1. Specification

   Processor: QuadCore Intel Core i5-4570R, 2.70 GHz

   Memory: 8 GB of 1333MHz DDR3 memory

   OS: Windows 10 教育版 64 bits

   Graphics: Intel Iris Pro Graphics 5200

   IDE: Code Blocks 16.01

   Compiler: C++11 5.3.0 - GNU C++ Compiler with options: -lm -lcrypt -O2 -std=c++11 -pipe -DONLINE_JUDGE

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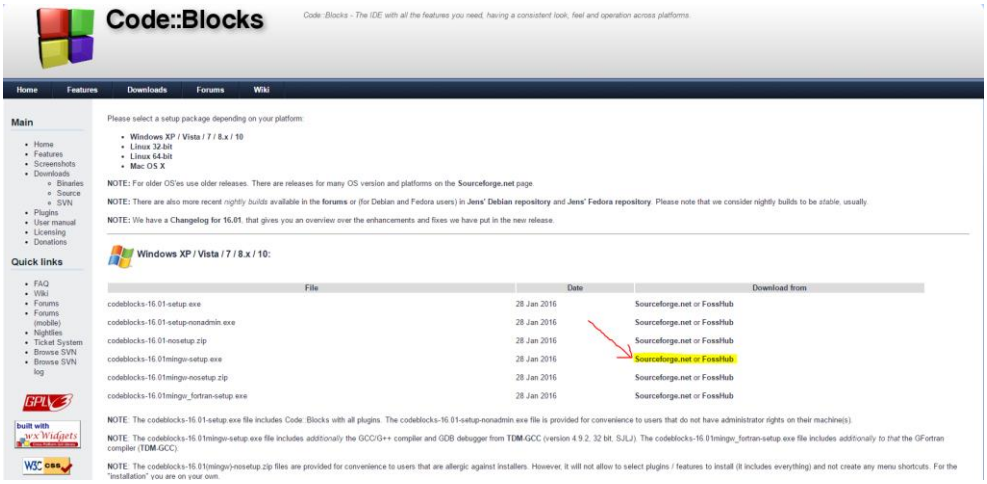
2. How to run the project

   Due to the implement consisting of API SFML and I built it on the IDE Code::Blocks, please follow the series of step to set up the proper environment.

   I. Download the IDE Code::Blocks.

   http://www.codeblocks.org/downloads/26



   (Be aware of you exactly downloading the fourth row. It is critical for SFML)

II. Download SFML 2.4.2(I have put it in the rar)

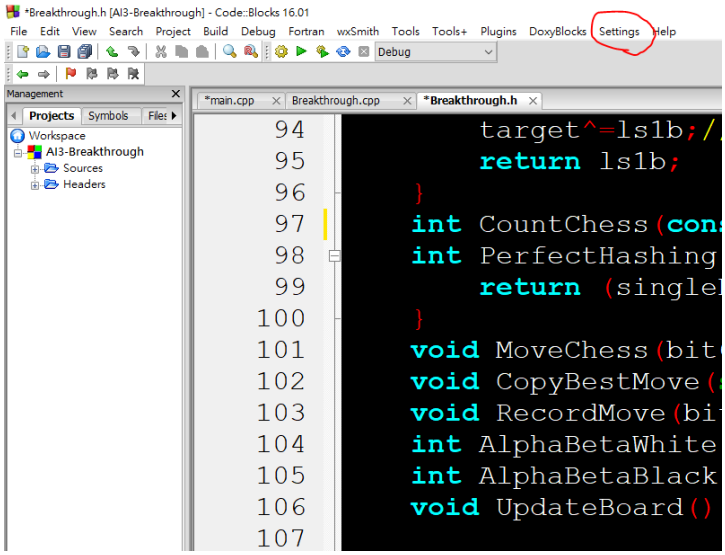
https://www.sfml-dev.org/download/sfml/2.4.2/

(This selection matches the corresponding IDE you had just downloaded.)

