PLAYING YAHTZEE WITH DEEP REINFORCEMENT LEARNING - A SYSTEMATIC COMPARISON OF DIFFERENT APPROACHES

A PREPRINT

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ABSTRACT

In this paper we present an open source Q-learning algorithm for the dice game yahtzee. We implemented a variation of the Q-learning algorithm as used by Mnih [**?**], which he used for playing Atari games. The specific obstacles of yahtzee are thereby to handle two different types of possible actions: 1) choose what dice to re-roll; 2) choose a category on the score board, the significantly larger number possible actions of type 1 compared to an Atari game controller and the randomness in the response of the game to the players actions of type 1. By presenting different implementations of increasing complexity, we give the reader an overview of different concepts to improve the performance of Q-learning for certain situations and evaluate their performance in the specific use case. Among those concepts are different exploration strategies, concepts to handle randomness and a technique for the efficient handling of the two decision types. The most successful implementation achieves superhuman performance within a few thousand training cycles.

***K*eywords** Q-learning · neural networks · exploration strategies · replay memory

1 Introduction

The complete source code of this project is publicly available at

`https://github.com/markusdutschke/yahtzee`

Since Mnihs famous publication 'Playing Atari with deep reinforcement learning' [**?**] strong research interest has evolved around the possibilities of Q-learning in combination with neural networks. Thereby computer and board games turned out to be an excellent playground for this research, due to their complex character, their easy reproducibility and the clear definition of the systems rules.

ToDo: One should mention some historic achievments with the corresponding machine learning technology here. This should include - gackgammon (ibm, temporal time difference) - go (deepMind, ?) and many more (chesss?, poker?, doom?).

Solving these puzzles often paved the path for more complex applications like ToDo: - thermomix, which evolved out of the solution for fruit ninja (this is false and just an example) - more eamples of this structure

Especially the dice game Yahtzee has a set of interesting properties, which makes it an highly interesting test system for our purpose:

*Use footnote for providing further information about author (webpage, alternative address)—*not* for acknowledging funding agencies.

- Yahtzee is a broadly known game. This makes it easy for many researchers to evaluate a certain decision of the algorithm.
- Even after several hundred games, Yahtzee is still challenging for a human player. It thereby represents a challenge, which goes bejond the development of a few best practice strategies.
- There is a mixture of randomness and strategy involved. This makes it an interesting application which combines the reproducible domain of games with the influence of statistical uncertainty in real-life applications.
- Yahtzee is exactly solvable. The solution is far beyond the human abilities but can be used to evaluate the performance of the Q-learning implementation.

2 The dice game Yahtzee

2.1 Rules

2.2 Implementation

Relate the rule with the different classes in the code. Especially: Dice, ScoreBoard, Game and AbstractPlayer

2.3 Solutions and huristics

3 Q-learning

This chapter contains all the theoretical background of the code.

3.1 Background

3.2 Handling the two decision types

3.3 Information encoding

3.4 Exploration

3.5 Concepts to handle a stochastic system response

4 Implementations

This chapter is just a description of the different implementations and their performance.

4.1 Naive Implementations

- random implementation - greedy implementation with and without re-roll

4.2 AI player Version 0

4.3 AI player Version 1

4.4 AI player Version 2

5 Benchmark

In this chapter the benefit of different Q-learning concepts are quantitatively benchmarked. The implementation of these benchmarks can be found in the functions bench... in main.py with player implementations in botBench.py

5.1 Information encoding

Different encodings. Not yet sure, what to compare. Maybe: rgrSC with - 13 inputs (-1 for empty, otherwise score) - 26 inputs (first 13: 0 for empty, second 13: 0 or 1 for empty and used) - a good encoding (check maybe player v2)

5.2 Exploration

- epsilon greedy - softmax - minMaxRat

5.3 Concepts to handle a stochastic system response

- implicitly in MLP regressor (v0) - explicitly in mlprgr with pretraining and benchmarking (this is v1) - exactly by lookup table (v2)

6 Conclusion

Collection of key facts, whatever turned out to bring the most significant improvement.

7 NOW FOLLOWS THE TEMPLATE

8 Headings: first level

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See Section 8.

8.1 Headings: second level

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$$\xi_{ij}(t) = P(x_t = i, x_{t+1} = j|y, v, w; \theta) = \frac{\alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})}{\sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})} \tag{1}$$

8.1.1 Headings: third level

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9 Examples of citations, figures, tables, references

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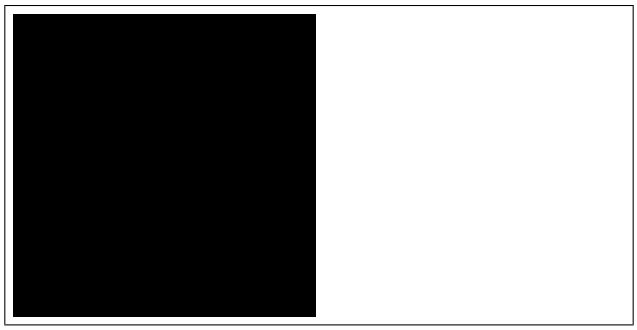

Figure 1: Sample figure caption.

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[1, 2] and see [3].

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`http://mirrors.ctan.org/macros/latex/contrib/natbib/natnotes.pdf`

Of note is the command `\citet`, which produces citations appropriate for use in inline text. For example,

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\citet{hasselmo} investigated\dots
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produces

Hasselmo, et al. (1995) investigated...

`https://www.ctan.org/pkg/booktabs`

9.1 Figures

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9.2 Tables

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See awesome Table 1.

9.3 Lists

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[2] Sample of the first footnote.

Table 1: Sample table title

	Part	
Name	Description	Size (μm)
Dendrite	Input terminal	$\sim$100
Axon	Output terminal	$\sim$10
Soma	Cell body	up to 10^6

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