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# Reinforcement Learning-Driven Optimal Control of Perfect Entangling Two-Qubit Gates

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Noisy intermediate-scale quantum (NISQ) computers promise a new paradigm for what is possible in information processing, with the ability to tackle complex and otherwise intractable computational challenges, by harnessing the massive intrinsic parallelism of qubits. Central to realising the potential of quantum computing are perfect entangling (PE) two-qubit gates, which serve as a critical building block for universal quantum computation. Quantum optimal control, which involves shaping electromagnetic pulses that drive quantum gates, aims at optimising the use of NISQ computers. In this work, Reinforcement Learning (RL) was leveraged to optimise for pulses which can generate PE gates. We train a range of RL agents within robust simulation environments to identify pulse shapes that push gate operation towards their theoretical limits. In particular, a trained RL agent can generate a 12 ns pulse, with a 50 ps sampling time, that yields near-maximal entanglement for the two-qubit gate, while maintaining unitarity error on the order of 10-4. Selected agents are then validated on higher-fidelity simulations, proving how RL-based methods can reduce overhead in hardware calibration and accelerate experimentation. Moreover, this approach is hardware agnostic, enabling broad applicability across different quantum platforms. Ultimately, this work shows how RL can be used to expedite optimisation and refine control processes in the presence of vast and intricate parameter spaces.

**Author:** GRECH, Leander (University of Malta)

**Co-author:** HIRLAENDER, Simon (PLUS University Salzburg)

**Presenter:** GRECH, Leander (University of Malta)

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