UNIVERSITY OF TECHNOLOGY SYDNEY

Characterization and Control of Quantum Systems using Machine Learning and Information Theory

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under the supervision of

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Akram Youssry Abdelaziz Mohamed declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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DECLARATION OF PUBLICATIONS INCLUDED IN THE THESIS

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List of Abbreviations

CAD	Computer-Aided Design
CDD	Concatenated Dynamical Decoupling
CPMG	Carr–Purcell–Meiboom–Gill
CPTP	Completely-Positive Trace-Preserving
CRAB	Chopped Random Basis
DD	Dynamical Decoupling
GRAPE	Gradient Ascent Pulse Engineering
GRU	Gated-Recurrent Unit
GST	Gate Set Tomography
LS	Least-squares Estimation
LSTM	Long Short-Term Memory
MEG	Matrix Exponentiated Gradient
MLE	Maximum Likelihood Estimation
NISQ	Noisy Intermediate-Scale Quantum
NN	Neural Network
OC	Optimal Control
PDD	Periodic Dynamical Decoupling
PGD	Projected Gradient Descent
PSD	Power Spectral Density
QCVV	Quantum Characterization, Verification, and Verification

QIP Quantum Information Processing
QNS Quantum Noise Spectroscopy
QPT Quantum Process Tomography
QST Quantum State Tomography

RNN Recurrent Neural Network
RWA Reconfigurable Waveguide Array

SPAM State Preparation and Measurement

UDD Uhrig Dynamical Decoupling

Abstract

The tasks of characterization and control of quantum systems are becoming more challenging with the advancement of quantum technology. Standard methods that were successful for simple quantum systems are becoming inadequate for more complex engineered systems. Modelling assumptions and approximations (such as Markovianity) are not justifiable anymore. As a result, the usual models fail to fit experimental measurements. In this thesis, we use state-of-the-art machine learning methods, assisted by tools from information theory as needed, to develop new frameworks that try to address these challenges. We focus on three directions. The first is developing an efficient online quantum state estimation algorithm with provable convergence properties. The second is developing a deep learning framework for characterizing and controlling closed quantum systems. The final direction is upgrading that framework to be suitable for characterization and control of open quantum systems. This thesis opens the door for a novel way of utilizing machine learning techniques for applications in quantum information specially and physics in general.