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Defensive Yahtzee

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Abstract

In this project an algorithm has been created that plays Yahtzee using rule based heuristics. The focus is getting a high lowest score and a high 10th percentile. All rules of Yahtzee and the probabilities for each combination have been studied and based on this each turn is optimized to get a guaranteed decent high score. The algorithm got a lowest score of 79 and a 10th percentile of 152 when executed 100 000 times.

Sammanfattning

I detta projekt har en algoritm skapats som spelar Yahtzee enligt regelbaserad heuristik. Målet var att få en hög lägstapoäng samt en hög tionde percentil. Reglerna och sannolikheterna för spelet har studerats och baserat på detta är varje runda optimerad för att garantera en hög lägstapoäng. Efter 100 000 körningar fick algoritmen en lägstapoäng på 79 samt 152 som tionde percentil.

Contents

Chapter 1

Introduction

Yahtzee is a famous dice game, owned by Hasbro, that is played all over the world. The idea is that you have five dice, which you roll, and depending on what combinations they form you get a certain amount of points. The goal of the game is to get the highest score. [1]

1.1 Purpose

There are plenty of strategies that have the aim to win when playing Yahtzee. These strategies could be a bit risky, and there might be an interest in playing safe to minimize the risk of loosing when playing a game of many players. The purpose of this work was to raise the lowest score, but even more to raise the 10th percentile as high as possible.

Chapter 2

Background

2.1 Origin

The game Yatzie was originally made by Milton Bradley in the 1940s. Later it was marketed as Yahtzee in the 1950s. Currently the game is owned by Hasbro.

2.2 Rules of Yahtzee

Category	Description	Score
Aces	Any combination	Sum of all aces
Twos	Any combination	Sum of all twos
Threes	Any combination	Sum of all threes
Fours	Any combination	Sum of all fours
Fives	Any combination	Sum of all fives
Sixes	Any combination	Sum of all sixes
Three of a kind	At least three dice of the same	Sum of all dice
Four of a kind	At least four dice of the same	Sum of all dice
Small Straight	Four sequential dice	30
Large Straight	Five sequential dice	40
Full House	Three of one kind and another pair	25
Chance	Any combination	Sum of all dice
Yahtzee	Five of the same kind	50

You have three possible rolls on each turn and there are 13 turns during a game. You can save favorable combinations of dice to increase the possibility of achieving the categories stated above in order to get the highest possible score. If there are no possible category to choose after three throws, you have to cross one category out.

If the upper section (Aces to Sixes) has a combined score of 63 or higher, a bonus score of 35 is awarded.

2.3 Other versions of Yahtzee

There are many other versions or rules of Yahtzee, but some of the more popular ones that are excluded in this report are:

Yatzy

Mostly popular in Scandinavian countries and contains two extra categories; one pair and two pairs, as well as having different scoring than the original Yahtzee. [2]

Bonus Yahtzee

If the Yahtzee category has already been taken, a bonus of 100 points is awarded if another Yahtzee is achieved. [1]

Joker rule

if the Yahtzee category has already been taken, the Full House, Small straight or Large straight category can be awarded full points if another Yahtzee is achieved.

2.4 Calculating all outcomes

The probabilities of dice rolls are well known, and there are plenty of studies made within this particular subject. There is an optimal way of playing Yahtzee, which involves calculating all paths for the rest of the game, from every scenario, and always following the path which gives the highest score. To do this many calculations are required, which makes it a slow and complex process. [4]

2.5 Calculating each turn

The other way of playing Yahtzee is by trying to make an optimal decision on each turn based on what scores have been taken and what numbers are showing on the dice at the moment. It is harder to get a good score this way, but the implementation and algorithm is much faster to implement and run.

Chapter 3

Method

3.1 Previous reports

Older works within the same field have been studied, to create an algorithm that plays Yahtzee in a defensive way which lowest score beats the lowest scores of the versions used in the older reports.

