**Project 3: 4-In-A-Line**

*Analysis with Output*

Christopher Rivas

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Professor Atanasio

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**Approach**

4-In-A-Line or Connect Four is a fairly popular and common game. The game has existed for over thirty years and was first solved by James Allen on October 1st, 1988. There is a mathematical solution to the game. First off, the game is a two-player game and both plays have access to “perfect information”. This means that players have complete knowledge of all the moves that have taken place and any potential moves than can take place for any given game state. In terms of complexity, the board is traditionally a 6x7 grid with 6 rows and 7 columns. There are exactly 4,531,985,219,092 unique game states.

In order to get an idea about the complexity of the game an estimate is presented of the number of different positions which can be achieved, if the game is played according to the rules. A position which can occur during a game is called a legal position, while a position which cannot be achieved is called illegal. Each square can be in one of three states: empty, ‘O’ or an ‘X’. If the total number of occupied squares in a given position is odd, the number of white men is one more than the number of black men. If the total of occupied squares is even, these numbers are equal. Furthermore, if a column contains an empty square, all squares higher than this square are also empty. If a position contains four connected men, the position concludes a game. Since the last move ended the game, at least one of the four squares in the connected group must be the highest filled square in its column. If this is not the case, or both players have connected four men, the position is illegal. If one player has more than one connected group this position can only be legal if these groups share a square which contains the last man played. In the calculations we are going to make, we do not rule out positions in which are illegal for the reason mentioned above. We also do not rule out positions which are not legal, because they cannot be achieved, during normal play.

**Analysis**

Most articles on computer chess assume that readers have some basic knowledge about chess. If an endgame of King and Queen versus King is considered it is tacitly assumed that the readers know that it is very easy for the King and Queen to mate the other King. Although many people have seen a ’Connect-Four’ set before, and a lot of them have played the game sometimes, very few seem to have encountered at least some of the basic strategics of the game. For this reason in this chapter we try to fill in this gap of knowledge.

Zugzwang is a very important concept in playing ConnectFour. In finding the result of a game starting at a given position after correct play of both players, it is very important to determine which player has control of the Zugzwang. First we try to define Zugzwang: Zugzwang forces a player to make a move which he would rather not make. The force simply consists of the fact that each turn exactly one move must be made.

**Findings**

The game can be forcibly won by the player who starts first. Assuming the player plays every most perfectly, the first player can force a win on or before the 41st move by starting in the middle of the column. The game will automatically be a draw if the first player starts in the columns next to the center. Strategic rules have been defined for Connect-Four. These rules are similar to the rules expert players use to determine which move to make. Using an algorithm to combine these rules it is sometimes possible to determine the game-theoretical value of a position. Sometimes these rules cannot be used to find a result.

**Output**

**Run #1**

Welcome to Christopher's 4-In-A-Line

Would you like to go first?(y/n)

y

Enter the amount of time in seconds for the bot to think:

1

1 2 3 4 5 6 7 8

A - - - - - - - -

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Choose your next move[a-h][1-8]:

a1

1 2 3 4 5 6 7 8

A O - - - - - - -

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Score: -20.0

A1

1 2 3 4 5 6 7 8

A O X - - - - - -

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Score: 10.0

Turn 1 Score:10.0

1 2 3 4 5 6 7 8

A O X - - - - - -

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Choose your next move[a-h][1-8]:

a3

1 2 3 4 5 6 7 8

A O X O - - - - -

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Score: -20.0

A3

1 2 3 4 5 6 7 8

A O X O X - - - -

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Score: 10.0

Turn 2 Score:10.0

1 2 3 4 5 6 7 8

A O X O X - - - -

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Choose your next move[a-h][1-8]:

a8

1 2 3 4 5 6 7 8

A O X O X - - - O

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Score: -10.0

A5

1 2 3 4 5 6 7 8

A O X O X - X - O

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Score: 20.0

Turn 3 Score:20.0

1 2 3 4 5 6 7 8

A O X O X - X - O

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Choose your next move[a-h][1-8]:

a7

1 2 3 4 5 6 7 8

A O X O X - X O O

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Score: -20.0

A4

1 2 3 4 5 6 7 8

A O X O X X X O O

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -

Score: -10.0

Turn 4 Score:-10.0

1 2 3 4 5 6 7 8

A O X O X X X O O

B - - - - - - - -

C - - - - - - - -

D - - - - - - - -

E - - - - - - - -

F - - - - - - - -

G - - - - - - - -

H - - - - - - - -