Automated Reversi Player

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Abstract

Reversi is a board game for two players and is played on a 8×8 board. It has long been an interesting game because the rules are very simple and the possibility of it is enormous. For the same reasons, Reversi has become a great place to demonstrate the power of artificial intelligence. In this project, I reviewed the history, rules and strategies of Reversi. Then I realized some strategies by implementing the algorithms in Python. A GUI was implemented to better visualize and test the performance of the AI's. Finally, the strategies were compared by playing against each other and analysis followed.

1 Background

It was hard to actually find a formal research paper talking about Reversi. However, I did find some online guide where history and strategies were discussed. Here I summarized what I read.

1.1 History

The board game, Reversi, was first invented in England in 1883 by either Lewis Waterman or John W. Mollett. Several journals, such as The Saturday Review and The New York Times, recorded this invention. The modern version of the game was patented in Japan in 1971 by Goro Hasegawa. He named the game Othello as a reference to the play Othello, the Moor of Venice by Shakespeare.[1]

Two years later in 1973, Hasegawa established the Japan Othello Association and held the first National Othello Championship on April 4, 1973. In late April, Tsukuda Original, a Japanese game company,

launched Othello and it was a great success.

In 1977, the first World Othello Championship was held in Tokyo. It became an annual event and more honors were competed in recent years, such as Female Champion and Youth Champion on top of World Champion.

1.2 Rules

Listed is the rules of Reversi or Othello:

1. Reversi or Othello takes place between two players, black and white, on an 8×8 board of 64 squares. There are 64 discs coloured black on one side and white on the other.

2. As shown in Figure 1(a)The board is set up initially with two black discs (i.e. a disc with black side uppermost) placed on squares 54 and 45 and two white discs on 44 and 55.

3. Black always plays first with players then taking alternate turns.

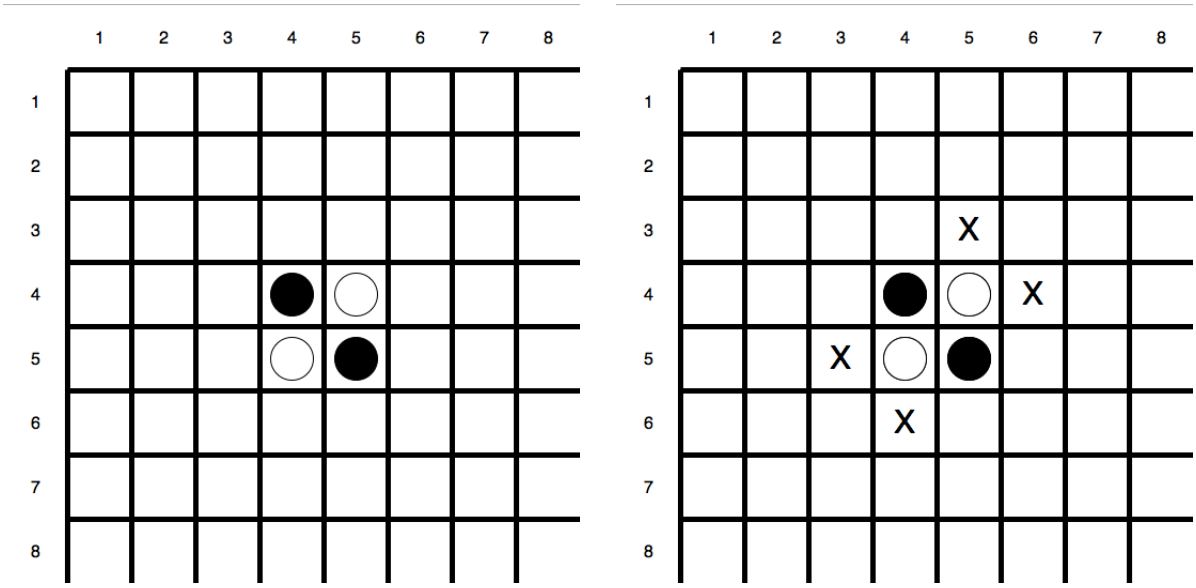
4. At each turn a player must place a disc with their color face up on one of the empty squares of the board, adjacent to an opponent's disc such that one or more straight lines (horizontal, vertical or diagonal) are formed from the newly placed disc, through one or more of the opponent's discs and up to other discs of their own color already on the board. All the intervening discs of the opponent's color are flipped to the color of the newly laid disc. Figure 1(b) shows the valid moves for black at initial state.