There are many results from earlier studies in the same field which contains algorithms that could be used to improve the defensive algorithm. Some of the ways the algorithm could be optimized is by combining other algorithms, and by calculating the probabilities of different combinations and results. As the focus is not on getting a high mean score, the focus will be on reliability and stability. One thing that could be used to measure success is the 10th percentile, which is supposed to be as high as possible.

3.2 Probabilities and expected values after one throw

Category	Score	Avg. score	Probability (%)	Expected Value
Aces	1-5	3	59,8	1,79
Twos	2-10	6	59,8	3,59
Threes	3-15	9	59,8	5,38
Fours	4-20	12	59,8	7,18
Fives	5-25	15	59,8	8,97
Sixes	6-30	18	59,8	10,77
Three of a kind	5-30	17,5	19,29	3,38
Four of a kind	5-30	17,5	1,93	0,338
Small Straight	30	30	15,43	4,63
Large Straight	40	40	3,08	1,23
Full House	25	25	3,86	0,965
Chance	5-30	17,5	100	17,5
Yahtzee	50	50	0,77	0,386

All values ignore the possibility of getting a score of 0 since that means it is crossed out and if that is the case another category would be chosen instead.

3.3 Average scores

In the reports from previous studies we found some diagrams which showed average scores for each pattern. One clutch element seems to be the upper part, or more specific whether you get the bonus or not. This is the main difference between the two main algorithms we have looked into so far, thus

we believe that the upper part is where we should put our focus to be able to get a high 10th percentile result.

3.4 Our algorithm

Our algorithm uses a rule based heuristic to decide which dice to roll, and where to place the combinations. The combinations will be placed based on how many points we have up to the current point, and what combinations we have left. There are also rules that will record 0 as score for one of the lower categories if the combination after all three rolls is not applicable to any of the categories.

The main goal the algorithm has is to get the bonus score, which means the score on the upper section of the game is taken into account at every turn.

If the number score is too low to get a bonus we are under certain circumstances putting the score in numbers instead of three of a kind, four of a kind, or yahtzee. When zeroing different categories the bonus score is checked first to see if the upper part or the lower part is most important at the moment.

The algorithm also sorts the different categories in the lower section (Three of a kind to Yahtzee) based on their respective expected value (table at section 3.2).

3.5 How the algorithm works

In the beginning of each turn the algorithm rolls all five dice once. If large straight is available, and the dice forms a large straight it stops rolling. If large straight or small straight is available and we have a small straight, it keeps on rolling the last dice.

If no straight is available, the dice with the highest number and count, out of the combinations on the upper part that is available, is kept. The rest of the dice is re-rolled.

This process is repeated twice, as specified by the rules. After that, the current combination of dice is matched against the different available combinations. If the algorithm puts the score into any combination the process is stopped, and the next round is started.

First the algorithm checks for Yahtzee. If the dice forms a Yahtzee, but the sides facing up are sixes, and if the bonus score is lower than 38, the score is put into sixes instead of Yahtzee. A full house is then checked for, and if the dice forms a full house, it is scored accordingly.

Regarding four of a kind and three of a kind the algorithm uses the same logic as for Yahtzee. This means it is putting the score into the upper part instead of the lower part if the dice forming the four, or three, of a kind are sixes, and the bonus score is lower than 43 respectively 48.

The algorithm will look at the dice with the highest number and count, out of the combinations on the upper part that is available, and unless the bonus score is too low when scoring fours through sixes the score will be put into each combination.

Finally, if no combination is available, the score will be put into chance if it is 10 or higher, otherwise the algorithm will start zeroing different

combinations. The lower part will be zeroed first, followed by the upper part in ascending order.

