Creating information utilization platform by integrating mathematical and information sciences, and development to society

2021 Principal Investigator

Year 2021
Annual report

Mohammad Emtiyaz Khan

RIKEN Center for Advanced Intelligence Project
Team Leader

A new Bayes-Duality principle for adaptive, robust, and life-long learning of AI

§1. Summary of research results

The aim of our research is to develop the theory of Bayes-duality, and apply it to obtain adaptive, robust, life-long learning AI systems. The goal for this year (Oct. 2021-Mar. 2022) was to form an initial understanding and estimate difficulty of the projects, and also start a few seed projects that will eventually lead to the achievement of our goals. But we exceeded our expectations, and already start seeing good results from the projects we just started.

On theory side, the Bannai and Khan group worked on establishing fundamental connections between Information Geometry and Bayes, leading to a result that could reveal the "inherent" geometry of all Bayesian solutions. We also took the first few steps to bring in tools of information geometry to design better algorithms for Bayes, and connect them to those in optimization. The Khan group worked on using convex-duality on the Bayes objective to draw surprising connections to robust deep-learning methods, which could bring improvements in both the Bayesian and deep-learning communities. The Khan group made progress on a paper laying out the foundations of the Bayes-duality principle. Finally, the Khan and Yokota groups made significant progress on the application of Bayes duality, specifically on the projects to understand and analyze the "memory" of deep-learning models. We have made more progress than we originally planned for, and the results we have so far exceed our expectations.

§1. 研究成果の概要

本研究はベイズ双対性の理論を発展させ、それを応用することで適応的で頑健な継続学習が可能なAIシステムを構築することを目的とする。今年度(2021年10月～2022年3月)の目標は、プロジェクトの初期検討と難易度の見積もりを行い、最終目標達成につながるシードプロジェクトをいくつか立ち上げることであった。しかし、期待以上の成果を上げることができ、すでに開始したばかりのプロジェクトからも良い結果が出始めている。

理論面では、坂内グループとKhanグループが情報幾何学とベイズ理論の根本原理の共通部分を発見することに取り組み、ベイズ理論から得られる解のもつ「固有の」幾何学を明らかにする結果につながった。また、ベイズのアルゴリズムをより良く設計するために情報幾何学のツールを導入し、最適化のアルゴリズムと結びつけるための手がかりをつかんだ。Khanグループは、ベイズの目的関数に凸関数の双対性を用いて、ロバストな深層学習法との新たな関連性を導き出すことに取り組み、ベイズ理論と深層学習の両分野に改善をもたらすことができた。さらに、Khanグループは、ベイズ双対原理の基礎を示す論文の執筆を進めた。最後に、Khanグループと横田グループは、ベイズ双対性の応用、特に深層学習モデルの「記憶」を理解し、分析するプロジェクトで大きな進展が得られた。当初予定していた以上の進捗があり、これまでに得られた成果は期待以上のものであった。

§ 2. Research implementation system

(1) Khan Group

1) Principal investigator: Mohammad Emtiyaz Khan (Team Leader, Center for AI project, RIKEN)

2) Research Items

- A new theory of duality for machine-learning
- A generalization of convex duality to non-convex problems
- New theoretical guarantees on generalization error of adaptive systems.
- Bayes-duality for knowledge representation
- Knowledge representation, Uncertainty, & architecture search
- Knowledge transfer
- Knowledge collection

(2) Bannai Group

1) Principal Co-researcher: Kenichi Bannai (Professor, Faculty of Science and Technology, Keio University)

2) Research Items

- A new theory of duality for machine-learning

(3) Yokota Group

1) Principal Co-researcher: Rio Yokota (Associate Professor, Global Scientific Information and Computing Center, Tokyo Institute of Technology)

2) Research Items

- Bayes-duality for knowledge representation
- Knowledge representation, Uncertainty, & architecture search
- Knowledge transfer
- Knowledge collection