Preface

The main theme of this research monograph is modeling and control of a special class of open quantum systems that shall be referred to as linear dynamical quantum systems. They are also referred to in the literature as linear quantum stochastic systems with the qualifier "stochastic" added because these systems are coupled to and driven by quantum stochastic processes (i.e., "quantum noise"). For brevity, we will often refer to them simply as linear quantum systems. Such systems are frequently encountered in fields such as linear quantum optics and opto-mechanics, to name a few, with applications in areas including continuous-variable quantum communication and quantum precision sensing. They are essentially a quantum analogue of the distinguished class of classical (non-quantum) linear systems that have played a foundational role in the development of modern and post-modern systems and control theory.

The reader may wonder, is there a place for a research monograph dedicated to this class of quantum systems? Certainly, this monograph would not be the first text to discuss linear dynamical quantum systems. Indeed, the now standard reference text "Quantum measurement and Control" by Wiseman and Milburn [1] already has sections devoted to linear dynamical quantum systems (see Sects. 5.6 and 6.6 therein). The present monograph complements existing textbooks that treat the subject of quantum feedback control, as the text of Wiseman and Milburn and the more recent "Quantum Measurement Theory and its Applications" by Jacobs [2], in terms of its emphasis and approach. It focuses on the class of linear quantum systems and provides an in-depth treatment of the system-theoretic foundations of such systems, and the control theoretic formulation of quantum versions of familiar problems from the classical (non-quantum) setting, including estimation and filtering, realization theory, and linear quadratic control. Some of these topics may be unfamiliar to researchers in quantum control coming from outside of the control theory discipline. It is our hope that the monograph can at least partly bridge this gap and serve as good introduction to these topics as a stepping stone towards understanding more general nonlinear quantum stochastic systems.

The monograph is aimed at graduate students and researchers with a background in control theory, physics, or mathematics who have an interest in the topic of quantum feedback control theory, and linear quantum systems in particular. It assumes that the reader has working knowledge of quantum mechanics, at least at the undergraduate level, such as in D.J. Griffith's text "Introduction to Quantum Mechanics" (Pearson Education). It also assumes that the reader from a non-control theory background has working knowledge of modern control theory, in particular with the state-space representation of linear dynamical systems. Some exposure to continuous-time stochastic filtering and control theory would also be valuable.

With the 2012 Nobel Prize in physics being awarded to experimental physicists Serge Haroche and David Wineland for their groundbreaking contributions to experimental quantum control techniques, and continuously improving experimental capabilities in controlling quantum systems, it would not be an exaggeration to say that it is currently exciting times for quantum control. Linear quantum systems model a wide range of quantum systems that are taking part in the broader ongoing quantum revolution, which promises to significantly increase technological capabilities in sensing, communication, and computing. The quantum future looks bright, and it is our hope that this monograph can play a part in that future.

HN thanks Clare Donald for proofreading the language in some parts of the monograph, and Zhan Shi for her assistance in providing some figures for Sect. 6.2. HN and NY also thank Oliver Jackson from Springer, for inviting them to write this monograph and facilitating the writing process, and Karin de Bie, for technical assistance in preparing the monograph prior to her retirement.

Sydney, Australia — Hendra I. Nurdin
Yokohama, Japan — Naoki Yamamoto
November 2016

References

[1] H.M. Wiseman, G.J. Milburn, *Quantum Measurement and Control* (Cambridge University Press, Cambridge, 2010)
[2] K. Jacobs, *Quantum Measurement Theory and its Applications* (Cambridge University Press, Cambridge, 2014)

Springer

http://www.springer.com/978-3-319-55199-9

Linear Dynamical Quantum Systems
Analysis, Synthesis, and Control
Nurdin, H.I.; Yamamoto, N.
2017, XV, 262 p. 68 illus., Hardcover
ISBN: 978-3-319-55199-9