Bidirectional Quantum Control

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Quantum devices share the common aspect of being controlled by classical analog signals, related nontrivially to the device operation. The control signals need to be optimally adjusted to provide a high-fidelity operation of the device. A common approach to predicting control signals required to prepare the target quantum state, i.e., the inverse control model, minimizes an ad hoc selected distance metric in the classical control space. However, the values of control signals are given by the technical implementation and are often ambiguous. We propose and experimentally test a novel idea for constructing the inverse control model. We develop an unsupervised-like deep learning approach combining the inverse and direct control models, as depicted in the Figure. The classical control signals play the role of latent variables with no required quantification in the latent space. By minimizing the error in the space of quantum states, various models and devices, even with a different number of control signals, can be optimized and compared. We demonstrate our approach in a use case of polarization state transformation using twisted nematic liquid crystals controlled by several voltage signals. Furthermore, the method is used for local preparation and remote preparation of polarization-encoded qubits with unprecedented accuracy.

References

[1] D. Vašinka, M. Bielak, M. Neset, and M. Ježek, Bidirectional deep learning of polarization transfer in liquid crystals with application to quantum state preparation, Phys. Rev. Applied 17, 054042 (2022).

Figures

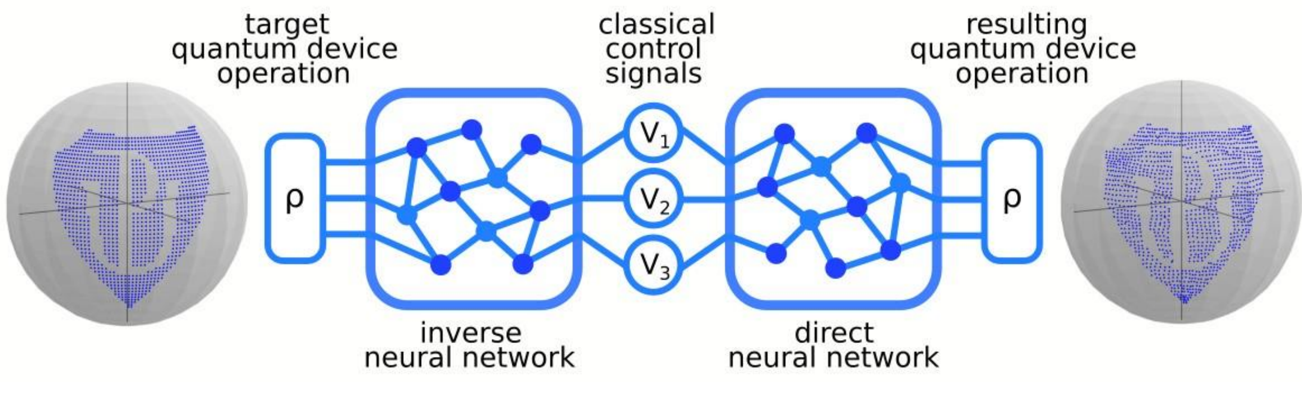

Figure: Representation of the compound neural-network model created by connecting the inverse model to the pre-trained fixed direct model. The input and output Bloch spheres depict the Palacký University logo consisting of hundreds of target and controlled quantum states of a single-photon polarization qubit, respectively.