Joint CQSE & CASTS Seminar

「Oct. 16, 2020 (Friday)」

- **Time** : 14:30~15:30
- **Place** : Rm104, New Physics Building
- **Speaker:** Prof. Hao-Chung Cheng 鄭皓中
  Dept. of Electrical Engineering, NTU
  臺大電機工程學系
- **Title** : On the sample complexity of learning quantum states and measurements

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**Sponsored by Center for Quantum Science and Engineering (CQSE) 量子科學與工程研究中心
and Center for Advanced Study in Theoretical Sciences (CASTS) 理論科學高等研究中心, NTU
**Course: 109-1 (Phys8146) Applications of Quantum Computation

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2020
October 16, Friday

TIME Oct. 16, 2020, 2:30~3:30pm
TITLE On the sample complexity of learning quantum states and measurements
SPEAKER Prof. Hao-Chung Cheng
Department of Electrical Engineering, NTU
PLACE Rm104, Chin-Pao Yang Lecture Hall,
CCMS & New Physics Building, NTU

Introduction

In this work, we provide an elegant framework to analyze learning matrices in the Schatten class by taking advantage of techniques in matrix concentration inequalities. We establish the fat-shattering dimension, Rademacher/Gaussian complexity, and entropy number of learning bounded operators and trace class operators. By characterizing the tasks of learning unknown quantum states and two-outcome quantum measurements into learning matrices in the Schatten-1 and ∞ classes, our proposed approach directly solves the sample complexity problems of learning quantum states and quantum measurements.

Our main result in the paper is that, for learning an unknown quantum measurement, the upper bound, given by the fat-shattering dimension, is linearly proportional to the dimension of the underlying Hilbert space. Learning an unknown quantum state becomes a dual problem to ours, and as a byproduct, we can recover Aaronson's famous result [Proc. R. Soc. A 463, 3089-3144 (2007)]. In addition, other famous complexity measures like covering numbers and Rademacher/Gaussian complexities are derived explicitly under the same framework. We are able to connect measures of sample complexity with various areas in quantum information science, e.g. quantum state/measurement tomography, quantum state discrimination and quantum random access codes, which may be of independent interest. Lastly, with the assistance of general Bloch-sphere representation, we show that learning quantum measurements/states can be mathematically formulated as a neural network. Consequently, classical machine learning algorithms can be applied to implement the two quantum learning tasks.

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Biography Brief

Dr. Hao-Chung Cheng is a scientist and engineer in the quantum information frontier. He is currently an Assistant Professor at the Department of Electrical Engineering, and the Graduate Institute of Communication Engineering, National Taiwan University (NTU). Dr. Cheng received his bachelor's degree in the Department of Electrical Engineering, NTU. He received his Ph.D. degrees at the Graduate Institute of Communication Engineering, NTU, and at the Centre for Quantum Software and Information, School of Software, University of Technology Sydney. After receiving his Ph.D. degrees, Dr. Cheng joined the Department of Applied Mathematics and Theoretical Physics, University of Cambridge as a Postdoctoral Research Associate, and he also affiliated with the Darwin College. His research and scientific interests include quantum information processing, quantum communication, quantum machine learning, statistical signal processing, and matrix analysis.

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