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ORIGINAL ARTICLE

Optimizing deep reinforcement learning in data-scarce domains: a cross-domain evaluation of double DQN and dueling DQN

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Abstract The challenge of limited labeled data is a persistent concern across diverse domains, including healthcare, niche agricultural practices, astronomy and space exploration, anomaly detection, and many more. Limited data can lead to biased training, overfitting, and poor generalization in Artificial Intelligence (AI) models. In response to this ubiquitous problem, this research explores the potential of deep reinforcement learning (DRL) algorithms, specifically Double Deep Q-Network (Double DQN) and Dueling Deep Q-Network (Dueling DQN). The algorithms were trained on small training subsets generated by subsampling from the original training datasets. In this subsampling process, 10, 20, 30, and 40 instances were selected from each class to form the smaller training subsets. Subsequently, the performance of these algorithms was comprehensively assessed by evaluating them on the entire test set. We employed datasets from two different domains where this problem mainly exists to assess their performance in data-constrained scenarios. A comparative analysis was conducted against a transfer learning approach widely employed to tackle similar challenges. The comprehensive evaluation reveals compelling results. In the medical domain, Dueling DQN consistently outperformed Double DQN and transfer learning, while in the agriculture domain, Double DQN demonstrates superior performance compared to Dueling DQN and transfer learning. These findings underscore the remarkable effectiveness of DRL algorithms in addressing data scarcity across a spectrum of domains, positioning DRL as a potent tool for enhancing diverse applications with limited labeled data.

Keywords Scarce datasets · Overfitting · Deep reinforcement learning · Double deep Q network · Dueling DQN

1 Introduction

In recent years, Artificial Intelligence (AI) and deep learning (DL) have seen a tremendous surge, resulting in groundbreaking applications across myriad domains (Pinheiro and Collobert 2015; Simonyan and Zisserman 2014; Girshick et al. 2014; Krizhevsky et al. 2017). Central to this advancement is the availability of vast datasets, enabling models to learn and generalize across complex tasks. However, the reality is that many real-world scenarios don't have the privilege of access to such expansive data. This underscores the critical challenge of limited datasets, an issue that is especially pertinent in specialized domains such as healthcare, niche agricultural practices, astronomy and space exploration, anomaly detection etc. The challenges associated with scarce datasets are manifold. First, training on limited data increases the risk of overfitting, where models perform exceptionally well on the training set but falter when

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