

Quantum-Enhanced Reinforcement Learning for Robotic Control

M. Lautaro Hickmann¹[0000-0002-9501-4004], Lea Schmitz¹[0009-0005-3974-7739],
Hans-Martin Rieser¹[0000-0002-1921-1436], and Daniel A. Braun²[0000-0002-8637-6652]

¹ Institute for AI Safety and Security, German Aerospace Center (DLR), Rathausallee 12, 53757 Sankt Augustin & Wilhelm-Runge-Str. 10, 89081 Ulm, Germany

² Ulm University, Institute of Neural Information Processing, James-Franck-Ring, 89081 Ulm, Germany
`lautaro.hickmann@dlr.de`

A wide variety of Quantum Machine Learning (QML) approaches, particularly those employing Variational Quantum Circuits (VQCs), have shown potential for solving learning tasks beyond classical capabilities. The combination of quantum circuits and Reinforcement Learning (RL), known as Quantum Reinforcement Learning (QRL), has recently been explored to enhance learning efficiency in challenging environments. In (Q)RL, an agent learns optimal interaction strategies with an environment through trial and error, receiving rewards based on its behaviour. Although the field of QRL is still in its early stages, recent work has shown promising results using quantum-enhanced RL algorithms with VQCs as function approximators [1]. Experimental speedups for QRL have been shown using effective quantum algorithms on environments created with both classical and quantum communication channels between the agent and the environment [2].

This work investigates the potential of QRL for robotics, specifically controlling a 5-degree-of-freedom (DoF) robotic arm to reach target positions by adjusting its joint rotations. This task presents a complex continuous-state/continuous-action environment with a manageable 15-dimensional observation vector amenable to quantum circuit encoding. We implement an actor-critic QRL framework by enhancing the Proximal Policy Optimization (PPO) algorithm using VQCs [3].

We carried out an extensive hyperparameter search over both VQCs and PPO parameters, repeating each configuration multiple times with different random seeds and aggregating the results using the interquartile mean to enhance robustness. Our results show that the quantum architecture can solve the robotic task using continuous state and action spaces and immediate rewards. Overall, the quantum agent showed potential for solving various QRL robotic tasks.

References

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