RIKEN Quantum Workshop

"Quantum-Like Modeling" in Cognitive & Social Sciences

Friday, 11 October, 2024, 14:00~19:00
Wako RIKEN Main Research Bldg (C01) Suite 359

Prospectus: Recently, there has been a growing trend to consider cognitive, and social phenomena as Open Quantum Systems, and to mathematically define the fundamental principles behind them through so-called "Quantum-Like Modeling". It has been extremely difficult to systematically explain complexities of such phenomena within humans' cognitive traits based on classical "rational" reasoning. Quantum-Like Modeling suggests that using quantum probability calculus and its applications could be useful to rationalize such phenomena and expand previous understandings, obtained through simple linear algebra, by applying quantum formalizations. Just as physicists explored a new branch of mathematics, the theory of operators in complex Hilbert space, to describe the quantum phenomena in an effective way, considerations here will be built on the methodology and mathematical apparatus of quantum theory and directed to applications outside of physics, namely to, cognition, psychology, decision-making, economics, finances, as well as the social and political sciences.

Programme

14:00~14:10 **Atsushi Iriki**: ***Introduction.*** *Potential of quantum computing for humanities*

14:10~15:10 **Andrei Khrennikov**: ***Tutorial.*** *Ubiquitous Quantum: from genetics and biological evolution to cognition, psychology, decision making, and social science*

15:10~15:40 **Masanao Ozawa**: *Quantum Instrument -- Measurement to cognition with QC-simulation*

Break

16:00~16:30 **Haruki Emori**: *Applications of quantum computers to cognitive sciences based on Quantum Instrument*

16:30~17:00 **Miho Fuyama**: *Subjective Experiences and Superposition State in Narrative Reading*

17:00~17:30 General Discussion

18:00~19:00 Networking Mixer (*RIKEN canteen #1*)

Speakers and Abstracts

Atsushi Iriki: ***Introduction. Potential of quantum computing for humanities***

The purpose and background of this workshop and the current status of this research field will be overviewed, in relation with the development of quantum computation and quantum computers and their expected potential application to the studies of humanities and social sciences in the immediate future.

Ref: Iriki A, Tanaka S. (2024) Potential of the *Path Integral* and quantum computing for the study of humanities: An underlying principle of human evolution and the function of consciousness. *Global Perspectives,* **5**, 115651.

Iriki is a primate cognitive neuroscientist, who had been a RIKEN Team Leader (2004~2023, BSI & BDR) and is currently a PI of RIKEN-Quantum's Humanities section, and a Research Supervisor of JST CREST Multi-Sensing projects. He proposed an original theory of human evolution named "Triadic Niche Construction" (*Phil Trans Royal Soc B,* **367**: 10~23, 2012), that led him to study its path integral nature.

Andrei Khrennikov: ***Tutorial. Ubiquitous Quantum: from genetics and biological evolution to cognition, psychology, decision making, and social science***

This is introduction to quantum-like modeling, applications of the methodology and formalism of quantum theory outside of physics, in cognition, psychology, decision making, social and political sciences, economics and finance, genetics and evolutionary biology. It is important to point out that systems under consideration are macroscopic. So, quantum-like theory should be sharply distinguished from It starts with the brief introduction to quantum theory (so one need not be educated in this field); the information and probabilistic counterparts will be highlighted. The motivations for quantum-like modeling will be presented and illustrated by applications to agents' irrational behavior - disjunction and order effects. The latter in combination with another psychological effect, the response replicability effect, leads to the use of theory of quantum instruments. Quantum-like approach is used in biology, e.g., in genetics and epigenetics, for modeling adaptive dynamical interactions with environment, e.g., phenotype's generation. Recently such models found applications in medical diagnostics of neurological diseases.

Ref: *A. Khrennikov, Open Quantum Systems in Biology, Cognitive and Social Sciences, Springer, 2023*

Khrennikov is a Professor of Mathematics and Director of the International Center for Mathematical Modeling at Linnaeus University, Sweden. His research activity is extensively multi-disciplinary, which includes mathematics, physics, and biology, cognition, psychology and behavioral economics.

Masanao Ozawa: ***Quantum Instrument – Measurement to cognition with QC-simulation***

The successful modeling of compatibility of the question order effect and the response replicability effect in opinion polls opens a new research field in which quantum instrument theory unifies quantum measurement and quantum cognition with quantum computer simulation.

Ref: Ozawa M. (1984) Quantum measuring processes of continuous observables, *Journal of Mathematical Physics,* **25**, 79.
Ozawa M. (2002) Conservative quantum computing, *Physical Review Letters,* **89**, 057902.
Ozawa M., Khrennikov A. (2021) Modeling combination of question order effect, response replicability effect, and QQ-equality with quantum instruments, *Journal of Mathematical Psychology,* **100**, 102491.

Ozawa has studied mathematical physics, mathematical logic, and philosophy of science. He developed quantum instrument theory and quantum set theory with contributions to foundations of quantum measurement theory, quantum information, and quantum computing, for which he received the International Quantum Award in 2010. Recently, he is extending his research interest to quantum cognition.

Haruki Emori: ***Applications of quantum computers to cognitive sciences based on Quantum Instrument***

When people are asked a series of questions, the response statistics are affected by the question-order effect and the response-replication effect. The quantum instrument model, which was originally developed as a universal mathematical model of quantum measurements, has been proposed as a model to simultaneously explain these two effects. In this study, we demonstrate the effectiveness of the quantum instrument model in cognitive science by implementing it on a quantum computer.

Ref: Emori H, Ozawa M, Tomita A. (2024) Disturbance Evaluation Circuit in Quantum Measurement. *arXiv:*2405.11447.

Emori is a PhD student at Hokkaido University and RIKEN Student Researcher. His research is based on quantum measurement theory, focusing on the foundations of quantum physics, quantum information, and cognitive science. In particular, he advances his research through both theoretical and experimental approaches, using quantum computers as simulators of quantum systems.

Miho Fuyama: ***Subjective Experiences and Superposition State in Narrative Reading***

In literary studies, it has been suggested that the indeterminacy of interpretation during narrative reading evokes a reader's aesthetic sense and immersion. This study modeled interpretive states with indeterminacy as a superposition using quantum probability theory, and conducted empirical research to explore how this superposition relates to subjective experiences, including transportation. This presentation will introduce and discuss part of these findings.

Ref: Fuyama, M. (2024). Estimating a Time Series of Interpretation Indeterminacy in Reading a Short Story. In *Proceedings of the Annual Meeting of the Cognitive Science Society, **46**, 2681-2686.*

Fuyama is a cognitive scientist focusing on text comprehension, with an academic background in physics and literature. Since 2022, she has been an Associate Professor at the College of Letters, Ritsumeikan University. Currently, she is leading an interdisciplinary collaborative research to explore indeterminacy in human cognition and its effects, as a PI of one of JST-CREST Multi-Sensing projects.