Exploration of the strategies to win a game of connect 4

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Abstract

The aim is to explore the strategies to win a game of connect 4 using a combination of a statistical and a strategic approach. Using the work of the original solvers, I show and explain how powerful it is playing first and in the middle column, in comparison to the other columns. I also show how player 2 can still win with a knowledge and skill advantage.

0.1 Introduction

0.1.1 Objectives

- To analyze the strategies used to win a game of connect 4 with both a statistical and strategic approach.

0.1.2 Rules

This is a two player game with a vertical board with 7 column and 6 rows turn by turn each player places a circular disc shaped object (which will be called "disc" throughout the rest of this report) into one of the columns and the objective of the game is to connect 4 vertically, horizontally or diagonally before your opponent.

0.1.3 Background

Connect 4, Captain's Mistress or Four In A Row, [1] a game that has a lot history, development and lineage. Oct 1 1988 the game was weakly solved by James Dow Allen, what this means is that he solved the game by making an algorithm that provides a win or a draw against any opponent playing from the start of the game. The analysis will primarily be to test these "weak" solutions and the conditions they must meet. He created a famous, comprehensive book that is the must-read for anyone looking to explore the strategies presented in this report further as this report merely captures a droplet of the vast ocean of knowledge. It must be noted for completeness that the game was also solved

independently by Victor Allis in his thesis. [2]. There have been many advancements made in solving this game since then[4][5], but I will be zooming into the weakly solved aspects of the game - more on this in the methods section.

0.1.4 Nomenclature

Each column will be defined from letters a to f, right to left correspondingly. Each row will be defined from numbers 1 to 6, south to north correspondingly. I will refer to specific spot like this "columnRow" e.g. A4 is the middle column first row. A remaining position that would lead to other player connecting 4 if you place your disc there, this is called a "threat" and often a game between skilled players will likely end up near the end game where all the columns have been filled up - this is referred to as an "endgame threat".[1]

0.2 Methods

The code used for the methods adapted, the original author [3] and references that were used in the process of adapting code can be found in in this report and can be found in this link: here. The basic "template" of the configured code does the following:

- Randomizes the inputs of player 1 and player 2.

- Keeps playing connect 4 games until their is an error.

- Stores who wins in a .txt file named "Leaderboard" I then configure the code to allow me to control and run different set plays and then the winners stored while keeping everything else constant. After 10000 to 11000 games I then analyse the winners in excel to determine relationships between running these plays and winning. All variations and results of those variations will be available in this link: here

What this allows me to do is change the code to specific scenario and produce large dataset to test hypothesise and draw analyses and conclusion.

0.2.1 The best row 'A' move

According to the aforementioned weak solvers, assuming each player plays perfectly and you play first, if you place your disc in A4 you will always win. This is the most famous and most of noted solution of connect 4. Using the code made in Python and changing where a disc is placed by Player 1 but keeping all events after as random. Then repeating this process for each column. I graph this data to display percentage wins for player 1 to determine whether or not their is a relationship between the column and percentage wins.

0.2.2 How to win as player 2

Even though there is an advantage to playing as player 1, it does not guarantee victory in the slightest because the perfect player is very rare if they even exist! There are strategies that can be employed if you are player 2 and I will explore them further in the analysis section.

