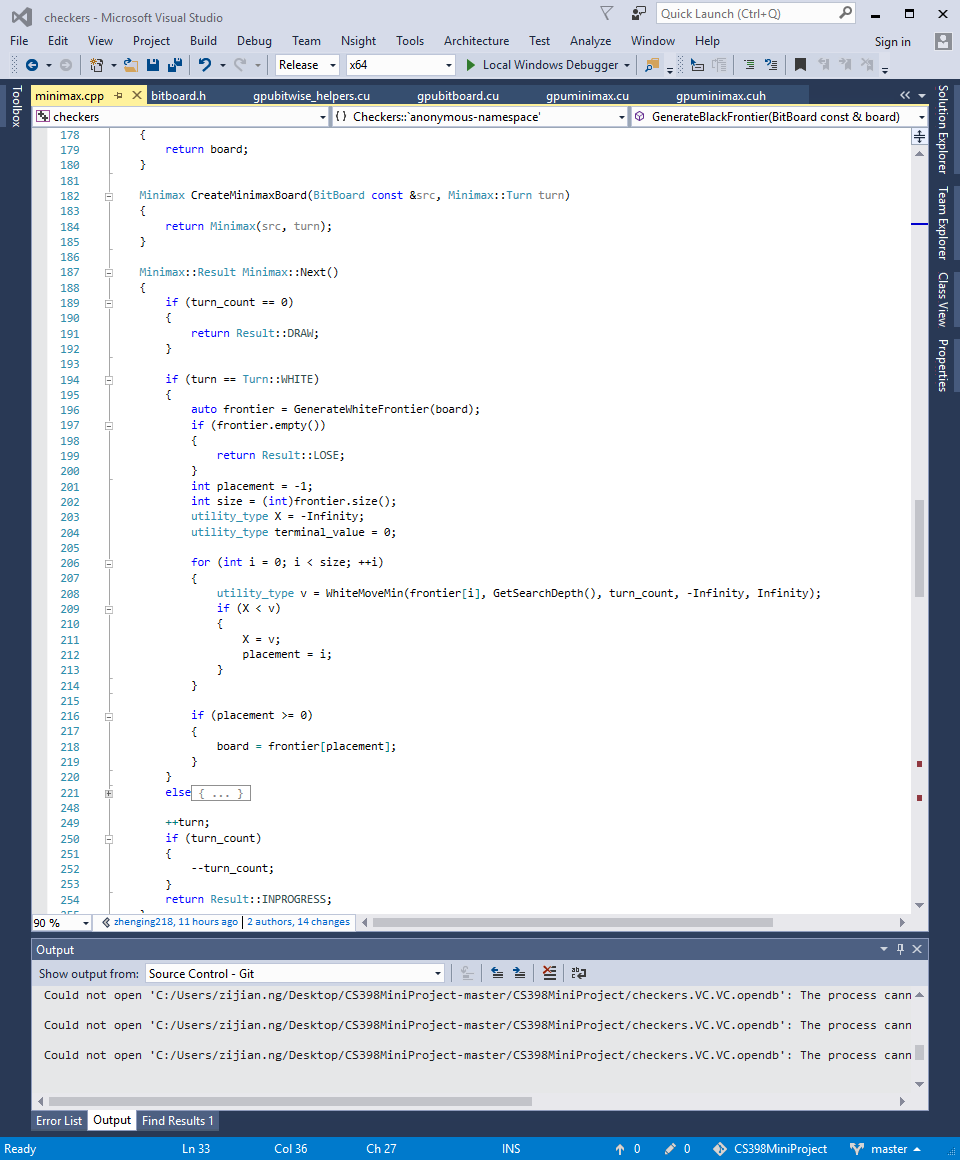