5. Discs may be flipped from one color to the other but once played are not moved from one square to another or removed from the board.

6. When one player has no valid move anymore, the other player could win the game early without occupying the whole board.

1.3 Strategies

There are many strategies available online to help make decisions in a Reversi game. They provide good guideline in designing an automated player. In this section, the concept of stable discs, motility and



(a) Initial state of the board (b) Possible moves for black discs

Figure 1: Initial state and valid moves

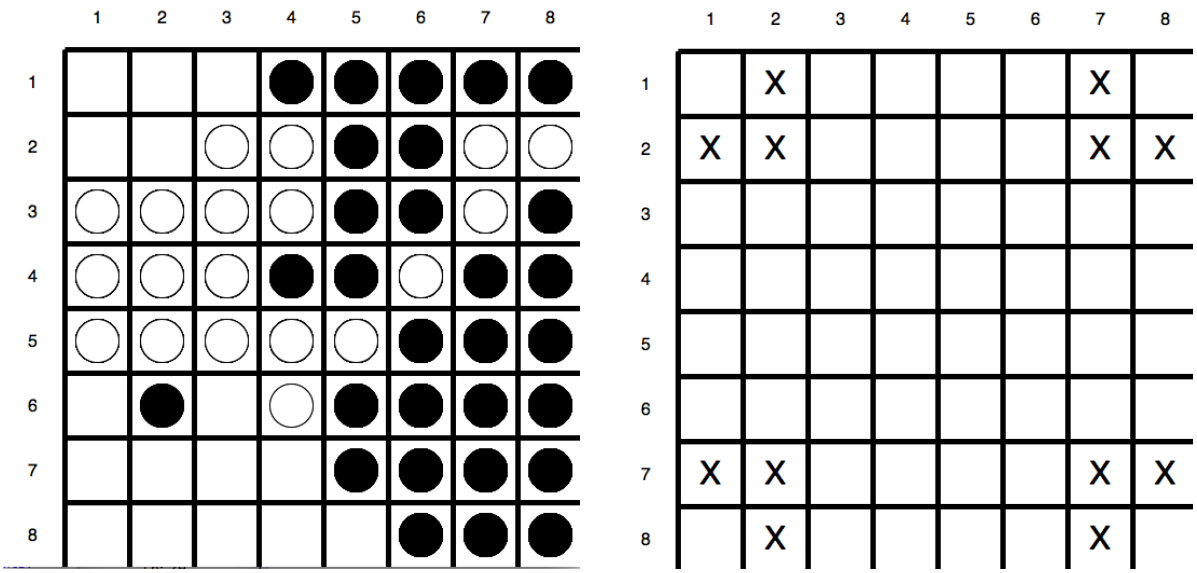
dangerous moves are presented. Maximum discs strategy, evaporation strategy and frontier strategy are discussed.

1.3.1 Stable discs

Stable discs are those which cannot be flipped by opponents' moves. The most apparent stable discs are the four corners. Discs connected with corner discs in a consecutive manner are usually stable, too. As shown in Figure 2(a), black has a bunch of stable discs at bottom right corner while white remains vulnerable at the center.

1.3.2 Motility

Motility is defined as the number of move options a player can make at a stage of a game. When playing Reversi, we often come across with a situation that one of the players is forced to make dangerous move because that's the only valid move. In order to avoid this kind of situation, we value motility in Reversi games and one of the most successful strategies of Reversi is based on maximizing the motility of your color while minimizing the motility of your opponents'.



