

Paradoxes of High-Dimensional Quantum Models

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Abstract

This presentation explores the intricate training dynamics of quantum machine learning models, framed as an interplay between classical optimization and the vast geometry of the Hilbert space. We move beyond the common trope of Hilbert space “vastness,” focusing instead on a geometry sculpted by quantum entanglement and operational constraints resulting in counter-intuitive paradoxes of high-dimensional models. We elucidate the classical optimizer’s struggle to refine classical parameters without insight into their quantum representation or their role in evolving qubit states. From a purely geometric perspective, we analyze how the high dimensionality of both the parameter and Hilbert spaces culminates in training pathologies like Barren Plateaus, Orthonormal Desert, and the Measurement Sparsity. Ultimately, we argue for the necessity of “quantum-aware” optimizers—tools capable of navigating the subtle curvature of the quantum manifold that standard gradient-based methods ignore.

Keywords:

Quantum Machine Learning, Quantum Model Optimization, Hilbert Space, Curse of Dimensionality, Barren Plateaus, Orthonormal Desert, Measurement Sparsity, Quantum Natural Gradient

Reference:

Jacob L. Cybulski, “A Dance of the Blind Puppeteer: The Interplay Between a Classical Optimizer and the Hilbert Space”, in Oswaldo Zapata (Editor), *A Portrait of Quantum Technologies in Finance*, The Quantum Finance Boardroom, 2026.

https://jacobcybulski.com/publications/2026-zapata/chapter_v1_4_final.pdf

Bio Note



Jacob Cybulski is the founder of Enquanted, providing research, training and consulting services in quantum computing. Jacob’s projects involve quantum machine learning for understanding complex data, as well as, development of algorithms and applications for prediction and anomaly detection in business, engineering, and science. He is dedicated to education and promotion of quantum technology. Jacob’s work also concerns classical machine learning, business analytics and data visualisation. He collaborates internationally with a wide network of quantum researchers and developers.