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Membership of Academic Societies:

IEEE (The Institute of Electrical and Electronics Engineers), The Mathematical Society of Japan, JPS (The Physical Society of Japan), IEICE (The Institute of Electronics, Information and Communication Engineers)

Research Interest:

- Quantum Information Theory, Information Theory, Foundation of Quantum Theory

Research Summary:

My research area is mathematical theory for information and its application, especially, I have studied mathematical theory for communication, statistical inference, and cryptography. These topics have different applied aspects, and have different communities due to their historical reason. However, these topics have common mathematical aspects. Hence, a common mathematical treatment is possible for these topics. I have investigated these topics based on the common mathematical properties. In particular, I have studied these topics mainly for quantum systems but also for non-quantum (classical) system. Recently, using this method, I study the foundation of thermodynamics.

Recently, I am mainly studying the following points. One is mathematical treatment for quantum information processing based on group representation theory. Group symmetry simplifies many kinds of problems in quantum systems by removing the basis dependence. In fact, even if a given information processing problem requires a difficult analysis due to the complexity of the problem, the group symmetry simplifies the problem by reducing the complexity. Using the group symmetry, we can construct universal protocols that works independently of the basis. Since the group-theoretical approach to quantum systems are not finished, further developments are required. The second is mathematical theory for information-theoretical secrecy. Recently, I have proposed several approaches for this topic, however, their relations are not so clear and several problems still remain open. Thus, further researches are required for this topic. The third is the foundation of quantum theory. Although this topic had not been studied in the viewpoint of information theory previously, it is investigated from the operation viewpoint with information theory now. I am studying this research direction.

Major Publications:

- [1] M. Hayashi and H. Nagaoka, "General formulas for capacity of classical-quantum channels," *IEEE Transactions on Information Theory*, **49** (2003), no. 7, 1753-1768.
- [2] M. Hayashi, "Information Spectrum Approach to Second-Order Coding Rate in Channel Coding," *IEEE Transactions on Information Theory*, **55** (2009), no. 11, 4947 - 4966.
- [3] M. Hayashi, S. Ishizaka, A. Kawachi, G. Kimura, and T. Ogawa, *Introduction to Quantum Information Science*, Graduate Texts in Physics, Springer (2014).

- [4] M. Hayashi, *Quantum Information Theory: A Mathematical Foundation*, Graduate Texts in Physics, Springer (2017).
- [5] M. Hayashi, *A Group Theoretic Approach to Quantum Information*, Springer (2017).
- [6] M. Hayashi, *Group Representation for Quantum Theory*, Springer (2017).

Awards and Prizes:

- 2010 Japan IBM prize in the computer science section
- 2010 Funai Foundation for Information Technology Award in the computer science category
- 2011 IEEE Information Theory Society Paper Award
- 2015 JSPS PRIZE
- 2016 Japan Academy Medal
- 2017 IEEE fellow

Education and Appointments:

- 1998 JSPS Research Fellow at Kyoto University
- 2000 Researcher, Brain Science Institute, RIKEN
- 2003 Research Manager, ERATO Quantum Computation and Information Project, Japan Science and Technology Agency
- 2007 Associate Professor, Tohoku University
- 2012 Professor, Nagoya University
- 2020 Chief Research Scientist, Southern University of Science and Technology (double position)

Message to Prospective Students:

Now, I am working in Southern University of Science and Technology under academic leave except for January. Since Nagoya University has exchange agreement with this university, I can supervise graduate student of Nagoya University. In this case, my supervision will be done via online, the student needs to satisfy the minimum requirement for online style with a self motivated style. The following are candidates of topic for Master course:

Quantum information theory, Quantum statistical inference, Information theory.

Since these topics are linked to each other, it is possible to tackle one topic based on knowledge obtained from another topic. The following text and the above texts [5] and [6] are useful for these topics.

- M. A. Nielsen, I. L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press (2000).

Since quantum information is a new area, students can relatively easily publish their own research article while the possibility depends on their efforts and their ability. Required preliminary knowledge is level 1, which corresponds to the contents for first, second, and third year courses. In particular, I ask students to master linear algebra, calculus, and elementary probability, which contains the central limit theorem but does not necessarily contain measure theory, because they are very important for these topics. Since these topics are opened to other research area, students are required to study topics outside of mathematics. Since the above research topics are applied to practical problems, it is required not only to understand mathematically formulated problems but also to grasp the target problem itself. For doctoral course, I can supervise group-theoretical approaches to the above topics as well as the above topics themselves.