(a) Black has stable discs at bottom right corner

(b) Dangerous moves are denoted by ”X”

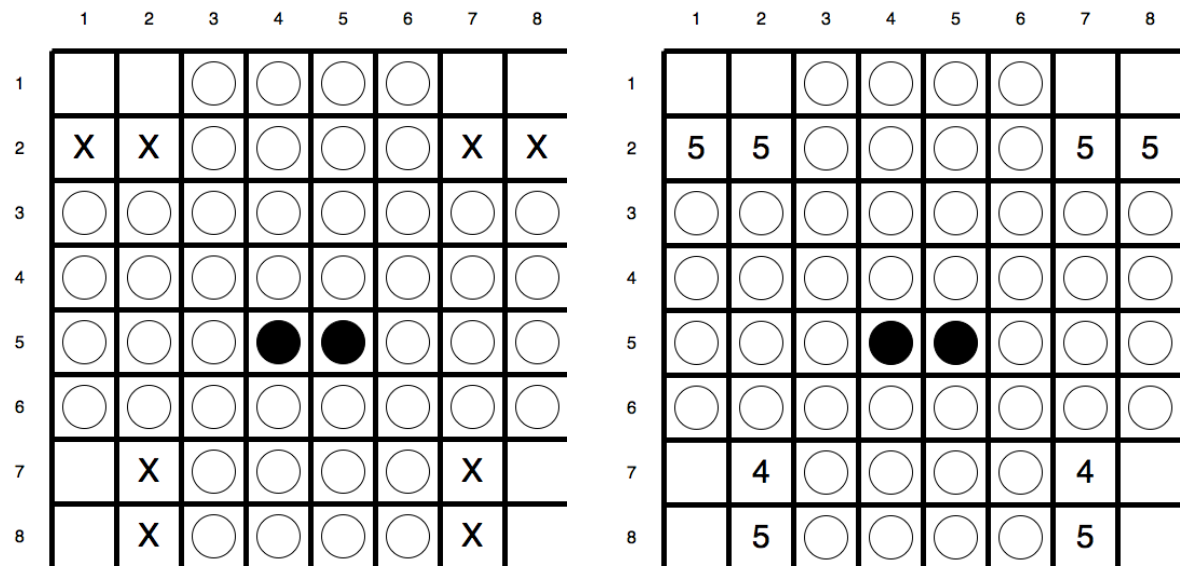
Figure 2: Stable discs and dangerous moves

As illustrated in Figure 4(a), all possible moves for black discs are marked with ”X”. There are 8 X’s, so the motility of black discs at this stage is 8.

1.3.3 Dangerous moves

Since stable discs cannot be flipped anymore and can stabilize other discs which are connected with them, they are very strategically important, among which corner discs are the most important because they themselves are already stable without help from other discs. Therefore, players should be always looking for corner moves while avoiding given them away to opponents. This gives rise to the concept of dangerous moves, which are likely to give corners away to opponents.

As shown in Figure 2(b), all corner related dangerous moves are denoted by ”X”. Note that there could be other dangerous moves we need to avoid, but they usually depend on the specific situations. The corner related dangerous moves are always dangerous no matter what situation we are in. So it is a good idea to beware of those moves and try to force opponents to make those moves.



