PLAYING YAHTZEE WITH DEEP REINFORCEMENT LEARNING - A INTRODUCTORY GUIDE

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ABSTRACT

In this paper we present a 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

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. Especially 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.

Especially the dice game Yahtzee has a set of interesting properties, which makes it especially suitable for a Q-learning test system.

- Yahtzee is a broadly known game.
- Even after several hundred games, Yahtzee is still challenging for human player.
- There is a mixture of randomness and strategy involved.
- Yahtzee is exactly solved, but this is far beyond the score of the abilities of a human brain.

2 Headings: first level

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

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See Section 2.

2.1 Headings: second level

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

2.1.1 Headings: third level

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3 Examples of citations, figures, tables, references

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[1, 2] and see [3].

The documentation for `natbib` may be found at

`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…

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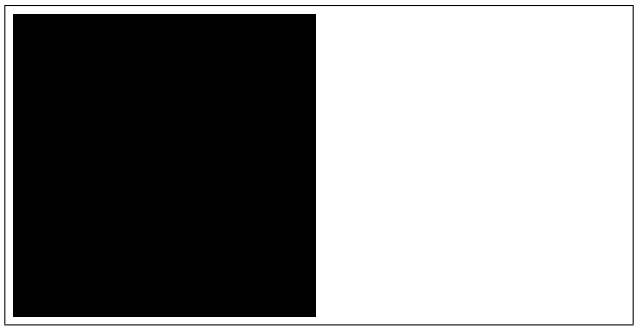

Figure 1: Sample figure caption.

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

3.1 Figures

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3.2 Tables

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See awesome Table 1.

3.3 Lists

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References

[1] George Kour and Raid Saabne. Real-time segmentation of on-line handwritten arabic script. In *Frontiers in Handwriting Recognition (ICFHR), 2014 14th International Conference on*, pages 417–422. IEEE, 2014.

[2] Sample of the first footnote.

[2] George Kour and Raid Saabne. Fast classification of handwritten on-line arabic characters. In *Soft Computing and Pattern Recognition (SoCPaR), 2014 6th International Conference of*, pages 312–318. IEEE, 2014.

[3] Guy Hadash, Einat Kermany, Boaz Carmeli, Ofer Lavi, George Kour, and Alon Jacovi. Estimate and replace: A novel approach to integrating deep neural networks with existing applications. *arXiv preprint arXiv:1804.09028*, 2018.