III. Set up the IDE environment

(More detailed information in the reference of point 5)

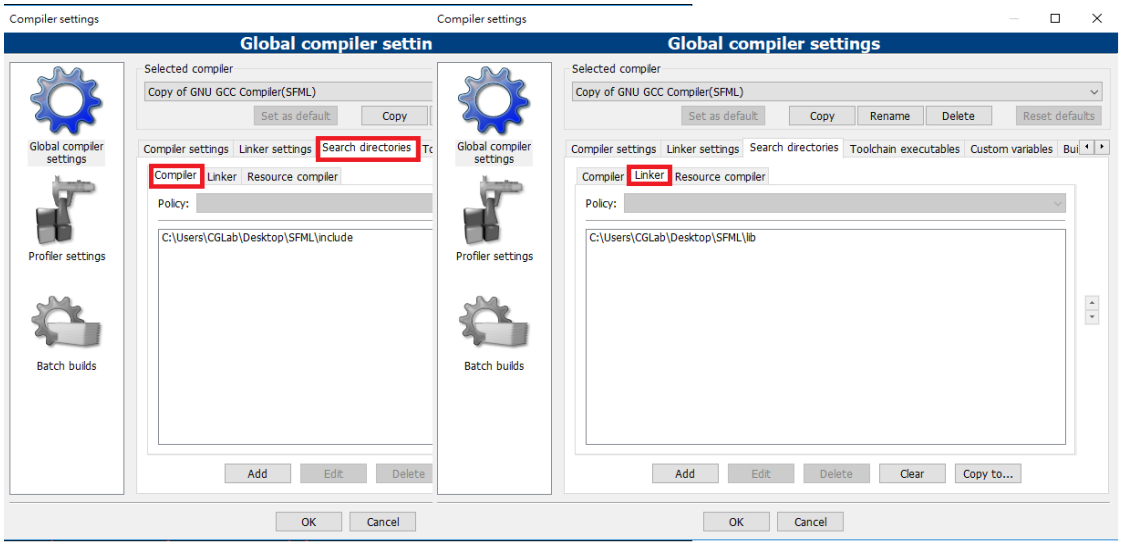
A. Choose Settings→Compiler…



B. Choose “Search directories”.

Add the path of your downloading SFML\include to the “Compiler”.

Add the path of your downloading SFML\lib to the “Linker”.