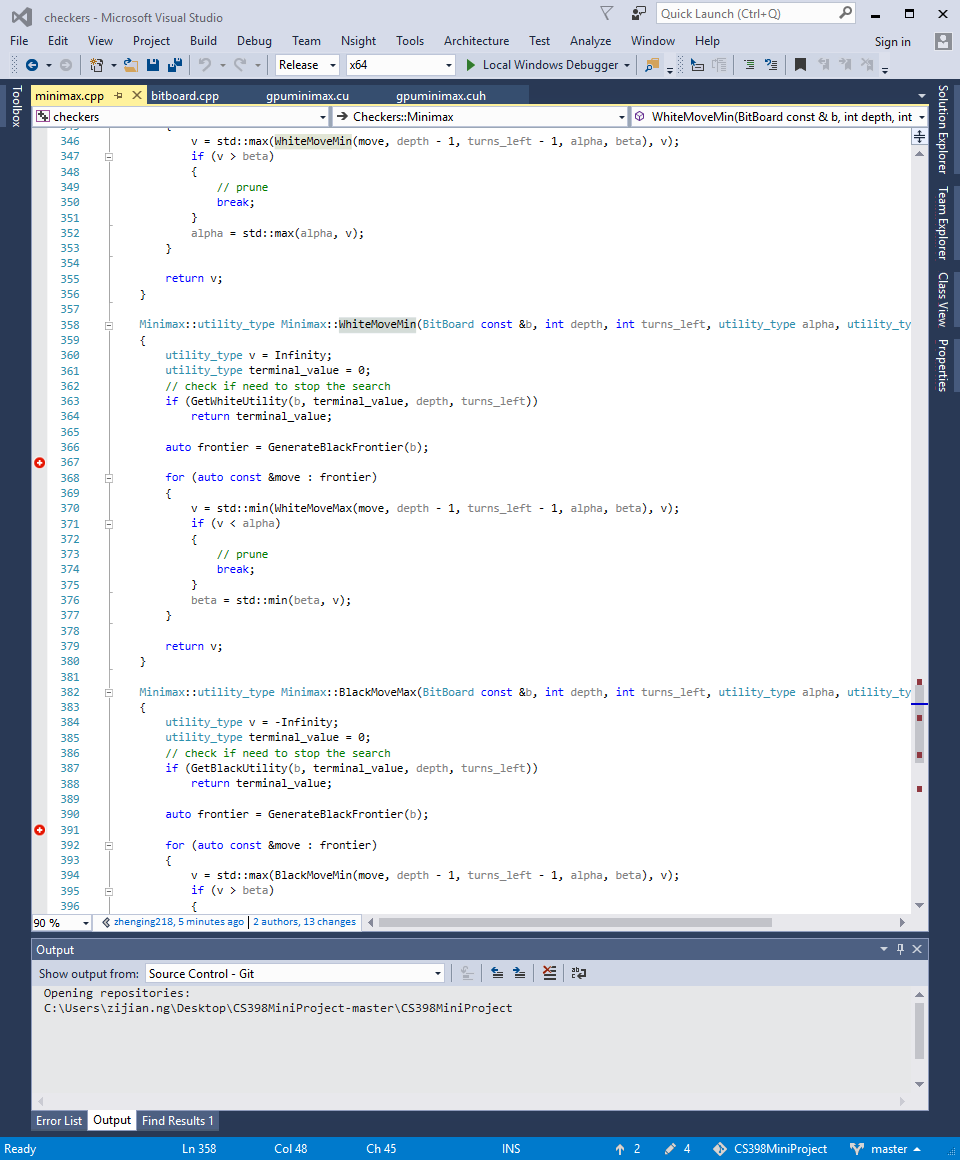