(a) Illustration of motility for black discs

(b) Choice of evaporation strategy

Figure 3: Motility and evaporation strategy

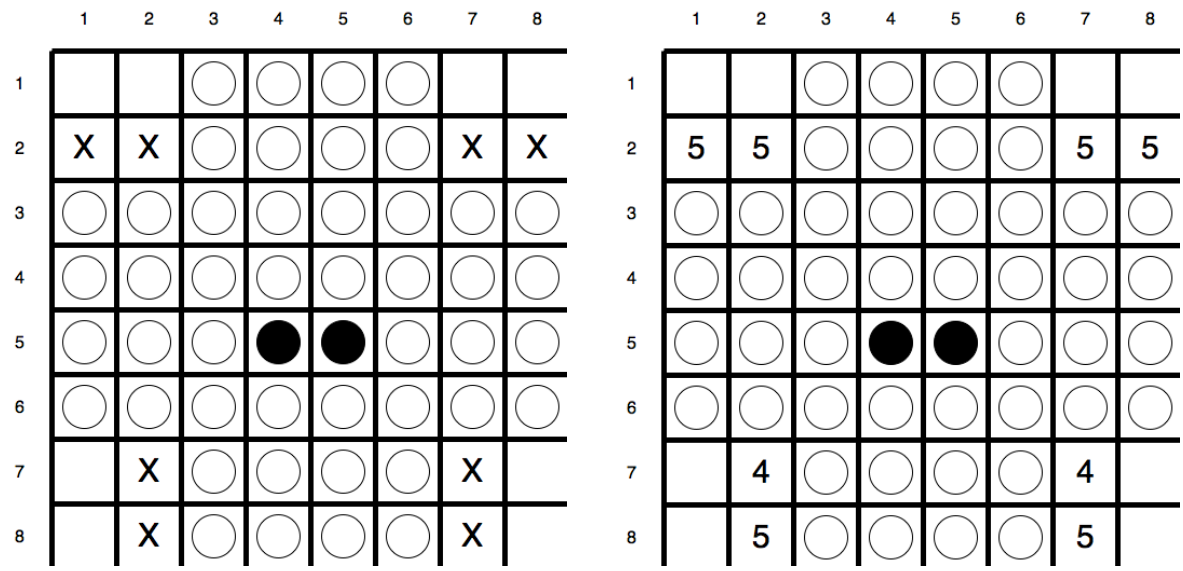
1.3.4 Maximum discs strategy

The goal of Reversi game is to occupy more space of the board than opponents. Beginners usually started by interpreting the end game requirement as their strategy for the whole game, that is, try to take as many discs in every move. This strategy sometimes works, at beginner level games, where both players don't have better strategy to work carefully on. However, in a game with more experienced players, it is easy to punish maximum discs strategy.

As shown in Figure 5(a), although white discs occupies most squares at the current stage, there is no more valid move for white discs, which in my rules results in a early loss.

1.3.5 Evaporation strategy

The key idea of evaporation strategy, minimizing the discs on the board at early game, roots from the game of motility. By minimizing the discs, the motility of your color is increased greatly while the motility of your opponents' is decreased as a result. Figure 4(b) shows how evaporation strategy makes decision in this particular situation. The numbers on the board indicates how many discs black will have after making move at that spot. Apparently, 4 is a better choice than 5 in evaporation strategy. Hence, the final decision



(a) Illustration of motility for black discs

(b) Choice of evaporation strategy

Figure 4: Motility and evaporation strategy

would be either (2,7) or (7,7).

1.3.6 Frontier strategy

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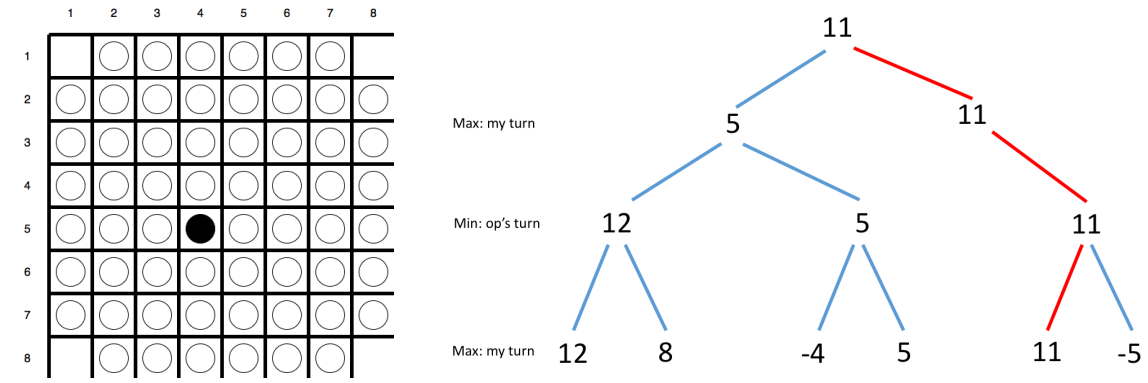
Discs that are adjacent to blank squares form the frontier, while those are not form interior. More frontier you have means more mobility your opponents have. Therefore, in order to minimize the opponents' mobility, one needs to minimize his frontier.