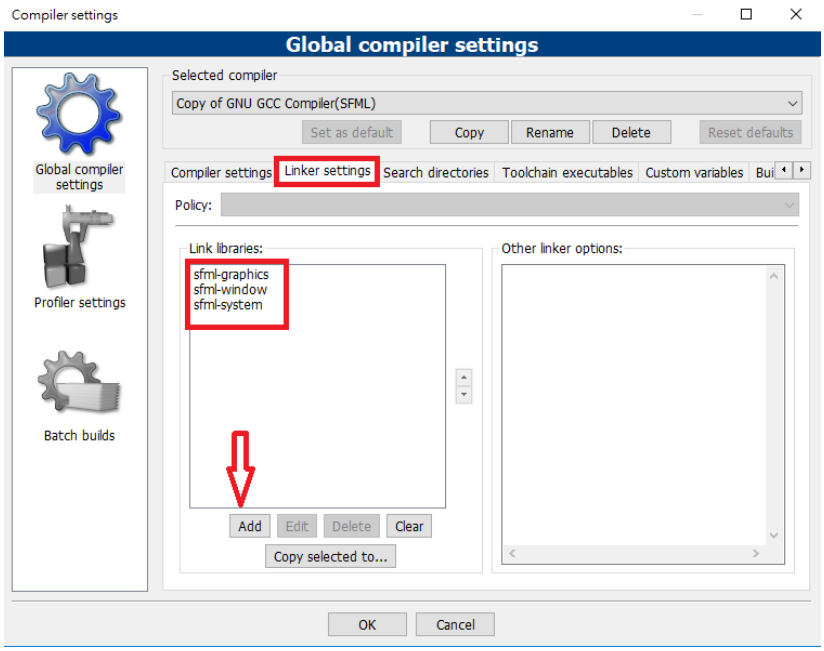


C. Choose “Linker settings” and add three link libraries.

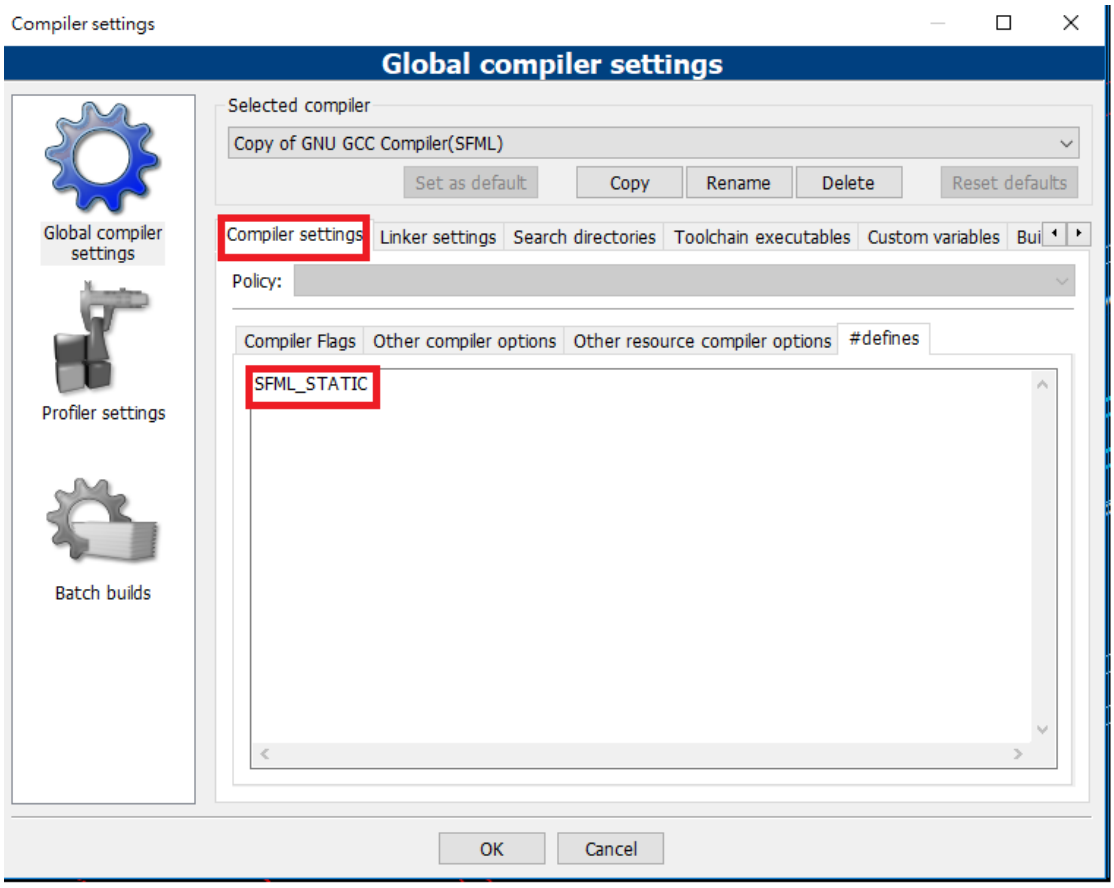
sfml-graphics

sfml-window

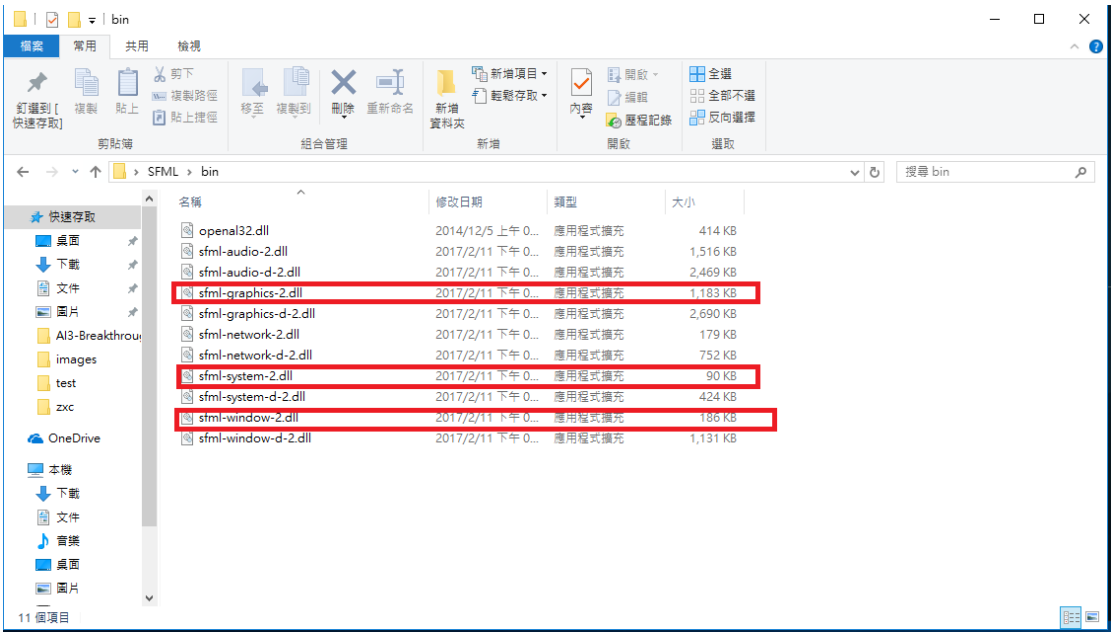
sfml-system

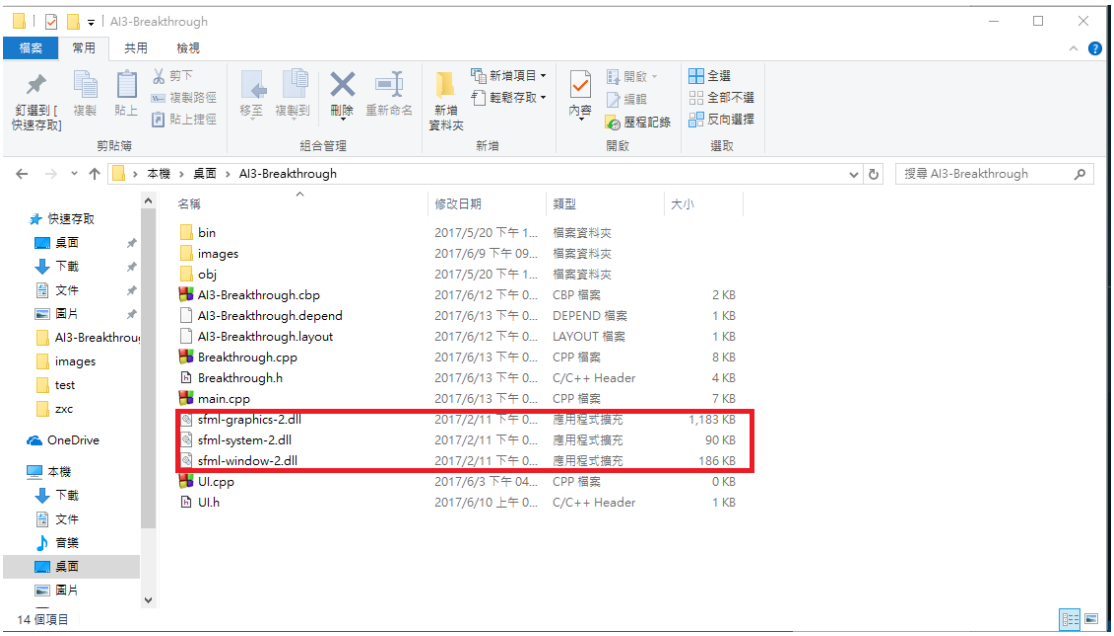


D. Final, choose “Compiler settings” and add “SFML_STATIC”.



IV. Go to SFML\bin and copy three .dll files consisting of sfml-graphics-2.dll, sfml-window-2.dll and sfml-system-2.dll into the project file.(I have put it in the project)