Figure 5b. Main function of minimax

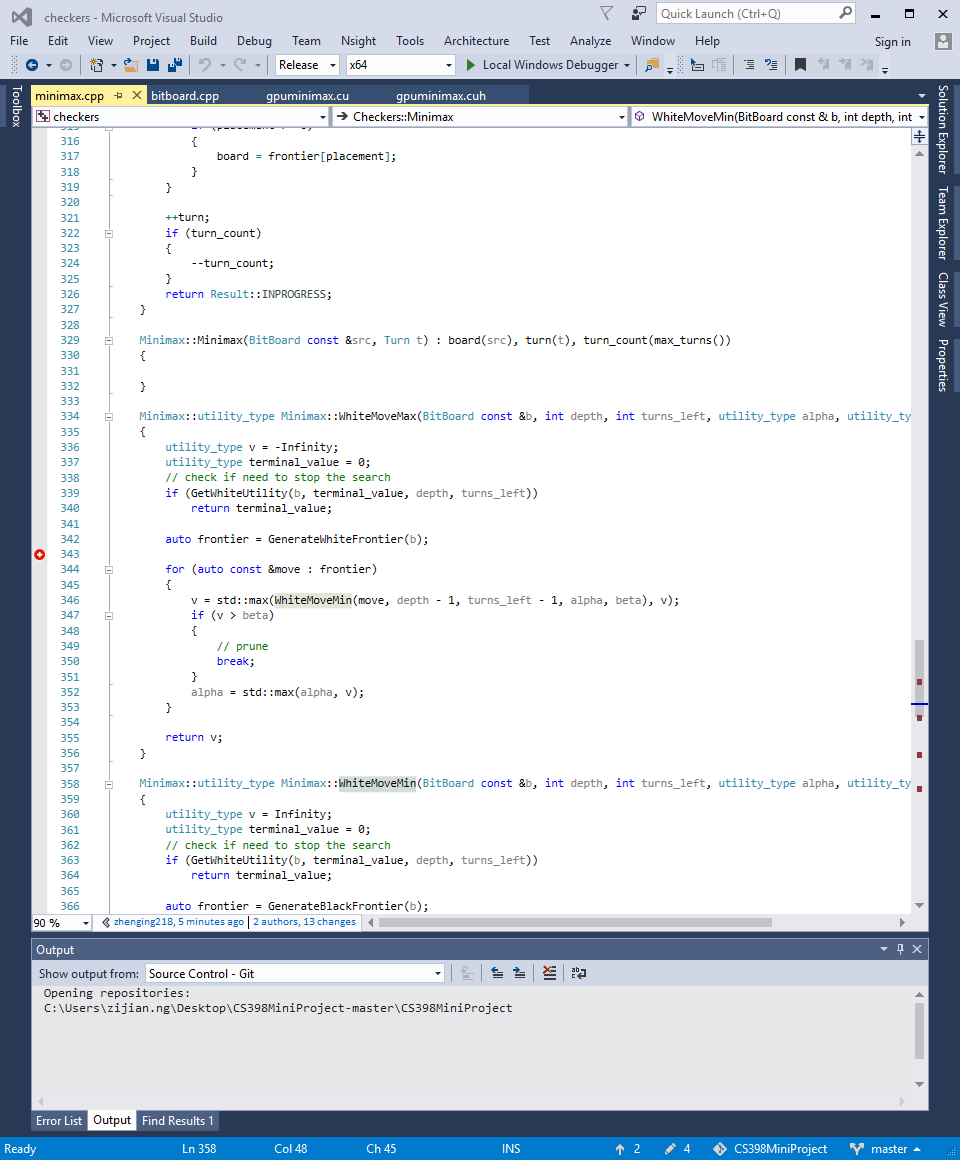
In this main function of minimax is where it calls for the creation of possible moves in Section 5 and evaluates them to see which of the following frontier that was generated, has the best value out of all the frontier available. It commences by calling the min function of each corresponding function of the pieces.

## Min function of minimax

Figure 5c. A min function of minimax algorithm

In this min function of the minimax, we start by initializing the value as infinity and slowly, it will be filled with values as it traverse down.by calling the max function until it has reached the specified depth. The values that is derived from these function is then passed back to the previous function to be compared, if there is a better frontier else there isn’t a need to expanding into the siblings froniter

## Max function of minimax



## Using GPU minimax