Data Efficient Deep Learning for Imaging and Parameter Estimations

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In recent years, deep learning has been a driving force in the development of innovative computational tools and methodologies for solving complex scientific problems. One of the notable example is AlphaFold, a neural network-based approach for protein structure prediction, which was awarded the 2024 Nobel Prize in Chemistry. Within this context of these exciting developments, this project aims to develop efficient deep learning-based methods for parameter estimation in imaging and high-dimensional data processing.

The focus of this research lies in computational approaches for imaging data, which arise from diverse real-world applications, including for example healthcare and astronomy. A key mathematical challenge in these areas stems from the high dimensionality of the underlying problems, as imaging data is typically very high dimensional. To analyse such data accurately, sophisticated analytical models are often required, and these also come with significant computational costs. Recent advances in deep learning offer a promising alternative for addressing the high-dimensional challenges due to the flexibility and expressiveness of neural networks in modelling complex data, as well as the fact that, once trained, deep learning models are computationally efficient. However, the current major successes of these approaches largely rely on the availability of large quantities of high-quality, labelled training data. In many scientific applications, manual labelling is often infeasible or prohibitively expensive. This project seeks to unlock the potential of deep neural networks in data-limited settings by exploiting inherent structures and patterns in the data to aid the learning process, hence reducing the dependence on extensive labelled data.

The research will explore unsupervised learning methods to extract statistical information from directly or indirectly measured data, which can guide deep neural networks in estimating unknown parameters of a system. Furthermore, the project will investigate how incorporating prior knowledge and mathematical information into deep learning frameworks can enhance the accuracy and efficiency of parameter estimation and high-dimensional data processing. With the additional information, we aim to make the learning models data efficient and better suited for the tasks.

The successful delivery of this project would contribute to the development of new computational tools and learning frameworks in addressing various scientific domains where high-dimensional imaging data is involved. Additionally, this research provides an opportunity to work on diverse applications of deep learning, where data efficiency is a critical concern.