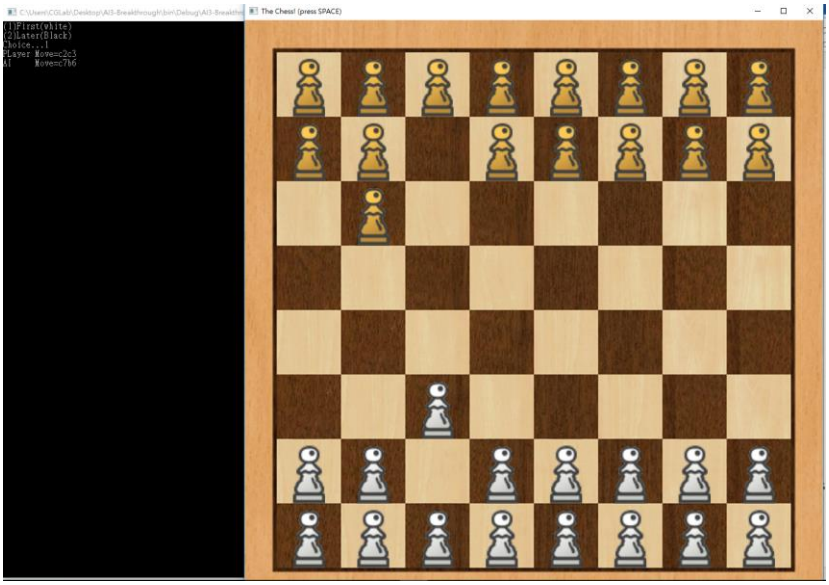


Then, all should be working well.

V. Run the project.

It will ask you the side. White go first then black.

When it is your turn, drag your chess to the proper place. The MS-DOS window shows every moves of AI and the player in the global form(a1~h8).
※Because of picture, I use orange chess stands for black and grey chess stands for white.



Because the program didn't detect the illegal move of players, you can cheat by move your chess to the final. You should not move the AI's chess,

it will lead to error. Be a good player.

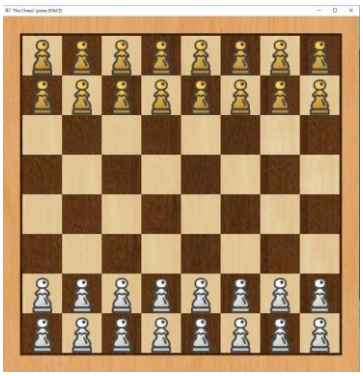
If the game is over, the UI will halt for 5 second then exit.

3. Data Structures, Skills, Testing and Features

I. Data structures

A. Bitboard

I used type of unsigned long long int in total 64 bits to show the bitboard. Only one for black chess and only one for white chess because there is one kind of chess.



White:0xFFFF000000000000
Black: 0x000000000000FFFF

White:0x6F80002401000000
Black: 0x000042000061096E

II. Skills

A. Alpha-beta pruning with negamax

Based on the requirement of this assignment. The below is the pseudocode.

```
Function AlphaBeta(depth,alpha,beta){
 If(win)return 999999
 If(loss)return -999999
 If(depth<=0)return 0;

 While(nextMove=GenerateNextMove() )
  moveScore=evaluate(nextMove)//審局函數
  If(nextMove eat a chess)
   value=eat point+ depth*5+moveScore+opponent's threaten
   UpdateBitboard
   If(depth=1)value-= AlphaBeta(1,-beta+value,-alpha+value)
   else          value-= AlphaBeta(depth-1,-beta+value,-alpha+value)
  else //just walk , no eating
```

UpdateBitboard
value=moveScore- AlphaBeta(depth-1,-beta+moveScore,-alpha+moveScore)

```
if(value>alpha)
  alpha-value
  recordMove//the current best move
if(value>=beta)
  return value;//cut off

return alpha;
```

B. Quiescence search

In the pseudocode, there is a line "If(depth=1)value-= AlphaBeta(1,-beta+value,-alpha+value)".
If the chess can eat the opponent's chess and the depth is 1, we should do one more depth to see whether the opponent could beat us more severely by eating our chess.