Chapter 4

Result

4.1 Early versions

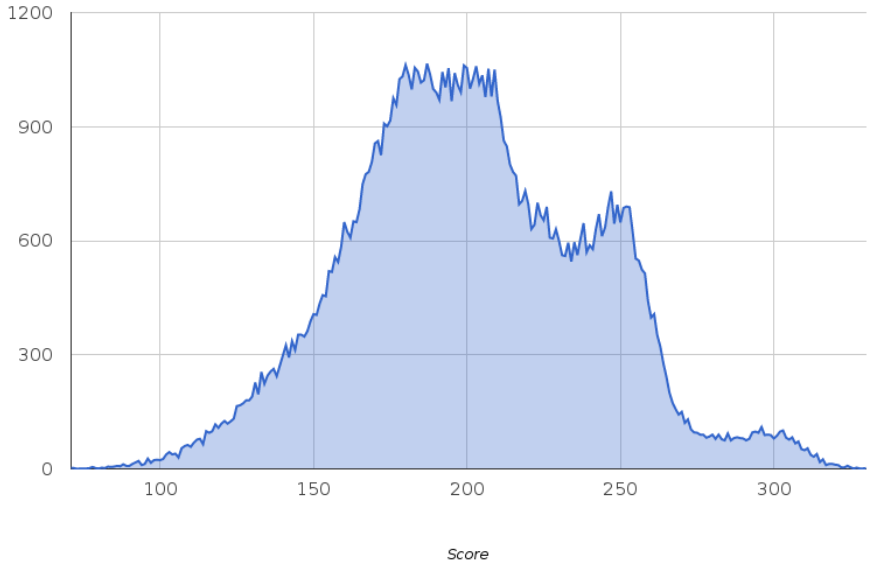
The first version of the algorithm reached a score of around 112-113. With some tweaking it reached an average score of 192, which is close to the algorithm used in "Optimal Yahtzee" [5]. When this version of the algorithm was executed 10 000 times it achieved a lowest score of 56, and a highest score of 330. Compared to the "Optimal Yahtzee" [5] algorithm which had a lowest score of 62, and a highest score of 346, it performs quite well for being the first version of the optimized algorithm.

4.2 Final version

When executing the final version of the algorithm 100 000 times it got a lowest score of 79 and a highest score of 330. The 10th percentile was 152 and the average score was 201,468. Compared to the "Optimal Yahtzee" [5]

algorithm this version achieved a higher lowest score, and a lower highest score.

4.3 Distribution of scores



These are the results after 100 000 runs where each individual score from the lowest (79) to the highest (330) is represented by the number of times it was achieved.

Chapter 5

Conclusion

Based on our results compared to the work done by Nils Dahlbom Norgren and Philip Svensson [5] we got an average score within 5% of theirs. However the lowest score of our algorithm was 17 points higher than their algorithm's, 27% higher, which was our main goal. Our bonus score was more than double of what they had.

Based on this we can conclude that it is possible to focus on certain combinations to get a higher lowest score than when playing in a riskier way. Of course the optimal way of playing is still by calculating the full game each turn and making a selection based on every outcome.

Chapter 6

Discussion

Looking at the results our goal was met, but not by a large margin. There are always small things to tweak in the heuristic algorithm to gain extra points, but it could most likely be improved far beyond that. The largest pitfall of this work is that after the first roll most of the decisions are made. If there is a high probability of getting a full house, and there has been no full house earlier in the game, it will go for a full house; ignoring most other combinations.

If there are no good combinations the algorithm will not re-roll all the dices to try again, it will instead choose the least bad decision. This is also the reason it does quite well in the first place, the algorithms purpose is to play it safe. Since we did not try to solve the problem solely based on mathematics, we had to rely on heuristics which made every possible branching difficult to predict.

Many of the decisions were based on calculations made in order to get a maximum score, which was not the purpose of this work. Therefore the algorithm sometimes tries to get a higher score instead of choosing the

safer score. This was something that was difficult to steer away from, as the common goal for all the sources being used was to score as high as possible. The calculations for the highest scores are often the best way to go, but for the purpose of this work it is always better to play it safe.

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