Reproducibility Package – Reproducibility Engineering: Quantum Reinforcement Learning

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I. Introduction

Reproducibility is one key factor in conducting scientific research for (dis)proving new theories. For example Karl Popper as one major scientific philosophers describes repititions for scientific obversations as necessary to convince oneself that one is not confronted with a random coincidence.[Pop02] In contrast to this idea of philosophy of science, there is the apprehension of a reproducibilty crisis in science, shared for instance in surveys by one of the most popular research magazines. A majority of the participated 1576 researchers sees a reproducibility crisis and has failed to reproduce the experiments of other scientists.[Bak16]

To make a contribution in the meaning of reproducibility, this paper documents the approach of reproducing current research about reinforcement learning in quantum compting with Variational Quantum Deep Q-Networks (VQ-DQN) by Franz et al.[FWP+]

II. Research: Uncovering Instabilities in Variational-Quantum Deep Q-Networks

The given research project includes a general approach for analzying the potential of quantum computing for the usage in problems of deep Reinforcement Learning (RL). RL is one field in Machine Learning with the general idea to train an agent without further instructions, so the agent has to find out which actions and general policies result in the highest reward. The training information evaluates the actions instead of using instructions for (in)correct actions. Popular examples of RL include the training of agents for videogames like the Game of Go.[SB18] Deep RL approaches have hardware intense requirements for achieving and outperforming human benchmarks like described by Badia et al. for exceeding the human benchmark in Atari games.[BPK+20]

At this point, quantum computing with its computational speedup potentials comes in, for example in quantum mechanical algorithms for database search[Gro96].

The proposed strategy for this research is the usage of VQ-DQN described by Chen et al. so classical deep RL algorithms for von Neumann architectures have a quantum computing representation.[CYQ+20], For this purpose, variational quantum circuits are used to create a quantum equivalent of deep Q-learning. Q-learning in general follows the idea to approximate directly the optimal action-value function based on the learned action-value function instead of using a strict policy.[SB18] The main difference between classical deep Q-networks and quantum deep Q-networks lies in the replacement of the deep neural network by variational quantum circuits. Those variational quantum circuits follow a design of a fixed structure of gates, operating on a set of qubits.[BLSF19]

For the usage of VQ-DQN, it is necessary to map a state of the classical markov deciscion process to a quantum state. Lockwood and Si use Scaled encoding and Directional encoding.[LS20] Skolik et al. add Continous encoding to those possibilities.[SJD21]

Based on the research and reproduction study of Franz et al.[FWP+], we reconstruct the reproduced training process of Lockwood and Si[LS20] and Skolik et al.[SJD21] regarding the training of VQ-DQN agents on the CartPole-v1 task. We use the approaches of Continuous, Scaled & Continuous and Scaled & Directional encoding and the Q-value extraction methods Local Scaling, Global Scaling and Global Scaling with Quantum Pooling like descirbed by Franz et al.[FWP+].

III. Reproducibility Package

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