C. Evaluation function

Every position stands for the specific point can be get if a chess at this position. Make the AI occupy the more favorable place. The points is organization by observing the top players' movements. The website is listed in the reference of point 3.

＊The followings are the more detailed skills operating the bitboard.

D. Generate the next whole moves

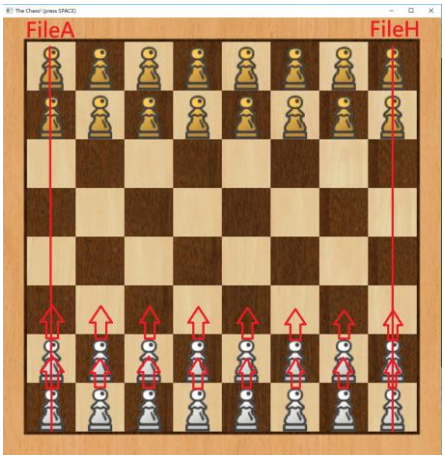
A chess has three directions can move. For white chess, it can go left-up, up and right-up and the black chess goes the opposite directions. There is a way can make all chess move to a direction in one operation.

Take white chess for example.

Goal1: White goes up.

white:0xFFFF000000000000

black: 0x000000000000FFFF



The places are not be occupy can be first calculate as a bitboard. It can filter out the illegal movements.

→Empty=0xFFFFFFFFFFFFFFFF&~black&~white

Goal=(white>>8)&Empty

Goal2: White goes up-left.

white:0xFFFF000000000000

black: 0x000000000000FFFF

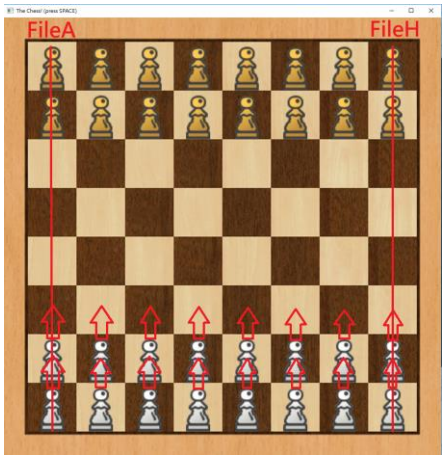
Goal=(white&~FileA)>>7&(0xFFFFFFFFFFFFFFFF &~white)

White chess cannot move to left-up from FileA. The chess will go wrongly. And it can eat black chess so delete the “&~black” limit.

White going right-up and the movements of black are quite same with above method. More detail in the project breakthrough.h file.

E. Extract a single move:LS1B

The above describe how to make whole movements in this step. But we should apply one movements one by one in the alpha-beta pruning algorithm.



The movement of white going up can be expressed by a bitboard.
→0xFF00FF0000000000
The LS1B function can extract the least bit in the bitboard.
So, we can get next movement=0x0000010000000000.
(LS1B function codes also in the breakthrough.h file, implemented by bit operations.)

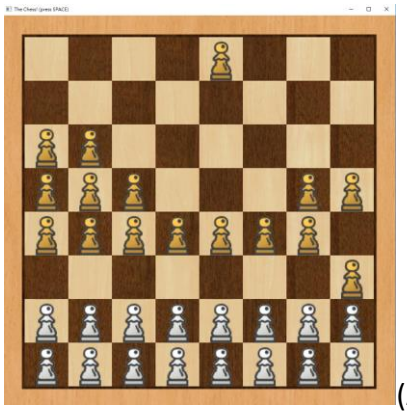
F. Perfect hashing

When a chess moves to a new place, we need to get the evaluation points. Now, we only know the movement bitboard like 0x0000010000000000. We can divide it by 2 to get the index of the chess position, but division is very slow with comparison to bit operation. Perfect hashing is an efficient way to get the index of the chess by bit operation and multiplication.

III. Testing

A. Don't rush to the end.

What will the board be if I don't move and AI keep moving?


(AI:black)

The AI will not let the chess rush to the white side even the white side doesn't make any movements. The AI takes the most careful movements to make sure the victory even competing with an un-smart player.