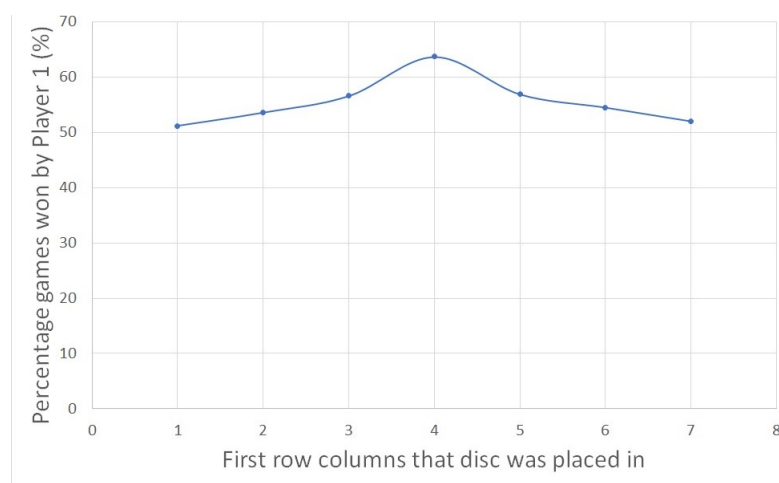## 0.3 Analysis and discussion

0.3.1 Row A moves

Figure 1: graph of player 1 row 'a' moves

Figure 1 evidently shows a positive increase in the percentage wins for player 1 as he places his disc closer and closer towards the middle and then a clear peak in percentage wins by player 1 when he plays games placing his disc in a4. There are few reasons for this, if you pick 7x6 up a connect 4 board you can clearly see that the middle column has the most potential ways to produce 4 in a row this in turn then leads to being able to threaten a 4 in a row on both halves of the board and taking center control is beneficial for player 2 as well! Generally if you play first you can set up the threats much earlier on that favor you in the endgame forcing the other person to play their disc so they can lose and you can connect 4. What threats should you make as player 1? Allen and Allis call them "odd row threats"[1][2] using our nomenclature it would be rows c and e (row a would count but that would not be an endgame threat as you could just place it in the column at any time!). Why? This is because player 1 plays in odd turns and when there is an even number spaces to fill while player 2 plays even turns when there is an odd number of spaces to fill this means they fill there threats at those times[2]. So set up your threats in spots that would

mean when you place your disc there is a threat waiting there to let you win.

0.3.2 How to win as player 2

Despite the statistical advantage player 1, you may still find that you win more often as player 2 anyway, a quote from James D Allen's book page 10 "when two experts play each other, Red [player 1] almost always wins, but non expert play varies" [1]. The skill required by player 2 is greater and will require better understanding and awareness of the threat principles and potentials that have been briefly mentioned in the section prior. Most of this skill has to be hard won through practice but there are principles you should look out for which are found by both of the weak solvers [2][1].The first principle is that player 2 plays even row threats. Same idea as player 1 but maintain threats in columns b,d and f. This is because during endgame and one final column is left to be filled, player 2 will place their disc second [1]. The second principle is to know that even row threats that are in separate columns as player 1's odd row threat [2] will result in a player 1 victory Why? Generally this means their are two columns left to fill one has player 2's threat and the other has player 1's threat, player 1 will just play odd turn in his column because his threat will be setup in c/e forcing player 2 to play into his threat or sacrifice his own threat and prolong the inevitable. Final principle [1] I will mention is two adjacent threats assure victory this basically means strive to get threats that would mean if the opponent places there disc to block a 4 in a row, they would then be leaving themselves open to the second threat making them lose automatically.

0.3.3 Limitations and errors

Before I perform the analysis I would like to mention the limitations of this model that is being used to analyze the data collected, I could not get the code to detect draws so there is no analysis of them and when there was a draw the code would stop and produce an error. Another limitation is player 1 has an inherit advantage in this model because it is like "running a race with luck as your legs" and whoever starts a race first has a slight advantage by simply being able to connect 4 first. This limitation makes it hard to analyse player 2 moves.

0.4 Summary and conclusion

To summarize playing first has an advantage that now the reader of this report knows however knowing this does not assure victory because the second player understanding the aforementioned principles and having a overall higher level play can very well come out on top. This report only touches the tip of the iceberg that comes with improving in a strategic game like this and the resources mentioned throughout the text will serve to deepen your expertise further if that is what you desire.

Bibliography

[1] James Dow Allen. *The complete book of Connect 4 : history, strategy, puzzles*. Sterling ; Lewes, 2010.

[2] Louis Victor Allis. A knowledge-based approach of connect-four. *J. Int. Comput. Games Assoc.*, 11(4):165, 1988.

[3] Oscar Nieves. Programming a connect-4 game on python - oscar nieves - medium, 2021.

[4] John Tromp. John's connect four playground, 1995.

[5] Yoshiaki Yamaguchi, Kazunori Yamaguchi, Tetsuro Tanaka, and Tomoyuki Kaneko. Infinite connect-four is solved: draw. In *Advances in Computer Games*, pages 208–219. Springer, 2011.