The key ideas of frontier strategy and evaporation strategy are essentially the same. They both try to play in a mobility point of view. Evaporation strategy does it in an indirect way while frontier strategy does it more directly.

2 Algorithms

Based on the strategies and guidelines discussed above, Four automated player agents have been implemented. Maximum-disc agent, minimax-maximum-disc agent, evaporation agent and frontier agent are coded in Python and they are allowed to play against each other to show the relative performance.



(a) Dilemma of maximum discs strategy

(b) Minimax search example

Figure 5: Maximum discs strategy and minimax search tree

The only search algorithm implemented is minimax-maximum-disc agent. Algorithms for other agents are followed from Section 1.3 in a very straight-forward way.

In this section, we only briefly describe how minimax algorithm works in searching for optimal solutions. Other algorithms are also submitted as supplementary materials.

2.1 Minimax-maximum-disc agent

Minimax algorithm gives optimal solutions to a two-player game of perfect information. By adversary search, minimax algorithm finds best solutions when we assume that the opponents play really well. Thus, it avoid all the worse cases. Although sometimes by chance a higher score can be obtained, minimax gives a solution with minimum risk.

Figure 5(b) sketches the searching process of minimax. Although at the first step if I picked 5, I would possibly get 12 in the end, there was a big risk that i could end up with a 5 if my opponent plays properly. Therefore, the best choice in the first place in 11.

3 Result and analysis: Championship for algorithms

In order to compare the performance of each algorithm, I held a Championship for the 4 algorithms I have implemented: *maximum agent*, *minimax agent*, *evaporation agent* and *frontier agent*.

3.1 The format of the Championship

1. The Championship has two phases: round robin and single elimination.
2. In round robin phase, each pair of algorithms play against each other 10 times. Winning a single game, an algorithm will get 3 scores, while a tie means 1 score and a loss means 0.
3. In single elimination phase, 1st place and 4th place will play against each other, and 2nd and 3rd place will play against each other. Winners will go to the final and losers will be eliminated.

3.2 Round robin

Cross-table for the round robin phase is the following:

	Maximum	Minimax	Evaporation	Frontier
Maximum		6:1:3	9:0:1	6:0:4
Minimax	3:1:6		8:1:1	4:1:5
Evaporation	1:0:9	1:1:8		3:0:7
Frontier	4:0:6	5:1:4	7:0:3	

The scores and rankings:

Algorithm	Score	Rank
Maximum	64	1
Frontier	49	2
Minimax	48	3
Evaporation	16	4

3.3 Single elimination

Results are shown as follows:

Maximum		
7:1:2	Maximum	
Evaporation		
	6:0:4	Maximum
Minimax		
4:0:6	Frontier	
Frontier		

3.4 Analysis

Congratulations *Maximum agent*!

As the most simple minded and direct algorithm, maximum disc algorithm wins the Championship. Why those ”advanced” algorithms lost?

There could be a couple of reasons:

1. Because of the rule. Here the rule is: if there is no valid move at your turn, you lose. This could result in the failure of late game coming back strategy, especially evaporation.

2. The minimax algorithm also maximizes discs to decide moves. Maybe it is too conservative so that it missed some chances to win.

3. The frontier agent also played well, placed right behind the champion maximum agent. This shows that, despite the failure of evaporation agent, the mobility strategy still works.

4 Conclusion

The Championship for algorithms showed that maximum discs strategy worked best among the 4 strategies in this work. However, this does not mean being greedy in Reversi is always advantageous. There are many strategies that are better than greedy in theory. In practice, those algorithms need to be further optimized to adapt in the strategies properly.

All the Python code are submitted along with this document.The `revfuncs.py` is reproduced from the

online tutorial Ref 3.[3] All other files are my original code, including a simple GUI displayBoard.py, several automated players myAI.py and an agent comparing function function_test.py.

References

[1] History of reversi. https://en.wikipedia.org/wiki/Reversi.

[2] Strategy guide. http://www.samsoft.org.uk/reversi/strategy.

[3] Invent with python: Reversi. https://inventwithpython.com/chapter15.html.