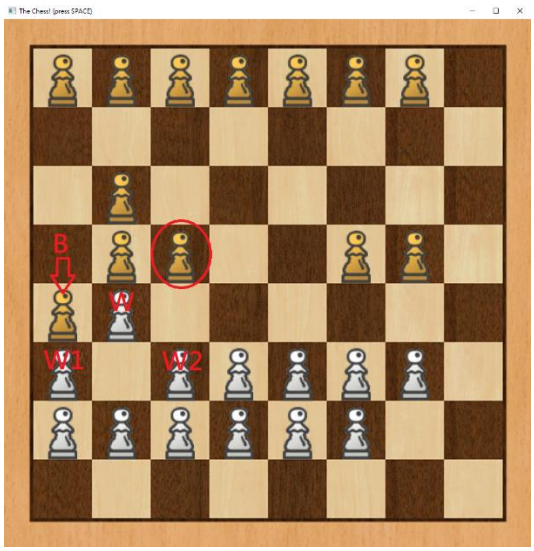
B. Different movements

Some classmates told that their AI had a strange temper choosing the same movement fight with different players. The mistake might occur in the evaluation function and eating points. My AI will take proper movements according to the opponents' movements.

C. Trade off/ Eager to win fast

The AI won't eat opponent chess in every times(the circled blacked chess doesn't eat the left-down white chess). If the AI eat my white chess, it knows that the white chess w1 or w2 will eat back,

even get the better place to the end. So, the AI move the black chess B down as a better decision.



If there are no other concerns, the UI will eat for winning soon. It credits to the proper set of value of the eating points and evaluation function and other factors.

IV. Features

A. Efficiency

The who project I never use the division and multi-dimension array except UI(it cost less than 0.1% running time).

B. Quite smart

AI often wins.

C. Delegate UI

The UI is implemented by SFML, fast and simple. This is my first time using SFML and is able to realize what is it doing in short time. The graphic UI provides user a convenient way to interact with AI.

4. Reference

1.從暗棋參考盤面設計、資料結構
http://dtim.mis.hfu.edu.tw/before/2008DTIM_PAPER/paper/B215.pdf
http://www.csie.ntnu.edu.tw/~linss/Students_Thesis/2011_06_29_Lao_Yung_Hsiang.pdf

2.Surakarta 棋實現技術之審局函式與 bitboard
http://myweb.npu.edu.tw/~tcga2017/Paper_Submission.html

3. Evaluation setting by observing the top player's movements.
https://www.littlegolem.net/jsp/main/

4.UI example(Using SFML)
https://www.youtube.com/watch?v=_4EuZI8Q8cs&list=PLB_ibvUSN7mzUffhi

ay5g5GUHyJRO4DYr&index=14

5.SFML and Code::Blocks (MinGW) settings
https://www.sfml-dev.org/tutorials/2.0/start-cb.php

5. Difficulties

I. Necessary for Graphic UI

In this project, it is necessary to use a graphic UI to show the board, or the user cannot realize what is the situation, especially after several movements.

It is the first time I make a UI. Fortunately, there is a good resource on the youtube that show all the detailed. This is an extra load I think I must do.

II. Timer

In the beginning of the game, there are less legal moves so the AI running time is fast. In the middle of the game, more and more legal moves spending much more time. I should add a timer giving the AI a constant time to think, and the alpha-beta pruning should be iterative deepening. The latter is easy to achieve, but the timer need more time and exercise to make it. Next time, I will add it to the project.

III. Thread

According to the paper on the TCGA, it suggested that the multithreads can greatly improve the speed. I also saw that implemented on a famous open source program called “stockfish”, a AI for chess not breakthrough. With the same reason, I don’t have enough time to learn about it. It is a pity.

IV. Alpha-beta pruning is not good enough

Although we can try to optimize the data structure and algorithm to make the running time a great progress, it has the bottleneck after all. The neuron will be a better way to train the AI. Alpha-beta pruning try to give a best move in the certain depth, but the neuron network gives a most possibility to win the human.